STATUS AND PROSPECTS OF THE NOVOSIBIRSK FEL FACILITY

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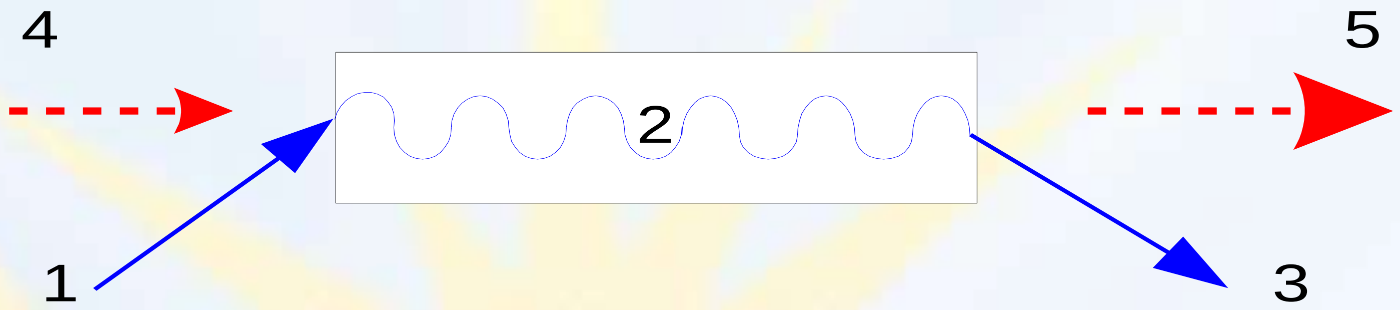
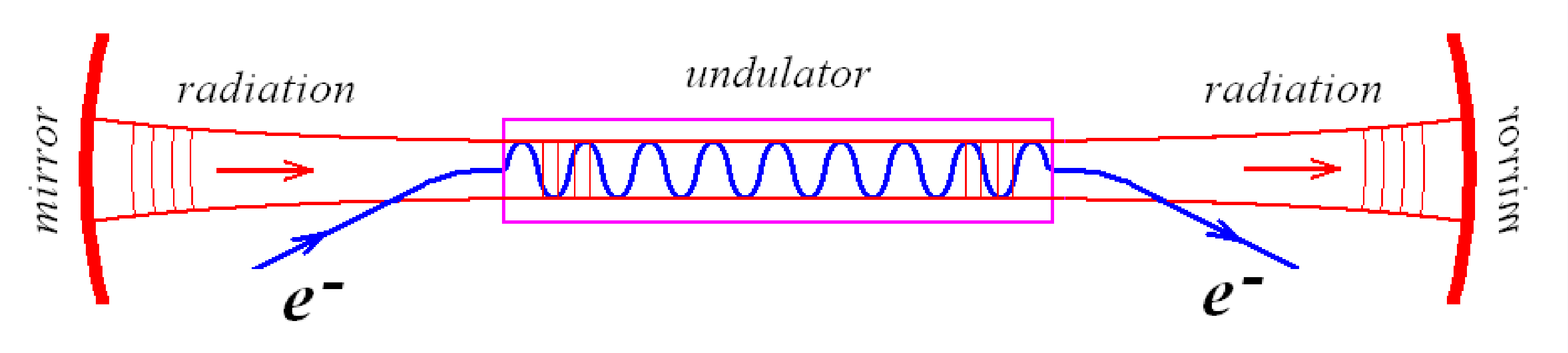
Budker INP, Novosibirsk, Russia

Free Electron Laser (FEL)

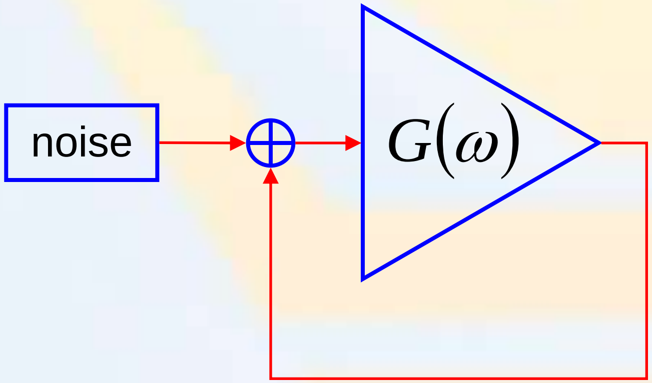


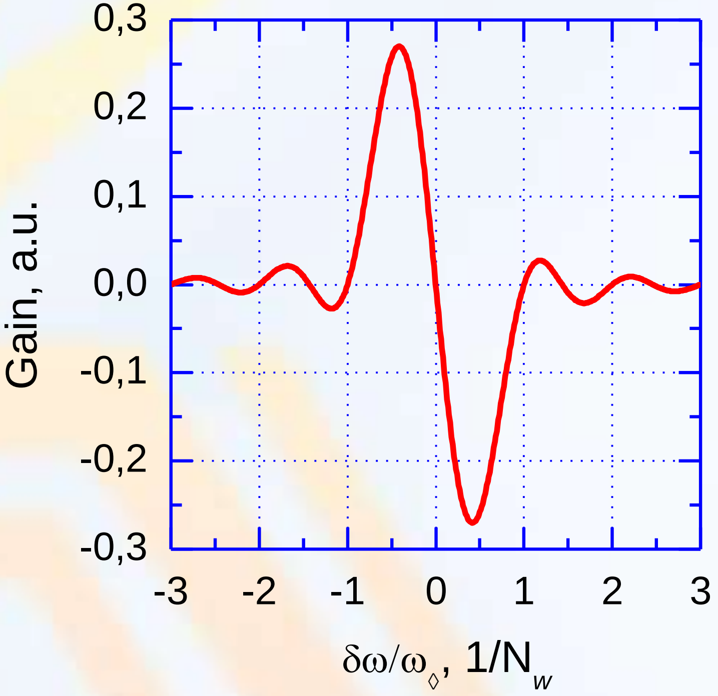
1 – incoming (“fresh”) electron beam, 2 – undulator,
3- used electron beam, 4 – input electromagnetic radiation,
5 – amplified radiation.

The scheme of the FEL oscillator



Equivalent scheme of FEL oscillator





Narrow bandwidth amplifier with feedback

FEL advantages compared to other types of lasers:

- capability to provide radiation at any given wavelength (from 1 Å to 1 mm);
- capability of tuning of the radiation wavelengths;
- high average power of radiation (up to 10^4 – 10^6 W).

FEL disadvantages: size and cost.

Electron efficiency of FEL is rather low (~1%), therefore energy recovery is necessary for a high power FEL.

Energy recovery

- **decreases radiation hazard and**
- **makes possible operation at high average current.**

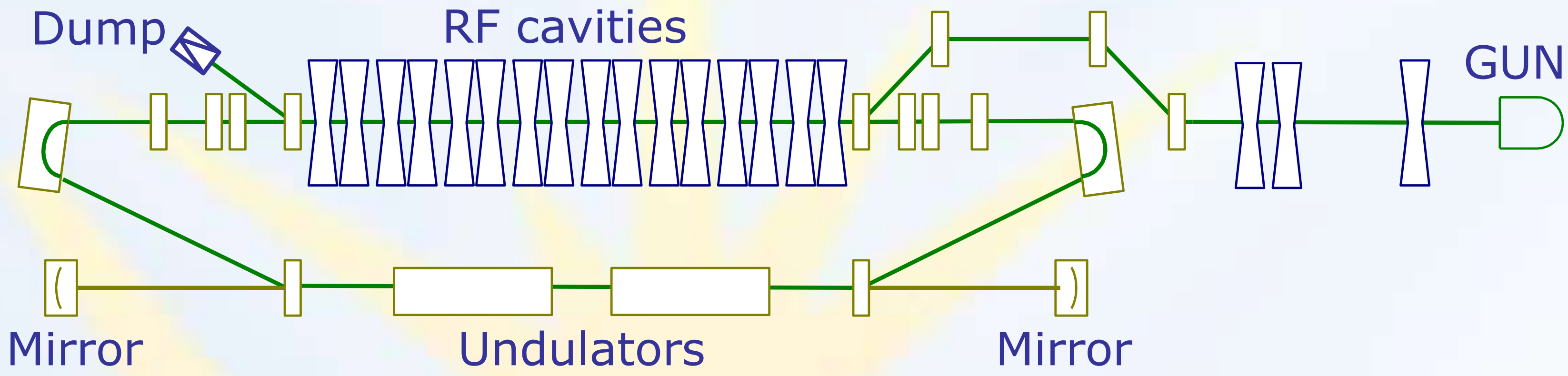
Energy Recovery Linacs for FELs

3 ERLs are in operation now. All they works for FELs.

Jefferson Lab. (USA) and JAERI (Japan) ERLs use superconducting RF.

Novosibirsk ERL uses normal-conducting RF. It is the only one with two orbits (two accelerations and two decelerations).

First stage: submillimeter (THz) FEL



Electron beam from the gun passes through the bunching RF cavity, drift section, two accelerating cavities, the main accelerating structure and the undulator, where a fraction of its energy is converted to radiation.

After that, the beam returns to the main accelerating structure in a decelerating RF phase, decreases its energy to its injection value (2 MeV) and is absorbed in the beam dump.

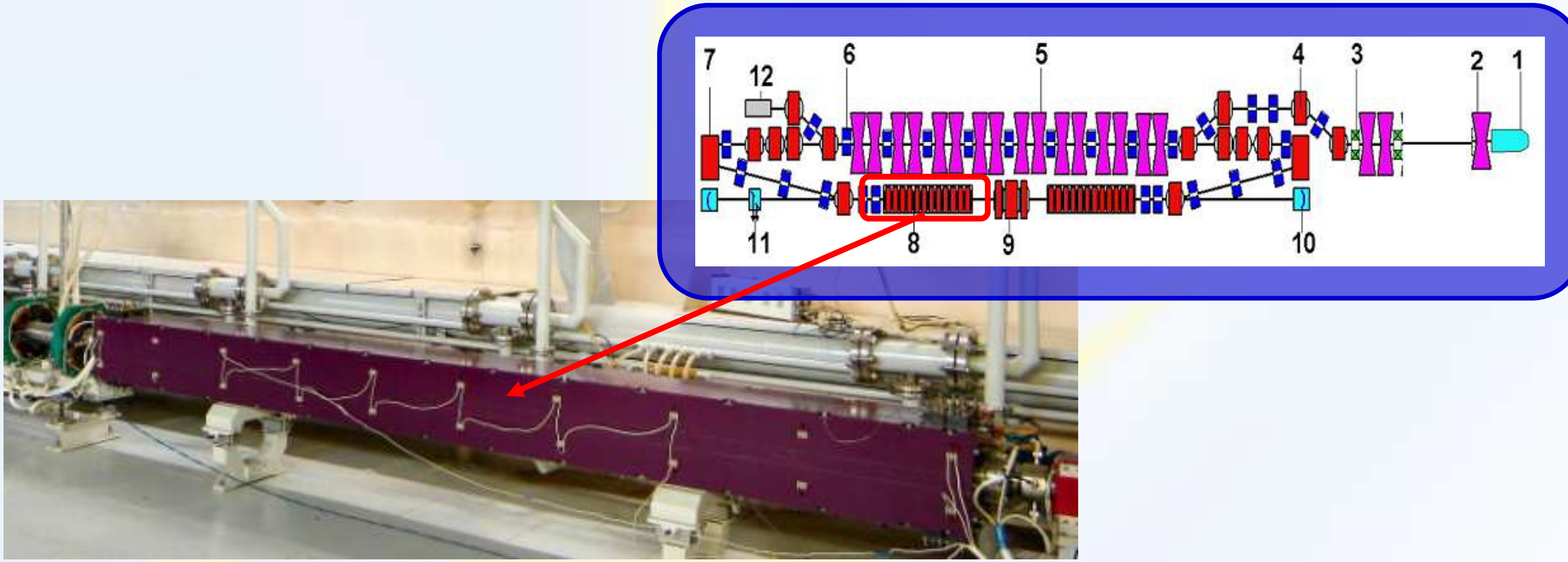
Siberian center of photochemical research

THz FEL (old)

First Stage Accelerator-Recuperator Parameters

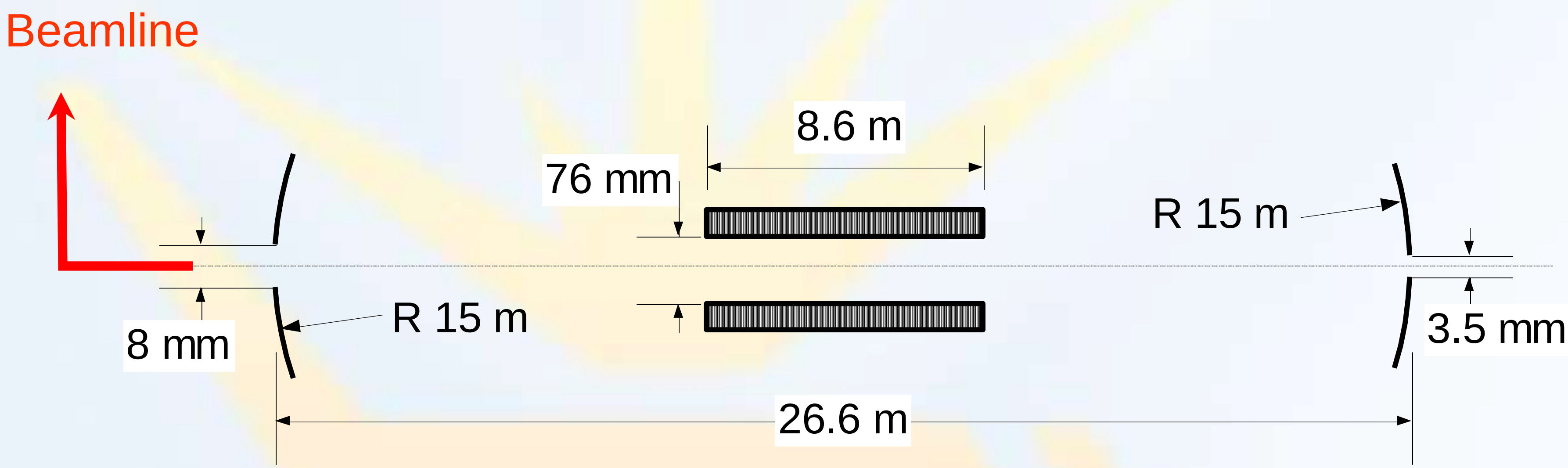
♦ Bunch repetition rate, MHz	22.5
♦ Average electron current, mA	30
♦ Maximum energy, MeV	12
♦ Bunch length, ps	100
♦ Normalized emittance, mm*mrad	30

Undulator



Period, cm	12
Maximum current, kA	2.4
Maximum K	1.25

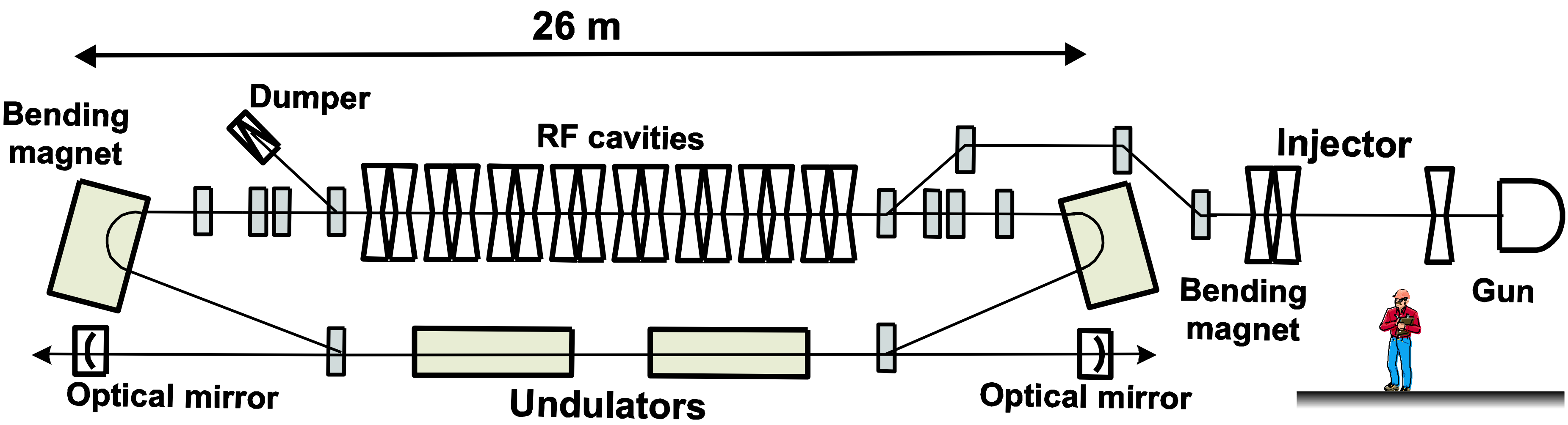
Layout of the optical resonator

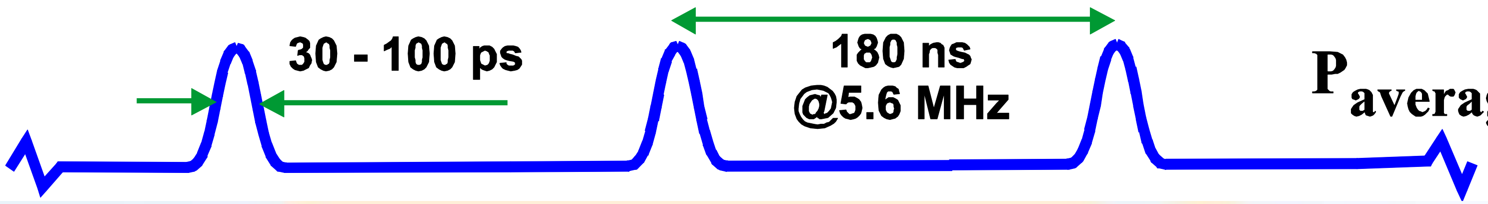


Free Electron Laser (old) Parameters

♦ Wavelength, mm	0.12-0.24
♦ Pulse duration, FWHM, ps	~50
♦ Pulse energy, mJ	0.04
♦ Repetition rate, MHz	11.2
♦ Average power, kW	0.5
♦ Peak power, MW	1
♦ Minimum relative linewidth, FWHM	$3 \cdot 10^{-3}$

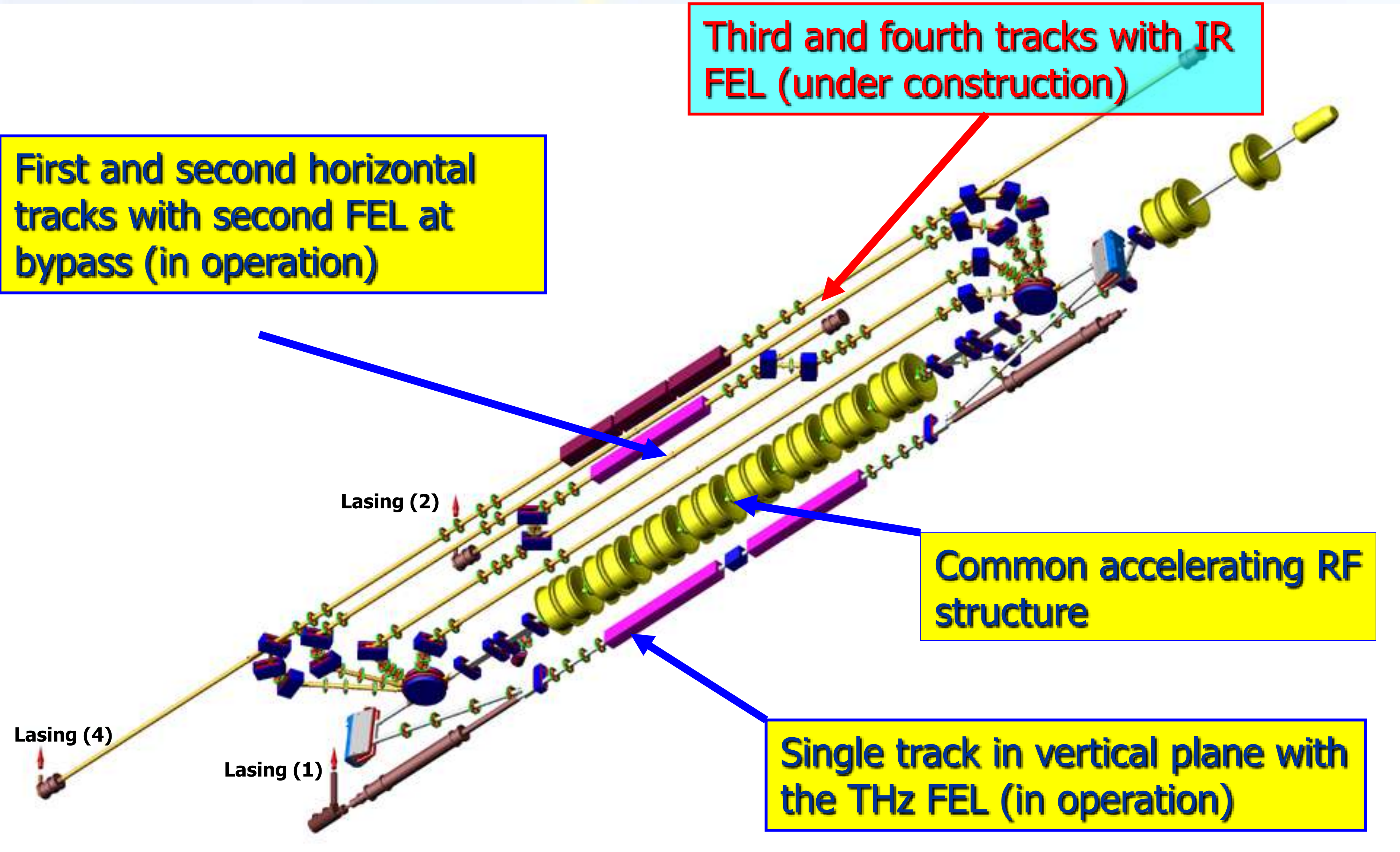
Novosibirsk FEL (1st stage) and radiation power time-dependence



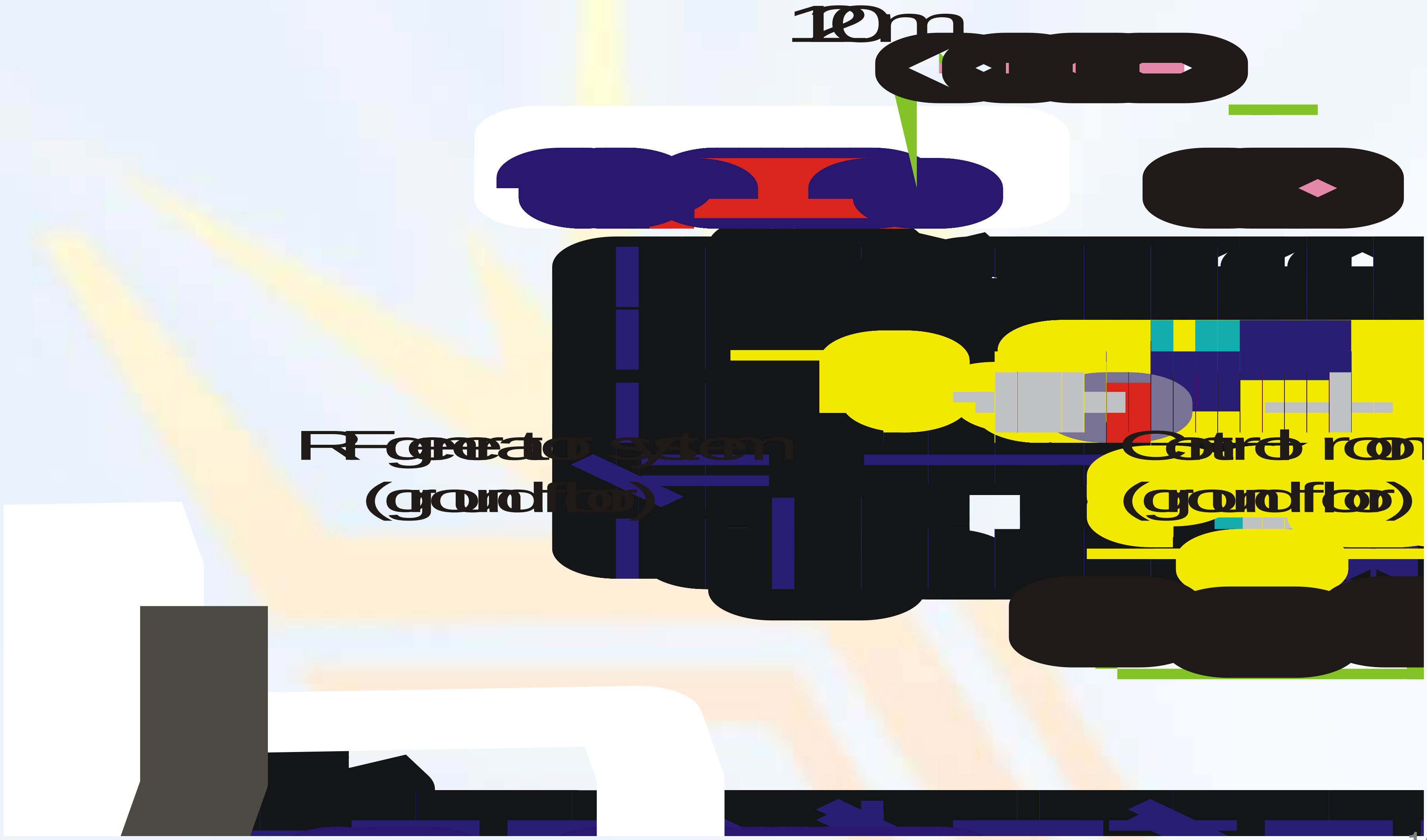


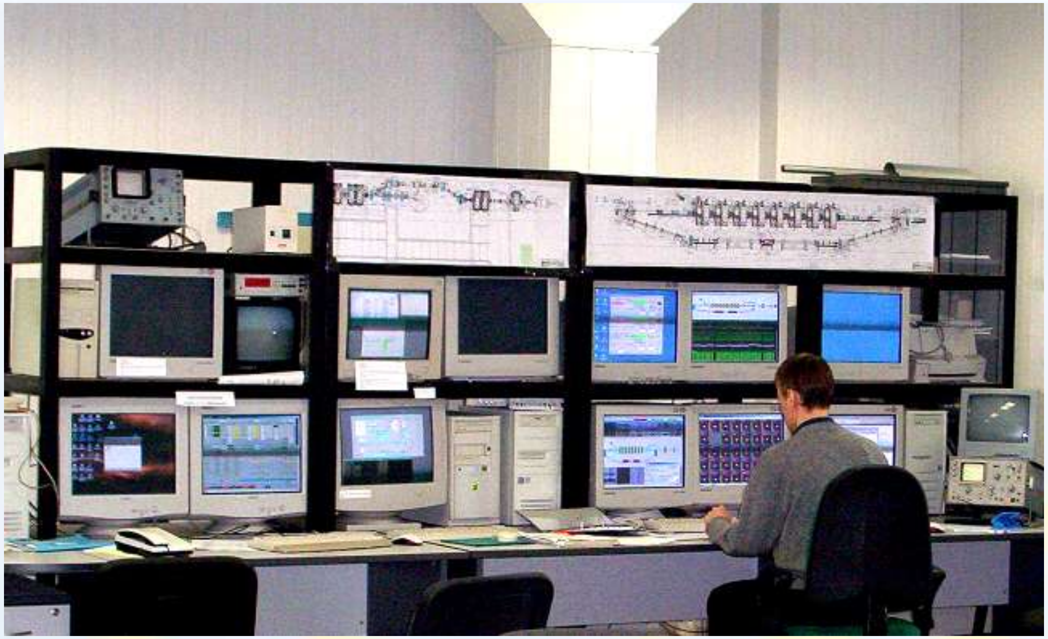
$P_{average} \leq 0.4$ kW

Novosibirsk ERL with 3 FELs



Layout of terahertz FEL and user stations





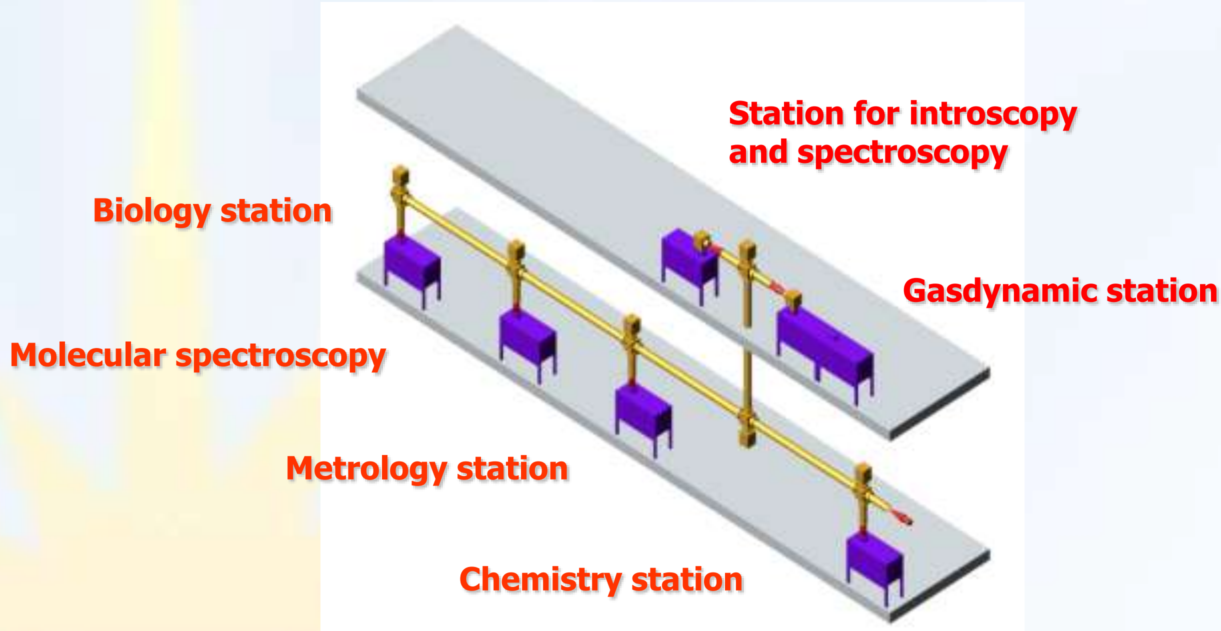


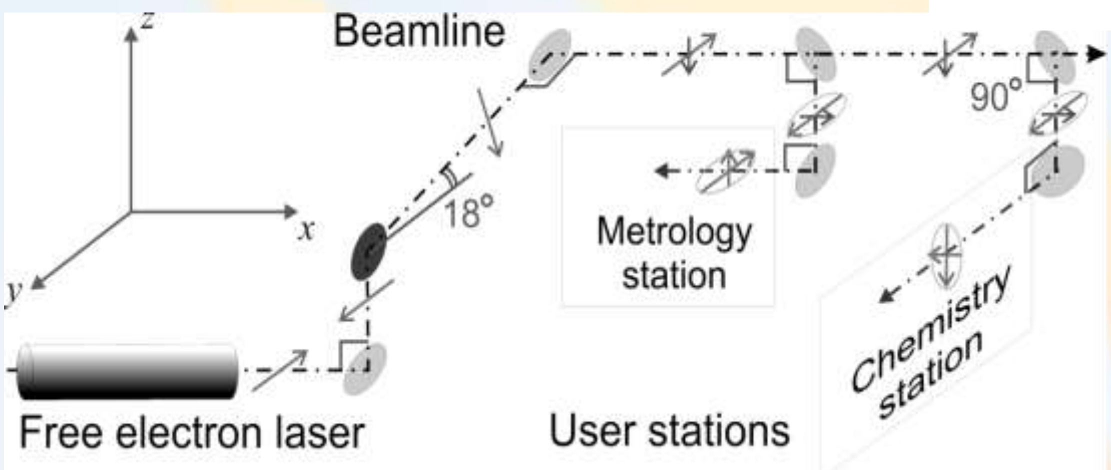

2005

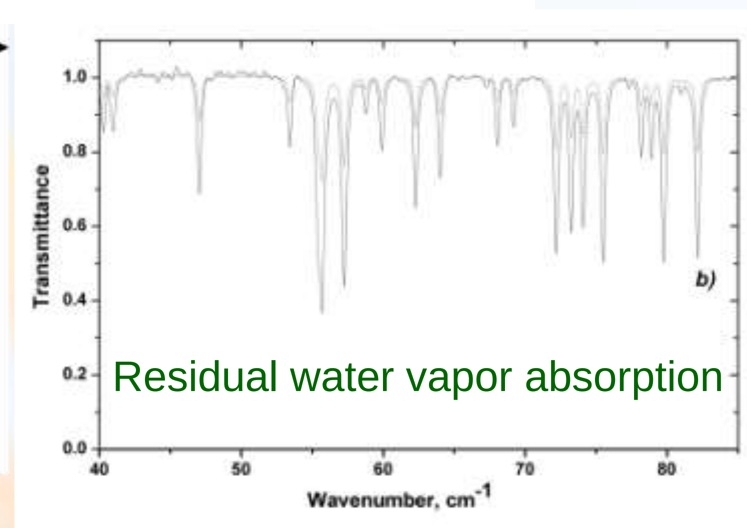
2006

Beamlines and user stations at NovoFEL

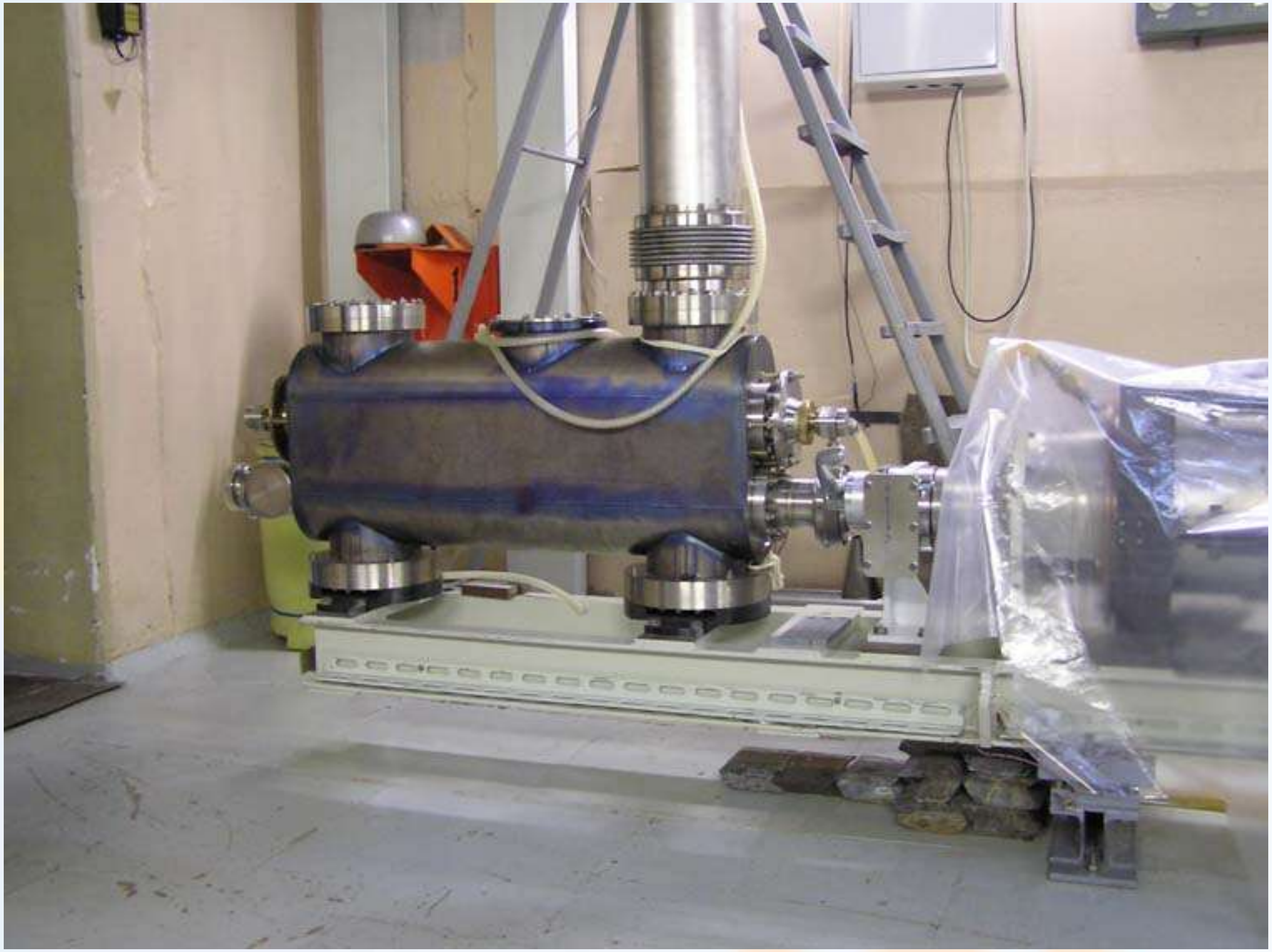
Laser radiation is transmitted through an optical beamline filled with dry nitrogen to the two experimental halls. Six user stations are now under operation.







Optical beam expander



User stations at NovoFEL

Introscopy and spectroscopy

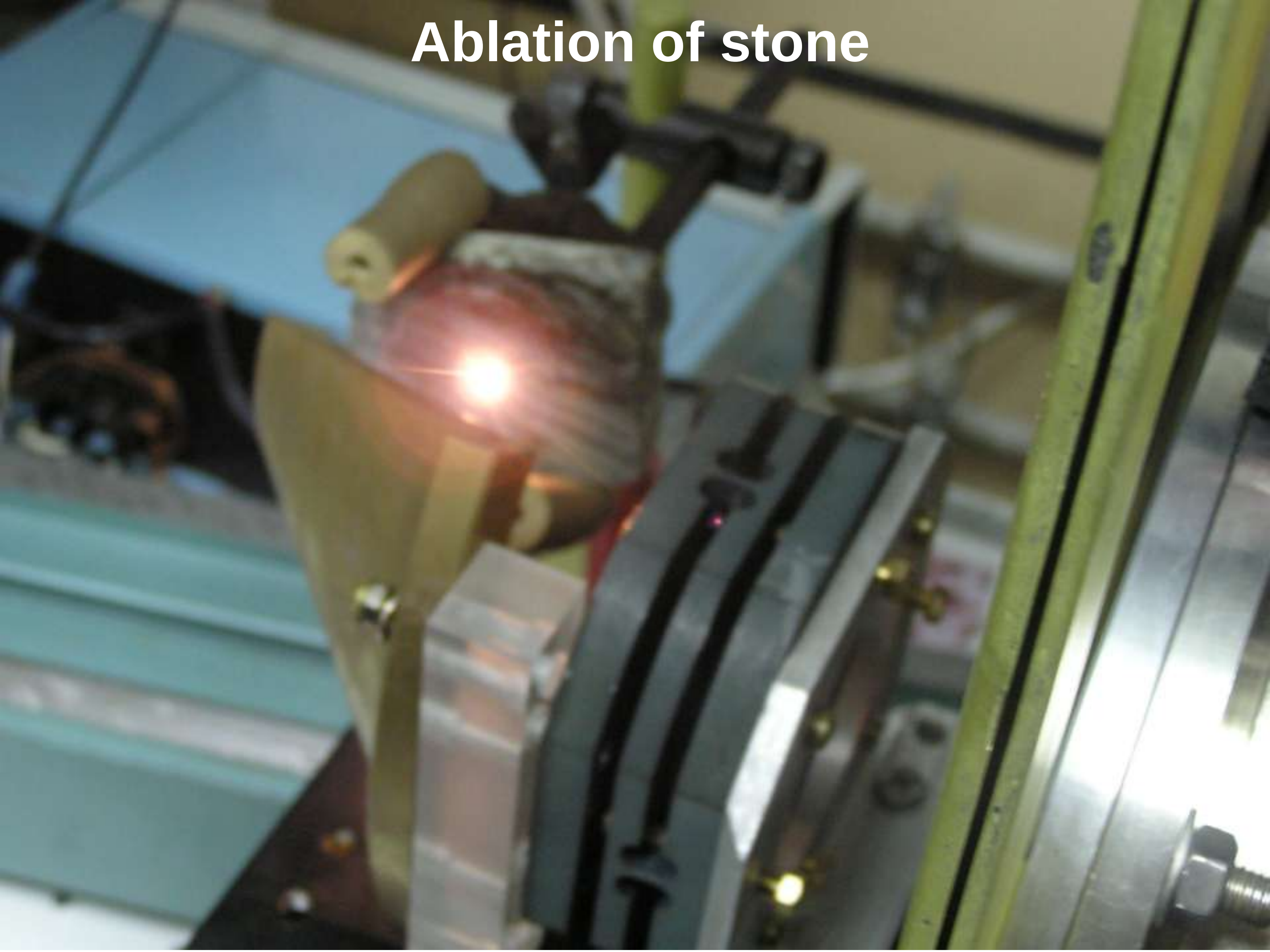
Gas dynamics

Metrology

Biology

Molecular spectroscopy

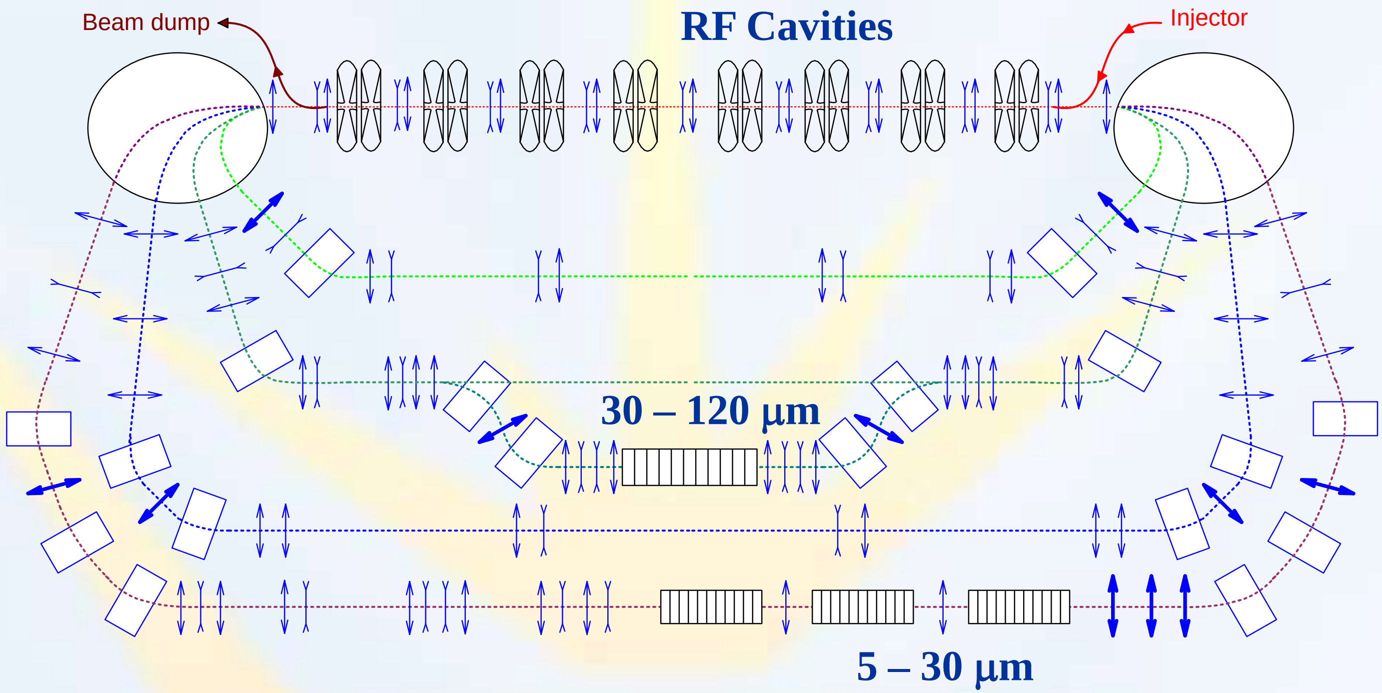
Ablation of stone



Status

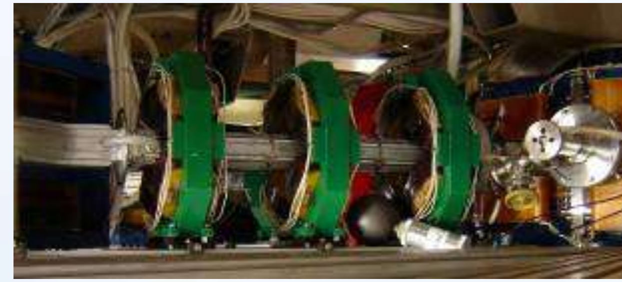
- ERL works at 12 MeV and up to 30 mA average current (world record for ERLs).
- Up to 500 W of average power at 110 – 240 micron wavelength range is delivered to users. Linewidth is less than 1%, maximum peak power is about 1 MW. Third harmonics lasing (near 70 micron, 10 W) was observed.
- Five user stations are in operation.
- Second stage of ERL and FEL was commissioned last year.

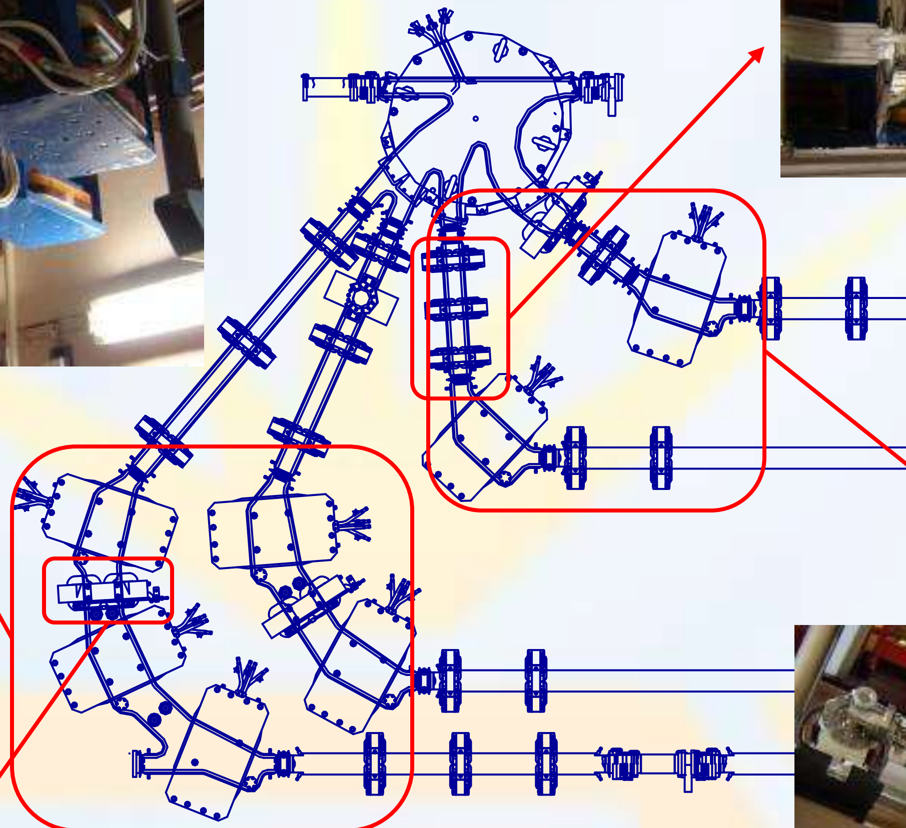
2-nd stage Novosibirsk FEL (in horizontal plane)



Radiation wavelength	**5 – 240 μm**
Average power	**Up to 10 kW**
E-beam energy	**up to 40 MeV**
Maximum repetition rate	**90 MHz**
Maximum mean current	**150 mA**

Magnets and vacuum chamber of bends



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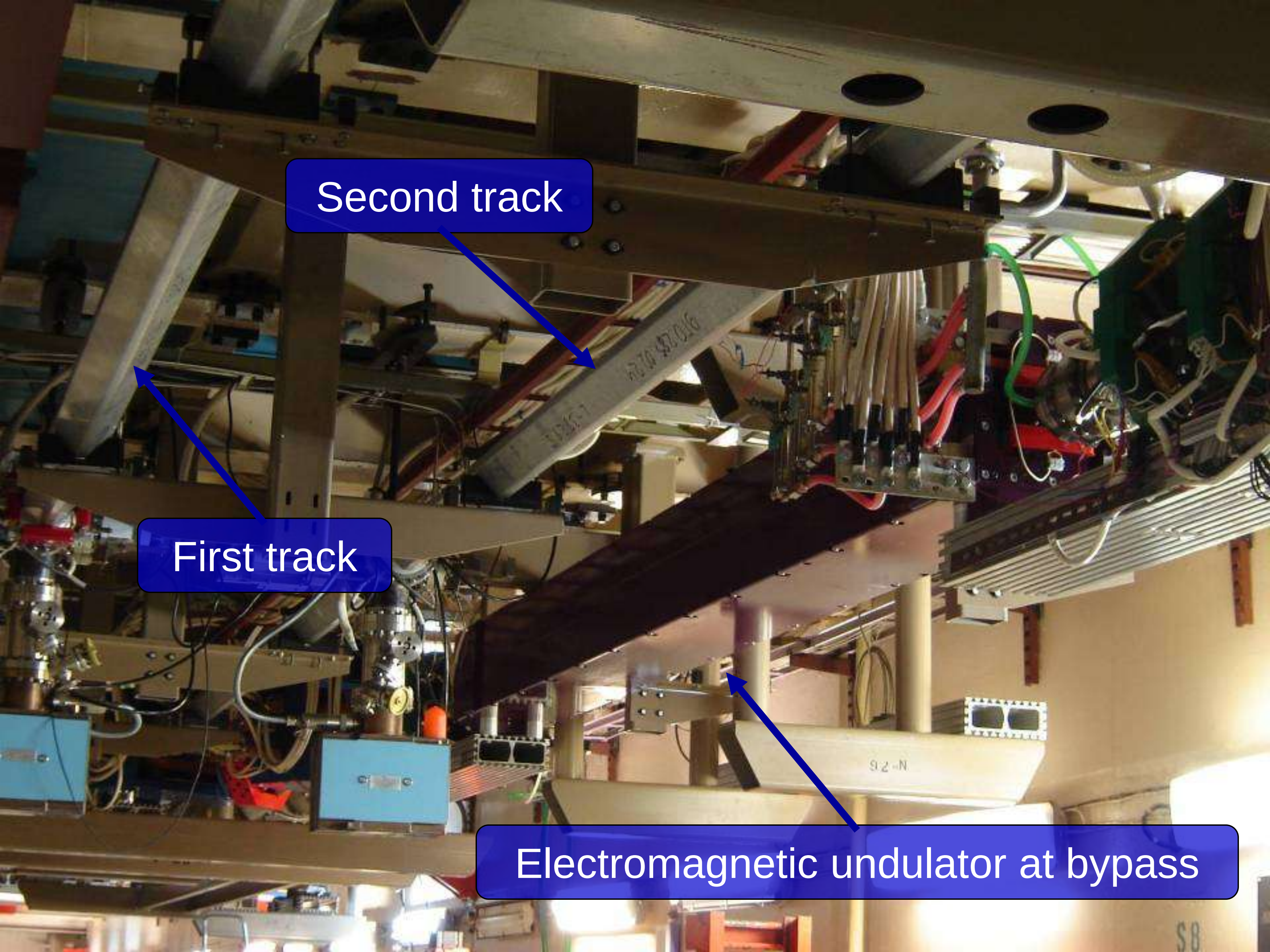
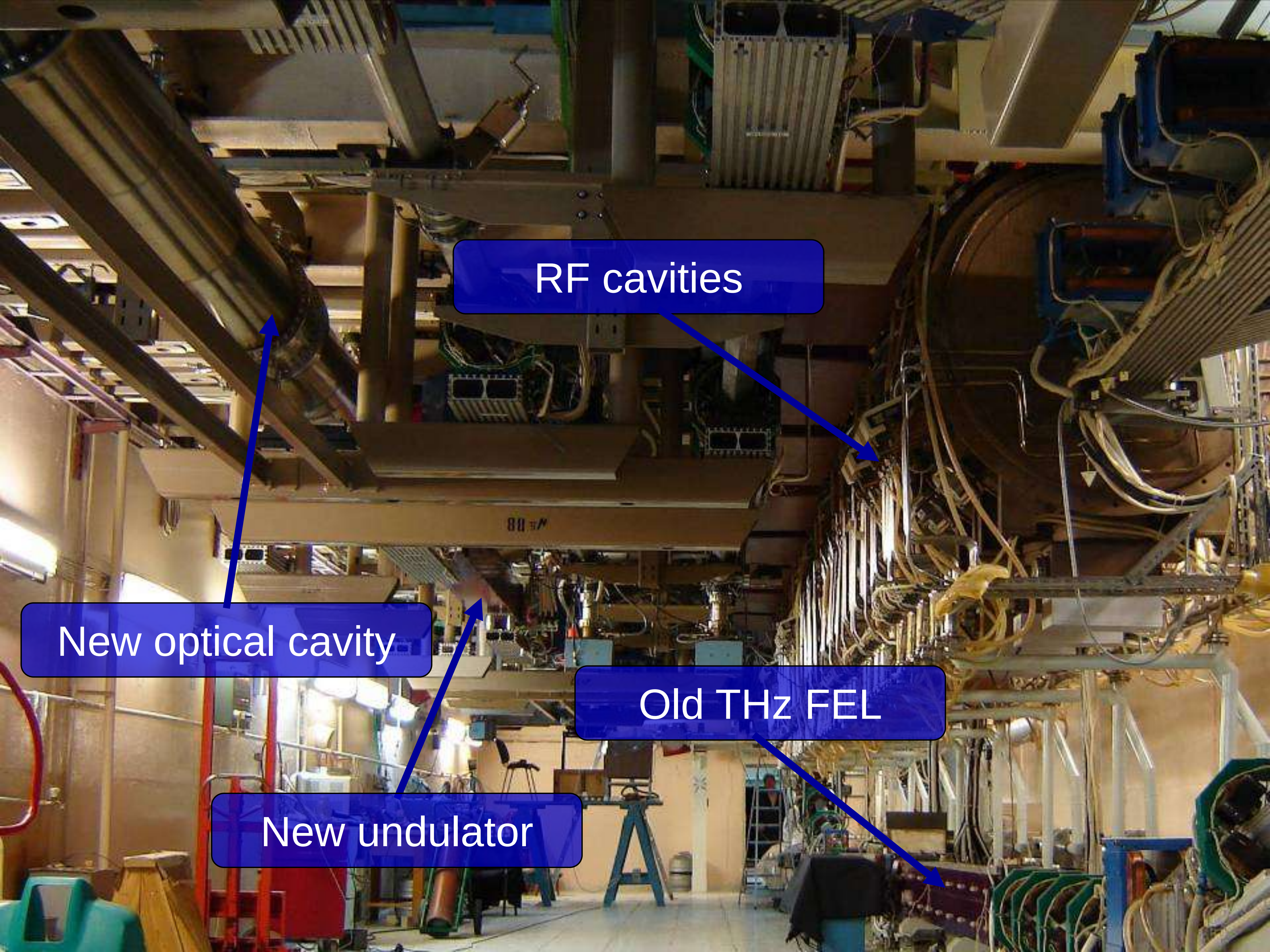
The bends are hanged on the ceiling.

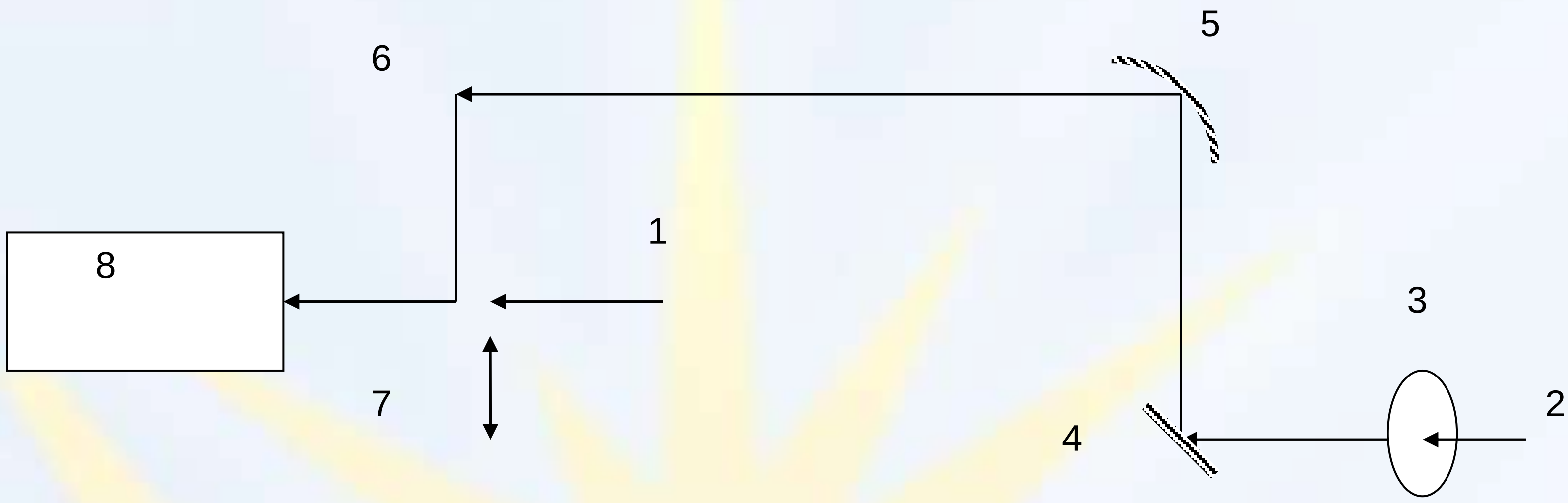
Round magnet is at the top left corner, the old THz FEL magnetic system is at down-left.

Elements of the optical resonator for the second-turn FEL are yet at the floor (down-right corner).


Second track
First track
Electromagnetic undulator at bypass


RF cavities
New optical cavity
Old THz FEL
New undulator

Optical scheme of the second stage FEL beamline



1 – radiation from the first stage FEL, 2 - radiation from the first stage FEL, 3 – diamond window, 4 and 6 – flat mirrors, 5 – thoroidal mirror, 7 – retractable flat mirror, 8 – user station distribution system.

The second stage FEL beamline

The retractable mirror unit

The second stage FEL radiation comes down. The mirror is inserted bottom-up.

Status of the second stage ERL and FEL

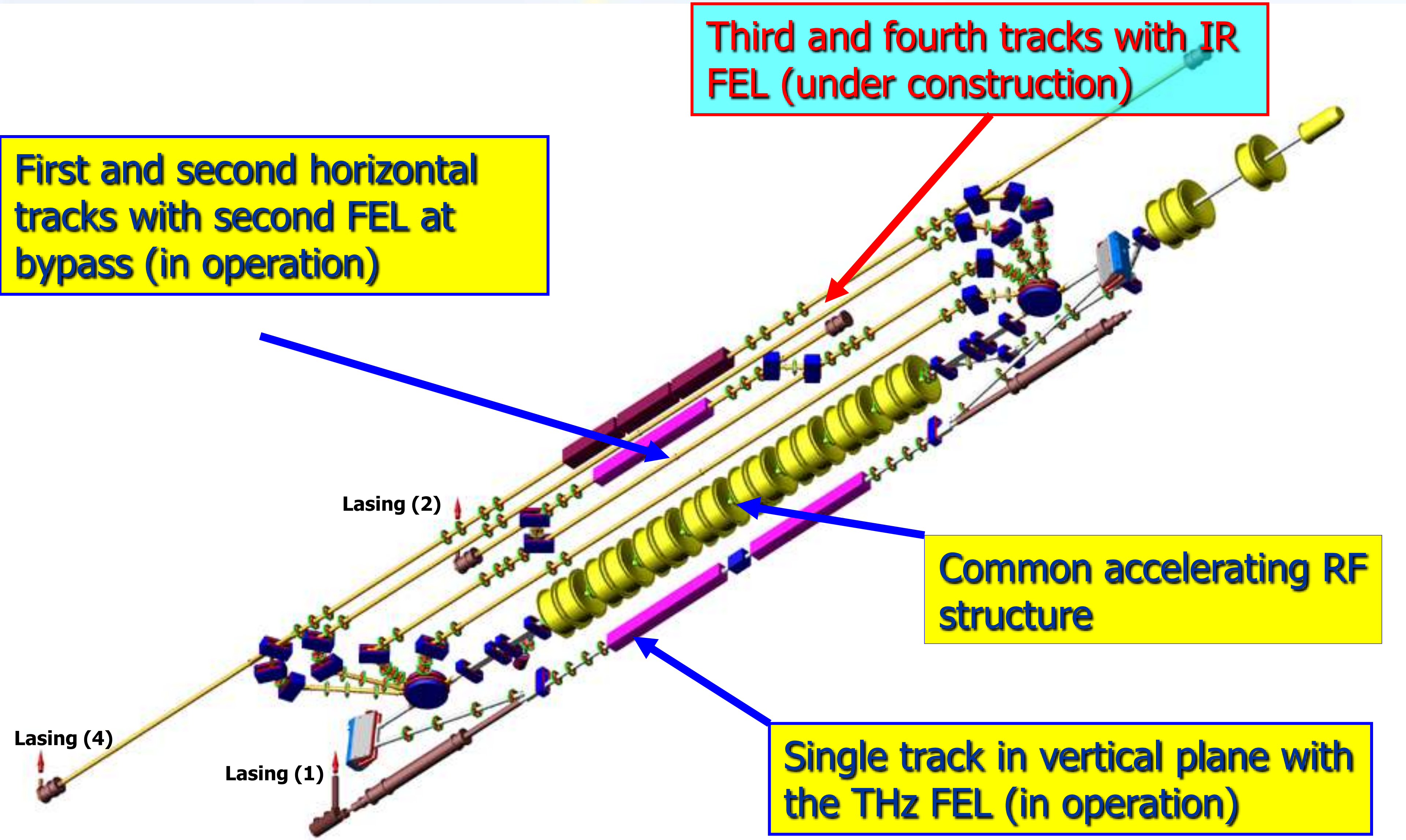
- First in the world multi-turn ERL is in operation.
- The wavelength range is 40 – 80 micron.
- Average power is about 0.5 kW yet.
- Radiation of new FEL is delivered to the existing experimental stations.
- First shifts for users took place this year.

Problems

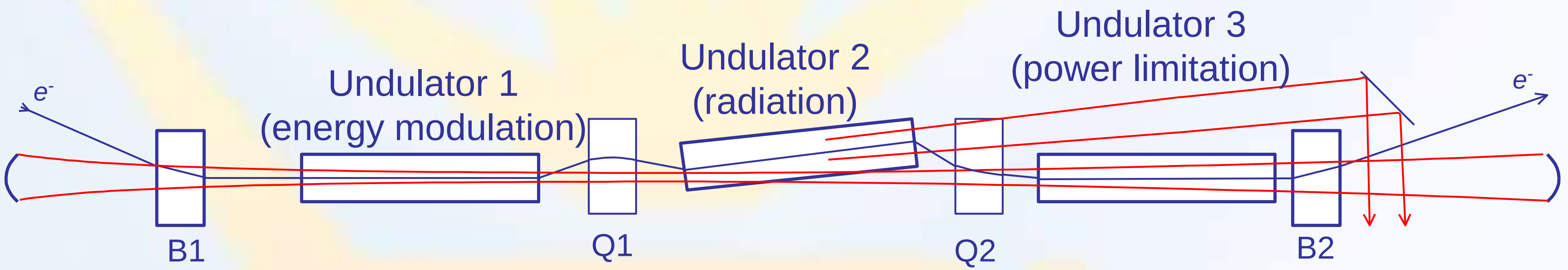
1. Large energy spread after FEL leads to the beam loss increase. – Solution: sextupole corrections were inserted in some quadrupoles to make second order achromat.
2. Complicated focusing and trajectory correcion at common tracks (with two beams).

Third stage
(4th orbit FEL with “electron outcoupling” of radiation)

Novosibirsk ERL with 3 FELs



Electron outcoupling scheme of Novosibirsk FEL



Thank you