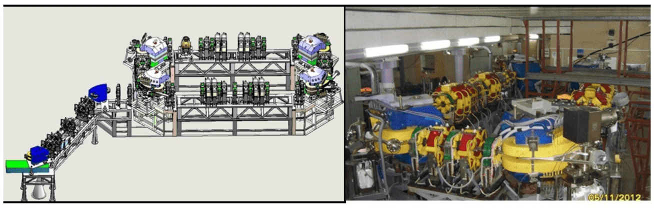
Redesign of NESTOR storage ring lattice

A. Kalamaiko, P. Gladkikh, A. Zelinskiy, A. Shcherbakov, A. Mytsykov, I. Karnaukhov
National Scientific Center Kharkiv Institute of Physics and Technology, Kharkov, Ukraine

NESTOR project



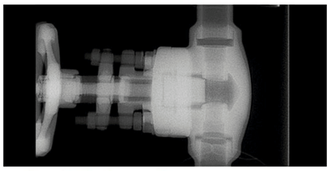
The X-ray source NESTOR based on the Compton scattering of intense laser beam on low-energy relativistic electron beam is under design and development in NSC KIPT.

SfP-977982

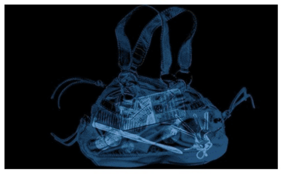
The main task of the project is to develop the intense X-ray and gamma-beam source with the yield up to 10^{13} phot/s and range of the hard X-rays from 30 to 700 KeV .

Some applications of X-ray and gamma radiation

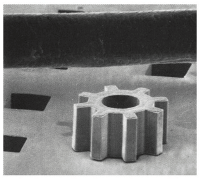
Radiography



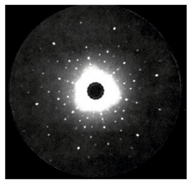
Security



Nanotechnology and micromechanics



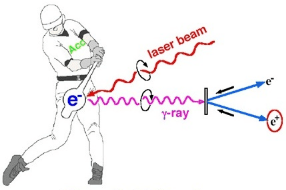
Crystallography



Medicine

Main requirements for the ring lattice

Compton scattering



Picture by T. Omori

In single collision the number of scattered photons is determined by the luminosity L and total cross-section of the Thompson scattering σ.

$$n_\gamma = L\sigma$$

Luminosity in general case is determined by both colliding beams intensity n_e, n_l and collision geometry G.

$$L = n_e\, n_l\, G$$

To obtain high X-ray yield we have to design storage ring with small transversal and longitudinal electron beam size at the collision point.

Beside, a technology must to allow a small collision angle.

Main requirements for the ring lattice

Electron beam dynamics

1. Electron energy in single collision decreases significantly. Due to quantum fluctuations of the Compton scattering beam energy spread becomes large. ⇒ **Large energy acceptance of the storage ring**

To obtain large energy acceptance one needs a storage ring with low momentum compaction factor (**α**).

$$\sigma_{rf} \propto \sqrt{V_{rf} / \alpha_1}$$

Under large momentum deviation the transversal beam displacement becomes depending on quadratic term of the momentum deviation and quadratic dispersion

$$\Delta x = \eta_1\, \Delta p / p + \eta_2 \left(\Delta p / p\right)^2 + ... = \eta_1\, \delta + \eta_2\, \delta^2 + ...$$

Momentum compaction factor becomes dependent on momentum deviation

$$\alpha = \alpha_1 + \alpha_2 \delta$$

At low linear momentum compaction the ring energy acceptance may decrease.

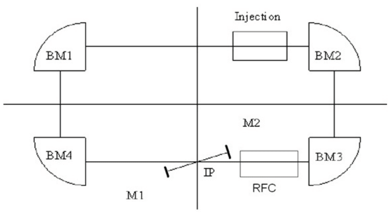
Momentum compaction is a compromise value

2. Quadratic and higher order terms effects on both transversal and longitudinal dynamics because of large beam energy spread. ⇒ **Suppression of aberrations in ring lattice**

3. Strong beam focusing limits the dynamic aperture ⇒ **Correcting of dynamics aperture**

Low energy Compton ring scheme

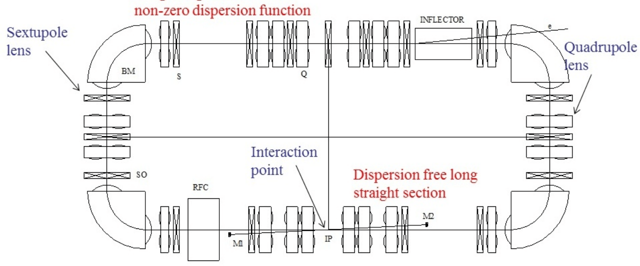
Lattice with controlled momentum compaction factor



- **amplitude functions at interaction point must be as small as possible;**
- **momentum compaction factor must be as small as possible;**
- **number of sextupoles in ring lattice must be enough to correct the chromatic effects and dynamics aperture**

Lattice of the laser-electron storage ring NESTOR

Lattice with controlled momentum compaction factor



Bending radius and bending angle **ρ = 0.5 m**, φ_{BM} **= 90°**, correspondingly, field index is equal to **n = 0.6**. The maximal magnetic induction B_{max} **= 1.5 T** at the maximal electron beam energy E_{0max} **= 200 MeV**. The length of quadrupoles **150 mm**, maximal quadrupole gradient $G_{max} \approx$ **25 T/m**. The length of all sextupole **100 mm**. The maximal length of the drift spaces is **1.2 m** and what allows to place the **700 MHz** RF-cavity and injection system elements on those drifts. Ring circumference **C = 15.418** m, harmonics number ***h* = 36** and one can store **1, 2, 3, 4, 6, 9, 12, 18** and **36** bunches on beam orbit.

Lattice redesign

Reasons

1.The field indexes of the produced bendings were lower, than calculated ones approximately 10 %. Quadrupole gradients were different from one bending to other. Due to lower quadrupole strength the vertical betatron frequency was closed to the integer resonance $Q_y \approx 2$.

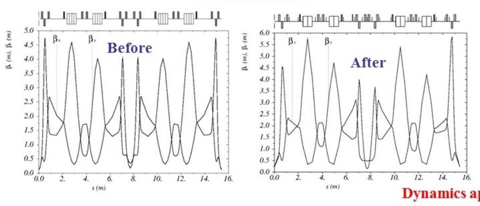
2.The drift length between final quadrupole triplets did not allow to install optical resonator for the laser beam stacking.

Result

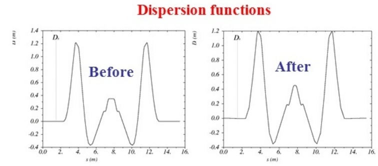
Parameter	Initial	Redesigned
Betatron tunes:		
Horizontal	3.15	3.13
Vertical	2.10	1.78
Linear momentum compaction factor	0.0096	0.0108
Amplitude functions at CP (m):		
Horizontal	0.12	0.21
Vertical	0.14	0.23
Drift length for optical cavity (m)	0.45	0.75

Lattices comparison (before and after redesign)

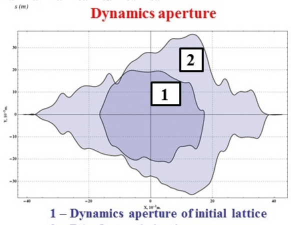
Beta functions



Dispersion functions



Dynamics aperture



1 – Dynamics aperture of initial lattice
2 – DA after optimization