Recent Progress of the UVSOR-FEL

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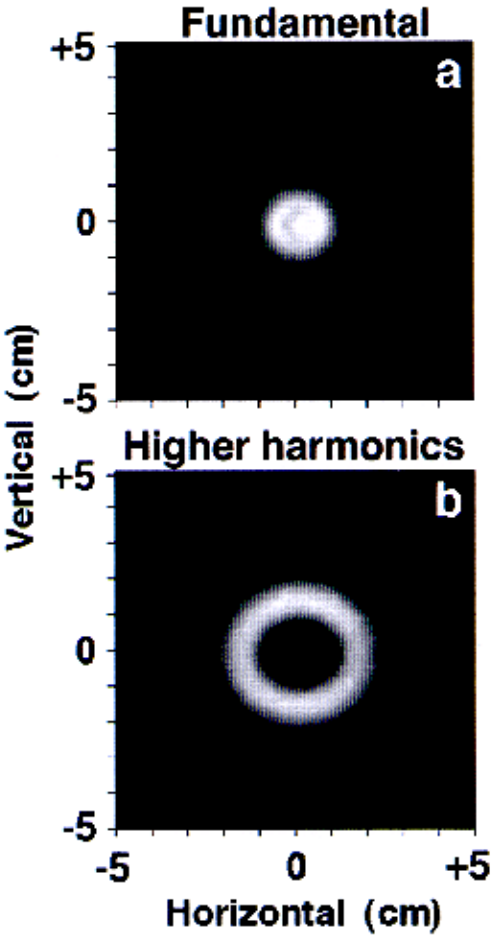
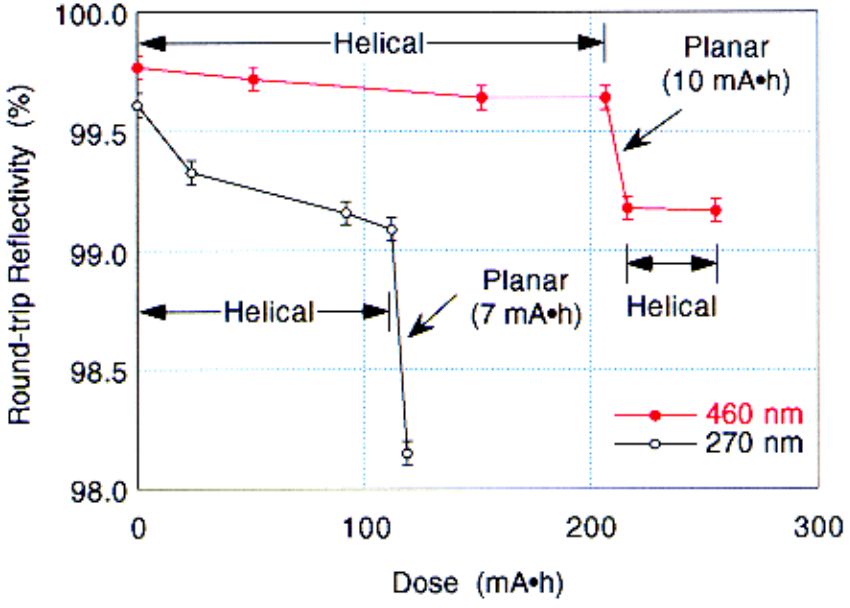
Demonstration for mirror degradation with a helical optical klystron (UVSOR-FEL)



<= Calculated spatial intensity distribution (UNKO-3@600 MeV)

Mirror degradation rate (600 MeV)



Mirrors

Dielectric multilayers for high reflectance mirror

Quarter-wave multilayer with High-index and Low-index material

Low-index :	SiO_2	transparent down to ~160 nm	
High-index:	Ta_2O_3	Super-ACO	at 350 nm
	HfO_2	UVSOR	at 240 nm
		Duke	at 240 nm
	Al_2O_3	NIJI-IV	at 210 nm

High-index material	Absorption band (nm)
Ta_2O_3	~ 300
HfO_2	~ 220
Al_2O_3	~ 170

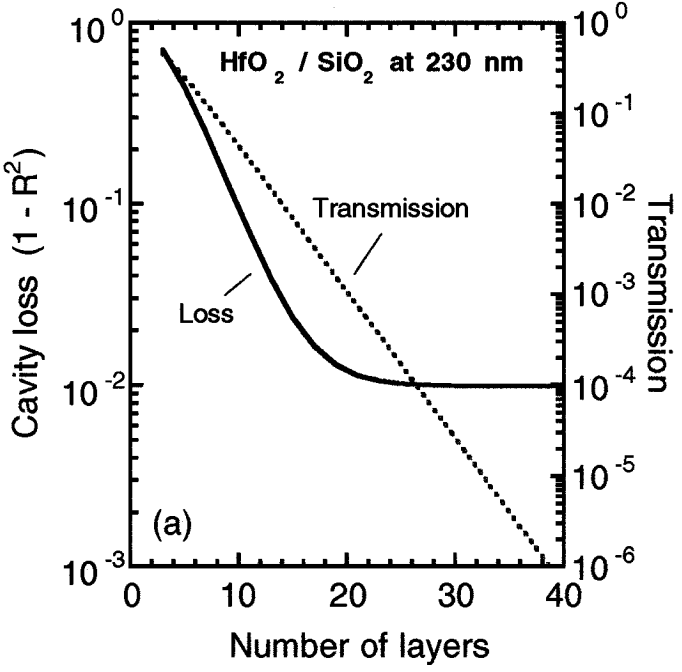
Koppelmann limit for maximum reflectance

$$R_{max} = 1 - 2\pi \frac{k_H + k_L}{n_H^2 + n_L^2}$$

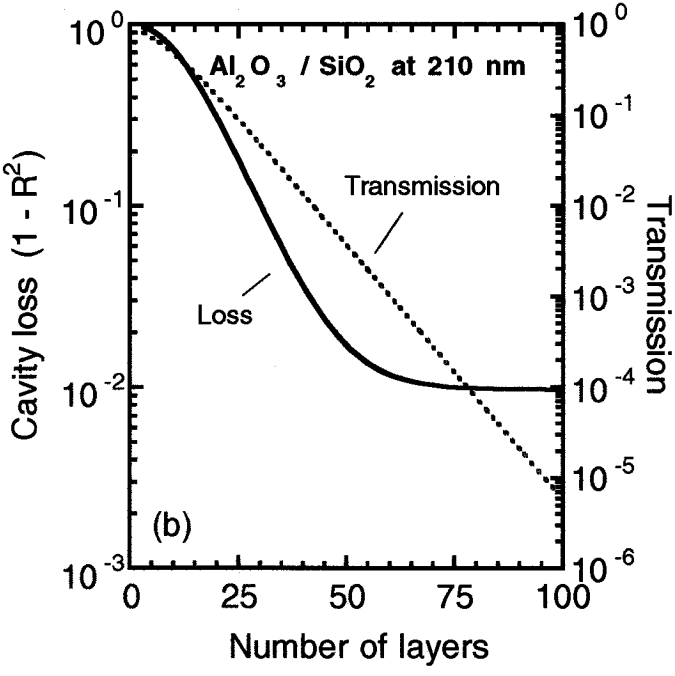
$n - ik$; optical constants n ; reflective k; extinction

Calculated reflectance and transmission with perfect polishing of substrate and layer coating

HfO_2 / SiO_2



Al_2O_3 / SiO_2



Maximum reflectance (Koppelmann limit)

Multilayer	wavelength [nm]	max. R	saturated N	Transmission
$Hf\,O_2 / Si\,O_2$	230	~ 99.5 %	> 31	< 0.000018
$Al_2\,O_3 / Si\,O_2$	210	~ 99.5 %	> 93	< 0.000014

Transmission rate may steeply decrease with the number of layers

If one wish transmission > 1 %,

$Hf\,O_2 / Si\,O_2$	13 layers R = 98.1 %	T = 1.45 %
$Al_2\,O_3 / Si\,O_2$	41 layers R = 98.3 %	T = 1.18 %

Cavity loss => $1 - R^2$ 4 % loss for both cases => gain should be > 4 % !!!

Outcoupled power => $P_{out} = mirror\ transmission \times P$

To obtain the highest extraction efficiency, the BEST fabrication technique is required !

Optical Cavity Stability

Detuning range vs Macrotemporal structure (UVSOR-FEL)

Zone	CW	Macropulse	Quasi-CW
$\|Df_{rf}\|$	< 4 Hz	< 25 Hz	< 200 Hz
$\|Df_{rf} / f_{rf}\|$	$< 4 \times 10^{-8}$	$< 3 \times 10^{-7}$	$< 2 \times 10^{-6}$

$\frac{\Delta f_{RF}}{f_{RF}} \leq 10^{-8}$ to keep the highest saturation level.

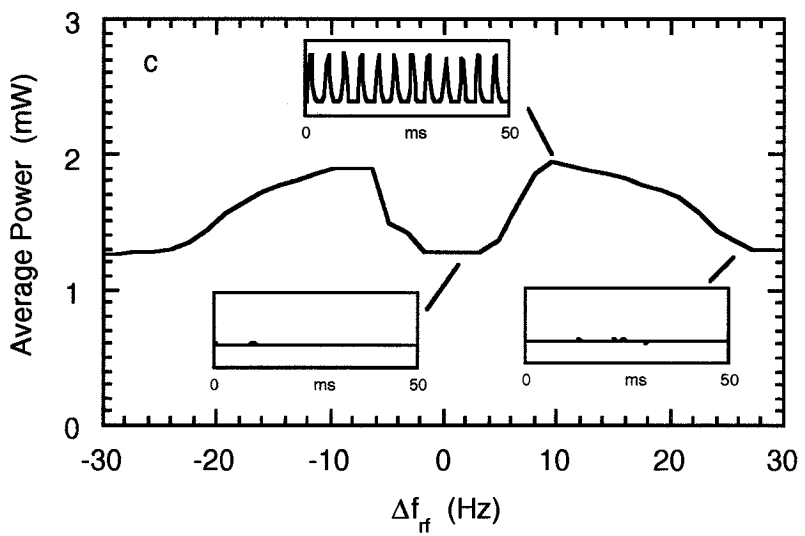
Cavity length => $\frac{\Delta L_{cavity}}{L_{cavity}} \leq 0.5\ \mu m$

i) Beam bunch jitter (usually very small < 10 ps)

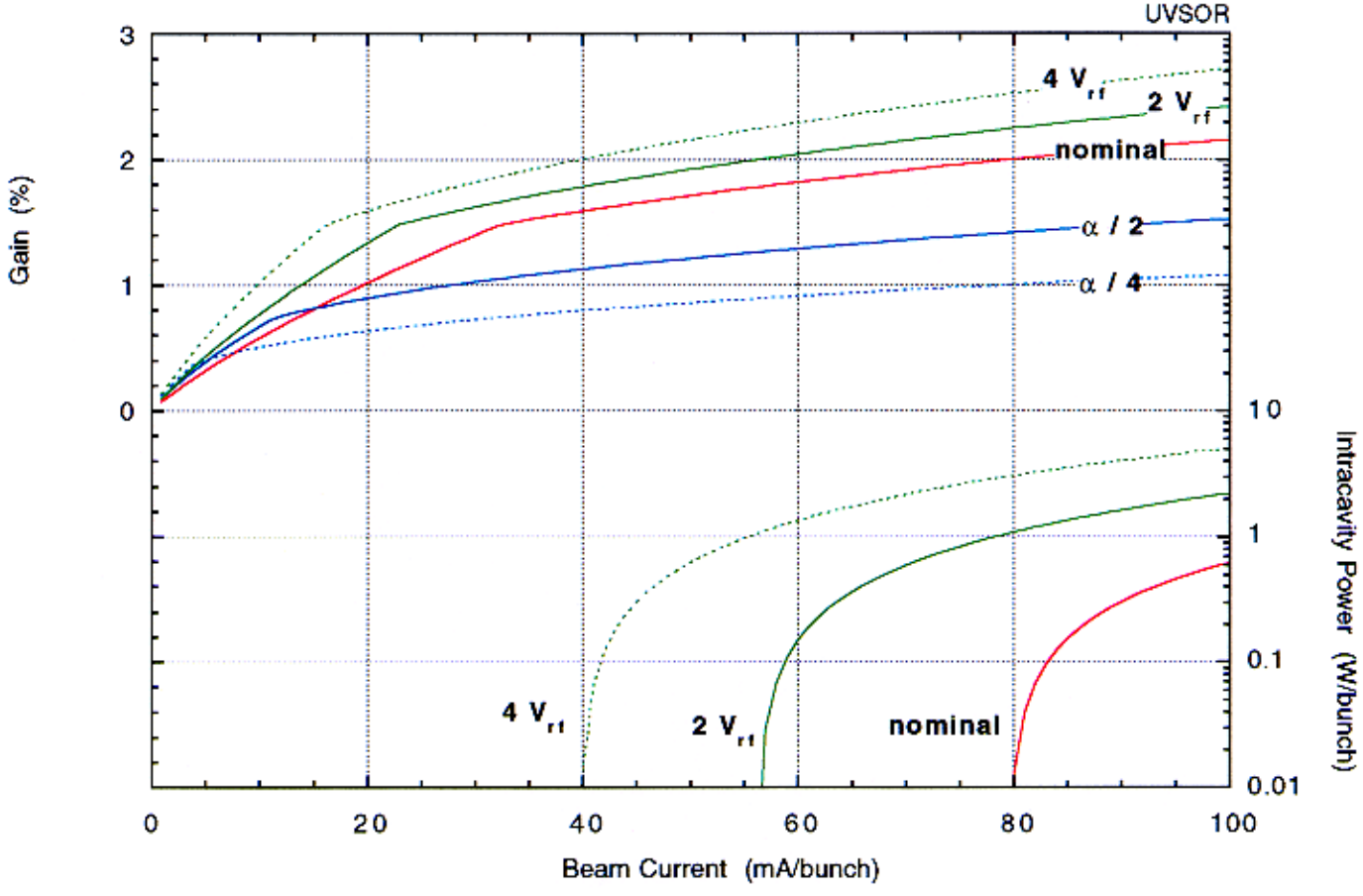
ii) Mechanical vibration of mirror mount

iii) Deformation of environment due to heat-up

Feedback system is absolutely necessary !!!!



Estimated Gain and Intracavity Power



Future Prospect of the UVSOR-FEL

[1] Beam energy

600 MeV => 750 MeV
- high power
- long lifetime
- 2-color experiment with FEL and SR

[2] Ring impedance

0.7 Ω => 0.2 ~ 0.3 Ω
- Replace the beam pipes

[3] Mirrors

T = 0.005 % => T = 0.1 %
- Optimization of number of layers
- ~ 100 mW outcoupled power

HfO_2 / SiO_2 => Al_2O_3 / SiO_2
- below 240 nm lasing

[4] Optical cavity
(new one is under construction)
- Heavy and solid base (marble stone, ~ 2 t)
- Longitudinal feedback using a photon sampling oscilloscope
- Good thermal contact for mirror holder