MO-P-01

High-Gain FEL on the Coherent Bremsstrahlung of a Relativistic Electron Beam in a Crystal*

Hamlet K. Avetissian, Arthur L. Khachatryan, Garnik F. Mkrtchian (Yerevan State University)

The problem of creation of shortwave coherent radiation sources in general aspects reduces to implementation of free electron lasers. Various schemes of X-ray FELs have been considered based on the coherent accumulation of relativistic electron beam radiation in resonant processes. Among these versions, at the present the undulator scheme is actively developed. However, the other versions such as stimulated radiation of charged particles' beam in crystals may appear more reasonable in practice for X-ray FELs due to easier set up requirements; in particular, the use of electron beams of considerably lower energies.

In this paper a possible way to achieve lasing in the X-ray domain due to coherent bremsstrahlung of an electron beam in the crystal is considered. The high-gain regime is investigated when charged particles move close to the crystal lattice plane or axis. The consideration is based on the self-consistent set of the Maxwell-Vlasov equations. We also investigated the case when the electron beam is initially modulated. Coherent length in this scheme is confined by the electrons multiple scattering in a crystal. The latter drastically increases the lasing threshold for the beam density. We have also considered the ways to minimize damage to crystals from high current densities.

* This work was supported by International Science and Technology Center (ISTC) Project No. A-353.

MO-P-02

Optical-Klystron FEL Oscillators, Pulse Propagation Effects and Super Mode Structures

Riccardo Bartolini, Giuseppe Dattoli, Luca Giannessi, Pier Luigi Ottaviani (ENEA)

We discuss the problems associated with pulse propagation effects in optical-klystron FEL oscillator devices. We show that, in analogy with the ordinary FEL oscillators, the self-reproducing structure of the Super Mode type exists, and that most of the relevant dynamics can be reproduced by means of simple scaling relations.

MO-P-03

Use of Dynamical Undulator Mechanism to Produce Short Wavelength Radiation in Volume FEL (VFEL)

Vladimir G. Baryshevsky, Konstantin G. Batrakov (Research Institute of Nuclear Problems)

VFEL lasing in system with dynamical undulator is described. In this system radiation of long wavelength creates the undulator for lasing on shorter wavelength. Two diffraction gratings with different spatial periods form VFEL resonator. The grating with longer period pumps the resonator with long wavelength radiation to provide necessary amplitude of undulator field. The grating with shorter period makes mode selection for short wavelength radiation. Lasing of such a system in TeraHertz frequency range is discussed.

MO-P-04

Operation of an Optical Klystron with Small Dispersion*

Stephen V. Benson (TJNAF)

The IR Upgrade design at Jefferson Lab uses an optical klystron in order to enhance the flexibility of the free-electron laser system. The theory of optical klystrons usually assumes a strong dispersion section with several tens of effective periods [1]. The IR upgrade design assumes operation with a dispersion section strength of only a few periods in order to allow the full range of efficiency of our FEL to be explored. This paper will study the behavior of an FEL with an optical klystron in this small dispersion limit. The peak gain vs. dispersion section strength has an oscillatory behavior, suggesting that the dispersion section strength should be adjusted in unit steps rather than continuously. The gain vs. the effective number of periods is calculated and found to be slower than a uniform wiggler. This is partially offset by the constant optical mode volume.

* This work supported by the Office of Naval Research, the Joint Technology Office, the Commonwealth of Virginia, the Air Force Research Laboratory, and by DOE Contract DE-AC05-84ER40150.

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MO-P-05

Simulations of High-Power Free Electron Lasers With Strongly Focused Electron and Optical Beams*

J. Blau, T. Campbell, W. Ossenfort, P. P. Crooker, W. B. Colson (NPGS)

High-power free electron lasers (FELs) are being designed in collaboration with Jefferson Laboratory, University of Maryland, and Advanced Energy Systems using short Rayleigh-length resonators to increase the spot size at the mirrors and hence avoid mirror damage. A short Rayleigh-length implies a very small optical mode waist in the center of the cavity. It may be desirable to strongly focus the electron beam as well, to improve overlap with the intense optical fields in the interaction region. Three-dimensional simulations are used to study the effects of varying the electron beam radius and angular spread to enhance FEL gain and efficiency. The effects of off-axis shifting of the electron beam are also studied.

* This work is supported by DARPA, NAVSEA, and JTO.

MO-P-06

Effect of Axial Magnetic Field on Undulator Radiation and Gain

Shailendra Singh Chauhan (Devi Ahilya University); Ganeswar Mishra (BESSY)

In a free electron laser, a beam of relativistic electrons undergoes transverse oscillations when it is injected in to an undulator magnet. These oscillations cause spontaneous emission that provides an important diagnostic parameter for a wide number of free electron laser experiments and related applications. The spectral features of the undulator radiation depends on a large number of beam parameters. For this reason various analytical methods and numerical codes have been developed in recent years and incorporate the important effects of beam energy, emittance spread, low-energy corrections, and off-axis field contributions to the wiggler-undulator radiation [1,2]. The study allows a transparent understanding of the underlying physics and offers the diagnostic of the emitting beam and the laser source employing both linear and helical undulators. The study further stimulates investigations of other alternate concepts of undulator radiation using two-undulator, two-harmonic, two-frequency undulator schemes for possible gain and efficiency improvement and meaningful illustration [3,4]. In this paper we attempt to include the effect of axial magnetic field on undulator brightness with and without betatron motion, and outline two procedures to enhance the gain of the system in the presence of an axial magnetic field.

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MO-P-07

The Free Electron Laser Interaction with a Short-Rayleigh-Length Optical Mode*

W. B. Colson, J. Blau, R. L. Armstead (NPGS)

High-power, short-wavelength free electron lasers (FELs) can make use of a short-Rayleigh-length optical mode in order to reduce the intensity on resonator mirrors. The conventional FEL interaction attempts to optimize the coupling between the electron beam and optical mode by minimizing the optical mode volume around the electron beam. In contrast, the short-Rayleigh-length FEL focuses optical power in a small region of the undulator, which accelerates the electron bunching process. As a result, the fundamental FEL interaction is significantly altered with a rapidly changing optical field and phase along the undulator. Advantages and disadvantages of FELs designed with a short-Rayleigh-length optical mode are discussed.

* This work is supported by DARPA, NAVSEA, and JTO.

MO-P-08

A Study of the Stability of a High-Power Free Electron Laser Utilizing a Short Rayleigh Length*

P. P. Crooker, A. Kalfoutzos, V. Bouras, J. Blau, W. B. Colson (NPGS)

In order to avoid mirror damage on a high-power free electron laser (FEL), the design can utilize a short Rayleigh-length optical cavity in combination with a short magnetic undulator. The short Rayleigh length increases the mode area and reduces the intensity at the mirrors, but also alters the basic FEL interaction and the stability of the laser itself. In particular, mirror misalignment may significantly affect the behavior of the cavity modes. We present a study of the effects of short Rayleigh lengths on FEL performance and stability, including the effects of mirror tilt, mirror displacement, and mirror radius change due to heating. The results are presented within the framework of proposed high-power lasers.

* This work is supported by DARPA, NAVSEA, and JTO.

MO-P-09

Theory of Free-electron Laser with Double Undulator

Zhimin Dai (Shanghai Institute of Nuclear Research)

In this paper, we present a general theory of the free-electron laser with double undulator, in which an additional undulator with period close to that of electron betatron oscillations in the main undulator is introduced. A set of self-consistent equations is developed to describe the evolution of the optical wave in this device. The basic equations are analyzed in the low-gain regime, high-gain regime, and saturation regime, respectively. Numerical simulations of the basic equations are performed to check the validity of the analytical results. It is shown that, under proper conditions, the gain or efficiency of the free-electron laser may be increased by the second undulator.

MO-P-10

Electron Trajectories in a Helical Free-Electron Laser with or without an Axial Guide Field

J. T. Donohue (Centre d'Etudes Nucléaires de Bordeaux-Gradignan);
J. L. Rullier (CEA/DAM, Departement de Physique Théorique et Appliqué)

An earlier study of the motion of electrons in a helical wiggler with an axial guide field is extended to allow the axial field to be zero. The present treatment, like its predecessor, provides analytic but approximate expressions for the trajectories. In particular, it is able to adequately describe those trajectories which do not encircle the axis. When the axial field is zero, the new treatment allows us to obtain closed form expressions for the trajectories, which depend parametrically on the ratio of the helical invariant to the on-axis wiggler field. In the limit of high energy or low wiggler field, further simplifications occur, and we find a simple yet detailed description, which agrees with exact numerical calculations of the trajectories. Using our approach, we discuss the detailed space and time dependence of the beam shape as it propagates through the wiggler.

MO-P-11

Off-axis Orbits in Realistic Helical Wigglers Revisited

J. T. Donohue (Centre d'Etudes Nucléaires de Bordeaux-Gradignan);
J. L. Rullier (CEA/DAM Département de Physique Théorique et Appliquée)

Many years ago Fajans, Kirkpatrick, and Bekefi [1] studied off-axis orbits in a realistic helical wiggler, both experimentally and theoretically. They found that as the distance from the axis of symmetry to the guiding center increased, both the mean axial velocity and the precession frequency of the guiding center varied. They proposed a clever semi-empirical model that yielded an excellent description of both these variations. We point out that an approximate model proposed by us several years ago also predicts these delicate effects correctly, provided we pay proper attention to a seemingly minute detail. Illustrative comparisons of our model with numerical calculation are presented.

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MO-P-12

Optimization of Electron Bunch Profile for Increasing Peak Power of Superradiance Pulses

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K. Kurihara, H. Shirasaka, R. Ando, K. Kamada (Kanazawa University)

In the previous theoretical works [1,2] it was assumed that the electron pulses with a plane waveform are the most suitable for superradiance (SR) emission (similar to the case of steady-state generation). It is shown in this paper that, due to nonstationary nature of SR emission to enhance peak amplitude of SR pulse, an accelerating voltage should vary over electron pulse duration. In the case of SR from an electron bunch moving in wiggler field and interacting with forward propagating wave with group velocity exceeding electron longitudinal velocity, SR pulse peak power enhancement takes place when energy of particles decreases from leading to trailing edges. When a short SR pulse occurs inside interaction space and shifts towards leading edge of electron bunch due to slippage, it is beneficial that this pulse interacts with the "fast" electrons which possess longitudinal velocities exceeding phase velocity of synchronous combination wave. In the process of growth of an amplitude in time of SR pulse, this pulse can effectively extract energy from electrons with velocities strongly different from a synchronous value. Based on average time-domain model it is shown that optimization of profile of voltage and current pulses provides possibility for increasing peak power of SR pulses in several times.

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MO-P-13

Beam Conditioning for a Laser Pumped FEL Operating in the X-Ray Regime

Daniel F. Gordon (Icarus Research, Inc.); Phillip Sprangle (NRL); Bahman Hafizi (Icarus Research, Inc.); Charles W. Roberson (ONR)

In a laser pumped free electron laser (LPFEL), the electromagnetic field of a laser beam replaces the conventional static wiggler field. The short wavelength of the electromagnetic wiggler makes it possible to generate x-rays using an electron beam with an energy of only a few MeV. However, the spread in the axial velocities of the electrons must be extremely small in order for lasing to occur. Recent estimates indicate that current photocathode technology yields electron pulses with velocity spreads approximately at the limit of what would be acceptable for an LPFEL. These marginal velocity spreads could be reduced by using beam conditioning techniques involving a conventional wiggler and an rf field [1,2].

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MO-P-14

Analysis of Betatron Harmonic Radiations from Single and Dual Harmonic Undulator for Low Energy FELs

Upma Gupta (Devi Ahilya University); Ganeswar Mishra (BESSY)

There exists interest and recent efforts to operate free-electron lasers at short wavelengths. One of such possibilities is to lase at the harmonics [1,2] with lower energy electron beams. The dual harmonic undulator [3] proposed recently gives enhanced gain with moderate wiggler parameters. Formulas of the coupling factor and small signal gain at each harmonic are derived and provide a useful tool to obtain simultaneous laser power at different harmonics [4]. In this paper we discuss and study the distortion induced in the radiation spectrum by inclusion of the effects of off-axis motion of the electron with sextupolar magnetic field contributions of harmonic field undulators. The modifications induced in the brightness by the inclusion of sextupolar terms which arise when the electrons are injected off the undulator axis are much worse in free electron experiments using low energy accelerators.

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MO-P-15

Spontaneous and Amplified Radiation at the Initial Stage of a SASE FEL*

Zhirong Huang, Kwang-Je Kim (ANL)

At the initial stage of a self-amplified spontaneous emission (SASE) free-electron laser (FEL), spontaneous undulator radiation in certain experimental configurations can dominate the amplified signal over an extended undulator distance. In this paper we study both the spontaneous and the amplified radiation in the framework of the paraxial wave equation and determine the transition from the spontaneous emission to exponential amplification. We compare theoretical expectations with SASE simulation codes GINGER and GENESIS.

* Work supported by the U. S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

MO-P-16

Physics of Super Pulses in Storage Ring FEL*

Vladimir N. Litvinenko (DUKE)

It is a wide-spread misconception that storage ring FELs have low peak power caused by a soft saturation in gain. In contrast with this perception, storage ring FELs with substantial net gain can operate with peak power reaching GW level in so-called super-pulse mode. This paper describes the physics of "phase-space" refreshment responsible for this unusual phenomenon. Detailed theoretical studied of the super-pulse dynamics and the value of the peak power on the net FEL gain, cavity loss and the synchrotron frequency are presented. In addition, the results of self-consistent simulations of super-pulses are compared with experimental date from the OK-4/Duke storage ring FEL.

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MO-P-17

Study of Radiation Spectrum in a Free-Electron Laser Oscillator from Noise to Saturation

Yosef Pinhasi, Yuri Lurie, Asher Yahalom (The College of Judea and Samaria)

Free-electron lasers can be employed as sources of coherent electromagnetic radiation when operating in an oscillator configuration. The radiation, excited and amplified by the accelerated electrons passing through the undulator, is circulated in a feedback loop, which forms a resonator. At the first stage, the spontaneous emission of the wiggling electrons, entering the undulator at random, interferes and combines with the circulating radiation field in the resonator. If the single-pass gain is higher than the total resonator losses, the radiation intensity inside the resonator increases and becomes more coherent. After several round trips, the radiation is built up until arriving at the nonlinear regime and saturation.

Previous studies of FEL oscillators have been carried out in a framework of space-time models. We present here 3D space-frequency model for analysis and simulation of radiation excitation in a FEL oscillator. The total electromagnetic field is presented in the frequency domain as an expansion in terms of transverse eigenmodes of the (cold) resonator.

Coupled-mode formulation is utilized in an analytical approach and in a numerical simulation to follow linear and nonlinear processes, taking place during radiation buildup, which lead to the establishment of single-mode lasing. The evolution of the radiation spectrum is investigated also in 'grazing,' when the group velocity of the radiation is equal to the axial velocity of the electrons.

MO-P-18

Chaotic Behavior in a Realizable Helical-Wiggler Field

Soon-Kwon Nam, Ki-Bum Kim (Kangwon National University)

The motion of an individual electron for the case where the wiggler magnetic field is described by a realizable helical wiggler is investigated. The dimensionless vector potential is considered to the leading-order vector potential for an ideal helical wiggler and the correction of the vector potential. Chaotic behavior in a realizable helical wiggler field is examined for the expanded Hamiltonian in a free-electron laser. We also analyze the focusing force provided by higher-order terms in the vector potential expansion, the effects of self-field, the particle trajectories and chaotic phenomena due to the wiggler field amplitude in a realizable helical wiggler by the numerical simulation.

MO-P-19

Dynamics of Low Coupling Parameter Free-Electron Laser Oscillator

Hiroyuki Nishiyama, Makoto Asakawa (OsakaU); Yoshiaki Tsunawaki (Osaka Sangyo University); Manabu Heya, Kunio Awazu (OsakaU); Kazuo Imasaki (Institute for Laser Technology)

The effects of resonator desynchronism and losses on the free-electron laser oscillator fed by the electron bunch with comparable length to the optical pulse are reported. In our experiments, the spacing of the resonator mirrors were controlled with the minimum step of 1/3 μm. The experiments were performed using four mirrors with the coupling hole of 0.5, 1.5, 2.0 and 3.5 mm in diameter. The shortening of the resonator reduce the start-up time. The one dimensional numerical simulation shows this reduction is attributed to the superradiance in the trailing region of the electron bunch. In the saturation regime, the optical output fluctuates under the most of experimental condition, while the stable output is observed at a certain resonator length. It is inferred from the simulation that the fluctuation originates the change in the electron bunch length, and the resonator shortening balances the change in the current density, consequently stabilizes the optical output fluctuation.

MO-P-20

Lethargy Effect in FEL Oscillators at Zero Detuning of an Optical Cavity

Nobuyuki Nishimori, Ryoichi Hajima, Ryoji Nagai, Eisuke Minehara (JAERI)

The sustained saturation in an FEL oscillator at perfect synchronism of an optical cavity ($\delta L = 0$) was experimentally verified recently despite the well-known lethargy effect [1,2]. Our numerical simulation reproduced the lasing at $\delta L = 0$, though its physical mechanism has not been clarified yet. Here we show numerically and semi-analytically that the optical field is amplified by interaction with an initially unbunched electron beam at resonant energy and the sustained lasing at $\delta L = 0$ can be established. The lethargy disappears after sufficient round trips because the gain becomes constant regardless of the FEL longitudinal position.

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MO-P-21

High-Order Generation in a Cerenkov FEL

Israel J. Owens, James H. Brownell (Dartmouth College)

Cerenkov FELs have primarily operated on the fundamental guided mode of the dielectric waveguide. Higher-order generation would allow short wavelength emission in a relatively large-scale resonator. We find that gain on higher-order modes can be significant in a planar CFEL. This analysis will be presented with a discussion of practical limits.

MO-P-22

Correlation Function Equation for the SASE FEL

Oleg A. Shevchenko, Nikolai A. Vinokurov (BINP)

In this paper we develop a new approach to the SASE FEL theory. It is based on the well-known system of Klimontovich-Maxwell equations. In the 1-D case the special choice of the independent variable makes it possible to eliminate an electromagnetic field. That allows us to write down the BBGKY hierarchy for the s-particles' distribution functions by standard averaging of the Klimontovich equation. Due to the smallness of the high-order correlations, we consider only two equations from the beginning of this hierarchy. We also discuss the possible generalization for the 3-D case.

MO-P-23

Real-Time Animation of Synchrotron Radiation

Tsumoru Shintake (RIKEN)

Real-time animation of the synchrotron radiation and the undulator radiation will be presented. This software draws electric field lines of radiation from a moving charge in real time. It is based on simple mapping of wavefront and field lines and thus runs very fast. All field variables are derived by a simple algorithm. This software is available as freeware from http://c-band.kek.jp.

MO-P-24

Application of Volume Diffraction Grating for TeraHertz Lasing in Volume FEL (VFEL)

Vladimir G. Baryshevsky, Konstantin G. Batrakov, Victor I. Stolyarsky
(Research Institute of Nuclear Problems)

The generation of induced radiation in volume resonator formed by metal threads is considered. It is shown that using of such volume diffraction grating allows increasing of lasing effectiveness in TeraHertz range. The requirements on beam and grating parameters are obtained.

MO-P-25

Gain and Diffraction Effects of the Flat Beam FEL

Raphael V. Tumanian, Lekdar Gevorgian (Yerevan Physics Institute)

The gain of the FEL with flat beam is considered for use in certain cases. Eigenvalues and eigenfunctions for flat beams are found. The differences between flat and circular beams FEL gain and other important parameters are investigated. Diffraction effects are taken into account.

MO-P-26

A 3D Particle Tracking Technique for FEL Start-up and Saturation Effects

M.J. de Loos (Eindhoven University of Technology); S.B. van der Geer, C.A.J. van der Geer (Pulsar Physics); A.F.G. van der Meer, D. Oepts (FOM); Rudi Wuensch (FZR)

Self-consistent simulation of the FEL process by time-domain particle tracking can give very detailed results on both the produced radiation and the evolution of the electron bunch. We show that when special subsets are tracked, instead of individual macro-particles, only a few of these subsets are required to obtain converging results. The subsets used are short longitudinal arrays of macro-particles, of the order of a few ponderomotive waves, distributed longitudinally in such a way that they are almost only sensitive to stimulated emission. This new approach has been carried out with the 3D General Particle Tracer (GPT) code and a set of axisymmetric Gaussian waves propagating in free space. Due to the from-first-principles approach, it can be used for a variety of radiation problems, including studies of FEL start-up and saturation effects. The model and two applications will be presented.

MO-P-27

Harmonic Contents of and Detailed Study on the High-Gain Harmonic Generation FEL*

J. H. Wu (BNL)

Based on some recent upgrades of the TDA code, in this paper we calculate the harmonic content of an HGHG FEL at saturation. We discuss the degradation of the electron beam phase space due to the undulator radiation, the coherent radiation in the dispersion section, and wakefields in the undulators and its consequence to the FEL. We study the emittance effect in such an HGHG FEL scheme.

* This work is done under contract DE-AC02-98CH10886 with the U.S. Department of Energy.

MO-P-28

Characteristics of Even Harmonic Oscillation in Free Electron Lasers

Ming Xie (LBNL)

Recently, new coupling mechanisms for FEL interaction were identified and FEL equations were reformulated accordingly [1]. Based on the new formulation, we present in this paper specific calculations including small signal gain, transverse mode profile, polarization state, and saturation efficiency for FEL oscillation at even harmonics.

[1] Ming Xie, "New Mechanisms of Interaction for Even Harmonic Generation in Free Electron Lasers," to be published in the Proceedings of 2001 FEL Conference.

MO-P-29

Statistical Properties of Radiation from SASE FEL Driven by Short Electron Bunches

Evgeny L. Saldin, Evgeny A. Schneidmiller (DESY-Hamburg); Mikhail V. Yurkov (JINR)

We analyze statistical properties of the radiation from a SASE FEL driven by short electron bunches. It is shown that in the linear regime the radiation from a SASE FEL is a Gaussian random process. When approaching saturation point, statistical properties of the radiation change drastically on a scale of one gain length. Particular attention is devoted to the analysis of fluctuations of radiation energy after a narrow-band monochromator. It was found that fluctuations are significantly suppressed when electron pulse length becomes comparable with cooperation length.

MO-P-30

Coherence Properties of the Radiation from SASE FEL

Evgeny L. Saldin, Evgeny A. Schneidmiller (DESY-Hamburg); Mikhail V. Yurkov (JINR)

We present a comprehensive analysis of coherence properties of radiation from SASE FEL. The effective transverse correlation function is calculated by means of numerical simulations with the code "FAST." This allows us to calculate area and degree of transverse coherence. Evolution of these parameters is traced from the beginning of the undulator up to the deep nonlinear regime. It is shown that the degree of transverse coherence reaches maximum value at the saturation point. Then it drops drastically because of pure transverse coherence of the radiation produced in the nonlinear regime.

MO-P-30A

Statistical Properties of Radiation Power Levels from a High-Gain, Free-Electron Laser at and beyond Saturation*

William M. Fawley, Eric Esarey, Carl B. Schroeder (LBNL)

User applications for the output radiation from high-gain, short-wavelength FELs such as the proposed LCLS and TESLA-FEL will have varying sensitivity to shot-to-shot power fluctations. We present numerical and analytical results concerning the statistical properties of the power from a high-gain free-electron laser (FEL) operating in the nonlinear regime. We consider the case of an FEL amplifier reaching saturation whose shot-to-shot fluctuations in input radiation power follow a given distribution. We also consider the case of an FEL operating in the self-amplified spontaneous emission (SASE) mode. It is well known that the radiation power obeys a negative-binomial probability distribution in the linear regime of the SASE FEL. We analyze the expected fluctuation level of the radiation power at and beyond the first saturation of the SASE FEL, obtaining numerical results using the polychromatic, time-dependent simulation code GINGER. The effects of a taper in the undulator's magnetic field upon the power fluctuation characteristics beyond saturation are also examined.

* Work supported by the U. S. Department of Energy under Contract No. DE-AC03-76SF00098.

MO-P-31

A Simulational Study on the Energy Recovery from Spent Electron Beams in an S-band Linac

Shinya Matsumura, Kai Masuda, Toshiteru Kii, Kazunobu Nagasaki, Hideaki Ohgaki, Tetsuo Yamazaki, Kiyoshi Yoshikawa (Institute of Advanced Energy, Kyoto University)

For improvement of wall plug efficiency in free-electron laser equipment, it was found extremely efficient to recirculate the spent electron beam to the super-conducting linac in the opposite phase and recover its kinetic energy as the rf power [1,2]. Though the energy recovery system may not be effective with the normal-conducting linac, it will be effective to decrease the load of shieldings. We performed simulations about the same-cell energy recovery with a normal-conducting S-band linac and a thermionic rf gun as the injector, using a particle simulation code, KUBLAI [3]. As a result, we found that the energy recovery is feasible even for S-band linac, although more careful treatment of phase matching is required. And we also found the whole efficiency can be improved by reducing beam energy of the injector output, because the results indicate that the spent beam energy can be fully recovered up to its energy gained in the acceleration. However, with a too low injected beam energy, the difference of energies between accelerated and spent beams becomes large at both ends of the linac. To overcome this, it would be effective to reverse the incident direction of the spent beam. We evaluated increase of beam emittance and so on, due to the fact that the beam was influenced greatly by crossing the spent one. We will discuss these beam properties as well.

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[3] K. Masuda, Ph.D. thesis, Kyoto University (1997).

MO-P-32

Progress of the Volume FEL (VFEL) Experiments in Millimeter Range*

Vladimir G. Baryshevsky, Konstantin G. Batrakov, Alexandra A. Gurinovich, Igor I. Ilienko, Alexander S. Lobko, Pavel Molchanov, Valery I. Moroz, Pavel F. Sofronov, Victor I. Stolyarsky (Research Institute of Nuclear Problems)

Use of non one-dimensional distributed feedback lets essentially increase the effectiveness and reduce the threshold of FEL generation. Besides, it gives possibility of frequency tuning. The main goal of experiments is to observe the frequency tuning with the diffraction grating rotation. In present work the results of VFEL experiments with two diffraction gratings of different periods are presented. Dependence of lasing process on geometry is discussed.

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MO-P-33

Electron Beam Dynamics through a Return-Arc and a Deceleration Path of the JAERI Energy-Recovery Linac

Ryoichi Hajima, Eisuke J. Minehara (JAERI)

An energy-recovery linac (ERL) for a high-power FEL has been developed at JAERI (Japan Atomic Energy Research Institute), and a research program towards a 10-kW FEL is in progress. In the JAERI-ERL, an electron beam after the FEL interaction is transported through a triple-bend arc and reinjected to the main superconducting module, where the electrons are decelerated down to 2 MeV, same as the injection energy. Since the electron beam has large energy-spread introduced by FEL interaction, special attention should be paid to both transverse and longitudinal phase-space manipulation through the return-arc and the deceleration path. We present the results of beam dynamics simulations coupled with a 1-D FEL code, and discuss the limitation of FEL extraction efficiency determined by phase-space acceptance of the return path. The design of a beam dump at 2 MeV is also described.

MO-P-34

Cyclotron Autoresonance between Ultrarelativistic Electron and Free-Space Mode Radiation

Makoto Asakawa (OsakaU); Aichi Marusaki (Osaka Sangyo Univ.); Hiroyuki Nishiyama (OsakaU); Yoshiaki Tsunawaki (Osaka Sangyo Univ.); Kazuo Imasaki (Institute for Laser Technology)

Cyclotron autoresonance (CAR) between the ultrarelativistic electron bunch (max. 150 MeV) and the optical wave (50-500 μm) will be presented. In principle, electrons injected in resonance with optical wave (free-space mode bphase=1, not waveguide mode) will remain in resonance even if electrons change their energy through the interaction. The CAR laser, thus, is potential for high-efficiency and high-power operation. The experiments are performed on the UV-FEL resonator at iFEL by replacing the undulator with a 3-m-long solenoid. Use of high-energy electrons (a hundred times higher than that used in CAR masers) gives rise to large Doppler upshift from the cyclotron frequency, thus electrons emit the infrared radiation in a moderate magnetic filed of 0.5 T produced by the normal conductor solenoid. This cyclotron radiation is stored in the the optical cavity so as to interact with successive electron bunches. Possibility of the CAR laser will be discussed. Furthermore, the radiation emitted by electrons which undergo only a half cyclotron motion is investigated. The property of such a short pulse radiation will be also discussed.

MO-P-35

Selective Properties of Planar Bragg Reflectors and their Application for Multichannel Masers

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In this paper we discuss selective properties of planar reflectors composed of a pair of 1-D or 2-D Bragg gratings with various types of their surfaces corrugated. These reflectors can realize one- or two-dimensional distributed feedback for microwave generation in the resonator of a maser. Such reflectors are used at the ELMI-device that is operated at 75 GHz as a FEM oscillator driven by a sheet electron beam [1]. In recent experiments at the ELMI-device its resonator consisted of two different reflectors. The first one is an upstream 2-D Bragg reflector, which provides synchronization of radiation across the sheet electron beam. The downstream 1-D Bragg reflector provides sufficient reflectivity for the FEM self-excitation. Spectral properties of 1-D and 2-D reflectors and the resonator composed by them are investigated theoretically in computer simulations and in 'cold' measurements. In addition, theoretical investigations show that 2-D Bragg reflectors can Nproduce a mutual exchange of transverse radiation flows between adjacent FEM oscillators in a multichannel device and synchronize generation in the FEMs [2]. According to this, the same planar FEMs can be combined in a single superpower generator. One-dimensional Bragg reflectors with a special type of corrugation can be also used in planar FEMs for high efficiency output of generated 4-mm radiation. The results of computer simulations for optimizing corrugated surfaces to achieve maximum output power are presented in this paper.

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MO-P-36

Variable-Energy Microtron for a Compact Wide-Band FIR Free Electron Laser

Grigori M. Kazakevitch, Young Uk Jeong, Byung Cheol Lee (KAERI); Rustam R. Akberdin, Nikolai G. Gavrilov, Mikhail N. Kondaurov (BINP)

A microtron-injector [1] of the KAERI compact far infrared free electron laser (FIR FEL) facility has been upgraded to provide the tuning of the FEL wavelength range more than 100-300 μm. The wide-band tunability of the radiation has been achieved by changing the kinetic energy of the accelerated electrons from 6.5 to 4.9 MeV. The position of an rf cavity inside the microtron is movable within the range of 200 mm, and it changes the maximum orbit number of electrons during acceleration from 8 to 12. The operating parameters and extraction conditions of the microtron have been chosen to provide acceptable conditions of the electron beam for the stable operation of the wide-band FIR FEL, i.e., minimal values of the energy spread, emittances and bunch repetition rate deviations with the maximal beam extraction efficiency in the full range of the electron beam energy variation. Measured main parameters of the accelerated beam and corresponding lasing results of the FIR FEL are presented and discussed.

[1] G.M. Kazakevitch et al., "Magnetron Driven Classical Microtron as an Injector for a Wide Band Tunable Compact Far Infrared Free Electron Laser," Proc. of PAC2001, pp. 2739-2741 (2001).

MO-P-37

KAERI Infrared FEL Driven by a 40-MeV Superconducting Accelerator

Byung Cheol Lee, Young Uk Jeong, Sung Oh Cho, Seong Hee Park (KAERI); Sergey Miginsky (BINP)

A high-average-power infrared free electron laser driven by a 40-MeV recirculating superconducting accelerator is being developed at the Korea Atomic Energy Research Institute (KAERI). The IR FEL system is composed of a 2-MeV injector and two 20-MeV superconducting accelerator modules, a FEL oscillator, and an energy recovery beamline. The average current of the recirculating electron beam is 10 mA. The resonance frequency of the injector is being modified from 180 MHz to 176 MHz. A 352-MHz superconducting accelerator module has been transported from CERN and is being installed and tested at KAERI. A 400-W, 4.5K cryogenic system has been constructed successfully. Two 50-kW, 352-MHz rf generators have been fabricated and are being installed. The injection beamline from the injector to the main acceleration cavity is being fabricated. Design of the recirculation beamline and the infrared FEL resonator is in progress.

MO-P-38

Design Studies of IR-FEL at IAE, Kyoto University

Isao Tometaka, Hideaki Ohgaki, Koshiro Yamane, Toshiteru Kii, Kai Masuda, Kiyoshi Yoshikawa, Tetsuo Yamazaki (IAE, Kyoto U.)

An infrared FEL facility for bio/chemical energy research is under construction at the Institute of Advanced Energy, Kyoto University. The electron beam of 30-40 MeV with macro-pulse length up to 3 μs will be generated by an S-band linac with a thermionic rf gun. A 4.5-cell rf gun and a 3-m accelerator tube have been installed, and measurement of beam characteristics is underway. For the first stage, the undulator installed is planar type of 4-cm period, period number of 40, and peak magnetic field of 0.25 T to obtain an IR-FEL with wavelength from 5 μm to 15 μm. The beam transport system is calculated with the TRANSPORT/TURTLE code and beam quality is estimated with the PARMELA and KUBLAI [1] codes. A simulation of the FEL has been made using the TDA3D computer code. The required electron beam parameters and design of the optical cavity will be discussed in this conference.

[1] K. Masuda, Ph.D thesis, Kyoto University (1997).

MO-P-39

Spectral Measurements of the Second Harmonic of the SASE FEL Radiation at APS*

Vadim V. Sajaev, Zhirong Huang (ANL)

We present the z-dependent spectral measurement results for the second harmonic of the SASE FEL radiation before and after saturation. The measurements were performed at the Advanced Photon Source FEL with a fundamental wavelength of 530 nm. The spectral properties of the second harmonic are compared with those of the fundamental and with the theoretical expectations.

* Work supported by the U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

MO-P-40

Regime of Nonresonant Trapping in FEM Amplifier*

Andrey V. Savilov, Ilya V. Bandurkin, Vladimir L. Bratman, Alexey E. Fedotov, Nikolay Yu. Peskov, Sergey V. Samsonov (Institute of Applied Physics)

A new regime is proposed for mm-wave free-electron amplifiers [1]. In this regime, electrons are far from the resonance with the wave at the beginning of the interaction region. Due to a tapering, the resonant energy decreases with the coordinate so that resonance is provided at an arbitrary point inside the coupling region. In this resonant point, the wave traps electrons due to deepening of the potential well, which is caused by increasing RF amplitude. Further tapering provides effective extraction of the energy of trapped particles. This regime is very insensitive to the spread in electron velocity; electrons with different velocities begin their interaction with the rf wave at different points of the coupling region. Since the resonant point of the coupling region is arbitrary, no resonant frequency is fixed in this system; this provides an ultrabroad frequency band. For various types of free-electron mm-wave amplifiers with weakly/moderately relativistic electron beams (FEL-ubitron, fundamental and high-harmonic cyclotron-resonance masers), theory of this regime, as well as schematics of near-future experiments are discussed. According to simulations, the proposed regime can provide simultaneously a high (over 50%) electronic efficiency and a broadband (tens percent) frequency tuning.

* This work is supported by the Russian Foundation for Basic Research (Grant No.02-02-17205) and by the Science Support Foundation.

[1] A.V. Savilov, Phys. Rev. E 64, 066501 (2001).

MO-P-41

Submillimeter Moderately-Relativistic Free-Electron Maser

Andrey V. Savilov, Nikolay Yu. Peskov (Institute of Applied Physics); Alim K. Kaminsky (JINR)

A number of experiments with moderately-relativistic (0.8-1.0 MeV) free-electron oscillators demonstrated a possibility for achieving high-power (tens of MW) mm-wave radiation with a high electron efficiency (over 20%) [1]. In these experiments, high electron efficiency and weak sensitivity to the electron velocity spread were provided by the use of the regime of "reversed" guiding magnetic field, when the direction of the electron rotation in a helical magnetostatic wiggler (and, correspondingly, the rotation of the circularly-polarized operating wave) is opposite to the cyclotron rotation in the guiding field. The feedback was provided by Bragg mirrors reflecting a part of mm-wave power back into the operating waveguide. As a development of these experiments, it seems attractive to use this backward mm wave as a "secondary" wiggler and provide its stimulated scattering on the electron beam into a forward submillimeter wave [2] exciting at a multiple frequency. An effective scattering can be achieved if the Bragg mirrors change the polarization of the mm wave. In this case, for the backward mm wave the guiding magnetic field becomes not "reversed" but "straight," and the electron wiggling increases. According to simulation, the proposed scheme can provide the output sbmm power of hundreds of kW.

* This work is supported by the Russian Foundation for Basic Research (Grant No.00-02-17232), by the Presidium of RAS, and by the Science Support Foundation.

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MO-P-42

Magnetic Field Analysis of Hybrid Helical Wiggler with Multiple Poles per Period

Yoshiaki Tsunawaki (Dept.of Electrical Engineering & Electronics, Osaka Sangyo University); Nobuhisa Ohigashi (Department of Physics, Kansai University); Makoto Asakawa (Institute of FEL, Osaka University); Kazuo Imasaki (Institute for Laser Technology); Kunioki Mima (Institute of Laser Engineering, Osaka University)

The free electron laser (FEL) at the Institute of FEL, Osaka University, has been operated in the wavelength regions of 5-22, 20-60, 1-6, and 0.23-1.2 μm by using four different wigglers and electron beams with three respective energies (30, 75, 165 MeV) in each wiggler. Thus both the electron beam energy and the period of the wiggler are selected according to the wavelength of FEL, i.e., in the infrared region these parameters are low and long, respectively. If the highest energy (165 MeV) of electron beam is used to radiate mid- to far-infrared FEL, a much longer period wiggler is necessary, but it is expected to make the electron beam enter into the wiggler more efficiently and obtain much higher power of FEL from the higher energy electron beam. When we apply a wiggler with a long period, such as >10 cm, it will be demanded to employ a wiggler with multiple poles per period in order to get a uniform sinusoidal magnetic field in it because a usual wiggler gives a flat-top distribution of the wiggler field. Based on our previous work on hybrid helical microwigglers [1,2], simulation analysis of the magnetic field has been, in this work, given to hybrid helical wiggler with multiple poles per period. In most simulations the period and gap length of the wiggler were assumed to be 14 and 2 cm, respectively, for FEL in the mid- to far-infrared. It was found that the number of poles, 8, 12 or higher, is suitable to get a uniform and high wiggler field around 1 T.

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[2] Y. Tsunawaki, Y. Masaki, Y. Okuda, M. Kusaba, N. Ohigashi, K. Imasaki and K. Mima, submitted to IEEE J. Quant. Electr.

TU-P-01

Calculations and Measurements of Electron-Beam Emittance in the Electrostatic Accelerator Free Electron Laser

Amir Abramovich, Yosef Pinhasi (The College of Judea and Samaria);
Mark Volshonok, Zakir Seidov, Avi Gover (TelAvivU)

The design of electron-optic devices requires knowledge of the electron-beam phase-space parameters like emittance and energy spread. Those parameters are ultimately limited by the parameters of the cathode, however imperfect electron-beam elements may increase the emittance significantly. This is especially the case when space-charge effects are involved. This is the case in the injector section of the accelerator where, due to the low energy of the beam, space-charge effects are significant.

An experimental and numerical simulation study of emittance growth in the injector of the electrostatic accelerator has been conducted by us in connection with upgrading of the Tandem FEL performance. Though electrostatic accelerators are expected to have very small emittance and energy spread (as demonstrated in the UCSB FEL facility), our preliminary experiments indicate emittance growth primarily in the injector section that includes four solenoids and a narrow tube. The effects on the e-beam phase-space distribution of electron-optical aberrations of the solenoids combined with space-charge effects and of "wake fields" along the tube, have been studied experimentally using the "Pepper-Pot" method. The results are compared to numerical simulations in the space-charge limited regime. The results of the study were used to simulate the e-beam propagation along the entire FEL structure and estimate its performance limitations.

TU-P-02

First Measurements at the Photo Injector Test Facility at DESY Zeuthen*

Juergen W. Baehr, PITZ Collaboration (DESY-Zeuthen)

The photo injector test facility at DESY Zeuthen (PITZ) was built to develop electron sources for the TESLA Test Facility Free Electron Laser (TTF-FEL) and future linear colliders. The main goal is to study the production of minimum transverse emittance beams with short bunch length at medium charge (~1 nC). The facility includes a 1.5-cell L-band cavity with coaxial rf coupler, a solenoid for space-charge compensation, a laser capable of generating long pulse trains, an UHV photocathode exchange system, and different diagnostics tools. Besides an overview of the facility, its main components, and their commissioning, this contribution will concentrate on the first measurements at PITZ with photoelectrons. This will include measurements of the transverse and longitudinal laser profile, charge and quantum efficiency, momentum and momentum spread, transverse electron beam profiles at different locations, electron bunch length, and probably first results on transverse emittance.

* The project is funded partially by the HGF Vernetzungsfonds.

TU-P-03

A Horizontal Test Facility for the BESSY FEL Superconducting Linac Cavities

Jens Knobloch, Wolfgang Anders, Rene Bakker, Dieter Krämer, Eberhardt Jaeschke (BESSY); T. Junqera, S. Bousson, H. Saugnac (IPN)

Superconducting TESLA cavities are planned for the booster and linac sections of the CW BESSY FEL*. A number of challenges and unknowns must be investigated prior to finalizing the design and parameter list. These include the demonstration of long-term, high-gradient CW cavity and rf coupler operation, the measurement and reduction of microphonics, the optimization of the input coupling, the precise rf regulation of very narrow-bandwidth cavities, and the investigation of the cryogenic parameters such as optimal bath temperature and achievable pressure stability. To enable systematic tests with rapid turnaround, BESSY is constructing a horizontal cavity test facility similar to the CRYHOLAB system developed at Orsay. This facility will enable the off-line testing of 9-cell TESLA cavity pairs with all the ancillary devices needed for the final linac. Included are the helium tank, tuner, input coupler, HOM couplers, and monitor probe. Piezo stacks will be integrated in the tuner system to both study and cancel out microphonics to minimize the required rf power. First cavity tests are planned for late 2003.

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TU-P-04

A Composite Open Resonator for Compact X-ray Source

Evgueni G. Bessonov, Ruslan M. Fechtchenko (Lebedev Physical Institute RAS)

We consider a composite open resonator consisting of two mirrors. The reflectivity of the first mirror and the main part of the second mirror is R1. The second mirror has a circular insertion at the axis of the resonator made from another material with the reflectivity R2, where $1-R1 << 1-R2 << 1$. The radius of the insertion "a" is much less than the radius "w" of the fundamental mode of the resonator at the surface of the mirror. Both mirrors can be dielectric multilayer mirrors and the insertion part of one of two mirrors can be coated by Au. Such mirrors can be used in Laser-Electron storage rings where the backward Compton scattering of laser photons by electron beams is used for production of X-ray radiation. The main reason for degradation of one in two mirrors can be deposition of chemical components on the mirror surface by X-ray radiation. Below we calculate the dependence of finesse of such a composite resonator on the ratio "a/w" and show that when dimension of the insertion is larger then the effective transverse dimension of the X-ray beam and much less than the diameter of the fundamental mode, then the mirror degradation time can be increased to a great extent and the finesse of the resonator can be decreased unessentially.

TU-P-05

Advances in High-Brightness Electron Guns for FEL Drivers at AES*

Alan M.M. Todd, Hans P. Bluem, Michael D. Cole, John Rathke, Tom Schultheiss (AES)

Advanced Energy Systems has a number of projects involving the development of advanced, high-brightness electron guns. Each of these guns is suitable as an injector for an advanced FEL. These projects include a fully superconducting, CW RF gun that utilizes the niobium surface as the photocathode material. This gun is presently being fabricated with testing scheduled for Spring 2002. Another project involves an integrated DC/SRF gun that is ideal as an injector for ERL-type light sources in addition to a CW FEL. This injector is in its late design stage. In the early stages of design is a high-power, CW, normal-conducting L-band RF gun. The performance figures for this gun show good promise for its use as a high-brightness injector. Lastly, a fully axisymmetric RF gun, operating in X-band, is being studied as a source of extremely bright electron bunches. The FEL applications span the range from compact, lower power CW FELs through high-power CW FELs and SASE FELs.

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TU-P-06

Electro-Optic Sampling of Single Electron Beam Bunches of Ultrashort Duration*

Paul R. Bolton, Jym E. Clendenin, David H. Dowell, Patrick Krejcik, Jeffrey Rifkin (SLAC)

For the Linac Coherent Light Source (LCLS)at SLAC, relativistic electron beam bunches entering the undulator section are designed to be of ultrashort duration and single-bunch diagnostics become important. The nonradiative radial field of a single bunch can be sampled noninvasively using known electro-optic techniques. This has been demonstrated with 46-MeV electrons of 1.7 picosecond duration using the electron bunch field as the bias source for inducing dynamic birefringence that is attributed to the Pockels effect in electro-optic crystals [1]. In this work the chirped laser probe pulse provides the time-frequency correlation needed to extract the time-dependent beam field for a single bunch and therefore also the longitudinal charge density distribution. Although diagnostic capability for ultrashort time resolution is available, ultrafast beam dynamics can impose limitations on this spectral method. Differences between probe group velocities and the beam field phase velocity in a crystal for a copropagating geometry become more significant in the ultrashort case. Also, rapid temporal variations of refractive indices can impose additional phase modulation on the probe waveform inducing spectral shifts that can exceed the original probe bandwidth. These behaviours indicate the need for ultrafast time-dependent spectral data in diagnosing ultrashort electron bunches. The effects of ultrafast single-bunch dynamics on electro-optic sampling schemes will be presented.

* SLAC is operated by Stanford University for the Department of Energy (DE-AC03-76SF00515).

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TU-P-07

Investigation of Short Pulse Effects in IR FELs and New Results of Their Simulation *

Marco Brunken, Lars Casper, Harald Genz, Christoph Hessler, Sergiy Khodyachykh, Achim Richter (TU-D); Giel Berden, Maria Grigore, Alex F. G van der Meer (FOM); Vivek Asgekar (Department of Physics, University of Pune, Pune 411 007, Maharashtra, India)

The Darmstadt IR FEL is designed for generating wavelengths between 3-10 μm and driven by the superconducting electron linear accelerator. The pulsed electron beam has a peak current of 2.7 A leading to a small signal gain of 5%. Currently investigations of the energy transfer process in the undulator using the 1-dimensional time-dependent simulation code FAST are performed. We will present simulation results for the spectrum, the pulse duration, and the efficiency for different desychronisations and tapering parameters and a comparison with experimental data from the S-DALINAC IR-FEL and from FELIX. Furthermore, a compact autocorrelation system giving the possibility of a background free measurement of the optical pulse duration will be presented. The measurement was based on frequency doubling in a 2-mm-long $ZnGeP_2$-crystal yielding a time resolution of 300 fs and a conversion efficiency of 5% in a first test experiment at FELIX.

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TU-P-08

Spectral Properties of Two Harmonic Undulator Radiation and Their Influence on FEL Performance

Sandra G. Biedron (ANL); Franco Ciocci, Giuseppe Dattoli, Giuseppe Felici (ENEA); Henry P. Freund (NRL); Stephen V. Milton (ANL); Pier Luigi Ottaviani (ENEA)

We discuss the Two Harmonic Undulator (THU), a tool conceived to enhance the higher harmonic generation. We consider two different schemes: the plane parallel and plane perpendicular configurations and analyze the relevant design details. We study the spectral features of the radiation emitted in these magnets by ultrarelativistic electrons and the associated FEL dynamics, both for oscillator and single-pass SASE devices. We present a complete analysis of the coherently generated harmonics by discussing the advantages on normal configurations.

TU-P-09

Experimental Studies of Advanced Photocathodes*

D. W. Feldman, P. G. O'Shea (UMD); K. L. Jensen (NRL); M. Virgo (UMD)

We have begun a program to develop dispenser cathodes for use in high-power rf photoinjectors. The dispenser cathode has a number of advantages for photoinjectors, including the ability to be rejuvenated *in situ* without the complexity of extraction and insertion apparatus, and to operate at temperatures high enough to retard the adhesion of deleterious species from the environment. Much technological development has gone into the evolution of the dispenser cathode for themionic emission, but with little attention to its photoemissive proerties. We [1] and other investigators [2] have carried out preliminary studies of the photoelectric properties of several types of dispenser cathodes. The results to date are suffiently encouraging to warrant the further exploration of this technology. We will be studying some existing varieties of cathodes, and plan to develop cathode configurations involving new and promising components, We will describe our results to date and our plans for our future theoretical [3] and experimental efforts.

* This work supported by The Joint Technology Office/Office of Naval Research and The Naval Research Laboratory

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[2] B. Leblond, Nucl. Instrum. Methods A317 (1992) 365-372.
[3] K. L. Jensen et. al., "Theory and Simulation of Advanced Photo-Cathodes," these proceedings.

TU-P-10

Undulator System for the VUV-FEL at the TESLA Test Facility - Phase 2

Bart Faatz, Ulrich Hahn, Joachim Pflueger, Markus Tischer (DESY-Hamburg)

The Phase-1 of the VUV FEL at the TESLA Test Facility finishes in 2002. Phase-2, an extension of Phase-1 to shorter wavelengths as low as 6 nm, is under construction and will be ready for operation in 2003. A radiation wavelength of about 6 nm could be obtained using the same undulator and raising the electron energy to 1 GeV. Compared to Phase-1, six instead of three undulator segments will be needed, doubling the total length to almost 30 m. Instead of the integrated focusing system, a separated electromagnetic doublet structure will be installed. This requires substantial changes in the layout of the undulator system. We report about these changes of the undulator, the undulator vacuum system, the quadrupoles with their special alignment systems, and the modified monitor system consisting of pick up monitors and wirescanners.

TU-P-11

A Device for the Enhancement of the Micro-pulse Peak Power and the Shortening of the Macro-pulse Duration

Hisanao Hazama, Keiji Nomaru (KHI); Haruo Kuroda, Koji Nakai (SUT)

In the case of the mid-infrared FEL apparatus (MIR-FEL) now in operation in the IR FEL Research Center of the Tokyo University of Science (FEL-SUT), the micro-pulse peak power is up to about 5 MW with the duration time of 2 ps and the repetition frequency of 2856 MHz, and the macro-pulse duration is about 1 \mus. However, some applications of MIR-FEL require a much higher micro-pulse peak power, and at the same time, a significantly shorter macro-pulse duration. We have developed a Q-switching device for increasing the micro-pulse peak power to about one hundred times of the above-mentioned value and for shortening the macro-pulse duration. The device is composed of a Pockels cell with a CdTe crystal and Brewster windows made of germanium, and they have been installed into the optical resonance cavity of MIR-FEL. By operating this device, the micro-pulse peak power is expected to be a few hundreds megawatts with the macro-pulse duration of 23 ns, within an operating wavelength range of 5-8 μm.

TU-P-12

Proposal for the Edge Focusing Wiggler for SASE

Goro Isoyama, Masahiro Fujimoto, Ryukou Kato (OsakaU);
Shigeru Yamamoto, Kimichika Tsuchiya (KEK)

We are developing a new type of wiggler with strong focusing force, named the edge focusing (EF) wiggler, which is a Halbach-type wiggler made with permanent magnet blocks with an edge angle f. The three-dimensional magnetic field in such a wiggler is calculated with the magnetic charge method, and the focusing force is evaluated by calculating electron trajectories in the magnetic field. An application is given for SASE in the shorter wavelength region, and it is shown that the electron beam size is made considerably smaller with the alternate focusing scheme using the EF wiggler.

TU-P-13

Advanced Photocathode Simulation and Theory*

*Kevin L. Jensen**, Patrick L. O'Shea, Donald W. Feldman (UMD)*

A low-work-function dispenser-type photocathode that is self-annealing or repairing would have a substantial impact on free electron lasers (FELs). On such a cathode, the emitting surface is constantly renewed by replenishment of low-work-function material. A photo-dispenser cathode should operate at a relatively low temperature compared to a conventional dispenser cathode (but higher than a metal photocathode to improve lifetime), and is anticipated to be robust and long-lived. Coatings cause a reduction in the transport barrier experienced by the electrons through a complex modification of the potential at the surface, e.g., a reduction in work function due to dipole effects. In this work, we address several such theoretical components in the theory and simulation of advanced photocathodes as part of a program, concurrent with experimental efforts [1], to develop dispenser cathodes for use in high power rf photoinjectors. Issues in a theoretical description of the emission process include: the nature of the energy distribution of the photo-excited electrons (used, e.g., in beam formation and emittance growth simulations); methods to model emission; the dependence of the emitted current on coverage; the nature of the low-work-function coating (and its effects on the emission barrier); and environmental conditions such as background pressure and operational temperature. Developments in and the status of these emission models will be the subject of the present work.

* This work supported by Joint Technology Office/Office of Naval Research and the Naval Research Laboratory.

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[1] D. W. Feldman et al., "Experimental Studies of Advanced Photocathodes," these proceedings.

TU-P-14

Integrating a Machine Protection System for High-Current Free Electron Lasers and Energy Recovery Linacs*

Kevin Jordan, James Coleman, Richard Evans, Al Grippo (TJNAF)

A fully integrated Machine Protection System (MPS) is critical to efficient commissioning and safe operation of all high-current accelerators. The MPS needs to monitor the status of all devices that could enter the beam path, the beam loss monitors (BLMs), magnet settings, beam dump status, etc. This information is then presented to the electron source controller, which must limit the beam power or shut down the beam completely. The MPS for the Jefferson Lab FEL generates four different power limits, or beam modes, which are passed to the drive laser pulse controller (DLPC) (photocathode source controller). These range from no beam to 2 megawatts of electron beam power. Automatic masking is used for the BLMs during low-power modes when one might be using beam viewers. The system also reviews the setup for the two different beamlines--the IR path or the UV path--and will allow or disallow operations based on magnet settings and valve positions. This paper will describe the approach taken for the JLab 10-kW FEL.

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TU-P-15

The Fabrication of an S-band Linac Based FEL for Generating a Far Infrared Light Source at FEL-SUT

Hidehito Koike, Masaaki Sobajima (KHI); Vasilly M. Popik (SUT); Minoru Yokoyama, Fumihiko Oda, Masayuki Kawai (KHI); Kouichi Toyoda, Koji Nakai, Haruo Kuroda (SUT)

The FIR-FEL project group, a collaboration of Tokyo University of Science and Kawasaki Heavy Industry, Ltd. (KHI), has completed a design of an S-band linac based FIR-FEL device at a spectral range between 300 and 1000 micrometers in 2000. The FEL device has already been installed in the IR FEL Center at Tokyo University of Science in April 2002. Our optical resonator is composed of a waveguide with a gap of 4.5 mm and two cylindrical mirrors positioned among the waveguide surfaces in order to improve a slippage problem and diffraction losses. The waveguide makes a slippage length reduce and makes a lasing at the spectral range easier. The fabrication of the FIR-FEL device, rf components, linac, optical resonator, and beam transport line etc., are described in detail.

TU-P-16

A Pure-Permanent Magnet Undulator for a Far-Infrared FEL

Vinit Kumar, Sanjay Chouksey, Srinivas Krishnagopal (CAT)

We have designed and built a 5-cm period, 2.5-m-long (50 periods), pure-permanent magnet undulator using NdFeB magnets. We present details of the design of the undulator and results from field-mapping. We also discuss the use of this undulator for a far-infrared FEL.

TU-P-17

Status of IR FEL Research Center, FEL-SUT

Haruo Kuroda, Koji Nakai (SUT); Masayuki Kawai (Kawasaki Heavy Industry)

The IR FEL Research Center was established in April 1999 in the Noda Campus of the Tokyo University of Science as an FEL user facility for developing new applications of IR FEL. R&D concerned with infrared FEL machine is also carried out as a part of the activities of this research center. The whole research program that is going on in this research center has been named the FEL-SUT Project. A compact mid-infrared FEL machine, MIR-FEL, was constructed by Kawasaki Heavy Industry (KHI). The official commissioning of MIR-FEL was done in May 2001. Since then MIR-FEL has been stably providing light for application experiments. Examples of such research subjects are as follows: multiphoton dissociation of gaseous molecules, isotope separation of silicon, dynamic processes of vibrationally excited states of organic molecules, IR near-field scanning microscopy, laser ablation of materials by a micro-focus irradiation, and so on. The installation of another FEL machine, FIR-FEL, which covers the wavelength region of 300-1000 microns, is now going on. This paper gives an overview about the present status of the activities of the FEL-SUT Project.

TU-P-18

Design of the Mirror Switch-Yard for Duke Storage Ring FELs*

Gary Swift, Vladimir Litvinenko (DUKE)

The wide tunability range of the Duke storage ring FELs and rather narrow reflectivity bands of dielectric mirrors require frequent changes of the optical cavity mirrors. In this paper we present the design of the UHV system providing in-situ change of the mirrors for the OK-4 and OK-5 FELs. The system provides for loading and unloading of new and used mirrors and for fast in-vacuum change of the mirror sets. The 54-m-long optical cavity and small Rayleigh range put very stringent requirements on the accuracy of the angular positioning of the mirrors. We present the design of the system and the results of the prototype test.

* Work is supported by AFOSR grant F49620-00-10370.

TU-P-19

Observations of z-Dependent Microbunching Harmonic Intensities Using COTR in a SASE FEL*

A. H. Lumpkin, S. G. Biedron, R. J. Dejus, W. J. Berg, M. Borland, Y. C. Chae, M. Erdmann, Z. Huang, K.-J. Kim, J. W. Lewellen, Y. Li, S. V. Milton, E. R. Moog, V. Sajaev, B. X. Yang (ANL)

The interest in nonlinear generation of harmonics in a self-amplified spontaneous emission (SASE) free-electron laser (FEL) continues to grow as experimental results are reported. Complementary to such studies is the search for information on the electron beam microbunching harmonics as may be revealed by coherent optical transition radiation (COTR) experiments. An initial z-dependent set of data has been obtained with the fundamental at 530 nm and the second harmonic at 265 nm. The data were collected after every other undulator in an eight-undulator string. The SASE fundamental intensity is about 500 times the COTR fundamental, and the SASE second harmonic intensity is about 100 times the COTR second harmonic. Experiments have also been done with the SASE fundamental at 660 nm, which enables the UV-sensitive cameras to sense the second and third harmonics. The same system will be used on the COTR harmonics, and results will be presented as available.

* Work supported by U. S. Department of Energy, Office of Basic Energy Sciences under Contract No. W-31-109-ENG-38.

TU-P-20

Positioning System for the LCLS Undulators*

Oleg A. Makarov (ANL); Vladimir G. Tcheskidov (BINP); Emil M. Trakhtenberg (ANL)

The Linac Coherent Light Source (LCLS) Project includes the undulator subsystem that has 33 undulator magnetic structures each 3.4 m long. Positioning of the LCLS undulators along the undulator line with an accuracy of 50 microns in the vertical transverse direction is required. A prototype of the LCLS undulator has been built with a positioning system based on three stages with cam shafts. Two stages allow two-coordinate positioning and the third one is a one-coordinate stage. Each cam shaft produces reciprocating motion with a range of ± 3 mm. A servomotor with integrated brake, incremental rotary encoder, servo-amplifier, and controller (SmartMotor from Animatics Inc.) is used with a 100:1 ratio gear box to drive each cam shaft. Resolution of the motion control is about 0.05 micron. Wirewound potentiometers were installed to sense the cam shaft positions. The control program was developed using the Experimental Physics and Industrial Control System (EPICS). SmartMotors are connected in parallel through an RS-485 interface to the serial port of the computer. With this approach, the control system is easily expandable; up to 120 SmartMotors can be controlled with one serial port. An LCLS undulator positioning accuracy of about 10 microns is demonstrated.

* Supported by the U.S. Department of Energy, Office of Science, BES, under contract No. W-31-109-ENG-38.

TU-P-21

A 2-MV DC Electron Gun and Injector for High Power FELs with a Depressed Geometry

Eisuke J. Minehara, Ryoichi Hajima, Masaru Sawamura, Ryoji Nagai, Nobuhiro Kikuzawa, Nobuyuki Nishimori, Toshiyuki Shizuma (JAERI)

A 2-MV DC electron gun and injector system have been designed to construct a high power and compact FEL with a depressed geometry. The multi-generator stack to recover the decelerated beam energy, and photocathode and thermionic cathode options with very high repetition rate up to 0.5 GHz will be discussed.

TU-P-22

A 100-kW CW 1497-MHz Klystron Amplifier for the Jefferson Lab FEL Driver Accelerator

Albert Mizuhara (CPI, Inc.)

A 100-kW CW 1497-MHz Klystron Amplifier was developed to drive the cryogenic cavities in the injector stage of the FEL Driver Accelerator at Jefferson Lab. The measured saturated power output of the klystron was 112 kW CW at an rf input power of 0.32 W. The efficiency was 51%. The beam voltage is 33.5 kV and the beam current is 6.6 A. When installed in the accelerator, the klystrons will be operated at the 80-kW CW level in order to realize an incremental gain of 0.5 dB/dB required to allow tight regulation of the power output and phase. The tube is 58" (147 cm) long and the focusing solenoid is 18" (46 cm) in diameter. The diode electron gun contains a tungsten matrix cathode and the body assembly consists of six tunable rf cavities, a short length of output waveguide, a pillox window, and a WR-650 standard waveguide flange. To meet Jefferson Lab's requirement that the klystron be expecially rugged and robust, the entire klystron was designed to dissipate more power than normal. The collector was designed with a significant margin of safety and is capable of dissipating considerably more than the normal 220-kW DC beam power. A total of three klystrons were delivered to Jefferson Lab.

TU-P-23

Construction of Compact FEM Using Solenoid-Induced Helical Wiggler

Nobuhisa Ohigashi (Kansai University); Yoshiaki Tsunawaki (Osaka Sangyo University); Kazuo Imasaki (Institute for Laser Technology); Kunioki Mima (Institute of Laser Engineering, Osaka University)

This paper presents a prototype of a compact Free-Electron Maser (FEM) operated in a small scale laboratory. As the electron beam energy is lower, a stronger guiding magnetic field is also needed in addition to the wiggler field. A solenoid-induced helical wiggler consisting of staggered-iron-array sets inserted into a solenoid field is optimum [1] to satisfy this condition from the viewpoint of saving electric power restricted by the source capacity of the laboratory. In this work, we selected the wiggler period of 12 mm and then the wiggler field of 92 G was obtained in case of the solenoid field of 3.2 kG. In the first experiment, we choose the electron beam energy of 62-120 keV utilizing a conventional CW DC electric power source on the market. Ordinary theory of waveguide mode FEL suggests the oscillation at the wavelength region from 10 to 20 mm, and the output power is estimated about 10 W. The electron gun designed by the E-gun code is built in a vacuum chamber. The electron beam is thermally emitted from a LaB_6 cathode heated by a CO_2 laser [2]. At present, this compact FEM machine was constructed and the fundamental experiment has been proceeding.

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TU-P-24

Convenient Methods for Implementing Nonadiabatic Injection in a Helical Undulator*

Vitaly A. Papadichev (P.N. Lebedev Physical Institute)

Numerical calculations have been performed for three new correction systems to achieve precision nonadiabatic injection into a helical undulator [1-4]. These permit to avoid possible injection errors due to inexact winding at intersections of the correction and regular windings overlapping on one cylinder. The first system consists of an element for angular correction and one or two elements for correction of orbit displacement. All elements are placed successively before the regular winding, thereby excluding intersections. Displacement of the regular orbit is < 0.1% of its amplitude. The second system consists of a half-period of a double spiral with two closing semi-circumferences. It is wound on a cylinder of radius R_c, which is larger than for the regular winding R_r: R_c/R_r = 1.1 - 2.0. The current feeding the element is proportional to R_c/R_r. The third system uses correction elements in the form of flat rectangulars or circular turns, and also consisting of two arcs of a circumference and two segments of rectilinears on the cylinder generatrices. Correction elements consisting of arcs of spirals can be prepared by fashioning on lathes and, therefore, possess greater accuracy. The production tolerances have been calculated. The results can be employed for other parameters using similitude conditions.

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TU-P-25

End Field Formation in Planar Hybrid Undulators to Ensure Gap Independence of the First and Second Field Integrals *

Vitaly A. Papadichev, George V. Rybalchenko (P.N. Lebedev Physical Institute)

Magnetic field amplitude in pure permanent magnets (PPMs) or hybrid undulators is varied by changing the gap. It is necessary to ensure that for all gaps the first and second field integrals be very close to zero, especially in the XFEL project where dozens of undulator sections are to be used, each about 5 m long [1]. Since a high field amplitude is required, a hybrid undulator must be used. Field calculations were carried out using the "Radia" code [2]. In contradistinction to PPM undulators, hybrid ones require more sophisticated schemes of minimizing field integrals because of the essential three-dimensionality of stray fluxes which redistribute at the undulator ends with changing gap. Saturation of iron poles aggravates solution of the problem. Both effects were studied and several compensating methods were found. Parameters of the permanent magnets and iron poles of the first undulator period (end field forming one) were varied in order to change the form and mean value of the curves of the first and second integrals versus undulator gap.

* Work partially supported by INTAS under contract INTAS-97-32041.

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TU-P-26

Cerenkov Free Electron Maser for Industrial Applications

Christos Petichakis, Robert A. Stuart, Ahmed I. Al-Shamma'a, James Lucas (Univ. of Liverpool)

We have constructed a Cerenkov maser designed to operate at 16.9 GHz with an electron beam accelerated to 70 kV, using an alumina tube with internal radius of 3 mm and external radius of 5 mm. Although we have achieved nearly 100% transmission of a 100-mA electron beam over a distance of 54 cm using a solenoid longitudinal magnetic field, no interaction has been observed despite the fact that the theoretical small signal gain was expected to be 300%. We have carried out various tests to measure the dispersion curve associated with the Cerenkov device and have found that the alumina tube behaves as though it is uniaxial in that its dielectric constant is different along the axial direction compared with the radial to such an extent that the interaction expected at 70 kV does not occur but is located at a much higher voltage. It is suggested that this asymmetry in the dielectric constant of alumina tubing is due to the crystallisation process, which occurs during manufacture. In this paper, we will present the design and construction of a low-voltage Cerenkov FEM for industrial applications.

TU-P-28

Magnetic Analysis of the Arc Dipoles for the JLAB 10 kW Free Electron Laser Upgrade*

T. J. Schultheiss, V. A. Christina, J. W. Rathke (AES); G. H. Biallas, D. R. Douglas (TJNAF)

The infrared free-electron laser (IRFEL) at Jefferson Lab has achieved steady-state, 3- to 6-micron lasing at power levels over 2 kW. Efforts to upgrade this device to 10-kW operation over the next three years are underway. As a result of this success, free electron lasers must be considered an option for high-power applications. The required specifications include field quality of the dipoles to within 10^{-4} over large regions. The 180° dipole, a window frame style, includes an embedded path-length corrector and a diagnostic view port very near the "good field" region. The first magnet of the reverse bend pair, which are both H style magnets, designated the GX, is skewed in shape with full and half coil excitation to act as a switch between the IR and UV beamlines. This skewing along with the field quality requirements necessitates a complicated pole tip shape with dimensional variations of 0.001 inches. The second magnet of the reverse bend pair, designated GQ, requires a wider "good field" region than the other two magnets, resulting in a complicated pole tip shape as well. The details of the analysis, the design of the pole tips, and preliminary data are presented here.

* This work supported by the U.S. Deptartment of Energy, the Commonwealth of Virginia, the Office of Naval Research, the Laser Processing Consortium, the Joint Technology Office, and the Air Force Research Laboratory.

TU-P-29

Improvement of KHI FEL Device at FEL-SUT

Minoru Yokoyama, Fumihiko Oda, Keiji Nomaru, Hidehito Koike, Masaaki Sobajima, Hidenori Miura, Masayuki Kawai (KHI); Haruo Kuroda, Koji Nakai (SUT)

FEL lasing with the saturated power in the wavelength of 4-16 μm was achieved by using the KHI (Kawasaki Heavy Industries, Ltd.) FEL device. The macro-pulse length of the electron beam was improved by using the LaB_6 cathode instead of the dispenser cathode as a cathode of the OCS rf gun. The improvement led to saturation of the FEL power. The FEL energy within a macro-pulse was 2-40 mJ. In addition to it, the vertical position (the same direction as the electron beam from the cathode) of the rf-gun cathode was tuned. As a result, the FEL energy was increased to 2-65 mJ. This is due to the improvement of the beam emittance, which is measured in order to confirm that. The relation between the emittance and the FEL gain agrees well with the FEL theory.

TU-P-30

Total Reflection Mirrors for VUV Free Electron Lasers

Barbara Steeg, Josef Feldhaus (DESY-Hamburg); Sandra Jacobi (GKSS Geesthacht); Carsten Michaelsen (Incoatec GmbH, Geesthacht)

Reflecting optical elements with thin film coatings of very high radiation stability are required for FEL applications in the VUV and X-ray spectral region. In order to avoid radiation damage, coatings of low-Z elements with lowest possible absorption and high reflectivity have been investigated. Single-layer sputter-deposited carbon coatings have been prepared at GKSS and characterized at DESY using a soft X-ray reflectometer. For comparison, layers produced by several manufacturers have also been investigated. The micro-roughness of the coatings was measured with a scanning force microscope. Annealing experiments have been performed to test the thermal stability of the carbon films. The damage thresholds of sample coatings have been determined using the focused VUV FEL radiation beam at the TESLA Test Facility (TTF). The optical layout of the FEL user facility at the TTF is based on these results.

TU-P-31

Linac Pulse Synchronization and Time Control System for FEL

Andriy Styervoyedov, Mykhaylo Silkin, Yana Shashel (Kharkiv National University); Vladimir Farenik (Scientific Centre of Physical Technologies)

The pulse synchronization and time control system for various units and parts of a linear accelerator in many respects determines high characteristics and stability of beam parameters of accelerated particles. Especially high and stable beam characteristics are necessary for elaboration of FEL, where the pulse synchronization system has to provide a wide range and small step of program controlled intervals to start up electron source modulators, klystron microwave amplifiers, initiating generator, and also for other technological and scientific devices. The new synchronization and time control system structure, hardware, and software are presented in this article.

TU-P-32

Photon Beam Diagnostics for the FEL in the Second Phase of the TESLA Test Facility

Kai Tiedtke, Bart Faatz, Josef Feldhaus, Christopher Gerth (HASYLAB at DESY); Alexander Gottwald, Udo Kroth (Physikalisch-Technisches Bundesanstalt, Berlin); Ulrich Hahn, Ulf Jastrow (HASYLAB at DESY); Mathias Richter, Andrei Sorokin (Physikalisch-Technisches Bundesanstalt, Berlin); Barbara Steeg (HASYLAB at DESY)

Currently the energy upgrade of the TESLA Test Facility is being prepared. First user experiments at the FEL user facility are planned to start in 2004. In general the efficient use of the FEL radiation requires permanent information about the photon beam parameters like wavelength, pulse energy, beam position, timing, etc.. Therefore photon beam diagnostics with single-pulse resolution become an essential part of the experimental systems at the users' end stations. This contribution presents an overview of the online radiation diagnostics for the FEL user facility. A newly designed device including absolute, time-resolved intensity detector, beam position monitor, and gas absorber will be described in particular.

TU-P-33

Commissioning of Multi-Segmented Undulators at the TESLA X-ray FEL

Markus Tischer, Ulrich Hahn (DESY-Hamburg); Petr Ilinski (ANL); Joachim Pflueger, Horst Schulte-Schrepping (DESY-Hamburg)

Commissioning of the TESLA X-ray FEL undulator cells will start at low electron energy and long wavelength (~6 nm) corresponding to the bottom end of TTF phase II operation. Electron and photon diagnostic schemes will be used to monitor the beam trajectory through the various undulator segments. Furthermore, photon diagnostics have to control all undulator gaps and prove the phase tuning of adjacent segments. Using higher harmonics of the spontaneous radiation of individual undulator segments, the photon diagnostic station can cover a wide spectral range and will be able to cope with the progression towards lower SASE wavelength (~1 Å). The use of variable-gap undulators allows us to realize the photon diagnostic section in a single device located in the photon beamline downstream of the last undulator cell.

TU-P-34

A Transport and Diagnostic System for the IR Beam of ELBE

Thomas Dekorsy, Eckart Grosse, Manfred Helm, Wolfgang Seidel, Dietrich Wohlfarth, Andreas Wolf, Rudi Wuensch (FZR)

Starting in 2003 the undulators at the ELBE electron linac will produce infrared light in the range 3-150 microns by means of two permanent-magnet undulators. The beam will be delivered from one of the outcoupling holes in the resonator mirror through a diagnostic station into 6 laboratories over a distance of 20-35 m. The transport system includes vacuum pipes, diagnostic elements, and plane and curved mirrors reflecting the beam at an angle of 90°. Toroidal, gold-covered copper mirrors with radii of curvature in the ratio 1:2 ensure identical sagittal and tangential focal lengths. The designed transport system produces a beam waist at a selected spot in every laboratory representing a magnified image of the outcoupling hole. Spot size and position are independent of the wavelength. Linear polarization is expected to be conserved. To ensure the desired beam properties the transport system has been analyzed by means of various ray and wave optical models. The diagnostic system includes a multichannel optical spectrometer, various power detectors working in different power ranges and a second-order autocorrelator set-up measuring the pulse duration. The average FEL power can be continuously reduced by an attenuator. A polarization rotator allows one to change the polarization from horizontal to vertical. To reduce the micropulse repetition rate, a semiconductor plasma switch excited by a synchronized Nd:YAG amplifier will be installed.

TU-P-34A

Degradation of Resonator Optical Properties in UV Storage Ring Free Electron Lasers

David Garzella (CEA-Saclay); Alexandre Gatto (Fraunhofer Institut für Angewandte Optik und Feinmechanik); Philippe Torchio (Institut Fresnel Marseille, LOSCM, ENSPM, Domaine Universitaire de St Jérôme); Valerie Reita (ESPCI); Mauro Trovò (ELETTRA); Norbert Kaiser (Fraunhofer Institut für Angewandte Optik und Feinmechanik); Claude Albert Boccara (ESPCI); Marie-Emmanuelle Couprie (CEA-Saclay)

In storage ring free-electron laser oscillators, the fundamental processes leading to a degradation of the mirror properties, though already partially known, are not completely explained or prevented. This is prejudicial to a routine operation of the laser in the UV region between 190 and 350 nm, where especially third-generation SRFELs operate and laser performances have to be furthermore controlled. Synchrotron-radiation-induced degradation tests have been performed with identical mirrors on Super ACO and ELETTRA, for completely different irradiation conditions, respectively at 800 MeV and 2 GeV of beam energy, with planar and helical undulator configurations. The spectral and spatial content of the emitted radiation in a very broad photon energy range has been numerically evaluated, under the real irradiation conditions, then checked with direct measurements. In parallel, the environmental conditions (e.g., gas content in the chamber) have been checked and analysed during irradiation tests. Finally, optical and non-optical analysis characterization methods for the mirrors have been used before and after irradiation in order to correlate the degradation process to the different initial conditions. The results obtained on several sets of samples allowed us to retrieve a general behaviour, whatever the SR source and the environmental conditions are. This gives precious information on the control of mirror performances during the laser operation.

TU-P-35

Super-ACO FEL Oscillation with Longitudinal-to-Transverse Coupled Beam Dynamics

Christelle Bruni (CEA-LURE); David Garzella (CEA); Giovanni De Ninno (ELETTRA); Gian Luca Orlandi, Marie-Emmanuelle Couprie (CEA); Riccardo Bartolini, Cyril Rippon, Giuseppe Dattoli (ENEA)

An alternative operating point of the Super-ACO storage ring presents a dispersion function in the undulator straight section and a reduced momentum compaction factor with respect to the nominal one. The dispersion function expresses the link between the bending radius trajectory of a particle and its energy. The momentum compaction factor is the ratio between the relative trajectory deviation of a particle and its relative energy variation, with respect to the synchronous particle's one. The longitudinal-to-transverse electron beam dynamics coupling resulting from the dispersion function induces a modified dynamic of the Super-ACO Free Electron laser. The FEL characteristics, such as the FEL power, pulse duration, and detuning curve are presented and analysed in terms of storage ring FEL dynamics.

TU-P-36

Longitudinal Dynamics of a Detuned Storage Ring FEL

G. De Ninno (ELETTRA); D. Fanelli (KTH)

The longitudinal dynamics of a storage ring FEL strongly depend on the longitudinal overlap between the electron bunch and the light pulse at each pass inside the optical cavity. Different regimes for both the intensity and the centroid position of the laser distribution are displayed, depending on the detuning amount. While a considerable theoretical effort has been done in the past for characterising the laser pulse propagation close to the perfect tuning, an exhaustive theoretical analysis of the detuned FEL dynamics is still lacking. The aim of this paper is to investigate the temporal evolution of the laser longitudinal profile in different detuning conditions. In particular, the late time behaviour is explored to clarify the existence of a "real" stationary condition. For this purpose, a phenomenological model that contains all the relevant features of the laser-electron beam interaction is numerically studied.

TU-P-37

Q-Switching Operation of the UVSOR-FEL

Masahito Hosaka, Akira Mochihashi, Masahiro Kato, Jun-ichiro Yamazaki, Kenji Hayashi, Yoshifumi Takashima (Institute for Molecular Science); Hiroyuki Hama (TohokuU)

In the storage ring FEL, the CW output power is limited by the heating effect of the electron bunch due to the interaction with the FEL optical pulse. On the other hand, much larger peak power can be obtained using the Q-switching technique, because lasing is started from a completely damped state of the energy spread of the electron bunch. On the UVSOR, the Q-switching is performed by repetitive jump of rf frequency. In the method, the coherent synchrotron oscillation is excited due to the rf jump. However, the observed damping of the oscillation is faster than the calculated synchrotron damping by factor 100 and, therefore the influence on the FEL lasing is very small. We have carried out experiments in various conditions to investigate the damping process and found its strong dependency on the stored beam current in the storage ring. In the presentation, detailed experimental results and theoretical analysis will be shown.

TU-P-38

Duke FEL Storage Ring Upgrade, Commissioning and First Results

Mark Emamian, Joseph E. Faircloth, Steve Hartman, Vladimir N. Litvinenko, Stepan F. Mikhailov, Peter H. Morcombe, Owen W. Oakeley, Maurice E. Pentico, Igor V. Pinayev, Victor G. Popov, Gary Swift, Patrick W. Wallace, Ping Wang, Ying Wu (DUKE); Nikolai G. Gavrilov, Eduard O. Gorniker, Grigori Ya. Kurkin, Yuri G. Matveev, Victor M. Petrov, Igor K. Sedliarov, Oleg A. Shevchenko, Dmitri A. Shvedov, Alexei G. Tribendis, Nikolai A. Vinokurov, Pavel D. Vobly (BINP)

The Duke FEL Storage Ring proceeds through a series of upgrades. The first upgrade encompasses modification of the magnetic system, new power supplies for the quadrupoles, and upgrade of the vacuum system including installation of new TSP pumps in the straight sections. The goal of this upgrade is to raise the maximum electron energy in the ring from the existing 1 GeV to 1.2 GeV, to improve the vacuum in the arc sections of the ring and drastically improve operational reliability of the machine. The next upgrades will be installation of a 34-meter-long OK-5 FEL with four helical undulators, construction of a 1.2-GeV booster synchrotron for top-up injection, modification of the injection straight section for new injection scheme, and installation of a new rf system with higher-order mode damping. This paper presents the first results of commissioning of the Duke Storage Ring after the first upgrade, as well as the current status of the subsequent upgrades.

TU-P-39

Experimental Analysis of the Super-ACO FEL Power

Gian Luca Orlandi, David Garzella (CEA); Christelle Bruni (CEA-LURE); Cyrille Thomas (TU-E); Marie-Emmanuelle Couprie (CEA); Luca Mezi, Riccardo Bartolini, Cyril Rippon, Giuseppe Dattoli, Alberto Renieri (ENEA); Mauro Migliorati (Univ. Roma)

The average power of a storage ring FEL can be directly measured or inferred from the induced bunch length and concurrent energy spread. The experimental results are compared to theoretical models and numerical simulations.

TU-P-40

Self-Consistent Harmonic Generation in Storage Ring FELs

Cyril Rippon, Riccardo Bartolini, Giuseppe Dattoli, Luca Giannessi (ENEA); Christelle Bruni, Marie-Emmanuelle Couprie (LURE); Giovanni De Ninno (ELETTRA)

We explore the self-consistent harmonic generation in storage Ring (SR) FEL devices operating in the ordinary and optical-klystron configuration. We use a numerical code which accounts for the SR FEL longitudinal dynamics, includes the laser pulse propagation, and gives an accurate image of the phenomenology of instabilities associated with the laser-electron beam interplay. The coherent harmonic generation evolution is developed using the bunching parameter theory. The analysis we develop yields the turn-by-turn evolution of the harmonics and provides an accurate physical insight into their dependence on the intracavity laser power. Schemes which may enhance the coherently harmonic generated power are also considered, including an analysis of the existence of different regions of the cavity length detuning which may lead to a stable mode of operation of the harmonics. The results obtained are finally compared to experimental data.

TU-P-41

Observation of the Electron Beam and Free Electron Lasers in the Compact Storage Ring NIJI-IV

Norihiro Sei, Kawakatsu Yamada, Masato Yasumoto, Hiroshi Ogawa, Tomohisa Mikado (AIST)

Some instabilities were observed in the electron beam in the compact storage ring NIJI-IV, and they suppressed the increase of peak electron density in an electron bunch. The microwave instability especially influenced the electron bunch. Thus we replaced the old vacuum chambers with low-impedance ones last year. Although the effect of this improvement was confirmed as the shortening of the electron bunch, the details will be announced by the other presentation in this conference. Before this improvement, we also observed the bunch lengthening due to potential well distortion and the emittance growth due to intra-beam scattering. The FEL gain enhanced only a little when the beam current was over 10 mA in the single-bunch operation. In this presentation, we will explain the performance of the electron beam and the FEL in the NIJI-IV before the improvement.

TU-P-42

Improved Performance of the NIJI-IV FEL through Ring-Impedance Reduction*

Kawakatsu Yamada, Norihiro Sei, Hiroshi Ogawa, Masato Yasumoto, Tomohisa Mikado (AIST)

Compared with SASE FELs, storage ring FELs with an optical cavity have substantial advantages, such as narrow line width, fine lateral mode distribution, good coherence, and easy synchronism with the synchrotron radiation from dipole magnets and other insertion devices. This feature, in addition to their wide wavelength tunability, enables them to be excellent tools for both excitation and measurement in the photon-related science. At the AIST, we have been making efforts to obtain FELs at wavelengths ranging from infrared down to vacuum ultraviolet using a compact storage ring NIJI-IV. To increase the peak beam current and enhance the laser gain, we replaced ring vacuum chambers with new low-impedance-type ones over 75% of the ring circumference. As a result, the ring impedance was reduced from 20 ohm down to at least 2 ohm. Resultant suppression of bunch lengthening due to microwave instability has led to a higher gain. Right now the gain reaches ~8.5% at 200 nm for an average beam current of 15 mA, which can be more enhanced by increasing the beam current and the input power to the rf cavity. Considering the optical loss of cavity mirrors we can obtain, lasing at the wavelength below 200 nm (hopefully shorter than 190 nm) is expected.

* This work is supported by Peaceful Utilization Technology of Nuclear Energy from the Ministry of Education, Culture, Sports, Science and Technology of Japan.

WE-P-01

Status of the UCLA PEGASUS Injector

Gerard C. Andonian, Pedro E. Frigola, Sven Reiche, James B. Rosenzweig, Soren W. Telfer (UCLA)

The Pegasus plane wave transformer injector has been conditioned to 20 MW of rf power. Initial operations show a 15-MeV dark current beam that will be used for beam radiation studies. The redesign of a new LaB_6 cathode will allow for both thermionic emission and photoinjection operation. Experiments currently planned include beam instrumentation and SASE FEL.

WE-P-02

RF Commissioning of the Photo Injector Test Facility at DESY Zeuthen

Ilja Bohnet, Juergen Baehr (DESY Zeuthen); Stefan Choroba (DESY Hamburg); Vasily Dzhordzhadze (DESY Zeuthen); Klaus Floettmann (DESY Hamburg); Hans-Juergen Grabosch (DESY Zeuthen); Michael von Hartrott (BESSY); Zhenghong Li, Dirk Lipka, Vladimir Peplov, Bagrat Petrosyan (DESY Zeuthen); Jörg Rossbach, Stefan Simrock (DESY Hamburg); Frank Stephan, Anne Oppelt, Thorsten Thon, Rainer Wenndorff, Michael Winde (DESY Zeuthen)

The photo injector test facility at DESY Zeuthen was built to develop, operate, and optimize photo injectors for future free electron lasers and linear colliders. First photo electrons were produced in January 2002. Extensive conditioning work on the rf gun has been done in order to achieve high gradients for different pulse lengths and repetition rates. To increase the efficiency and safety aspects of the rf commissioning, an Automatic Conditioning Program (ACP) was developed. In addition, a Data Aquisition system (DAQ), which enables a deeper analysis of the commissioning work, was realized. The conditioning procedures, the specific diagnostic elements, and the achieved results will be described. Furthermore, dark current measurements under different conditions will be presented.

WE-P-03

Preliminary Physics Design and Start-to-End Simulation of a Linac Driver for the FERMI FEL Proposal*

Michael D. Borland (ANL); Carlo J. Bocchetta, L. Tosi (Sincrotrone Trieste)

together with the INFM and other Italian institutes, Sincrotrone Trieste has proposed and developed FERMI@ELETTRA in response to the Italian government's call for proposals from national institutes for a multipurpose pulsed laser X-ray source. Details of this proposal are described in a companion paper in this conference [1]. In the present paper, we describe the design requirements, methods, and results for the linac and transport lines for the 1.0-GeV and 3.0-GeV phases of the project. Design goals are a 1-nC beam with normalized slice emittance of less than 2 mm-mrad and slice current of 600 A (for 1 GeV) and 2.5 kA (for 3 GeV). We performed optimization of the position and parameters of the bunch compressors, the phasing of the accelerating structures, and the configuration of focusing elements. Start-to-end simulation of the photoinjector, linac, and transport lines has been performed using PARMELA and ELEGANT. We predict that coherent synchrotron radiation effects will be significant but tolerable.

* M. Borland's work is supported by the U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

[1] C.J. Bocchetta et al., "Overview of FERMI@ELETTRA A Proposed Ultra Bright Coherent X-ray Source in Italy," these proceedings.

WE-P-04

Field-Enhanced Photoelectric Emission

C. H. Boulware, C. A. Brau (VU)

Previous experiments in field-enhanced photoelectric emission using pulsed UV lasers have demonstrated current densities as high as 10^{11} A/m^2 [1]. This could have enormous consequences for the brightness of both DC and rf photoelectric electron-beam sources. The quantum efficiency is observed to approach unity for laser illumination at 266 nm (quadrupled Nd:YAG) and electric fields of the order of 10^{10} V/m. These results have been extended to 337 nm (N_2 laser) where it is found that the quantum efficiency is 10-20 percent. Although somewhat less than the quantum efficiency observed at 266 nm, this is much larger than the quantum efficiency (about 10^{-3}) observed at 355 nm (tripled Nd:YAG).

[1] C. Hernandez Garcia and C. A. Brau, Proceedings of the 2001 International Free-Electron Laser Conference.

WE-P-05

RF Photoelectric Injectors Using Needle Cathodes

John W. Lewellen (ANL); Charles A. Brau (VU)

Photocathode rf guns, in various configurations, are the injectors of choice for both current and future applications requiring high-brightness electron beams. Many of these applications, such as free-electron lasers, require beams with high brilliance but not necessarily high charge per bunch. Field-enhanced photoelectric emission has demonstrated electron-beam current density as high as 10^{11} A/m^2, with a quantum efficiency in the UV that approaches unity at fields on the order of 10^{11} V/m. These fields can be achieved in rf cavities by configuring the cathode in the form of a blunt needle. We present an initial study on the use of needle cathodes in photoinjectors to enhance beam brightness while reducing beam charge. Benefits include lower drive laser power requirements, easier multibunch operation, lower emittance, and lower beam degradation due to charge-dependent effects in the post-injector accelerator. These benefits result from a combination of a smaller cathode emission area, greatly enhanced rf field strength at the cathode, and the charge scaling of detrimental post-injector linac effects, e.g., transverse wakefields and CSR.

WE-P-06

Accelerator Physics Issues for High-Average-Power FEL Driver Linacs*

David R. Douglas, Stephen V. Benson, Carlos Garcia-Hernandez, Geoffrey A. Krafft, Rui Li, Lia Merminga, George R. Neil (TJNAF); Christopher Tennant (The College of William & Mary and TJNAF); Byung C. Yunn (TJNAF)

We discuss beam physics issues relevant to the design of high-average-power FEL driver linacs within the context of high-repetition rate, energy-recovering superconducting rf-based systems. Phenomena may include, but are not limited to, space-charge effects at low (injection and dump) energies, beam quality degradation due to coherent synchrotron radiation and environmental impedances, multibunch, multi-pass beam break-up and the dissipation of power by higher-order modes, instabilities induced by the FEL/rf interaction, and ion accumulation. Furthermore, transverse and longitudinal phase-space management and matching to meet stringent beam phase-space requirements at an FEL and successfully recover an exhaust drive beam with potentially large momentum spread, and beam halo loss control impose additional design constraints. These will be addressed from the perspective of the proposed Jefferson Lab 100-kW IR FEL driver [1].

*This work supported by the U.S. Department of Energy, the Commonwealth of Virginia, the Office of Naval Research, the Laser Processing Consortium, the Joint Technology Office, and the Air Force Research Laboratory.

[1] S. V. Benson et al., "Status of the Jefferson Lab IR/UV High Average Power Light Source," these proceedings.

WE-P-07

Slice Emittance Measurements at the SLAC Gun Test Facility*

David H. Dowell (SLAC); William S. Graves (BNL); Paul R. Bolton, Jym E. Clendenin, Paul Emma, Stephen M. Gierman, Cecile G. Limborg, Brendan F. Murphy, John F. Schmerge (SLAC)

The goal of the Gun Test Facility (GTF) at SLAC is to investigate the production of high-brightness electron beams for the Linac Coherent Light Source (LCLS) X-ray FEL. High brightness in the rf photocathode gun occurs when the slice emittance is nearly the same as the cathode thermal emittance and when the slices are all lined up, i.e., their Twiss parameters are nearly identical. To achieve this experimentally, it is necessary to measure the thermal and slice emittances as well as the relative orientation of the slices to determine the best gun performance. In collaboration with the BNL Source Development Lab (SDL) [1], we have begun a systematic study of the slice emittance at GTF. The technique involves giving the bunch a near linear energy chirp using the booster linac and dispersing it with a magnetic spectrometer. Combined with knowledge of the longitudinal phase space [2], this establishes the energy-time correlation on the spectrometer screen. The slice emittances are determined by scanning quadrupoles in front of the spectrometer. Spectrometer images for a range of quadrupole settings are then binned into small energy/time windows and analyzed for the slice emittance and Twiss parameters. Results for various gun parameters are presented.

* SLAC is operated by Stanford University for the Department of Energy (DE-AC03-76SF00515).

[1] W.S. Graves et al., "Experimental Study of Sub-ps Slice Electron Beam Parameters in a Photoinjector," these proceedings.

[2] D.H. Dowell et al., "Longitudinal Phase Space Measurements at the SLAC Gun Test Facility," these proceedings.

WE-P-08

Longitudinal Phase Space Measurements at the SLAC Gun Test Facility*

David H. Dowell, Paul R. Bolton, Jym E. Clendenin, Stephen M. Gierman, Cecile G. Limborg, Brendan F. Murphy, John F. Schmerge (SLAC); Timur Shaftan (BNL)

Proposed fourth-generation light sources using SASE FELs to generate short pulse, coherent, X-rays require demonstration of high-brightness electron sources. The Gun Test Facility (GTF) at SLAC was built to test high-brightness sources for the proposed Linac Coherent Light Source (LCLS) at SLAC. The longitudinal emittance exiting the gun has been determined by measuring the energy spectrum after the linac as a function of the linac phase. The phase-space parameters defining the beam pulse width, correlated energy spread, and slice energy spread at the linac entrance (~5 MeV beam energy) are fit to the measured energy spectra. The known longitudinal wake in the S-band linac is included in the analysis. Results at low charge (150 pC) indicate an 8% (full width) correlated energy spread with 0.15% (full width) uncorrelated energy spread and a 3-ps (FWHM) electron bunch for a 4-ps (FWHM) laser pulse width. These results are compared with those from the BNL Source Development Lab [1]. Possible explanations for the large correlated energy spread are discussed and results for various gun parameters are presented.

* SLAC is operated by Stanford University for the Department of Energy (DE-AC03-76SF00515).

[1] T. Shaftan et al., "Bunch Compression Technique in the SDL Linac," these proceedings.

WE-P-09

Transverse Self-fields within an Electron Bunch Moving in an Arc of a Circle

Gianluca Geloni, Jan Botman, Jom Luiten, Marnix van der Wiel (TU-E); Martin Dohlus, Evgeni Saldin, Evgeni Schneidmiller (DESY-Hamburg); Mikhail Yurkov (JINR)

Self-interaction within an electron bunch moving under the action of external forces may spoil the high brightness required for SASE-FEL operating in the x-ray regime. Here we present part of the results achieved in [1], which deals with transverse self-interactions. We address the problem of a 1D line bunch moving in an arc of a circle analytically and from a fully electrodynamical viewpoint. First, we consider a two-particle system to find exact and approximated expressions for the transverse force in all possible transient configurations. We report a very good agreement with TRAFIC4. Second, we consider the transverse interaction between a line bunch and a test particle moving in an arc of a circle. In particular, the case of injection from a straight section into a hard-edge bending magnet is treated. Exact and approximated expressions for the transverse force result, again in very good agreement with TRAFIC4. Finally, by simple composition of rectangular bunches, an expression for the calculation of the transverse interaction is found for the case of a bunch with arbitrary density distribution. Such expression is regularized to a formula independent of the distance between test particle and bunch by subtraction of the steady-state transverse self-interaction.

[1] G. Geloni et al., DESY 02-048, May 2002.

WE-P-10

Bunch Length and Phase Stability Measurements with Sub-picosecond Resolution at the TESLA Test Facility

Ch. Gerth, J. Feldhaus, K. Honkavaara, S. Schreiber (DESY-Hamburg); I. Will (MBI)

A Pump-Probe facility with sub-ps time resolution combining a soft X-ray SASE FEL and an optical laser is currently under development at the TESLA Test Facility (TTF) at DESY in the framework of an European project. Besides electronic synchronization of the optical laser to the rf master oscillator driving the FEL, a precise measurement of the time delay between the optical laser and FEL with sub-ps resolution is a crucial issue for the synchronization. Synchrotron radiation emitted from a dipole magnet reflects the charge density distribution of the electron bunch and can be used as a reference for the FEL pulse. A feasibility study has been done at TTF phase 1 using a high-resolution FESCA-200 streak camera. For sub-ps time resolution, dispersion effects of the spectrally broad-band synchrotron radiation have to be suppressed. Furthermore, the phase stability of the FEL pulses with respect to the rf master oscillator, which is a critical parameter for the design of the synchronization scheme, has been studied with a streak camera operating in synchro-scan mode.

WE-P-11

Measurements and Simulation of Surface Roughness Wake Fields

Markus Huening (DESY)

An experiment has been carried out at the TESLA Test Facility (TTF) linac to investigate the wake fields generated by picosecond electron bunches in narrow beam pipes with artificially roughened inner surface. The energy structure imposed on the bunches by the wake fields has been analyzed with a magnetic spectrometer. Strong harmonic wake field effects are observed. The experimental results are compared with predictions from several wake field models. Implications for future FEL projects are discussed.

WE-P-12

Design of Photocathode RF Gun for LEBRA FEL at Nihon University

Koichi Kanno, Isamu Sato, Ken Hayakawa, Toshinari Tanaka, Yasushi Hayakawa, Kazue Yokoyama, Takeshi Sakai, Ken'ichiro Ishiwata, Keisuke Nakao, Eiko Hashimoto (Nihon University)

Improvement and upgrading of the linac for the free electron laser (FEL) continue at Laboratory for Electron Beam Research and Application (LEBRA) of Nihon University. The present linac of the LEBRA FEL system, which achieved lasing in the near infrared region with a wavelength of 1.5 μm in May 2001, is composed of a 100-kV DC gun, a bunching system, three 4-m accelerator structures, focusing equipment, and various beam diagnostic equipments. The normalized emittance at the exit of the linac is 20 π mm-mrad. In the case of generating ultraviolet laser using the LEBRA FEL system, the electron beam emittance should be lower than obtained in the electron beam by the present LEBRA linac. In order to meet the requirement, a photocathode rf gun is designed. The rf gun cavity is an optimised structure using SUPERFISH, and the beam dynamics are computed by using PARMELA. In this paper, the results of these simulations are mainly presented, and the performace of the photocathode rf gun for LEBRA FEL is evaluated.

WE-P-13

Improvement of Electron Beam Properties by Reducing Back-Bombardment Effects in a Thermionic RF Gun

Toshiteru Kii, Koshiro Yamane (Kyoto Univ., IAE); Isao Tometaka (,Kyoto Univ., IAE); Kai Masuda, Hideaki Ohgaki, Kiyoshi Yoshikawa, Tetsuo Yamazaki (Kyoto Univ., IAE)

A thermionic rf gun is an economical solution to produce a high-brightness electron beam compared to a photocathode rf gun. However, long macro-pulse operation is very difficult because backstreaming electrons make the cathode temperature unstable. To improve beam qualities, it is important to clear a back-bombardment mechanism. We have developed a 2-D particle simulation code KUBLAI [1] and calculated the electron trajectories in an rf gun. We first evaluated backstreaming beam power by using an infrared radiation thermometer [2]. By using a 1-D thermal conduction model in cathode material [3], we found that the quite low energy backstreaming electrons affect surface temperature. Thus we attached several types of electromagnets to diverge backstreaming electrons and measure the cathode surface temperature and beam qualities. In this conference, effects of the electromagnet and improvement of electron beam properties will be discussed.

[1] K. Masuda, Ph.D. thesis, Kyoto University (1999).
[2] T. Kii et al., Nucl. Instrum. Methods A 475 (2001) 588.
[3] T. Kii et al., Nucl. Instrum. Methods, in press.

WE-P-14

PARMELA Simulations for S-Band Photoinjectors

Cecile G. Limborg, Jym E. Clendenin, Dave H. Dowell, Stephen M. Gierman (SLAC); William S. Graves (NSLS); John F. Schmerge (SLAC)

The Linac Coherent Light Source (LCLS) X-ray FEL is to be built at SLAC in 2006. The first acceleration stage of this machine includes a high-brightness rf photocathode gun, emittance compensation solenoids, and two S-band accelerating structures. The requirements of the photoinjector beamline are to produce a 1-nC, 10-ps electron bunch at 150 MeV with a normalized projected emittance smaller than 1.2 mm.mrad and slice emittances smaller than 1.0 mm.mrad for 80 slices out of 100. Using PARMELA, a new optimization of this beamline consistent with operation of the gun run with a peak rf field of 120 MV/m was studied. PARMELA is also used to define the ranges of admissible errors on tuning parameters for which beam performances stay within the LCLS requirements. Jitter tolerances needed for good shot-to-shot stability are described qualitatively and quantitatively. Requirements for the stability and uniformity of both the transverse and longitudinal bunch shapes at emission have been studied. Thorough comparisons between PARMELA simulations and experimental results both at the SLAC Gun Test Facility [1] and at the BNL DUVFEL [2] have been made. Difficulties in correctly modeling the initial emission process (thermal emittance and Shottky effect) are discussed. The relatively good agreement obtained between PARMELA results and experimental data (projected emittance, slice emittances, Twiss parameters, longitudinal parameters) is discussed.

[1] D.H. Dowell et al., "Longitudinal Phase Space Measurements at the SLAC Gun Test Facility," these proceedings.

[2] W.S. Graves et al., "Experimental Study of Sub-ps Slice Electron Beam Parameters in a Photoinjector," these proceedings.

WE-P-15

The Simulation Study on the Photocathode RF Gun

Shengguang Liu, Yonggui Li (IHEP-Beijing)

A photocathode rf gun with a resonant frequency of 2856 MHz is designed in BFEL. In order to enhance the focusing force on electron beam, the length of the half cell is lengthened and the flat surface of the cathode wall is displaced by a wall with a hollow hole. A single emittance compensation solenoid is installed just behind the exit of the gun. A series of simulation calculations on the gun has been done. The result is very successful. With the electron bunch of 1 nc,10 ps, the rms transverse emittance can attain to 1.2 mm.mrad, and the energy spread can attain to 5.56 MeV. In addition, a series of simulation results on the beam dynamics in the gun is presented.

WE-P-16

Experimental Investigations on Coherent Diffraction, Synchrotron, and Transition Radiation

Jan Menzel, Philippe Piot, Frank Stulle (DESY-Hamburg); Peter Schmüser (UHamburg)

We have explored some of the properties of diffraction, synchrotron, and transition radiation emitted in the coherent regime by the ultra-short electron bunches generated at the TESLA Test Facility of DESY, Hamburg. The photon pulses radiated by the electrons via (1) diffraction from an edge, (2) transition though an Al-coated silicon wafer, and (3) synchrotron radiation have been characterized with an instrumentation that incorporates a far infrared Martin-Puplett interferometer.

The electromagnetic pulse length, temporal shape, along with its polarization and spectrum were measured with various detectors ranging from a He-cooled bolometer to a standard pyroelectric infrared detector. Prior to its usage within the accelerator, the experimental response was characterized with a chopped black-body radiator.

WE-P-17

Development of a CW, High-Average-Current 700-MHz Photoinjector at Los Alamos

Dinh C. Nguyen, Patrick L. Colestock, Steven J. Russell, Richard L. Wood (LANL); John W. Rathke (AES); Sergey S. Kurennoy, Lloyd M. Young, Dale L. Schrage, Robert W. Springer (LANL); Joan E. Yater (NRL); Ross E. Muenchausen (LANL)

High-gain FELs require electron beams with high peak current, low emittance and energy spread. These qualities have been achieved with many rf photoinjectors operating at low duty factors. For applications that require a high average current, such as high-average-power FELs, more work is needed to increase the bunch charge and duty factor of the photoinjector. The principal challenges for a high-duty-factor photoinjector are: 1) a high accelerating gradient necessary to control space charge, 2) cooling of the accelerating cavities, and 3) a photocathode with reasonable Q.E. and good stability. We present the design of a 700-MHz photoinjector with emittance compensation to produce 5 nC at 10.94 MHz. The design is based on a standing-wave, π-mode, 5.6-cell integrated structure. The cavities will have internal cooling passages for high-velocity flows of liquid nitrogen or water. The photoinjector's operating parameters are determined with the help of analytic calculations and simulations. Preliminary PARMELA calculations show a normalized rms emittance of 10 mm-mrad at 7 MV/m in the first cavity. We also investigate the cesiated silicon carbide with cesium dispenser and $In_xAl_yGa_{(1-x-y)}N$ as promising photocathodes for the high-current photoinjector.

WE-P-18

The SPARC Project: A High-Brightness Electron Beam Source at LNF to Drive a SASE-FEL Experiment

Luigi Palumbo (INFN-LNF and Universita' di Roma)*

The Project SPARC (Sorgente Pulsata e Amplificata di Radiazione Coerente), proposed by a collaboration among ENEA-INFN-CNR-Universita' di Tor Vergata-INFM-ST, was recently approved by the Italian Government. The aim of the project is to promote an R&D activity oriented to the development of a coherent ultra-brilliant X-ray source in Italy. SPARC collaboration identified a program founded on two main issues: the generation of ultra-high peak brightness electron beams and of resonant higher harmonics in the SASE-FEL process. The SPARC project is being designed in order to encompass the construction of an advanced photoinjector producing a 150-MeV beam to drive a SASE FEL in the optical range. The machine will be built at LNF, inside an underground bunker: it is comprised of an rf gun driven by a Ti:Sa laser to produce 10-ps flat-top pulses on the photocathode, injecting into two SLAC accelerating sections. We foresee conducting investigations on the emittance correction technique and on the rf compression technique, which are expected to increase the peak current achievable at the gun exit up to a few-kA level, with proper preservation of the transverse emittance. Although the system is expected to drive a FEL experiment, it will be used also to investigate beam physics issues like surface-roughness-induced wakefields, bunch-length measurements in the sub-ps range, emittance degradation in magnetic compressors due to CSR, and Compton backscattering production of sub-ps X-ray pulses.

* On behalf of the SPARC Project Group.

WE-P-19

A Fast Method to Estimate the Gain of the Microbunch Instability in a Bunch Compressor

Sven Reiche, James B. Rosenzweig (UCLA)

To reach high peak currents driving free-electron lasers, an initial chirped electron bunch is compressed in a bunch compressor. The interaction of the electron beam with its radiation field can yield a collective instability, which amplifies any initial modulation in the current profile. We present a model, which allows derivation of an explicit analytical expression for the gain of the microbunch instability. The results are compared to those of the more complex analytical models.

WE-P-20

Physics Design of a High-Average-Current, 700-MHz Photoinjector

Steven J. Russell, Dinh C. Nguyen, Lloyd M. Young, Patrick L. Colestock (LANL)

Recently, Los Alamos has investigated the practicality of a high-average-current (≤ 100 mA), 75-MeV electron accelerator for driving a high-average-power free electron laser. As part of this effort, we have undertaken the design of a high-average-current, 5-MeV photoinjector. The injector is a standing wave structure resonant at 700 MHz operating in the π mode. It is capable of an average current of 100 mA with a nominal charge per electron bunch of 3-5 nC and a normalized emittance less than 10 mm-mrad. Because the rf to the injector is CW, cooling of the photoinjector structure is a significant challenge. As a result, practical limits are placed both on the shape of the injector cavities and the average gradient at which they can operate. In turn, these restrictions present imposing obstacles to obtaining adequate beam quality.

WE-P-21

VUV FEL Driven RF Gun

Bart Faatz (DESY-Hamburg); Anatoly A. Fateev (JINR); Klaus Floettmann, Dirk Nölle, Philippe Piot, Evgeny L. Saldin, Holger Schlarb, Evgeny A. Schneidmiller, Siegfried Schreiber (DESY-Hamburg); Daniele Sertore (INFN-LASA); Kirill P. Sytchev, Mikhail V. Yurkov (JINR)

In this paper we describe a regeneration of electron bunches from the rf gun by back-reflected radiation from the VUV SASE FEL at the TESLA Test Facility (TTF) at DESY. The SASE FEL was running at the wavelength 96 nm with 30-100 fs pulses, a pulse energy was up to 10-20 μJ. "Nominal" electron bunches for lasing were produced by the rf gun with a Cs_2Te photocathode driven by a UV quantum laser system. "Parasitic" bunches with a charge up to 1-1.5 nC were extracted from the rf gun due to the VUV FEL radiation reflected from the mirror (placed downstream of the undulator) to the cathode. These bunches were separated from "nominal" ones by 650 ns (round-trip time between the mirror and the cathode) and were detected by toroids and beam position monitors of the TTF linac. Nontrivial dependence of a charge on a SASE pulse energy was found.

WE-P-22

Bunch Compression in SDL Linac

T. Shaftan, J. Wu, W. Graves, H. Loos, A. Doyuran, L. H. Yu, E. D. Johnson, S. Krinsky, J. Rose, B. Sheehy (BNL); D. H. Dowell (SLAC)

Electron bunch compression is critical to achieving the high peak currents required for efficient short wavelength FEL operation, but its success may depend sensitively on a number of parameters. From energy spectra of uncompressed bunches, we can characterize the longitudinal phase space (including bunch length, energy spread, and energy chirp) of these bunches as a function of the injector parameters. These data serve as initial conditions in our simulations, which are then compared to our measurements of compressed bunches made using the chicane bunch compressor in the SDL at the NSLS (BNL).

WE-P-23

Beam Dynamics in a 10-μm Linear Accelerator

Yury K. Alekseev, Alexey M. Gorokhov (MSU, Physics Department); Vasiliy I. Shvedunov, Andrey A. Vetrov (MSU, Institute of Nuclear Physics)

We have simulated beam dynamics in a 10-μm high-gradient linear accelerator. We studied low emittance beam generation with an autoemission cathode gun and its capture into acceleration by a graded-b structure. For relativistic beam we analyzed a rf quadrupole beam focusing in a 0.5-TeV maximum energy accelerator, calculated transverse and longitudinal wake fields, and got limits for charge which could be accelerated in this laser wavelength accelerator. Our results are applicable for different types of accelerating structures, including one based on the open resonator.

WE-P-24

Results of Beam Parameter Measurement of the ELBE Electron Accelerator after Commissioning

Jochen Teichert, Andree Buechner, Pavel Evtushenko, Frank Gabriel, Ulf Lehnert, Peter Michel, Joerg Voigtlaender (FZR)

The ELBE accelerator, an electron linac with superconducting cavities, is designed for a beam energy of 40 MeV, a CW current up to 1 mA, and a maximum bunch charge of 77 pC. After acceleration, the electron beam will be used to generate a variety of electromagnetic radiations with different wavelengths. Two FELs will deliver coherent infrared radiation, monochromatic x-rays will be produced by means of a channeling target and MeV photons with a bremsstrahlung target. Furthermore, converter targets for neutron and positron production will be installed. For the first commissioning tests, the injector with a thermionic gun, one cryomodule with two nine-cell cavities, and a diagnostic beamline were in operation. Energy and energy width were determined with a magnetic spectrometer. Transverse emittance measurements were carried out with a pepper-pot mask in the injector and with the quadrupole scan method for the accelerated beam. Bunch length was determined from the autocorrelation function of the coherent transition radiation with a Martin-Puplett interferometer. The results of these beam parameter measurements will be presented and evaluated.

WE-P-25

New E-gun Shape for Bunch Formation

Raphael Tumanian (Yerevan Physics Institute)

The possibility of bunch transverse compression by optimization of the e-gun cathode shape is considered. It is shown for the first time by theoretical and numerical investigations, that the cathode shape is possible, which offers a possibility to manage and to decrease the obtained bunch transverse sizes. The influence of space charge forces on the bunch sizes is taken into account.

WE-P-26

New Fast Method of Charged Particle Beams Cooling

Raphael Tumanian (Yerevan Physics Institute)

The charged particle beam average dynamics study results in the autoresonant laser (cyclotron maser) [1] are used for cooling of light and heavy charged particle beams. Base on averaged beam dynamics equations, the enhancement of resonant laser cooling is considered by use of the inhomogeneous magnetic field. For the first time it is shown that a new and very fast cooling method of various beams in different accelerators is possible due to laser wave-beam interaction in the presence of homogeneous or inhomogeneous magnetic fields. This result is very important, especially for electron and muon linacs, for those are lacking efficient cooling methods. The possibility of heavy particle beam cooling is investigated also.

[1] R.V. Tumanian, submitted to COOLING2002, Wisby, Sweden, 8-12 June 2002.

WE-P-27

Wake Fields, Charge Image Forces and Particles Dynamics of the Bunch in the Waveguide

Raphael V. Tumanian (Yerevan Physics Institute)

The influence of the waveguide on the recirculating beam of ERL is considered. Wake fields of the beam in the various waveguides and their effects on the beam motion, stability, and parameters are investigated. Charge image forces and their effects on the beam motion and parameters are taken into account. The values of these forces and conditions of their acting on the recirculating beam are illuminated.

WE-P-28

High-Brightness Electron Beam Generation from Mg Cathode

X. J. Wang, M. Babzien, R. Malone, Z. L. Wu (BNL)

The performance of the S-band 1.6-cell photocathode rf gun with a Mg cathode is presented in this report. The cathode was installed in 1999 and has been in routine operation at the Brookhaven Accelerator Test Facility (ATF) with quantum efficiency of 0.3% at an operating vacuum better than nanotorr. The ATF photocathode rf gun with the Mg cathode has provided more than 5000 hours user beam time in the last three years; the success of the High-Gain Harmonic-Generation (HGHG), Stella, and VISA experiments are the best illustrations of ATF high-brightness electron beam performance. Systematic measurements of electron beam transverse emittance, such as function of the rf gun phase, emittance compensation solenoid magnet field, and laser spot sizes, reveals that the thermal-emittance Mg cathode is much smaller than the popular theory predicted. Our data shows the upper limit of the thermal emittance of the Mg cathode is less than 0.4 mm-mrad. Furthermore, emittance for a 0.5-nC charge electron beam was optimized at 45 MeV. The optimized rms normalized emittance for a 0.5-nC charge is 0.7 ± 0.2 mm-mrad. Our experimental data demonstrated that an S-band 1.6 photocathode rf gun with a Mg cathode can deliver the beam required for proposed X-ray FEL projects around the world.

WE-P-29

Experimental Characterization of Surface Roughness Wakefield at the ATF

F. Zhou (BNL and UCLA); J. H. Wu, X. J. Wang, M. Babzien, I. Ben-Zvi, R. Malone, J. B. Murphy, M. H. Woodle, V. Yakimenko (BNL)

A surface roughness wake field from the long narrow undulator vacuum chambers of the proposed X-ray FEL projects could have significant impact on their performance. Theoretical and simulation studies offer quite diversified predictions based on the various assumptions. A surface roughness wake field experiment was carried out at the Brookhaven Accelerator Test Facility (ATF) to verify these theoretical predictions. Four one-meter-long beam tubes with internal diameters of 6 mm were employed in our experiment. Each was tested independently. The first beam tube is a regular beam pipe and is mainly used for baseline comparison. For the two tubes with periodic distributed bumps, the measured energy spread and energy loss agree with the model expectations that include both inductive impedance and a synchronous mode. For the tube with randomly distributed bumps, the energy spread agrees well with the inductive-impedance model prediction only, and energy loss is significantly reduced compared to that in the tube with periodic bumps. The synchronous modes decay significantly due to the randomization of the roughness pattern and cannot survive in the random roughness. This result contradicts the previous published experiment results and theoretical model [1-3]. The previous results can be valid only for the smaller aspect ratio, while the aspect ratio for a realistic situation is larger than 100.

[1] A. Novokhatski, A. Mosnier, PAC97, Vancouver, 1997.
[2] A. Novokhatski et al., Proc. of ICAP98, Monterey, September 1998.
[3] M. Hüning et al., Phys. Rev. Lett. 88, 074802 (2002).

WE-P-30

CW RF Cavity Design for High-Average-Current Photoinjector for High Power FEL

Sergey S. Kurennoy, Richard L. Wood, Lloyd M. Young (LANL); John Rathke, Mike Cole, Tom Schultheiss (AES)

This project is a coordinated effort among NAVSEA, LANL, and AES to develop a key enabling technology for high-power FEL called for by the HEL JTO: a high current rf photoinjector capable of producing continuous average current greater than 100 mA. The specific aim is a π-mode, normal-conducting rf photoinjector, 5 nanocoulombs of bunch charge, 100 milliamperes of current (at 21.88-MHz bunch repetition rate), and emittance less than 10 mm-mrad. This level of performance will enable robust 100-kW-class free-electron laser (FEL) operation with electron beam energy <100 MeV, thereby reducing the size and cost of the FEL. This design is scalable to the MW power level by increasing the electron bunch repetition rate from 21.88 MHz (the 32nd subharmonic of 700 MHz) to a higher value. The major challenges are emittance control and extremely high heat flux within the CW 700-MHZ rf cavites. Preliminary results of rf cavity designs and cooling schemes are presented, including both high-velocity water and forced-flow liquid-nitrogen cooling options.

WE-P-31

Stability of the LEBRA Infrared FEL

Kazue Yokoyama, Isamu Sato, Ken Hayakawa, Toshinari Tanaka, Yasushi Hayakawa, Koichi Kanno, Takeshi Sakai, Ken'ichiro Ishiwata, Eiko Hashimoto (Nihon University)

Free electron laser (FEL) lasing in a short-wavelength region requires an electron beam with a long pulse duration because of a small amplification gain. Characterization of linac beam performance in terms of energy spectra, current, and bunch length stability in the pulse duration is crucial for FEL quality. The LEBRA (Laboratory for Electron Beam Research and Application) FEL linac provides a beam with a pulse duration of 20 μs. From the specification of the undulator, less than 0.5% the full width at half maximum of the energy spread is required. Energy spectra and FEL gain were measured with different input rf power and phase of the injector. The results will show that the energy fluctuations have an effect on the FEL gain in the pulse duration. This report presents stability of the infrared (IR), from 0.8 μm to 5 μm, FEL at LEBRA of Nihon University.

WE-P-32

The BESSY Soft X-ray Single-Pass FEL Design

Michael Abo-Bakr, Wolfgang Anders, Rene Bakker, Michael von Hartrott, Eberhardt Jaeschke, Jens Knobloch, Dieter Krämer (BESSY); Atoosa Meseck (HMI); Ganeswar Mishra (DA Univ.); Godehard Wüsterfeld (BESSY)

BESSY* plans to construct a soft X-ray single-pass FEL for the spectral range from 20 eV to 1 keV. The central part of the project is a continuous-wave 2.25-GeV superconducting linac. A photoinjector and bunch-compression system will allow us to attain the required electron-beam target parameters, i.e., a peak-current of 3.5 kA with a bunch-charge of 1 nC. This paper presents design details and the expected performance. Results are based on start-to-end simulations, i.e., the electron-gun performance, followed by ELEGANT simulations of the acceleration system and bunch-compressors (including coherent synchrotron radiation effects), and GENESIS 1.3 FEL simulations.

* Funded by the Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie (BMBF), the Land Berlin and the Zukunftsfonds des Landes Berlin.

WE-P-33

Practical Formulae for FELs Operating in the High Gain Regime

Giuseppe Dattoli, Andrea Doria, Luca Giannessi, Pier Luigi Ottaviani (ENEA)

This presentation is dedicated to the analysis of some simple, semi-analytical, practical formulae for the simulation of a high gain FEL. This set of equations can follow the evolution of the radiation field emitted by the FEL up to the saturation; it can also take into account the inhomogeneous broadening introduced by the electron beam emittance and energy spread. The effect of extra focusing on the electron beam can also be considered in order to simulate a realistic experiment.

The aim of this formulary is to help the FEL physicist design a SASE FEL experiment that avoids having to run time-consuming codes every time they want to check some behaviour by varying one or more parameters. The formulae give a 1D result with a reliability of the order of 10% that can be considered more than adequate for a rapid test. A CAD code has also been realised in the MathCad framework for a very easy and friendly operation.

WE-P-34

Bunching and Exotic Undulator Configurations in SASE FELs

Giuseppe Dattoli, Andrea Doria, Luca Giannessi, Pier Luigi Ottaviani (ENEA)

It is well known for many years that the prebunching mechanism can be successfully used to increase emission in free electron generators and, more specifically, can reduce the saturation length in SASE-FEL devices. Many different mechanisms can be proposed to induce prebunching in an electron beam, but the most efficient is still a magnetic undulator, and thus an FEL itself. This presentation will illustrate a variety of possible schemes that can be designed to increase the radiation emission or to reduce the overall FEL length. For example biharmonic undulators can be used to increase emission at higher harmonics. This scheme can be complicated creating two sections: the first acts as a prebuncher, the second is the emitter at higher frequencies. Some examples for an FEL operating in the soft X-ray range will be reported.

WE-P-35

Observation of SASE at the BNL Source Development Laboratory

Adnan Doyuran, William Graves, Henrik Loos, Timur Shaftan, Brian Sheehy, Li Hua Yu, Louis F. Dimauro, Richard Heese, Erik Johnson, Samuel Krinsky, George Rakowsky, James Rose, John Skaritka, Juhau Wu, Yu Zhao (BNL)

The Deep Ultra Violet FEL experiment is being commissioned in the Source Development Laboratory (SDL) at NSLS in BNL. The goal of the project is to produce coherent radiation below 100 nm wavelength using High-Gain Harmonic Generation (HGHG) utilizing a seed laser. As a first step of this experiment, self-amplified spontaneous emission (SASE) has been achieved at 400 nm with electron beam energy at 140 MeV. We report the measurement of the SASE experiment. We measure the FEL properties for various electron beam conditions and discuss the performance of the FEL.

WE-P-36

The SASE FEL at the TESLA Facility as User Facility

Bart Faatz (DESY-Hamburg); Mikhail Yurkov (JINR); Markus Koerfer, Philippe Piot, Josef Feldhaus (DESY-Hamburg)

The last description of the TESLA Test Facility FEL was written in 1995 (TESLA-FEL report 95-03). Since then, many changes have developed compared to the design, partially because the design was incomplete, partly because of gained knowledge over the past few years. In addition, what used to be known as phase-2 of the project has been subdivided into a finer time scale, starting with the first beam through the machine until the complete user facility with its different possible extensions. This paper is therefore an upgrade of the above-mentioned Conceptual Design Report. It gives a more complete overview of the present status of knowledge on present and future developments towards the TTF-FEL user facility.

WE-P-37

Simulation Studies of a Possible Multi-stage XFEL at ELETTRA*

William M. Fawley, William A. Barletta (LBNL); Carlo J. Bocchetta (ELETTRA); Rodolfo Bonifacio (Univ. of Milan)

Presently there is strong interest in developing a fourth-generation light source at VUV and soft x-ray wavelengths at the ELETTRA facility at Trieste. One proposal centers around using the existing linac at ~1.0 GeV energy with a new photocathode and bunch compression to achieve an output beam at ~600 Amp current, ~2-4 mm-mrad normalized emittance, and ~0.05% instantaneous energy spread. To achieve output radiation in the 10- to 40-nm wavelength region, a multi-stage device is being considered initiated by a cohererent seed laser operating at 200 nm. We present numerical simulations of various undulator/optical-klystron configurations, seeking to optimize the overall output power level while minimizing the total length of undulator sections needed. We also discuss how shot-to-shot repeatability and spectral bandwidth requirements can place nontrivial constraints on the performance of various system components such as the photocathode, the accelerator, the beam compressor, and the seed laser.

* Work at LBNL supported in part by the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

WE-P-38

Simulation of Prebunching in Free-Electron Lasers*

Henry P. Freund (SAIC); Patrick G. O'Shea, John Neumann (UMD)

Prebunched beams are used in many coherent radiation sources. If the beam is bunched on scale lengths comparable or shorter than the desired wavelength, then the resonant wavelength is excited without a drive signal and grows faster than exponential. An FEL with a prebunched beam combines the best characteristics of amplifiers and oscillators. In comparison with oscillators, no drive signal is needed and the wiggler is short. In comparison with amplifiers, no resonator is needed. Simulation of prebunched beams has been demonstrated using the MEDUSA simulation code [1-3] for optical klystrons [2] and high-gain harmonic generation [3]. Here prebunching was accomplished by modulating the beam in one wiggler and enhancing that modulation in a magnetic chicane prior to injection into a second wiggler. We describe modifications to MEDUSA to simulate arbitrary prebunching schemes, and the application of the code to study requirements and limitations on the process.

* Work supported by ONR , JTO and ARL.

[1] H.P. Freund et al., IEEE J. Quantum Electron. 36, 275 (2000).
[2] G.R. Neil and H.P. Freund, Nucl. Instrum. Meth. A475, 381 (2001).
[3] S.G. Biedron et al., Nucl. Instrum. Meth. A475, 118 (2001).

WE-P-39

Evolution of Transverse Modes in a High-Gain Free-Electron Laser

Sandra G. Biedron, Stephen V. Milton (ANL); Giuseppe Dattoli, Alberto Renieri (INFN-LNF); William M. Fawley (LBNL); Henry P. Freund (SAIC); Heinz-Dieter Nuhn (SLAC); Pier Luigi Ottaviani (ENEA)

At the point of saturation in a high-gain free-electron laser (FEL) the light is fully transversely coherent. The number of and evolution of these modes is important particularly in designing multi-staged devices that rely on relatively stable saturation distances in each module. This is critical since each section will seed a latter section. Overall, in a single- or multi-stage device, experimental users will desire stability in power and in photon beam quality. Using three distinct numerical simulation codes, the evolution of the transverse modes in the high-gain free-electron laser (FEL) is examined via simulation and is discussed for small variation in the overall saturation length. In addition, the transverse modes in the first few higher nonlinear harmonics are investigated.

WE-P-40

Photon Beam Diagnostics of Intense, Ultra-Short VUV Radiation of a SASE FEL

Ch. Gerth, J. Feldhaus, B. Steeg, K. Tiedtke, R. Treusch (DESY-Hamburg)

A free electron laser (FEL) generating ultra-short (30-100 fs) radiation pulses in the vacuum ultraviolet region (80-180 nm) has successfully been operated at the TESLA Test Facility (TTF) at DESY. The FEL operates in the self-amplified spontaneous emission (SASE) mode. High-gain, exponential growth of the radiation power and saturation with peak powers at the GW level have been demonstrated [1]. This paper reports on the techniques used for the characterization of the photon beam properties in phase 1 of TTF. Methods developed for the on-line detection of single FEL pulses and latest results from absolute measurements are presented.

[1] Ayvazyan et al., Phys. Rev, Lett. 88 (2002) 104802.

WE-P-41

Spectral, Temporal, and Statistical Properties of a VUV FEL Operating in SASE Mode

Christopher Gerth, Evgeny Saldin, Evgeny Schneidmiller (DESY-Hamburg);*
Mikhail V. Yurkov (JINR)

The FEL at the TESLA Test Facility at DESY operates in the self-amplified spontaneous emission (SASE) mode and generates subpicosecond radiation pulses in the vacuum ultraviolet spectral region. In September 2001, saturation of the SASE process was achieved with radiation peak powers at the GW level [1]. The precise study of the spectral, temporal, and statistical properties of the SASE FEL radiation became possible due to the stable operation of the linac. Fluctuations of the energy in the radiation pulse, spectrally resolved with the use of a narrow bandwidth monochromator, have been measured for different amplification regimes. Measurements have been performed for various modes of linac operation and found to be in good agreement with the results of numerical simulations.

* For the TTF FEL Group

[1] Ayvazyan et al., Phys. Rev. Lett. 88 (2002) 104802.

WE-P-42

Characteristics of the Fundamental and 3rd Harmonic FEL at LEBRA

Yasushi Hayakawa, Isamu Sato, Ken Hayakawa, Toshinari Tanaka, Kazue Yokoyama, Takeshi Sakai, Koichi Kanno, Ken-ichiro Ishiwata, Eiko Hashimoto (Nihon University)

An FEL system at Laboratory for Electron Beam Research and Application (LEBRA) in Nihon University has been developed and lasing at a wavelength of 1.5 μm has been achieved. In addition, the phenomenon that seems to be the nonlinear third harmonic has been observed as the gain of fundamental FEL has grown. In order to study the characteristics of LEBRA FEL, measurements to obtain the gain and the spectrum of the radiations have been performed. The results will be reported and discussed.

WE-P-43

Characteristics Measurements of Higher Harmonics Generated in the SASE-FEL Process

Ryukou Kato, Masahiro Fujimoto, Tetsuya Igo, Satoshi Isaka, Toru Onishi, Shin-ichi Furukawa, Shuichi Okuda, Shoji Suemine, Goro Isoyama (OsakaU)

Nonlinear harmonic generation (NHG) of SASE is driven by the power of the fundamental radiation. In order to observe the NHG, therefore, it is essential that the fundamental radiation upraises sufficiently. We are conducting the experiments of SASE in the far-infrared region using the high-intensity single-bunch beam accelerated with the L-band linac at the Institute of Scientific and Industrial Research (ISIR), Osaka University. Two years ago, we observed the second harmonic peak in the wavelength spectrum of SASE and pointed out the possibility that the second harmonic radiation had been originated by NHG [1]. In the last FEL conference, we reported the preliminary results of the absolute energy per optical pulse and the spectral width of the second and the third harmonic radiation of SASE. Ever since, we have been measuring the characteristics of higher harmonics of SASE under various conditions. In addition to spectral measurements, we recently constructed an angular distribution measurement system of SASE and obtained preliminary results of angular distribution of monochromatized higher harmonic radiation. We will report analytical results of these experiments.

[1] R. Kato et al., Nucl. Instrum. Methods A475 (2001) 334-338.

WE-P-44

Time-Resolved Measurement of a 530-nm SASE FEL*

Yuelin Li, John Lewellen, Vadim Sajaev, Zhirong Huang, Stephen V. Milton (ANL)

We report on temporally resolved measurement of a SASE FEL output at 530 nm using the technique of frequency-resolved optical gating (FROG). The measurement reveals the phase and the amplitude of the FEL field as a function of time and frequency. The experimental data are compared with simulations.

* This work supported by the U.S. Department of Energy, Office of Basic Energy Sciences under Contract No. W-31-109-ENG-38.

WE-P-45

Macro Particle FEL Model with Self-consistent Spontaneous Radiation*

Vladimir Litvinenko, Oleg Shevchenko (DUKE)

Spontaneous radiation plays an important role in SASE FELs and storage ring FELs operating in giant pulse mode. It defines the correlation function of the FEL radiation as well as its many spectral features. The use of randomly distributed macro-particles with charge significantly exceeding the charge of one electron creates the problem of artificially strong spontaneous radiation and limits the capabilities of modern FEL codes.

In this paper we present the self-consistent macro-particle model allowing the exact simulation of multi-mode, multi-harmonic, and multi-frequency short-wavelength 3-D FELs including the high power and saturation effects. The use of macro-particle's clones provide the capability of treating both spontaneous and induced radiation in the same fashion. The simulations using this model do not require a seed and provide complete time and spatial structure of the FEL optical field. We present some results of the SASE simulation using this model as well as discuss its limitations.

* Work is supported by Dean of Natural Sciences, Duke University.

WE-P-46

Results and Analysis of VISA SASE FEL Performance at 840 nm

Alex Murokh, Ronald Agustsson, Pedro Frigola, Claudio Pellegrini, Sven Reiche, James Rosenzweig, Aaron Tremaine (UCLA); Marcus Babzien, Ilan Ben-Zvi, Erik Johnson, Robert Malone, George Rakowsky, John Skaritka, Xijie Wang, Vitaly Yakimenko (BNL); Louis Bertolini, Karl A van Bibber, Jeremy M Hill, Greg P Le Sage, Marcus Libkind, Arthur Toor (LANL); Roger Carr, Massimo Cornacchia, Lowell Klaisner, Heinz-Dieter Nuhn, Robert Ruland (SLAC)

VISA (Visible to Infrared SASE Amplifier) is a high-gain self-amplified spontaneous emission FEL, which achieved saturation at 840 nm within a single-pass 4-m undulator. A gain length shorter than 18 cm has been obtained yielding the gain of 2 × 108 at saturation. The FEL performance, including spectral, angular, and statistical properties of the radiation, has been characterized for different electron beam conditions. The results are compared to 3-D SASE theory and start-to-end simulations of the entire injector, transport, and FEL system. A detailed agreement between simulations and experimental results is obtained over the wide range of electron beam parameters.

WE-P-47

Electron Beam Diagnostics for TTF II*

Dirk Nölle (DESY-Hamburg)

This paper presents the electron beam diagnostic systems for the TTF II, the SASE FEL facility currently set up at DESY. This facility, serving not only as a SASE FEL light source but also as a test facility for the future linear collider TESLA, consists of a superconducting 1-GeV linac driving a 30-m-long undulator to produce intense soft X-ray and VUV radiation pulses up to the GW level. The paper will discuss the requirements of the diagnostic systems on the example of the systems developed for TTF II. In addition to the usual diagnostic systems for a linac, the special requirements due to the protections systems will also be presented.

* This work is carried out in the framework of the TESLA collaboration and therefore represents also the contribution of many coworkers within the collaboration, who cannot be mentioned there.

WE-P-48

Radiation Effects Studies at the Advanced Photon Source*

Maria Petra, Patrick K. Den Hartog, Elizabeth R. Moog, Shigemi Sasaki, Nicholas Sereno, Isaac B. Vasserman (ANL)

At the Advanced Photon Source (APS) concern for radiation-induced demagnetization of the insertion devices (IDs) in the storage ring and in the free-electron laser has initiated systematic radiation effects studies towards the development of efficient techniques for ID protection. A multifaceted approach is being employed that includes dose monitoring, study of the critical parameters and processes that lead to radiation-induced demagnetization, as well as a potential dedicated radiation effects facility at the APS providing GeV electron beams. Results from these radiation-damage studies will also be directly applicable to future-generation facilities, such as the Linac Coherent Light Source. Results and discussion will be presented on the multifaceted approach towards investigation of the radiation damage in magnets, as well as on the recent radiation-induced demagnetization of IDs in the storage ring.

* This work was supported by the U.S. Department of Energy, Office of Science, BES, under Contract No. W-31-109-ENG-38.

WE-P-49

Pulse Length Control in an X-Ray FEL by Using Wakefields

Sven Reiche (UCLA); Paul J. Emma (SLAC); Claudio Pellegrini (UCLA)

For the users of the high-brightness radiation sources of free-electron lasers it is necessary to reduce the FEL pulse length to 10 fs and below for time-resolving pump and probe experiments. Although it can be achieved by conventional compression methods for the electron beam or the chirped FEL pulse, the technical realization is demanding. In this presentation we study the impact of undulator wakefields and how their properties can be used to reduced the amplifying part of the bunch to the desired length. Methods of actively controlling the wakefields are presented.

WE-P-50

Advanced Pulse Compression and SASE FEL Experiments at BNL ATF

James B. Rosenzweig, Ronald Agustsson, Alex Murokh, Claudio Pellegrini, Sven Reiche (UCLA); Ilan Ben-Zvi, X. Wang (BNL); L. Palumbo (Univ. Roma); L. Serafini (INFN Milano)

With the installation of a chicane compressor designed and constructed at UCLA, the infrastructure at the BNL ATF is now capable of supporting advanced pulse compression and related SASE FEL experiments. The pulse compression experiments will investigate the the production of 0.2-nC pulses with 25-micron length, with emphasis placed on direct detection of coherent synchrotron radiation in the final bend magnet. Having studied ways to mitigate strong nonlinearities in the transport of ATF beamline 3, we are now proposing a series of SASE FEL experiments using the existing VISA system. This set of experiments will emphasize the lasing action in chirped systems that are fully or partially compressed, which are of interest for creating ultra-short radiation pulses.

WE-P-51

Scheme for Time-Resolved Experiments Based on the Use of Statistical Properties of the Third Harmonic of SASE FEL Radiation

Werner Brefeld, Bart Faatz, Josef Feldhaus, Markus Koerfer (DESY-Hamburg); Jacek Krzywinski (Instituteof Physics-Warsaw, Poland); Tomas Moeller, Joachim Pflueger, Evgueni Saldin, Evgueni Scheidmiller, Sigfrid Sreiber (DESY-Hamburg); Mikhail Yurkov (JINR-Dubna, Russia)

A closer inspection of the statistical properties of the third-harmonic radiation from a SASE FEL reveals that it is possible to select single, temporary coherent radiation spikes by using a simple intensity trigger. A carefully designed optical system for splitting, delaying, filtering, and recombining the radiation would then allow time-resolved measurements with a resolution down to the coherence time of the FEL, i.e., a few femtoseconds in the case of the TTF FEL [1].

[1] W. Brefeld, B. Faatz, J. Feldhaus, M. Körfer, T. Möller, J. Pflueger, E.L. Saldin, E.A. Schneidmiller, S. Schreiber, J. Krzywinski, M. V. Yurkov, DESY 02-038, March 2002.

WE-P-52

Pump-Probe Experiments in the Femtosecond Regime, Combining First and Third Harmonics of SASE FEL Radiation

Josef Feldhaus, Tomas Moeller, Evgueni Saldin, Evgueni Scheidmiller (DESY-Hamburg); Mikhail Yurkov (JINR-Dubna, Russia)

Two-color pump-probe experiments combining optical femtosecond lasers with short wavelength radiation from free electron lasers are very attractive for subpicosecond time-resolved studies. Since the synchronization between the two light sources to an accuracy of 100 femtoseconds is not yet solved, it is proposed to derive both radiation pulses from the same electron bunch [1]. In the present work we focus on the special case where pump and probe beams are generated by the same electron bunch in the same insertion device. Specifically we propose to combine GW-level VUV FEL pulses between 150 nm and 90 nm wavelength and 10-MW-level third-harmonic radiation between 50 nm and 30 nm. This scheme does not require any special synchronization or additional FEL hardware components since the nonlinear third-harmonic generation occurs naturally in the planar FEL undulator. Reflection optics is used for beam splitting and tunable delay; the two harmonics are separated by using notch filters. The effect on the pulse duration is negligible.

[1] J. Feldhaus, T. Möller, E. L. Saldin, E. A. Schneidmiller, M. V. Yurkov, DESY 01-215, December 2001.

WE-P-53

Scheme for Attophysics Experiments at an X-ray SASE FEL

Evgueni Saldin, Evgueni Schneidmiller (DESY-Hamburg); Mikhail Yurkov (JINR)

We propose a concept for production of high-power coherent attosecond pulses in the X-ray range. An approach is based on generation of 8th harmonic of radiation in a multistage HGHG FEL configuration starting from shot noise. Single-spike phenomena occur when the electron bunch is passed through a sequence of four relatively short undulators. The first stage is a conventional "long" wavelength (0.8 nm) SASE FEL which operates in the high-gain linear regime. The 0.1-nm wavelength range is reached by successive multiplication in a stage sequence (0.8 nm - 0.4 nm - 0.2 nm - 0.1 nm). Our study shows that the statistical properties of the high-harmonic radiation from the SASE FEL, operating in the linear regime, can be used for selection of radiation pulses with a single spike in the time domain [1]. The duration of the spikes is in the attosecond range. Selection of single-spike high-harmonic pulses is achieved by using a special trigger in the data acquisition system. The potential of X-ray SASE FEL at TESLA at DESY for generating attosecond pulses is demonstrated. Since the design of the XFEL laboratory at TESLA is based on the use of long SASE undulators with tunable gap, no special place or additional FEL undulators are required for attophysics experiments. The use of 10-GW-level attosecond X-ray pulses at the X-ray SASE FEL facility will enable us to track processes inside atoms for the first time.

[1] E. Saldin, E. Schneidmiller, M. Yurkov, DESY 02-070, May 2002.

WE-P-54

Status of LEBRA FEL at Nihon University

Isamu Sato, Ken Hayakawa, Toshinari Tanaka, Yasushi Hayakawa, Kazue Yokoyama, Takeshi Sakai, Kohji Kano, Kenichiro Ishiwata (Nihon University)

The FEL has been developed for the study of material, life, resource, and other sciences at the Laboratory for Electron Beam Research and Application (LEBRA) in Nihon University. The FEL system was designed to be based on a normal 125-MeV electron linac without subharmonic buncher. An experimental facility in LEBRA was completed in 2001. There are nine experimental rooms for the application to various fields, and FEL beams are supplied by a beamline. The first lasing of 1.5 μm FEL was achieved at the energy of 86 MeV in 2001. We report the recent status of LEBRA.

WE-P-55

Beam-Based Trajectory Alignment in the NISUS Wiggler

T. V. Shaftan, H. Loos, L. F. DiMauro, A. Doyuran, W. S. Graves, E. D. Johnson, S. Krinsky, J. Rakowsky, J. Rose, B. Sheehy, J. Skaritka, J. Wu, L.-H. Yu, Y. Zhao (BNL)

The Deep Ultra Violet FEL is under commissioning in the Source Development Laboratory (SDL) at NSLS. The goal of the experiment's first stage is to obtain 400 nm SASE. The magnetic system of the FEL includes the 10-m-long NISUS wiggler with 3.9-cm period. Deviations from the design trajectory should be less than 60 μm within one gain length. In this paper we describe the hardware and methods of trajectory control and alignment used for this experiment. Measurements of the actual beam trajectory, its correction, and a method to obtain the dipole field errors from trajectory measurements are presented.

WE-P-56

Measurements of Nonlinear Harmonic Radiation and Harmonic Microbunching from a Visible SASE FEL

Aaron Tremaine (LLNL); Xijie Wang, Marcus Babzien, Ilan Ben-Zvi (BNL); Max Cornacchia (SLAC); Alex Murokh (UCLA); Heinz-Dieter Nuhn (SLAC); Robert Malone (BNL); Claudio Pellegrini, Sven Reiche, James Rosenzweig (UCLA); John Skaritka, Vitaly Yakimenko (BNL)

Nonlinear harmonic radiation (NHR) up to the third harmonic from a visible SASE FEL has been experimentally characterized; gain lengths, spectra, and energies are compared to theory. Measurements, determined by coherent transition radiation (CTR), at saturation of the electron beam microbunching factors (b1 and b2) up to the second harmonic are presented. CTR and SASE energies are simultaneously measured for each micropulse over the complete FEL gain range; the microbunching growth for both modes is related to that of the SASE. These results experimentally correlate the NHR and electron beam microbunching modes to the fundamental SASE.

WE-P-57

High Gain Free Electron Laser Driven by Flat Electron Beam

Ming Xie (LBNL)

We present gain length calculations for a high-gain free electron laser driven by a flat electron beam. The calculation takes into account the effects of unequal emittance, unequal betatron focusing and unequal beam size in two transverse planes, and energy spread.

WE-P-58

Simulations for the FERMI@ELETTRA Proposal to Generate 40-nm and 10-nm Coherent Radiation Using the HGHG S Scheme

Li-Hua Yu, Juhao Wu (BNL)

We present the results of simulations for a free-electron laser system designed and based on upgraded parameters of the 1.0-GeV linac located at the third-generation synchrotron radiation facility ELETTRA. The calculation is carried out for two of the three beamlines of the project. For the first beamline the system is based on the HGHG scheme to generate 40-nm coherent radiation by a 200-nm seed laser. For the second beamline we consider cascading the HGHG scheme twice to generate 10-nm radiation.

WE-P-59

Image Charge Wakefield Undulator and SASE FEL*

Yuhong Zhang, Yaroslav Derbenev, Rui Li (TJNAF)

A relativistic electron beam moving very close to periodic conducting surfaces may undergo undulating motion due to its image charge wakefield. In this paper we present a study of a simple two-dimensional theoretical model of an image charge wakefield undulator with an infinite long thin current sheet passing through its center. We demonstrate that such undulating motion exists, and by applying one-dimensional FEL theory we show that SASE radiation associated with this undulating motion can be developed and should be observable experimentally. Such a Smith-Purcell-like undulator potentially provides a new type of single-pass, high-intensity and short-wavelength coherent hard radiation source with a very compact size and moderate requirements of apparatus.

* This work was supported by U.S. Department of Energy under Contract DE-AC05-84ER40150.

TH-P-01

X-ray Compton FEL on the Channeled in the Crystal Electron Beam*

Hamlet K. Avetissian, Garnik F. Mkrtchian (Yerevan State University)

As is known, the spontaneous radiation of relativistic electrons and positrons channeled in the crystal lays in the X-ray/ã-ray domain, and its spectral intensity exceeds the one of other radiation sources in this frequency range. So, stimulated channeling radiation of electron beams is of certain interest as a potential FEL in the short wavelength domain. In this work the scheme of X-ray coherent radiation generation by means of a mildly relativistic, high-density, channeled electron beam and a strong counter-propagating pump laser field is investigated. For the electron beams with relatively low energies (< 50 MeV) the states of channeled electrons are most stable, and a few discrete energy levels in the transverse potential well are formed which are nonequidistant. As a result, the probe and pump waves resonantly couple only two transverse levels. Then it is assumed that the pump laser radiation is resonant to those energy levels. In the result, the necessity of inverse population of transverse levels for lasing [1] vanishes and the cross section of considering process is resonantly enhanced by several orders with respect to the Compton process. The self-consistent set of Maxwell and relativistic quantum kinetic equations in the high-gain regime is solved.

* This work was supported by International Science and Technology Center (ISTC) Project No. A-353.

[1] H.K. Avetissian et al., Phys. Rev. A 56, 4121 (1997).

TH-P-02

High Harmonic Generation from Laser Driven Relativistic Electron Beams*

Sudeep Banerjee, Anthony Valenzuela, Rahul Shah, Katherine Korbiak, Donald Umstadter
(University of Michigan)

With the advent of high power table top laser systems it has become possible in recent years to study the physics of free electrons interacting with ultra-intense laser fields. Of particular interest has been the possibility of generating high order harmonics by the process of nonlinear Thomson scattering. Although this problem has been studied theoretically for several decades, experimental tests have been possible only recently. We present for the first time experimental signatures of this process in the high-order VUV emission from the plasma. Our experiments were done with a Nd:Glass laser interacting with an underdense plasma. Harmonics from free electrons are expected to be produced at high intensity and even with circular polarization. As such the spatial extent of free electron harmonics should be smaller than that from bound electrons and this is observed experimentally. In addition even order harmonics are seen which are forbidden by symmetry conditions for atomic processes. In our experiments we have studied harmonics in the range 180-40 nm. It is found that the harmonics are emitted as a beam in the forward direction with a narrow cone angle (2-3 deg.), due to Compton scattering from relativistic electrons playing a significant role. This opens up the possibility of a high brightness x-ray source based on laser Compton scattering.

*The Chemical Sciences, Geosciences and Biosciences Division of the Office of Basic Energy Sciences, Office of Science, U.S. Department of Energy and the National Science Foundation supported this work. The National Science Foundation through the Frontiers of Optical and Coherent Ultrafast Science supported the lasers.

TH-P-03

A Method of Electron Beam Bunching

Evgueni G. Bessonov (Lebedev Physical Institute RAS)

A method of energy modulation of an electron beam in the transverse direction and the transformation of this modulation to the longitudinal density modulation is considered. Thompson scattering of a standing wave produced by two counter- propagating short laser pulses stored in the open resonator by a low emittance electron beam intersecting the interference pattern at a 90° angle is used on the first stage; 180° geometry can be used [1]. The energy losses of electrons depend on their position in the laser beam where the interference fringes are created. Electrons moving in the bright zones of fringes will lose more energy than ones in the dark zones. Their energy will tend to the energy of electrons of the nearest dark zones. As a result, the electron beam will receive a periodic energy modulation in the transverse direction. On the second stage the electron beam passes through an undulator modulator for a time of a quarter of the period of phase oscillations, where the transverse energy modulation is converted to the longitudinal density modulation. Harmonic number in this case is determined by the ratio of the transverse separatrix dimension to the wavelength. The advanced accelerator requirements and necessary parameters of both electron and laser beams are discussed. For the case of an ion beam, a similar way of modulation based on the backward Rayleigh scattering was considered in [2]. Modulated electron beams can be used in the prebunched free-electron lasers.

[1] T. Shintake, Nucl. Instrum. Methods, A311 (1992), 453.
[2] E.G. Bessonov, Proc. of the Micro Bunches Workshop, Upton, New York, Sept 1995, p. 367.

TH-P-04

Overview of FERMI@ELETTRA a Proposed Ultra Bright Coherent X-ray Source in Italy

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R. Bakker (BESSY); W. A. Barletta, W. M. Fawley (LBNL); R. Bonifacio (Università degli Studi di Milano); S. G. Biedron, M. D. Borland*, S. V. Milton* (ANL); S. De Silvestri (INFM-Politecnico di Milano); R. P. Walker (DIAMOND); J. H. Wu, L. H. Yu (BNL)*

Together with the INFM and other Italian institutes, Sincrotrone Trieste has proposed and developed FERMI@ELETTRA in response to the Italian government's call for proposals from national institutes for a multipurpose pulsed laser X-ray source. The proposed FEL source will be located at the third-generation synchrotron radiation facility ELETTRA and will utilise the fully available 1.0-GeV normal conducting linac. The project is articulated along three consecutive lines of development allowing gradual improvements for the production of 40-, 10-, and 1.2-nm radiation. The first two phases involve upgrading the linac with a high-brightness photoinjector and bunch compressor for the generation of increasingly higher quality electron beams. The third phase requires both an increase in peak current and beam energy to 3.0 GeV. The requirements of the User community necessitate the use of systems that allow reproducible, polarised, and controlled radiation. APPLE-type undulators will therefore be implemented and schemes to seed the radiation will be used where possible. An overview of the proposal is presented elucidating linac upgrades and overall layout, electron beam simulations, and laser seed schemes.

* Work supported by U.S. Department of Energy, Office of Basic Energy Sciences under Contract No. W-31-109-ENG-38.

TH-P-05

Laser-Compton Scattering (LCS) Experiments at IAC*

Khalid Chouffani, Doug Wells, Frank Harmon (Idaho Accelerator Center); James Jones, Gregg Lancaster (Idaho National Engineering and Environmental Laboratory)

LCS experiments were carried out at the Idaho Accelerator Center (IAC); sharp monochromatic x-ray lines were observed. These are produced using the so-called inverse Compton effect, whereby visible laser photons are collided with a relativistic electron beam. The backscattered photons are then kinematically boosted to keV x-ray energies. We have first demonstrated these beams using a 20-MeV electron beam collided with a 100-MW, 10-ns Nd:YAG laser. We observed narrow LCS x-ray spectral peaks resulting from the interaction of the electron beam with the two Nd:YAG laser photon lines of 1064 and 532 nm. The LCS x-ray energy lines and energy deviations were measured as a function of the electron beam energy and energy-spread, respectively. The results showed good agreement with the predicted values. In addition to being viewed as a potential intense x-ray source, LCS could provide an excellent probe of electron beam pulse, direction, energy, and energy spread measurement. X-ray angular distribution and polarization measurements will also be presented.

* This research was supported by the U.S. Department of Energy under contract number DE-FG02-00ER45848 and by the Idaho National Engineering and Environmental Laboratory under contract number 00000069/TO3.

TH-P-06

Short Wavelength Free Electron Lasers in 2002*

W. B. Colson (NPGS)

Twenty-five years after the first operation of the short-wavelength free electron laser (FEL) at Stanford University, there continue to be many important experiments, proposed experiments, and user facilities around the world. Properties of FELs operating in the infrared, visible, UV, and x-ray wavelength regimes are listed and discussed.

* This work is supported by DARPA, NAVSEA, and JTO.

TH-P-07

Measurement of Smith-Purcell Radiation

Oscar H. Kapp, Yin-e Sun (UofC); Kwang-Je Kim (ANL); Albert V. Crewe (UofC)*

We are investigating the performance of a compact infrared radiator in which a grating is placed in the focal region of the electron beam of a Cambridge S-200 scanning electron microscope (SEM). Such a radiator was originally proposed and studied by the Dartmouth group [1]. The electron beam is generated and focused using the SEM's electron optical system. Light is generated by a Smith-Purcell process [2] as the beam passes close to the surface of the grating. Detection is accomplished using a polyethylene exit window and an external bolometer. At a beam current of about 200 μA the normalized rms emittance varied between 0.3 and 0.6 mm-mr. We have measured several picowatts of power utilizing a cut-on 100-μm filter. Using an aluminum diffraction grating with a period of 173 μm and a beam curent of 500 μA at 30 kV, we obtained a maximum output of about 35 picowatts. Electron beam diameters have varied from about 30 to 300 μm depending on conditions of lens current settings, accelerating voltage, and beam current. The power level is consistent with that expected from spontaneous Smith-Purcell emission.

* Work supported by U.S. Department of Energy, Office of Basic Energy Sciences under Contract No. W-31-109-ENG-38.

[1] J. Urata, M. Goldstein, M.F. Kimmitt, A. Naumov, C. Platt and J.E. Walsh, Phys. Rev. Lett. 80(3) 516 (1998).
[2] S.J. Smith and E.M. Purcell. Phys. Rev. 92, 1069 (1953).

TH-P-08

γ-Ray Generation for Nuclear Transmutation Research

D. Li, K. Imasaki, M. Aoki (Institute for Laser Technology)

A proposal for processing nuclear waste through nuclear transmutation method was presented and researched at the Institute for Laser Technology (ILT) in recent years. The γ ray employed to shine nuclear target is designed to produce through head-on collision of relativistic electrons and laser photons, which is well known as Compton back scattering experimentally demonstrated in some laboratories over the world. Conceptual research about this proposal is developing on New-Subaru storage ring, which can provide electron beam with energy of 1 GeV. A laser with wavelength of 1.064 is applied and thereby about 15-MeV γ-ray photons will be generated. This paper aims at analyzing the γ-ray photon production, energy spectrum, and the electron beam deformation after collision on such an experimental setup, with the available parameters. Reasonable experimental parameters are selected according to the optimized results through a computation code. Preliminary experimental research is introduced also, and application of a high-purity germanium coaxial photon detector system will deliver us with precise experimental data.

TH-P-09

FEL Options for the Proposed UK Fourth Generation Light Source (4GLS)

M. W. Poole, B. W.J. McNeil (Daresbury Laboratory)*

4GLS is a novel low-energy light source proposed as a complementary facility to the DIAMOND x-ray project for the UK, and would replace the present SRS at Daresbury in about five years time. This facility will use a combination of three separate FELs, undulators, and bending magnets to provide a unique source of high-brightness continuous and pulsed radiation from the IR to XUV (~100 eV). Here we give a brief description of the proposed FELs in the IR and VUV followed by a pre-design parameter study of the more technically challenging XUV high-gain FEL. The electron beam source for this FEL is a 600-MeV superconducting energy recovery linac with peak currents of a few kA, normalised rms emittance ~ 3 π mm mrad and rms energy spread ~5×10^{-4}. Computer simulations using the 3-D FEL code GENESIS 1.3 are used to investigate feasible undulator and beam focusing schemes, allowing estimates for achievable radiation powers and saturation lengths to be made.

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TH-P-10

FELICE - the Free Electron Laser for Intra-Cavity Experiments

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At FOM Institute "Rijnhuizen" a new FEL light source, dedicated to fundamental research of the structure and dynamics of (bio)molecules, clusters, and nanoparticles, is presently under development. This Free Electron Laser for Intra-Cavity Experiments (FELICE) is designed to generate pulsed infrared radiation, tunable in the region of 3-100 μm. It should allow intracavity experiments with optical beam energies in the interaction point of some 10 J, which is a factor of 100 higher than currently available for the users. Two permanent intracavity setups are planned: an FT-ICR mass spectrometer with appropriate ion sources and a molecular/cluster beam setup. FELICE will have a tunable-gap, permanent-magnet undulator with a spatial period of 63 mm and a minimum gap of 22 mm. In order to suppress the gain of the harmonics, the use of an aperiodic undulator is under consideration. Wavelength tuning of FELICE by a factor of 10 will be achieved by varying the energy of the driving electron beam in the range of 20-65 MeV. Another factor of three in wavelength tuning will be achieved by changing the undulator gap. The optical cavity will consist of three focusing mirrors, providing an additional focus at the sample. At wavelengths longer than 40 μm, a retractable two-plate system will be used to guide the optical mode in the undulator in order to reduce the diffraction losses.

TH-P-11

Coherent Radiative Phenomena Driven By a Pre-Modulated Electron Beam

Jonathan G Neumann, Patrick G O'Shea (UMD); William Graves, Brian Sheehy (BNL)

Coherent synchrotron radiation may lead to a microwave instability on the bunch at wavelengths much smaller than the bunch length. It is possible that ripples (prebunching) on the electron bunch distribution may seed such an instability. We report on research to explore this effect using a longitudinally modulated drive laser to generate a modulated electron beam. Our first step is to develop simulations that will help us study the microbunching process. The initial process will be explored with 3-D PIC code that can simulate the detail of the electron generation process. As the electron beam is accelerated, the simulation will be continued in PARMELA. Following the simulations there will be a preliminary experiment on laser beam modulation that will focus on frequencies in the THz regime. We plan to study both the positive and negative impact of prebunching. In some cases, particularly the FIR, we may enhance the performance of FEL devices by prebunching. We may also be able to separate the bunching and radiating mechanism, which can lead to more flexible devices where the wiggler can be entirely replaced by an alternative, more compact radiator. Eventually, we intend to implement our results on the Maryland Infrared Free Electron Laser (MIRFEL).

TH-P-12

Synchrotron Radiation by Charged Particle in Self Wake Field in Periodic Structure

Anatoly N. Opanasenko (NSC KIPT)

A new elementary radiation mechanism due to the oscillatory character of the radiation friction force appearing at motion of a relativistic charged particle along a periodic structure without external fields is studied. It is known that a charged particle moving with constant velocity along a periodic structure generates the Cerenkov radiation (CR) and the parametric Cerenkov radiation (PCR). The fields of this radiation called wake fields can be expressed as a spatial harmonics series according to Floquet's theorem. The action of the synchronous spatial harmonics on the particle results in the energy losses associated with the CR and PCR. The nonsynchronous spatial harmonics, under certain conditions, cause the oscillatory motion of the particle generating the synchrotron radiation (SR). The equation of motion for the relativistic particle in an periodic structure is solved. The radiation power is found. In the low frequency range where the diffraction is essential, the radiation manifests itself as a coherent interference of the PCR and SR. In the high frequency range, where the diffraction can be neglected, the SR only takes place which is similar to the conventional undulator radiation. So, due to the Doppler effect, the SR power may exceed the wake field power. This fact opens new possibilities to generate X and gamma rays by ultrarelativistic electron beams in the periodic structures without external undulator fields used in FEL.

TH-P-13

Conceptual Design of a High-Brightness Linac for Soft X-ray SASE-FEL Source*

Luigi Palumbo (INFN-LNF and Universita' di Roma)

FELs based on the SASE (self-amplified spontaneous emission) effect are able to generate coherent radiation with unique features. In principle the brilliance of the source is several orders of magnitude higher than the third-generation synchrotron radiation sources, and it is possible to reach the x-ray spectrum region with ultra-short pulses of hundreds of femtoseconds. This source is believed to be a powerful tool to explore the frontiers of basic sciences, from physics to chemistry to biology. Intense R&D programs have started in the USA and Europe in order to understand the SASE physics and to prove the feasibility of these sources. The allocation of considerable resources in the Italian National Research Plan (PNR) brought about the formation of a CNR- ENEA-INFN study group. An R&D program at LNF has been proposed, and possible schemes for linac sources have been investigated.

* Work presented on behalf of the study group: CNR-ENEA-INFN and Universita' di Roma II.

TH-P-14

SPARC and SPARX FEL Projects

Alberto Renieri (ENEA)

SPARC and SPARX are two distinct phases of an italian FEL SASE project involving different national institutions. SPARC is a high gain FEL project aimed at developing a source of visible and VUV radiation exploiting SASE mechanisms. A 150-MeV linac followed by a bunch compressor will provide a high quality e-beam to generate high brilliance FEL radiation at visible region at the fundamental wavelength and at VUV wavelengths with the harmonics. SPARC will allow investigation of velocity bunching mechanisms in the bunch compressor and coherent harmonic generation in the undulators. SPARX is a project aimed at the realisation of an FEL SASE source operating at 13.5 nm and 1.5 nm in two separate undulator channels with a 2.5-GeV e-beam. SPARX development is expected to take profit of the SPARC activities and part of the equipment. We describe here the main features of these two projects including accelerator systems, FEL sections, and applications.

TH-P-15

Photon Ring Multi-User Distribution System for a Soft X-ray SASE FEL Laboratory

Josef Feldhaus, Evgueni Saldin, Evgueni Schneidmiller (DESY-Hamburg); Mikhail Yurkov (JINR-Dubna, Russia)

Although the soft X-ray photon beam from a SASE FEL undulator is in principle a single user tool, just like an optical laser, an optical distribution system based on multifaceted reflectors can provide efficient ways to generate a multi-user facility--very similar to present day synchrotron radiation facilities [1]. Multifaceted reflectors involve multiple reflections from a series of plane mirrors. They can be repeated a number of times to form a complete ring. In principle, a few tens of beamlines with different experiments can be served by a single FEL source. Using movable mirrors in each photon ring cell it is possible to quickly switch the FEL photon beam from one experiment to the other, thus providing simultaneous multi-user capability.

[1] J. Feldhaus, E. L. Saldin, E. A. Schneidmiller, M. V. Yurkov, DESY 02-026, March 2002.

TH-P-16

VUV Lithography Based on SiC Reflective Optical Systems and SASE FEL Light Sources as a Natural Extention to Shorter Wavelengths of Present-Day Optical Lithography Technology

Carlo Pagani (INFN-LASA); Evgueni Saldin, Evgueni Scheidmiller (DESY-Hamburg); Mikhail Yurkov (JINR-Dubna, Russia)

The semiconductor industry growth is driven to a large extent by steady advancements in microlithography. According to the newly updated industry roadmap, the 50-nm generation is anticipated to be available in the year 2012. This report discusses the basic concepts of VUV lithography (VUVL), a relatively new form of lithography that uses vacuum ultraviolet radiation (VUV) with a wavelength in the range of 50 to 100 nm to carry out projection imaging [1]. This approach uses a SASE FEL as a source of radiation, a reflective mask, and a 4× reduction, all-reflective imaging system. The reflective elements for VUVL use SiC mirrors to produce normal incidence reflectivities at nearly 40%. The mask in a VUV system also uses the same type of SiC material. Recent advances in SASE FEL systems suggest the feasibility of flexible sources for microelectronic production facilities. A VUV SASE FEL source is economical for high-volume production because it can feed multiple steppers. The estimated SASE FEL source portion of the total cost is about $0.5 per 300-mm wafer. Since the wavelength of a SASE FEL source is adjustable, selection of new materials needed for photoresists may be much easier than for the case of a fixed wavelength source. SiC mirrors with characteristics required for VUVL optics are produced by industry. All components of the proposed SASE FEL source equipment have been demonstrated in practice. This is guaranteed success in the time requirement.

[1] C. Pagani, E. L. Saldin, E. A. Schneidmiller, M. V. Yurkov, DESY 01-179, November 2001.

TH-P-17

Ordering and Radiation of Superdense Bunches

Raphael Tumanian, Lecdar Gevorkian (YerPhI)

The coherent radiation of the electron beam with account of bunch ordering (particle position correlations) because of strong Coulomb interaction is considered. For the first time it is shown that the coherency of the radiation of the bunch with account of bunch ordering depends on the mean interparticle distance (mean density of the bunch). The conditions of coherency are found. The influence of deviations from mean distance on the radiation coherency is considered.

TH-P-18

Space Charge and Nonlinear Enhancement of FEL Radiation

Raphael V. Tumanian (Yerevan Physics Institute)

The influence of bunch self space charge forces on the particle spatial distribution in the superdense bunches [1] and the nonlinear theory of the FEL radiation of superdense bunches is considered. The ordering of dense bunches [2] and equation of their FEL radiation with account of correlations is investigated. It is shown that bunch density correlations give rise to a significant effect on the electromagnetic wave amplification and FEL radiation.

[1] R.V.Tumanian and L.A. Gevorgian, submitted to EPAC'02
[2] R.V. Tumanian and L.A. Gevorgian, NATO Workshop "Electron-Photon Interaction in the Dense Media," Nor-Hamberd, Yerevan, Armenia, 25-29 June, 2001, NATO Science Series,II.-Vol.49, H. Viedemann (Ed.), p. 295.

TH-P-19

High-Gain FEL and Beam Physics R&D at VISA

X.J. Wang, M. Babzien, X.Y. Chang, Z.L. Wu (BNL); A. Tremaine (LLNL)

After completion of the VISA experiment by the BNL/LLNL/SLAC/UCLA collaboration, we will be able to preserve most of the VISA experimental set up at the Brookhaven Accelerator Test Facility (ATF). We are exploring a new possible funding source to carry out single-pass FEL and beam physics R&D with the VISA set up. This report outlines the possible experimental program in the next couple of years. The shorter undulator (4-meter) and relatively low beam energy (71 MeV) make the VISA set up unique for FEL and beam physics studies. By lowering the beam energy to 63 MeV, it is possible to study laser-seeded FEL physics at 1 μm, such as noise power. Furthermore, by taking advantage of the large industrial products and technologies available at 1 μm, we are planning to carry out SASE output pulse shortening and monochromic experiments by chirped the electron beam energy. Another important aspect of our experiment program is the use of SASE and spontaneous output from the VISA undulator for electron beam characterization.

TH-P-20

Design Consideration and Optimization for a SASE-FEL Driven by BEPC Linac

Ming Xie (LBNL); Jiejia Zhuang (IHEP-Beijing)

We discuss design issues and present parameter optimization for a SASE-FEL driven by the BEPC linac.

TH-P-21

Temporal Characterization of Ultrashort Electron Beam Bunch at the Jefferson Lab FEL User Facility*

S. Zhang, S. Benson, J. Gubeli, G. Neil, M. Shinn, G. Williams (TJNAF)

We are developing an ultrashort electron beam bunch length characterization system for the Upgrade FEL. Femtosecond optical probe pulses generated by a pulse compressor are automatically synchronized with the electron beam and will provide bunch length information when correlated with synchrotron radiation in the THz spectral region. We will present detailed design simulations and ongoing experiments. Comparison with other methods will also be given.

* This work supported by the Office of Naval Research, the Joint Technology Office, the Commonwealth of Virginia, the Air Force Research Laboratory, and by DOE Contract DE-AC05-84ER40150.

WS-P-01

Quasi-Optical High-Sensitive Shottky-Barrier Detector for a Wide-Band FIR FEL

Vitaly V. Kubarev (BINP); Grigori M. Kazakevitch, Young Uk Jeong, Byung Cheol Lee (KAERI)

A wide-band FIR detector based on the Schottky-barrier diode has been developed for the application at a far infrared (FIR) FEL facility [1]. The detector consists of a Ge-Ga chip with diodes having submicrometer diameters and a travelling-wave antenna in a 90-degree corner-cube reflector providing effective transmission of the FIR power to the diode from the input FIR focusing lens. The antenna has been optimized for the wavelength of 337 μm. At the wavelength the detector shows a sensitivity of 200 V/W and noise equivalent power (NEP) of 0.1 nW/(Hz)^{12}. The measurement was accomplished by a HCN laser. For the radiation with a wavelength of 119 μm (H_2O laser) the values of the sensitivity and NEP were measured to be 20 V/W and 1.0 nW/(Hz)$^{1/2}$, correspondingly. Measured results of the radiation of the compact wide-band FIR FEL facility by the detector in the wavelength range 100-300 μm as well as investigation of its potential for a wide range of wavelengths are presented in this report.

[1] Y.U. Jeong et al., "Upgrade of the KAERI Compact FIR FEL for the Operation at 100-300 mm Wavelength Range," submitted to these proceedings.

WS-P-02

Recent Results Using the Intense FEL-Generated γ-ray Beam*

*Vladimir Litvinenko**, Henry Weller (DUKE)*

In this paper we present the experimental program and recent results at the High Intensity γ-ray Source (HIγS) facility. The HIγS, based on the OK-4/Duke storage ring FEL, generates polarized γ-ray beams of unmatched quality and intensity. These features of the HIγS were used for a number of key experiments in nuclear resonance fluorescence, photodisintegration of the deuteron, precise measurements of photon attenuation cross sections physics, to mention few. We present selected experimental results as well as the ongoing upgrades of the HIγS facility to the its final specifications.

* Work is supported by DOE and AFOSR grants and the Dean of Natural Sciences, Duke University.

** for HIγS collaboration

WS-P-03

Production and Application of High Power Femtosecond Terahertz Radiation*

George R. Neil (TJNAF); G. L. Carr (BNL); Joseph F. Gubeli, K. Jordan (TJNAF); Michael C. Martin, Wayne R. McKinney (LBNL); Michelle Shinn (TJNAF); Masahiko P. Tani (OsakaU); G. P. Williams (TJNAF); X.-C. Zhang (RPI University)

The terahertz (THz) region of the electromagnetic spectrum is attracting interest for a broad range of applications ranging from diagnosing electron beams to biological imaging. Most sources of short-pulse THz radiation utilize excitation of biased semiconductors by high peak power lasers. For example, this was done by using an undoped InAs wafer irradiated by a femtosecond free-electron laser (FEL) at the Thomas Jefferson National Accelerator Facility. Microwatt levels of THz radiation were detected when excited with FEL pulses at 1.06 microns wavelength and 10 W average power. Recently substantially higher powers of femtosecond THz pulses produced by synchrotron emission were extracted from the electron beamline. Calculations and measurements confirm the production of coherent broadband THz radiation from relativistic electrons with an average power of nearly 20 watts, a world record in this wavelength range by a factor of 10,000. We describe the source, presenting theoretical calculations and their experimental verification. Potential applications of this exciting new source include driving new nonlinear phenomena, performing pump-probe studies of dynamical properties of novel materials, and studying molecular vibrations and rotations, low-frequency protein motions, phonons, superconductor bandgaps, electronic scattering, and collective electronic excitations (e.g., charge density waves).

* This work supported by the Office of Naval Research, the Joint Technology Office, the Commonwealth of Virginia, the Air Force Research Laboratory, and by DOE Contract DE-AC05-84ER40150.

WS-P-04

Gelatin Photoablation Wavelength Dependency in the Range of 5.6-6.7 μm Using a Free Electron Laser

Manabu Heya, Yuko Fukami, Hiroyuki Nagata, Yuji Nishida, Kunio Awazu (OsakaU)

Efficient ablation of soft tissues is needed for non-invasive dermatological and corneal surgeries. Previous researches revealed smooth and efficient cutting of some soft tissues using a 6.45-μm free-electron laser (FEL), tuned to the amide-II band of proteins. In this study, we focus on the bending vibrational band of water (the maximum absorption wavelength is 6.1 μm) as a primary absorber because most soft tissues contain 70-80 wt% water. Gelatin ablation experiments have been carried out using a mid-infrared (MIR) FEL at the Institute of FEL, Osaka University. Gelatin was considered as a model of soft tissues and its water concentration was ~80 wt%. FEL wavelengths were varied within the range of 5.6-6.7 μm. The energy density of the macropulse was fixed at ~4.17 J/cm^2, resulting in material ejection due to water vaporization. The gelatin was efficiently ablated by the irradiation of ~5.95-6.2 μm. On the other hand, by the irradiation of ~6.4-6.6 μm, many small bubbles were observed in the irradiated volume, and the gelatin was not ablated but significantly melted. Thus, it was found that the probable wavelength for cutting soft tissues with high water concentration was ~6.1 μm but not ~6.45 μm.

WS-P-05

Nonlinear Infrared Properties of InAs/GaAs Self-Assembled Quantum Dots

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The high power, short time scale and tuning capabilities of infrared pulses delivered by CLIO enable the original and enlightening investigation of nonlinear infrared properties of InAs/GaAs self-assembled quantum dots. Some very recent results provide key information on the electronic structure and carrier dynamics of these semiconductor artificial atoms. That includes:

- the first experimental evidence of long **polaron lifetime** T_1 in self-assembled quantum dots using improved **pump-probe** techniques around 22 μm wavelength [1].

- time-integrated degenerate four-wave mixing experiment (**photon echo**) in resonance with intersublevel transitions of valence origin at 7.4 μm. Dephasing time T_2 and mechanisms [2].

- detailed nonlinear spectroscopy of intersublevel transitions by **second** [3] **and third** [4] **harmonic generation** using conduction and valence intersublevel transitions. Measurement of **giant optical nonlinearities**, highest ever reported in a solid.

Future developments using CLIO are strongly directed toward quantum information and quantum computing. Semiconductor quantum dots are indeed potential systems for the implementation of **quantum bits** (qubits) of information and the realization of simple and elementary quantum gates. CLIO stands for a suitable tool to investigate optical coherence properties, an important limiting factor for the manipulation of quantum dots as qubits. Future experiments such as photon echo, pump-probe techniques and Rabi splitting will go towards longer wavelength (30-40 μm) and will use the two-color lasing ability of CLIO.

[1] S. Sauvage et al., Phys. Rev. Lett. 88, 177402 (2002).
[2] Submitted to Phys. Rev. B, Ms #BMR833 (2002).
[3] S. Sauvage et al., Phys. Rev. B 63, 113312 (2001).
[4] S. Sauvage et al., Phys. Rev. B 59, 9830 (1999).

WS-P-06

Ablation of Various Materials Irradiated with Intense XUV Radiation

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The ablation efficiency and threshold of organic polymers and elemental solids irradiated by single pulses of XUV radiation emitted from Z-pinch, plasma-focus, and laser-produced plasmas were investigated. The ablation characteristics measured for these plasma-based sources will be compared with those obtained for irradiation of samples with XUV radiation generated by a free-electron laser. Mechanisms of XUV ablation based on nonthermal processes will be proposed. Possible ways to use XUV ablation for micromachining are discussed.

WS-P-07

Structural Changes of Solid Surfaces Irradiated with Femtosecond, Intense, VUV Pulses Studied at TTF-FEL

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Interaction of ultrashort ($\sim$ 50 fs), high intensity (up to 10^{13} W/cm^2), vacuum ultraviolet ($\lambda \sim 85$ nm) radiation with solids has been studied at TTF-FEL. Charged particles leaving the irradiated samples have been detected with a time-of-flight mass/energy spectrometer. Damaged surfaces have been investigated using light, electron, and atomic force microscopy. Dependence of the structural changes of the surface on the radiation intensity has been determined. Damage thresholds have been estimated. Results are presented for different materials: metals (Au), semiconductors (Si), insulators (Ce:YAG), and organic polymers (polymethylmethacrylate).

WS-P-08

X-Ray Free Electron Laser for Electron-Positron Pair Production on the Nuclei*

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The perspectives of powerful X-ray FELs, when the energy of the interaction of an electron with the field over a wavelength exceeds the electron rest energy, will open a new field of experimental studies of nonlinear quantum-electrodynamic phenomena. It especially permits the realization of electron-positron pair production at the focus of such lasers (at the presence of a third body). The theoretical description of those phenomena in such superstrong electromagnetic fields requires one to go beyond the scope of Quantum Electrodynamics-Feynman diagrams corresponding to the perturbation theory, and its experimental confirmation would verify the validity of the theory in the domain of strong fields.

In the present paper the production of electron-positron pairs via the scattering of intense beam of X-ray quanta on an ion/nucleus is considered. The process is moderately nonlinear for X-ray wavelength where in each interaction over a thousand quanta (with the KeV energies) are participating, in comparison with the laser beams where millions of photons are necessary, requiring fantastically large intensities of the optical beams [1]. The estimation of our results show that production of electron-positron pairs on the nuclei at the focus of expected X-ray FEL facilities is actually possible.

* This work was supported by International Science and Technology Center (ISTC) Project No. A-353.

[1] V. P. Yakovlev, Zh. Eksp. Teor. Fiz. 49, 318 (1965).

WS-P-09

Research and Development for X-ray Optics and Diagnostics on the Linac Coherent Light Source (LCLS)

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The Linac Coherent Light Source (LCLS) is a 1.5- to 15-Å wavelength free-electron laser (FEL) under development at the Stanford Linear Accelerator Center (SLAC). The photon output consists of high-brightness, transversely coherent pulses with duration < 300 fs, together with a broad spontaneous spectrum having total power comparable to the coherent output. The output energy density per unit area, pulse duration, repetition rate, and small FEL spot size pose special challenges for optical components and diagnostics downstream of the undulator. Planning for the photon beam transport, manipulation, and diagnostics downstream of the undulator has begun, backed by calculations and simulations of the FEL beam. We will discuss these preliminary plans and describe the supporting research and development program.

WS-P-10

Current Status and Future Plans for the JAERI Supercondcting rf Linac-based FEL Facility

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Current status and future plans for the JAERI supercondcting rf linac-based FEL facility will be presented to discuss FEL developmental roadmaps over the next 5 or 10 years. Possible applications for surgical knives, silicon isotope enrichment, fiber-transmittable light and heat sources, lithography and energy beaming will be discussed as well as how to realize industrial FELs in the roadmaps. A few-hundred-MeV superconducting rf L-band linac-based UV FEL driver with an energy recovery geometry and a few-tens-MeV high current and high-power IR FEL driver are also proposed for construction and to demonstrate the industrial FEL prototypes in the future plans.

WS-P-11

Proposed Experiments with SPIRIT at LEUTL*

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Laser or ion desorption followed by laser postionization (LDPI) and mass spectrometry is an extremely sensitive technique for trace analysis of materials with small dimensions. In the past, this technique has been successful in elucidating phenomena such as self-assembly in organothiols, diffusion in metals and semiconductors, and the isotopic content of presolar dust grains. Studies of large molecules have been difficult, however, due to the fragmentation caused by multiphoton ionization and the lack of a tunable source for doing single-photon ionization in the vacuum ultraviolet. The LEUTL provides this source, and an experiment has been established at the endstation (SPIRIT - single photon ionization or resonant ionization to threshold). SPIRIT will be used to probe molecular phenomena including carcinogenic DNA, layering and diffusion in polymers, and surface catalyzed reactions. It will also enable efficient detection of biologically important low-z elements such as C, H, O, N, P, and S.

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WS-P-12

Simultaneous Application Combining IR-FEL with SR X-ray at Saga-SLS

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We propose a novel application combining an infrared free-electron laser (IR-FEL) with X-rays from synchrotron radiation (SR X-ray). The IR-FEL is a freely tunable wavelength laser to promote resonant excitation of molecular vibration. On the other hand, the SR X-ray is commonly used for a short time analysis such as XAS and XRF. Thus, the SR-based XAS will perform the transient analysis of specific atoms whose molecular bonding is excited by the IR-FEL. In organic molecules, for instance, the transient local structure around a carbon atom is analyzed by the SR-based XAS, when the carbonate molecule is resonantly excited by the IR-FEL. The Saga Synchrotron Light Source (Saga-SLS) with a third-generation type is now under construction in Saga prefecture in Japan. The Saga-SLS is composed of the IR-FEL facility and a 1.4-GeV storage ring having SR X-ray beamlines. The IR-FEL facility covers the wavelength of 4~20 μm with several MW power per micropulse. The Saga-SLS is a suitable facility for studying the novel application because the IR-FEL is easily transported to the SR X-ray beamlines. Advantages and possible novel applications at the Saga-SLS will be presented.