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Project of the Dubna Electron Synchrotron

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Abstract

The project "Dubna Electron Synchrotron" aims to construct a synchrotron radiation source of the third generation at the Joint Institute for Nuclear Research, Dubna, Russia. © 2001 Published by Elsevier Science B.V.

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The Dubna Electron Synchrotron (DELSY) synchrotron radiation source will be constructed on the basis of the accelerator facility of the Institute for Nuclear Physics and High Energy Physics (NIKHEF), Amsterdam, Netherlands. This accelerator facility consists of a linear electron accelerator Medium Energy Accelerator (MEA) for the electron energy of 700 MeV and the electron storage ring Amsterdam Pulse Stretcher (AmPS) for the maximum electron energy of 900 MeV at the circulating beam current of 200 mA.

The DELSY storage ring is supposed to be constructed with the use of the AmPS [1] storage

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ring, the focusing system of which will be essentially modified: the ring circumference will be approximately 1.5 times smaller, the electron energy will be increased up to 1.2 GeV and the focusing strength will be enhanced. These measures will allow one to obtain the beam emittance at least ten times smaller which subsequently increases the synchrotron radiation brilliance by several orders of magnitude.

The rigging of the DELSY ring with the insertion devices — a superconducting wiggler with the magnetic field of 10 T and the so-called "vacuum hybrid miniundulator" is the principle feature of the new synchrotron radiation source. Both devices developed by Budker INP, Novosibirsk, will allow one to improve the DELSY characteristics by expanding its radiation spectrum to the region of the hard X-rays and increasing its brilliance up to 3×10^{18} photons/(s mm^2 mrad^2 0.1% b.w.).

The primary formation and acceleration of the electron beam in the DELSY facility is done within the MEA linear accelerator where electrons get the energy of 800 MeV [2] (Table 1). The linac acceleration system consists of 14 acceleration stations, which include RF generators. The electron linac itself contains an injector, buncher, chopper, preliminary energy compressor ("prebuncher"), the second buncher, 23 accelerator sections and an energy spectrum compressor. We plan to install two additional ("spare") accelerator sections to increase the electron energy from 700 to 800 MeV. RF power amplifiers are based on pulsed clystrons. The VA938 D clystrons of Varian company feed accelerator sections A0 and A01, chopper, prebuncher, buncher and acceleration section A. The other sections are fed by TH 2129 clystrons of the Thomson company.

The DELSY storage ring will be assembled with the elements of the AmPS ring (Table 2). It will be equipped with a superconducting wiggler, which will generate hard X-ray radiation. SR of a higher brilliance will be obtained by a vacuum miniundulator, the magnetic field of which is formed by permanent magnets. The detailed description of the ring structure is given in Ref. [3]. The maximum electron energy in the DELSY ring is increased up to 1.2 GeV from 0.9 GeV in AmPS. All these demand to modernize the AmPS dipole magnets. We decreased the magnet gap from 45 mm down to 38 mm., by which, the dipole magnet field is increased from 0.9 to 1.2 T without

Table 1
The parameters of the MEA linac

Length (m)	200
Electron energy (GeV)	0.8
Beam current peak (mA)	60
Average (mA)	50
Average beam power (kW)	34
Norm. emittance (π mm mrad)	25
Pulse duration (μs)	3.5
RF parameters of the acceleration section	
RF frequency (GHz)	2.856
Acceleration rate (MeV/m)	5–7
Pulse duration (μs)	0.1–3.5
Cavity power (MW)	20

Table 2
General parameters of the AmPS and DELSY rings

Electron ring	AmPS	DELSY
Electron energy (GeV)	0.9	1.2
Injection energy (GeV)	0.7	0.8
Circumference (m)	211.76	140.546
Bending radius (m)	3.3	3.3
Long section length (m)	32	7.2
Short section length (m)		5.6
Revolution period (μs)	0.706	0.4685
Horizontal tune	8.3	9.58
Vertical tune	7.214	3.56
Momentum compaction factor	2.7×10^{-2}	4.8×10^{-3}
Natural chromaticity (m)		
Horizontal	−9.39	−21.3
Vertical	−9.51	−17.5
Injection current (mA)	10	10
Stored electron current (mA)	250	300
Horizontal emittance (nm)	160	11.1
RF frequency (MHz)	476	476
Harmonics number	336	223
Synchrotron tune	0.031	0.007
RF voltage (kV)	350	350
Bunch length (mm)	15	8.67
Number of: Dipoles	32	32
Quadrupoles	68	64
Sextupoles	32	48

altering the dipole magnet current. The structure of the ring straight sections is mostly defined by the requirement of maximum brilliance of SR from the wiggler and undulator. One of the two straight sections is planned to be used to house the wiggler. The undulator will be placed in one of the shorter straight sections.

The SR parameters from the DELSY dipole magnets for the electron beam at the current of $I = 0.3$ A, beam emittance of $\varepsilon_x = 10$ nm and $\beta_x/\beta_y = \frac{12.5}{1.2}$ m are given in Table 3.

The vacuum miniundulator of 2.5 m length with 150 periods will allow one to exceed the SR brilliance from the dipole magnets by five orders of magnitude (Table 3). The brilliance achieved with the undulator does correspond to that of the third generation SR source. The superconducting wiggler with the magnetic field of 10 T [4] is designed

Table 3
Parameters of SR from the dipole magnets, undulator and superconducting wiggler

SR from	Dipole magnets	Undulator	Wiggler
Electron energy (GeV)	1.2	1.2	1.2
SR critical energy (keV)	1.16		8.6
Photon energy at first harmonic (keV)		0.58	
SR flux [photons/(s mrad 0.1% b.w.)]	7×10^{12}	8×10^{16}	2×10^{13}
SR brilliance, [Photons/(s mm^2 mrad^2 0.1% b.w.)]	2×10^{14}	3×10^{18}	4×10^{14}
SR power density (W/mrad^2)	2.8	310	181
SR linear power density (W/mrad)	2.4		542
SR power (kW)	16.6	0.17	6.9

Table 4
Parameters of the FEL oscillators and UV/SOFT X-ray SASE FEL at DELSY

FEL	IR	UV	SASE
Electron beam parameters			
Energy (MeV)	10–80	150–200	300–1000
Peak current (A)	30–50	30–50	500–2500
Bunch charge (nC)			1
Normalized *rms* emittance (π mm mrad)	20–30	20–30	2
Micropulse duration (ps)	10	10	0.3–1
Bunch separation (ns)	30–60	30–60	100
Rms energy spread (%)	1	1	0.3–0.1
Number of bunches per train			50
Repetition rate (Hz)	10–50	10–50	100
Undulator			
Length of undulator (m)	2–3	3–4	15–20
Period (cm)	3–4	3–5	2.8–4
Peak magnetic field (T)	0.5–0.8		0.5–1
Radiation			
Wavelength (nm)	10–1	2–0.2	5–100
Bandwidth (%)	0.1–1	0.1–1	0.5–1
Peak power (GW)			0.3–3
Average power (W)	0.1–1	0.1–1	3–10
Peak brilliance [Photons/(s mrad^2 mm^2 0.1% b.w.)]			10^{29}–10^{30}
Average brilliance [Photons/(s mrad^2 mm^2 0.1% b.w.)]			10^{21}–10^{22}

to generate SR with the photon energy in the range of 20–50 keV (Table 3).

By now a number of research programs and declarations of intent have been received from potential DELSY users in the fields of metrology, condensed matter physics, physics and chemistry of surfaces, crystallography, structured biology, medicine, development of new materials and drugs, and nuclear physics.

The linear RF accelerator of DELSY has a potential to reach the energy up to 1 GeV and a average power of tens of kilowatts. It seems very attractive to use this accelerator for driving the complex of free electron lasers. FEL oscillators can cover the wavelength range from the far infrared down to ultraviolet, 50–0.2 μm (see Table 4). Also, it is possible to produce shorter-wavelength radiation with a single-pass SASE scheme, similar to the Tesla Test Facility FEL at DESY [5]. At the energy of about 1 GeV the minimal achievable wavelength will be about 5 nm. Tuning the energy of the accelerator will allow one to cover the wavelength range from 5 to 200 nm. Table 4 gives an estimate of the DELSY SASE FEL parameters. A moderate upgrade of the present facility would allow one to construct the fourth generation synchrotron light source at DELSY. An upgrade will comprise installation of precise undulators, modification of the injection system of the linear accelerator, and installation of the bunch compressors.

Summarizing, the construction of the SR source of the third generation in Dubna will significantly extend the JINR research program. It will enable one to expand experimental studies in condensed matter physics, atomic physics, biology, medicine, chemistry and geology, and to develop new technologies based on SR applications. The project realization is of great interest to the scientific community and industrial companies of the JINR Member States.

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