Status of the Novosibirsk Terahertz FEL

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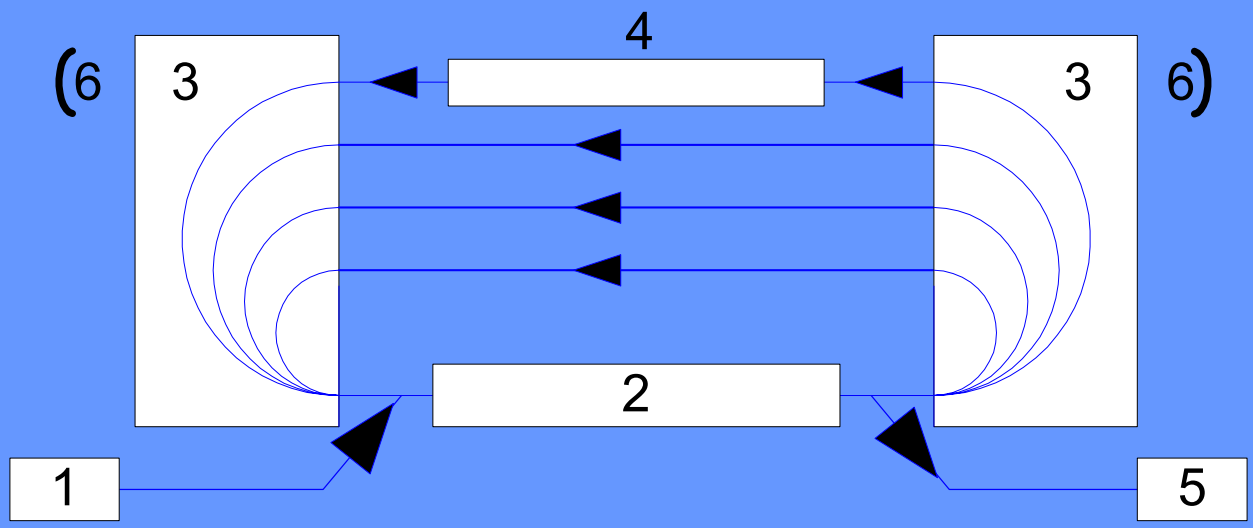
As the electron efficiency of FEL is low (~1%), the energy recovery is necessary for a high average power FEL.

Energy recovery

(i) decrease radiation hazard dramatically and

(ii) provide possibility to achieve high average beam current.

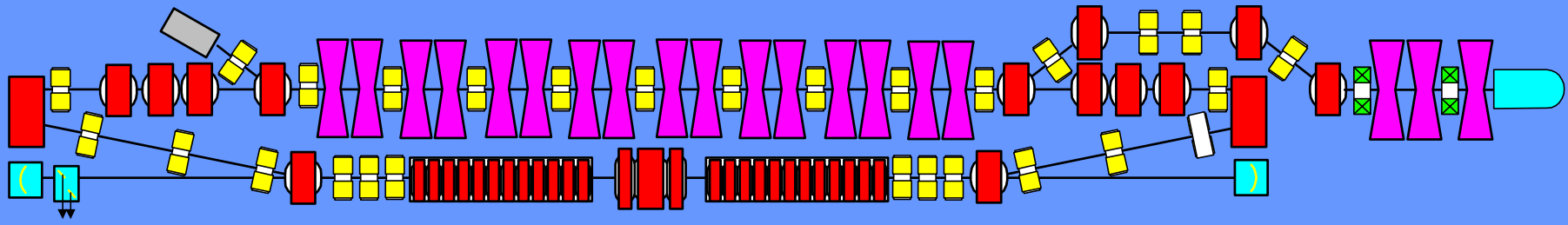
FEL based on accelerator-recuperator



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



RF-Cavities Bending Magnets Quadrupoles Solenoids

Undulators Buncher Mirrors Outcoupler

Accelerator-recuperator for FEL

Free Electron Laser

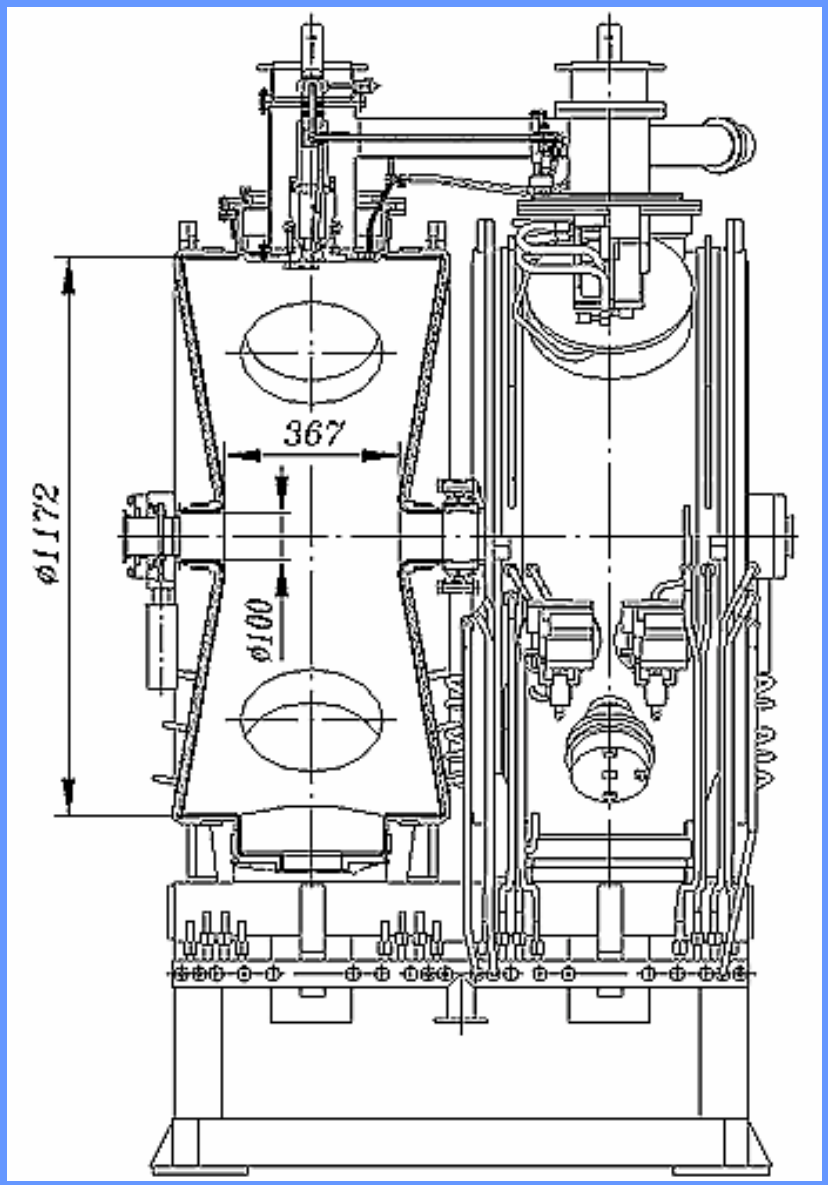
Features of RF system

- 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

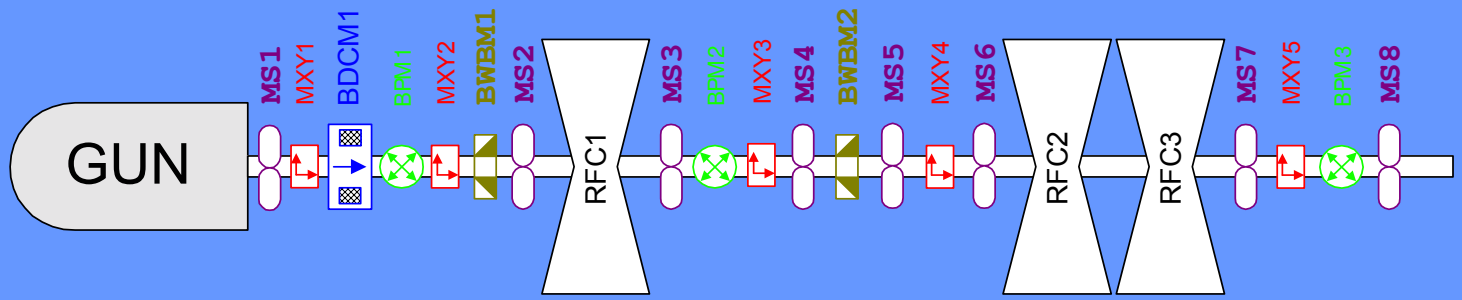
(for the fundamental TM_{010} mode)

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

1 MW RF generator hall

Tetrode-based output amplifier stages

2 MeV injector



MS : focusing solenoid

MXY : steering magnet

BDCM : beam current monitor

BPM : bean position monitor

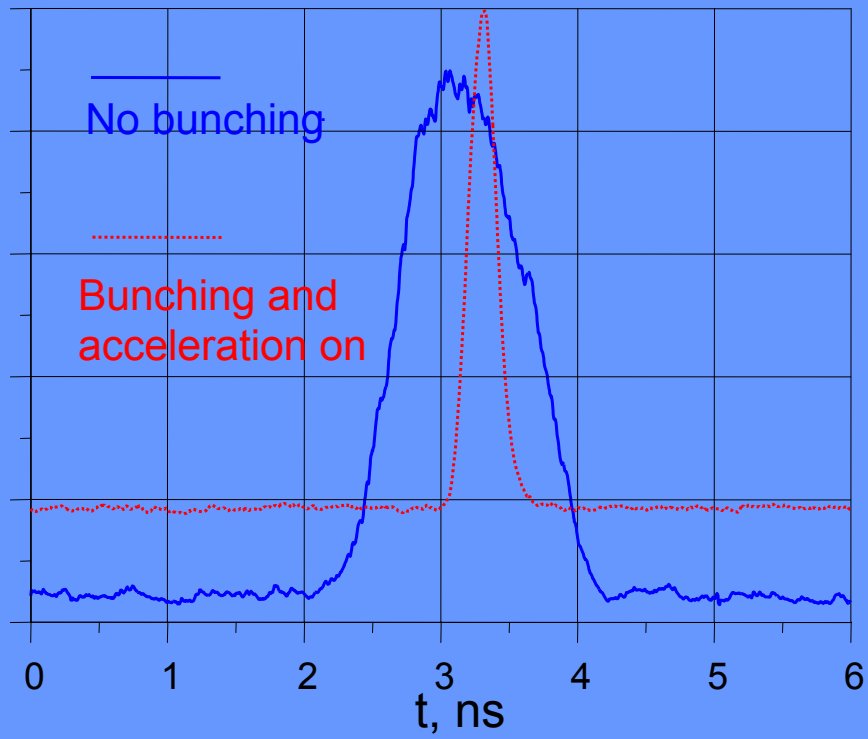
BWBM : strip line monitor

RFC : RF cavity

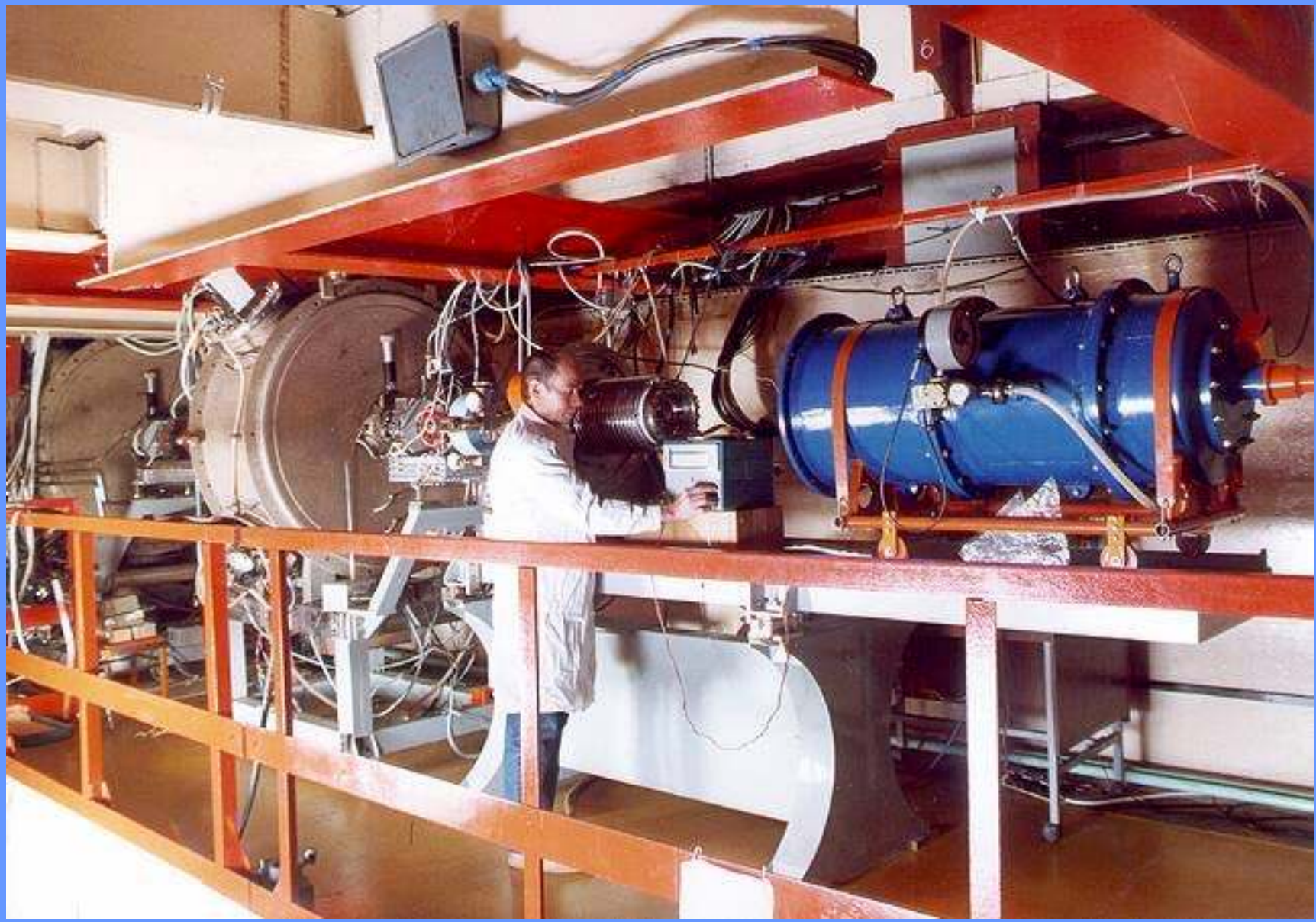
2 MeV Injector Parameters

♦ 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

Bunch profiles before and after bunching and acceleration

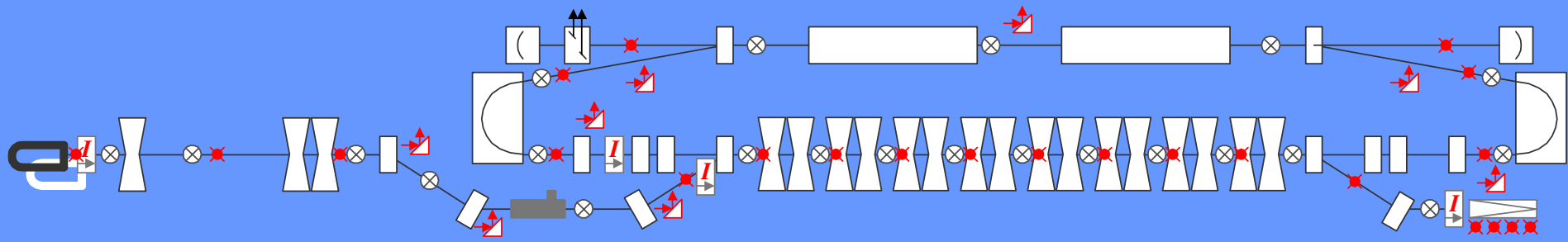


The 2 MeV injector



The second 2-MeV injector built for KAERI

Beam diagnostic system



- Beam position monitors
- Optical transition radiation screens
- Temperature monitors
- Beam average current monitors
- Dissector

Injection chicane

Magnetic mirror returns electron beam to the RF structure

First Stage Accelerator-Recuperator: Machine Parameters

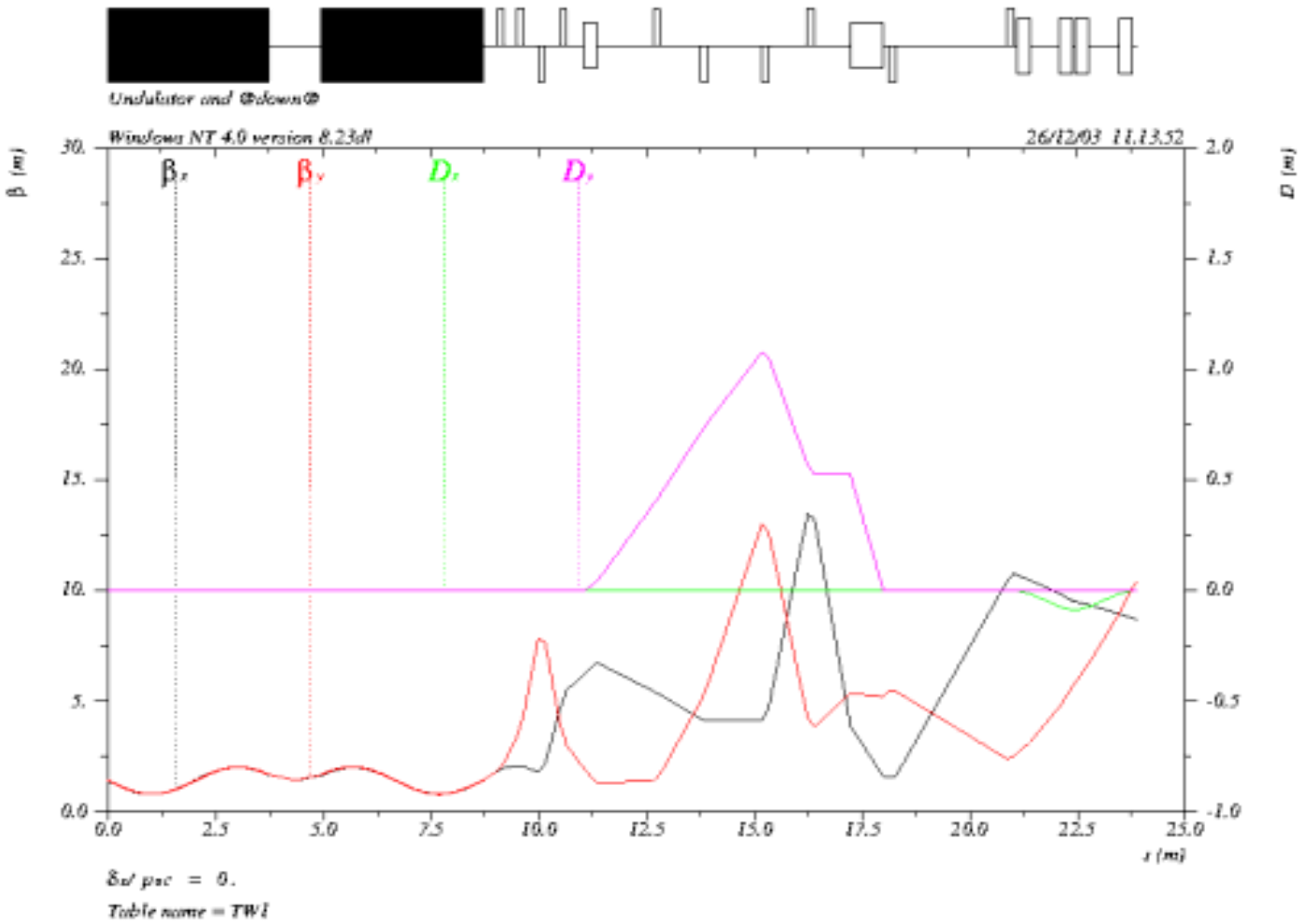
♦ Bunch repetition rate, MHz	22.5
♦ Average electron current, mA	20
♦ Maximum energy, MeV	12
♦ Bunch length, ps	100
♦ Normalized emittance, mm*mrad	30

Undulators parameters (one section)

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

Undulators, buncher and accelerating RF cavities

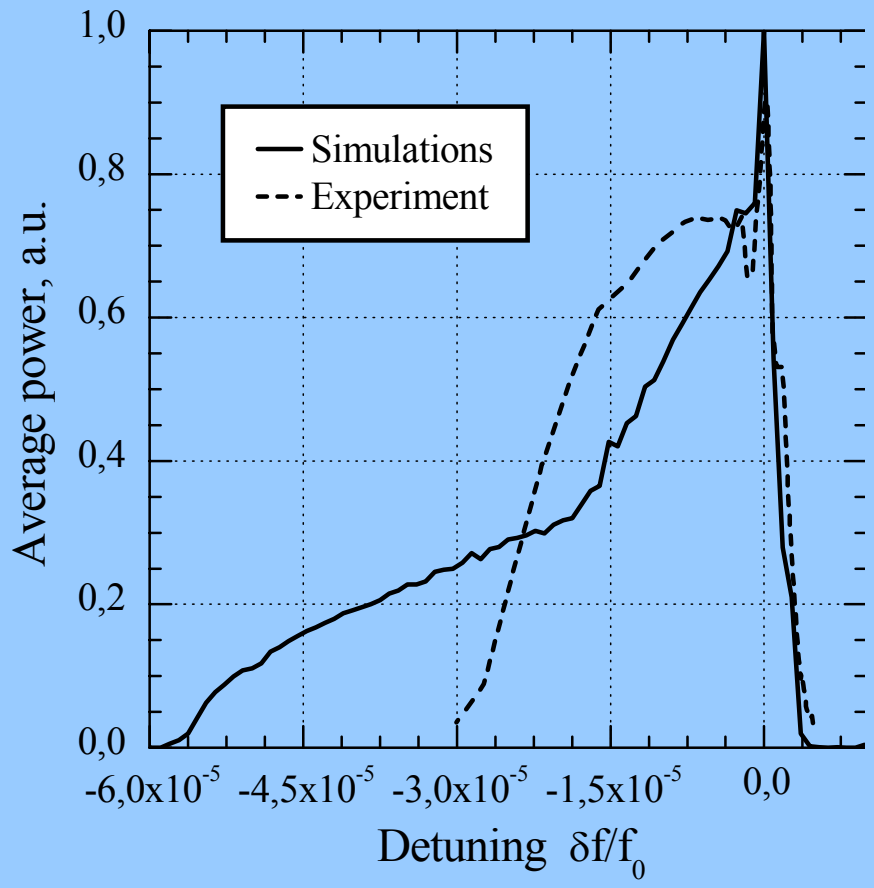
Lattice functions in undulator, 180-degree achromatic bend and injection chicane



Free Electron Laser Parameters

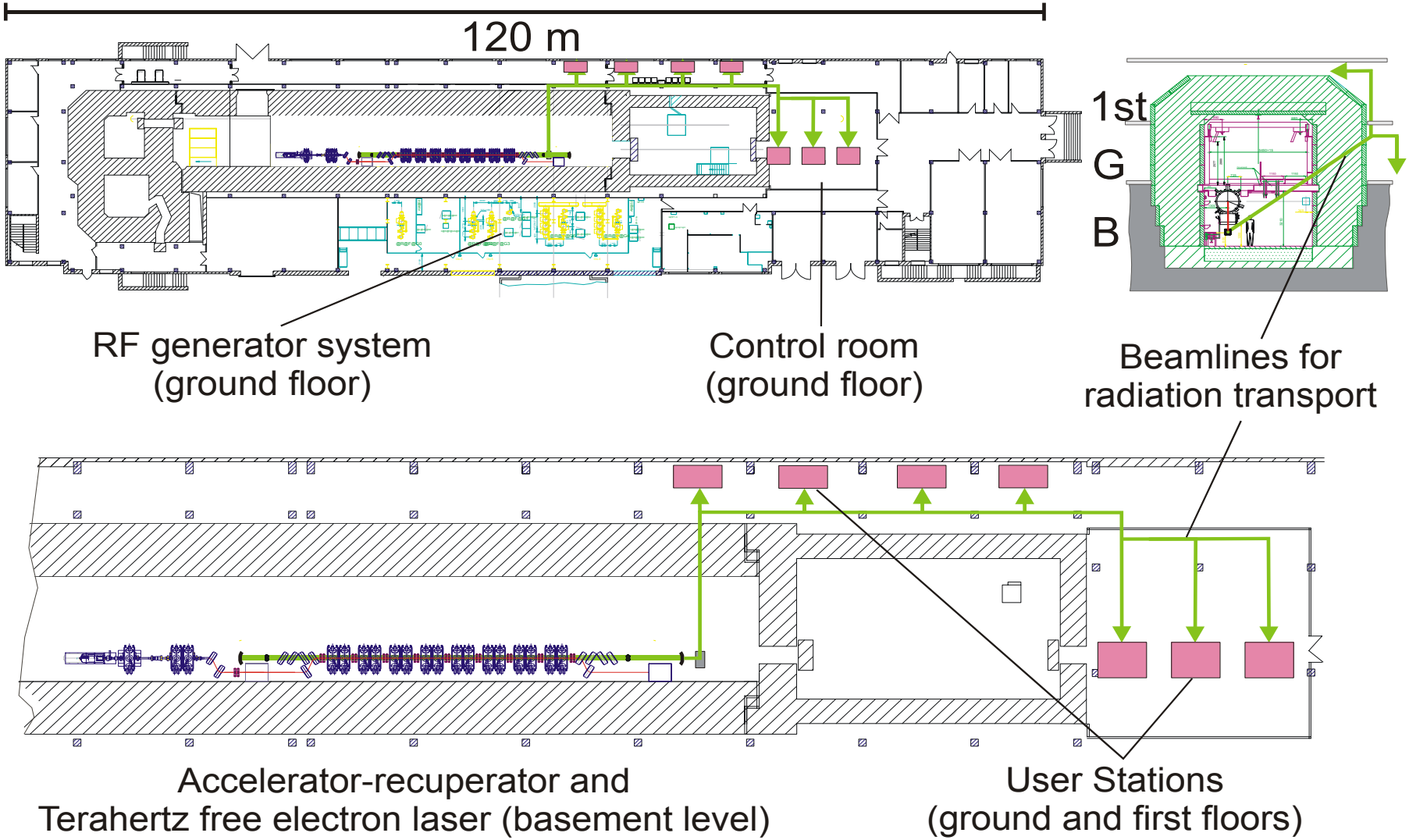
♦ Wavelength, mm	0.12-0.18
♦ Pulse duration, FWHM, ps	70
♦ Pulse energy, mJ	0.04
♦ Repetition rate, MHz	5.6 (22.5)
♦ Average power, kW	0.2
♦ Minimum relative linewidth, FWHM	$3 \cdot 10^{-3}$

Mirror of the optical resonator (inside)

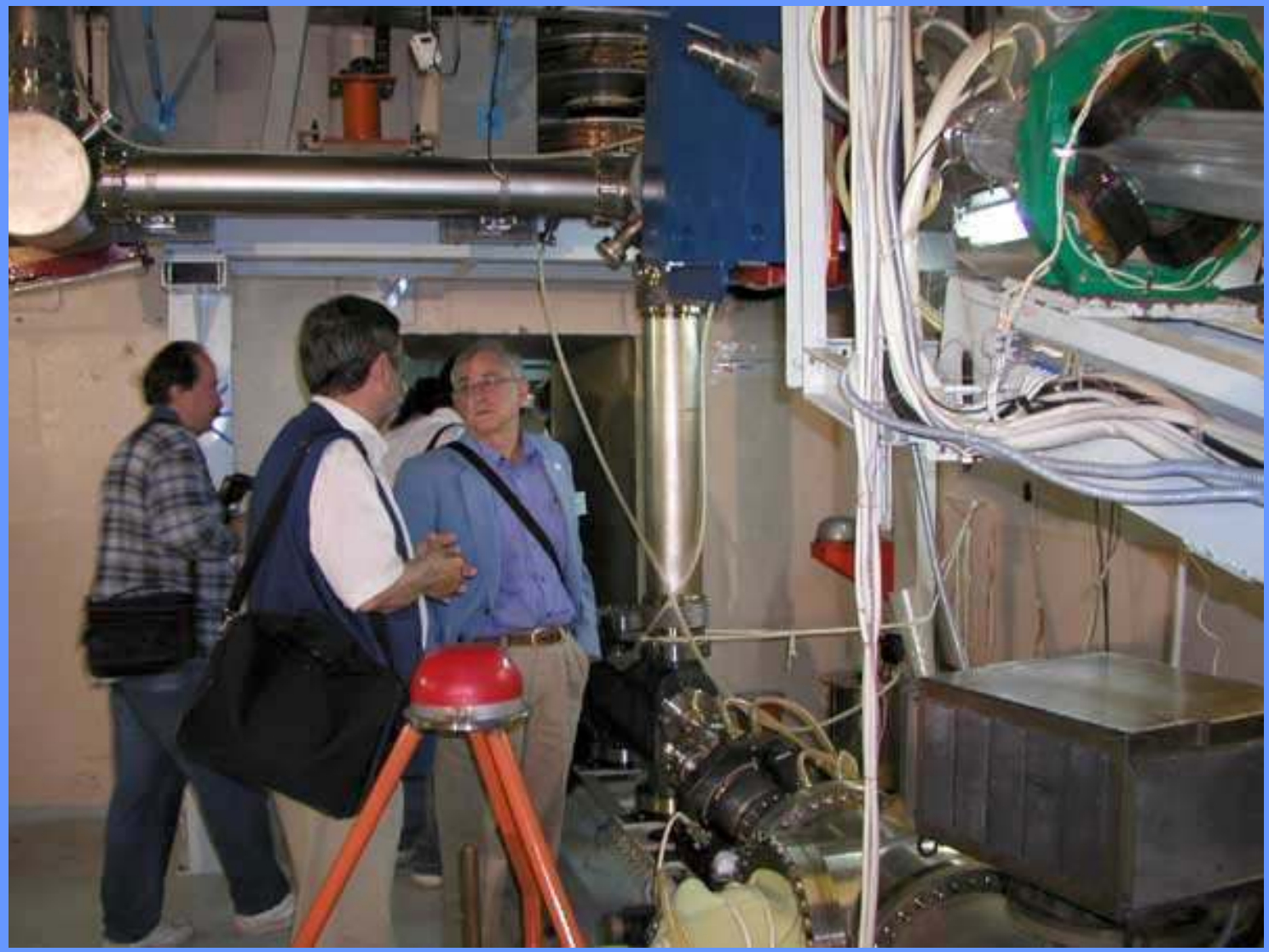


Dependence of the average power on the RF detuning

Layout of terahertz FEL and user stations



The beamline from the hole in the rear mirror to the user hall



The beamline from the hole in the rear mirror to the user hall

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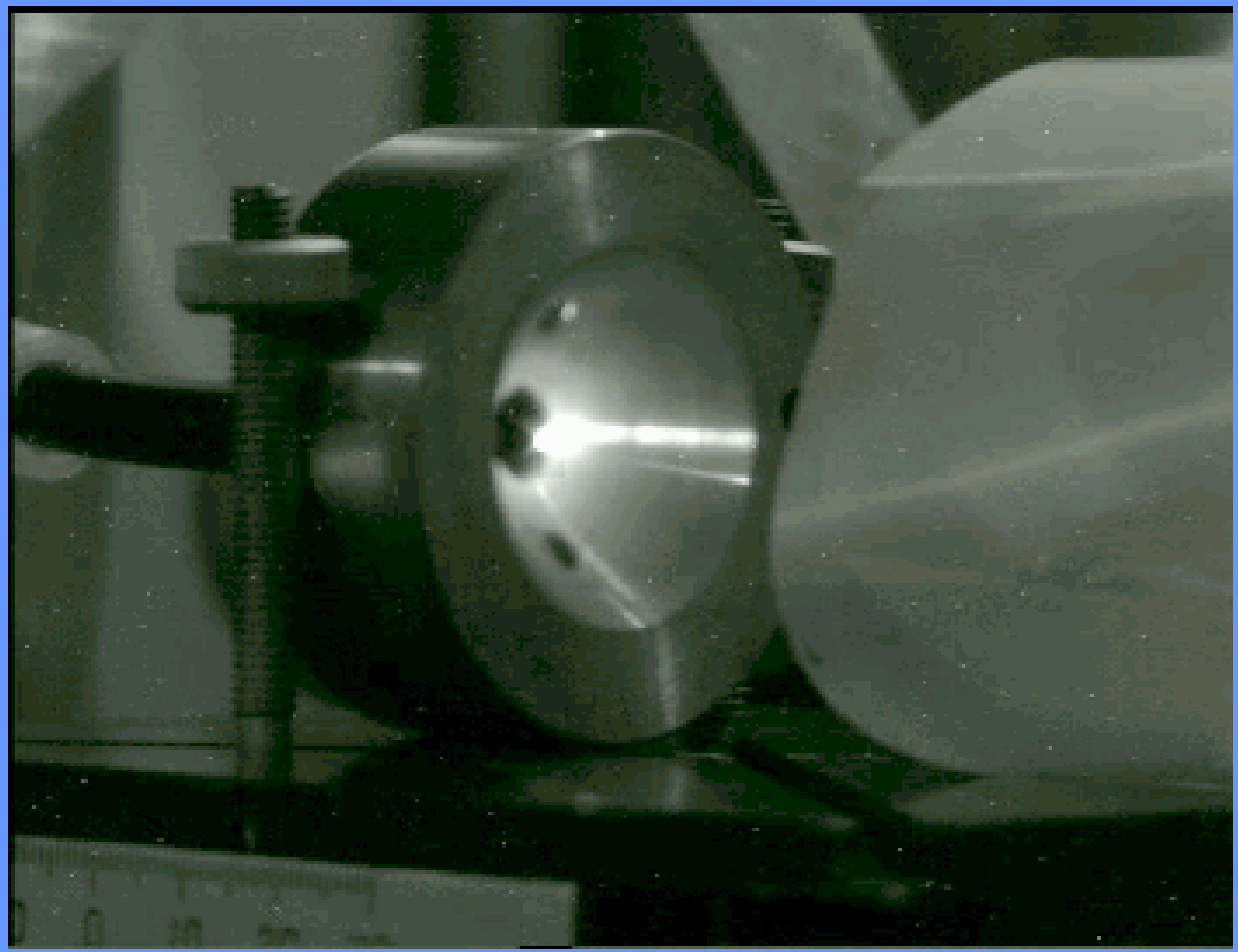
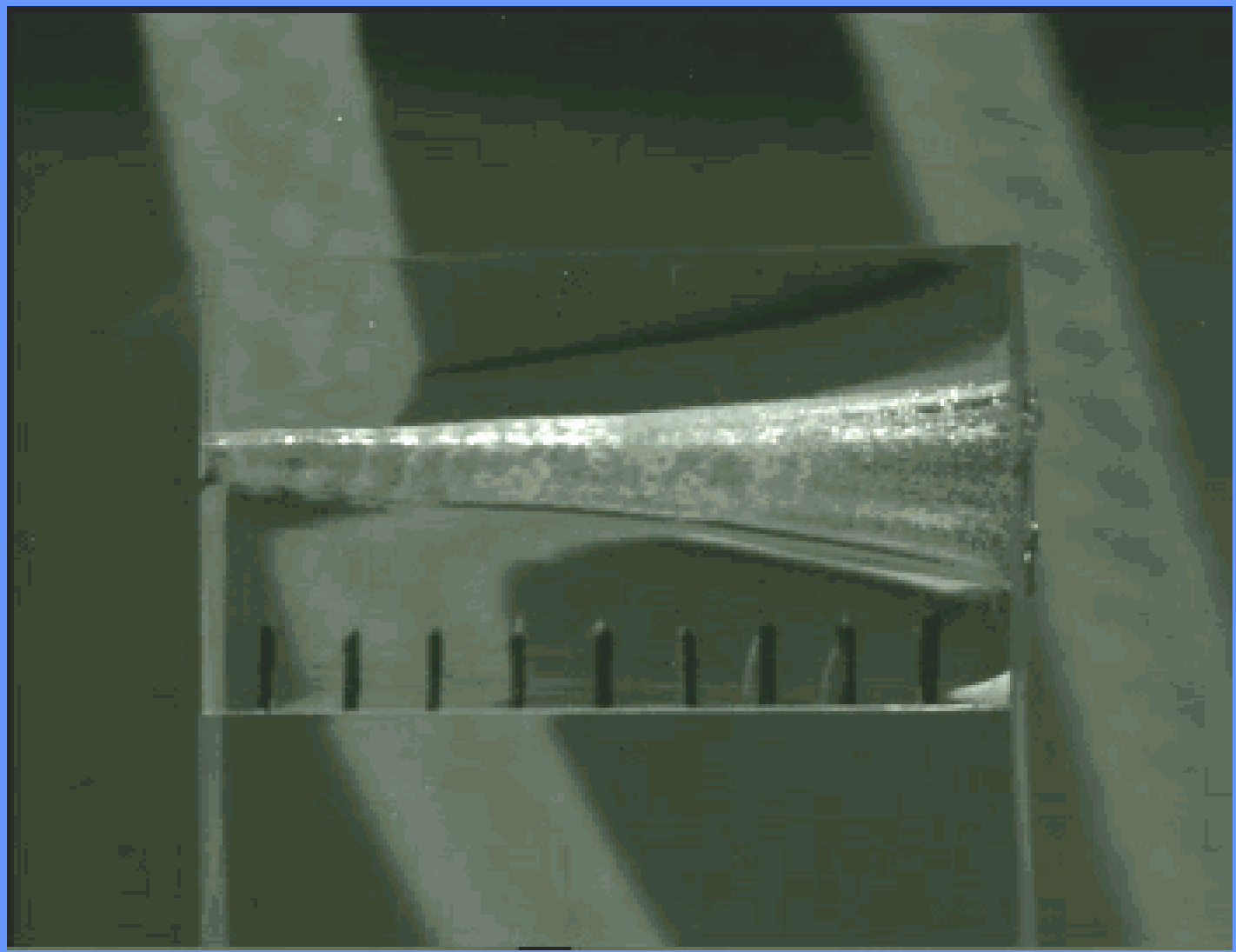
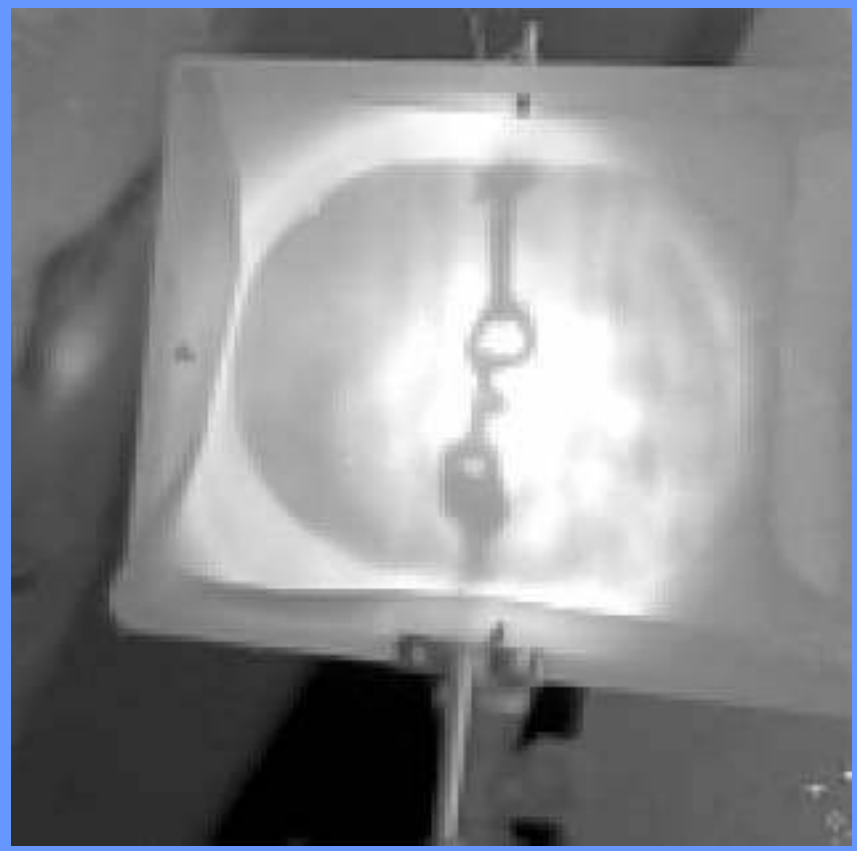
CW terahertz discharge in air



The conic hole in the PMMA cube, done with the terahertz radiation ablation. One division is 5 mm.



The terahertz image of keys inside the non-transparent envelope



Second stage FEL Parameters

Electron beam energy, MeV	50
Number of orbits	4
Maximum bunch repetition frequency, MHz	90
Beam average current, mA	150
Wavelength range, micron	3-20
Output power, kW	10

Conclusion

- Free electron laser is in operation now.
- The work to increase the average power is continuing.
- The beamline for transport of radiation to user stations is commissioned.
- First user station is designed.
- The design of the second stage of FEL is in progress.
- First optical experiments were performed.