STATUS AND PROSPECTS OF THE NOVOSIBIRSK FEL FACILITY

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Abstract

Multiturn energy recovery linacs (ERL) looks very promising for making ERLs less expensive and more flexible, but have serious intrinsic problems. At this time only one multiturn ERL exists. This Novosibirsk ERL operates with two orbits and two free electron lasers now. The Novosibirsk terahertz radiation user facility provides 0.5 kW average power at 50 - 240 micron wavelength range. Different users work at six stations. Two another orbits and third free electron laser are under construction. The operation experience revealed specific problems of ERLs(especially, of multiturn ones). Some solutions were proposed recently.

THE FIRST ORBIT FEL

A source of terahertz radiation was commissioned in Novosibirsk in 2003 [1]. It is CW FEL based on an accelerator–recuperator, or an energy recovery linac (ERL). It differs from other ERL-based FELs [2, 3] in the low frequency non-superconducting RF cavities and longer wavelength operation range. The one-turn ERL (which is the first stage of the full-scale four-turn ERL) parameters are listed in Table 1, and its scheme is shown in Fig. 1.

Table 1: Parameters of the first stage of Novosibirsk ERL.

Beam energy, MeV	11
Maximum average electron current, mA	30
RF frequency, MHz	180.4
Maximum bunch repetition rate, MHz	22.5
Bunch length, ps	100
Normalized emittance, mm·mrad	30
Charge per bunch, nC	1.5
RF cavities Q factor	$4 \cdot 10^4$

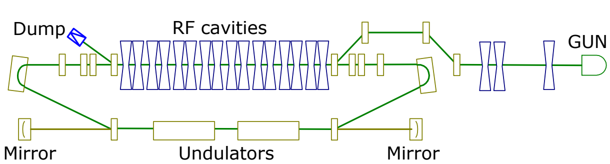

Figure 1: Scheme of the Novosibirsk terahertz free electron laser.

This first stage of the Novosibirsk free electron laser generates coherent radiation tunable in the range 120-240 micron as a continuous train of 40-100 ps pulses at the repetition rate of 2.8 - 22.5 MHz. Maximum average output power is 500 W, the peak power is more than 1 MW [4,5]. The minimum measured linewidth is 0.3%, which is close to the Fourier-transform limit. The third harmonics lasing was obtained recently. It was achieved by suppression of the first harmonics lasing using aperture-decreasing scrapers.

Five user stations are in operation now. Two other are in progress.

THE SECOND STAGE OF ERL AND FEL

Full-scale Novosibirsk free electron laser facility is to be based on the four-orbit 40 MeV electron accelerator-recuperator (see Fig. 2). It is to generate radiation in the range from 5 micrometer to 0.24 mm [6, 7].

Manufacturing, assembly, and commissioning of the full-scale four-turn ERL are underway. The orbit of the first stage with the terahertz FEL lies in the vertical plane. The new four turns are in the horizontal one. One FEL will be installed at the fourth orbit (40 MeV energy), and the second one is already installed and works at the bypass of the second orbit (20 MeV energy).

The bypass provides about 0.7 m lengthening of the second orbit. Therefore, when the bypass magnets are switched on, the deceleration of beam take place at the third passing through the accelerating system, and after that electrons come to the first orbit and, after the second deceleration, to the beam dump.

All 180-degree bends are achromatic. To reduce sensitivity to the power supply ripples, all magnets are connected in series. To simplify the mechanical design, all non-round (small) magnets are similar and parallel-edge. Water-cooled vacuum chambers are made from aluminium.

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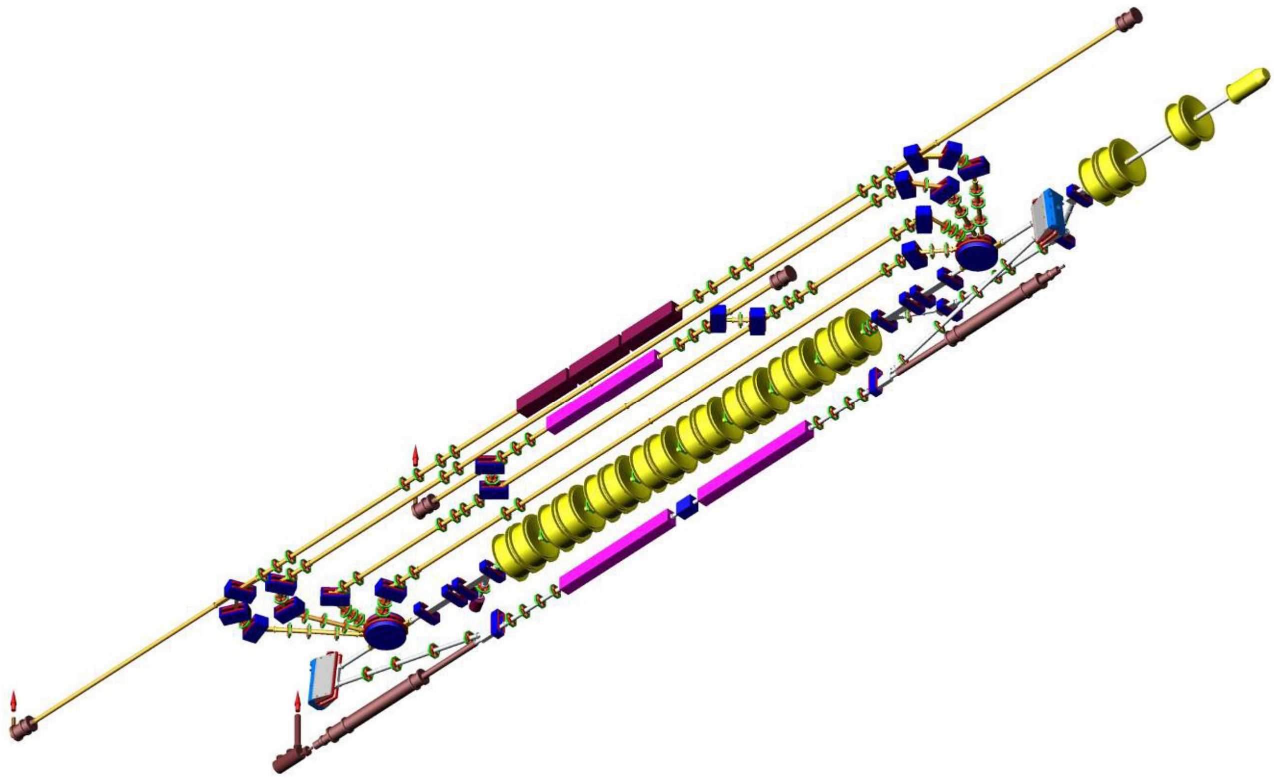

Figure 2: The full-scale Novosibirsk ERL with 3 FELs (bottom view).

The bypass magnetic system contains four bending magnets, quadrupoles, and undulator. The second orbit undulator is very similar to the old undulators of the first-orbit FEL, but its gap is lower. It is fixed-gap electromagnetic undulator. The main parameters of the undulator are listed in Table 2.

Table 2: Parameters of the second orbit undulator.

Period, mm	120
Gap, mm	70
Maximum field amplitude, T	0.12
Total length, m	3.9
Maximum bus current, kA	2.2
Maximum power consumption, kW	30

The undulator poles have the concave shape to equalize focusing in both transverse coordinates. It is necessary, as at 20 MeV this focusing is strong (matched beta function at the 0.12 T field amplitude is 1.1 m only).

The optical resonator length is 20 m (12 RF wavelengths). Therefore the bunch repetition rate for initial operation is 7.5 MHz (24^{th} subharmonics of the RF frequency). Mirrors are made of copper, water-cooled, and covered by gold. Outcoupling holes (3 and 4 mm diameter) serve also for alignment by visible reference laser.

The location of two FELs in accelerator hall is shown in Fig.3. The first lasing of the FEL at bypass was achieved in 2009. The radiation wavelength range is 40 - 80 micron. The maximum gain was about 40%. The significant (percents) increase of beam losses took place during lasing. Therefore sextupole corrections were installed to some of quadrupoles to make the 180-degree bends second-order achromatic. It increased the energy acceptance for used electron beam.

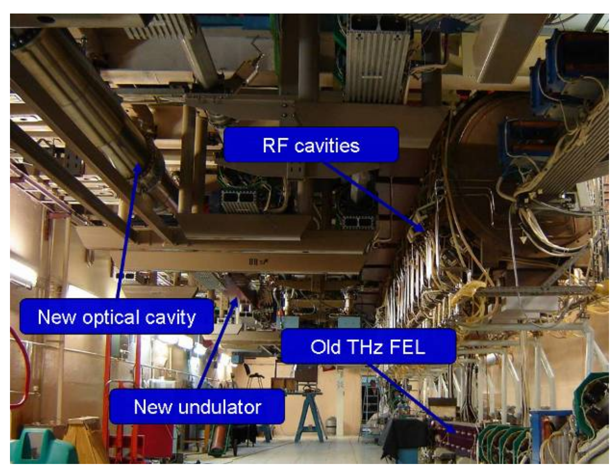

Figure 3: The location of two FELs in accelerator hall.

The beamline (Fig. 4), which delivered radiation from new FEL to existing user stations, is assembled and commissioned. The output power is about 0.5 kW at the 9 mA ERL average current. Thus, the first in the world multiturn ERL operates for the far infrared FEL.

Figure 4: The optical beamline which transport the radiation of the second FEL to the user stations.

THE PROSPECTS

The assembly of third and fourth orbits is in progress. The four-orbit ERL commissioning will start the next year.

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