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# STATUS OF NOVOSIBIRSK ERL

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*Abstract*

The Novosibirsk ERL is dedicated electron beam source for three free electron lasers operating in the wavelength range 8 – 240 micron at average power up to 0.5 kW and peak power about 1 MW. Radiation users works at 8 user stations performing biological, chemical, physical and medical research. The Novosibirsk ERL is the first and the only four-turn ERL in the world. Its peculiar features include the normal-conductive 180 MHz accelerating system, the DC electron gun with the grid thermionic cathode, three operation modes of the magnetic system, and a rather compact (6×40 m2) design. The facility has been operating for users of terahertz radiation since 2004. The status of the installation and plans are described.

## INTRODUCTION

The Novosibirsk free electron laser (FEL) facility [1] has three FELs, installed on the first, second and fourth orbits of the dedicated energy recovery linac (ERL). The first FEL covers the wavelength range of 90 – 240 μm at an average radiation power of up to 0.5 kW with a pulse repetition rate of 5.6 or 11.2 MHz and a peak power of up to 1 MW. The second FEL operates in the range of 40 - 80 μm at an average radiation power of up to 0.5 kW with a pulse repetition rate of 7.5 MHz and a peak power of about 1 MW. These two FELs are the world's most powerful (in terms of average power) sources of coherent narrow-band (less than 1%) radiation in their wavelength ranges. The third FEL was commissioned in 2015 to cover the wavelength range of 5 – 20 μm. The Novosibirsk ERL is the first and the only multiturn ERL in the world. Its peculiar features include the normal-conductive 180 MHz accelerating system, the DC electron gun with the grid thermionic cathode, three operation modes of the magnetic system, and a rather compact (6×40 m$^2$) design. The facility has been operating for users of terahertz radiation since 2004 [2].

## ERL

All the FELs use the electron beam of the same electron accelerator, a multi-turn ERL. A simplified scheme of the four-turn ERL is shown in Fig. 1. Starting from low-energy injector 1, electrons pass four times through accelerating radio frequency (RF) structure 2. After that, they lose part of their energy in FEL undulator 4. The used electron beam is decelerated in the same RF structure, and the low-energy electrons are absorbed in beam dump 5.

The electron source is a 300-kV electrostatic gun with a grid cathode. It provides 1-ns bunches with a charge of up to 1.5 nC, a normalized emittance of about 20 μm, and a repetition rate of zero to 22.5 MHz. After the 180.4-MHz bunching cavity the bunches are compressed in the drift space (about 3 m length), accelerated in the two 180.4-MHz accelerating cavities up to 2 MeV, and injected by the injection beamline and the chicane into the main accelerating structure of the ERL (see Fig. 2).

The accelerating structure consists of 16 normal-conducting RF cavities, connected to two waveguides. The operation frequency is 180.4 MHz. Such a low frequency allows operation with long bunches and high currents.

The Novosibirsk ERL has three modes, one mode for operation of each of the three FELs. The first FEL is installed under the accelerating (RF) structure (see Figs. 2 and 3). Therefore, after the first passage through the RF structure, the electron beam with an energy of 11 MeV is turned by

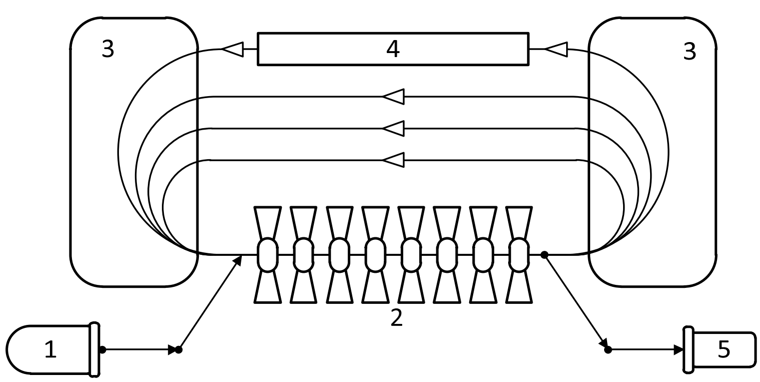


Figure 1: The simplified scheme of Novosibirsk ERL. 1 – injector, 2 – main accelerating structure, 3 – bending magnets, 4 – FEL, 5 – beam dump.

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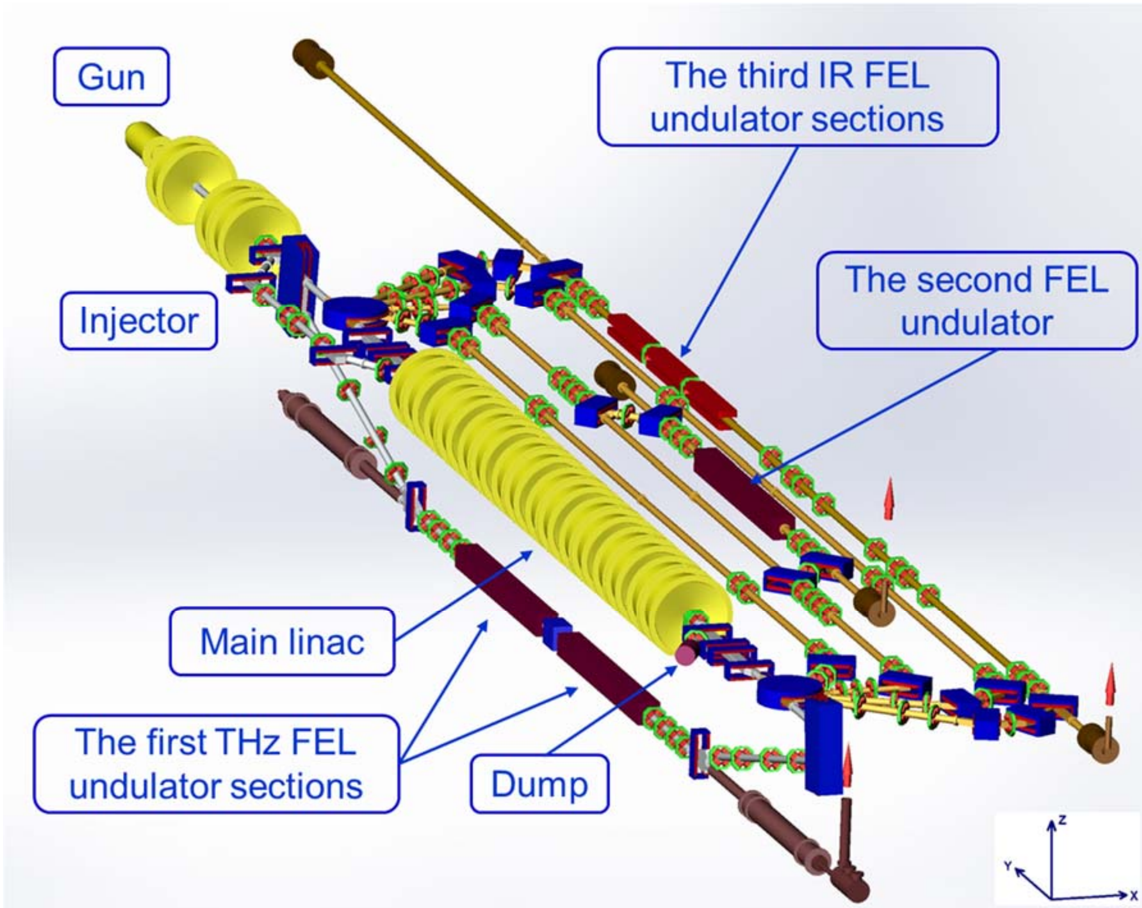


Figure 2: The Novosibirsk ERL with three FELs (top view).

180 degrees in the vertical plane. After the use in the FEL, the beam returns to the RF structure in the decelerating phase. In this mode, the ERL operates as a single-orbit installation.

For operation with the second and third FELs, two round magnets (a spreader and a recombiner) are switched on. They bend the beam in the horizontal plane, as shown in Fig. 2. After four passes through the RF accelerating structure, the electron beam gets in the undulator of the third FEL. The energy of electrons in the third FEL is about 42 MeV. The used beam is decelerated four times and goes to the beam dump.

If the four magnets on the second track (see Fig. 2) are switched on, the beam with an energy of 20 MeV passes through the second FEL. After that, it enters the accelerating structure in the decelerating phase due to the choice of the length of the path through the second FEL. Therefore, after two decelerations the used beam is absorbed in the beam dump.

A photo of the accelerator hall with the accelerating RF cavities and the FELs is shown in Fig. 3.

It is worth noting that all the 180-degree bends are achromatic (even second-order achromatic on the first and second horizontal tracks,) but non-isochronous. It enables beam longitudinal "gymnastics" to increase the peak current in the FELs and to optimize deceleration of the used beam.

The current of the Novosibirsk ERL is now limited by the electron gun. A new RF gun was built and tested recently. It operates at a frequency of 90 MHz. An average beam current of more than 100 mA was achieved [3]. The injection beamline for the RF gun is manufactured and installed to the beam test facility.

## CONCLUSION

Novosibirsk ERL is in operation for more than 15 years. It provides the beam for three FELs of the Novosibirsk FEL user facility in the collective research center "Siberian Synchrotron and Terahertz Radiation Centre". Several upgrades are planned to improve radiation parameters.

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Figure 3: Acclelerator hall with the accelerating RF cavities (upper left side) and the FELs (lower left and upper right sides).

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