Status of the Novosibirsk High Power Terahertz FEL

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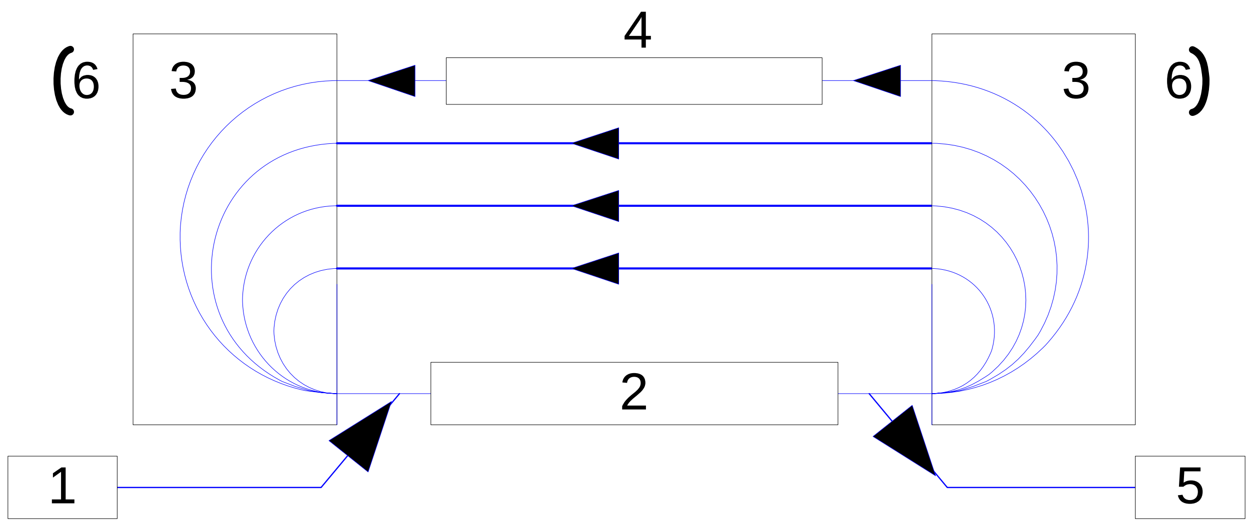
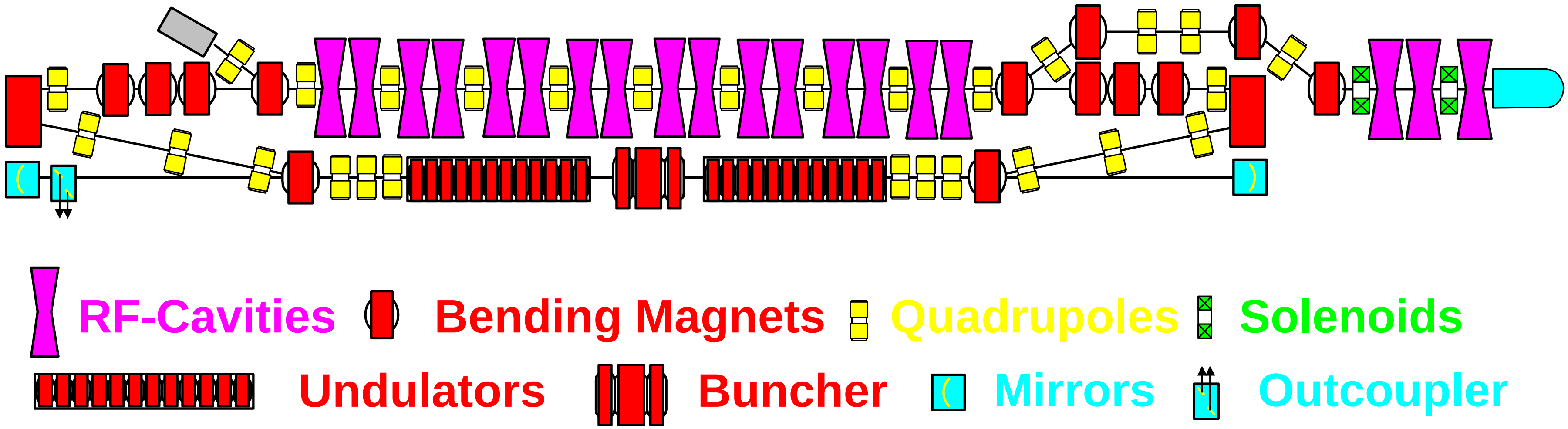
FEL based on accelerator-recuperator



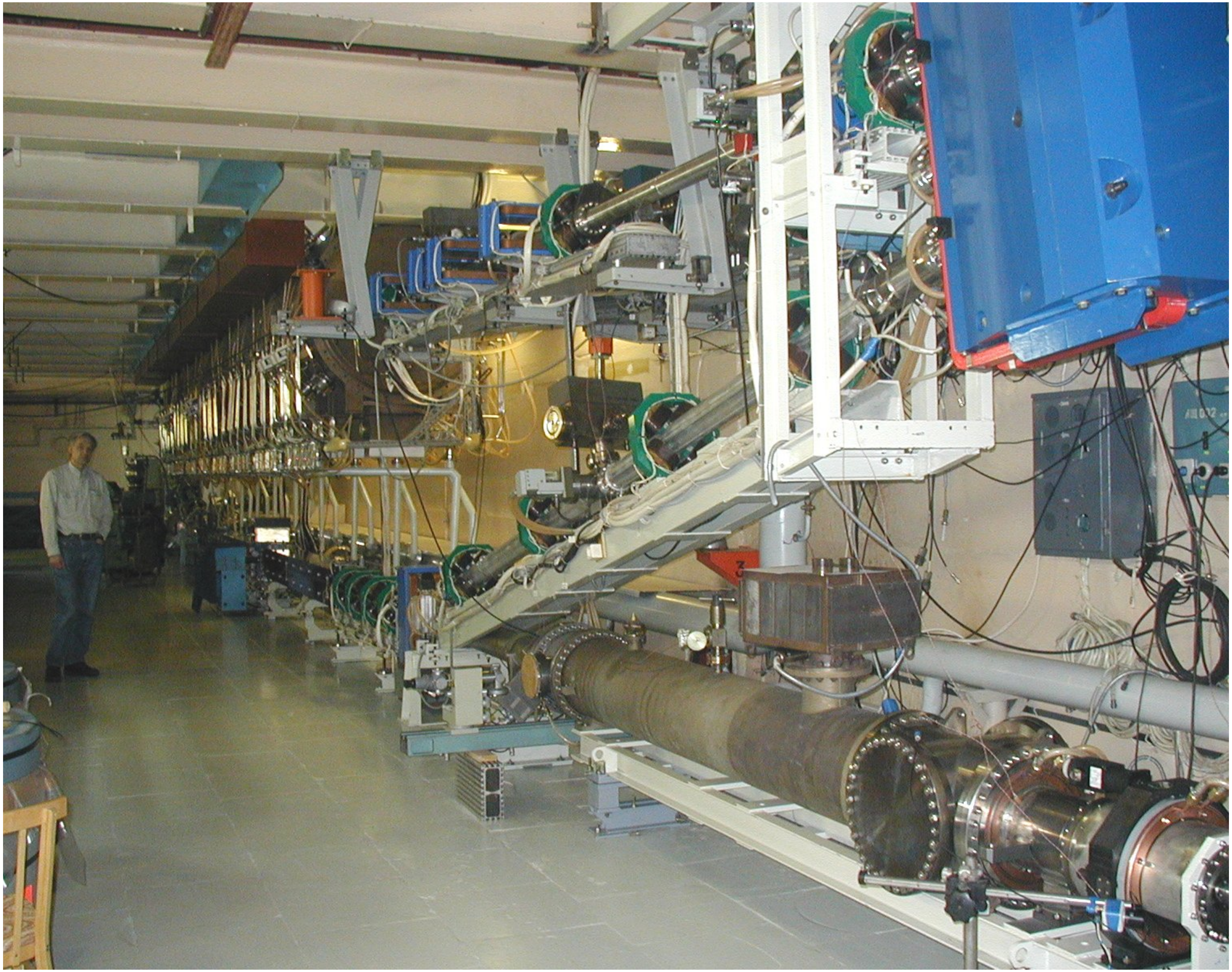
1 - injector, 2 - accelerating RF structure, 3 - 180-degree bends, 4 – undulator, 5 – beam dump, 6 – mirrors of optical resonator

Siberian Center for Photochemical Research

First stage: submillimeter (THz) FEL



Free Electron Laser



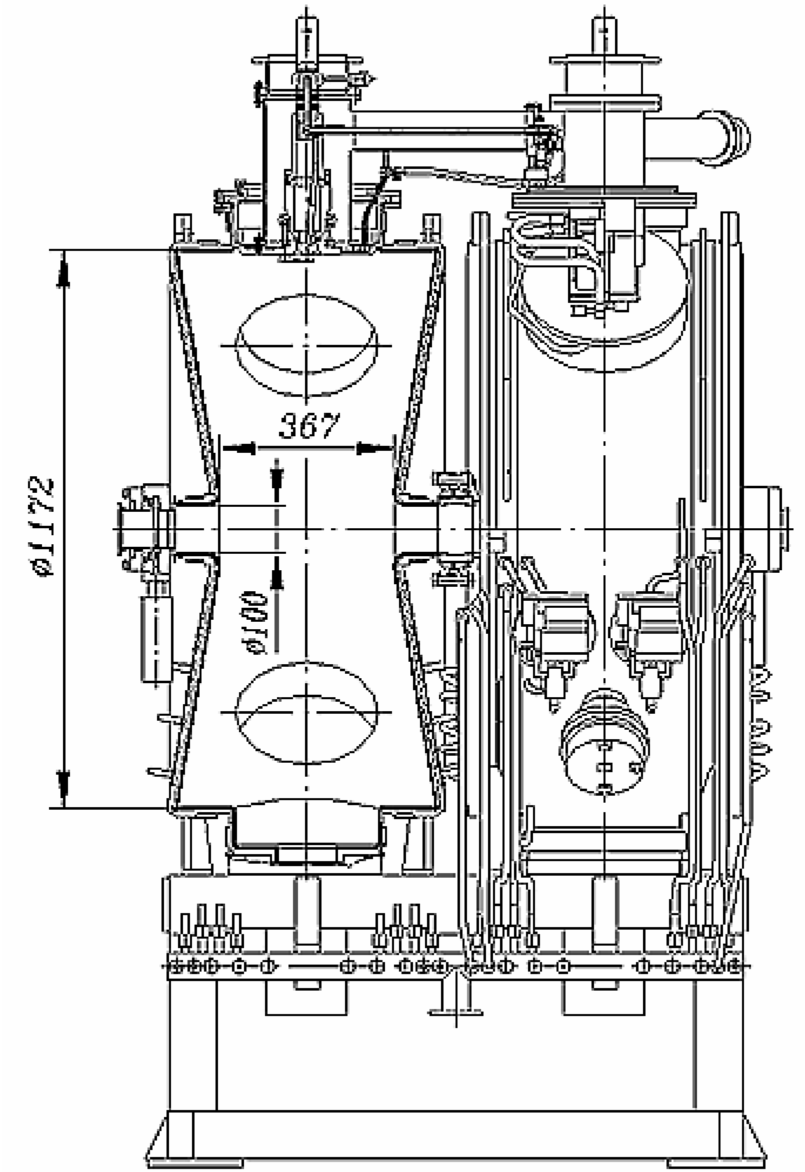
Features of RF system

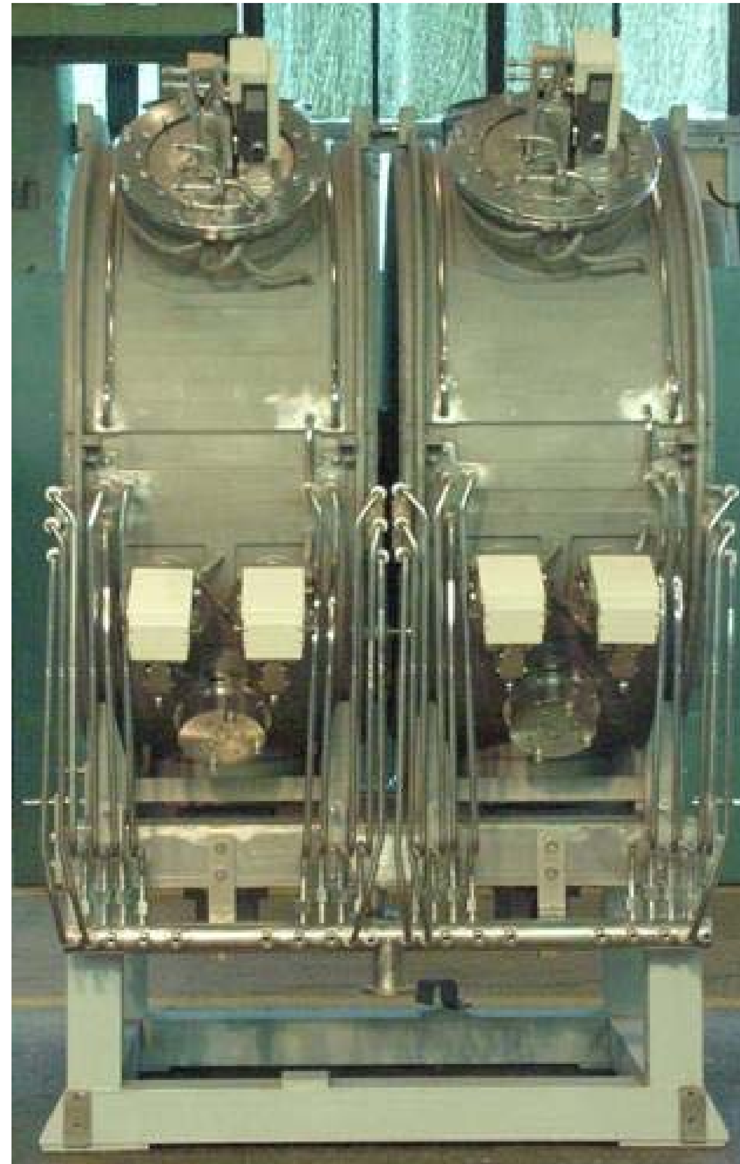
- Low frequency (180 MHz)
- Normal-conducting uncoupled RF cavities
- CW operation

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)
- Relaxed tolerances for orbit lengths and longitudinal dispersion

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





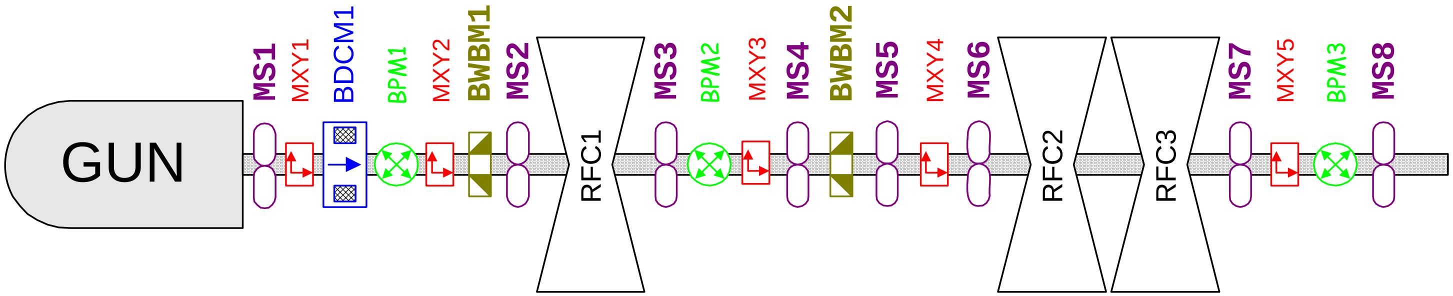
Bimetallic (copper and stainless steel) RF cavity tanks

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

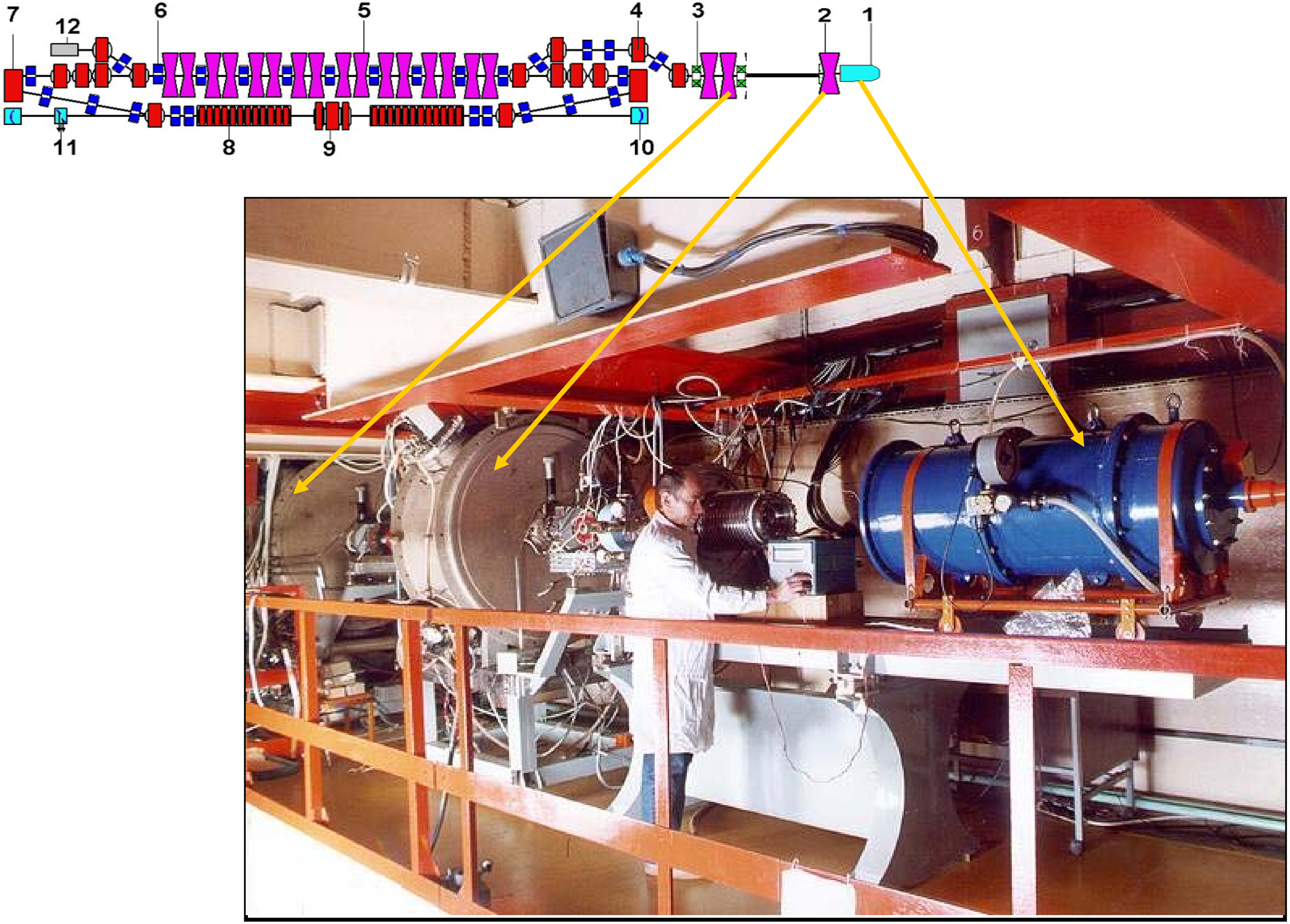
BWBM : strip line monitor

RFC : RF cavity

2 MeV Injector Parameters

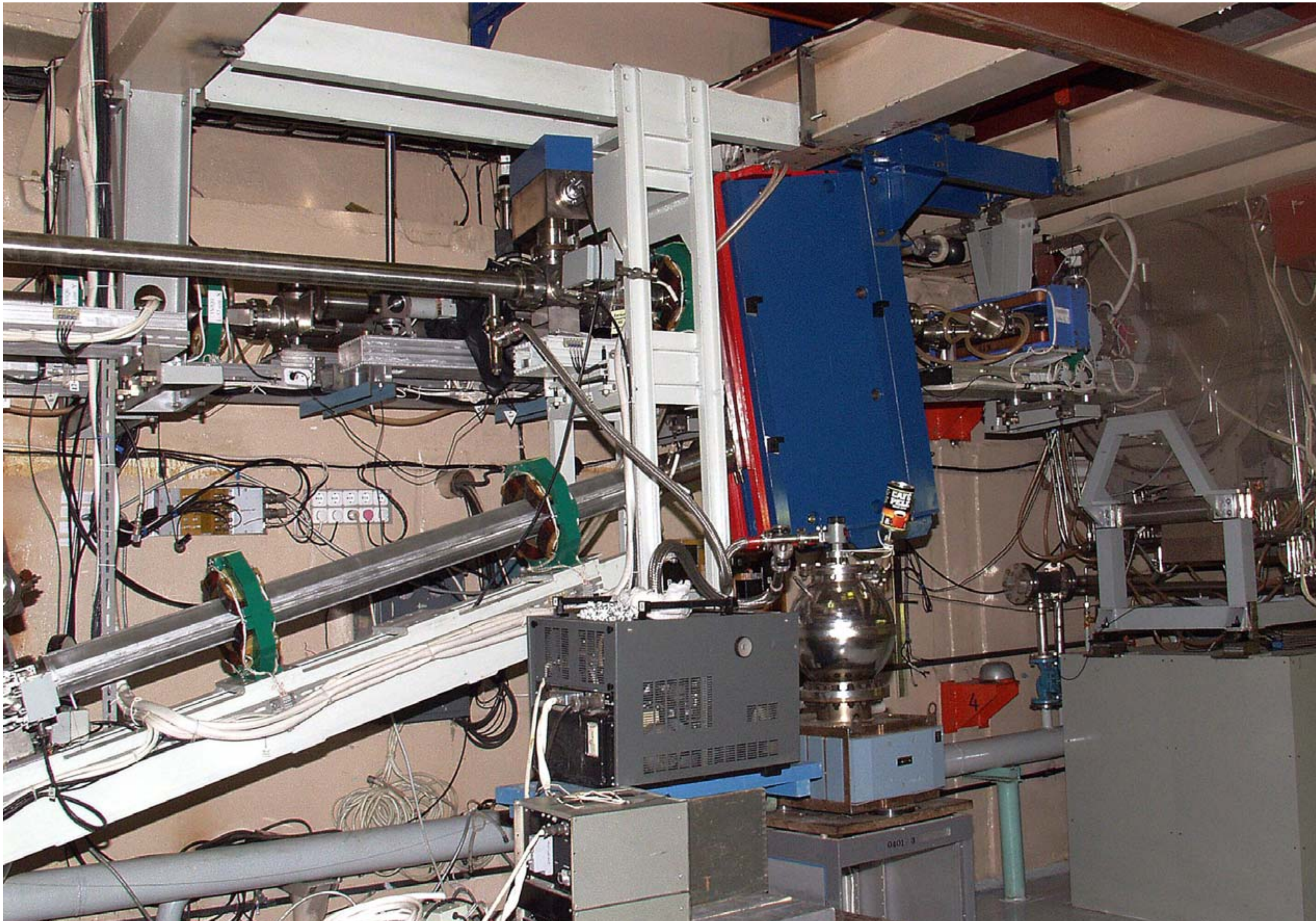
♦ Bunch repetition rate, MHz	up to 22.5
♦ Charge per bunch, nC	1.5
♦ Start bunch length, ns	1.5
♦ Final bunch length, ns	0.12
♦ Final energy, MeV	2

2 MeV injector



The second 2-MeV injector built for KAERI

Magnetic mirror returns electron beam to the RF structure



First Stage Accelerator-Recuperator: Machine Parameters

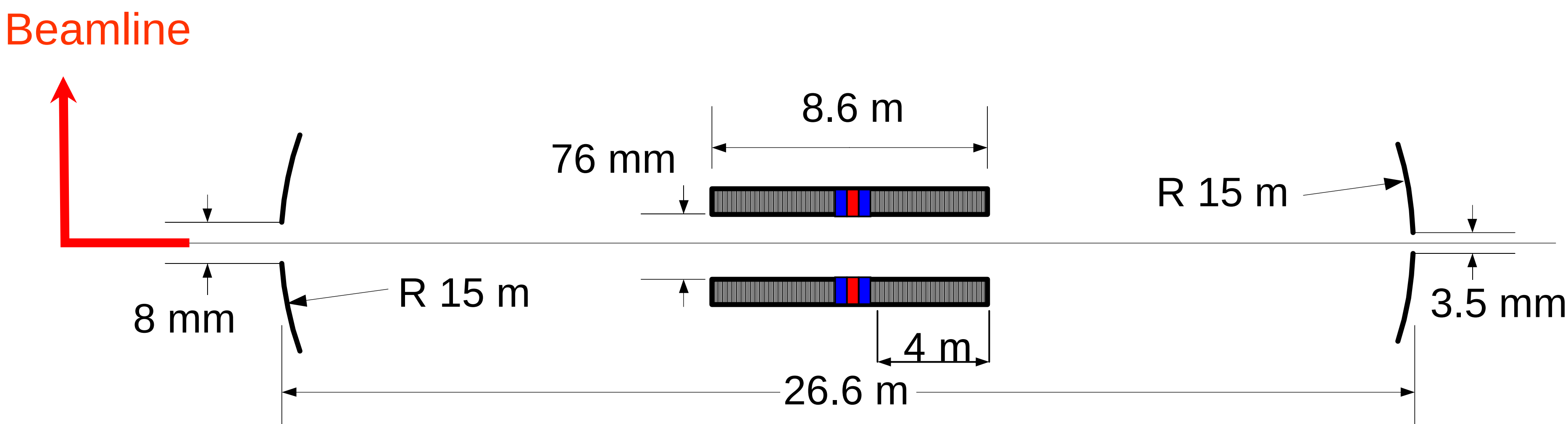
♦ Bunch repetition rate, MHz	11.2
♦ Average electron current, mA	20
♦ Maximum energy, MeV	12
♦ Bunch length, ps	100
♦ Normalized emittance, mm*mrad	30

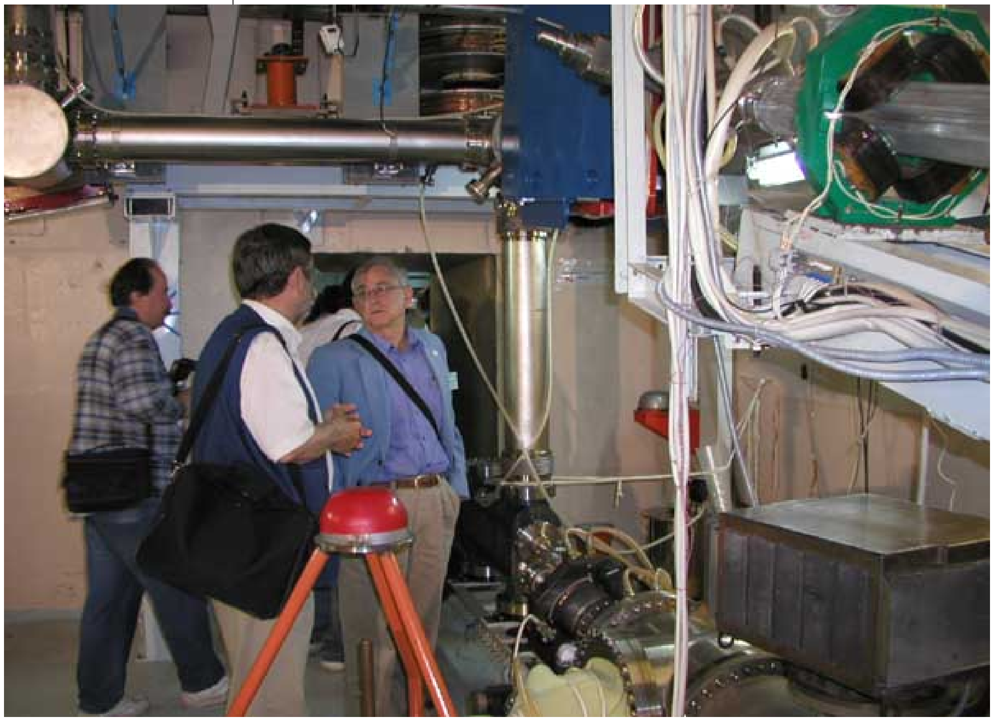
Undulator parameters (one section)

♦ 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 cavity and transmission line

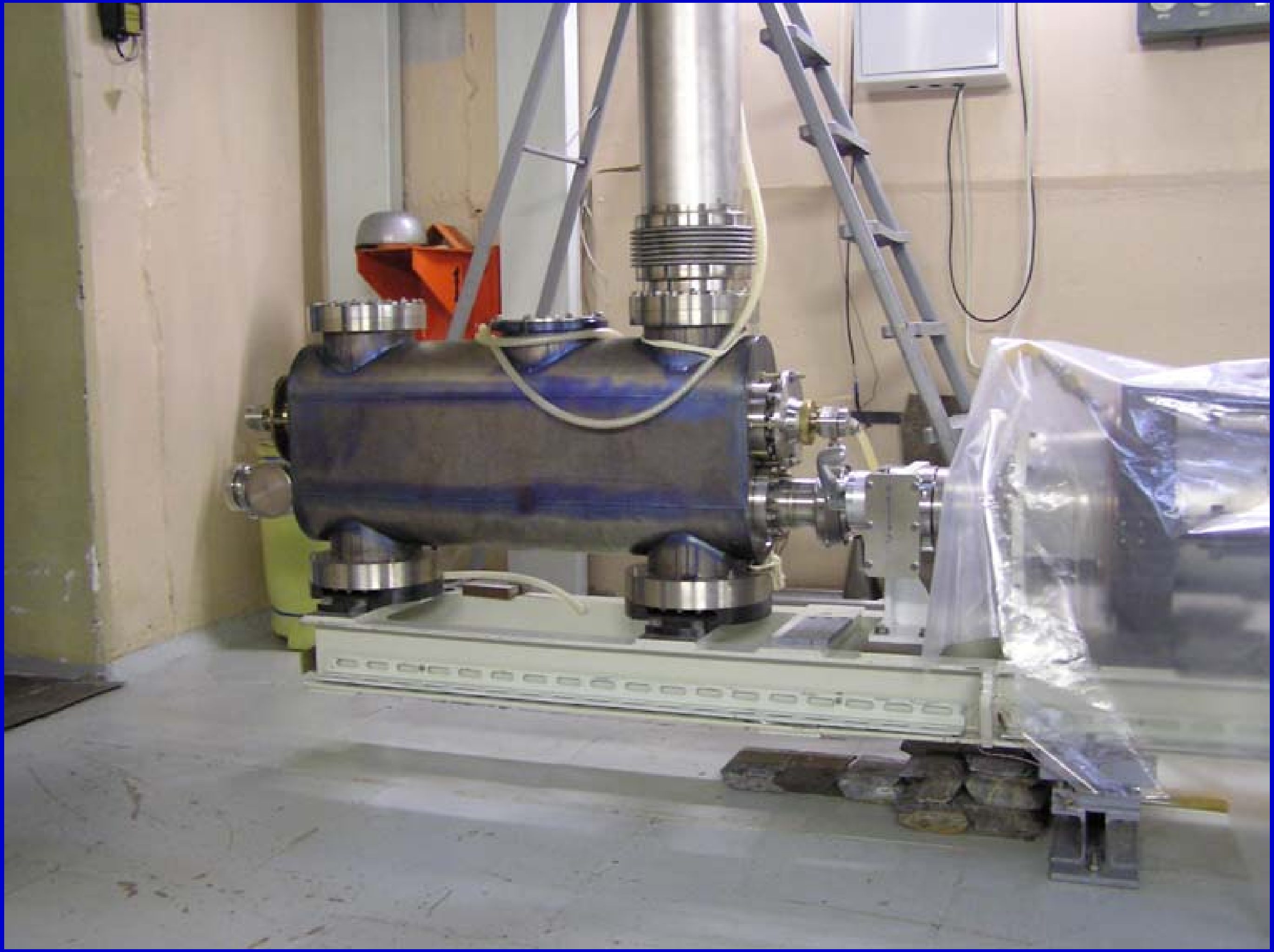




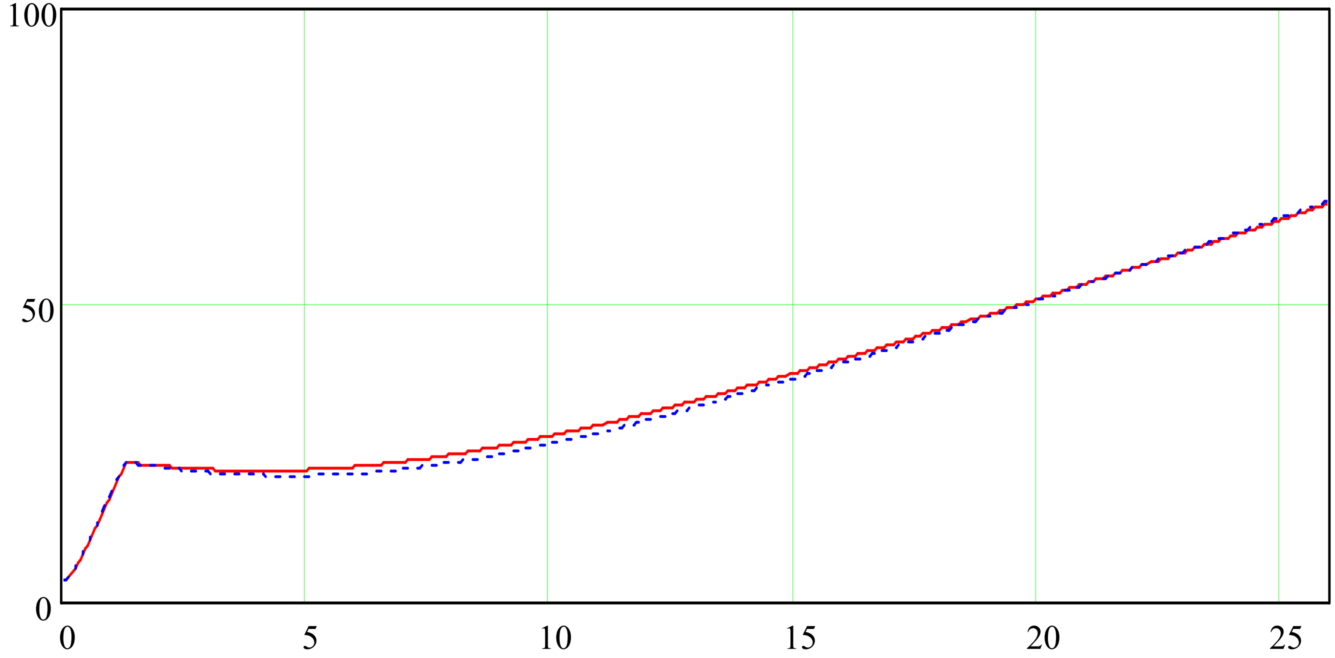
Beamline for radiation transport

Beamline outlets

Optical beam expander



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

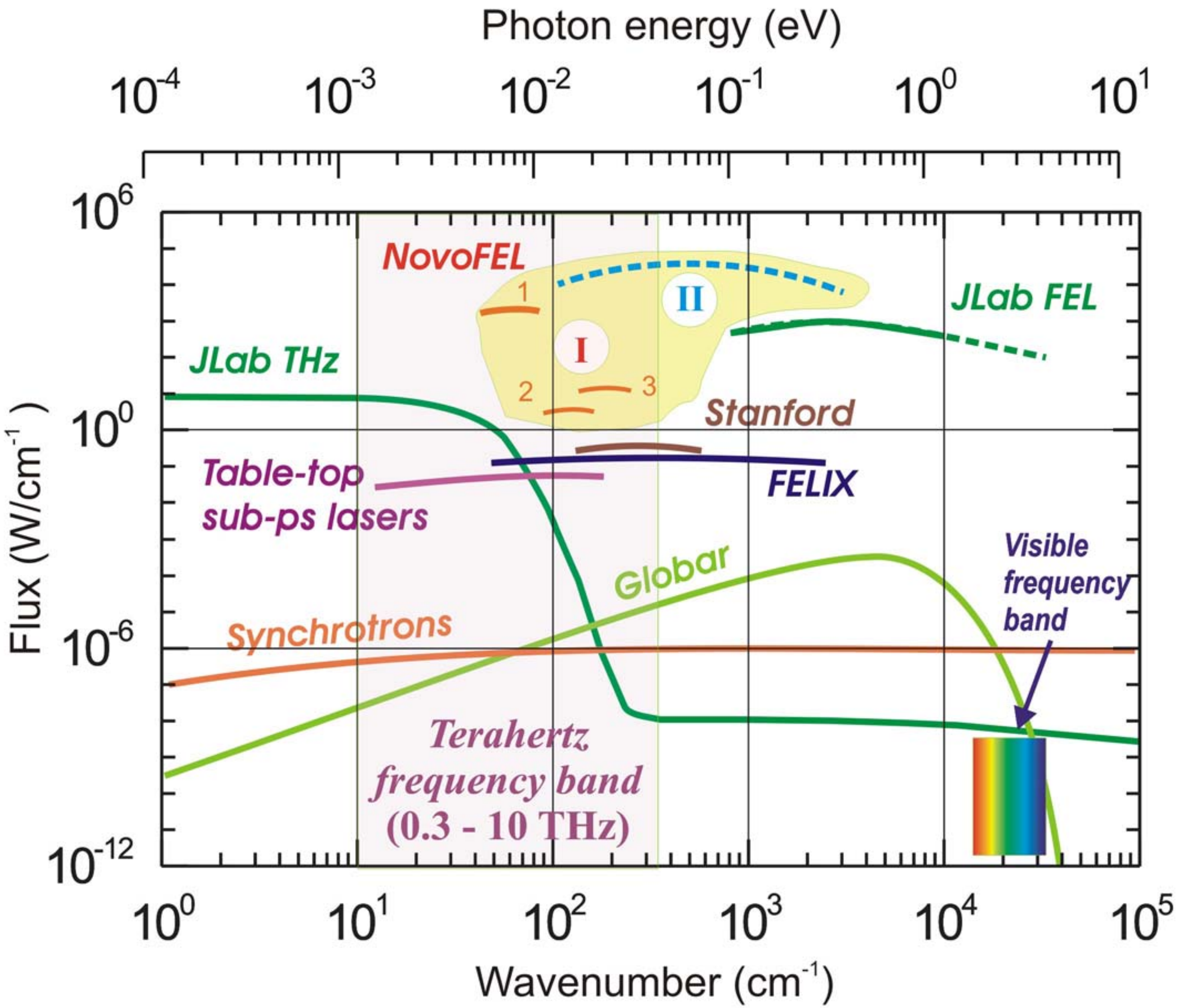


The end of the beamline with experimental stations

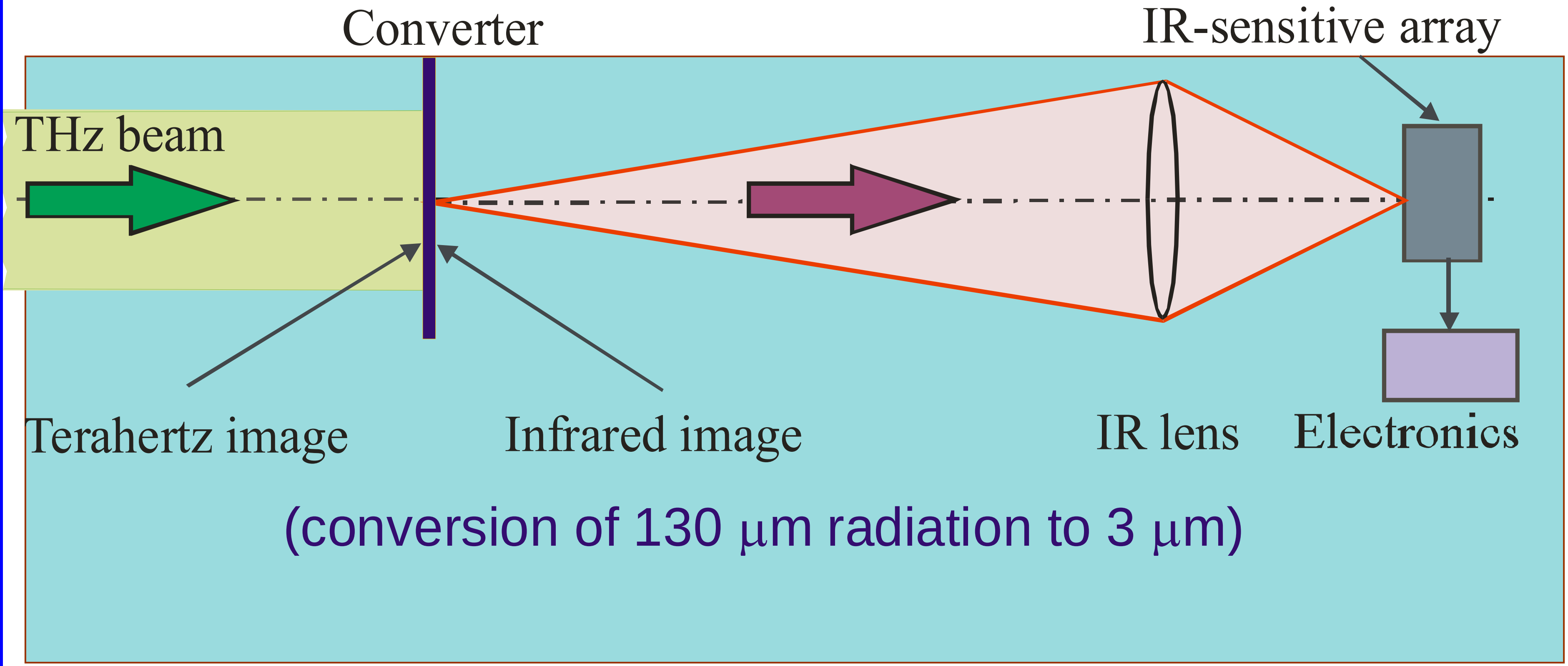
Free Electron Laser Parameters

♦ Wavelength, mm	0.12-0.23
♦ Pulse duration, FWHM, ps	70
♦ Pulse energy, mJ	0.04
♦ Repetition rate, MHz	11.2 (22.5)
♦ Average power, kW	0.4
♦ Minimum relative linewidth, FWHM	$3 \cdot 10^{-3}$

Radiation characteristics of THz sources

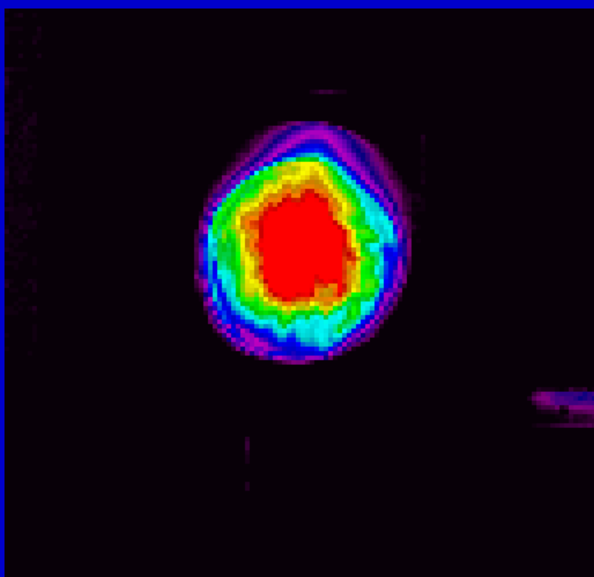


Visualization of THz radiation with IR TV camera

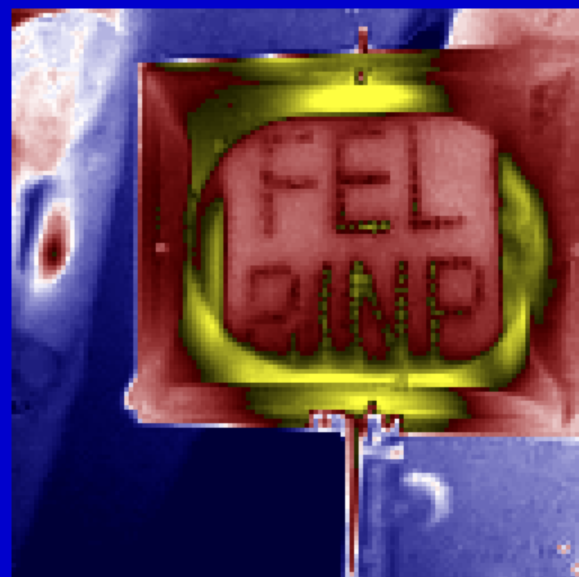


- Carbon paper screen serves as the convertor.
- Time resolution is about 1 s.

THz images



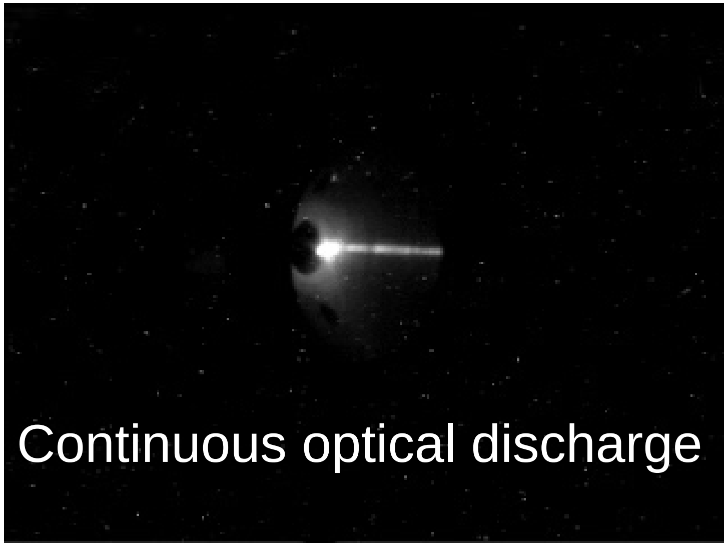
Beam profile

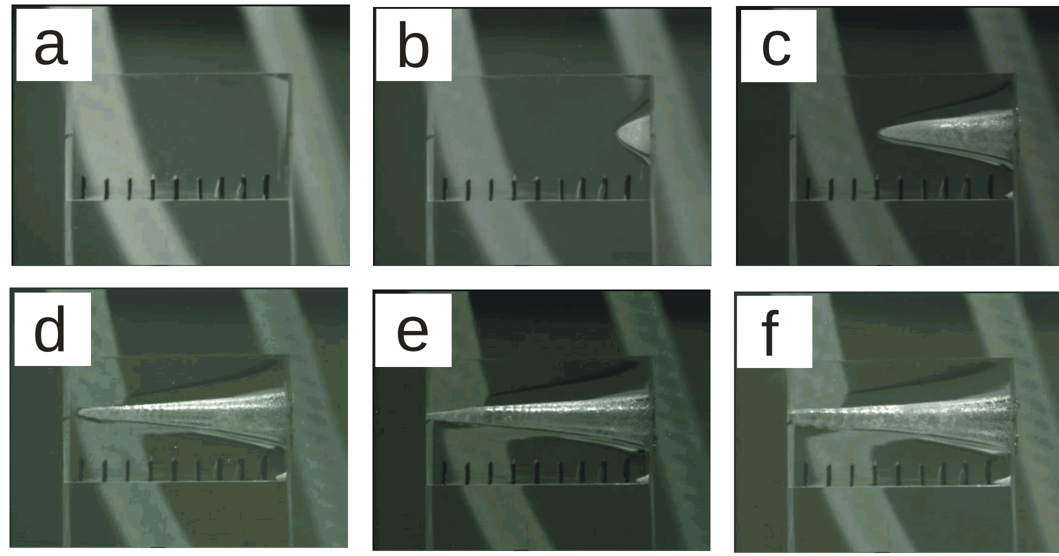


Metallic screen with holes

Keys inside paper envelope

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

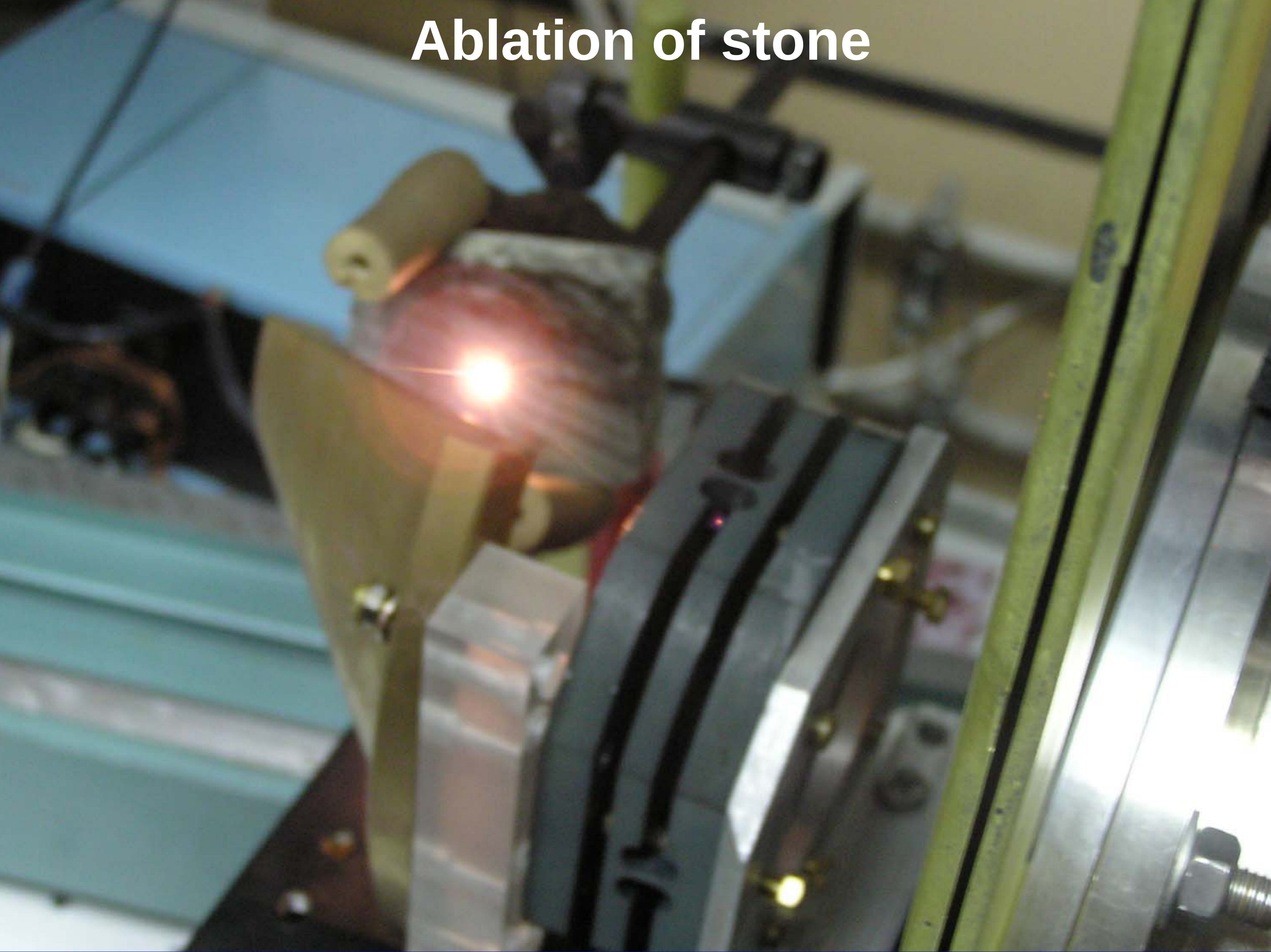




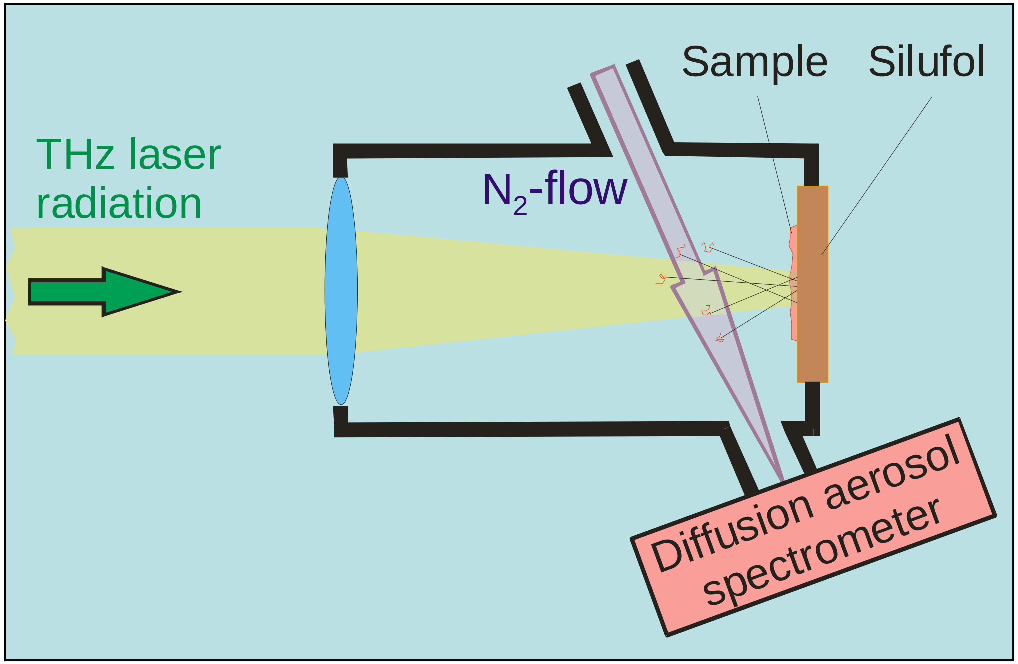
- Laser beam focused in the atmosphere with a parabolic mirror (f=1.0 cm) ignites a continuous optical discharge
- Unfocused laser beam drills an opening in 50-mm organic glass slab within three minutes (ablation without burning)
- These fenomena can be used for many fundamental and applied experiments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

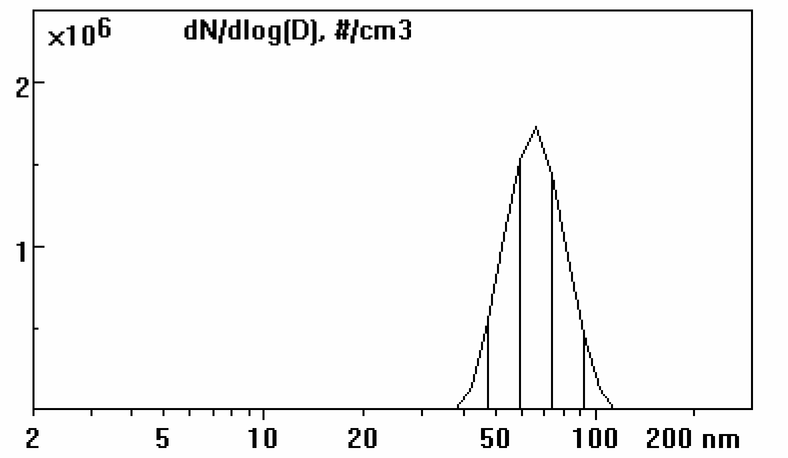
Biological user group at their station

Ablation of stone

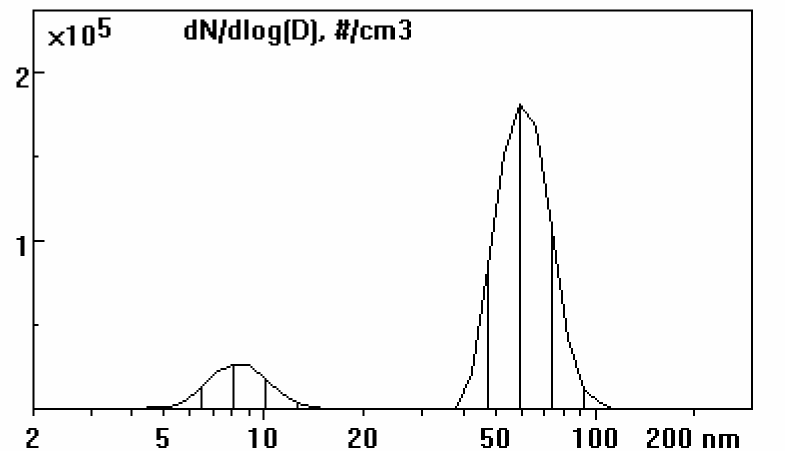


Ultra-soft laser ablation of DNA





Phage DNA



Phage DNA + plasmide DNA

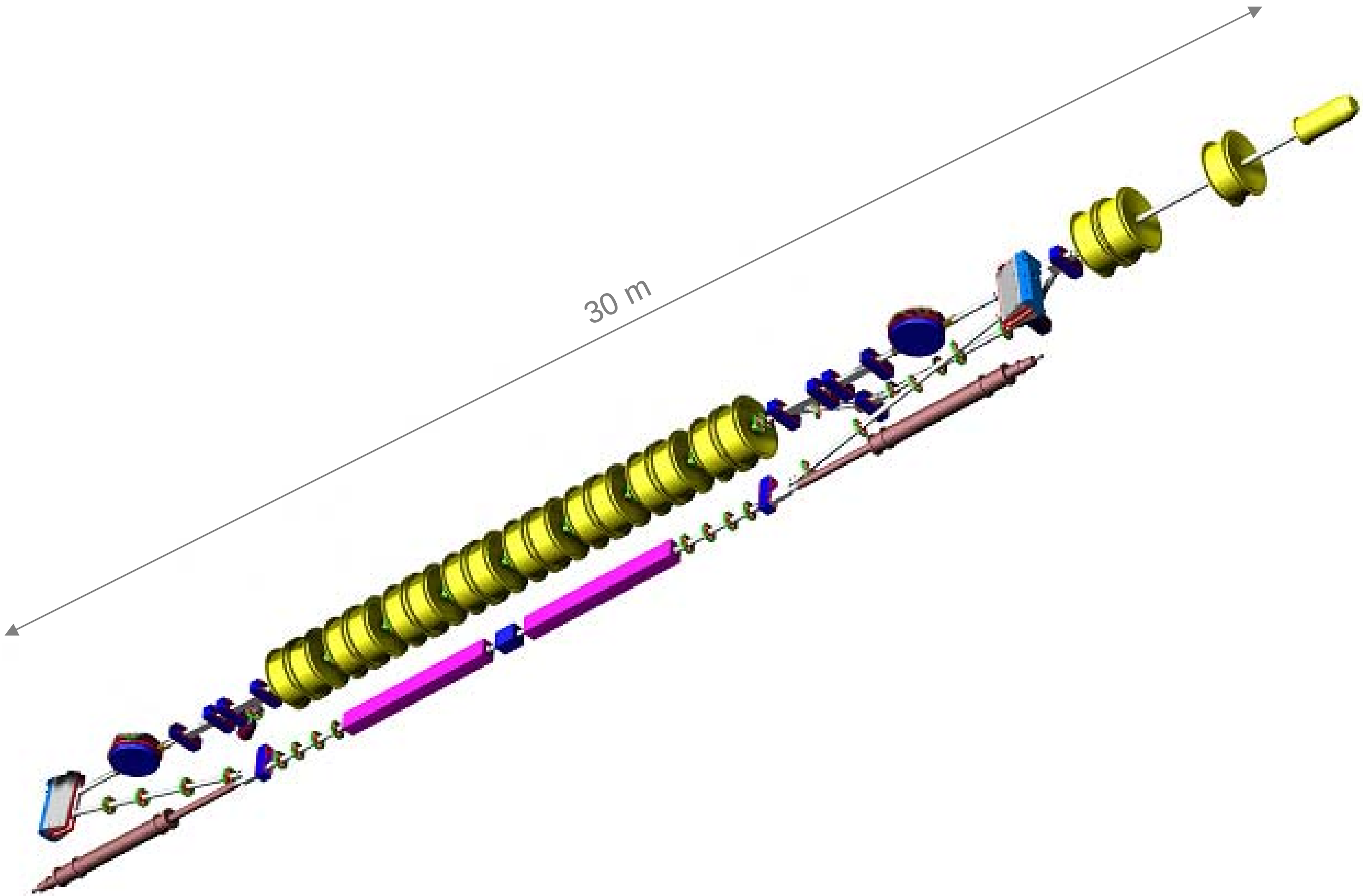
Demonstration of ultra-soft ablation of DNA samples without denaturation: when the power density of THz radiation is optimal, particle size spectra contain only the peaks corresponding to the initial particles. For higher power densities multi-peak spectra are observed.

Second stage of accelerator-recuperator and FEL

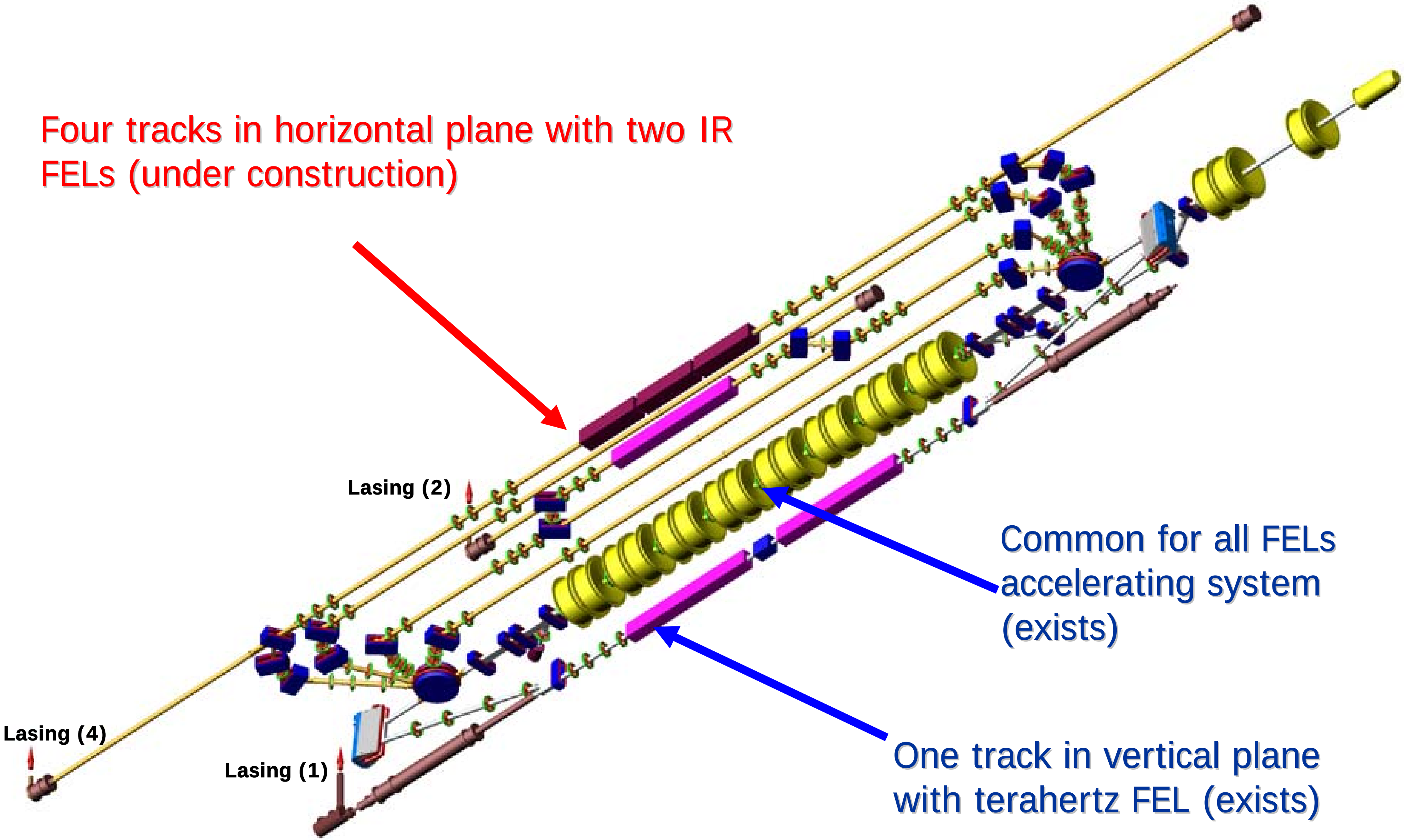
A full-scale 4-track accelerator-recuperator uses the same accelerating structure as the accelerator-recuperator of the 1st stage, but, in contrast to the latter, it is placed in the horizontal plane. Thus, the possibility to run the old FEL is conserved.

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.

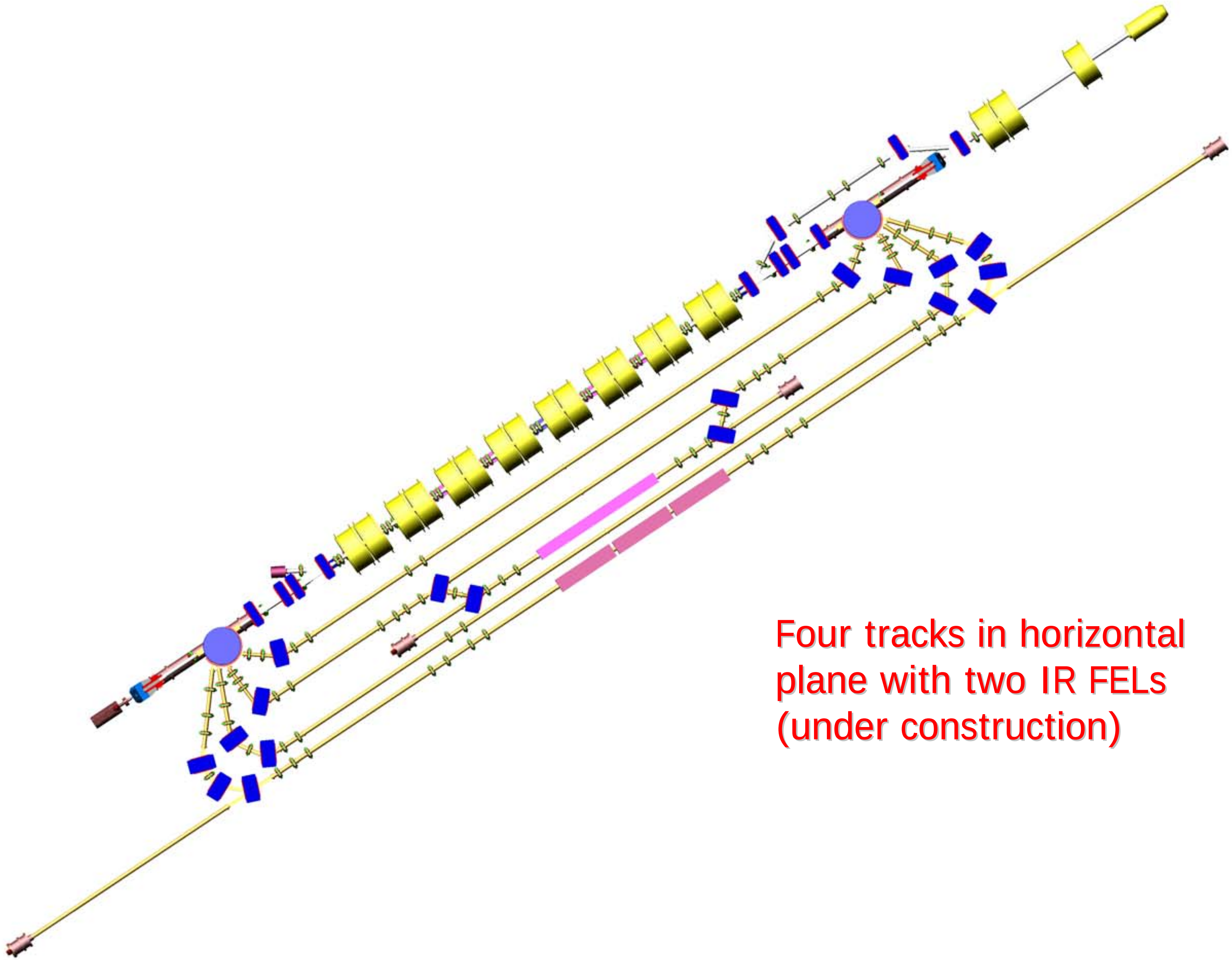
First stage of accelerator-recuperator and FEL



Full scale Novosibirsk FEL (bottom view)



Full scale Novosibirsk FEL (top view)

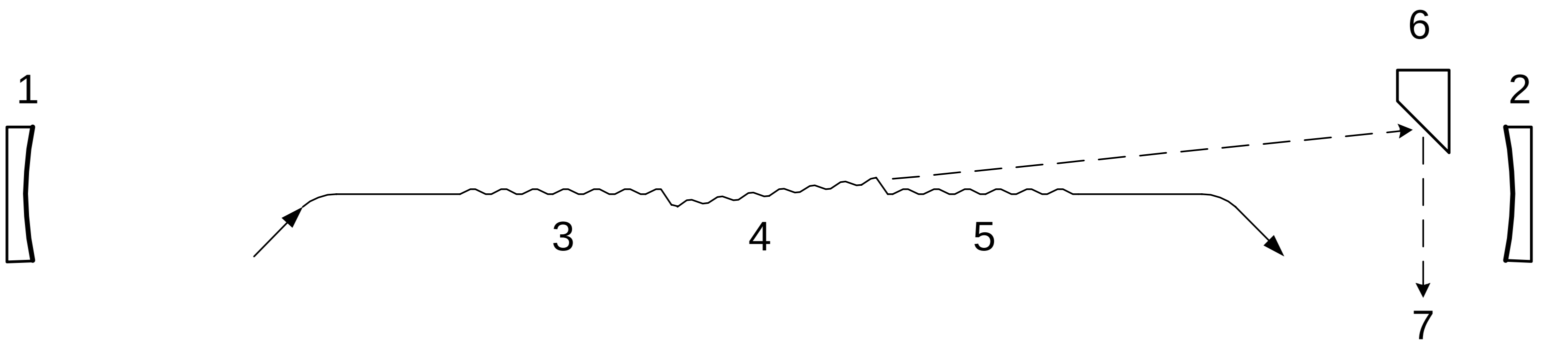


Four tracks in horizontal plane with two IR FELs (under construction)

Full scale FEL parameters

Electron beam energy, MeV	40
Number of orbits	4
Maximum bunch repetition frequency, 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.

Conclusion

- First 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.