# PROJECT OF THE DUBNA ELECTRON SYNCHROTRON

I.V.Titkova, V.A.Arkhipov, V.K.Antropov, N.I.Balalykin, P.F.Beloshitsky, O.I.Brovko, A.B.Butenko, S.B.Fedorenko, I.N.Ivanov, V.G.Kadyshevsky, V.V.Kalinichenko, V.V.Kobets, E.A.Krasavin, I.N.Meshkov, V.Minashkin, N.A.Morozov, YU.A.Polyakov, N.A.Russakovich, A.O.Sidorin, A.I.Sidorov, G.I.Sidorov, A.N.Sissakyan, N.G.Shakun, V.A.Shvets, V.I.Smirnov, A.P.Sumbaev, E.M.Syresin, S.I.Tyutyunnikov, A.S.Vodopyanov, M.V.Yurkov,
JINR, Dubna, Russia
H.Boer-Rookhuizen, E.Heine, W.P.J.Heubers, A.P.Kaan, F.B.Kroes, L.H.Kuijer, J.B. V.D.Laan, J.Langelaar, P.W.F.Louwrier, G.Luijckx, R.Maas, G.van Middelkoop, J.G.Noomen, J.B.Spelt,
NIKHEF, Amsterdam, The Netherlands
G.N.Kulipanov, E.B.Levichev, N.A.Mezentsev, E.M.Shatunov, A.N.Skrinsky, V.A.Ushakov, P.D.Vobly, Budker INP, Novosibirsk, Russia

*Abstract*

The project "Dubna Electron Synchrotron" (DELSY) is aimed to construct a synchrotron radiation source of the 3d generation at the Joint Institute for Nuclear Research. The DELSY synchrotron radiation source will be constructed on the base of the accelerator facility of the Institute for Nuclear Physics and High Energy Physics (NIKHEF), Amsterdam, the Netherlands. This accelerator facility consists of a linear electron accelerator MEA (Medium Energy Accelerator) for the electron energy of 700 MeV and the electron storage ring AmPS (Amsterdam Pulse Stretcher) 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 "Amsterdam Pulse Stretcher" (AmPS) [1] storage 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 obtaining 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 — the 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 to enrich the DELSY characteristics as the synchrotron radiation source expanding its radiation spectrum in the region of the hard X-rays and increasing its brilliance up to $3 \cdot 10^{18}$ photons/s/mm$^2$ /mrad$^2$ /0.1% b.w.
Now this facility is being dismounted and transferred to JINR.

## 1 STRUCTURE AND MAIN PARAMETERS OF THE DELSY FACILITY

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 fourteen acceleration stations, which include RF generators. The electron linac itself contains an injector, buncher, chopper, preliminary energy compressor ("prebuncher"), the second buncher, twenty-three accelerator sections and an energy spectrum compressor. We plan to install two additional ("spare") accelerator sections to increase the electron energy from 700 up 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.

Table 1. The parameters of the MEA linac.

| | |
|---|---|
| Length, m | 200 |
| Electron energy, GeV | 0.8 |
| Beam current peak, mA<br>Average, mA | 60<br>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 |

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 the 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 [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 suppose to decrease the magnet gap from 45 mm down to 38 mm. This measure allows one to increase the dipole magnet field from 0.9 T up to 1.2 T keeping the dipole magnet current at the same level as in the AmPS ring. 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.

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<br>Short section length, m | 32 | 7.2<br>5.6 |
| Revolution period, μs | 0.706 | 0.4685 |
| Horizontal tune<br>Vertical tune | 8.3<br>7.214 | 9.58<br>3.56 |
| Momentum compaction factor | $2.7 \cdot 10^{-2}$ | $4.8 \cdot 10^{-3}$ |
| Natural chromaticity, m<br>Horizontal<br>Vertical | <br>-9.39<br>-9.51 | <br>-21.3<br>-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<br>Quadrupoles<br>Sextupoles | 32<br>68<br>32 | 32<br>64<br>48 |

## 2 SYNCHROTRON RADIATION

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 $\beta_x/\beta_y$ = 12.5/1.2 m are given in Table 3.

The vacuum miniundulator of 2.5 m long with 150 periods will allow one to exceed the SR brilliance from the dipole magnets by 5 orders of magnitude (Table 3). The brilliance level to be 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 to generate SR with the photon energy in the range of 20÷50 keV (Table 3).

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

| SR from | Dipole magnets | Undu lator | Wiggler |
|---|---|---|---|
| Electron energy, GeV | 1.2 | 1.2 | 1.2 |
| SR critical energy, keV | 1.16 | | 8.6 |
| Photon energy at 1st harmonic, keV | | 0.58 | |
| SR flux, photon/(s·mrad·0.1% b.w.) | $7 \cdot 10^{12}$ | $8 \cdot 10^{16}$ | $2 \cdot 10^{13}$ |
| SR brilliance, Photon/(s·mm$^2$·mrad$^2$·0.1 % b.w.) | $2 \cdot 10^{14}$ | $3 \cdot 10^{18}$ | $4 \cdot 10^{14}$ |
| 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 |

## 3 PERSPECTIVE OF DELSY FOR THE FOURTH GENERATION SR FACILITY

Linear RF accelerator of DELSY has potential to reach the energy up to 1 GeV and average power of tens of kilowatts. It seems to be 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 micrometers (see Table 4 and ref. [6]). Also, it is possible to produce shorter-wavelength radiation with single-pass SASE scheme, similar to the Tesla Test Facility FEL at DESY [5]. At the energy of about 1 GeV minimal achievable wavelength will be about 5 nm. Tuning the energy of the accelerator will allow one to cover the wavelength range from 5 up to 200 nm. Table 4 gives an estimate of the DELSY SASE FEL parameters. A moderate upgrade of present facility would allow one to construct the fourth generation synchrotron light source at DELSY. An upgrade is mainly connected with installation of precise undulators, modification of the injection system of the linear accelerator, and installation of the bunch compressors.

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, $\pi\cdot$mm$\cdot$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, Photon/(sec mrad$^2\cdot$mm$^2$0.1% b.w.) | | | $10^{29}$ – $10^{30}$ |
| Average brilliance, Photon./(sec mrad$^2\cdot$mm$^2$0.1% b.w.) | | | $10^{21}$ – $10^{22}$ |

## 4 CONCLUSIONS

The construction of the SR source of the 3d generation in Dubna will enrich significantly the JINR research program. It will enable 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.

## REFERENCES


[1] Luickx G., Bijeveld J.H. M., Boer Rookhuizen et al., PAC, Chicago, 1989

[2] Kroes F.B., LINAC96 Conference, Geneva, 22-29 August 1996.

[3] I.Titkova, P. Beloshitsky, I. Meshkov, E. Syresin, Magnet Lattice of the Synchrotron Radiation Source DELSY. This Proceedings

[4] Grudiev A.V., Durba V.N. , Kulipanov G.N. et al., NIM, A 359 (1995), 101

[5] A VUV Free Electron Laser at the TESLA Test Facility: Conceptual Design Report, DESY Print TESLA-FEL 95-03, Hamburg, DESY, 1995.

[6] I.N. Meshkov, E.L. Saldin, E.A. Schneidmiller, E.M.Syresin, M.V. Yurkov, “Perspective of DELSY for the Fourth Generation SR Facility”, This Proceedings