17TH ADVANCED BEAM DYNAMICS WORKSHOP ON
FUTURE LIGHT SOURCES

Storage Ring FELs at the ETL

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ARGONNE NATIONAL LABORATORY, ARGONNE, IL U.S.A.

FEL RESEARCH AT THE ETL

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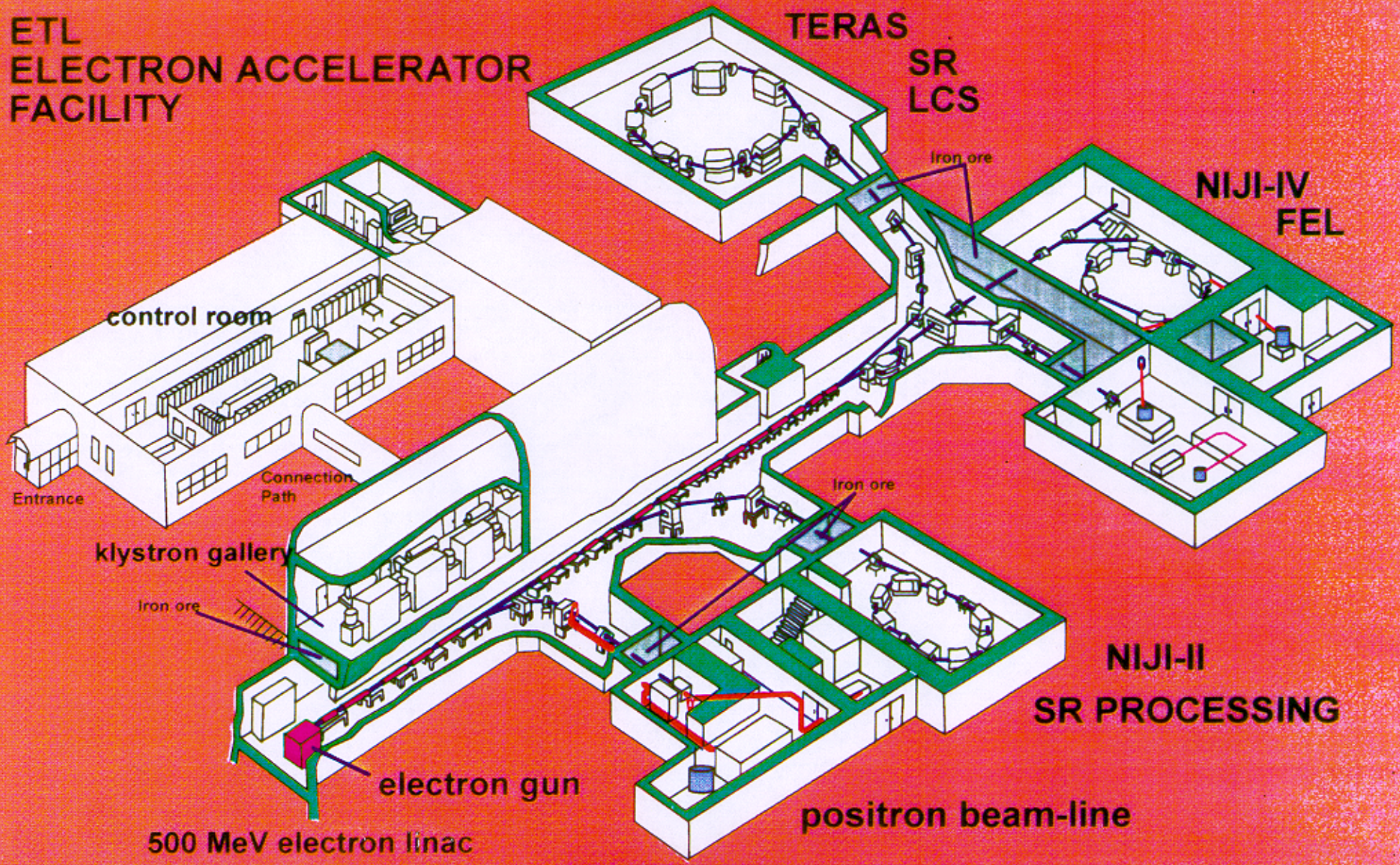
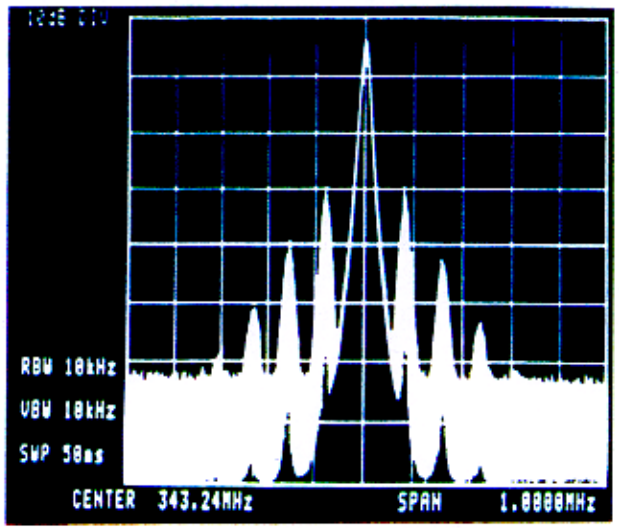
ETL-SRFEL

	TERAS	NIJI-IV
Oct. 1981	First storage	
May 1986	1.5-m Optical klystron	
Feb. 1989	Gain measurement	
Dec. 1990		Completed
Mar. 1991	Oscillation at ~595 nm	First storage
Sep. 1991	Q-Switching	
Apr. 1992	Shut-down of the FEL system	6.3-m Optical klystron
Aug. 1992		Oscillation at ~595 nm
Sep. 1992		Oscillation at ~488 nm
Aug. 1993		Modification of the ring
Aug. 1994		Oscillation at ~350 nm
Apr. 1997		SQS system (1 set)
Jan. 1998		SQS system (4 sets)
Jan. 1998		Chromaticity correction
Mar. 1998		Oscillation at ~300nm
May 1998		Oscillation at ~240 nm
Oct. 1998		Oscillation at ~220 nm at 212 nm


ETL
ELECTRON ACCELERATOR
FACILITY
TERAS
SR
LCS
Iron ore
NIJI-IV
FEL
control room
Entrance
Connection
Path
Iron ore
klystron gallery
Iron ore
NIJI-II
SR PROCESSING
electron gun
positron beam-line
500 MeV electron linac

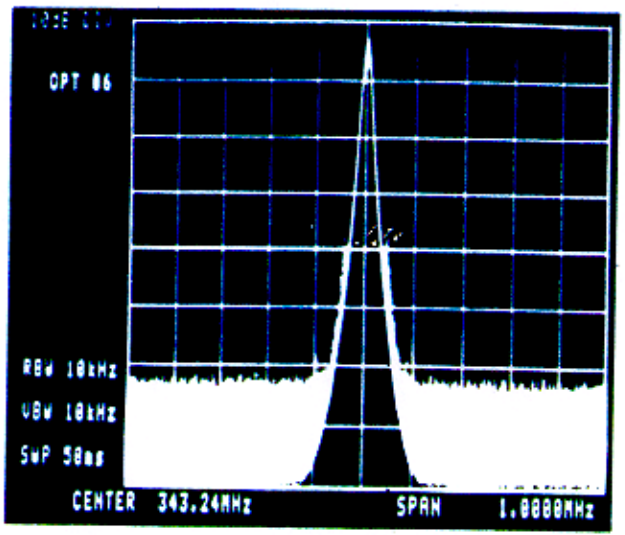
STABILIZATION OF PHASE OSCILLATION

two-cavity system



P_{LC} = 0 kW

I_B = 7.4 mA

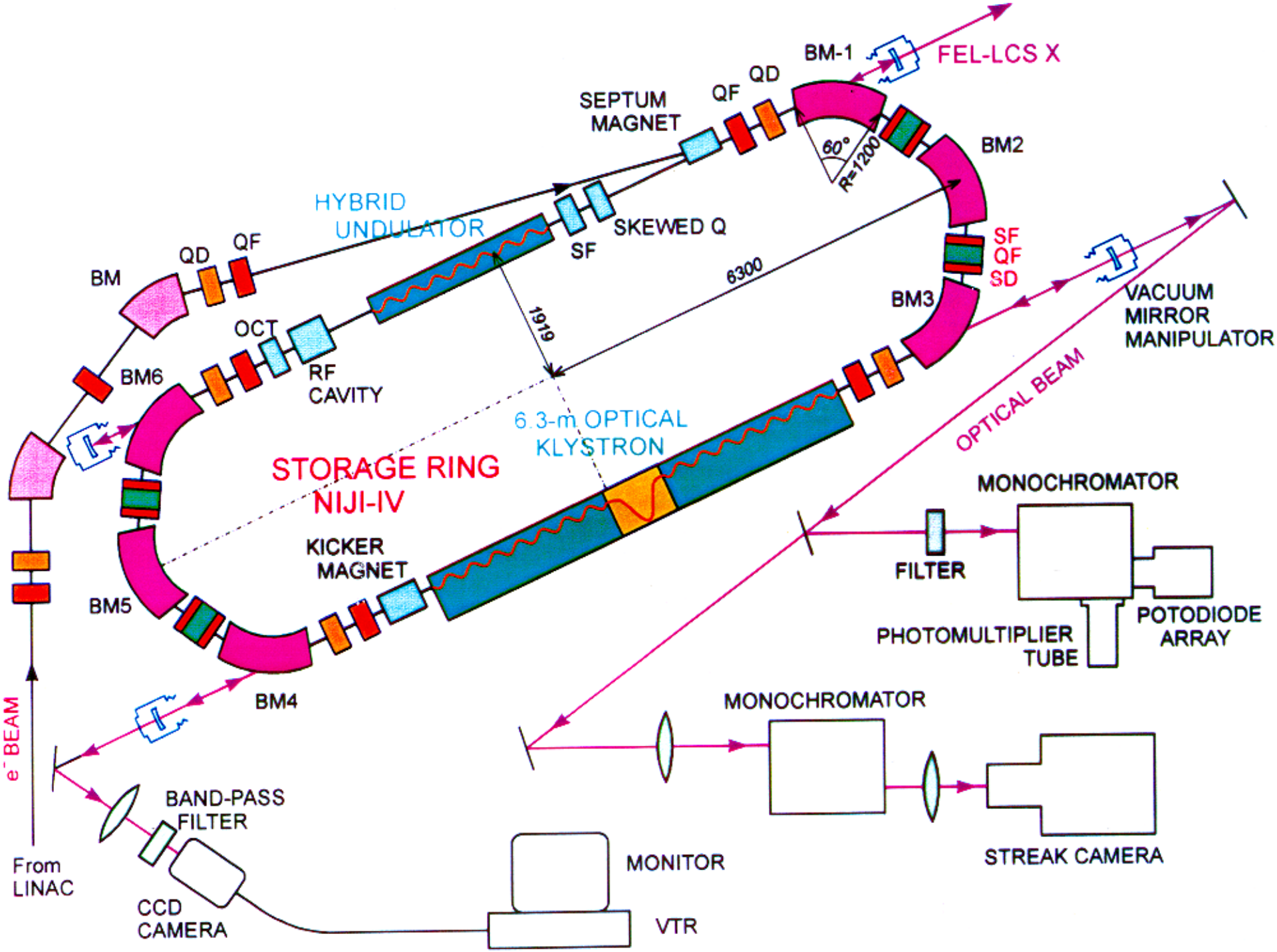


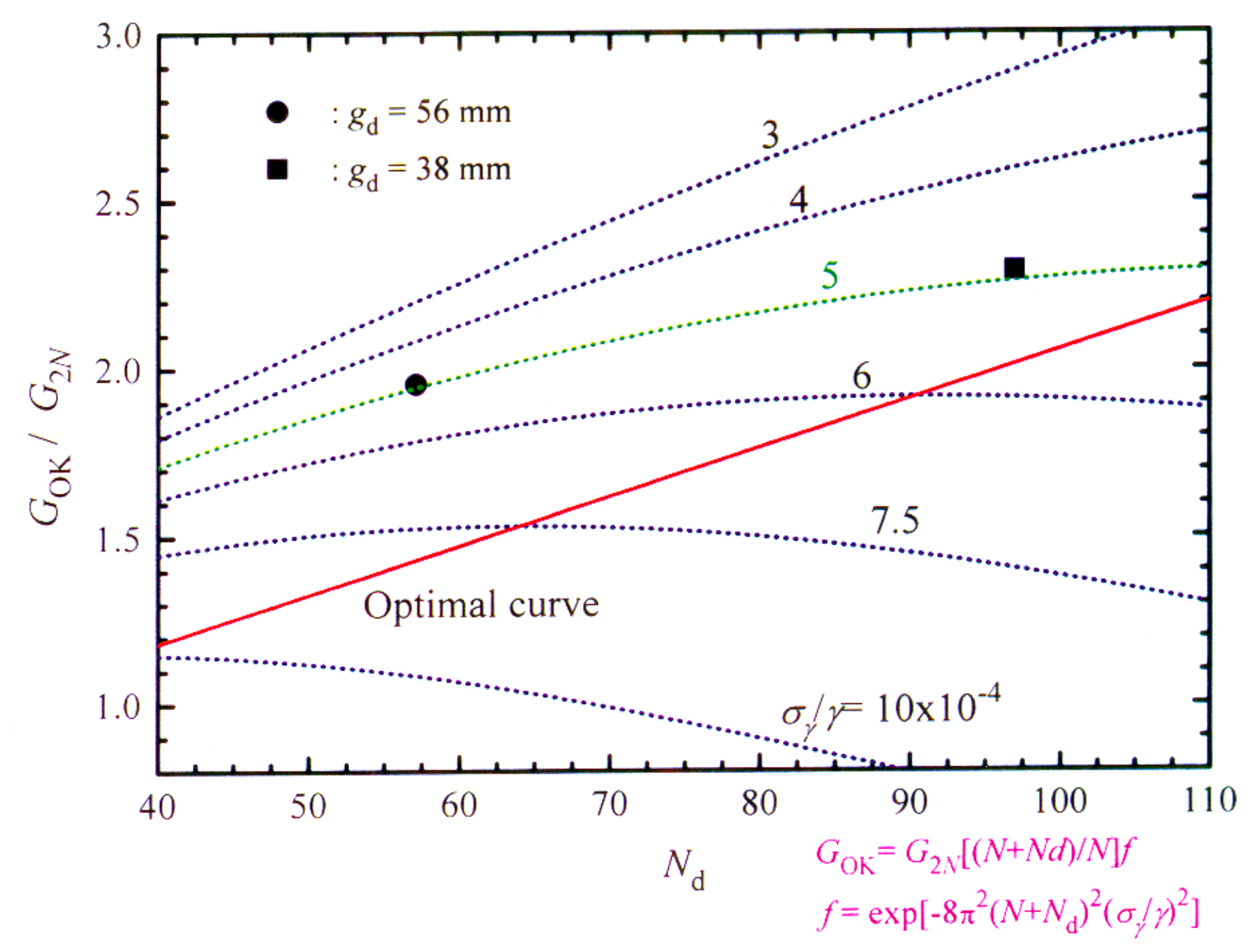
P_{LC} = 0.8 kW

I_B = 6.2 mA

after phase adjustment

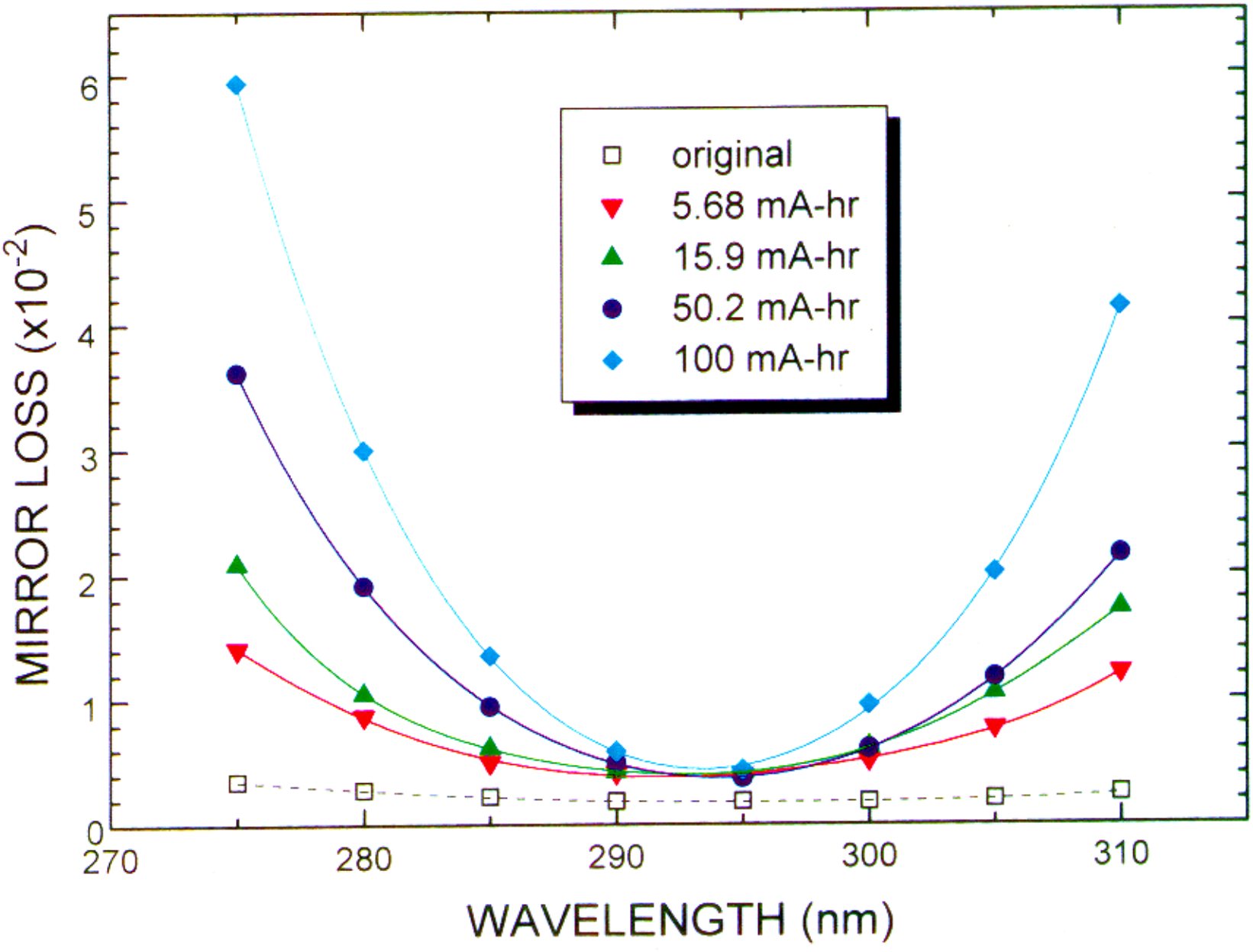
smaller σ_γ


BM-1
FEL-LCS X
SEPTUM MAGNET
QF
QD
60°
R=1200
BM2
HYBRID UNDULATOR
SKEWED Q
SF
SF
QF
SD
6300
1919
BM
QD
QF
OCT
RF CAVITY
BM6
BM3
VACUUM MIRROR MANIPULATOR
OPTICAL BEAM
6.3-m OPTICAL KLYSTRON
STORAGE RING NIJI-IV
KICKER MAGNET
MONOCHROMATOR
FILTER
POTODIODE ARRAY
PHOTOMULTIPLIER TUBE
BM5
BM4
MONOCHROMATOR
e⁻ BEAM
BAND-PASS FILTER
From LINAC
CCD CAMERA
MONITOR
VTR
STREAK CAMERA


3.0
2.5
2.0
1.5
1.0
40
50
60
70
80
90
100
110
G_{OK} / G_{2N}
N_d
● : g_d = 56 mm
■ : g_d = 38 mm
3
4
5
6
7.5
Optimal curve
σ_γ/γ= 10x10^{-4}
G_{OK}= G_{2N}[(N+Nd)/N]f
f= exp[-8π^2(N+N_d)^2(σ_γ/γ)^2]

Mo C03 P44

EVOLUTION OF DEGRADATION IN AN IBS MIRROR



SCHEMATIC DRAWING OF PLASMA REACTOR

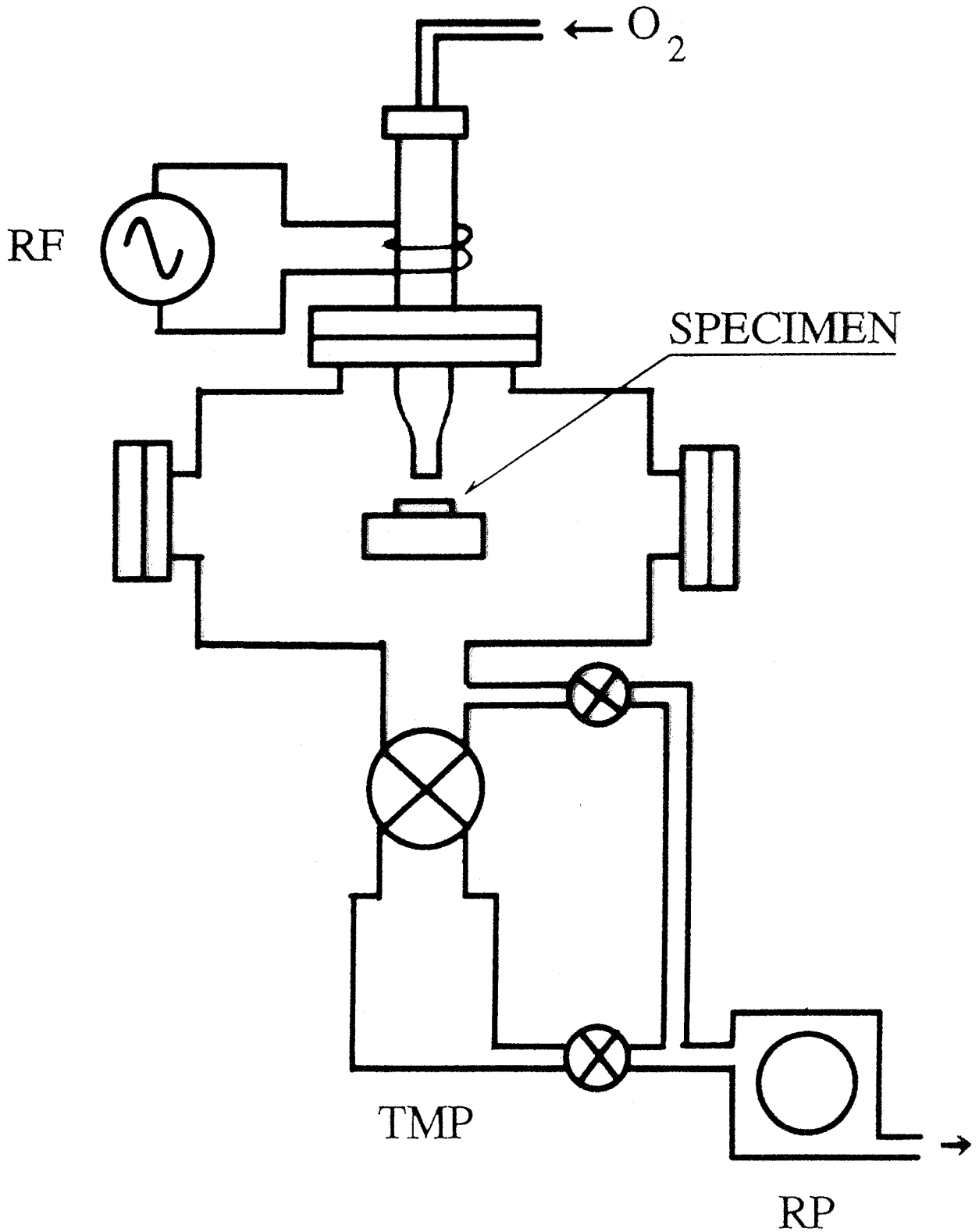
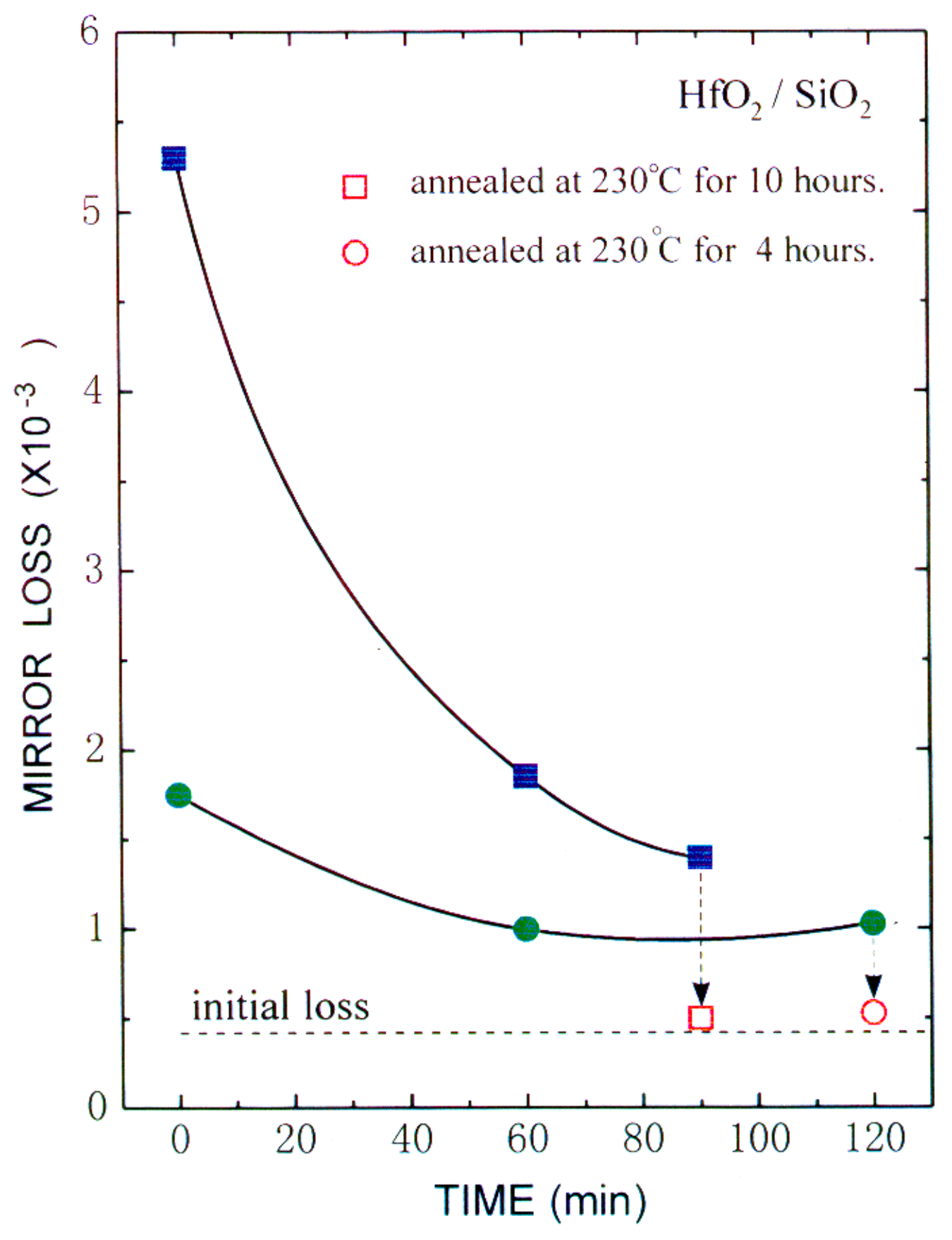


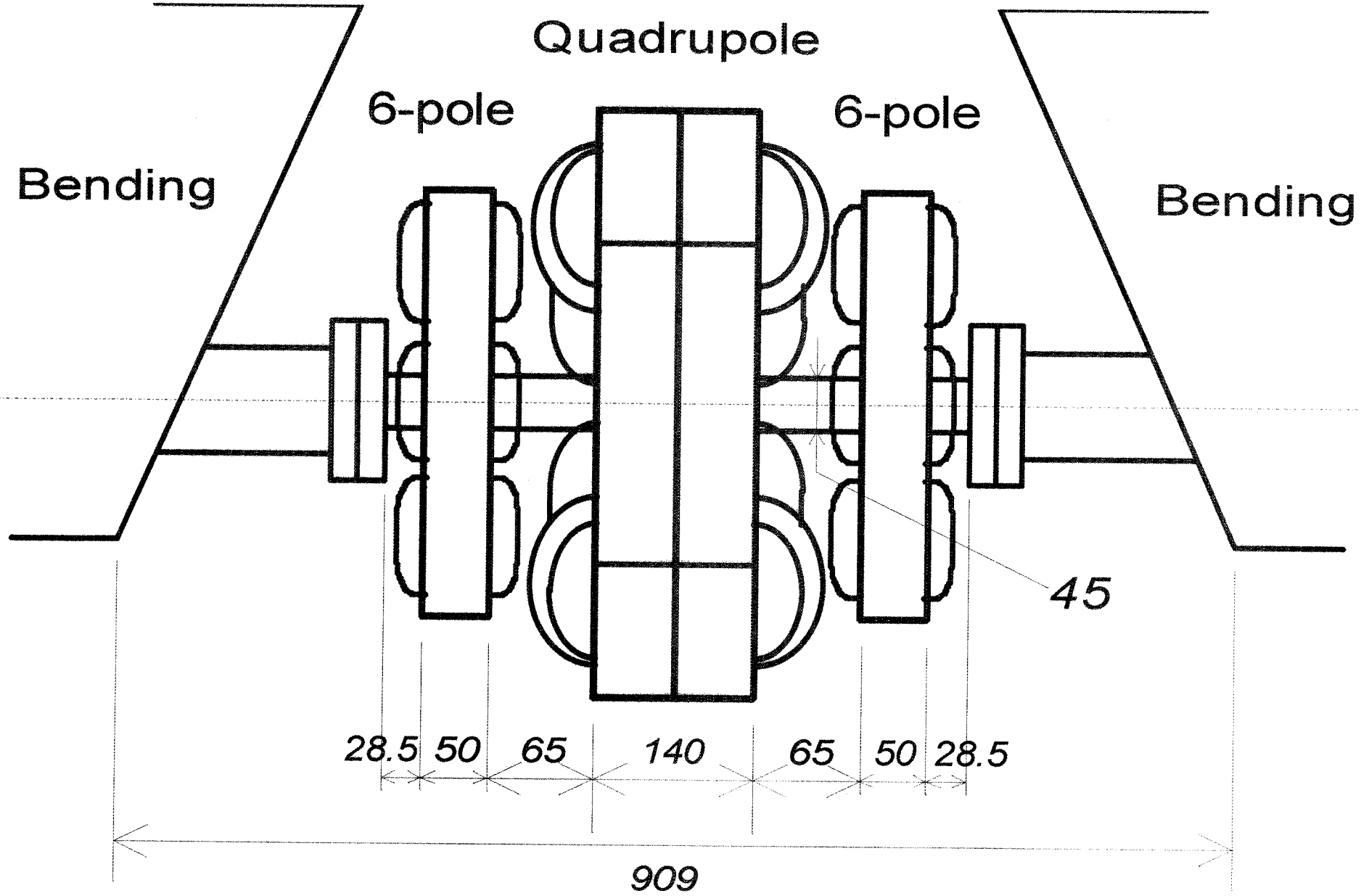
図５　光共振器ミラー表面処理装置


HfO_2 / SiO_2
annealed at 230°C for 10 hours.
annealed at 230°C for 4 hours.
initial loss
MIRROR LOSS (X10^{-3})
TIME (min)
0
1
2
3
4
5
6
0
20
40
60
80
100
120

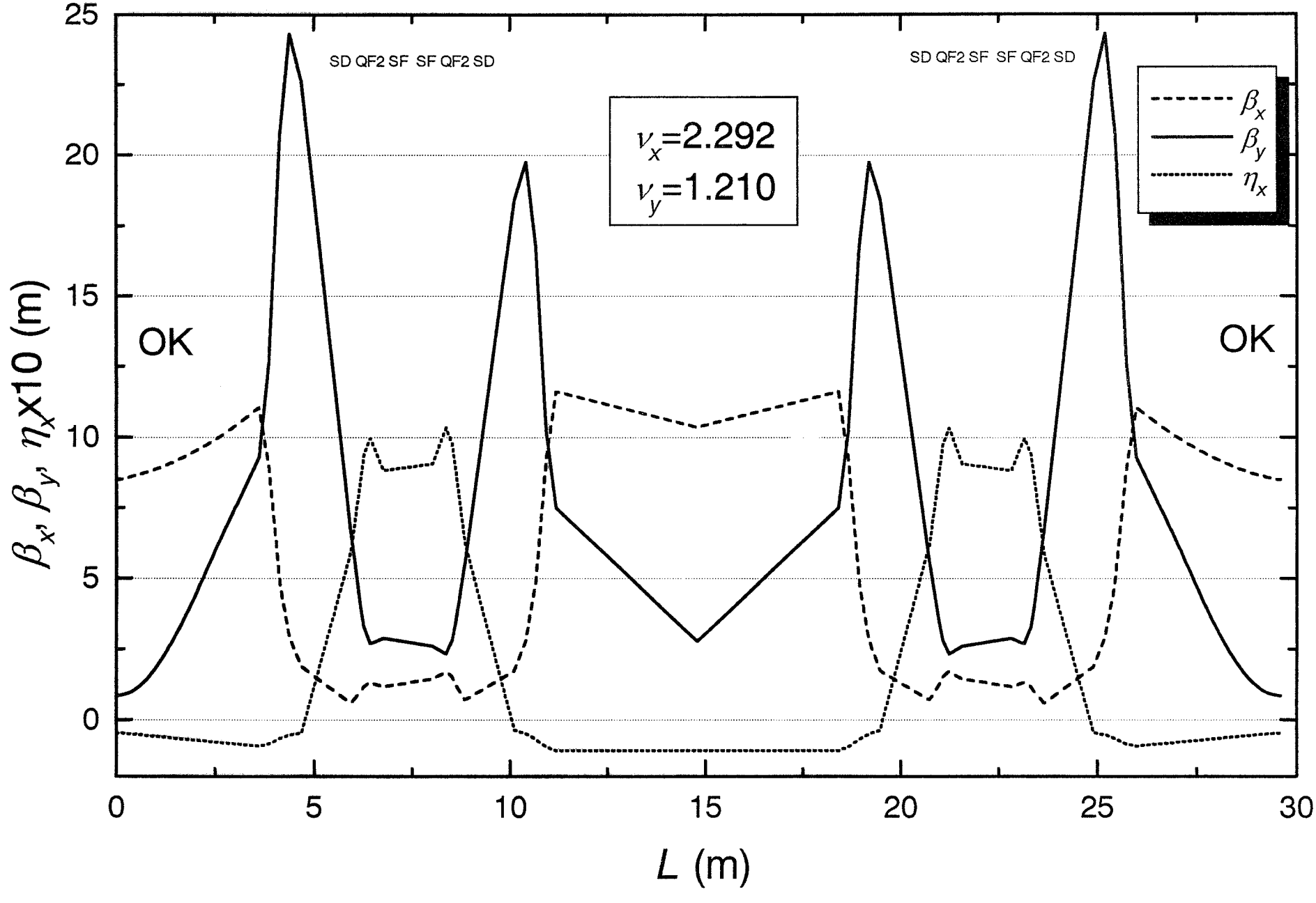
CALCULATED MACHINE PARAMETERS OF THE STORAGE RING NIJI-IV AT 300 MeV.

meas.

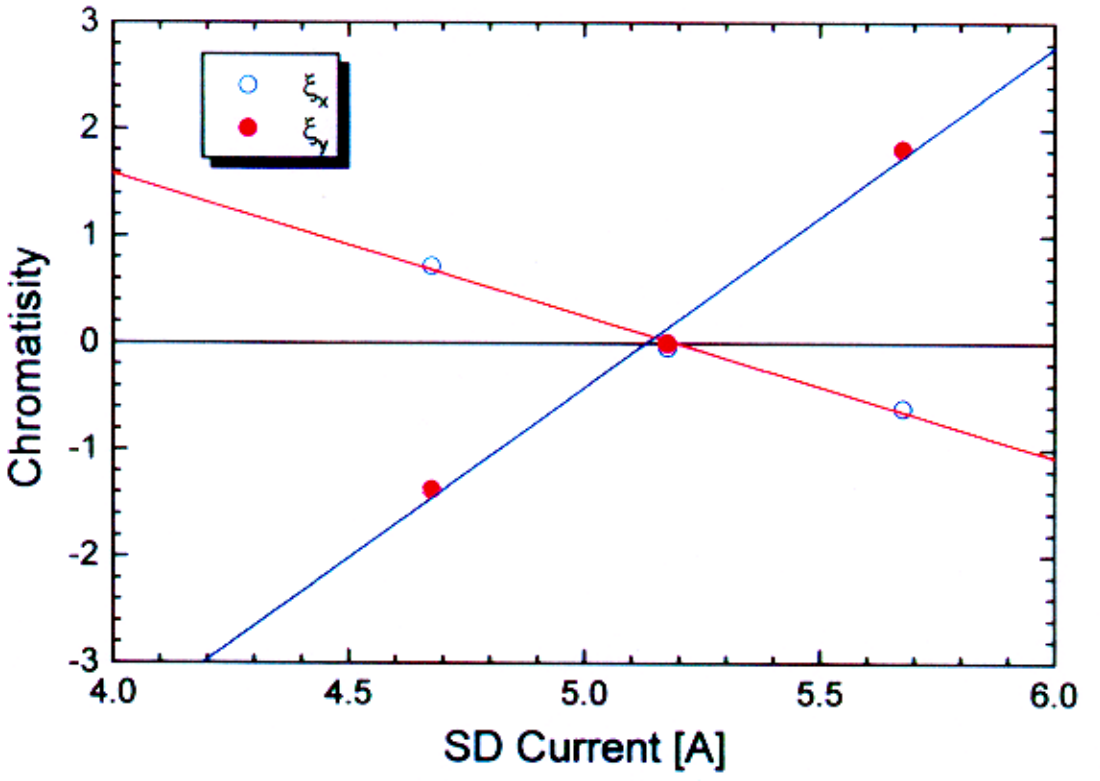
Parameters		Old mode	New mode	
Betatron tune	ν_x	1.595	**2.230**	
	ν_y	1.300	**1.344**	
Momentum compaction factor		0.251	0.0884 0.12 wt. OK	
Natural emittance [m rad]		3.988×10^{-7}	**4.913×10^{-8}**	7×10
Relative energy spread		2.13×10^{-4}	2.28×10^{-4}	4.9×1 @ 1.8
Bunch length [mm]		35~55	**22**	33
Damping time	τ_x[ms]	178	113	
	τ_y[ms]	99	99	
	τ_s[ms]	41	47	
Chromaticity	ξ_x	-1.61	-3.37	-2.2
	ξ_y	-2.22	-4.82	-2.7

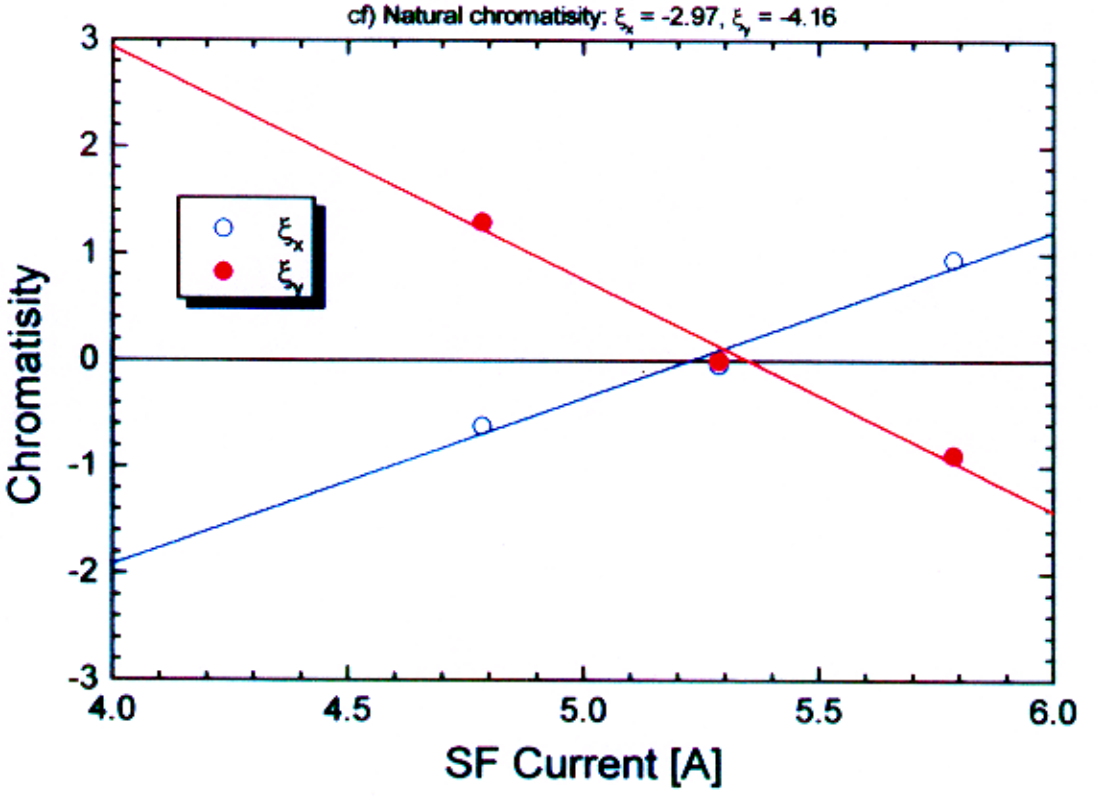


Overview of the 6-QF2-6 section.


SD QF2 SF SF QF2 SD
SD QF2 SF SF QF2 SD
ν_x=2.292
ν_y=1.210
β_x
β_y
η_x
OK
OK
β_x, β_y, η_xX10 (m)
L (m)
0
5
10
15
20
25
30

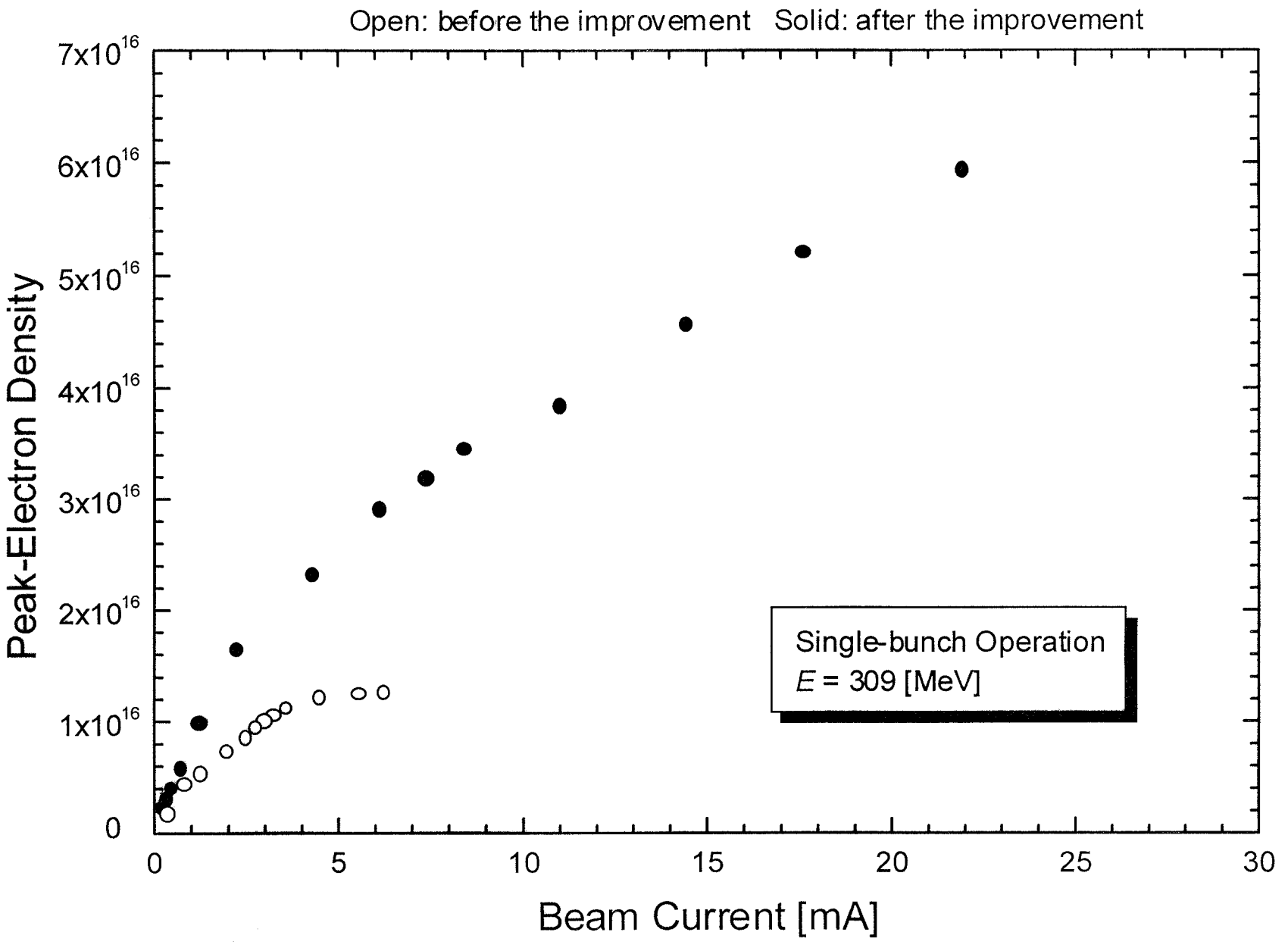
六極磁石のクロマティシティ補正効果



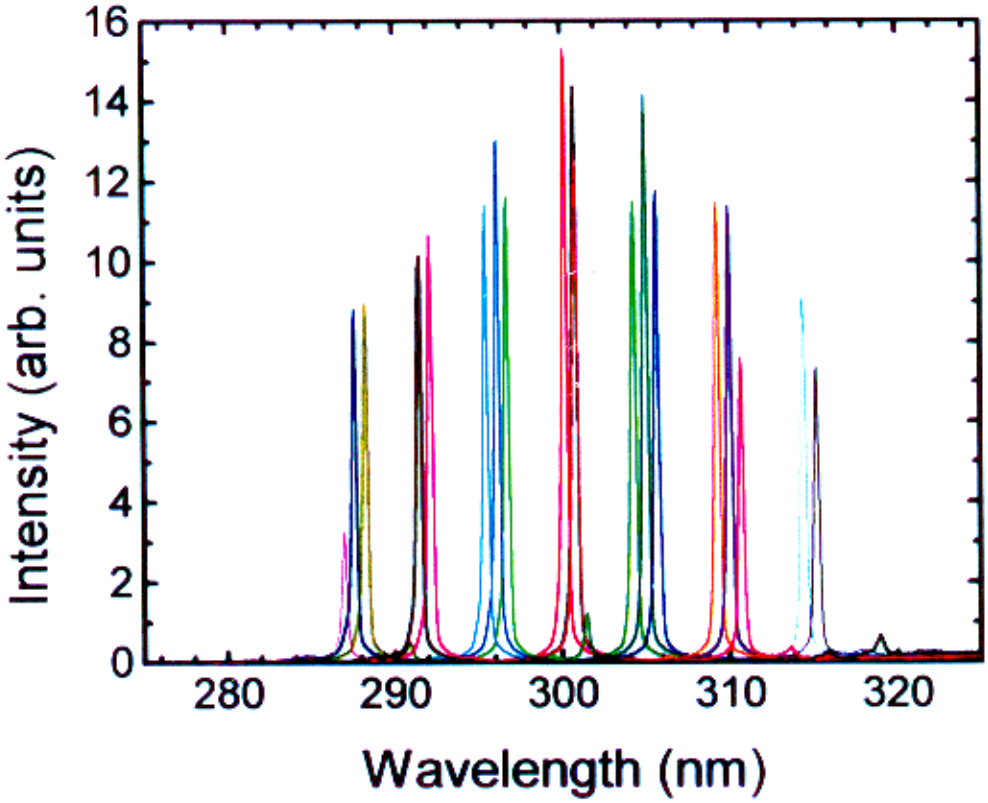


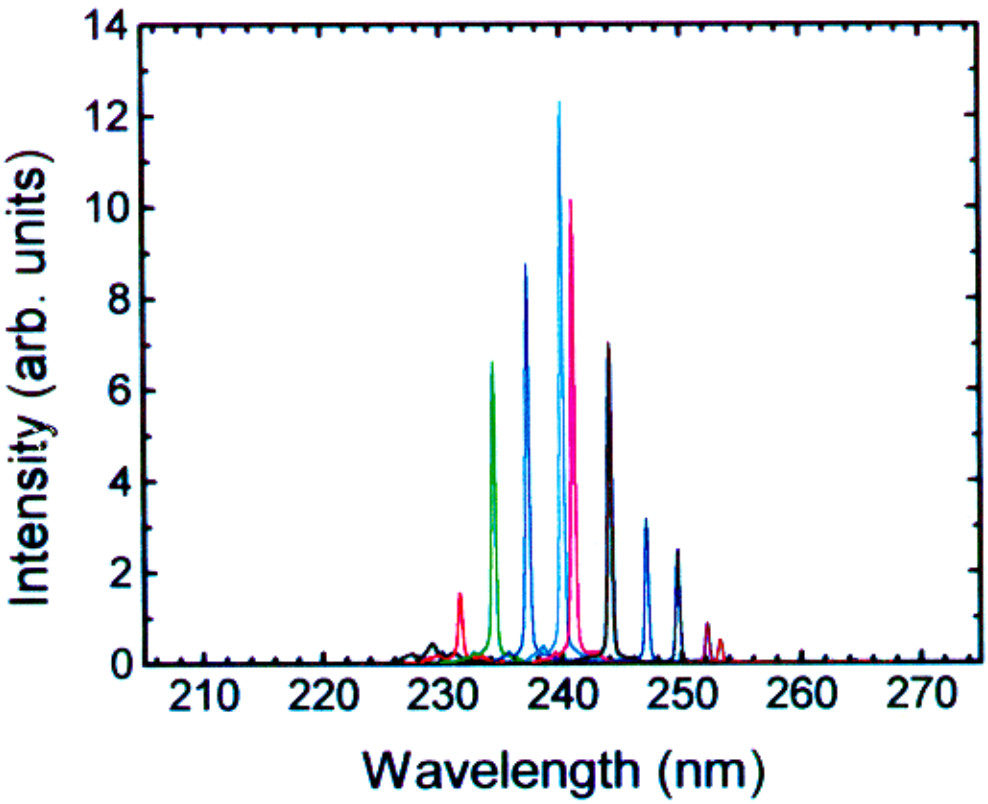
設計値のSD=SF=5Aでは、$\xi_x = -0.082$, $\xi_y = 0.341$でわずかにクロマティシティ補正が完全ではない.

現在のoperation modeでは、$\xi_x = 0.068$, $\xi_y = 0.147$で、ヘッドテイル不安定性を抑制するのに充分であると思われる.

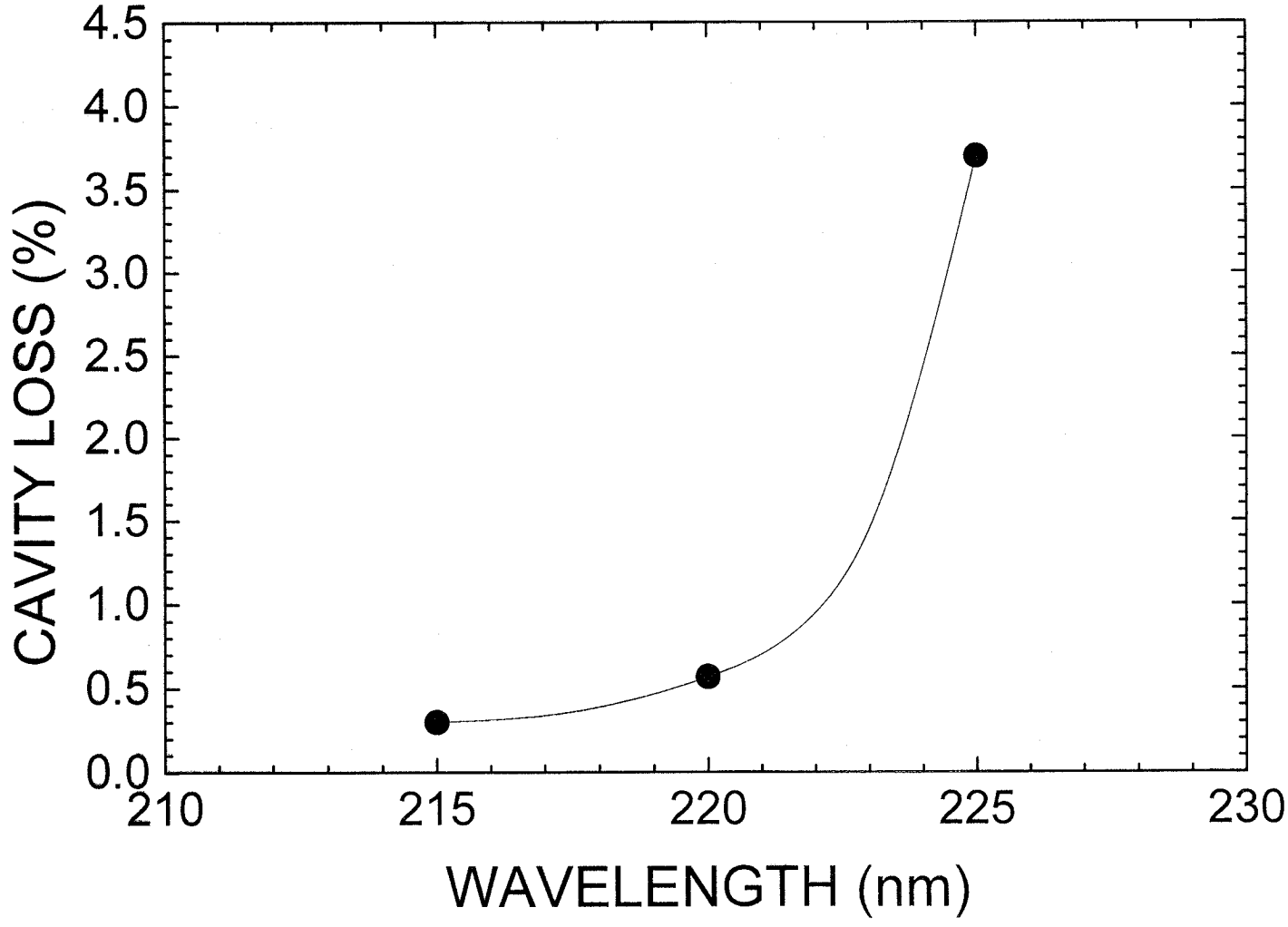

Open: before the improvement Solid: after the improvement
Peak-Electron Density
7x10^16
6x10^16
5x10^16
4x10^16
3x10^16
2x10^16
1x10^16
0
0
5
10
15
20
25
30
Beam Current [mA]
Single-bunch Operation
E = 309 [MeV]

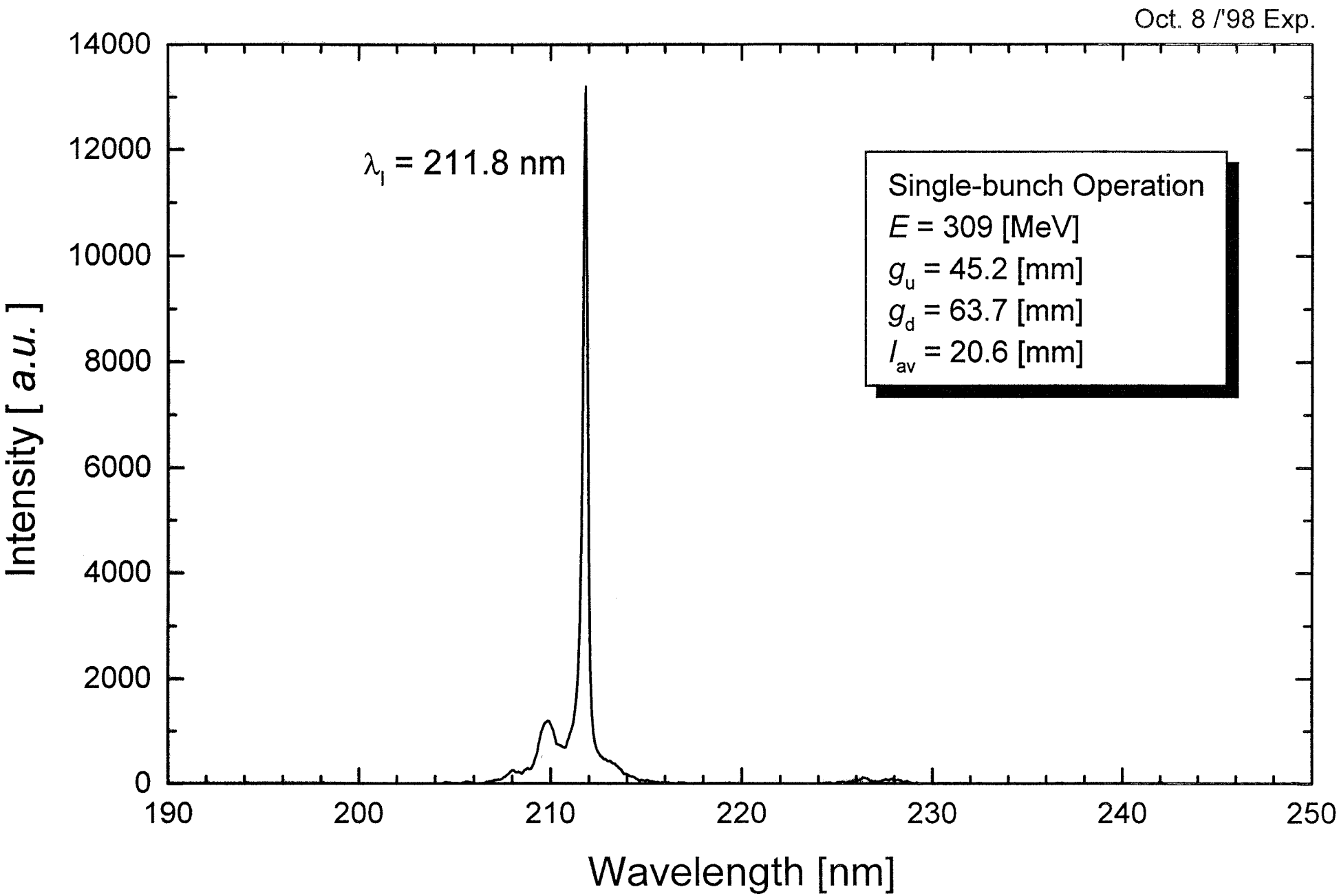
TYPICAL FEL SPECTRA AROUND 300 and 240 nm

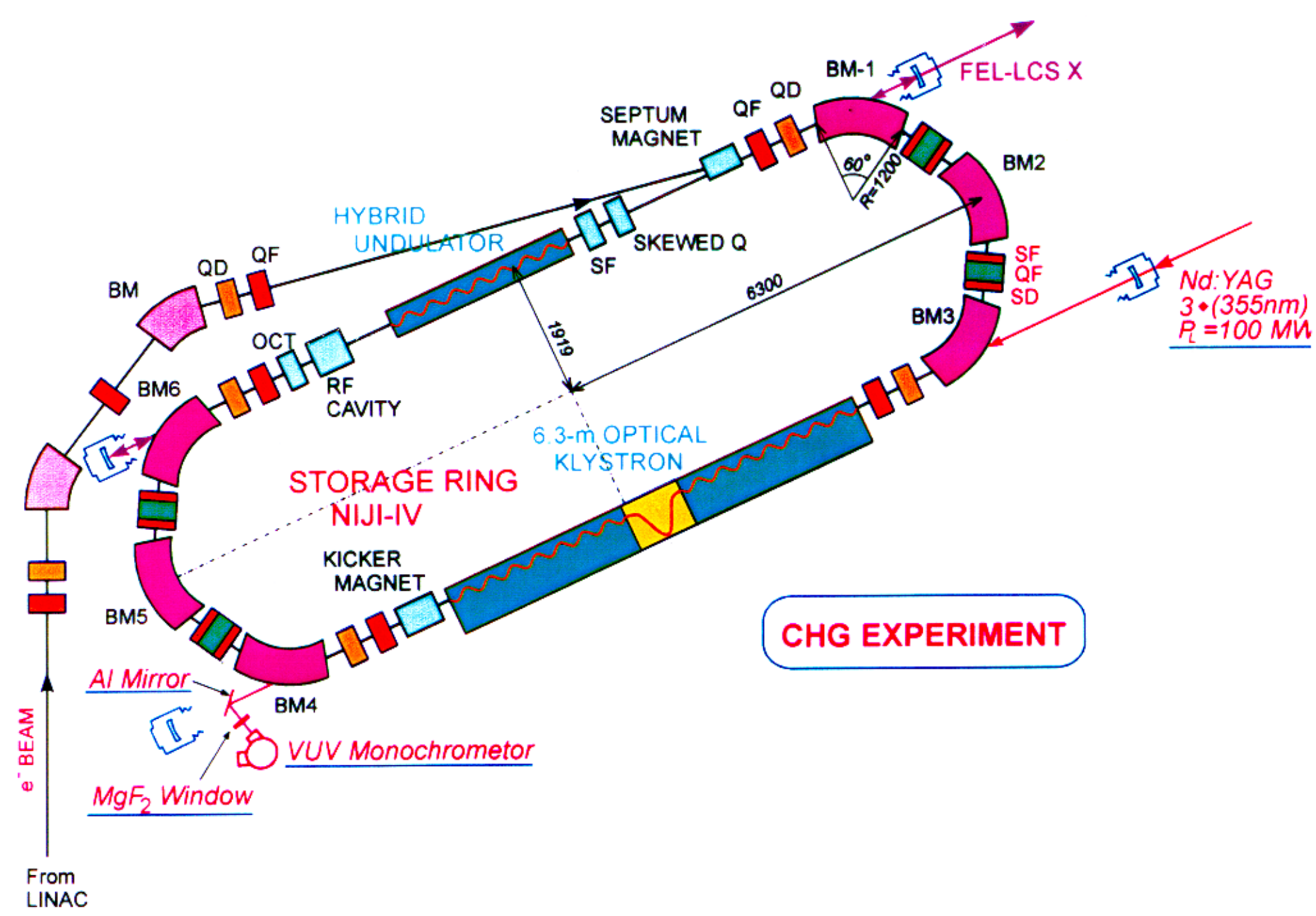




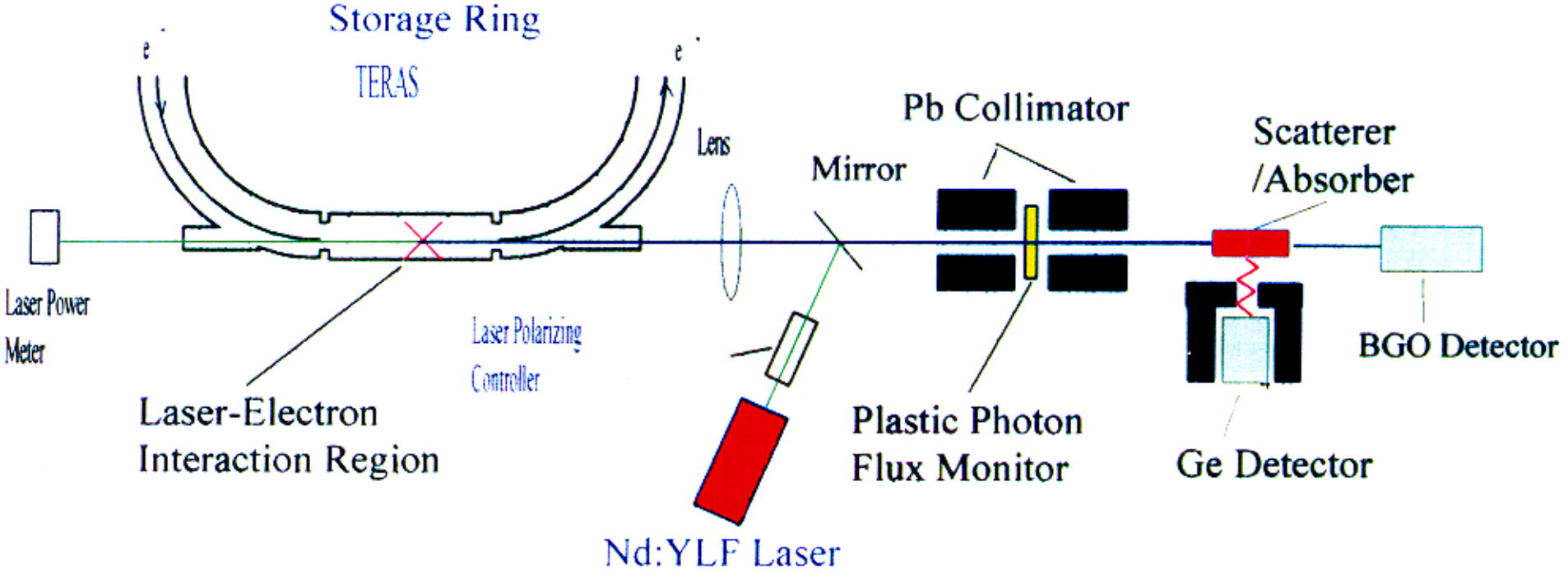
LOSS OF THE LASER CAVITY COMPOSED OF Al_2O_3/SiO_2 MIRRORS



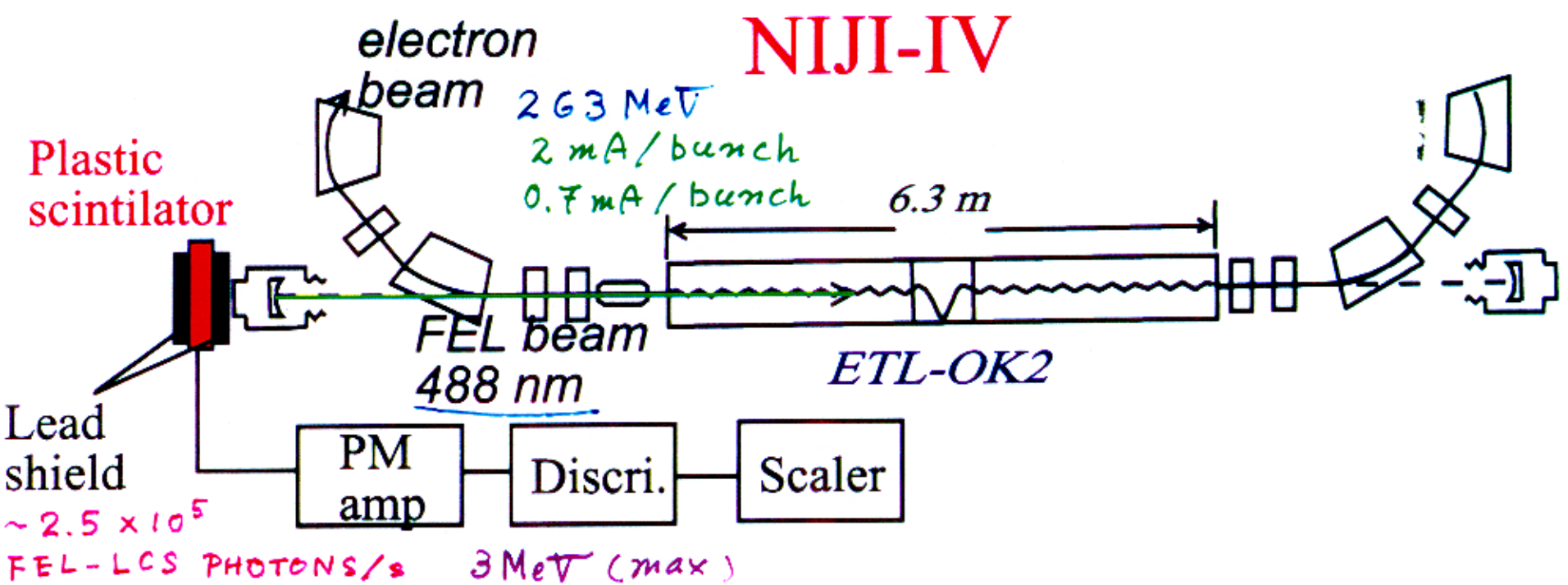

Oct. 8 /'98 Exp.
λ_l = 211.8 nm
Single-bunch Operation
E = 309 [MeV]
g_u = 45.2 [mm]
g_d = 63.7 [mm]
l_{av} = 20.6 [mm]
Intensity [a.u.]
Wavelength [nm]
0
2000
4000
6000
8000
10000
12000
14000
190
200
210
220
230
240
250


BM-1
FEL-LCS X
SEPTUM MAGNET
QF
QD
60°
R=1200
BM2
HYBRID UNDULATOR
SKEWED Q
SF
SF
QF
SD
Nd:YAG
3•(355nm)
P_L =100 MW
BM
QD
QF
6300
1919
BM3
OCT
RF CAVITY
BM6
6.3-m OPTICAL KLYSTRON
STORAGE RING
NIJI-IV
KICKER MAGNET
BM5
CHG EXPERIMENT
Al Mirror
BM4
VUV Monochrometor
MgF2 Window
e⁻ BEAM
From LINAC

ETL-LCS Facility



Th C10 P30



Experimental setup of the photon yield measurement with FEL Compton backscattering in storage ring NIJI-IV.

enhancement factor ~ 23