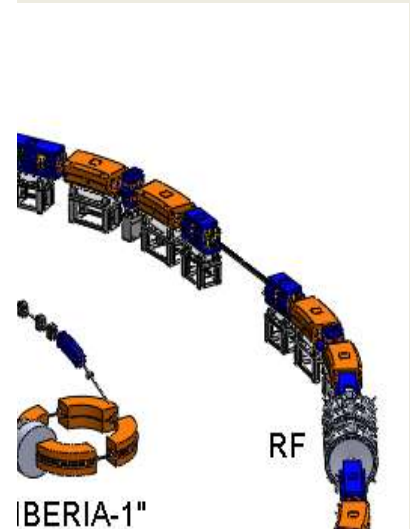
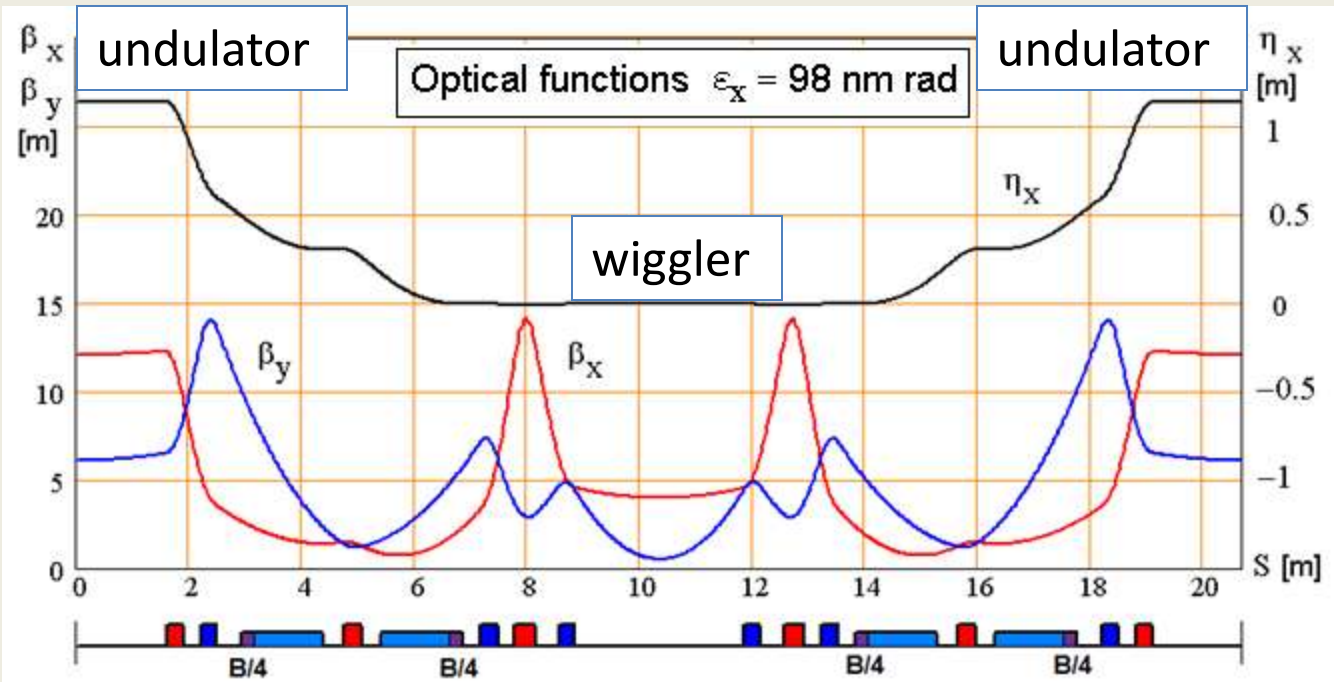


RADIATION SOURCES AT SIBERIA-2 STORAGE RING

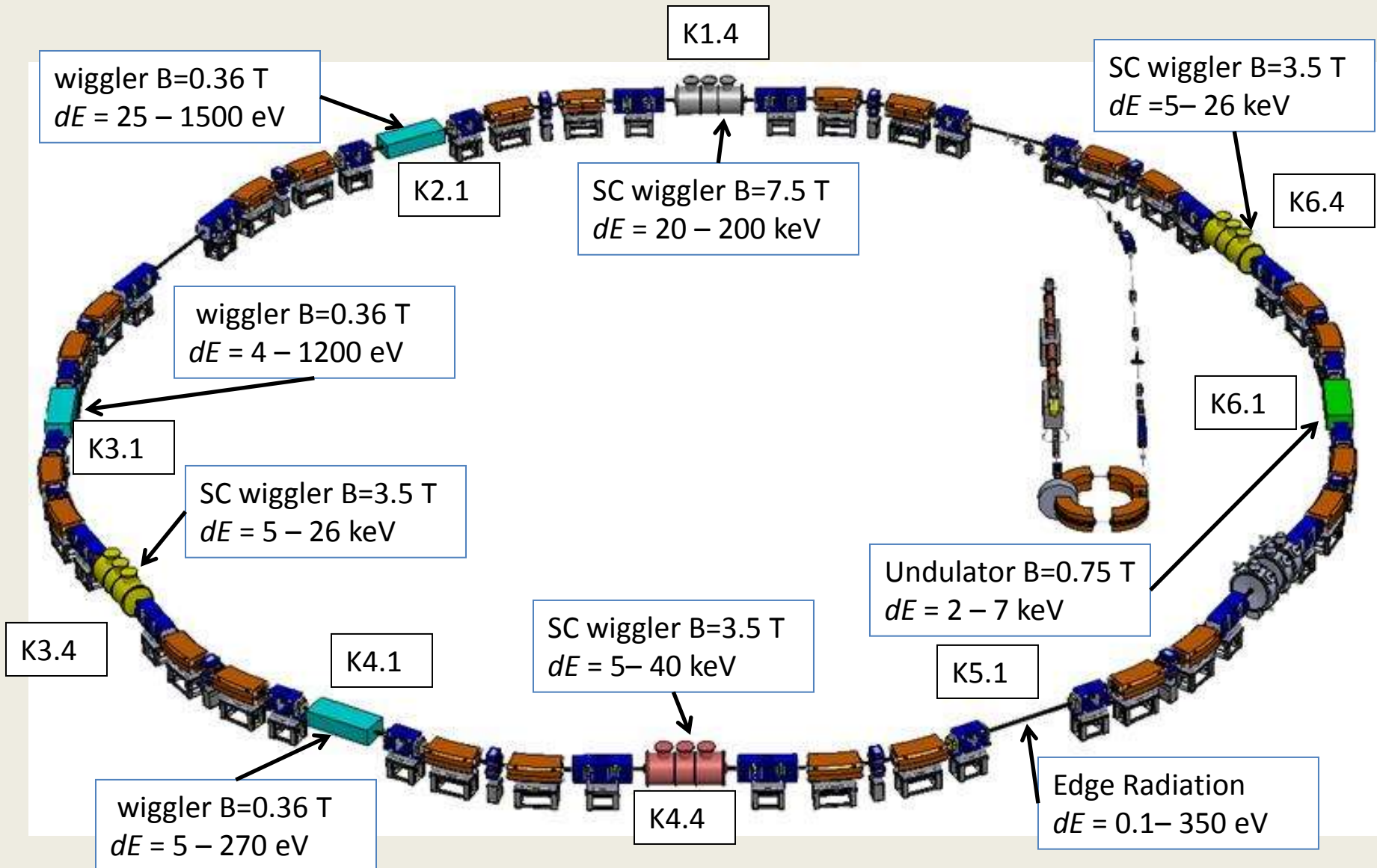
V.N. Korchuganov, N.Yu. Svechnikov,
N.V. Smolyakov, S.I. Tomin

RRC «Kurchatov Institute», Moscow, Russia

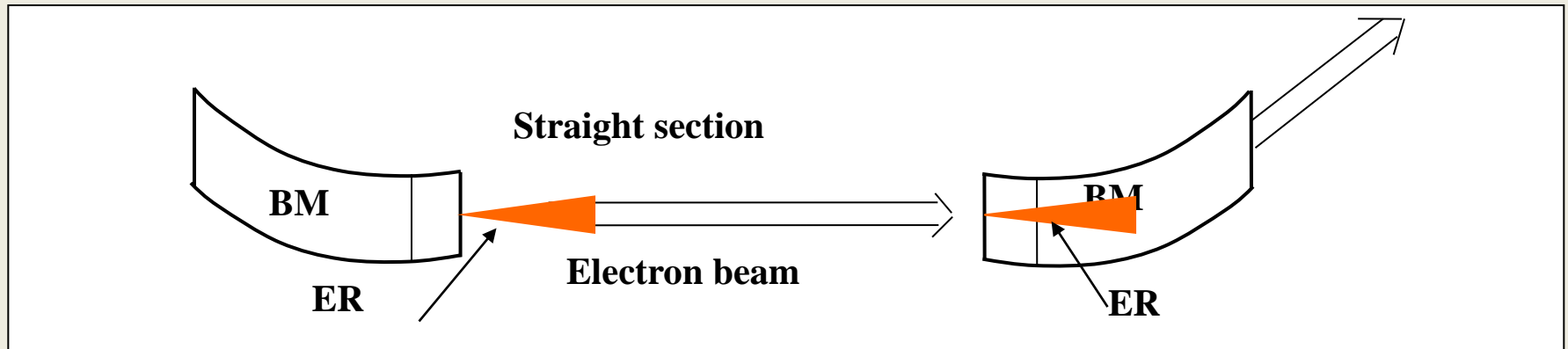
Kurchatov Center Synchrotron Radiation



Prospects for Siberia-2 insertion devices

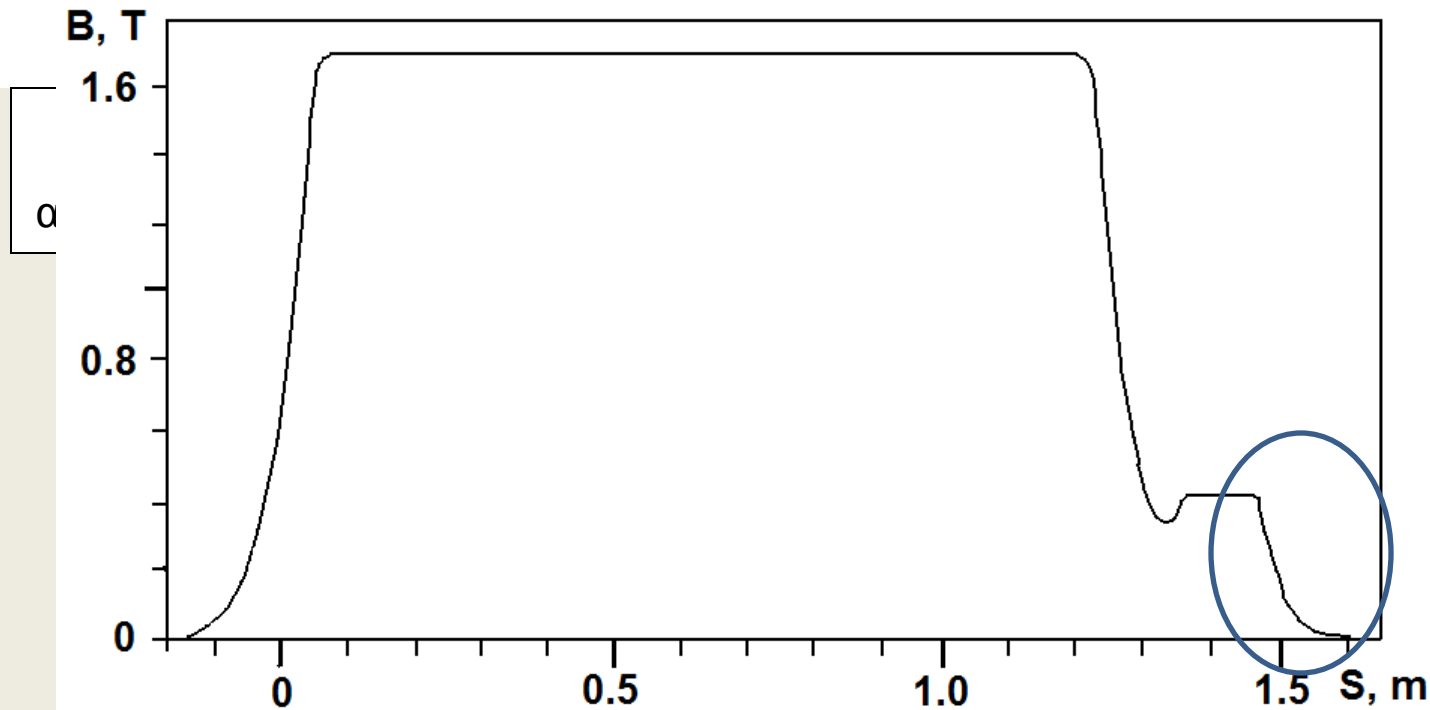
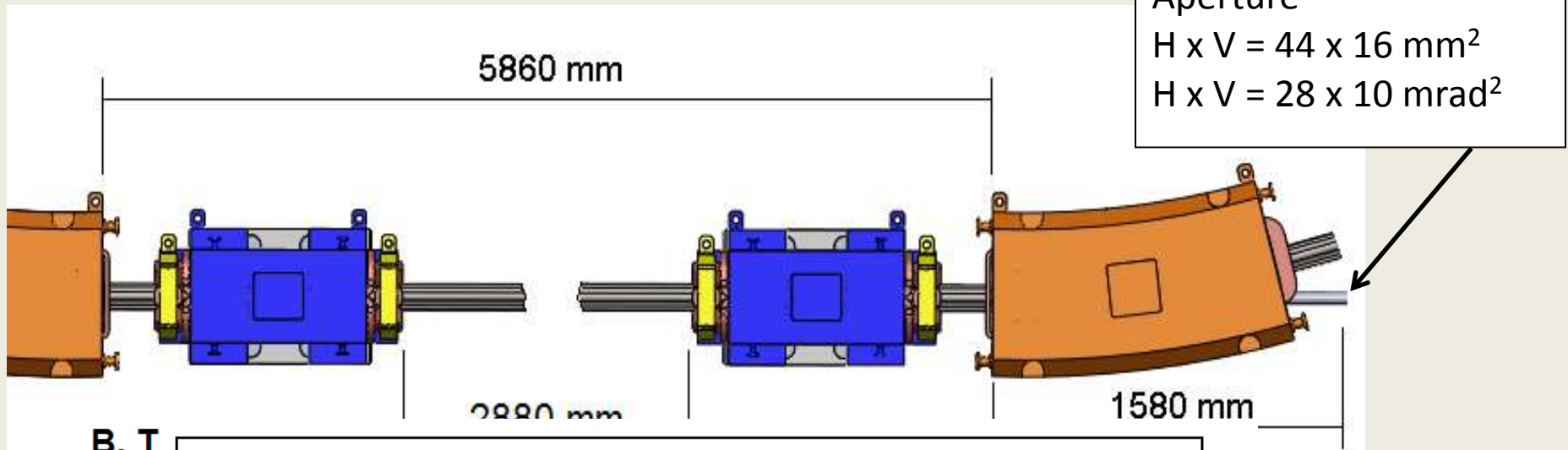


Edge Radiation



- ER is produced by relativistic electrons in fringe fields of the bending magnet edges. It was experimentally discovered in the late 1970s at Super Proton Synchrotron (SPS, CERN, Geneva) and at the electron synchrotron “Sirius” (INP, Tomsk, Russia).
- The photons, emitted at two adjacent bending magnets, appear in the same narrow cone and are subsequently synchronized by the electron itself. This leads to the interference of ER.

Edge radiation beamline



$R=1.96 \text{ m}$,
 $=1.75 \text{ keV}$

ER numerical simulation

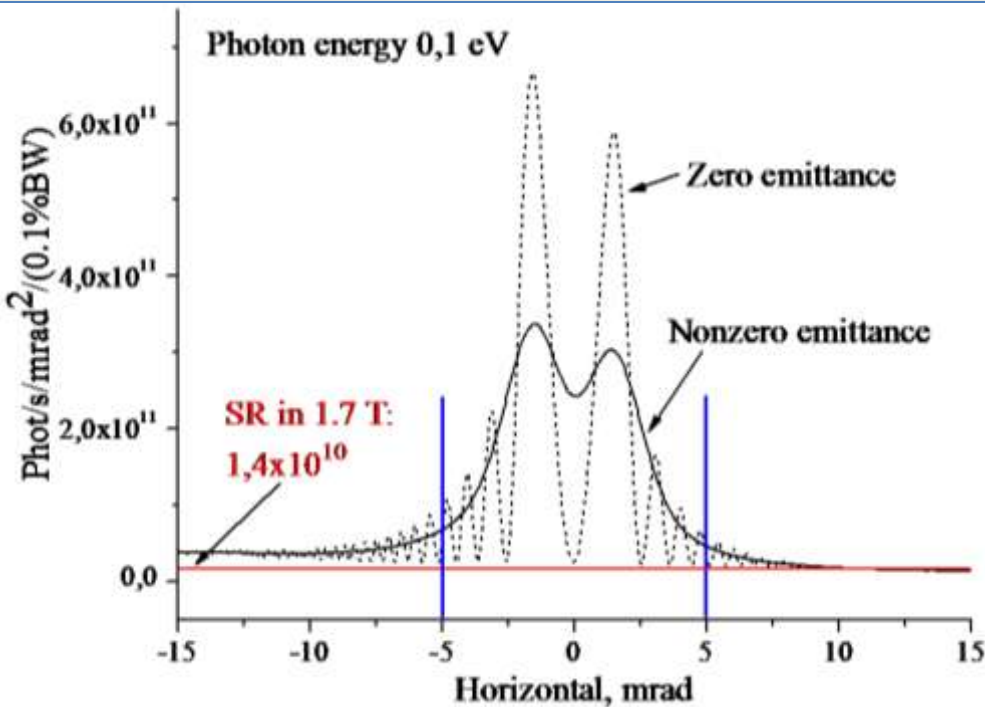
- Computer code SMELRAD - SiMulation of ELectromagnetic RADiation (Smolyakov N.V.)
- Emittance effects are included through convolution.

Electron beam parameters:

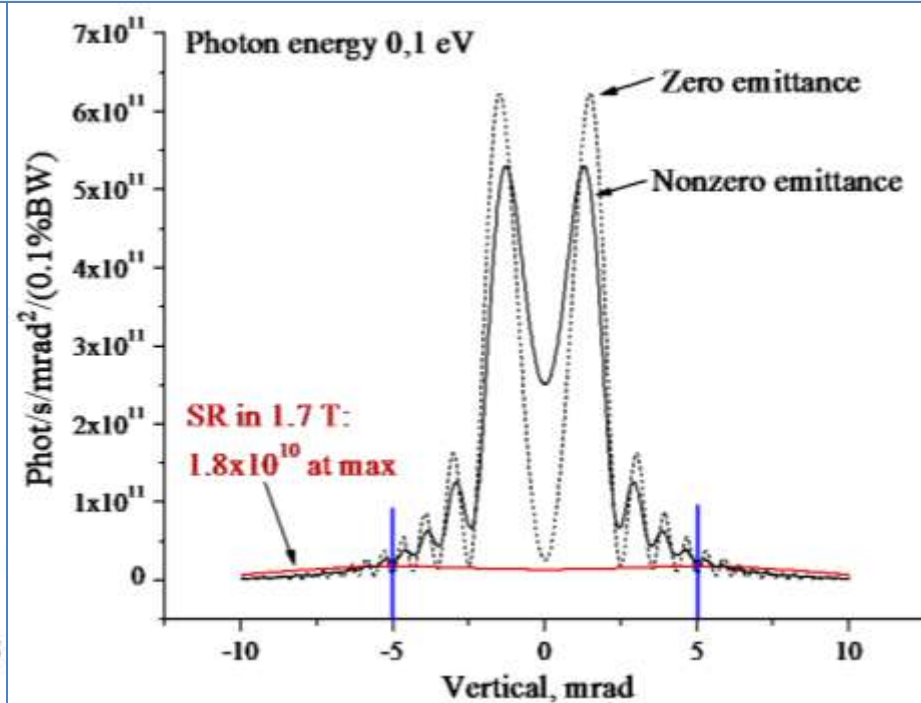
- $E=2.5$ GeV, $I_{\text{beam}}=100$ mA
- $\sigma_x=1.5$ mm, $\sigma_y=77$ μm
- $\sigma'_x=0.09$ mrad, $\sigma'_y=0.01$ mrad

ER intensity

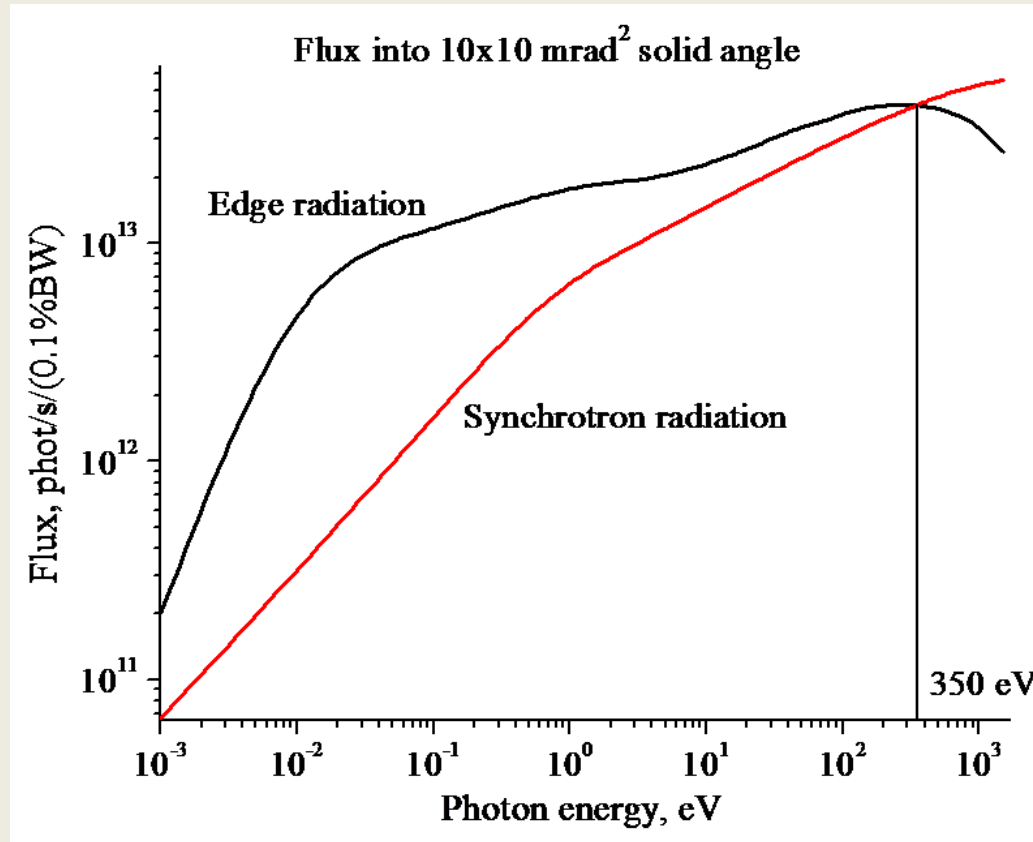
Angular distribution of ER intensity
in the horizontal plane



Angular distribution of ER
intensity in the vertical plane



The advantages of ER



ER flux vs. SR flux into 10×10 mrad² solid angle

- ER is inevitably generated by BM in any storage ring
- Small heat loading: ER – 10 Wt, SR – 110 Wt at $E=2.5$ GeV, $I_{\text{beam}}=100$ mA, into 10×10 mrad² solid angle

Mini-undulator as a diffraction limited source of X-Ray Radiation

- Spectral brilliance of light source

$$B = \frac{dn / (d\omega / \omega)}{4\pi^2 \Sigma_x \Sigma_y \Sigma'_x \Sigma'_y} \quad \Sigma_{x,y} = \sqrt{\sigma_{x,y}^2 + \sigma_R^2} \quad \Sigma'_{x,y} = \sqrt{\sigma'_{x,y}{}^2 + \sigma'_R{}^2}$$

$\sigma_{x,y}$ σ_R – electron and photon beam size, $\sigma'_{x,y}$ σ'_R – electron and photon beam divergence

- Photon beam emittance

$$\varepsilon_{ph} = \lambda / 4\pi$$

λ – wavelength of radiation

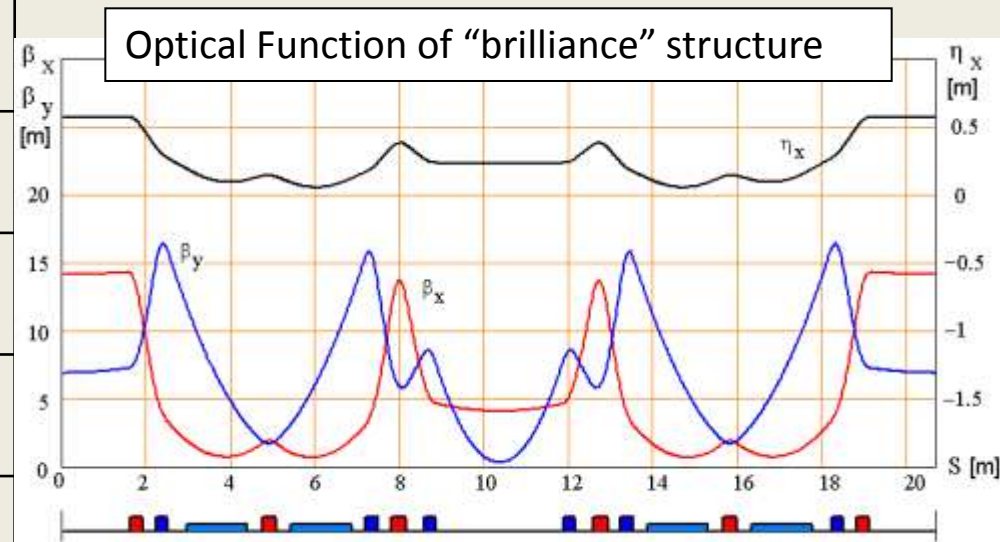
- Diffraction limited emittance of photon beam defines the minimum value of electron beam emittance at which brilliance is maximum
- Electron beam emittance is defined by magnet structure of storage ring

Emittance minimization

Work mode	“standard”	“brilliant”
Energy	2.5 GeV	1.3 GeV
Emittance	98 nm·rad	4.9 nm·rad
Beam size, mkm: σ_x / σ_y	1500/78	363/17
Circumference	124.128 m	
Coupling, $\varepsilon_y/\varepsilon_x$	0.01	
Momentum compaction	0.0103	4.2×10^{-3}
Betatron tunes: Q_x/Q_y	7.775/6.695	9.707/5.622
R.m.s. energy spread	9.5×10^{-4}	5×10^{-4}
Damping times: τ_x, τ_y, τ_s	3.2; 3; 1.5 ms	22; 22; 11 ms
Beam current	100-300 mA	

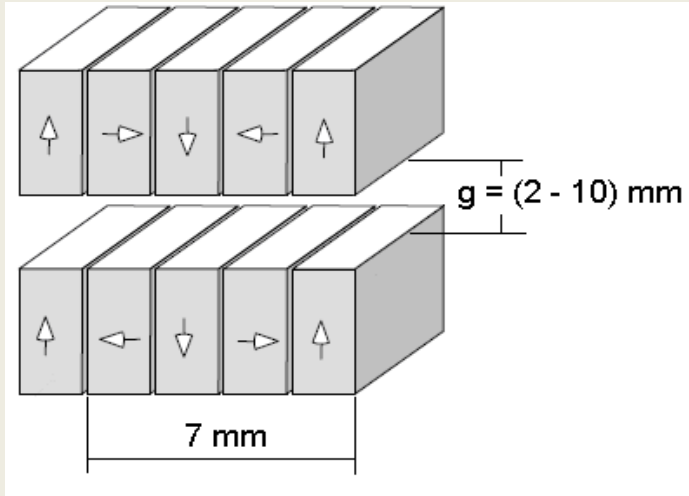
New brilliance lattice with horizontal emittance 18 nm·rad (on full energy) has been developed. The new lattice allows to obtain emittances $\varepsilon_x=4.9$ nm·rad and $\varepsilon_y=49$ pm·rad at 1.3 GeV.

Thus, vertical emittance of electron beam is equal photon emittance for 2 keV photons.



Undulator

Pure Permanent Magnet Structure



Wavelength of radiation λ for planar undulator

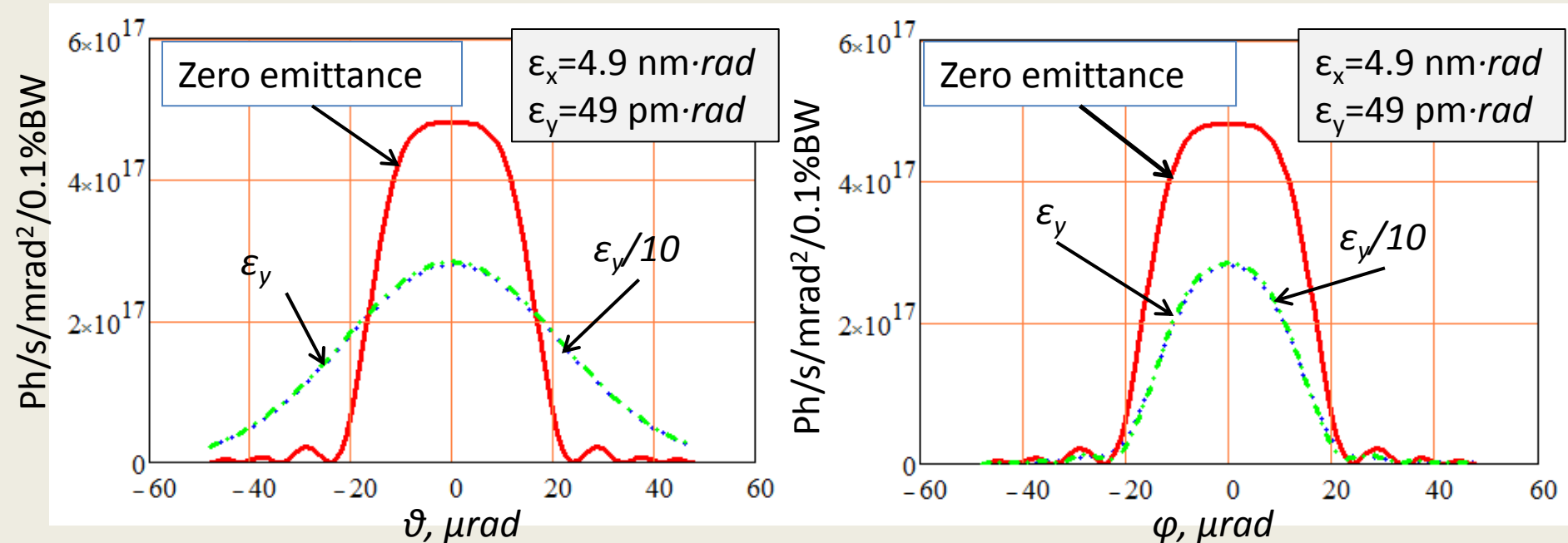
$$\lambda_n = \frac{\lambda_u}{2\gamma^2 n} \left(1 + \frac{K_u^2}{2} + (\gamma\theta_x)^2 + (\gamma\theta_z)^2 \right)$$

where $n=1,2,3\dots$ - harmonic number, θ_x, θ_z – horizontal and vertical observation angle with respect to the axis.

Gap	mm	2.2
Permanent magnet material		NdFeB
Residual field, B_r	T	1.2
Undulator period, λ_u	mm	7
Pole width, w	mm	50
Parameter field decrease in horizontal direction, ξ		1.5
Field amplitude, B_0	T	0.75
Undulator parameter, K_u		0.492
Undulator length, L_{ID}	m	2.1
Wavelength radiation, λ	Å keV	6.06 2.045

$$K_u = \frac{eB_0}{m_e c k_u} \quad \text{Undulator parameter}$$

Angular flux density of first harmonic

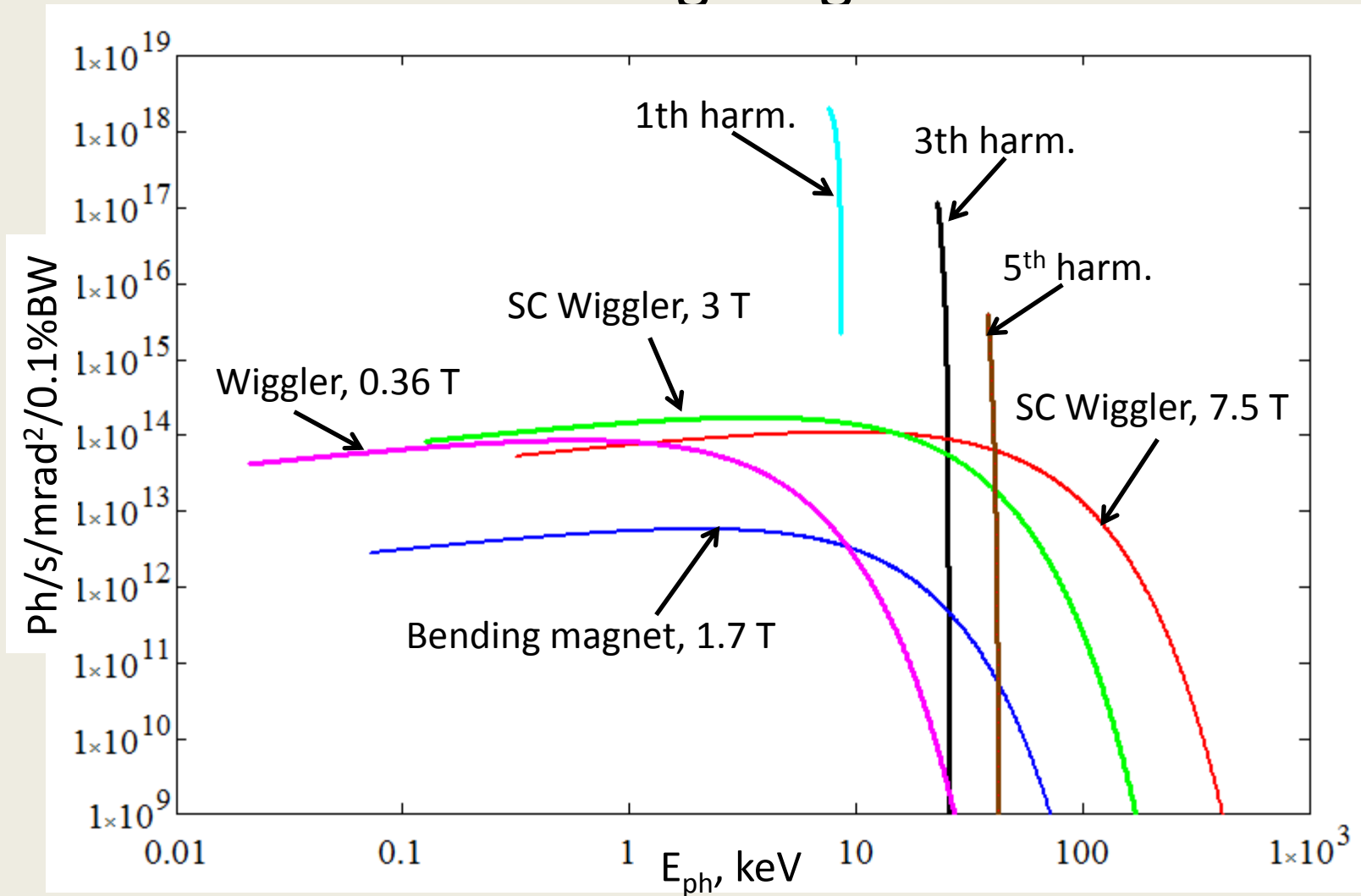


Angular distribution of intensity in the horizontal plane

Angular distribution of intensity in the vertical plane

- $E = 1.3 \text{ GeV}$, $I_{\text{beam}} = 100 \text{ mA}$
- Computer code SMELRAD

Spectral photon flux distribution from IDs and bending magnet



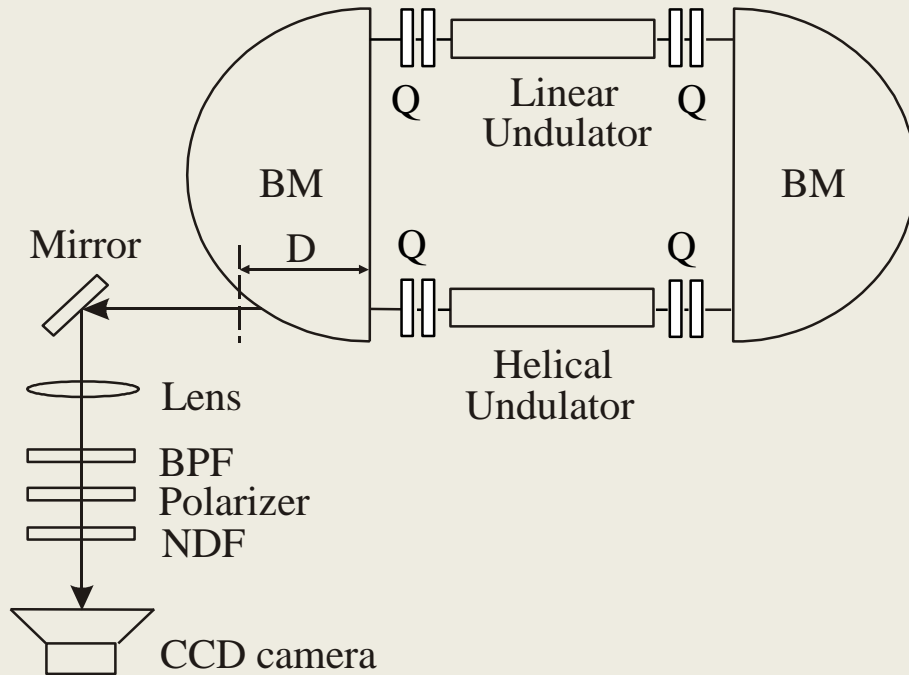
➤ $E = 2.5 \text{ GeV}$, $I_{\text{beam}} = 100 \text{ mA}$, $\varepsilon_{x,y} = 0$

➤ Intensity of undulator radiation at change of gap from 2 to 10 mm

Thanks for attention

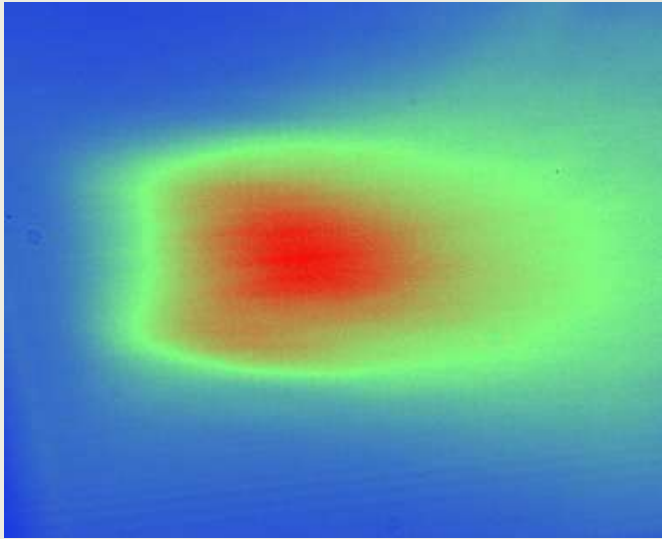
Experimental Data

Main parameters of HiSOR storage ring

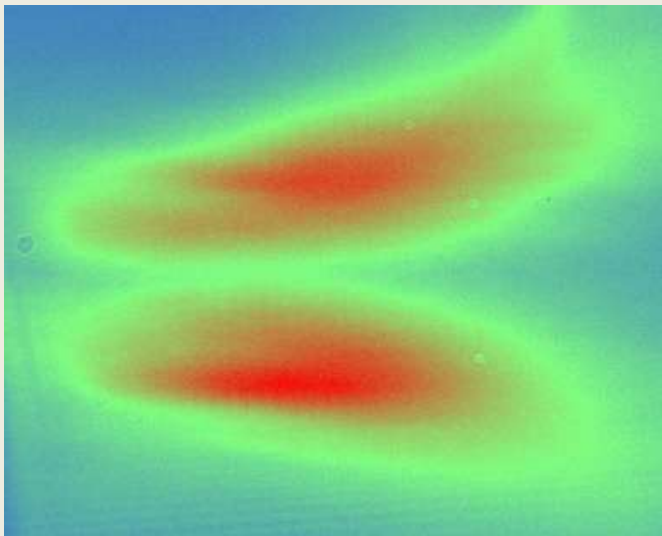
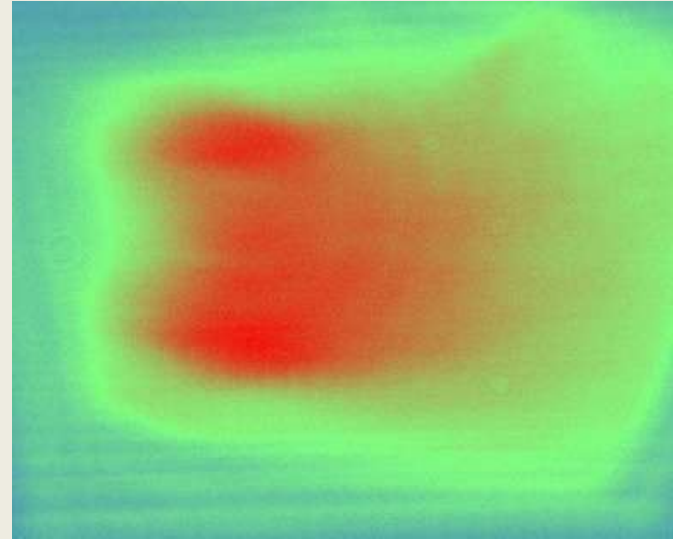


Energy	700 MeV
Circumference	21.946 m
Bending radius	0.87 m
Stored current (Max)	100 mA
Bending field	2.7 T
Critical wavelength	1.42 nm
Length of straight section	8.24 m

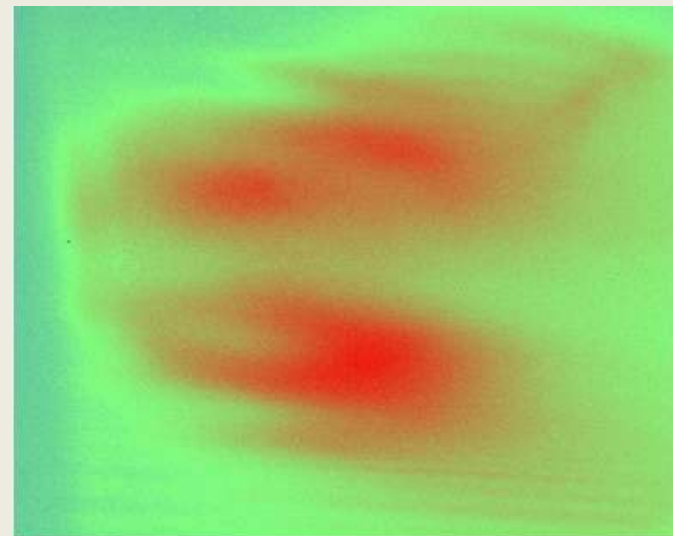
Experimental Data



σ



π



400 nm ER

950 nm ER

Conclusion

- Computer simulations of edge radiation and mini-undulator radiation spectra show that:
- Edge radiation flux far exceeds the SR flux for the photon energies less than 350 eV.
- In addition, ER beamline does not need any special insertion device.
- Insertion device with diffraction limited intensity in vertical direction is feasible at Siberia-2 storage ring