Status of the Novosibirsk High Power Terahertz FEL

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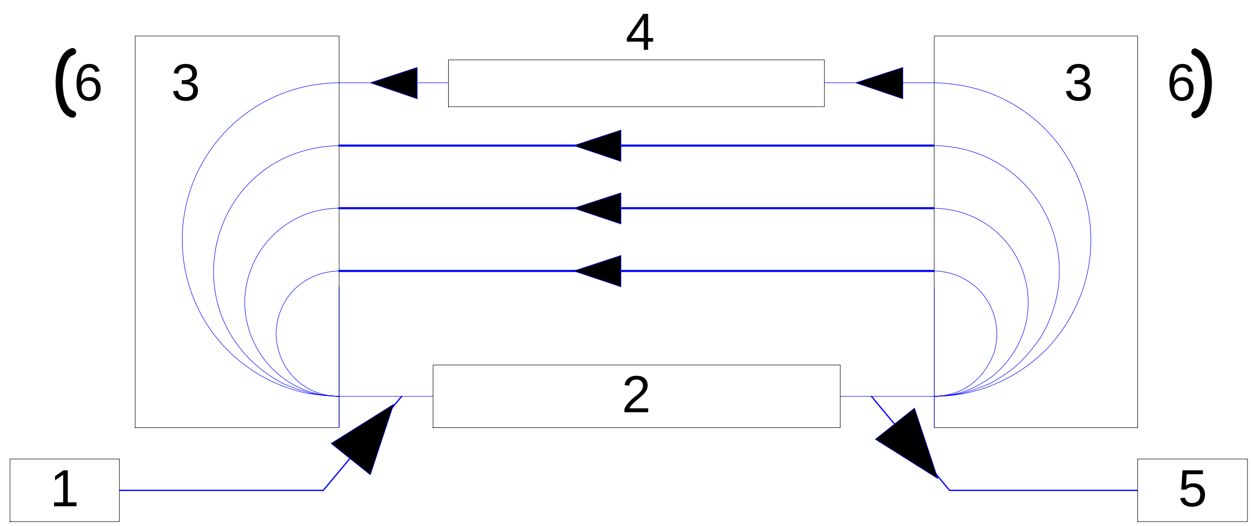
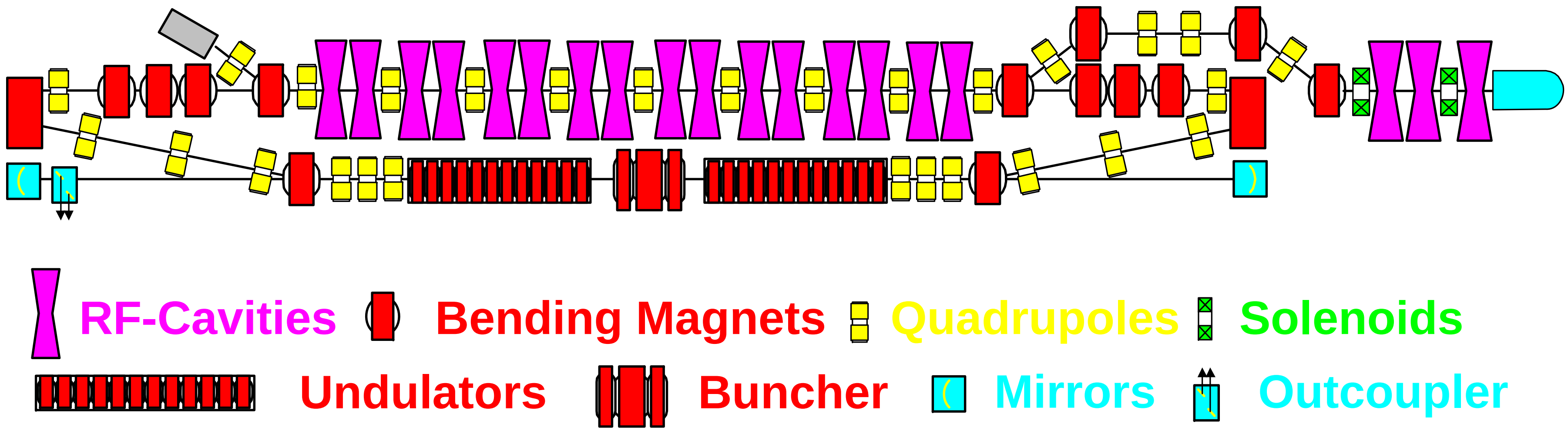
FEL based on energy recovery accelerator

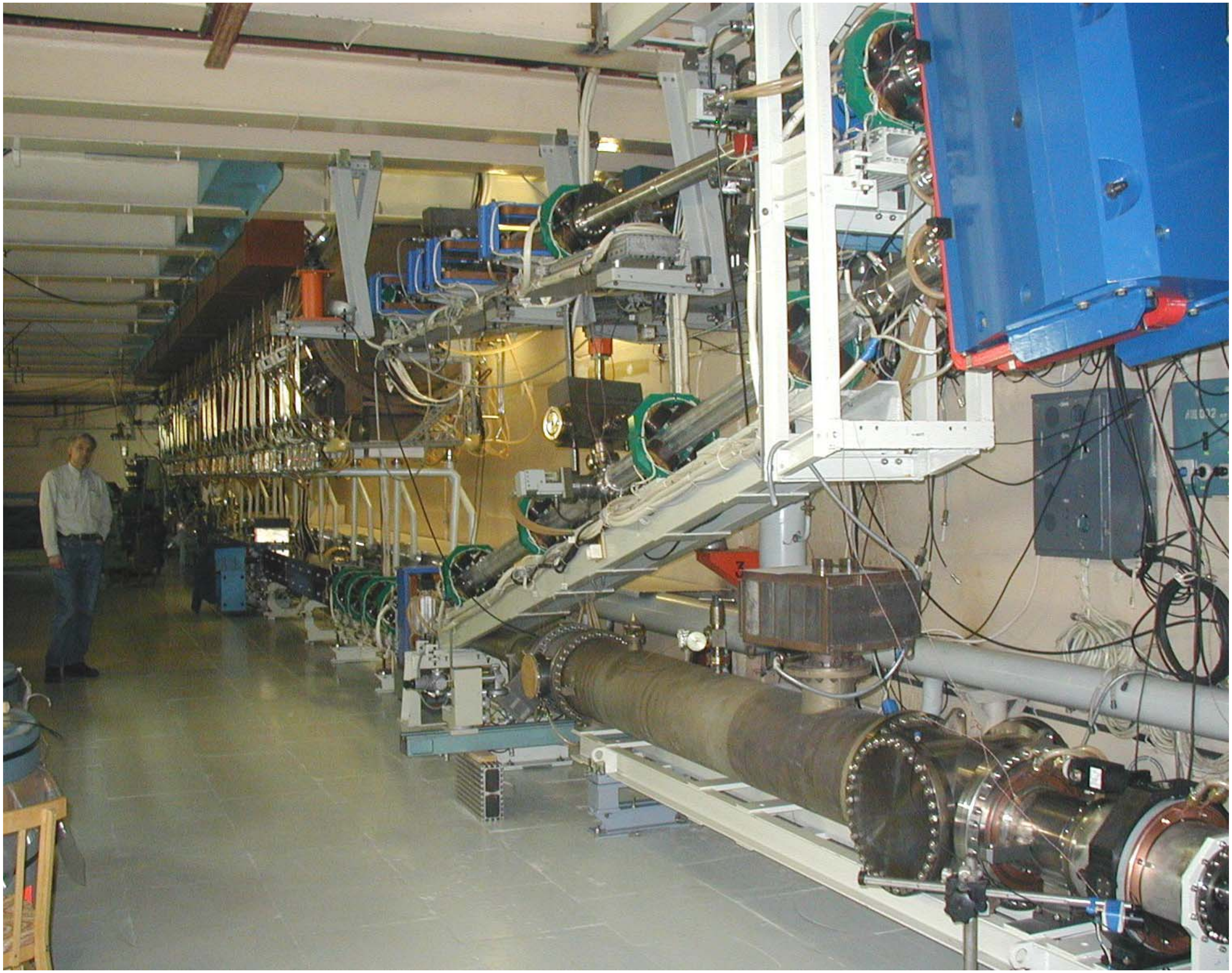


1 - injector, 2 - accelerating RF structure, 3 - 180-degree bends, 4 - undulator, 5 - beam dump, 6 - mirrors of optical resonator

First stage: ERL and submillimeter (THz) FEL



ERL and FEL



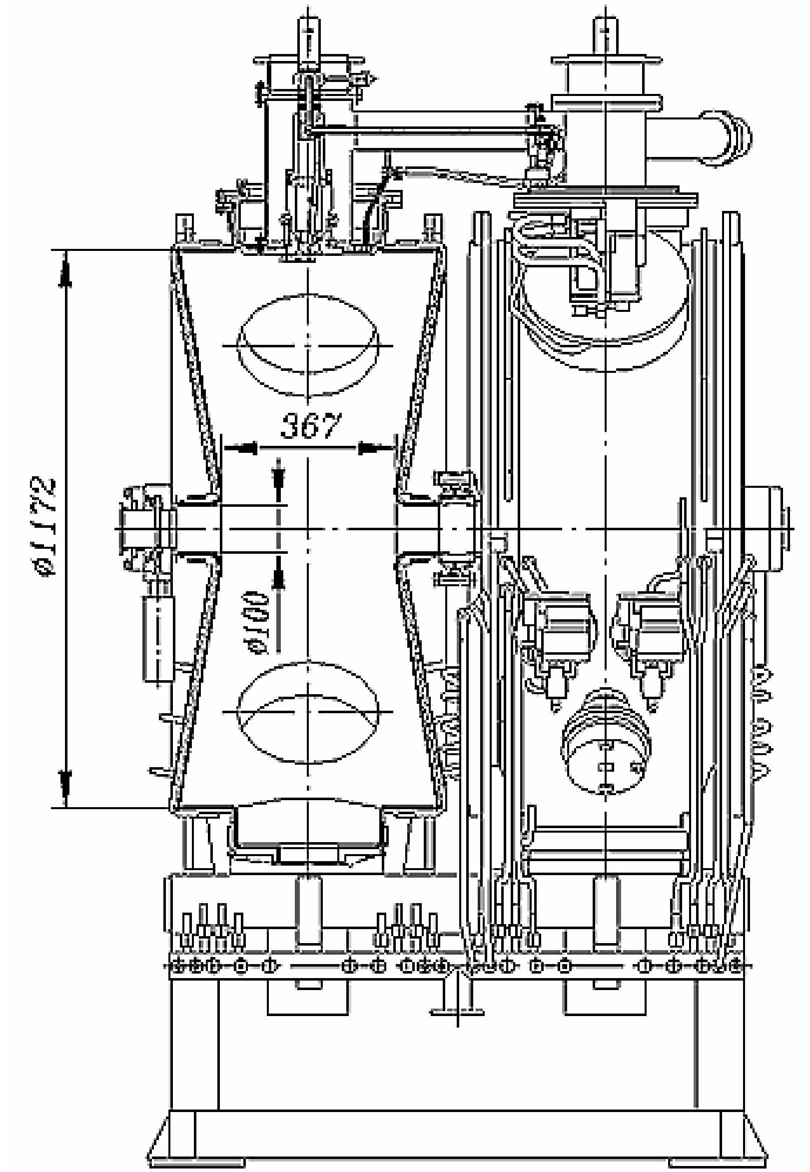
Features of RF system

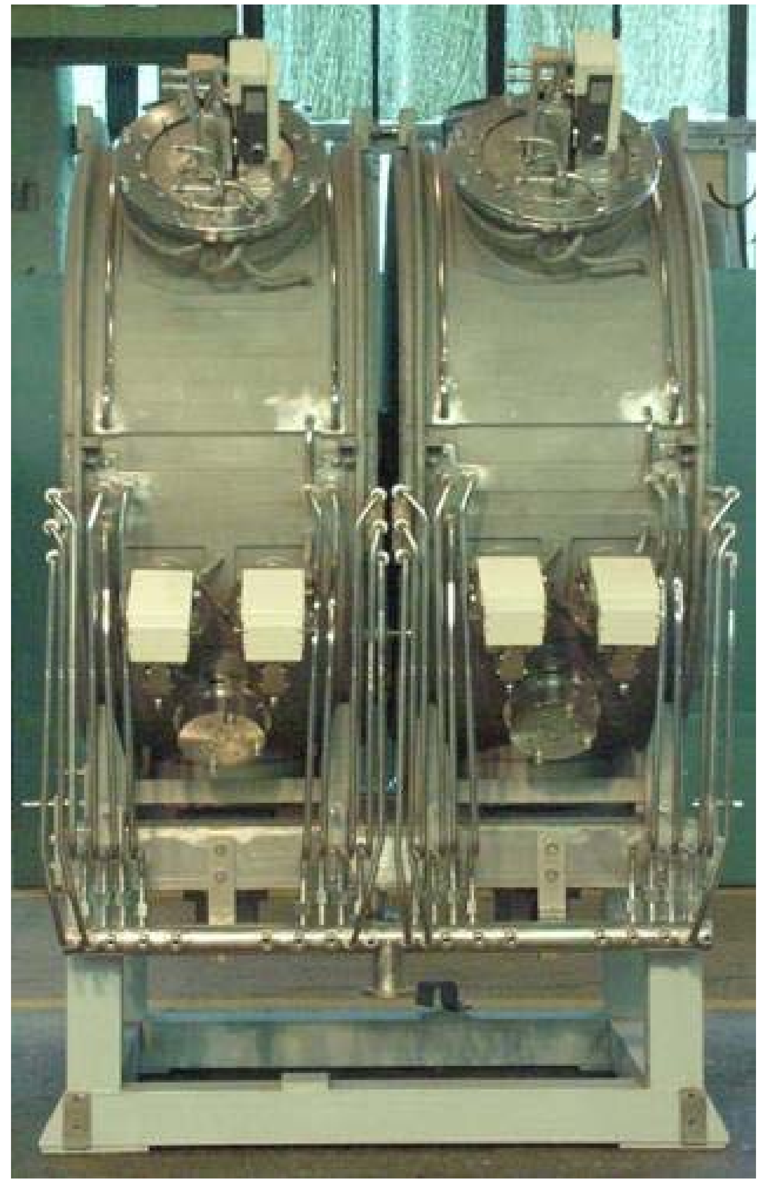
- Low frequency (180 MHz)
- Normal-conducting uncoupled RF cavities
- CW operation

Advantages

- High threshold currents for instabilities
- Operation with long electron bunches (for narrow FEL linewidth)
- Large longitudinal acceptance (good for operation with large energy spread of used beam)
- Moderate tolerances for orbit lengths and longitudinal dispersion

A pair of cavities (accelerating section) on a support frame



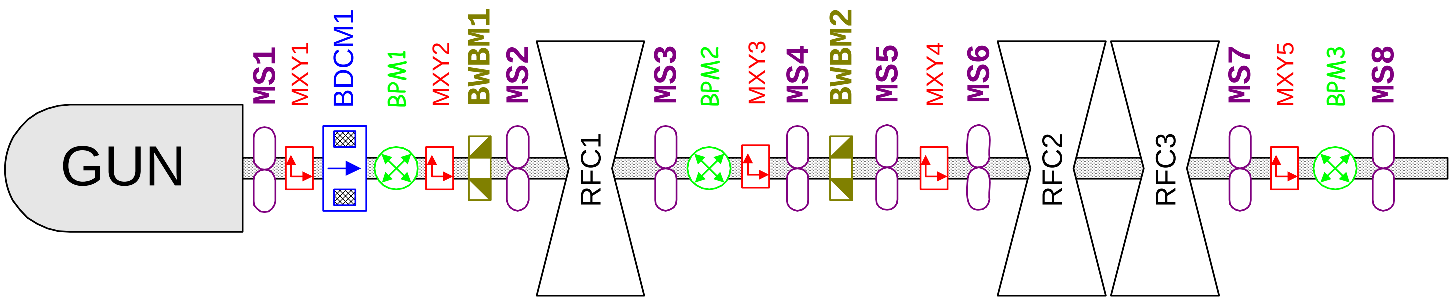


Main parameters of the cavity

(for the fundamental TM_{010} mode)

Resonant frequency, MHz	f_0	180,4
Frequency tuning range, kHz	Δf_0	320
Quality factor	Q	40000
Shunt impedance, MOhm	$R=U^2/2P$	5,3
Characteristic impedance, Ohm	$\rho=R/Q$	133,5
Operating gap voltage amplitude, MV	U	0-1.1
Power dissipation in the cavity, kW, at U=1100 kV	P	115
Input coupler power capability, kW (*tested, limited by available power*)	P_{in}	400

2 MeV injector



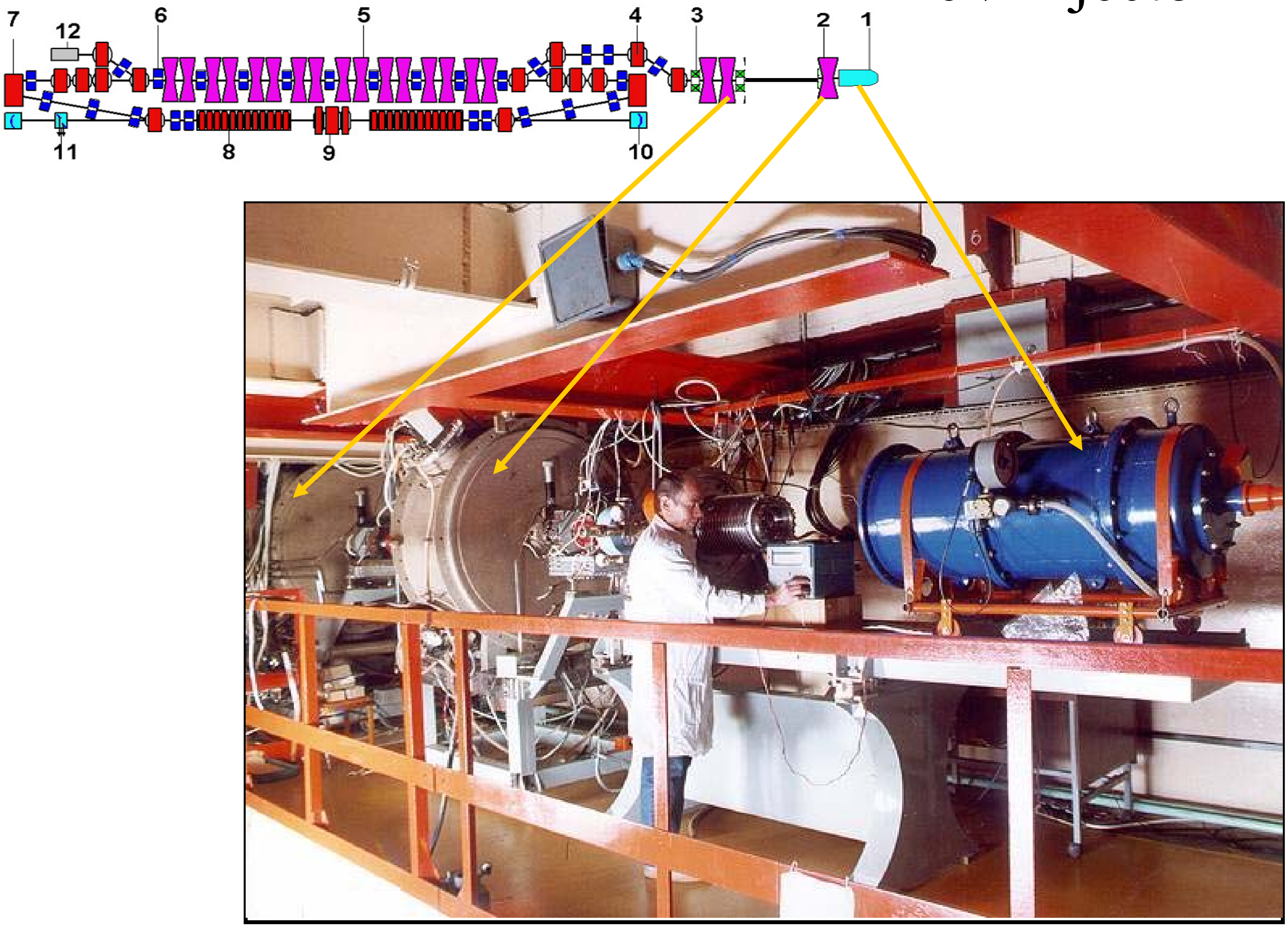
MS : focusing solenoid **MXY : steering magnet** **BDCM : beam current monitor**

BPM : bean position monitor **BWBM : wall current monitor** **RFC : RF cavity**

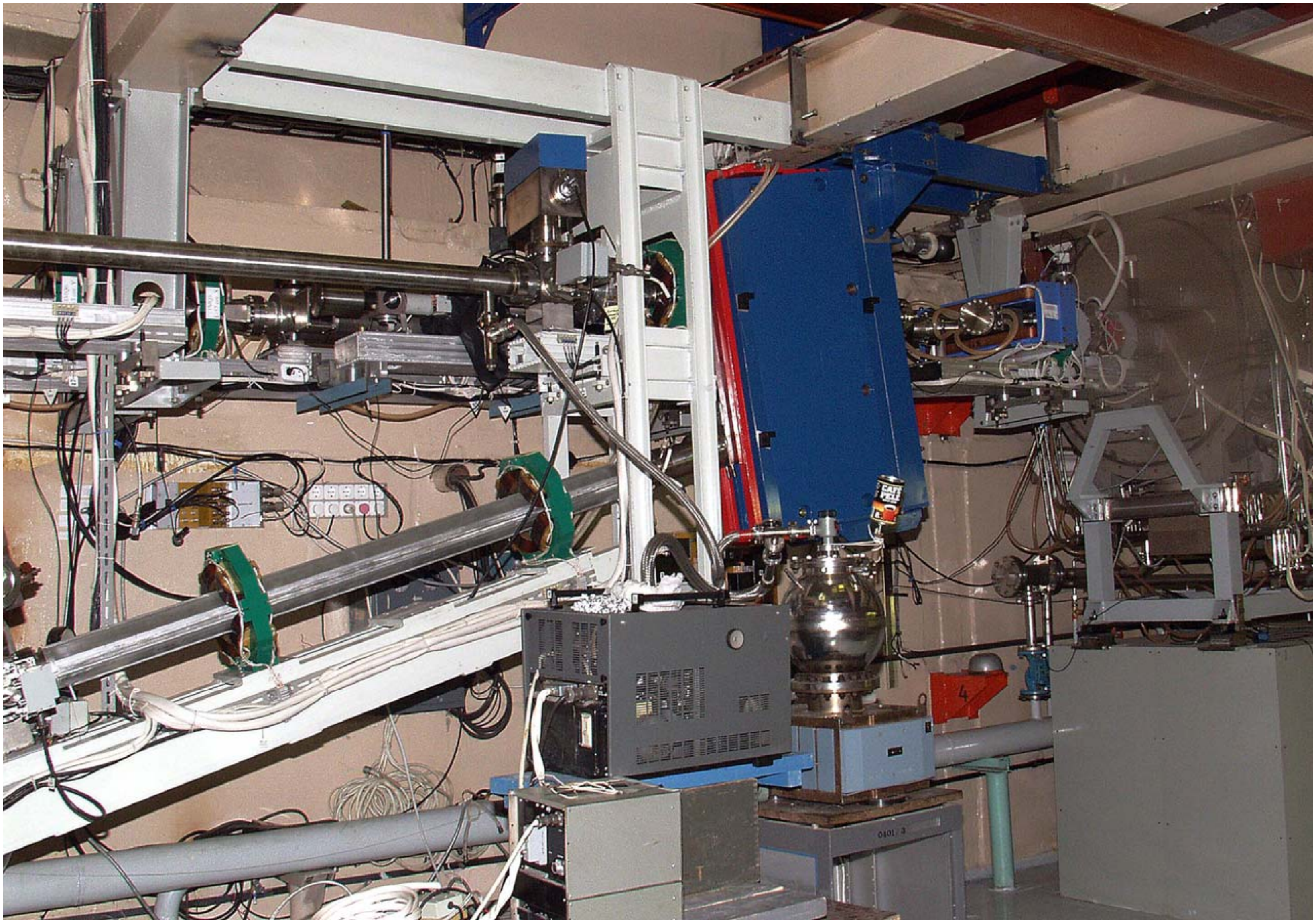
2 MeV injector parameters

♦ Bunch repetition rate, MHz	up to 22.5
♦ Charge per bunch, nC	2
♦ Start bunch length, ns	1.2
♦ Final bunch length, ns	0.1
♦ Final energy, MeV	2

2 MeV injector



Bent and injection beamline



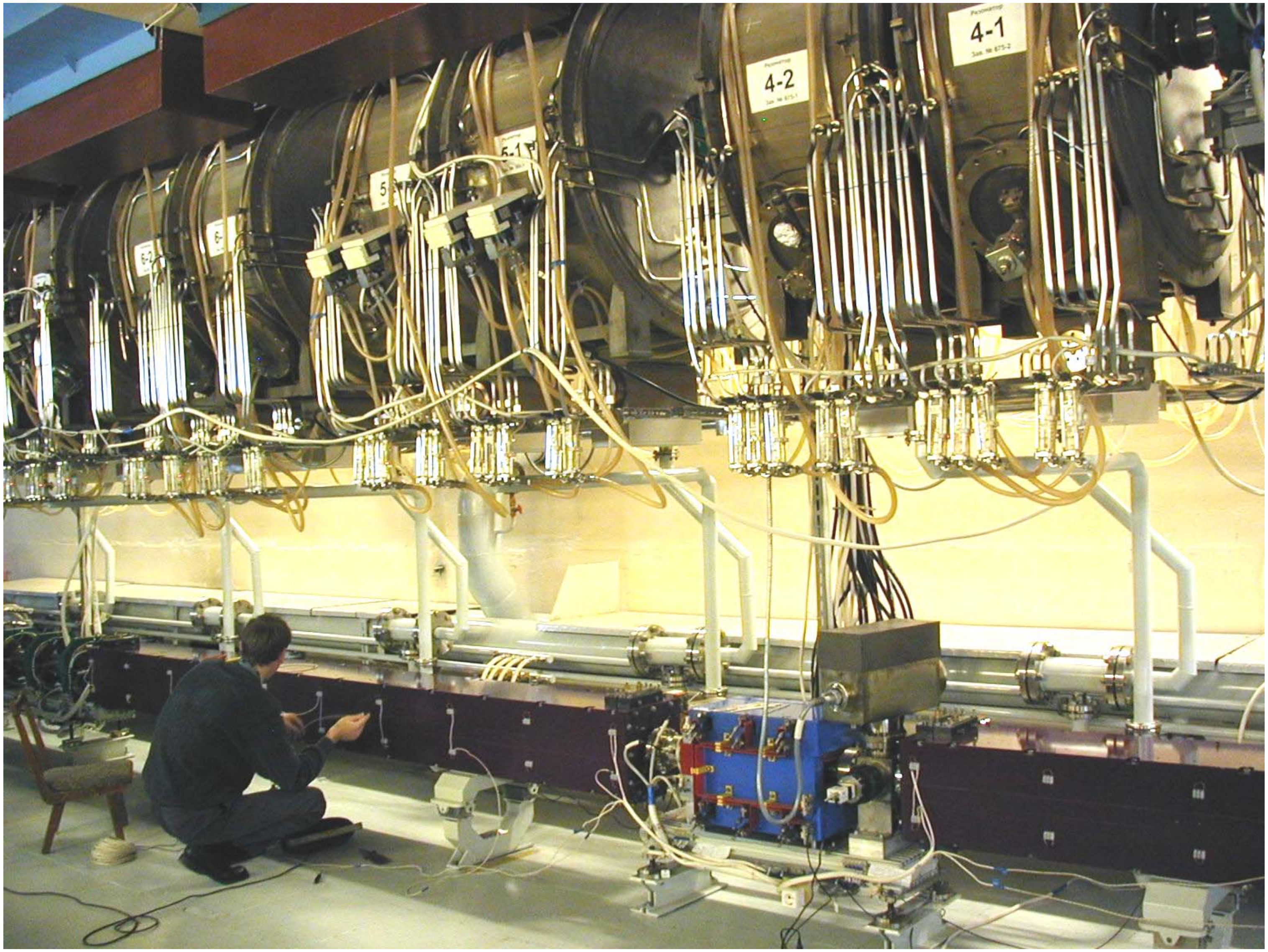
First-stage ERL:
machine parameters

♦ Bunch repetition rate, MHz	11.2
♦ Average electron current, mA	20
♦ Maximum energy, MeV	12
♦ Bunch length, ps	100
♦ Normalized emittance, mm*mrad	30

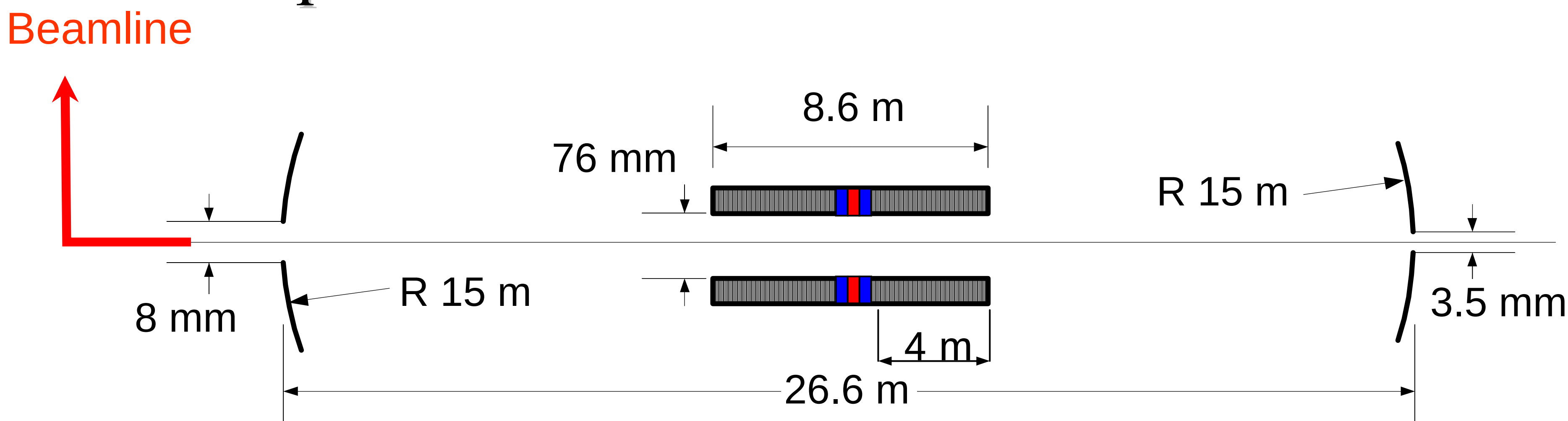
Undulator parameters (one section)

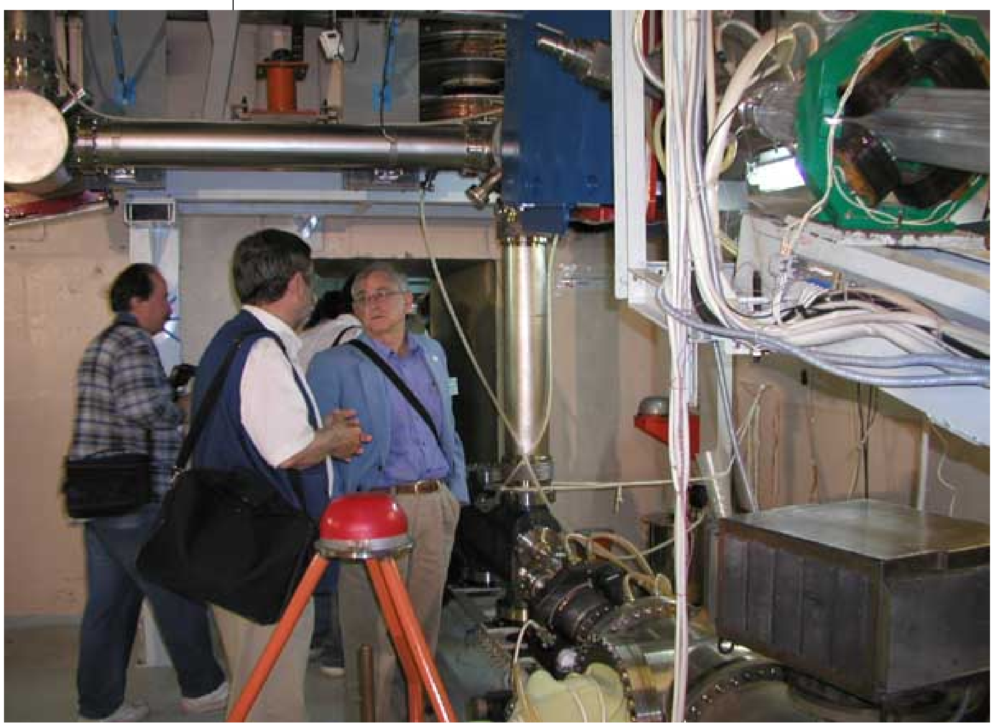
♦ Length, m	4
♦ Period, mm	120
♦ Number of periods	32
♦ Gap, mm	80
♦ Undulator parameter K	0 - 1.2

Undulators and accelerating RF cavities



Optical resonator and transmission line

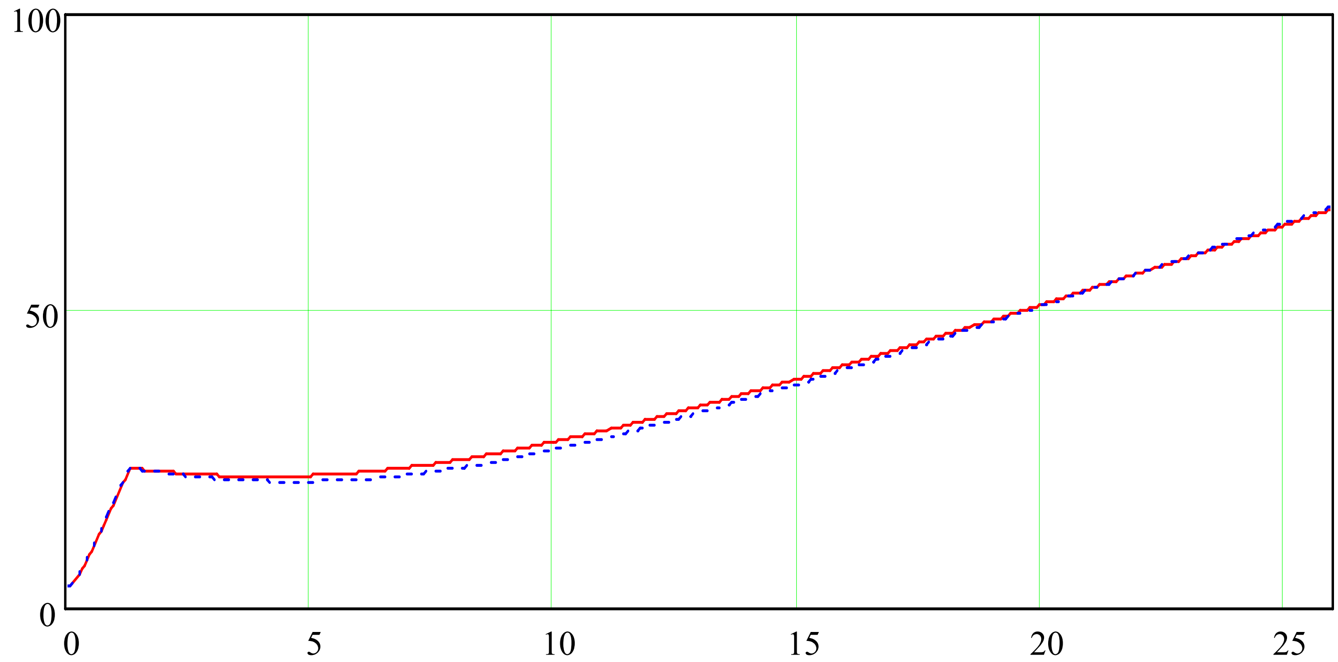




Beamline for radiation transport

Beamline outlets

Optical beam sizes (mm) vs. distance along the beamline (m)

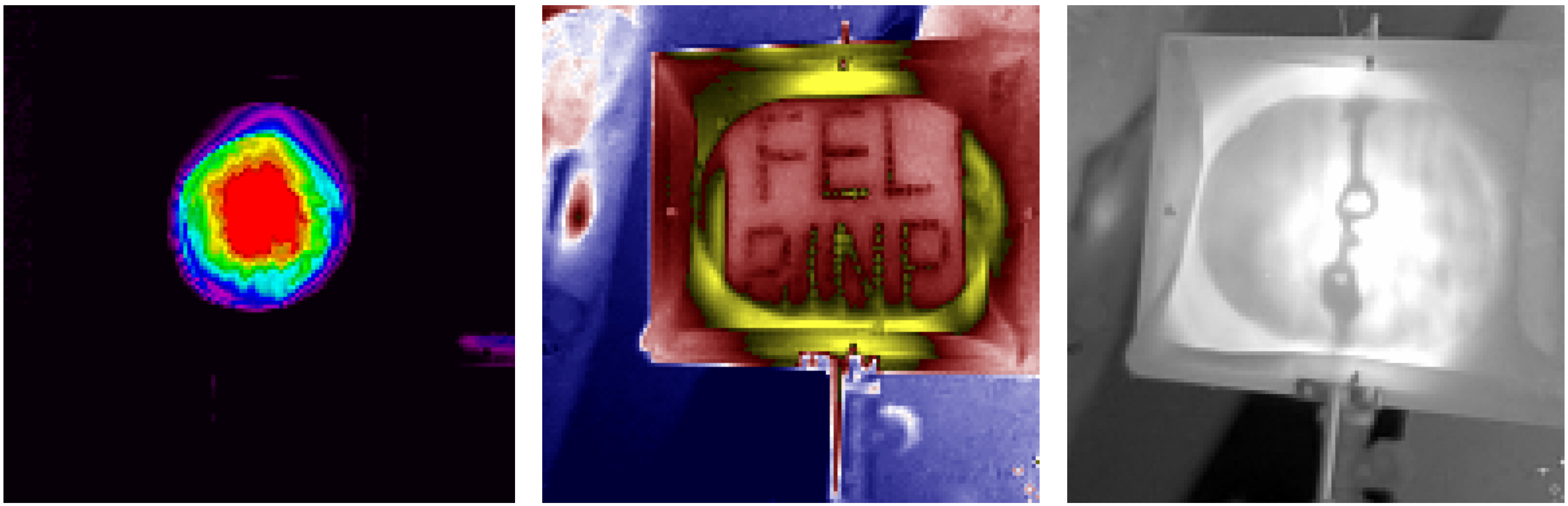


Experimental stations

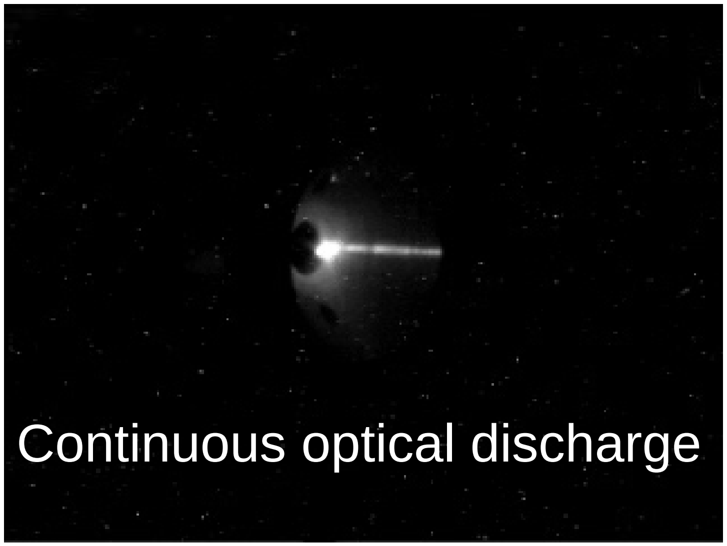
Free electron laser Parameters

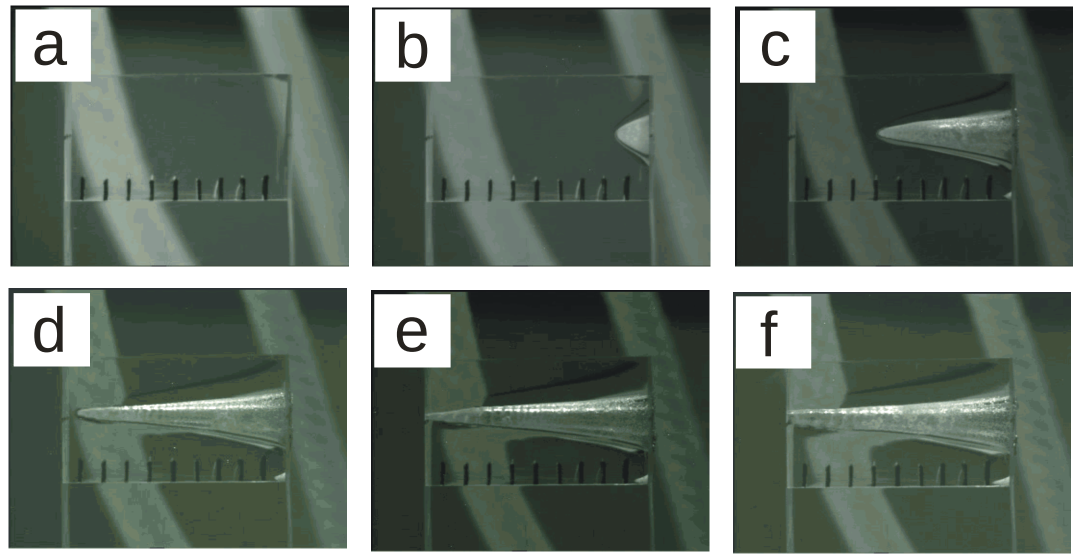
♦ Wavelength, mm	0.12-0.18
♦ Pulse duration, FWHM, ps	70
♦ Pulse energy, mJ	0.04
♦ Repetition rate, MHz	5.6 or 11.2
♦ Average power, kW	0.4
♦ Minimum relative linewidth, FWHM	$3 \cdot 10^{-3}$

THz images



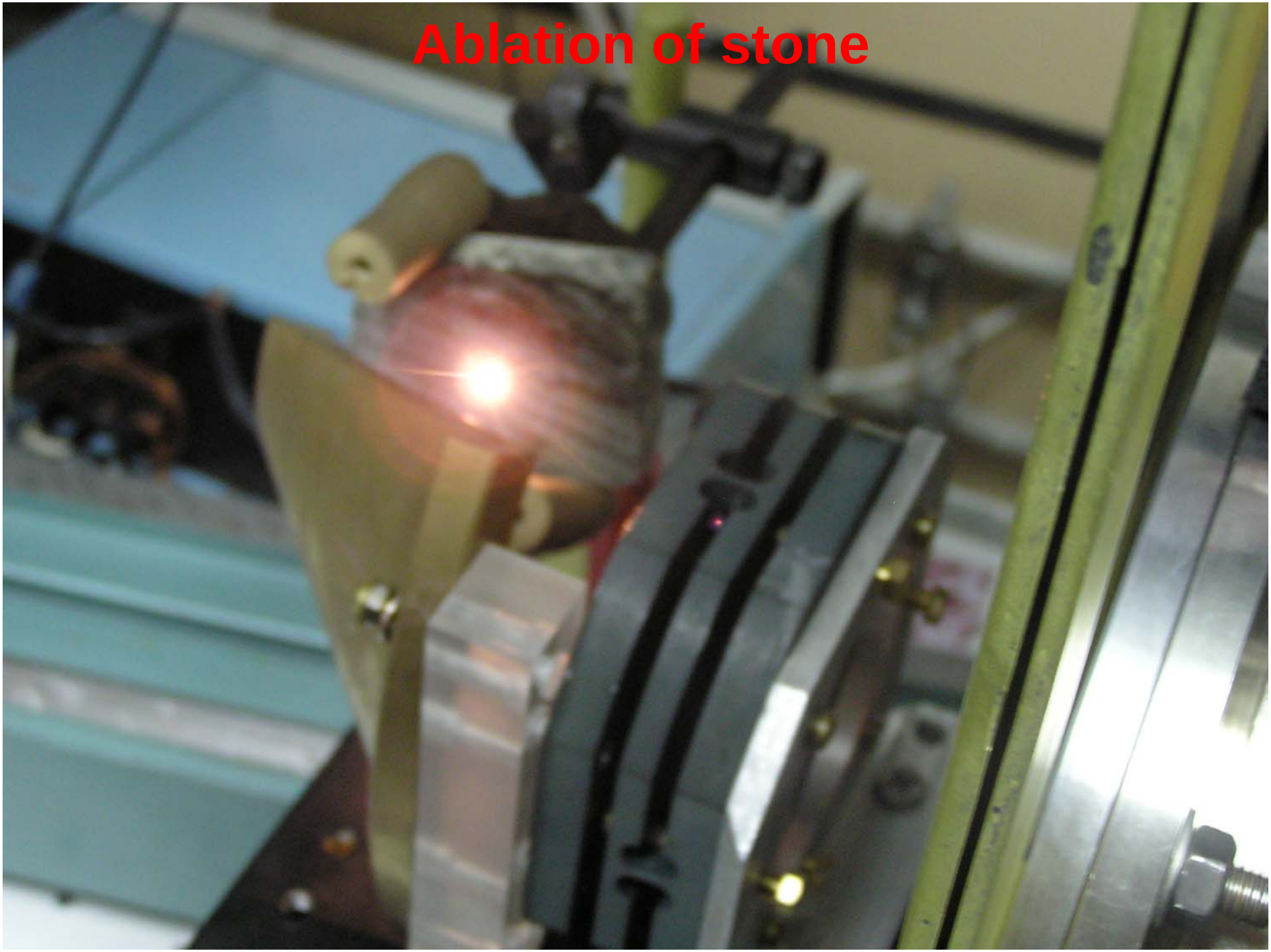
High average power of radiation (up to 400 W) in combination with high peak power (up to 1 MW) enables performing high power density experiments



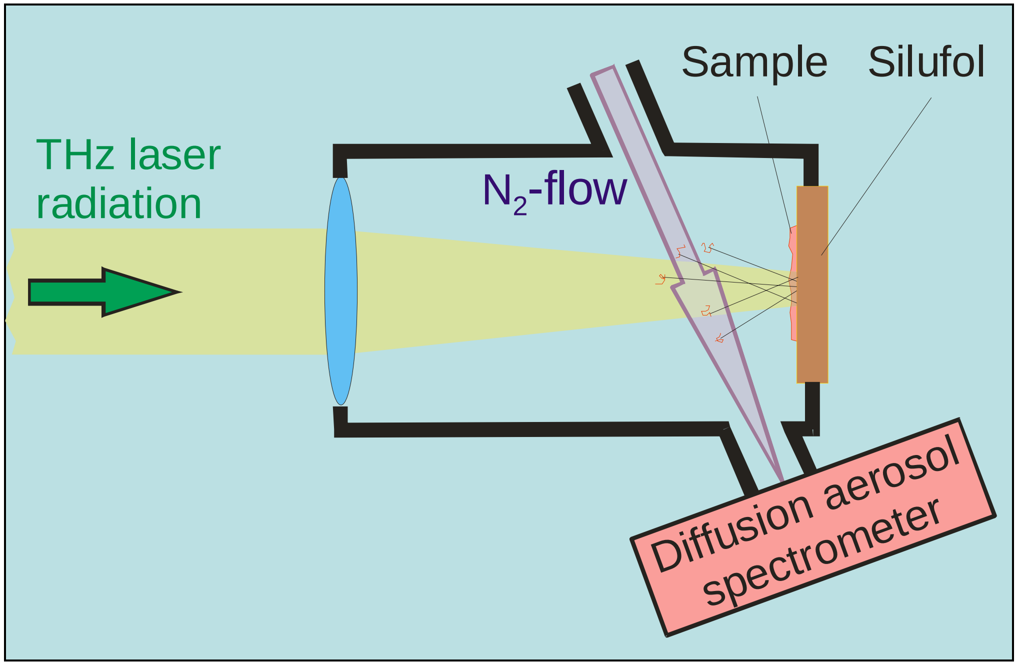


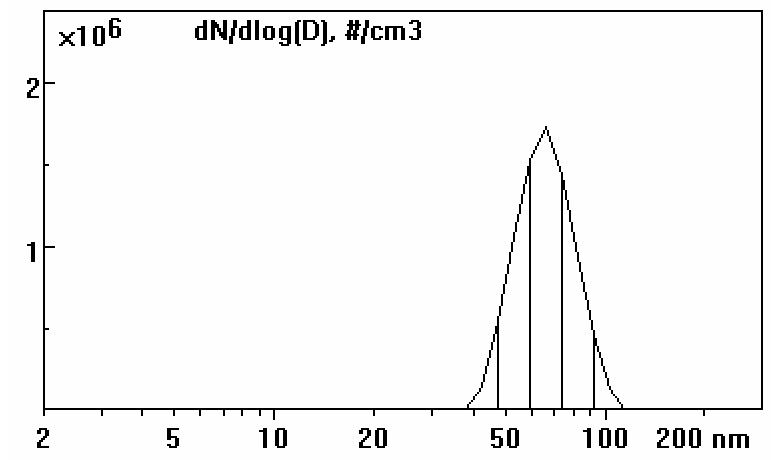
- Laser beam focused in the atmosphere with a parabolic mirror (f=1.0 cm) ignites a continuous optical discharge
- Unfocused laser beam drills an opening in 50-mm plexiglas slab within three minutes (ablation without burning)
- These fenomena can be used for many fundamental and applied experiments (plasma physics, aerodynamics, chemistry, material processing and modification, biology…)

Ablation of stone

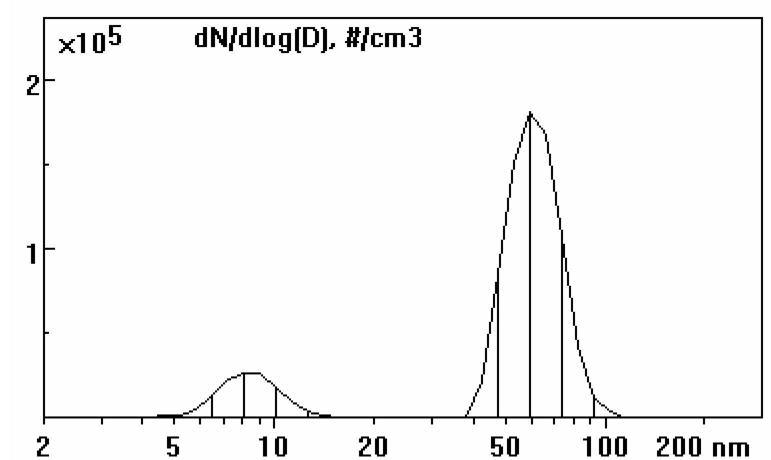


Ultra-soft laser ablation of DNA





Phage DNA



Phage DNA + plasmide DNA

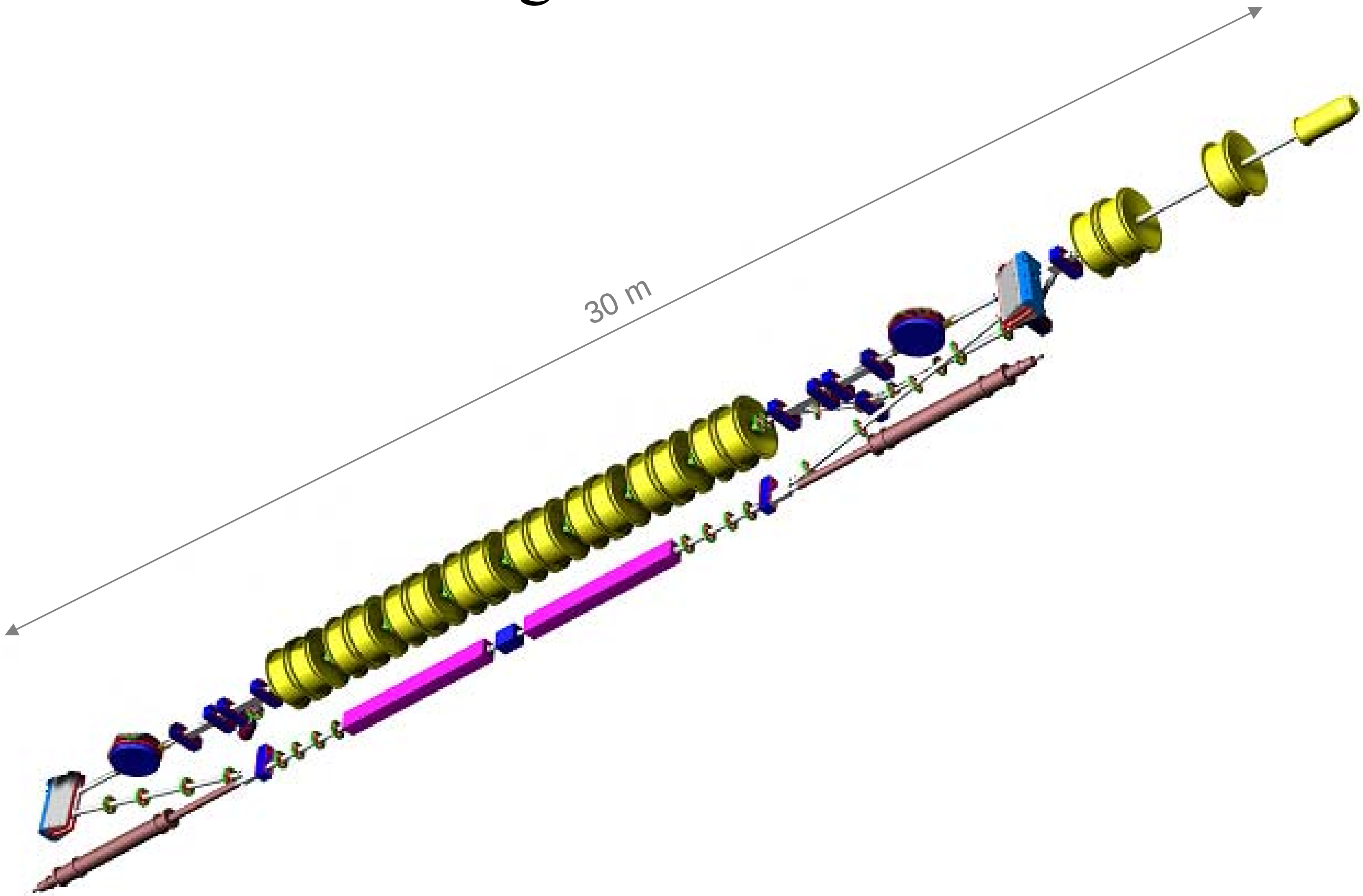
Demonstration of ultra-soft ablation of DNA samples without denaturation: when the power density of THz radiation is optimal, particle size spectra contain only the peaks corresponding to the initial particles. For higher power densities multi-peak spectra are observed.

Full-scale energy recovery accelerator and FEL

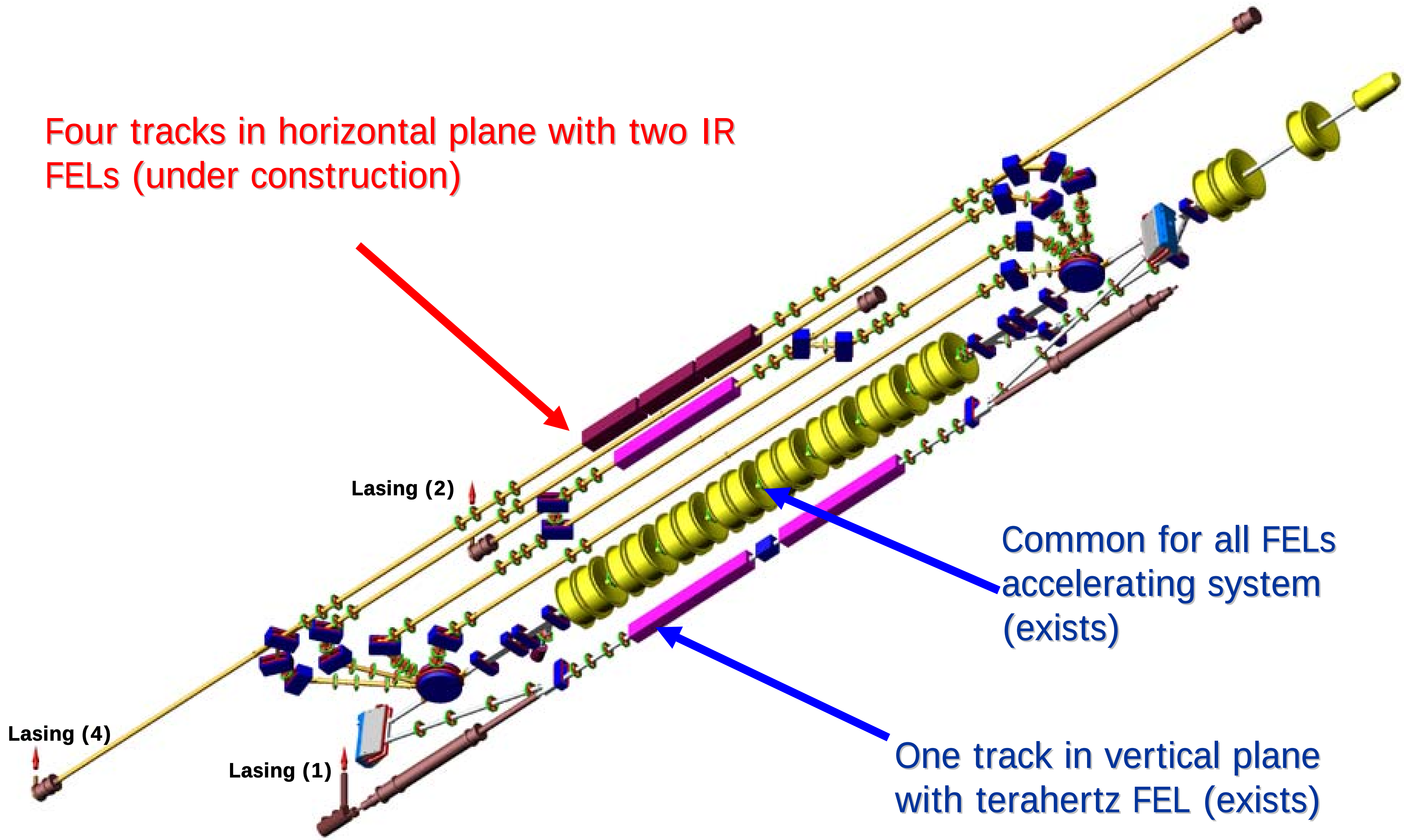
A full-scale 4-track energy recovery accelerator uses the same accelerating structure as the 1st stage ERL, but, in contrast to the latter, it is placed in the horizontal plane. Thus, the possibility to run the old FEL remains.

The choice of operation regime at one of two machines and one of three FEL will be achived by simple reswitching of the bending magnets.

First stage ERL and FEL



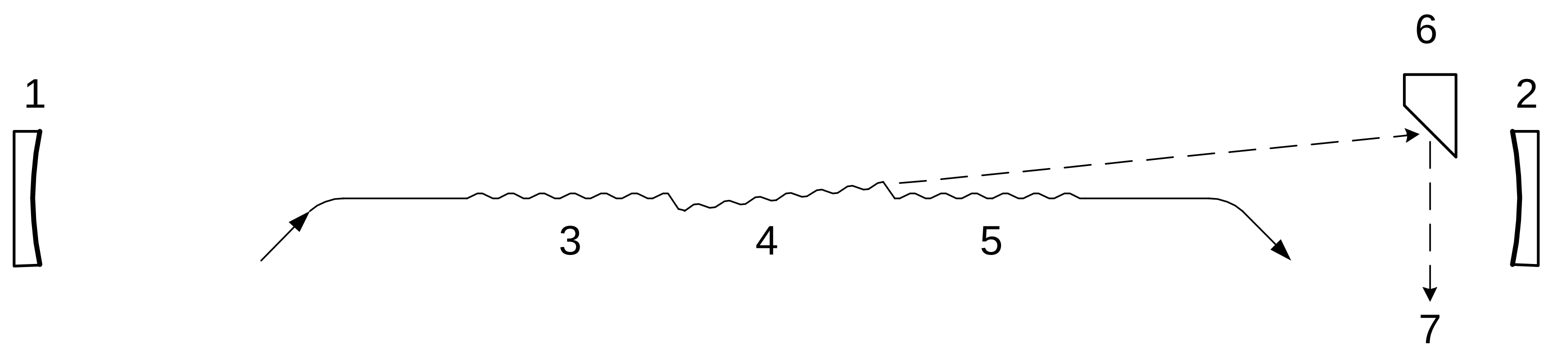
Full-scale accelerator and FELs



Full-scale FEL parameters

Electron beam energy, MeV	40
Number of orbits	4
Maximum bunch repetition rate, MHz	90
Beam average current, mA	150
Wavelength range, micron	5-240
Maximum output power, kW	10

Scheme of the electron outcoupling for the second stage of the Novosibirsk FEL



1 and 2 – mirrors of optical resonator; 3, 4, and 5 – undulators; 6 – 45-degree mirror; 7 – radiation output.

Conclusions

- First stage machine operates stably.
- Several user stations are in operation.
- Some optical experiments were performed.
- The work to increase the average power is continuing.
- The manufacturing of the second stage of FEL is in progress. Commissioning is expected in 2007.