17TH ADVANCED BEAM DYNAMICS WORKSHOP ON

FUTURE LIGHT SOURCES

WG7 Summary Viewgraphs

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LCLS Undulator Electron Beam Parameters

H.-D. Nuhn et al., SSRL/SLAC

Energy:	4.5 GeV	14.4 GeV
Emittance (normal):	2 π mm-mrad	1.5 π mm-mrad
Charge/bunch:	1 nC	1 nC
Peak current:	3400 A pk	3400 A pk
Bunches/pulse:	1	1
Pulse rep rate:	10-120 Hz	10-120 Hz
Bunch radius:	37 μm rms	31 μm rms
Bunch divergence:	6.1 μrad	1.7 μrad
Bunch length:	20 μm rms (67 fs rms)	20 μm rms
dE/E (uncorrelated):	0.07%	0.02%
dE/E (correlated):	0.2%	0.1%

LCLS Undulator Photon Beam Parameters

H.-D. Nuhn et al., SSRL/SLAC

Electron energy:	4.5 GeV	14.4 GeV

Spontaneous Radiation:

1st undulator peak:	15 Å (0.8 keV)	1.5 Å (8.2 keV)
Peak power/pulse:	8.1 GW	81 GW
Average power:	0.27 W	2.7 W
Beam radius:	52 μm rms	33 μm rms
Beam divergence:	6.2 μrad rms	2 μrad rms
Critical energy:	22 keV	200 keV

FEL Radiation:

Wavelength:	15 Å (0.82 keV)	1.5 Å (8.2 keV)
Peak sat. power/pulse:	11 GW	9 GW
Average saturation power:	0.36 W	0.51 W
Peak brightness:	$1.2\text{x}10^{32}$	$12\text{x}10^{32}$
Average brightness:	$0.42\text{x}10^{22}$	$4.2\text{x}10^{22}$
Peak flux:	$81\text{x}10^{24}$ ph/s	$7.1\text{x}10^{24}$ ph/s
Coherent photons/pulse:	$22\text{x}10^{12}$	$2.0\text{x}10^{12}$
Beam radius:	37 μm rms	31 μm rms
Beam divergence:	3.2 μrad rms	0.38 μrad rms
Pulse duration:	67 fs rms	67 fs rms

Electrons

Parameter	Range	Resolution		Technique	Comment
		Required	Available		
E	1 – 20 GeV	0.01%	0.01%	Spectrometer	
			0.1%	Undulator	
Charge	0.1 – 5 nC	1%	< 1%	BPM, Cavity, Toroid	
q(t)	0.1 – 5 kA	1%, 0.01 ps	Few %		
			0.1 ps	CTR, CSR,• CDR, COUR	
			~ 0.2 ps	Streak Camera •	Single bunch for > 1 nC
			~ 0.1 ps	Laser Cross Correlation	Potentially < 0.01 ps
			~ 0.1 ps	Laser Sampling	Potentially < 0.01 ps, jitter control?
			< 0.1 ps	PLAID, M56 •	
			3 ps	Fluctuation measurement •	Potentially much faster, Needs development

Electrons (cont'd.)

Parameter	Range	Resolution		Technique	Comment
		Required	Available		
Position	+/- 1 mm	1 um	< 1 um	Cavity, Buttons, • Stripline	Alignment for absolute accuracy?
				Imaging in wiggler or bends	
Profile	+/- 1 mm	1 um	~ 5 um	Single crystal screens, OTR	Intercepting
				Imaging in wiggler or bends	
			? 50 um	Higher moment BPMs	
			? 50 um	DR	Needs development
			< 10 um?	Wires	Intercepting
				Laser wires •	Non-intercepting Potentially < 10 um?
Divergence	0.1 – 10 uRad	0.1 uRad	3 uRad	Undulator •	
			30 uR (@600 MeV)	OTR interferometer, •	Intercepting
				Higher moment BPMs, 3 screens	
				Undulator	
				DR interferometer	Development!

Electrons (cont'd.)

Parameter	Range	Resolution		Technique	Comment
		Required	Available		
Emittance	1 – 2 mm mrad	< 30%	30%?	FEL, combine above	
6D Phase Map	NA	NA	NA	Tomography (multiple techniques: rotate, slice)	Many shots average, interfering

Photons

Treated in less detail

- **Position Monitor Identified**
- **Streak Camera for Time Resolution and some profile information**
- **Imaging available**

Challenges:

- **Power!!!! (see Optics Group Report)**
- **Coherence?**
- **Fast Time Structure?**

Development Areas

Coherent Radiation Techniques (CTR, CDR*, COUR*, CSR*, ...)
*** non-destructive**

Higher Moment BPMs

Tomography

All ultrafast techniques especially laser based

Need to get to fs level !!!

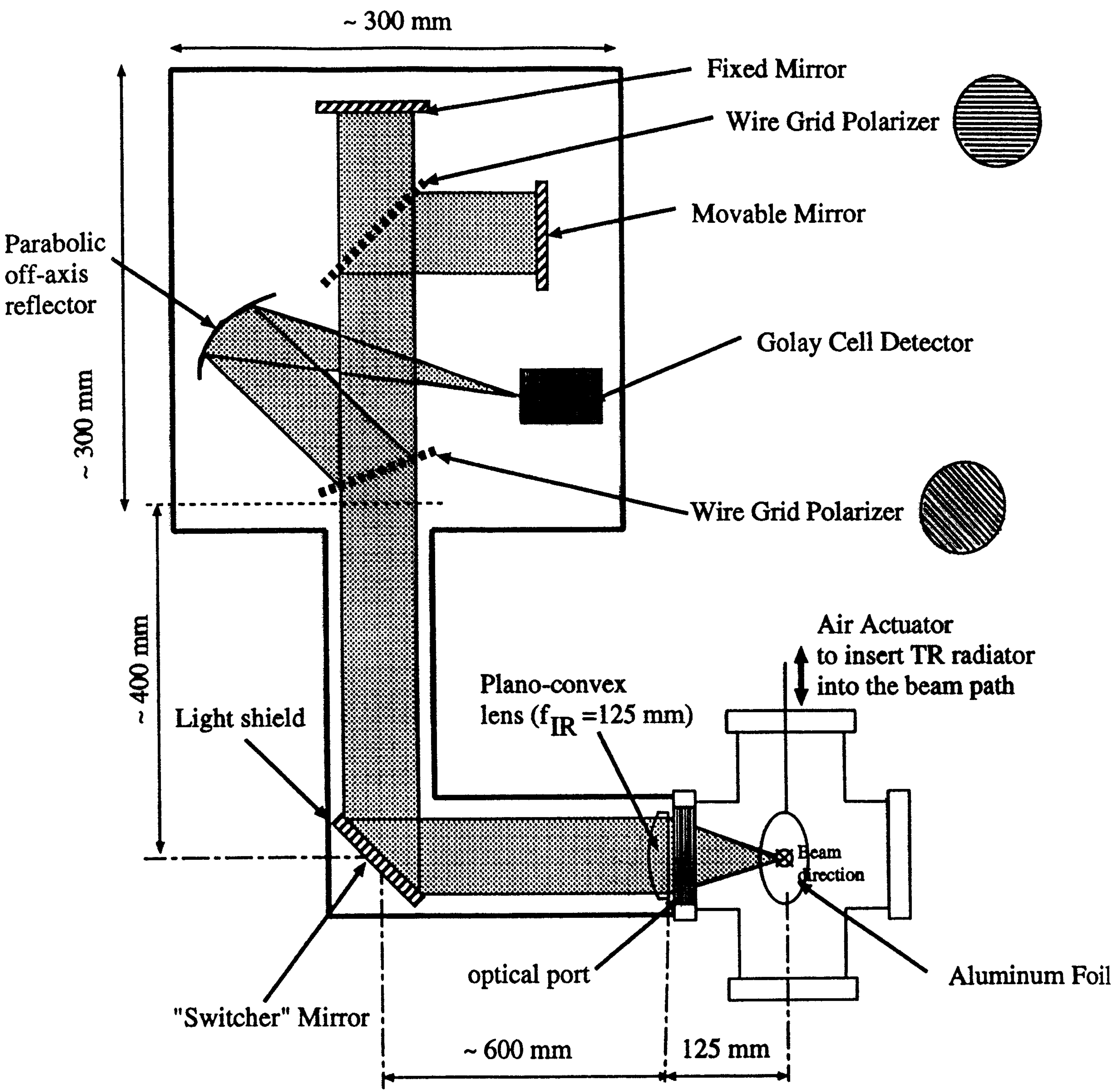
Streak Cameras for X-ray

Diagnostic undulator techniques

Alignment techniques for accuracy

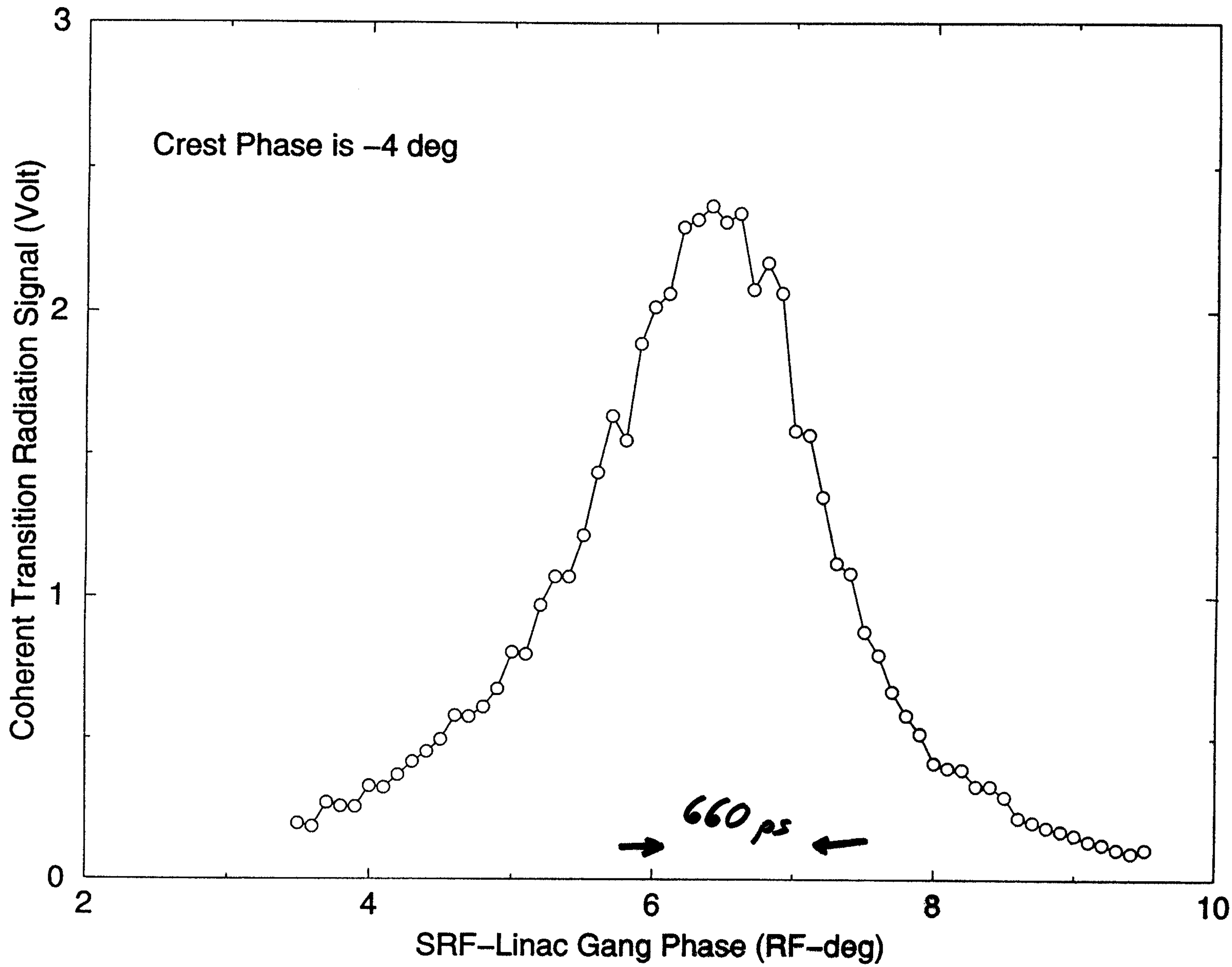
Precision timing

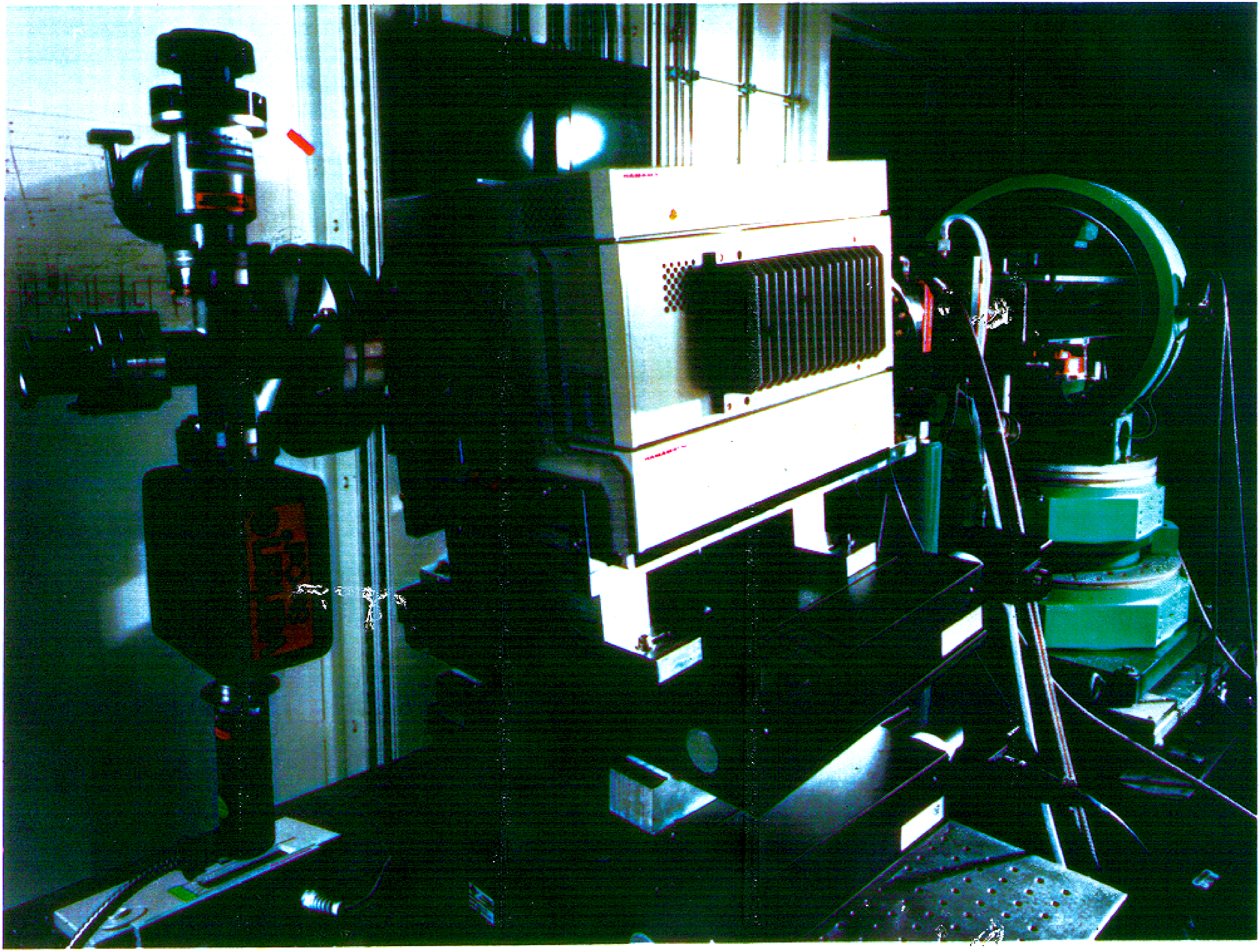
Xray optics techniques (overlap with user needs)



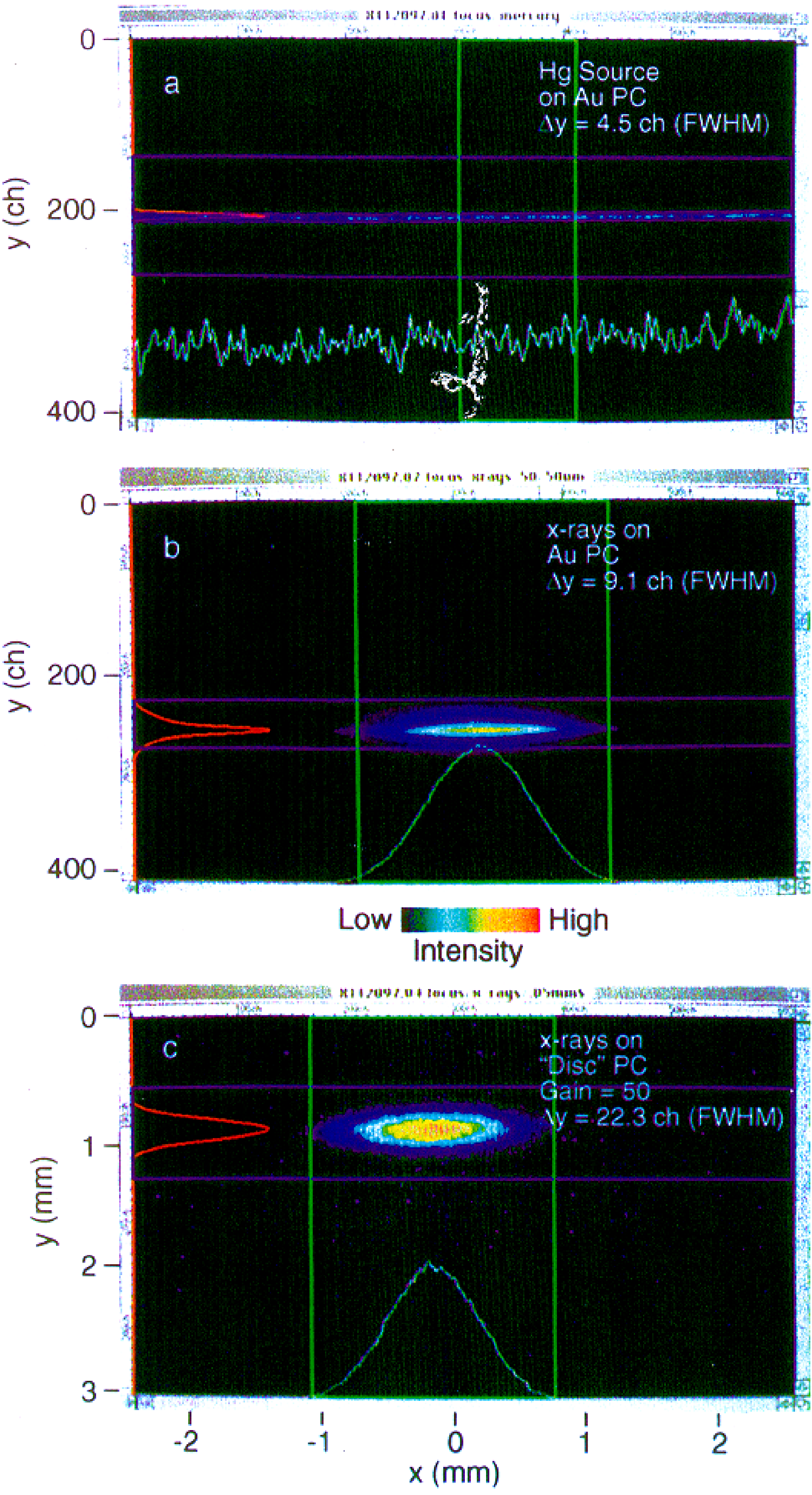
~ 300 mm
Fixed Mirror
Wire Grid Polarizer
Movable Mirror
Parabolic
off-axis
reflector
Golay Cell Detector
~ 300 mm
Wire Grid Polarizer
~ 400 mm
Air Actuator
to insert TR radiator
into the beam path
Plano-convex
lens (f_{IR} =125 mm)
Light shield
Beam
direction
optical port
Aluminum Foil
"Switcher" Mirror
~ 600 mm
125 mm

Maximizing Bunch Compression Using The Linac Phase

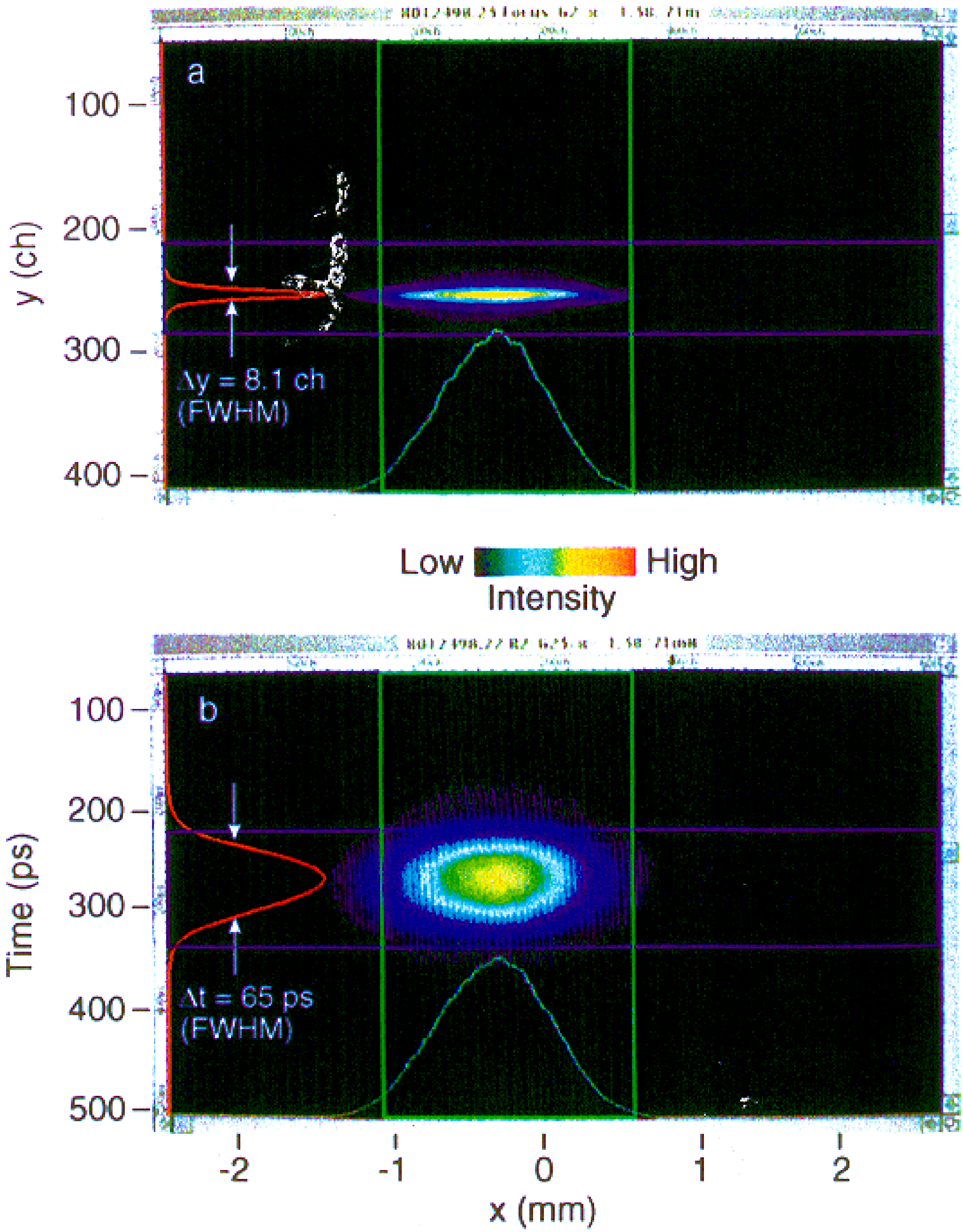




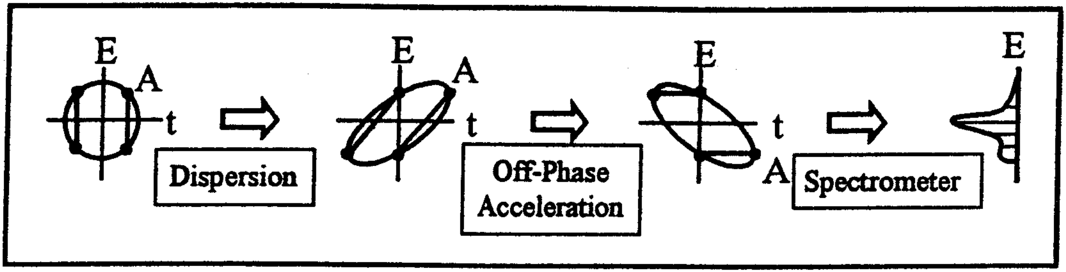
X-Ray Streak Camera Data (Focus Mode)



X-Ray Streak Camera Data (Focus and Synchroscan Modes)

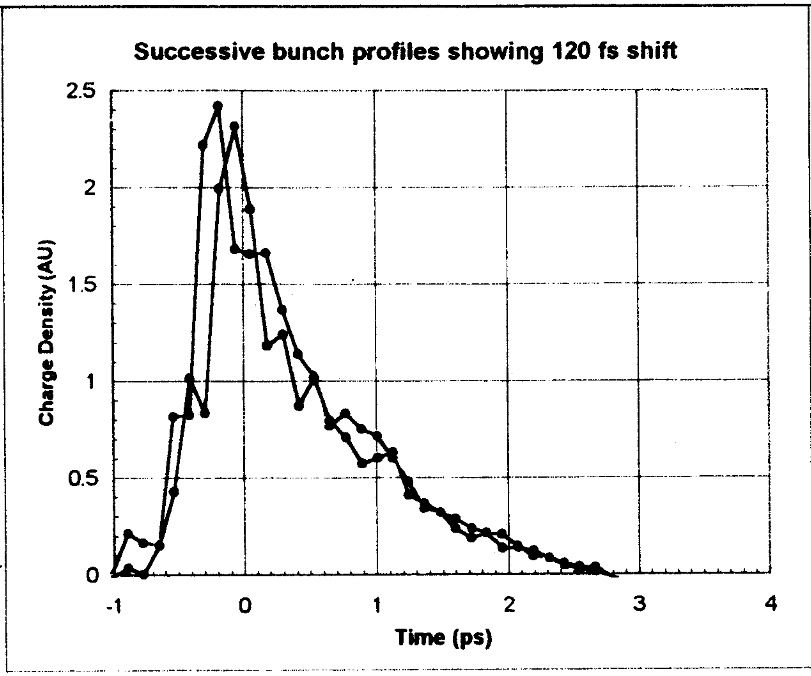


Phase-Space Transformations

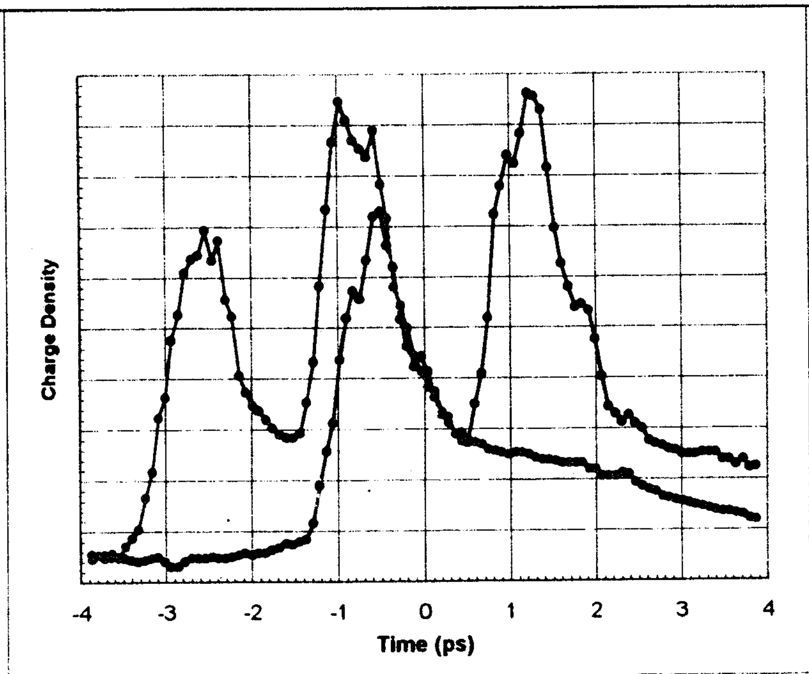


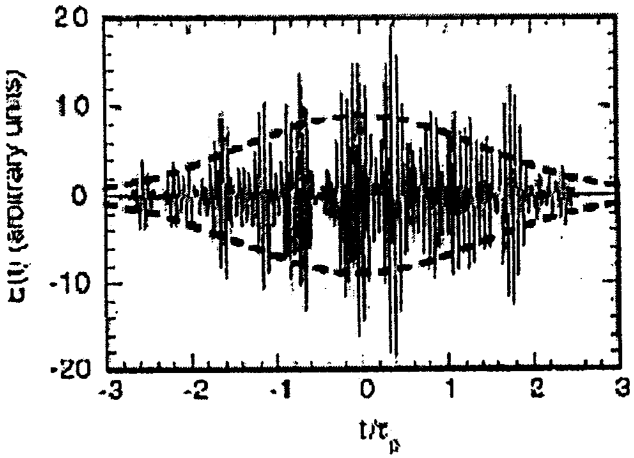
The linear transformation of phase space converts a temporal slice of the bunch, such as the segment containing point A, into a slice of the energy distribution which is imaged in the energy spectrometer. The stretching of the phase space in the dispersive section allows the phased acceleration to remove the initial energy spread from the slice.

Best resolution achieved so far: 120 femtoseconds



Acceptance of the system: Here an electron bunch profile is scanned twice in the energy spectrometer, with a phase shift of 1.9 ps between scans.

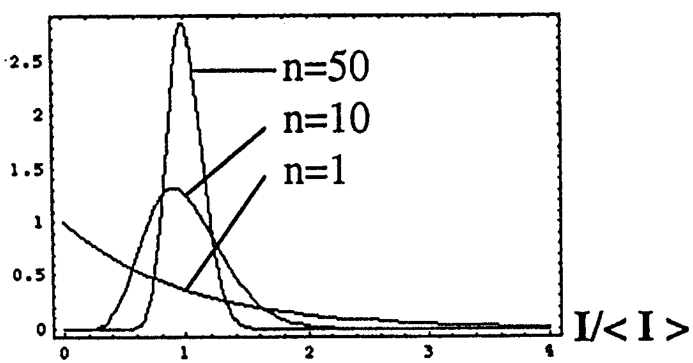




This how look input signal for amplifier. Before saturation, system was linear, and as result of slippage, bunching became superposition of this noise.
After saturation (bunching can not be >1) different pieces of noise start compete with each other and destroyed bunching. As a result is spectral broadening.

Number of spikes is $n \approx \dfrac{c\tau_b}{\lambda M_g \sqrt{Log[gain]}}$ (in linear case)

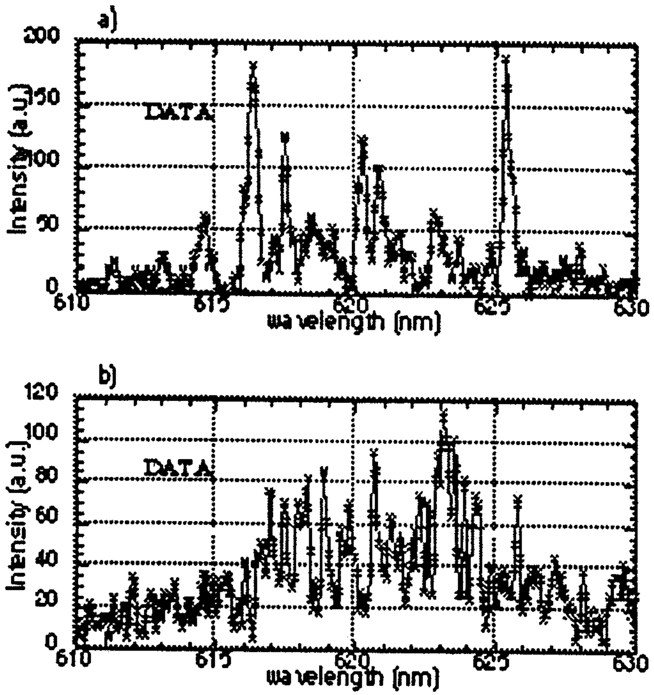
Each spike are independent and fluctuation of normalized intensity will follow of distribution of sum **n** independent Poisson process Gamma[n] distribution.



$$f(x;n) = \frac{x^{n-1} n^n e^{-nx}}{\Gamma(n)}$$

$$< x >= 1; \quad Variance = n$$

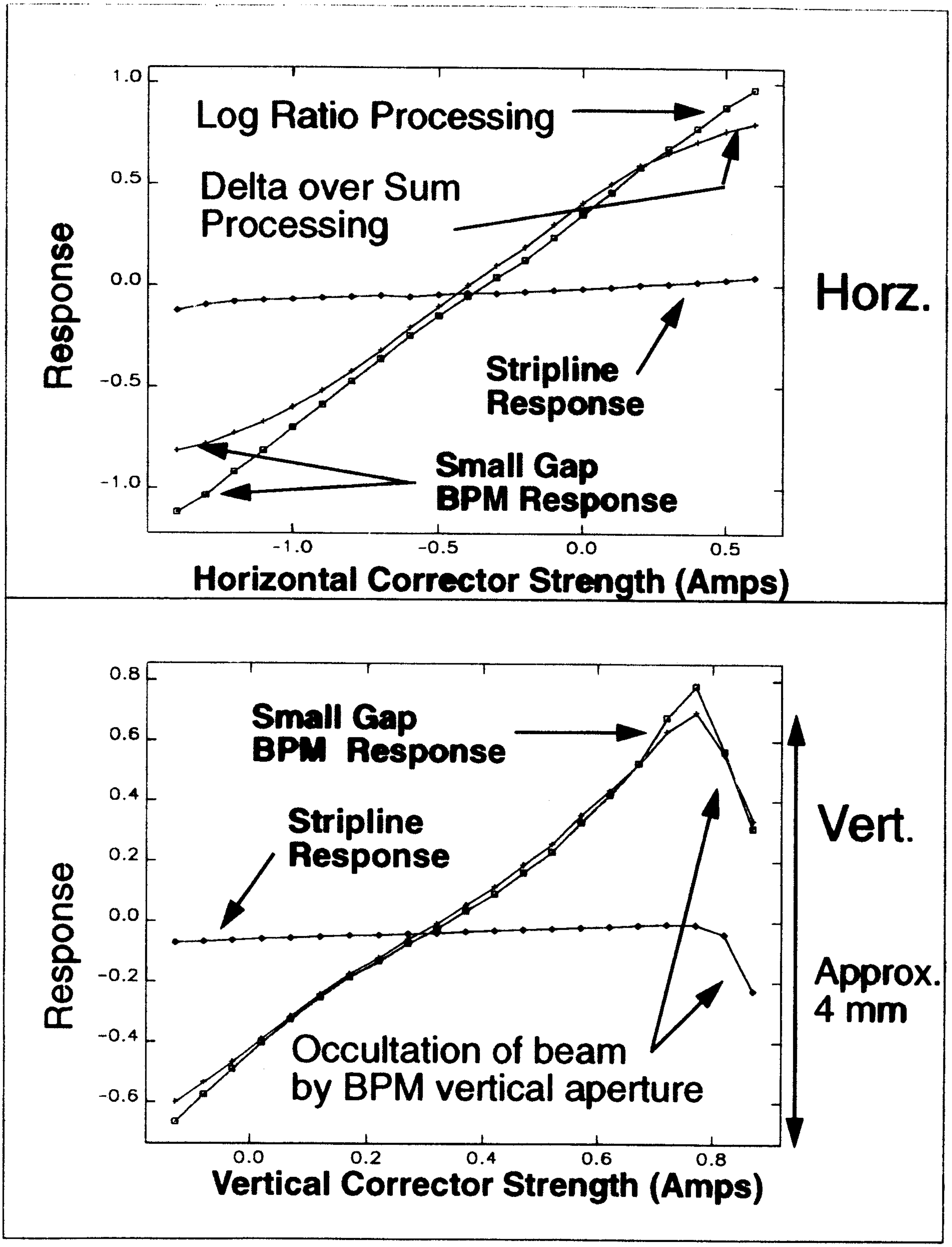
Spectral fluctuation



Spectral fluctuations: narrow spicks with width $1/\tau_{b.}$ In case of pure resolution of spectrometer or mixing radiation from source large than transverse coherence size or both distribution of normalize intensity of spikes will be Gamma distribution

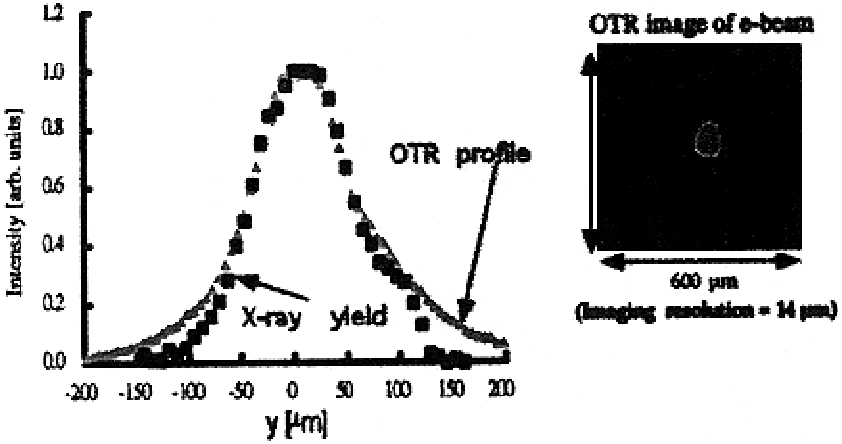
Palma Catravas et. all

Comparison of Small Gap vs. Standard Stripline BPM

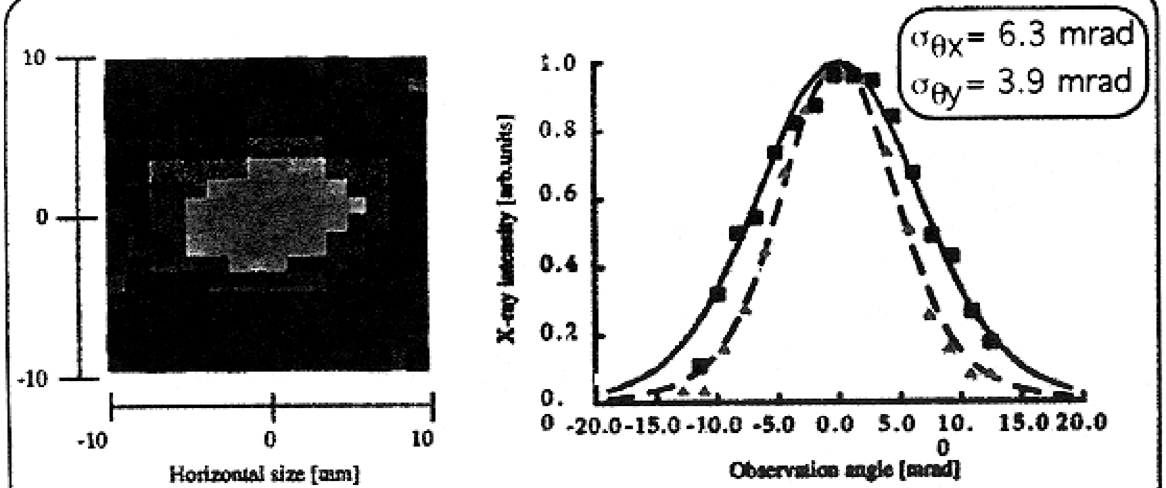


Transverse phase space information is obtained from 90° Thomson scattering

⇒ Vertical beam size is obtained by scanning laser vertically across electron beam



⇒ Beam divergence of a single 200 fs slice is obtained from the far field x-ray profile



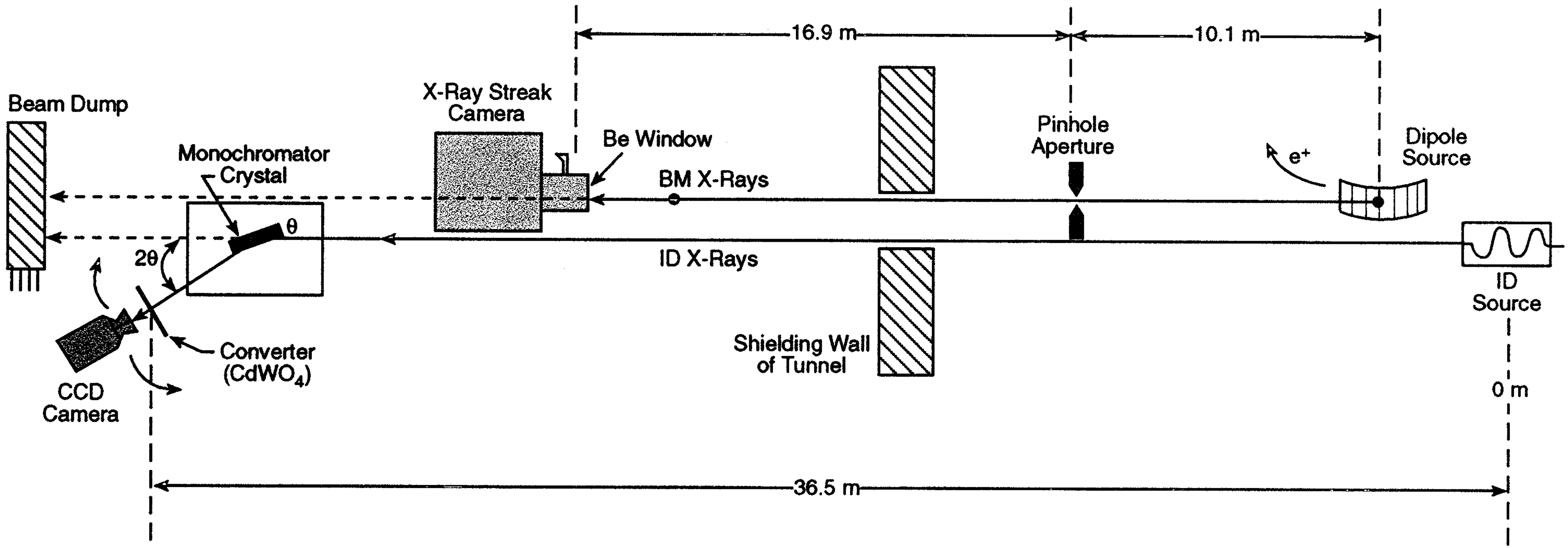
$$\frac{dP}{d\theta_x d\theta_y} \propto \int_0^{2\pi} d\phi \int_0^1 d\kappa\, F(\kappa)\kappa\left[1 - 4\kappa(1-\kappa)\cos^2\phi\right]$$

$$\times \exp\left[-\frac{\left(\theta_x - \gamma^{-1}\sqrt{\frac{1}{\kappa}-1}\,\cos\phi\right)^2}{2\sigma_{\theta x}^2}\right]$$

$$\exp\left[-\frac{\left(\theta_y + \gamma^{-1}\sqrt{\frac{1}{\kappa}-1}\,\sin\phi\right)^2}{2\sigma_{\theta y}^2}\right]$$

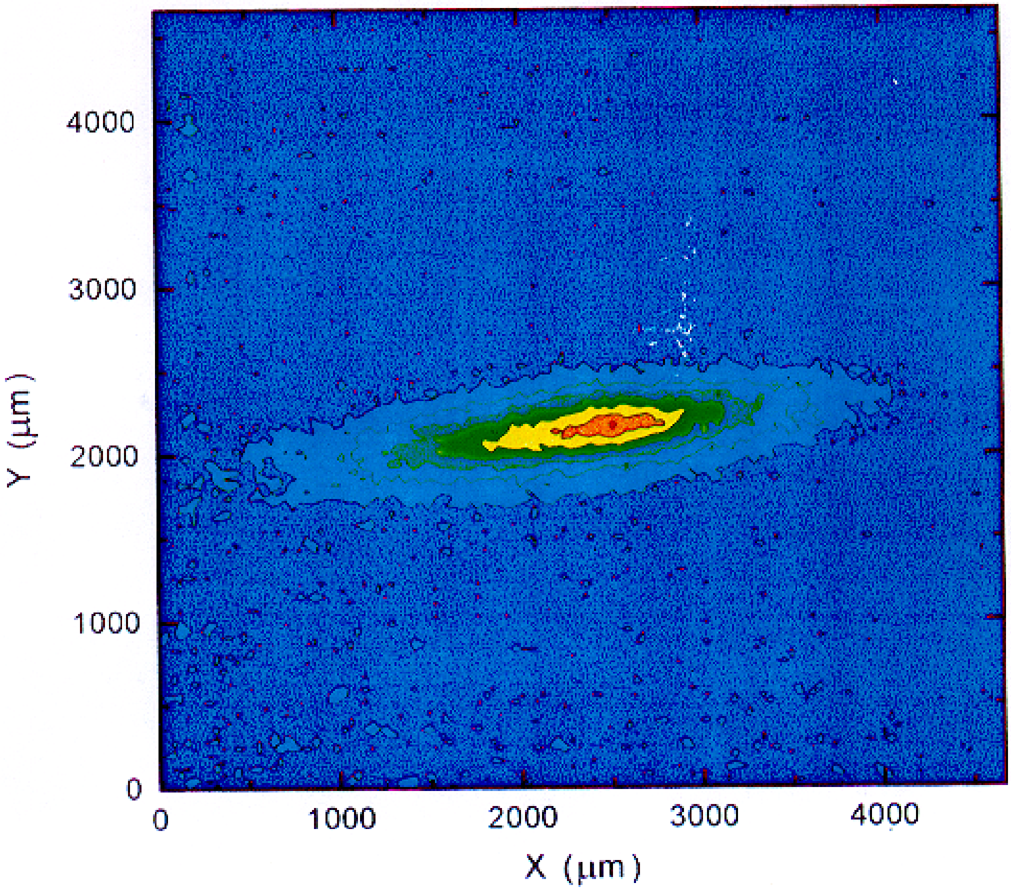
Schematic of the S35 Sources and Beamlines

Top View



SR BEAM DIVERGENCE MEASUREMENT (35-ID)

(After minimizing vertical divergence @ 25 mA, 6/16/97 2:30 PM)



SUMMARY OF MEASUREMENT*

	Horizontal Beam Size	Vertical Beam Size
Total measured value	870 μm	157 μm
Undulator cone	95 μm (2.6 μrad)	95 μm (2.6 μrad)
e^+-beam	314 μm	34 μm
e^+-beam divergence	806 μm (**22 μrad**)	122 μm (**3.3 μrad**)

* The transverse beam size was measured at 36.5 m from the e^+-beam waist. The beta functions were assumed to be at the design value: $\beta_x = 14.2$ m, $\beta_y = 10.1$ m.

TOTAL EMITTANCE = 7.1 ± 0.5 nm-rad

VERTICAL COUPLING ≐ 1.6%

OTR at 30 GeV - Beam divergence from 2-foil interference

Formation length (distance required to accumulate π phase shift):

$$L_f = \frac{\lambda}{\gamma^{-2} + \theta^2}$$

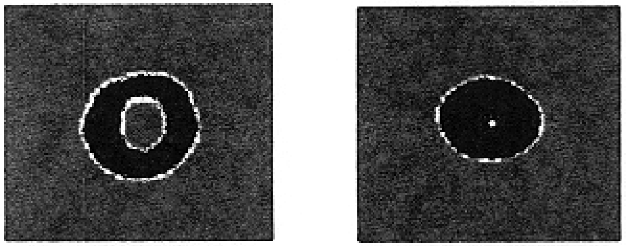
Intensity distribution:

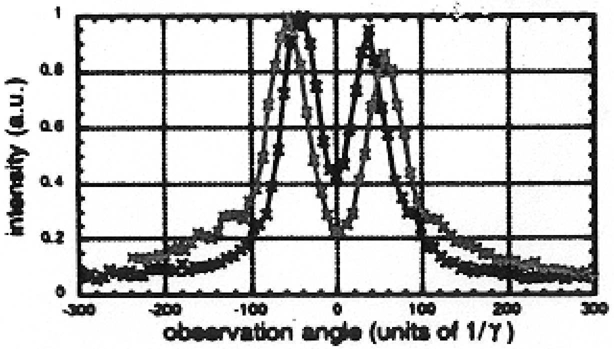
$$\frac{d^2 W}{d\omega d\Omega} = \frac{\theta^2}{\left(\gamma^{-2} + \theta^2\right)^2} \sin^2\left(\frac{L}{2 L_f}\right)$$

At 30 GeV $\lambda = 532\ nm$, $L \sim 0.6 m$, $L_f(\theta = 1/\gamma) \sim \underline{0.5 km}$ but: $L_f(\theta = 30/\gamma) \sim 0.6m \sim$ *foil separation, L*

2 foil interference patterns may be observed and utilized by collecting angles $>> 1/\gamma$

Wavelength dependence of measured intensity distribution and theory are in agreement.

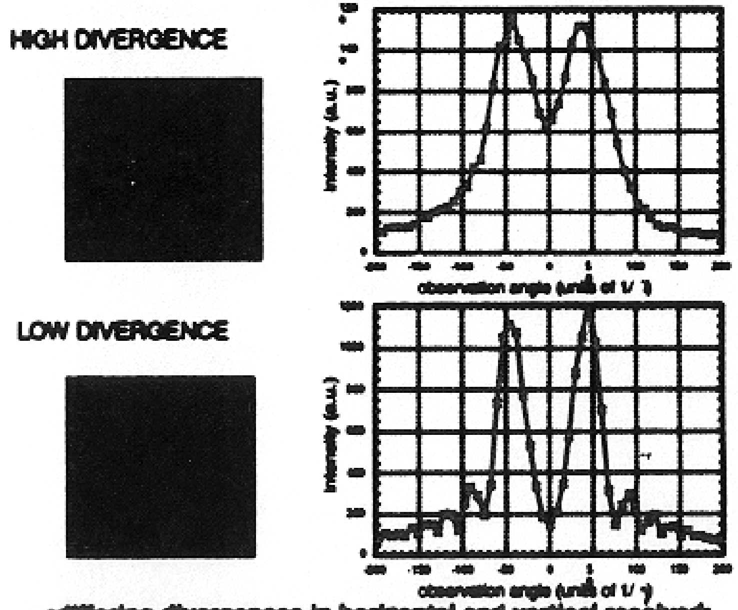




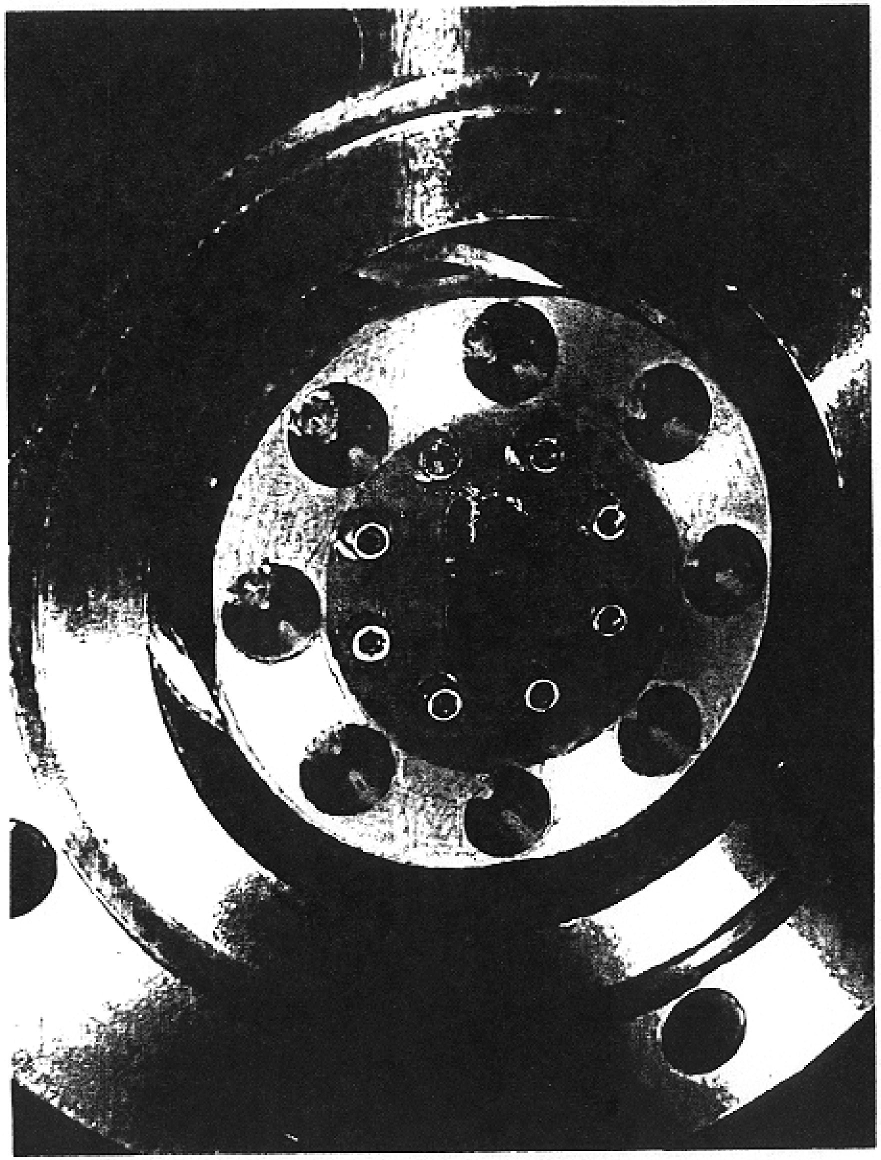
Application: beam divergence calibration

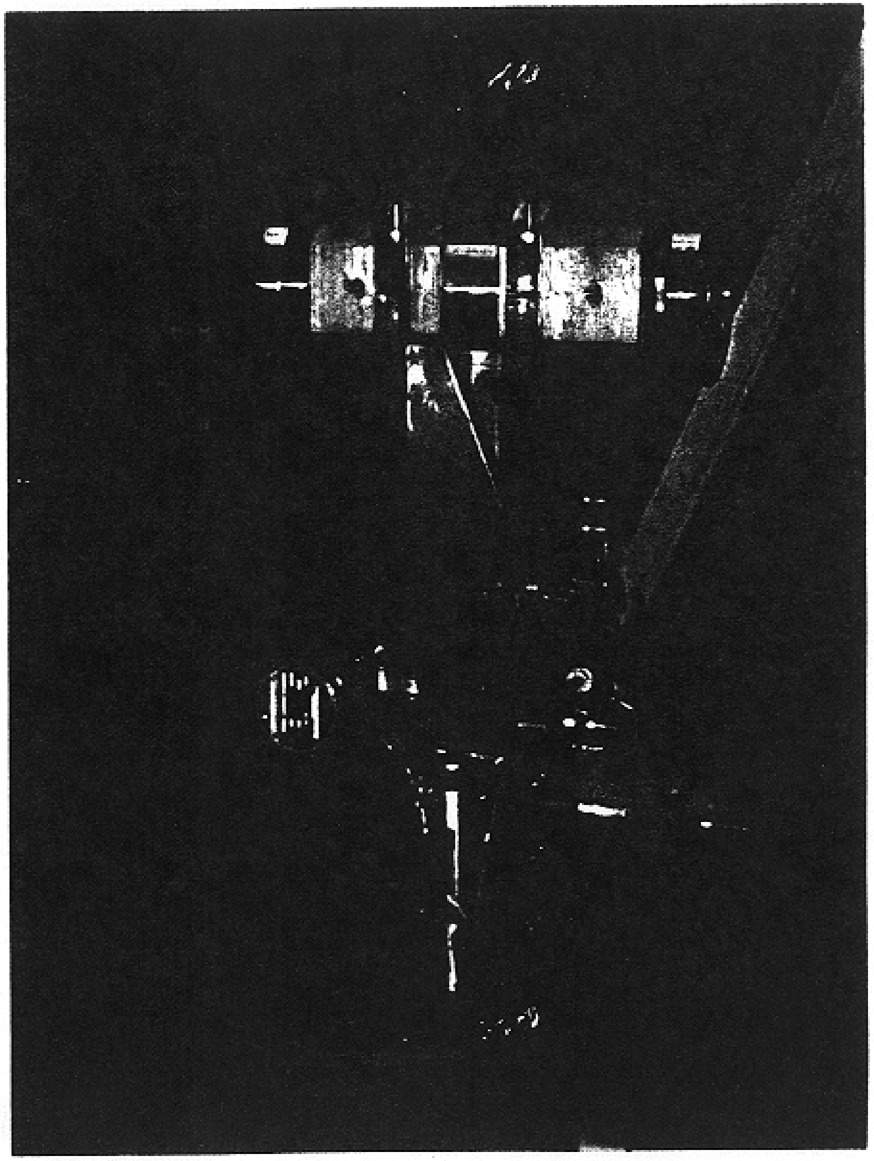
Sensitivity range adjustable via foil separation and wavelength BP.

Range of ~10-50/γ demonstrated below



- differing divergences in horizontal and vertical resolved;
- divergence evolution during quad scan resolved



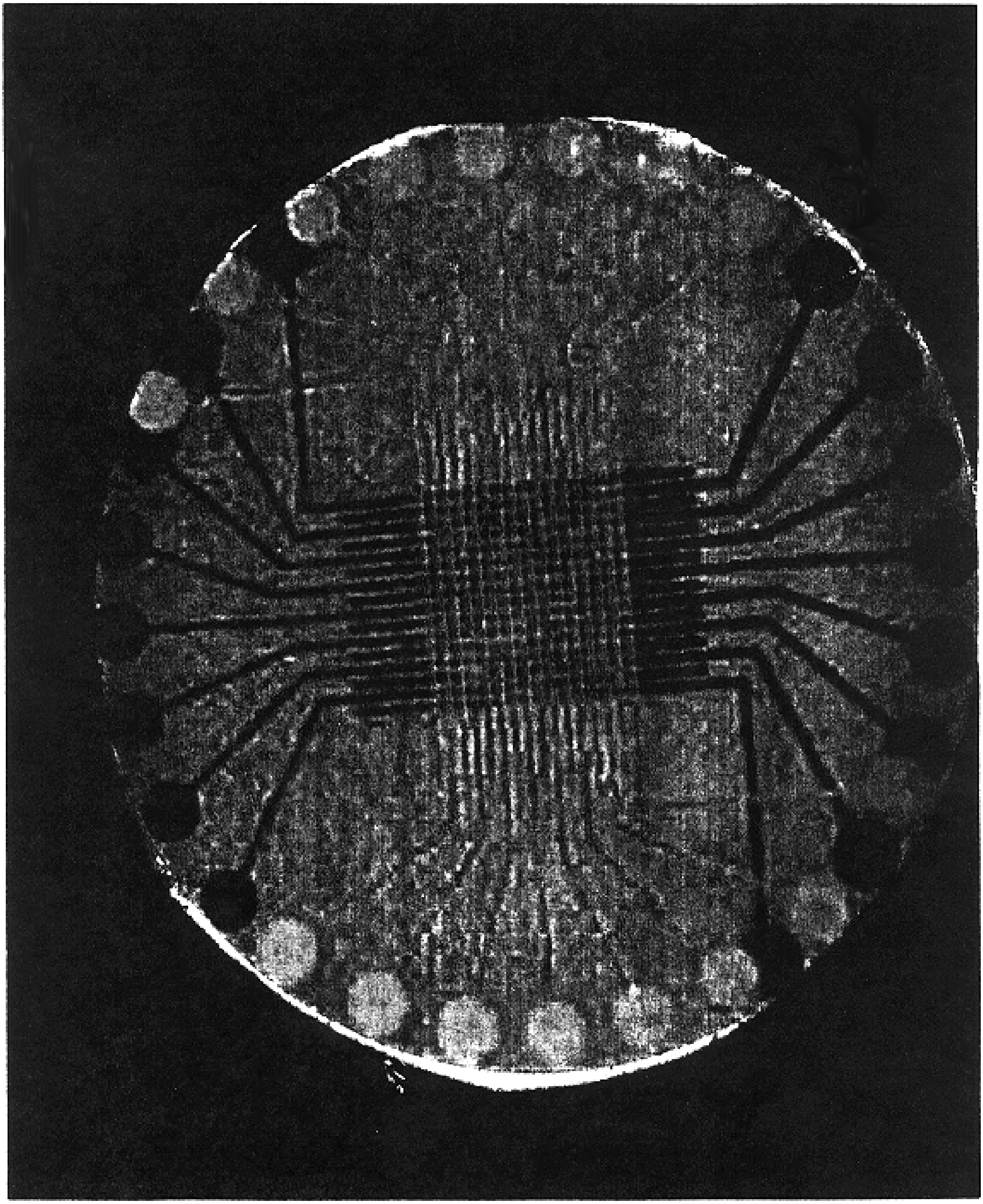


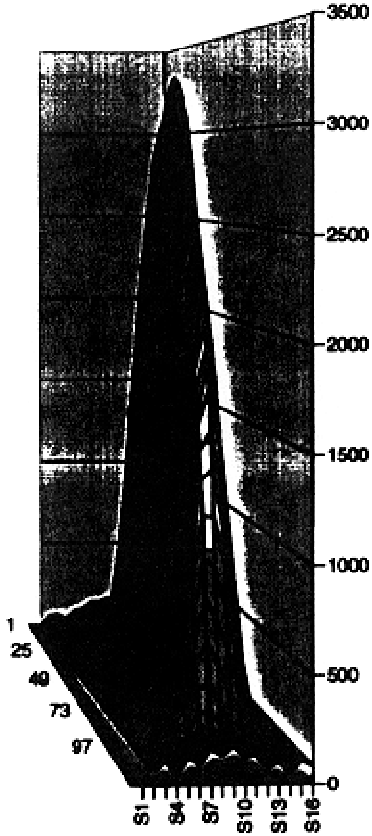
APS CVD Diamond Based XBPM

Combined with Fixed Mask for High-power-density X-ray Beam

APS 16 X 16 pixel Synthetic Diamond-Based

Position-Sensitive Photoconductive Detector (PSPCD) Prototype





A typical profile of APS undulator white beam directly measured by a 16-pixel linear-array PSPCD.