CREMLIN WP5 Workshop: "Towards a conceptual design for the Russian SSRS-4 facility"

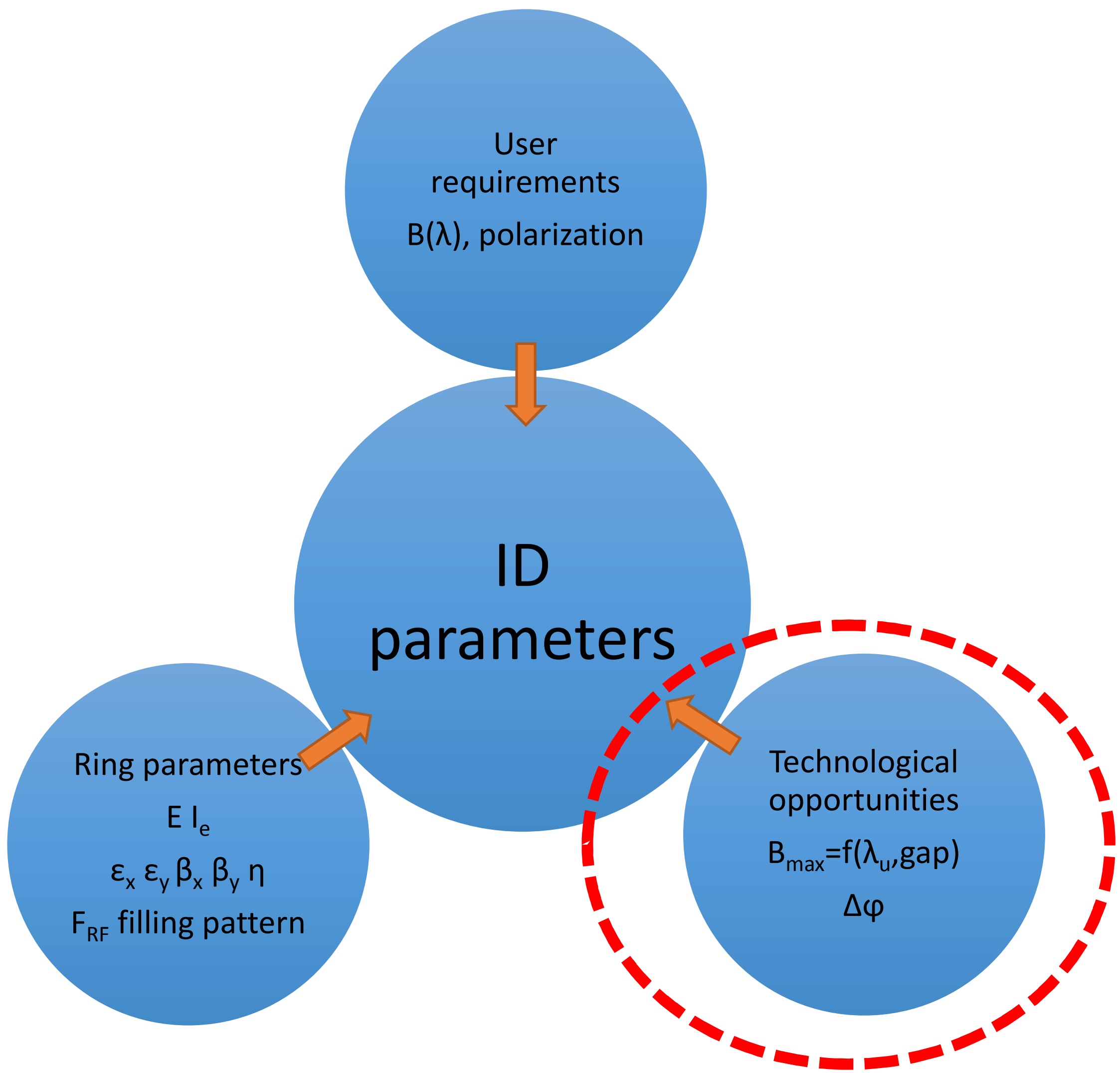
January 23, 2018
DESY Hamburg

The contribution of the Budker Institute to the SSRS-4 Insertion devices and RF system

Budker Institute of Nuclear Physics
Novosibirsk

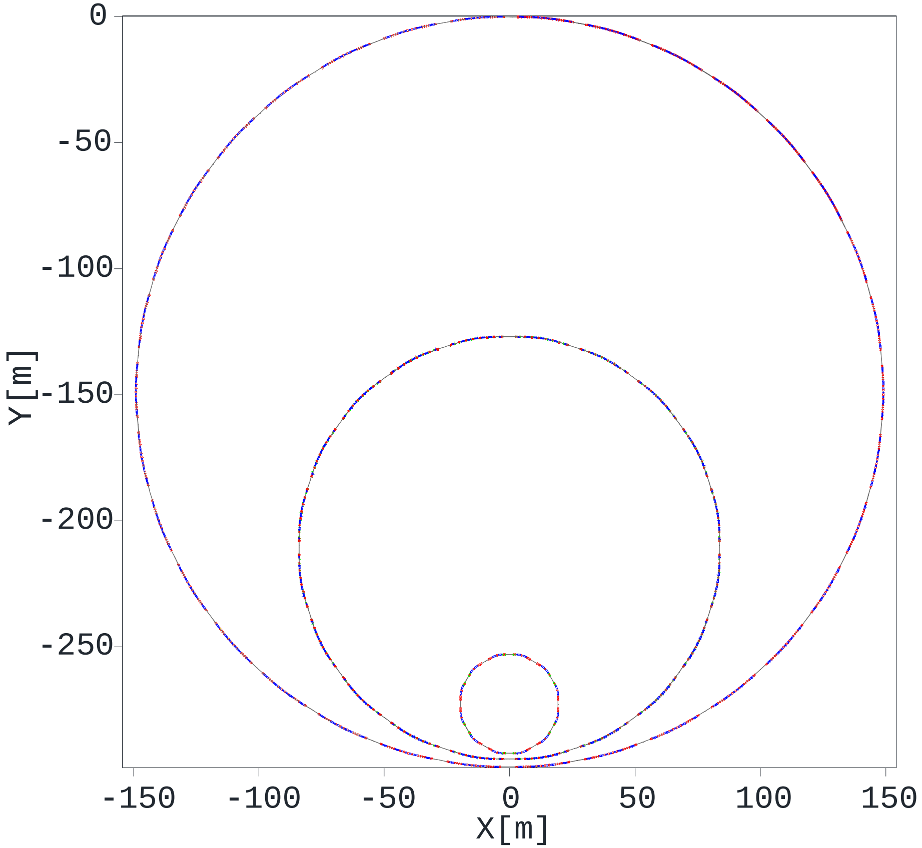
BINP Magnetic elements manufacturing

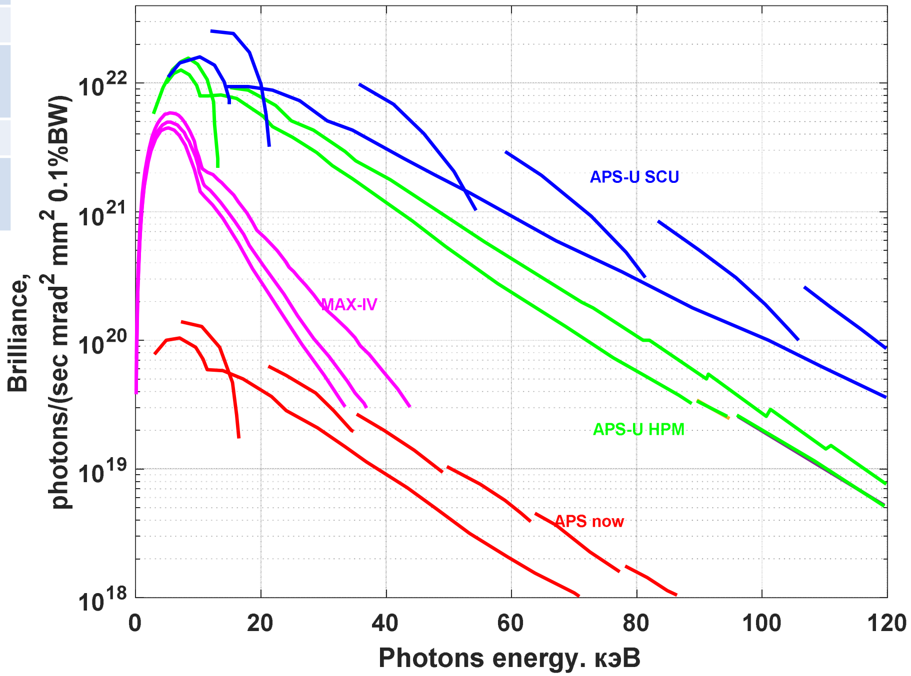
Common strategy for choice of insertion device

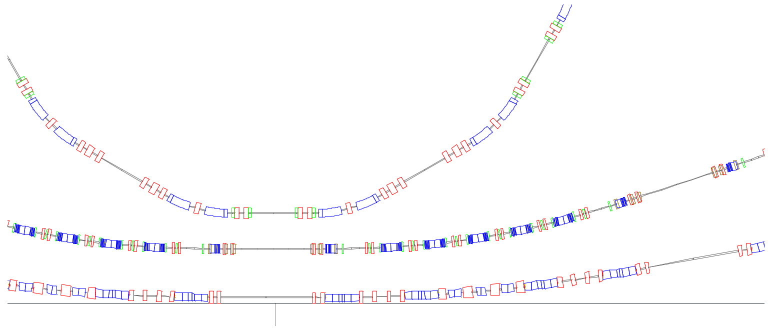


Scales of project

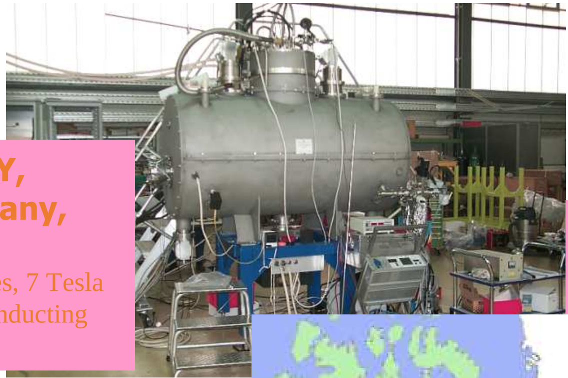
	Medium scale project	Large scale project
Energy	3 GeV	5 – 6 GeV
Circumference	About 500 m	1 – 1.5 km
Horizontal equilibrium emittance	250 – 400 pm·rad	50 – 90 pm·rad
Estimated cost	300 – 500 M€	About 1000 M€
Analogs	MAX-IV	ESRF-U, APS-U, SPring-8-U, HEPS







Superconducting multipole wigglers



BESSY, Germany, 2002
17-poles, 7 Tesla superconducting wiggler

ELETTRA, Italy, 2002
49-pole 3.5 Tesla

CLS, Canada, 2004
63-pole 2 Tesla
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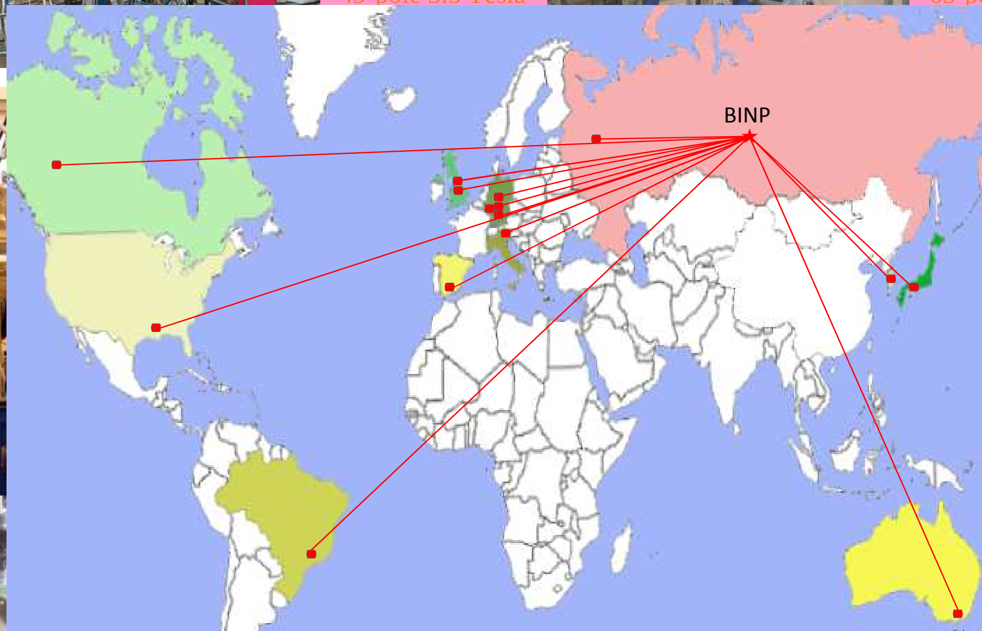
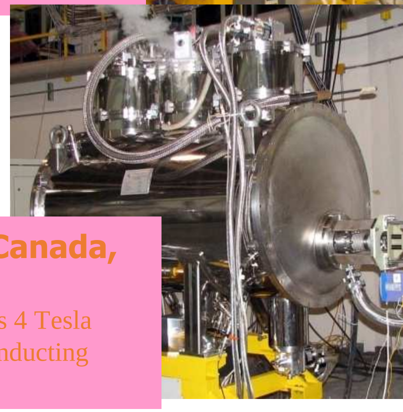


DLS, England, 2006
49-pole 3.5 Tesla superconducting wiggler



**S, Canada,
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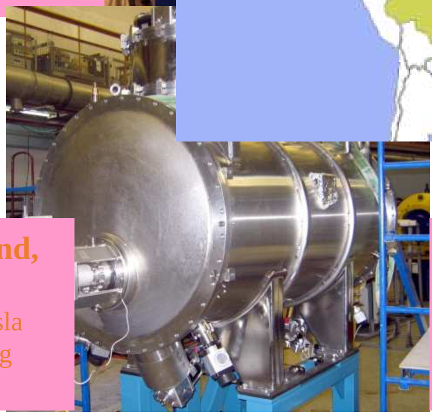
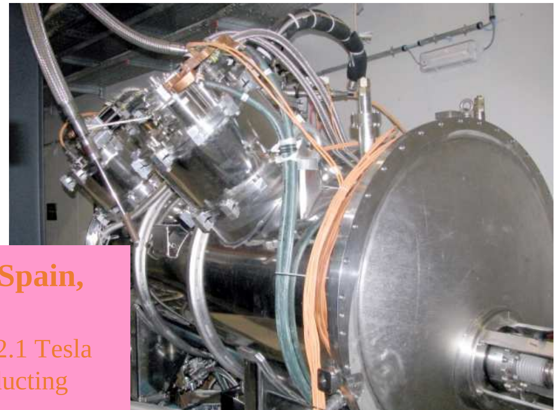


DLS, England, 2008
49-pole 4.2 Tesla superconducting wiggler

LNLS, Brazil, 2009
35-pole 4.2 Tesla superconducting wiggler

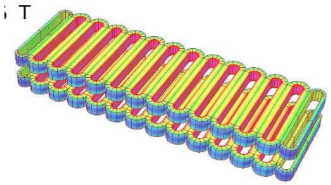


ALBA, Spain, 2010
119-pole 2.1 Tesla superconducting wiggler

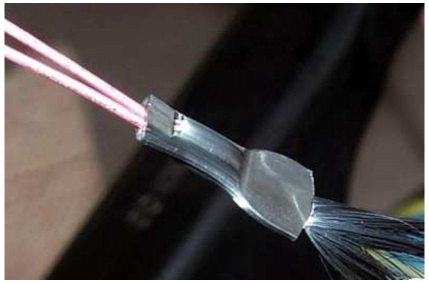
Superconducting wigglers

BINP SCW features

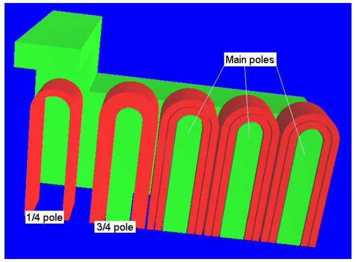
- Horizontal racetrack coils



- Coils connections with extra low resistance (~ $10^{-13} – 10^{-10}$ Ω)



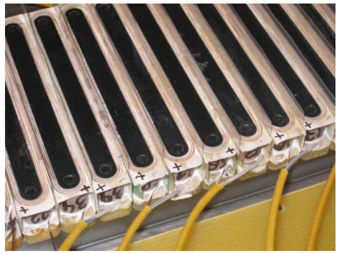
- Nested coils



- Gd_2O_2S powder in the epoxy compound for thermal stabilization

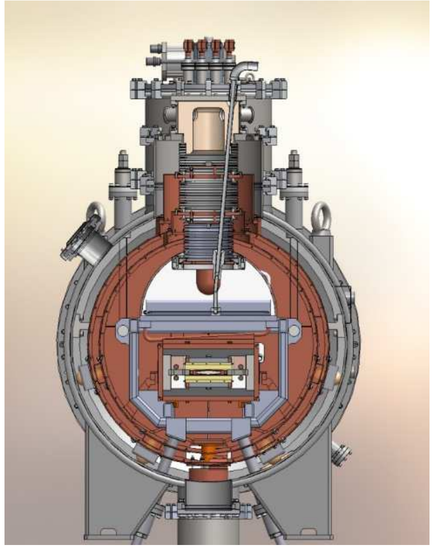
Long period SC multipole wigglers
(B_0 =7-7.5 Tesla, λ_0~150-200 mm)

Medium period SC wigglers
(B_0 =3.5-4.2 Tesla, λ_0~48-60 mm)



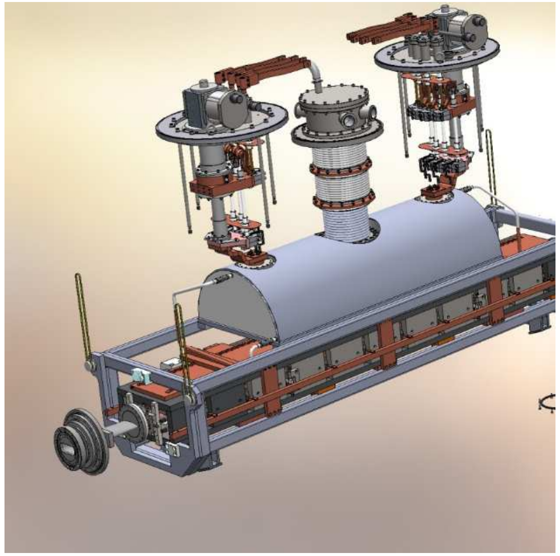
Short period SC wigglers
(B_0 =2-2.2 Tesla, λ_0~30-34 mm)

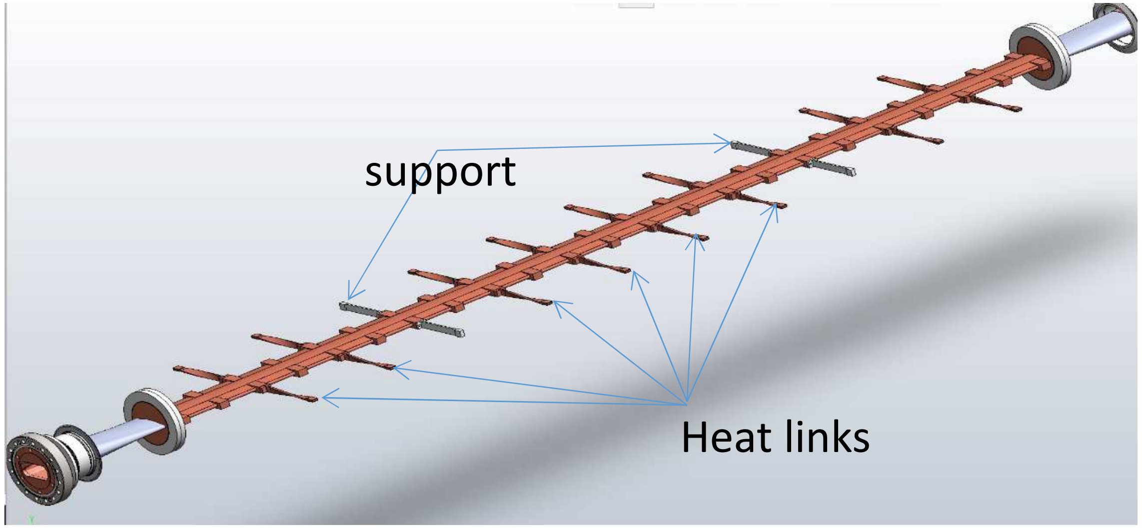
Indirect cooling cryostat



Advantages of indirect cooling

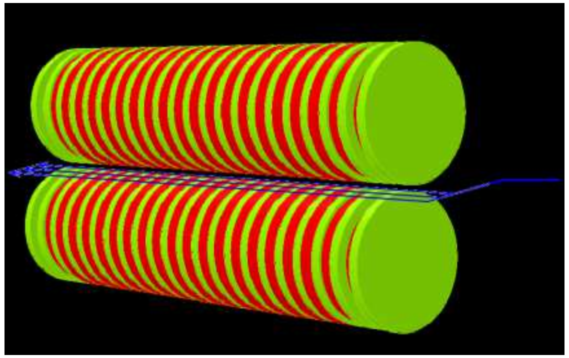
- Easy access to the magnetic system and to the beam vacuum chamber
- Possibility for exchanging of the elements of magnetic system (and whole system) without complex operation
- Possibility for exchanging the beam vacuum chamber
- Possibility for installing of the wigglers in the halls with lower ceilings
- Effective using of the magnetic gap
- Nitrogen filled heat pipes for quick initial cooling





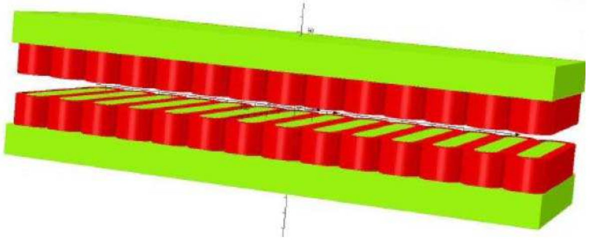
Superconducting undulators

Vertical racetrack coils



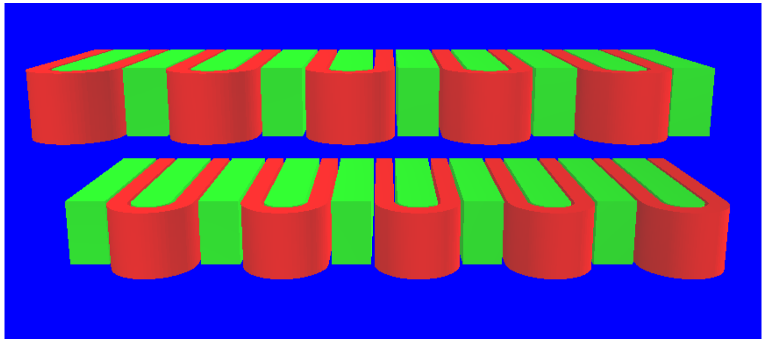
The main vertical field of an undulator is created by horizontal cross currents.

Horizontal racetrack coils



For windings of the limited sizes of coils the currents can be closed in the vertical plane (vertical racetrack coils) or in the horizontal plane (horizontal racetrack).

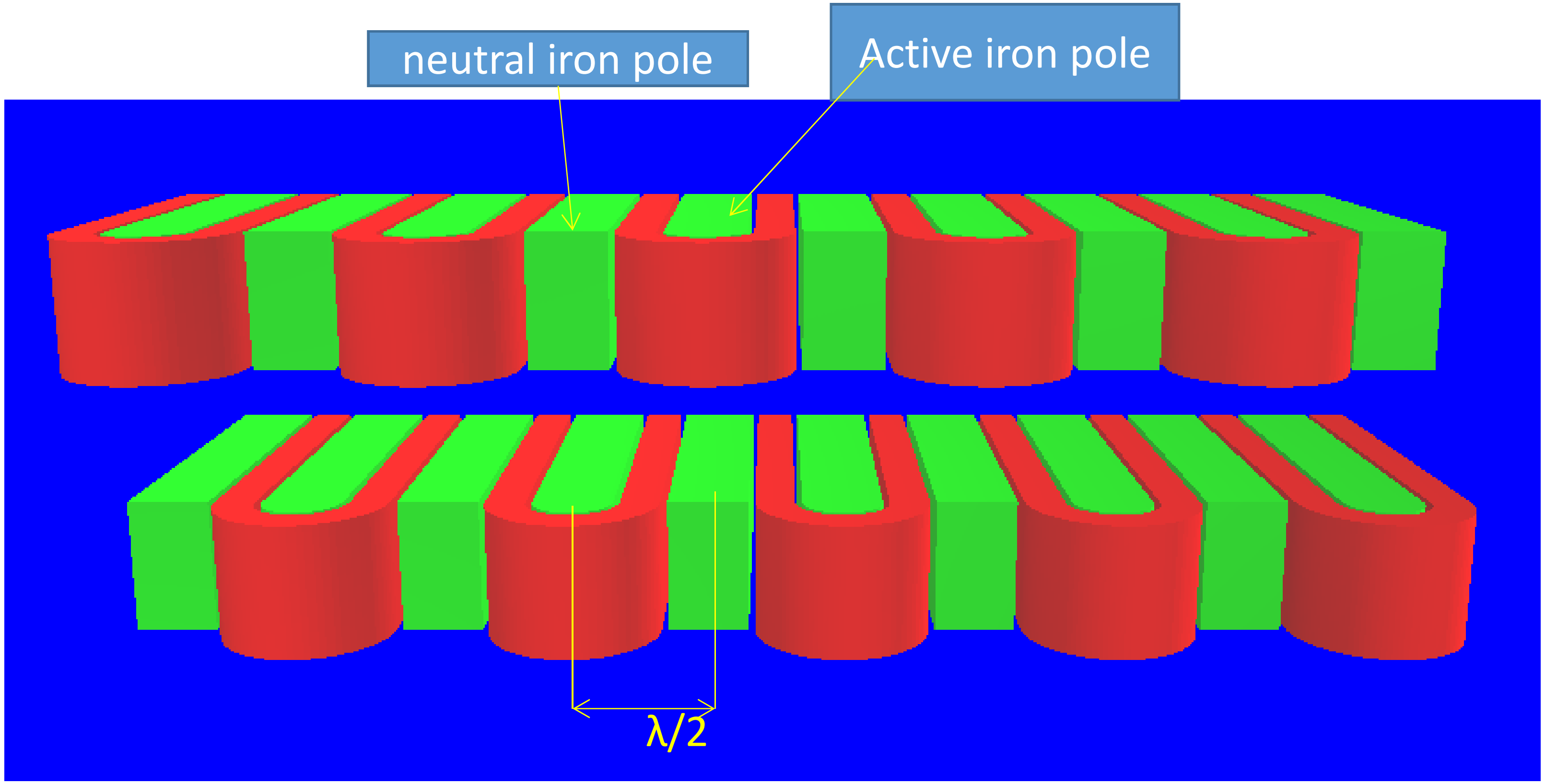
Horizontal racetrack coils with neutral poles



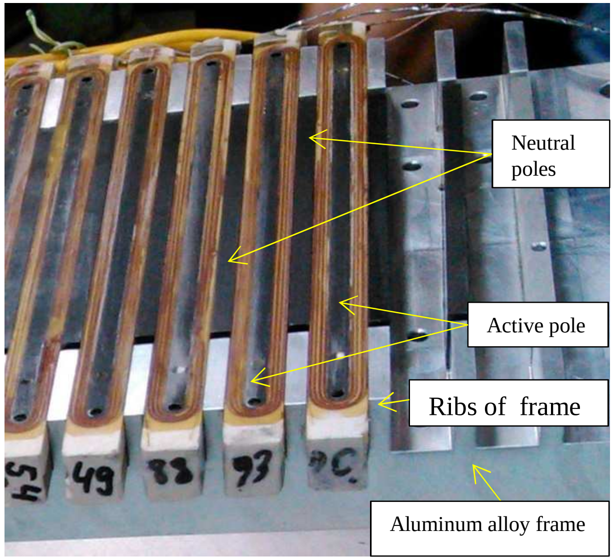
The way of windings with a current closing in the horizontal plane with use of a neutral pole was proposed in BINP.

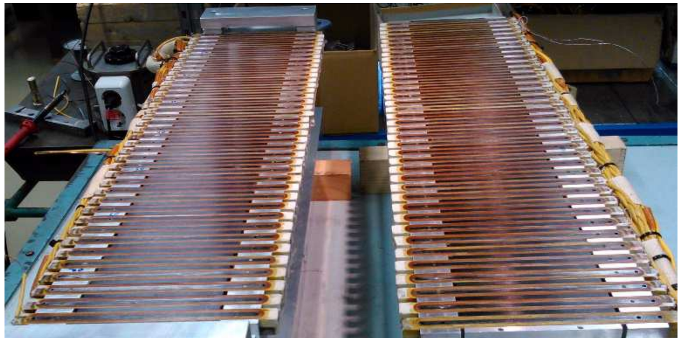
Superconducting undulator prototype with neutral poles

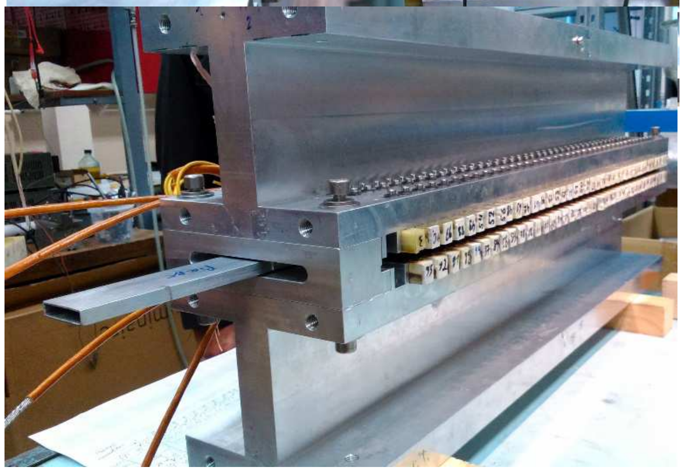
The magnet consists of two identical top and bottom halves. Windings are reeled up on the iron core. Between windings the iron core without windings (a neutral pole) is inserted. A combination a winding + a neutral pole make one period of an undulator. Halves of an undulator are powered equally and turned to each other so that magnetic fields are directed towards to each other. For creation of the cross field in the median plane one half is shifted concerning another on a half of the period.

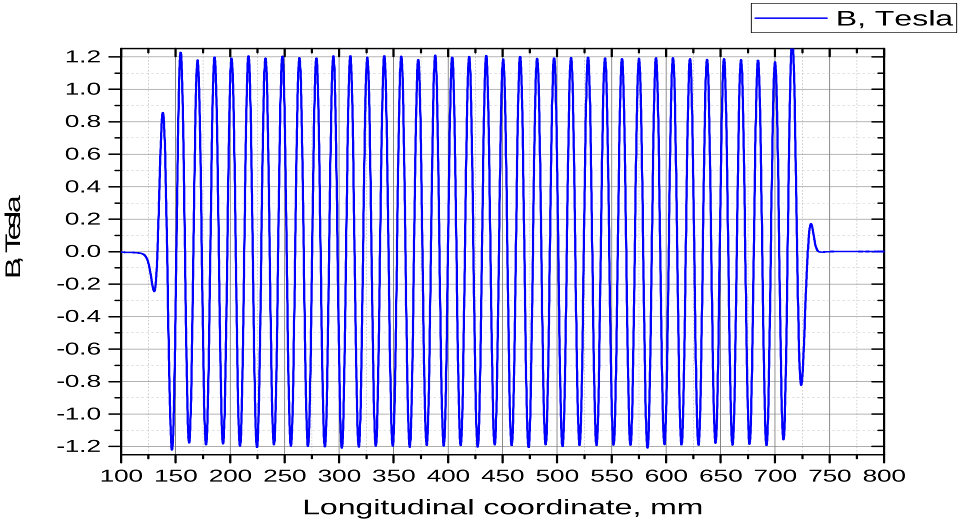


Superconducting undulators









- The prototype is made (λ=15.6 mm, pole gap 8 mm, B=1.2T) and the idea of use of a neutral pole for creation of a superconducting undulator with the period more than 12 mm is successfully checked.
- Test of the prototype was carried out in a bath cryostat with liquid helium and in a vacuum cryostat with indirect cooling by a cryocooler. Difference in stability of the field was not noticed.
- Design features of superconducting windings and assembly of the magnet allow to hope for the significant increase in accuracy of manufacture and decrease of cost of a magnet.
- The quantity of windings decreases twice.
- It is easily to provide mass production, high quality of pole fabrication, control of key dimensions and quality for every pole.
- High precision of regular structure of the undulator. Horizontal racetrack winding improves precision of coils dimensions. It should minimize phase errors.
- There is no limitation of undulator length.

Electromagnetic and permanent magnet undulators and wigglers

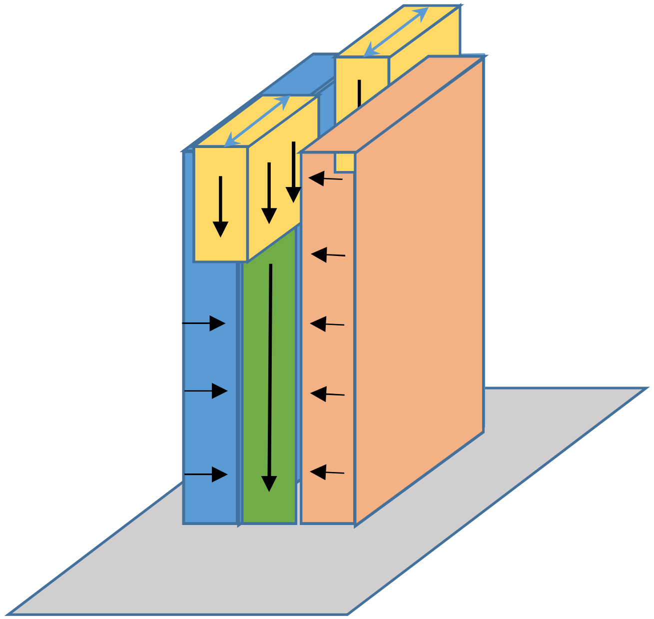
Undulator for SOLEIL (3 pcs., France, 2009)

Undulator (prototype) for XFEL (Germany, 2014)

Undulator for SLS PSI (2 pcs., Швейцария, 2004)

Dumping wigglers for PETRA III (24 pcs., Germany, 2010)

In-vacuum undulators



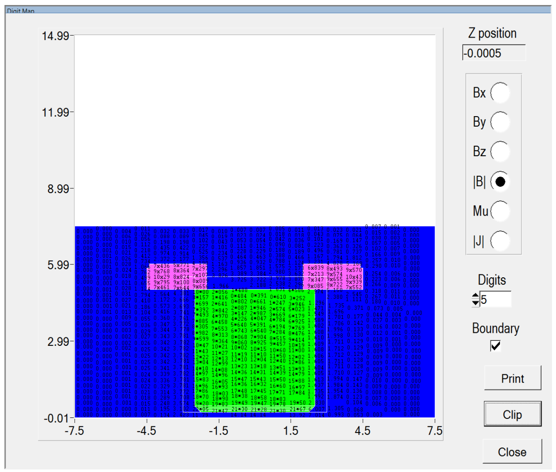
Vacuum in undulator proposal for MAX-IV (IVU19)

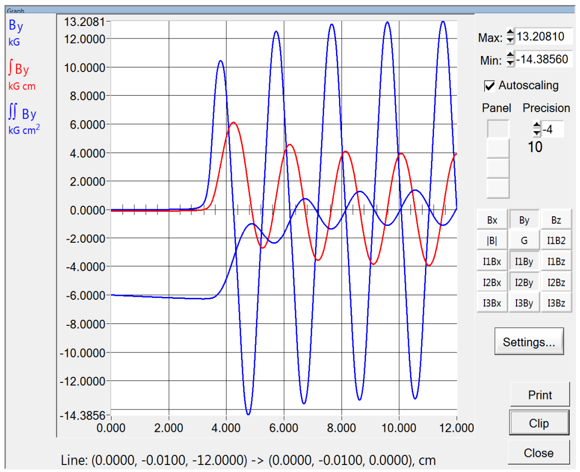
B = 1.4 T, λ_u = 30 mm

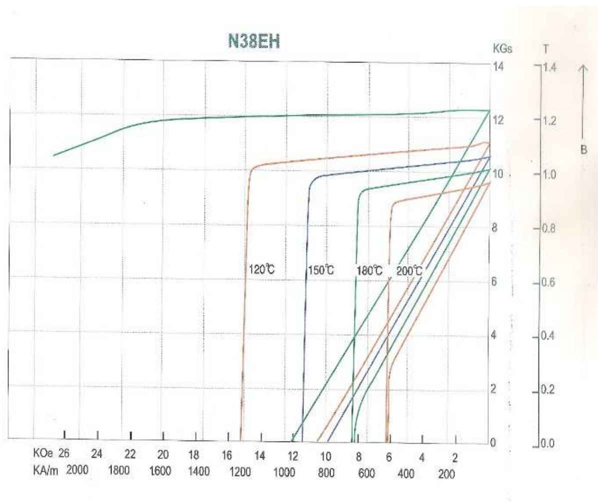
Designed by P. Vobly

Design permits use cheap magnetic material (NdFeB) N38EH

Small phase error < 3° for ΔM/M ~ 3%







Helical undulators

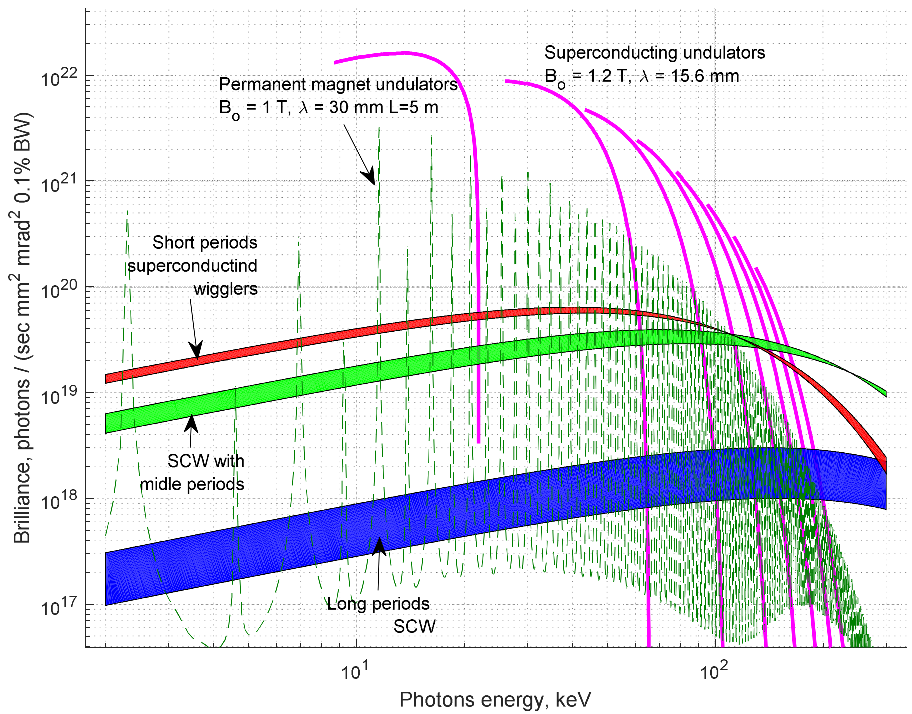
Helical undulators for coherent electron cooling ions beams RHIC (BNL, USA)

Parameter	Value
Magnetic field	0.14 T
Period	40 mm
Magnetic aperture	32 x 32 mm
Length	2500 mm
First integral	$< 3 \cdot 10^{-5}$ T·m
Second integral	$< 3 \cdot 10^{-6}$ T·m^2
Phase error	± 3°

Conclusions

Budker INP has developed technologies for producing IDs for SSRS-4:

- Superconducting wigglers (different types)
- Superconducting undulators (B=1.2 T, λ_u=15 mm)
- Electromagnetic undulators and wigglers
- Undulators with permanent magnets



BINP has not experience for producing Apple-II type and cryogenics permanent magnets undulators

For SSRS-4 undulators are preferable for almost all methodics

Wigglers can be used for extra hard X-ray spectroscopy and imaging

Shot period wigglers can be effective for XAFS-spectroscopy

RF system proposal for SSRS-4

Bimetalic (Cu/SLS) cavities 5-8

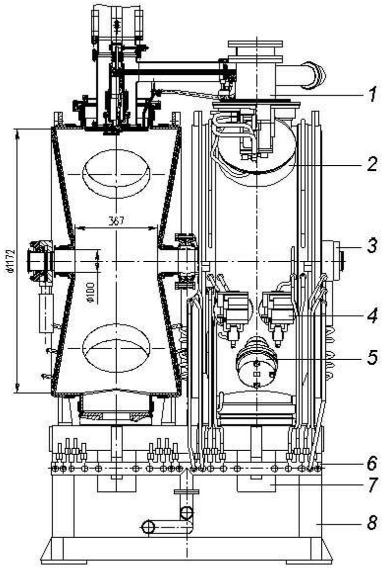
Generators tetrode TH781

(THALES, France) 150 kW

and solid state amplifiers for RF excitation

Similar to current Kurchatov light source

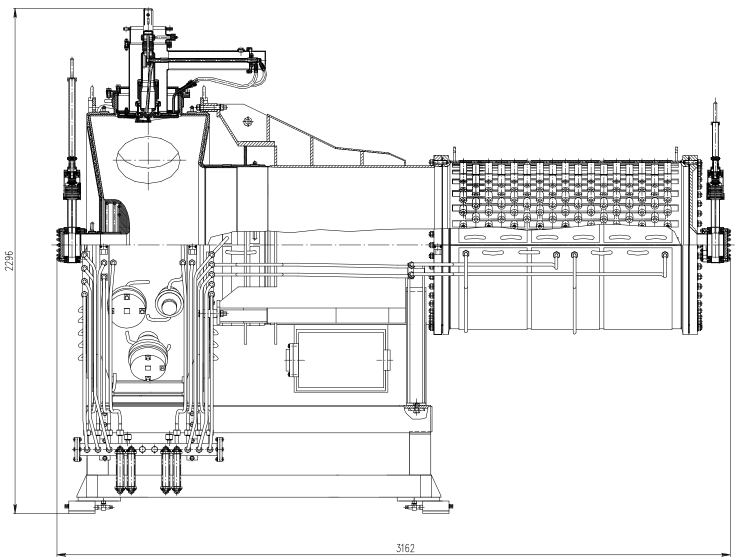
Parameter	Value		
Resonance frequency	f_0	180.4	MHz
Detuning range by using 2 tuner on the main mode	Δf_0	320	kHz
Natural Q-factor	Q_0	40000	
Flight coefficient	T	0.9	
Shunt resistance	R_S	4.3	MOhm
Characteristic resistance	R/Q	108.1	Ohm
Max voltage	V_{rf}	850	kV
Absorbed Power (V_{rf} = 750 kV)	P_{Cu}	85	кВт

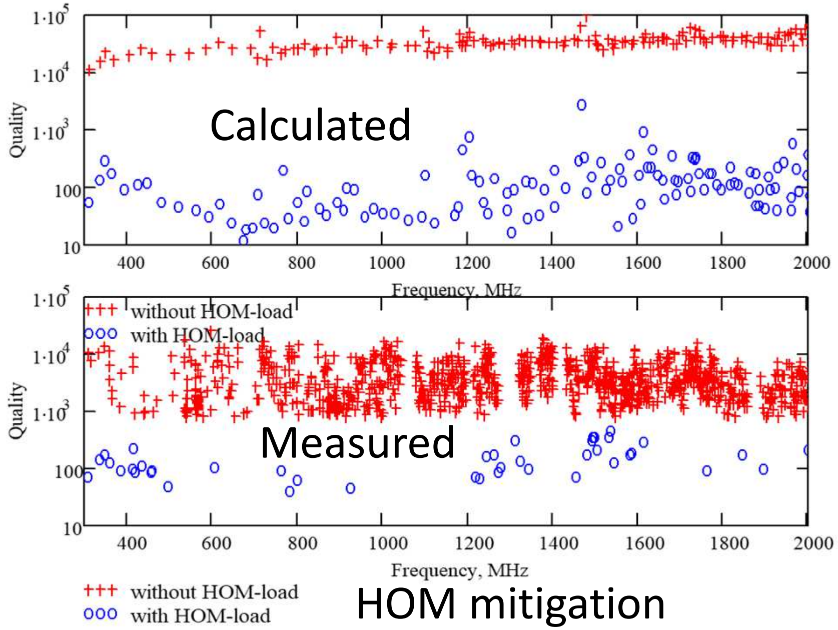


HOM cavities

DFELL (Duke Free Electron Laser Laboratory, Durham, NC, USA)

Parameter	Value		
Resonance frequency	f_0	178.5	MHz
Detuning range by using 2 tuner on the main mode	Δf_0	320	kHz
Natural Q-factor	Q_0	38 500	
Flight coefficient	T	0.764	
Shunt resistance	R_S	3.4	MOhm
Characteristic resistance	R/Q	88.6	Ohm
Max voltage	V_{rf}	750	kV
Absorbed Power (V_{rf} = 750 kV)	P_{Cu}	82.5	кВт





HOM mitigation

RF generators

Four modules RF generator for microtone in the NovoFEL for 8 cavities

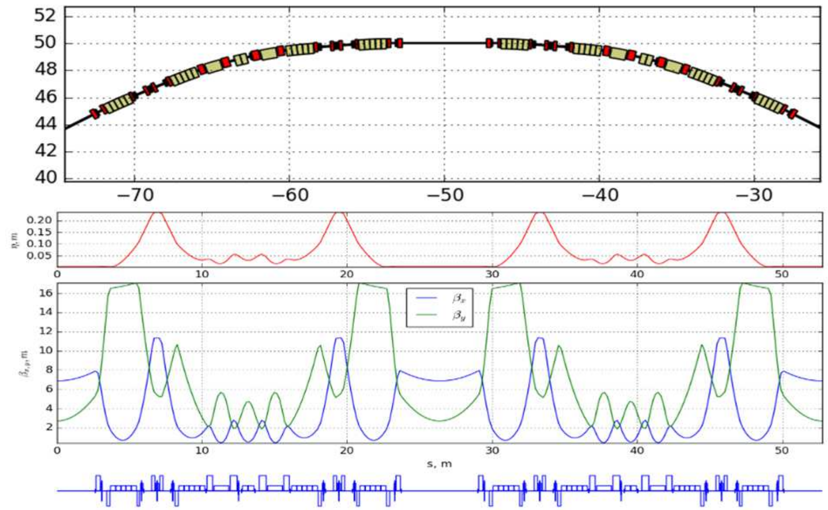
Two modules RF generator for Kurchatov light source

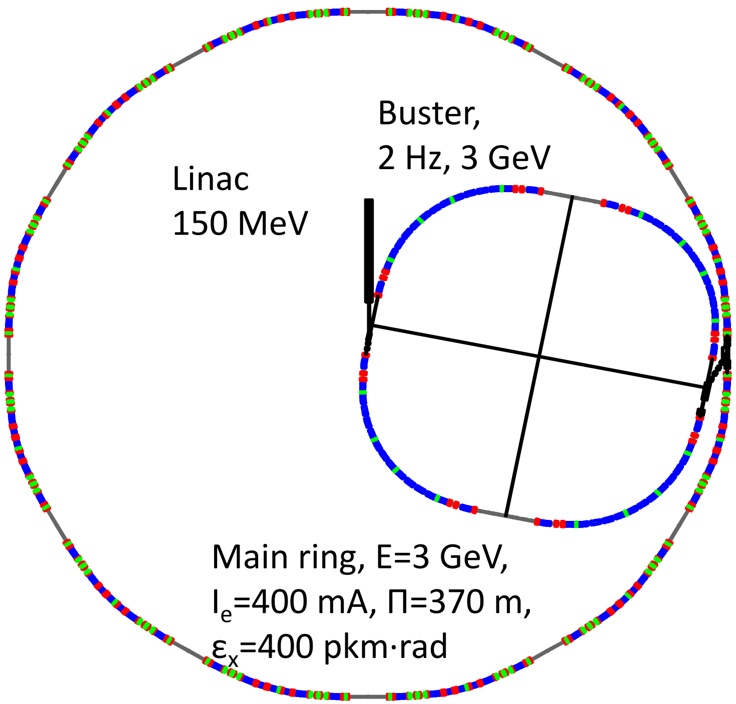
RF generators use tetrode tube TH781 (THALES, France) or Karnaval (Svetlana, Russia). Total power about 150 kW for every lamp.

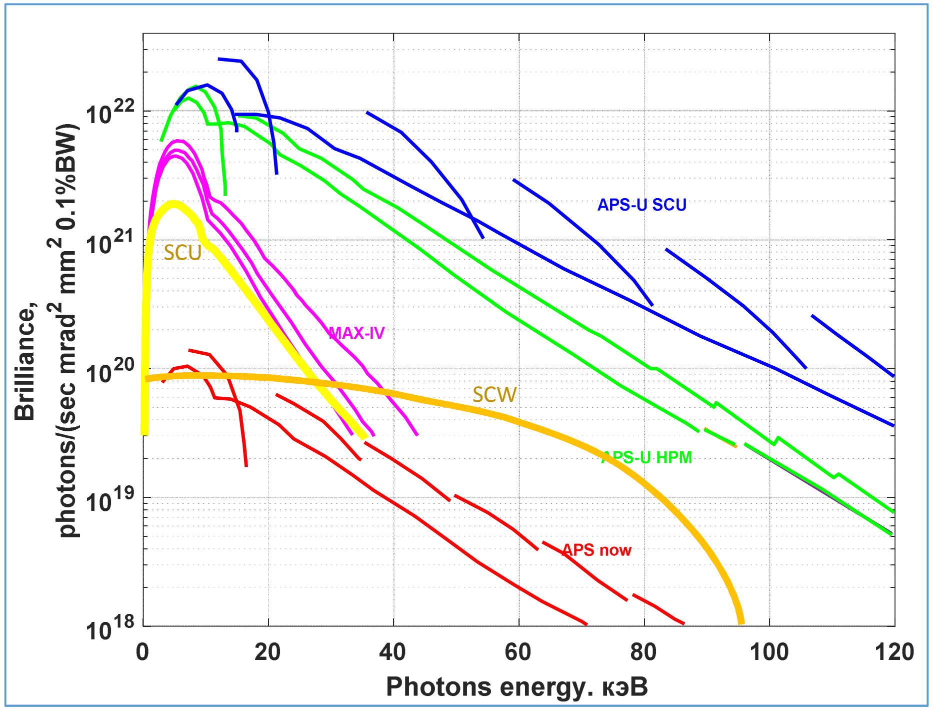
Solid state RF amplifiers used for preliminary cascades for RF excitation.

New source for Siberian scientific center

Energy	3 GeV
Beam current	Up to 400 mA (2 mA in one bunch)
Emittance	400 pkm rad
Injection	Top up
Circumference	~ 370 м
ID	12 undulators and wigglers
RF	180 MHz, HOM







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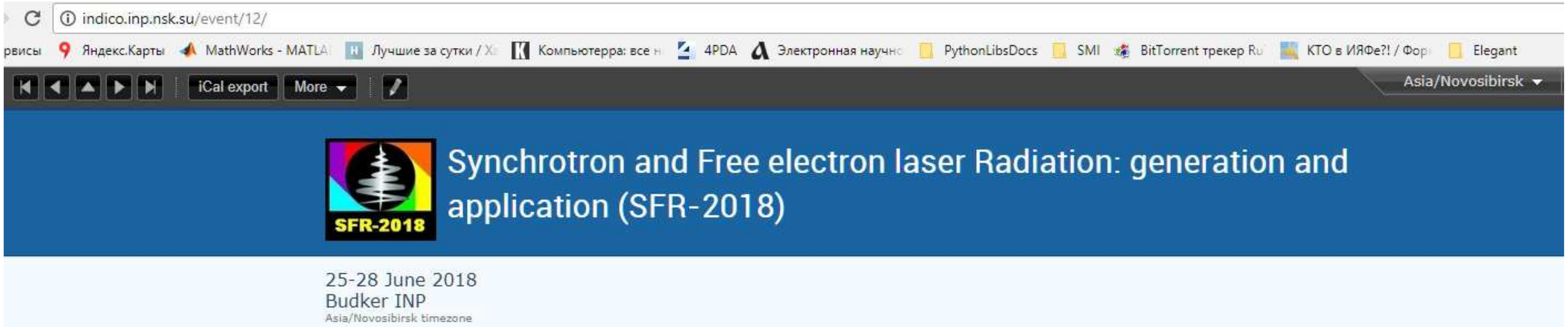

We are pleased to announce that SFR-2018, the International Conference "Synchrotron and Free electron laser Radiation: generation and application" will take place at Budker Institute of Nuclear Physics SB RAS, Novosibirsk, Russia from Monday June 25 to Thursday June 28, 2018. The Conference continues the series of Russian and International conferences on the application of synchrotron radiation held in Novosibirsk since 1975. As before, the primary goal is to deliver the achievements in the field of generation and application of SR and FEL radiation.
The scientific program of the Conference covers the following themes:
Status reviews and scientific programs of various SR and FEL centers;
SR and FEL radiation sources, instrumentations and experimental methods;
SR and FEL application in physics, chemistry, medicine, geology, material science, etc.
The Conference will include invited and contributed oral and poster presentations. The Conference languages are Russian and English.