SYNCHROTRON RADIATION FACILITIES IN BUDKER INP

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Budker INP is a pioneer in the field of use of synchrotron radiation (SR) and creation of special devices for SR generation. There are three storage rings VEPP- 2M, VEPP- 3 and VEPP- 4 which are used for experimental work with SR. Several types of superconducting wigglers for SR generation were designed and fabricated since 1978 up to nowadays.

1 Synchrotron radiation sources

There are three electron-positron storage rings in Institute which are used for experiments with synchrotron radiation (SR). On the basis of these storage rings the Siberian Centre of Synchrotron Radiation was founded where research groups not only SB RAS Institutes but also other regions of Russia and other countries are working.

SR works are carried out using dedicated shifts as well as shifts in parasitic mode if energy level permits to conduct this work when high energy physics experiments are conducted.

1.1 VEPP-2M storage ring

The VEPP-2M electron-positron storage ring with maximum energy of 0.7 GeV is a major facility used in SR research in the VUV and soft X-ray ranges at the Siberian Synchrotron Radiation Center.

The basic parameters of VEPP-2M as a SR source are given in Table bellow.

Energy, (MeV)	700
Circumference, m	17.88
Kind of particle	e^+, e^-
Operation mode	single / multi-bunch
Emittance, $nm \times rad$	460
Stored current, mA	200/300
Life-time, h	1-2
Critical radiation wavelength, $\AA$	
bending magnet	19.9
superconducting 7.5 Tesla wiggler	5.1

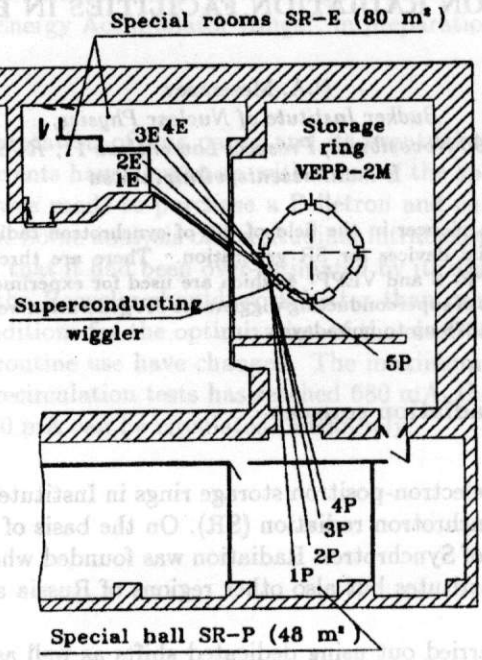

Figure 1: Schematic view of experimental area of VEPP-2M storage ring

Synchrotron radiation from bending magnet and superconducting 7.5 Tesla wiggler is used to conduct experiments with SR. There are two special rooms available for SR works. Two beamlines from superconducting wiggler and two beamline from bending magnet are available along electron direction. In the direction of positron motion four beamlines from bending magnet are available.

1.2 VEPP-3 and VEPP-4 storage rings

VEPP-3 and VEPP-4 storage rings are used as synchrotron radiation sources since 1972 and 1981 respectively. At present, the VEPP-3 storage ring is the main source of SR in X-ray range.

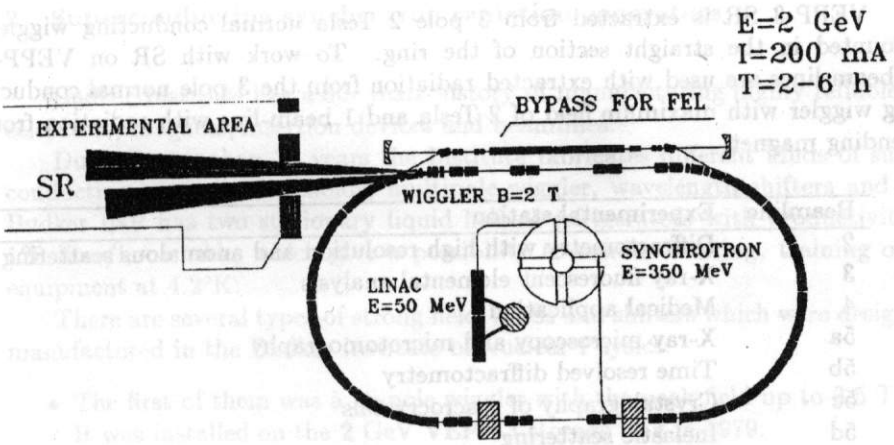

Figure 2: Schematic view of experimental area of VEPP-3 storage ring

The parameters of the storage rings are listed in the table bellow:

	VEPP-3	VEPP-4
Energy, (MeV)	2000	5500
Circumference, m	74.4	384
Operation mode	single / two-bunch	single bunch
Emittance, $nm \times rad$	291	1260
Stored current, mA	250	40
Life-time, h	3-6	3-5
Critical radiation wavelength, $\AA$		
bending magnet	2.6	0.77
1.2 Tesla 6-pole wiggler		0.5
2 Tesla wiggler	2.3	

VEPP-3 SR is extracted from 3 pole 2 Tesla normal conducting wiggler, mounted in the straight section of the ring. To work with SR on VEPP-3 8 beam-lines are used with extracted radiation from the 3 pole normal conducting wiggler with maximum field of 2 Tesla and 1 beam-line with radiation from bending magnet.

Beamline	Experimental station
2	Diffractometry with high resolution and anomalous scattering
3	X-ray fluorescent elemental analysis
4	Medical application
5a	X-ray microscopy and microtomography
5b	Time resolved diffractometry
5c	Crystalography of macrocrystals
5d	Inelastic scattering
5e	Small angle scattering
6	Time resolved luminescence
7	LIGA technology
8	EXAFS-spectrometry
10	X-ray lithography

The experimental stations which are used on VEPP-3 are as follow (see fig.3):

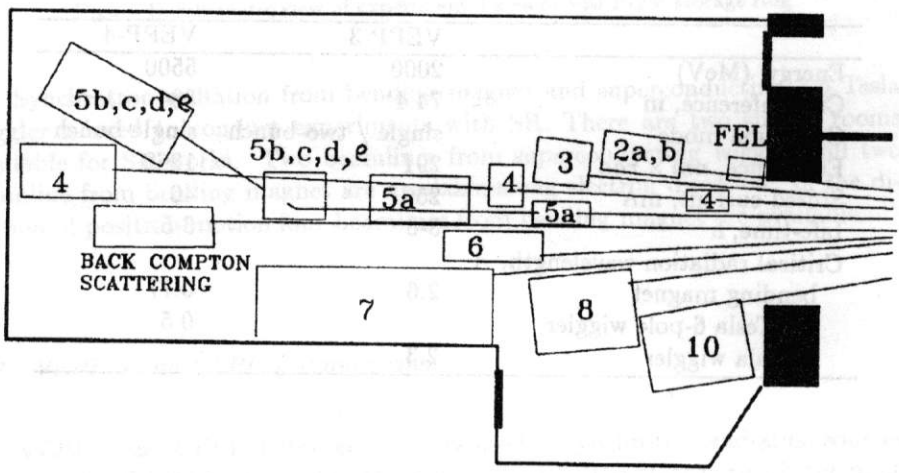

Figure 3: Arangement of the SR experemental stations at the VEPP-3 storage ring

Construction of several beam-lines on the VEPP-4 storage ring are finishing in new experimental hall and the beginning of work at these stations is planning in 1999 .

2 Superconducting synchrotron radiation generators

Budker Institute has a 35- years history of manufacturing highly reliable accelerators, magnets, insertion devices and beamlines.

During more than 20 years the Institute fabricates different kinds of superconducting magnets: solenoids, multipole wiggler, wavelength shifters and etc. Budker INP has two stationary liquid helium refrigerators with productivity of 120 liter/hour each, which give a possibility to conduct testing, training of an equipment at 4.2°K.

There are several types of strong field WLSs and shifters which were designed, manufactured in the Budker Institute of Nuclear Physics:

- The first of them was a 20-pole wiggler with the peak field up to 3.5 T [1, 2]. It was installed on the 2 GeV VEPP-3 storage ring in 1979.
- The highest field (8 T) WLS was inserted in VEPP-2M (E = 0.6 GeV) [3] at 1986 and is operating till nowadays.
- The extremely compact (only 35 cm of the total length) 4.5 T 3-pole WLS was developed for a small (450 MeV) SR source Siberia-1 in Moscow [4].
- The superconducting WLS 7.5 Tesla was fabricated under condition of the contract N 92S-119 with POSTECH (Pohang, Korea) for 2 GeV Pohang Light Source and delivered in 1995. [5, 6] (The maximum field of 7.68 Tesla was achieved.)
- The superconducting 7 Tesla WLS with fixed point of radiation in center of the WLS at any field level was fabricated under condition of the Contract with CAMD LSU (BID N B6FMB1752) and have been installed on the CAMD ring in 1998. (The maximum field of 7.5 Tesla was achieved.) [7]
- 10 Tesla 3-pole WLS is under fabricating now for Slow Positron Source Project on SPring-8 under condition of ISTC grant [8].

Main parameters of the wigglers are listed in the table bellow.

Parameters	VEPP-3	VEPP-2	Siberia-1	PLS	CAMD LSU	BESSY-2	SPring-8
Magnetic field,Tesla	3.5	7.5	4.5	7.5	7	7	10
Pole number	20	5	3	3	3	3	3
Pole gap,mm	16		32	48	52	53	42
Magnet length, mm	900		350		812	972	1042

The first high field superconducting multipole wiggler was put into operation in 1979 on VEPP-3 storage ring. 20-pole wiggler was designed and fabricated with total length about 1 meter, maximum magnetic field of 3.5 Tesla, poles spaced by 16 mm, vertical aperture accessible for the electron beam was about 8 mm. The used scheme for wiggler installation in a storage ring straight section provided the

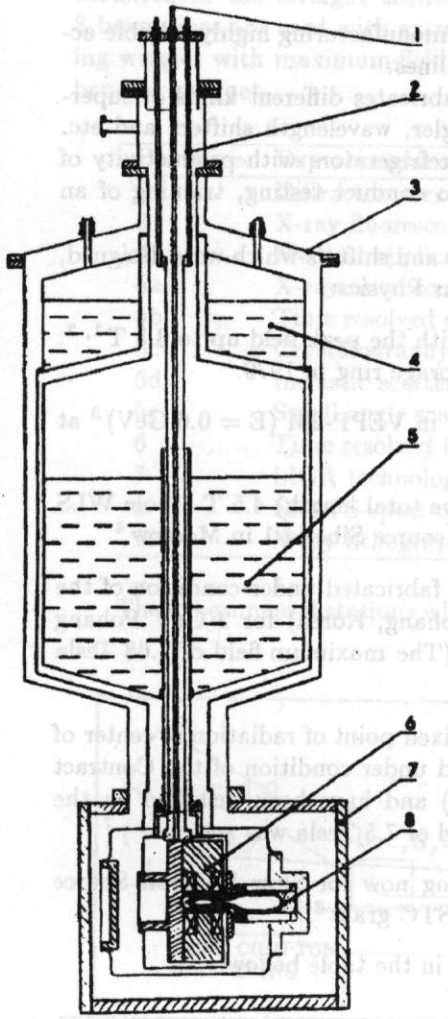

Figure 4: Schematic view of 20-pole 3.5 Tesla superconducting wiggler; 1 – liquid helium supply pipe, 2 – current leads, 3 – dewar, 4 – liquid nitrogen, 5 – liquid helium, 6 – supercon-ducting magnets, 7– vacuum container, 8 – storage ring vacuum chamber.

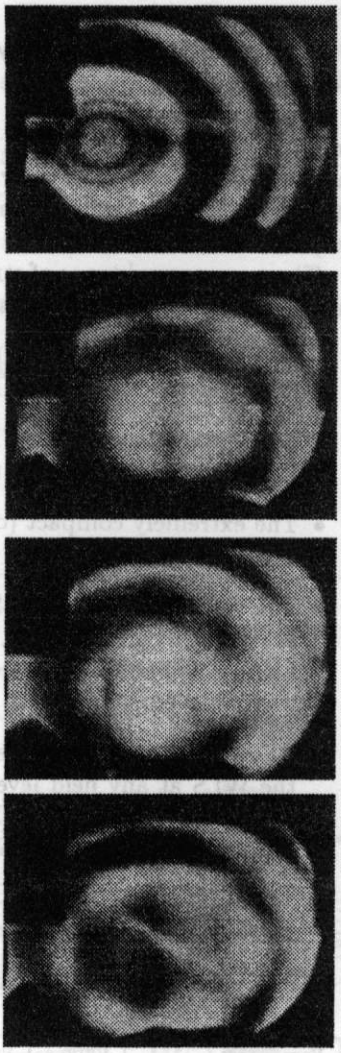

Figure 5: Red light radiated from 20-pole wiggler at electron energy 350 MeV and low level field in wiggler (undulator radiation). Intensity distribution of 1st, 2nd, 3rd and 4th harmonics of radiation from the snake

possibility to stack the electrons apart from the wiggler aperture using the full admittance of the storage ring with the subsequent shifting of the stored beam into the wiggler by means of local displacement of the orbit. Fig.4 shows the schematic view of the multipole wiggler and Fig.5 picture shows as an example of angle distribution of undulator radiation which was observed on this wiggler after passing through red filter. Four angle distributions are correspond to different low levels of magnetic field in wiggler (0-3kGs) and electron energy 350 MeV . Main mode of operation of the wiggler corresponds to field 33 kGs at electron energy of 2 GeV. The installation of this wiggler on VEPP-3 storage ring gave a possibility to increase spectral brightness at photon energy of 10 keV up to 200 times.

The first wiggler fabricated for another SR center was wiggler for PLS (Pohang Light Source) storage ring with energy 2 GeV in Korea in 1996. Maximum magnetic field was achieved 7.67 Tesla in this wiggler. Fig. ?? shows the wiggler with 400 liter liquid helium tank above the wiggler during test in PLS.

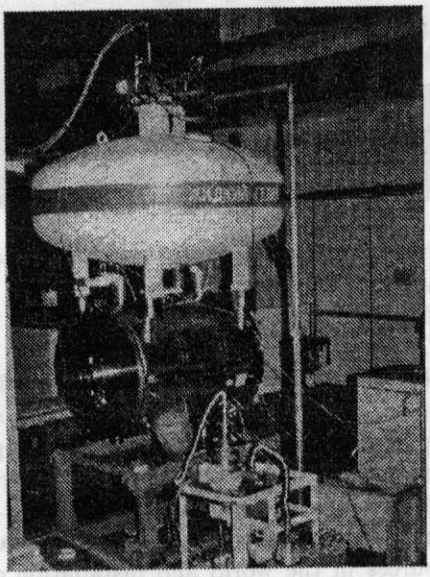

Figure 6: Testing of 7.5 Tesla wigglerin PLS

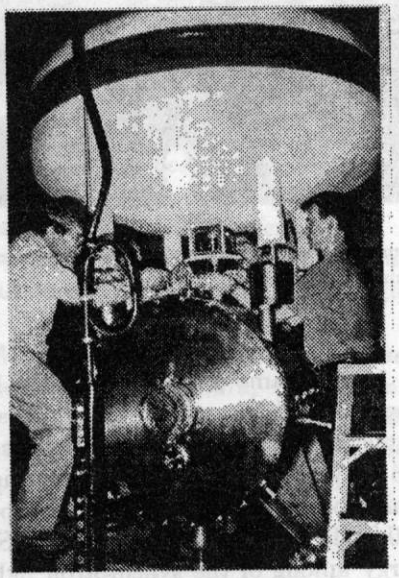

Figure 7: Assembling of 7.5 Tesla 3-pole superconducting wiggler at 2 GeV storage ring Pohang Light Source (PLS) Korea

Fig.?? shows assembling of the 7 Tesla wiggler on the LSU CAMD storage ring (USA). The difference of this wiggler from others consists in that the electron beam orbit inside the wiggler always passes through middle of the central pole. That is the large convenience for users working with wiggler at different field levels when a position of X-ray source is fixed and does not depend on field level. It is achieved by two special corrector magnet , which stand at the sides of the wiggler.

Another very similar wiggler is fabricating for BESSY-2 storage ring.

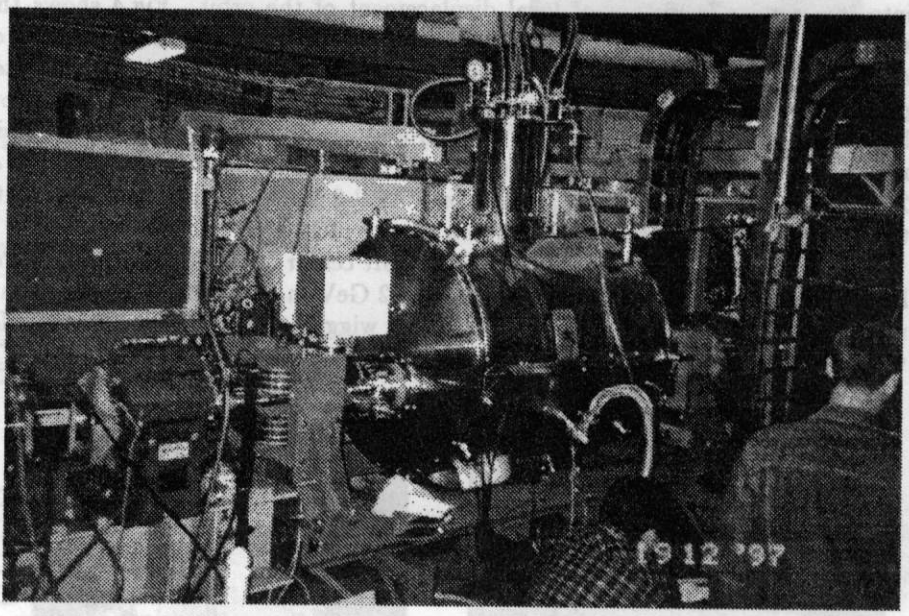

Figure 8: Assembling of 7 Tesla 3-pole superconducting wiggler at 1.5 GeV CAMD storage ring, Louiziana, USA

In the frame of ISTC grant the Budker INP in collaboration with VNIITF (Snejinsk)and Japan SPring-8 group is fabricating 10 Tesla 3-pole superconducting wiggler to install on SPring-8 storage ring (Harima, Japan) with electron energy 0f 8 GeV . The final objective of this project is to create Slow Positron Source of high brightness by installing of superconducting wiggler with magnetic field of 8-10 Tesla in SPring-8 storage ring. SPring- 8 storage ring has the highest beam energy among of the synchrotron light sources in the world and installation on this ring of the unique high field wiggler gives a possibility to create a unique low-energy positron source of high brightness using SR photons with energy more 1 MeV foe electron-positron pair production on special target and consequent positron moderation down to several eV or less. In January 1999 the first test of this wiggler was conducted and magnetic field level of 9.7 Tesla was achieved.

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