Cavity Optimization for Compact Accelerator-based Free-electron Maser

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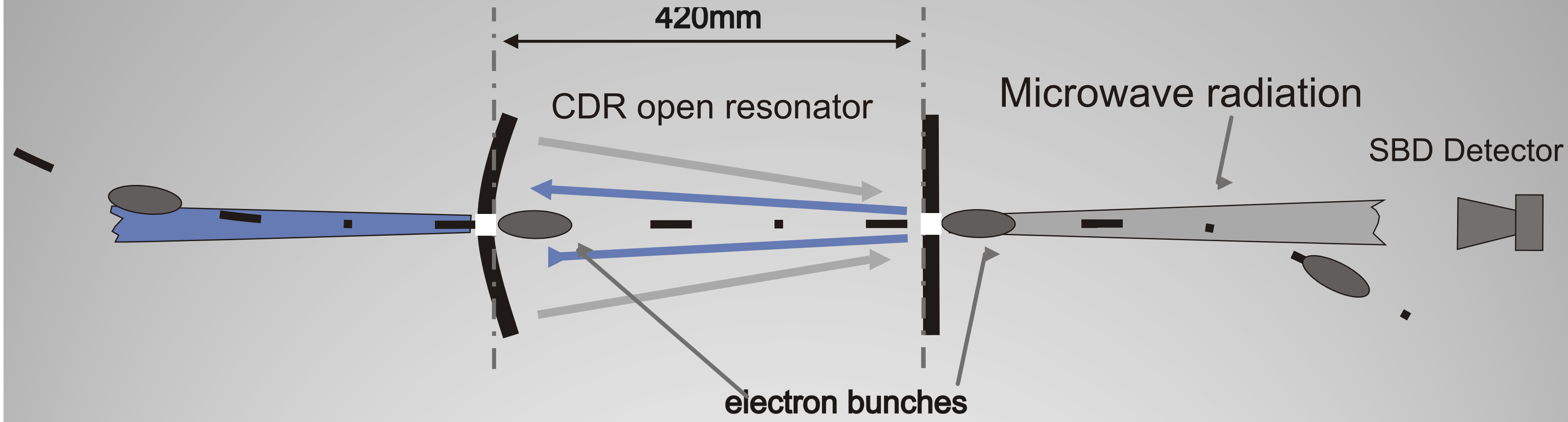
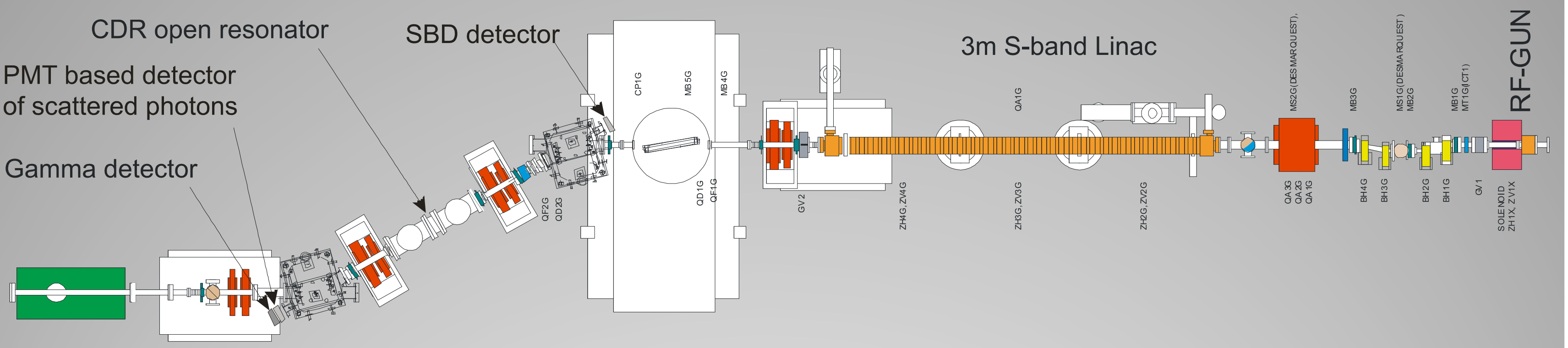


A.P. Potylitsyn, Phys. Rev. E 60 (1999) 2272.

Compact Accelerator-based Free-Electron Maser

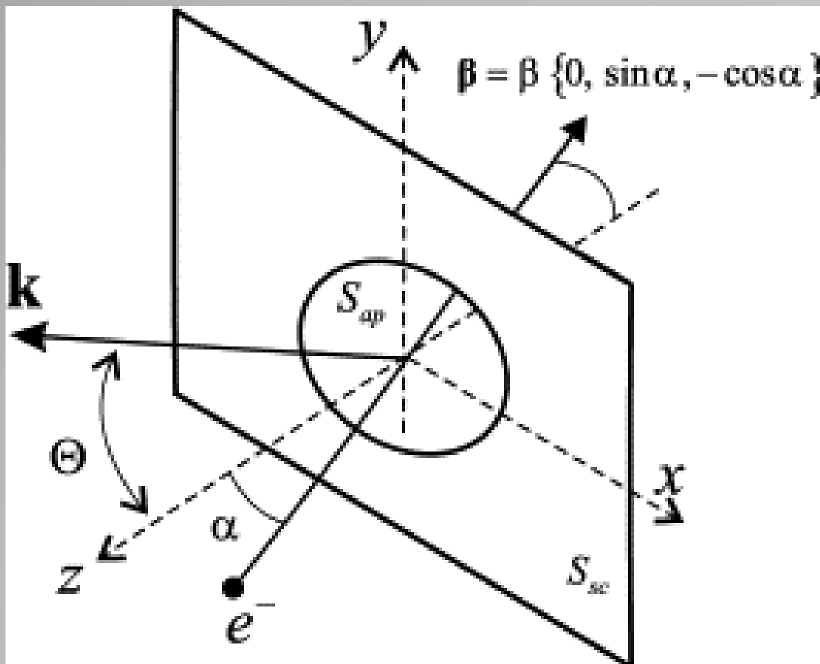


Energy	30 MeV (γ = 62)
Intensity	1 nC/bunch
Num. of Bunches	100
Bunch spacing	2.8 ns
Bunch length	<10 ps
Repetition rate, nominal	3.13 Hz
Emittance (round)	5 π mm•mrad
σ_x σ_y in SCDR chamber	200 μm, 200 μm

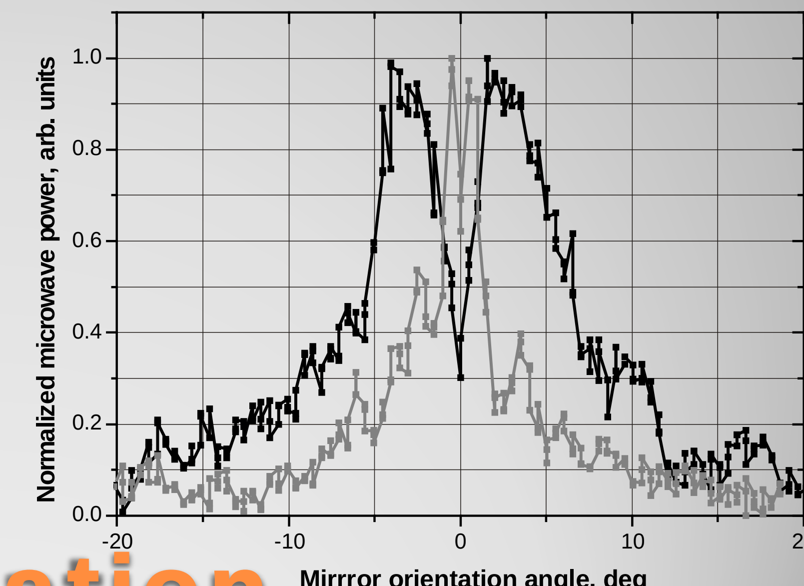
LUCX, compact linear accelerator

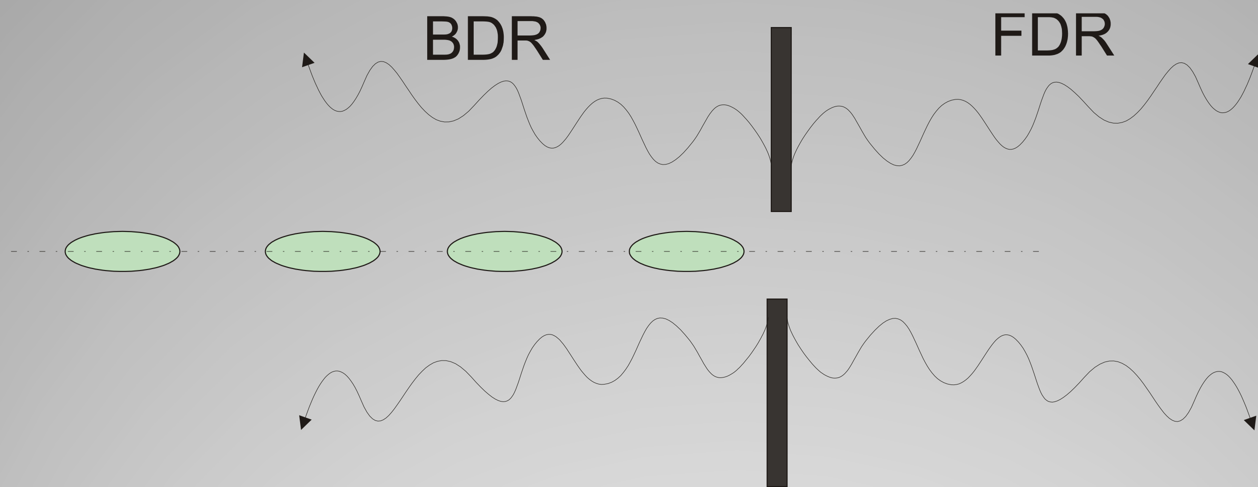
S. Liu, M. Fukuda, S. Araki, N. Terunuma, J.Urakawa, K. Hirano, N. Sasao, Nuclear Instruments and Methods A 584 (2008) 1-8.

Diffraction Radiation

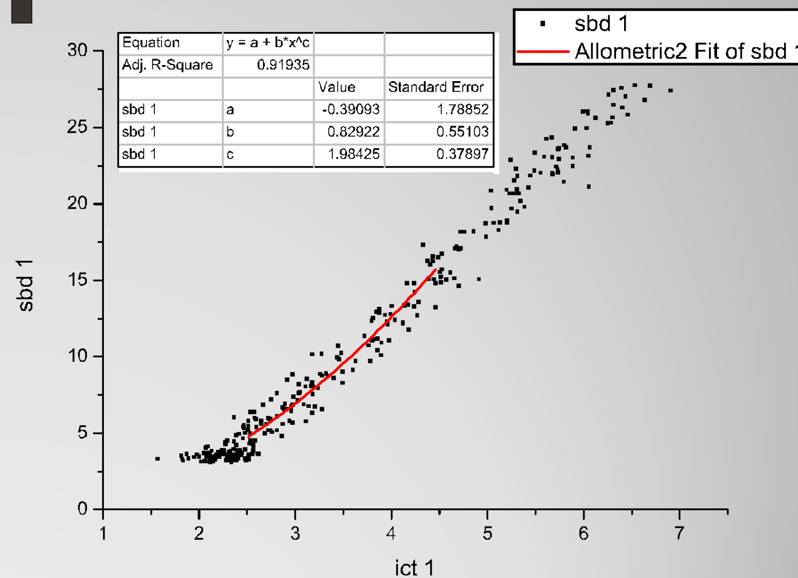


- Diffraction radiation (DR) appears when a charged particle moves in the vicinity of a medium
- $I_{DR} \sim N_e$

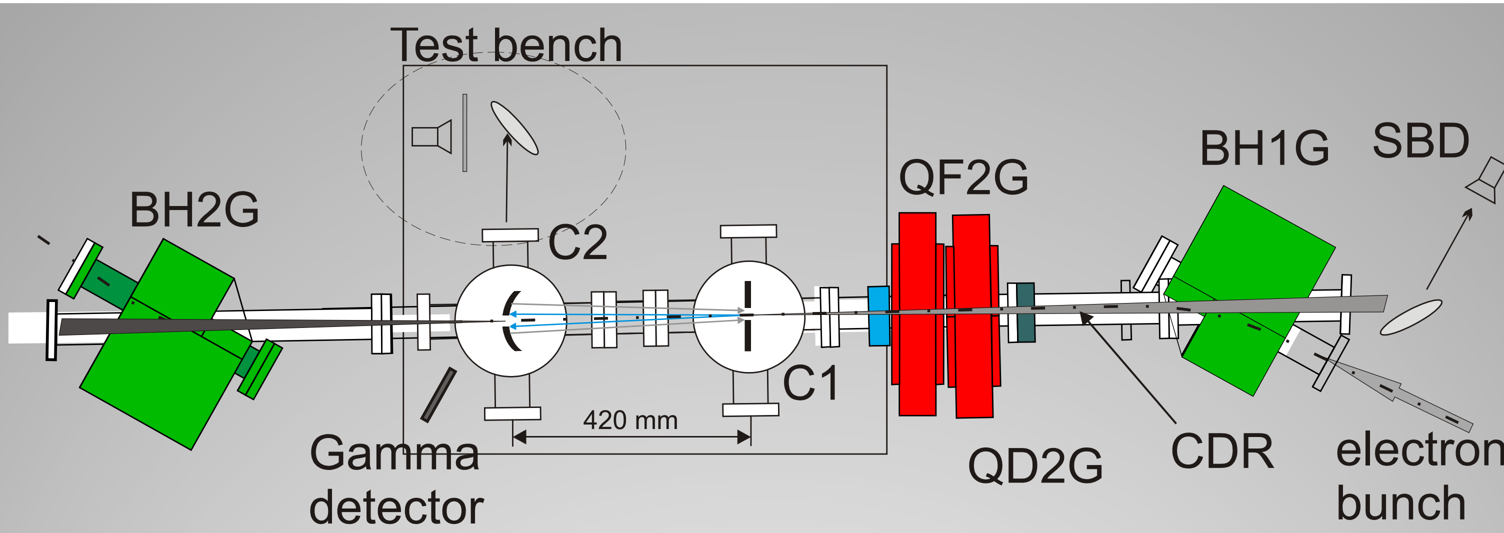




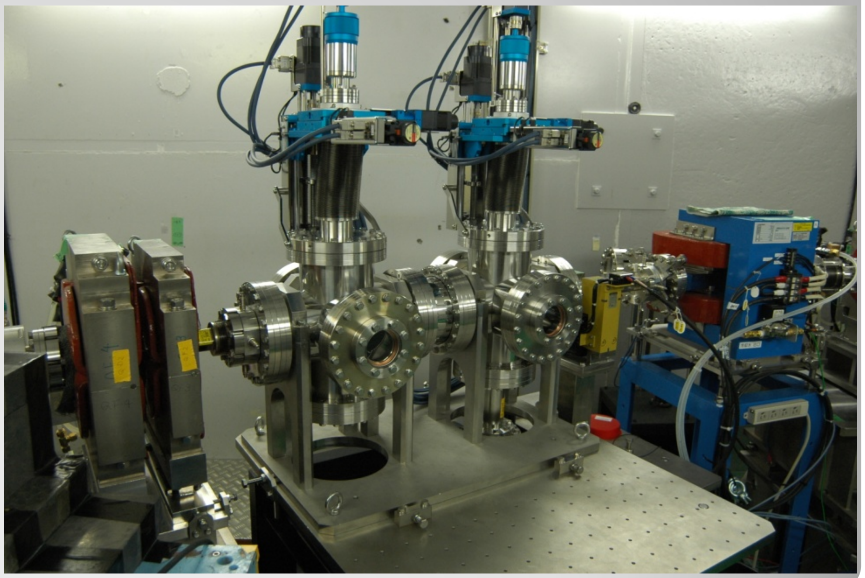
- CDR is generated by sequence of charged bunches
- $I_{CDR} \sim N_e^2$



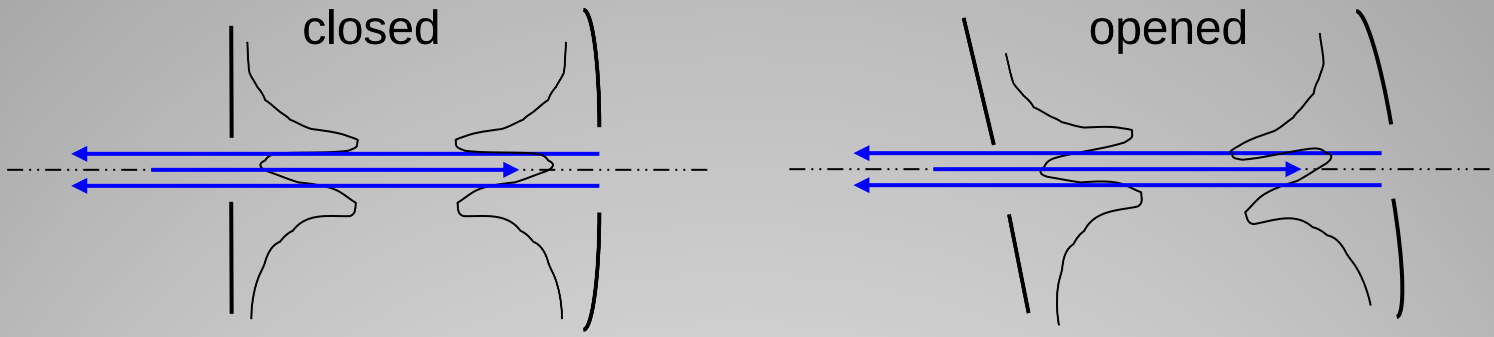
Coherent Diffraction Radiation

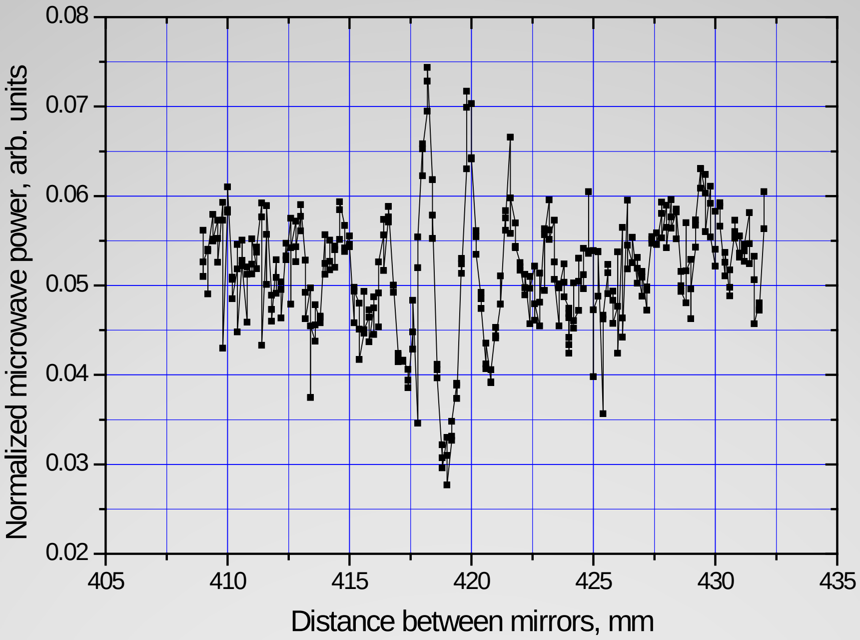


- 2 6-way crosses
- 2 4D vacuum manipulation systems
- 2 aluminum mirrors



CDR on LUCX





CDR on LUCX: Cavity length scan

Transmission calculation

$$T_0 = \frac{AT^2}{(1 + A^2R^2 - 2AR\cos\delta)}$$

$$R_s = \left(\frac{\cos\theta_i - n\sqrt{1 - \left(\frac{1}{n}\sin\theta_i\right)^2}}{\cos\theta_i + n\sqrt{1 - \left(\frac{1}{n}\sin\theta_i\right)^2}} \right)^2$$

$$T_s = 1 - R_s$$

$$\varepsilon = \varepsilon' + i\varepsilon''$$

$$n^2 + k^2 = \mathrm{Re}(\varepsilon) \qquad 2nk = \mathrm{Im}(\varepsilon)$$

Al

$$\varepsilon' = 1 - \frac{\omega_p^2}{\Gamma^2 + \omega^2}$$

$$\varepsilon'' = \frac{\omega_p^2 \Gamma}{\omega\left(\Gamma^2 + \omega^2\right)}$$

Si

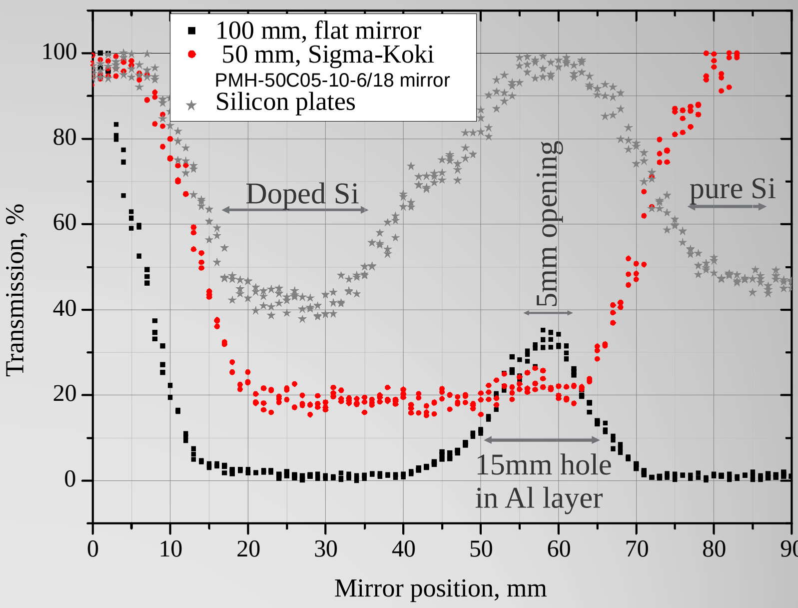
$$\varepsilon' = \varepsilon_\infty \left[1 - \frac{\omega_p^2 \tau^2}{1 + \omega^2 \tau^2} \right]$$

$$\varepsilon'' = \frac{\varepsilon_\infty \omega_p^2 \tau}{\omega\left(1 + \omega^2 \tau^2\right)} \qquad \omega_p = \frac{N_e e^2}{\varepsilon_0 \varepsilon_\infty m^*}$$

M.I. Markovic, A.D. Rakic. Determination of optical properties of aluminium including electron reradiation in the Lorentz-Drude model. Opt.and Laser Tech., v. 22, No. 6, 394-398, 1990.

R.T. Kinasewitz, B.Senitzky. Investigation of complex permittivity of n-type silicon at millimeter wavelengths. J. Appl. Phys., v. 54, No. 6, 3394-3398, 1983.

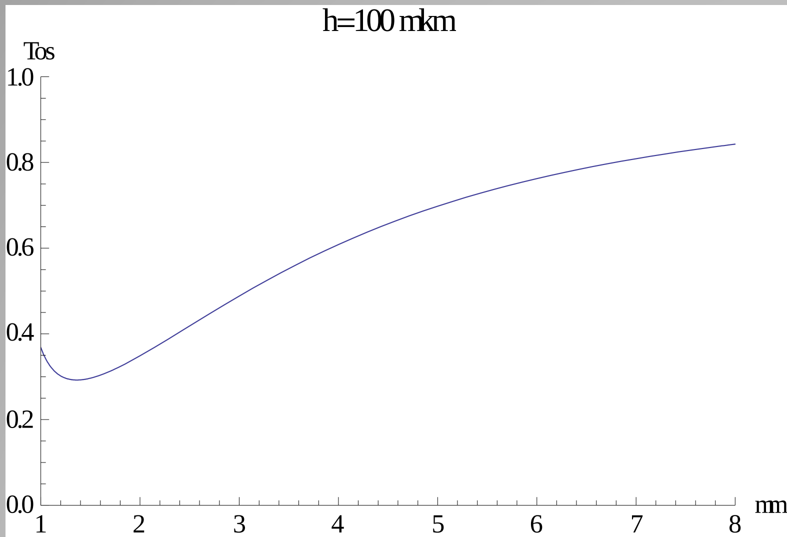
Material	Transmission coefficient	
	Experiment	*Theory*
Aluminized mirror	0	0
Doped silicon	0.42	0.42
Normal silicon	0.45	0.42



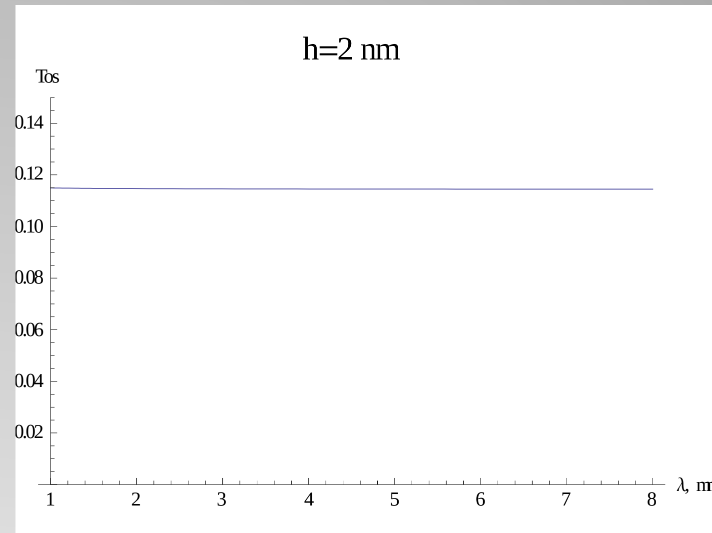
Mirror test bench

New mirror design

Si



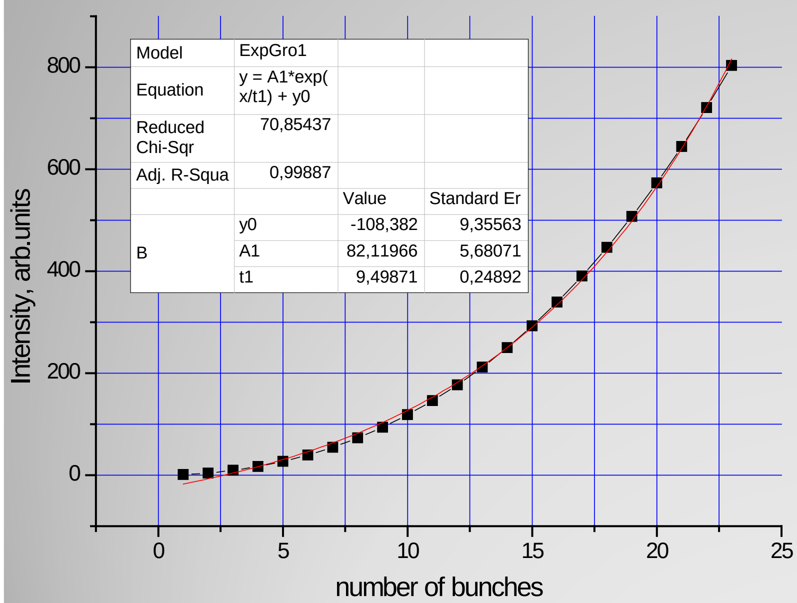
Al

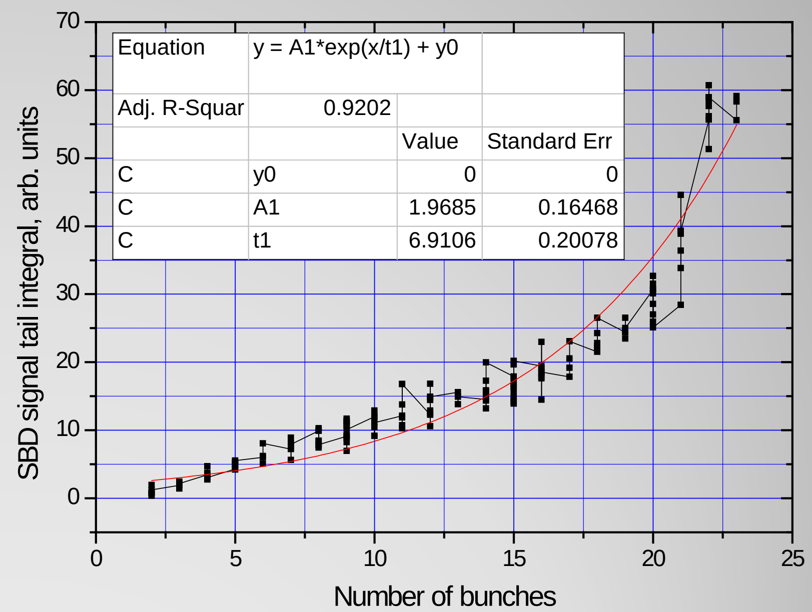


Aluminum, nm	*Silicon, mkm*	*Transmission coefficient, %*
2	100	6.5
	150	5.3
	300	4.0
3	100	3.4
	150	2.7
	300	2.1
4	50	2.7
	100	2.0
	150	1.6

Mirrror diameter = 100 mm
Thickness of Si substrate should be more than 100 mkm for durability

- E_{SCDR} = a E_{Cav} – addition to electric field by stimulation (depends on electric field stored in cavity)
- E_{DR} – electric field generated by single bunch
- d – loss in resonator
- $E_{tot,2} = d\,E_{DR} + E_{DR} + ad\,E_{DR} = E_{DR}\,(1 + d\,(1+a)) = E_{DR}\,(1+b)$ – electric field in resonator after second bunch
- $E_{tot,i} = E_{DR}\,(1-b^i)/(1-b)$ – electric field in resonator after i-th bunch

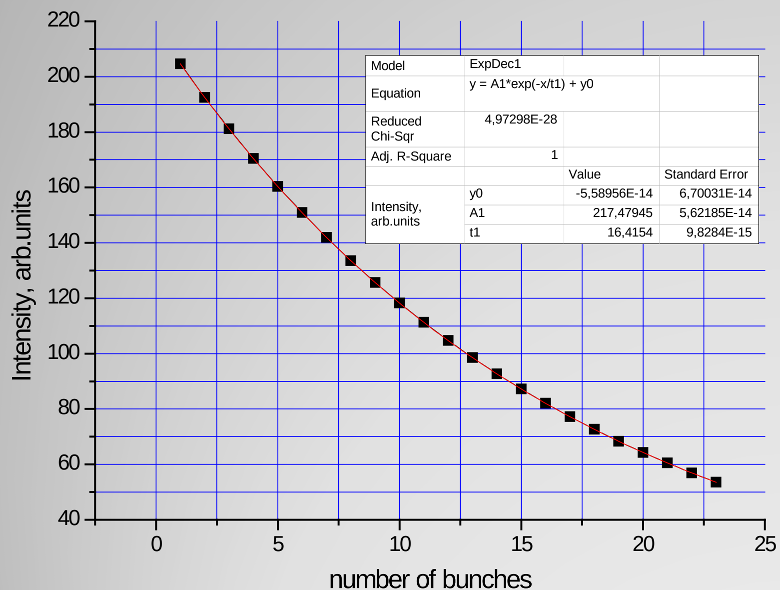


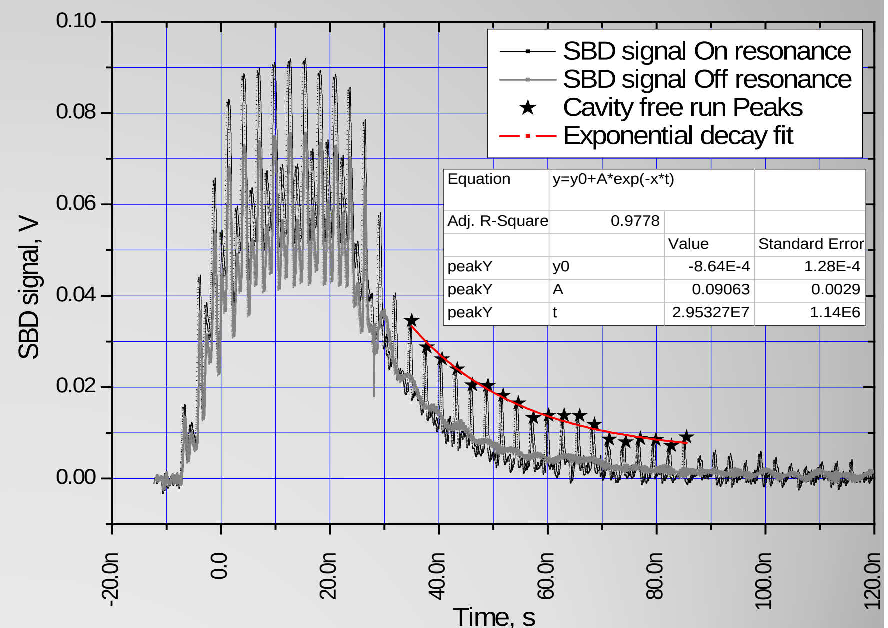


Stimulation

Chitrlada Settakorn, Michael Hernandez, and Helmut Wiedemann
Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94309, SLAC-PUB-7587 August 1997

- $E_{tot,i} = E_{DR}\,(1-b^N)/(1-b)\,d^{i-N}$ – where N is number of bunches in train (i>N)





A. Aryshev, et. al., IPAC’10, June 2008, Kyoto, Japan, MOPEA053

Cavity decay

Thank you for attention