The FEL-THz facility driven by a photo-cathode injector

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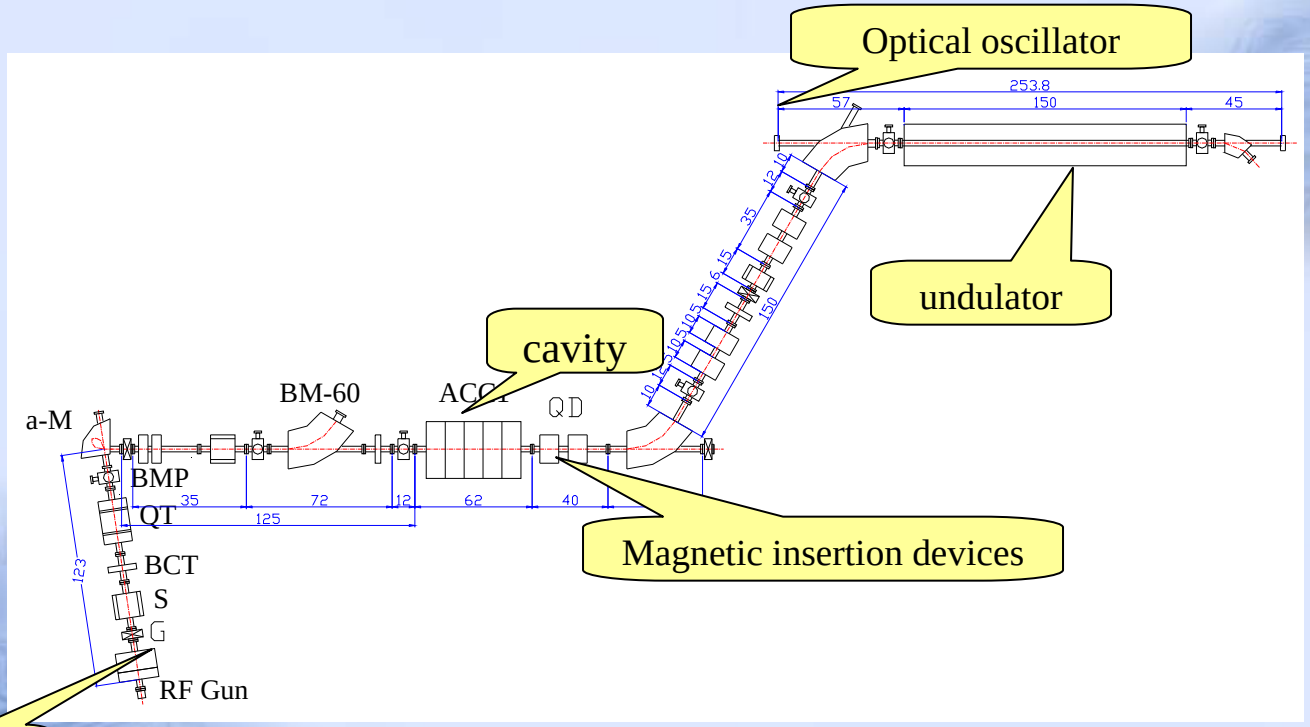
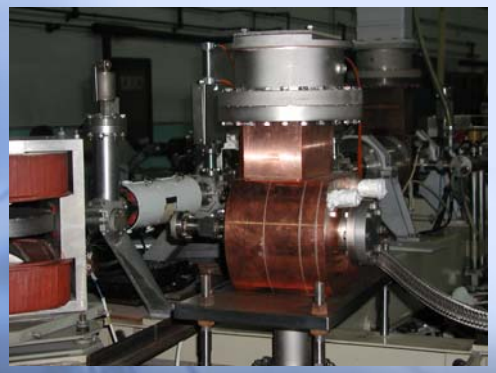
Outline

- Introduction of the FEL-THz work in CAEP
- THz-FEL facility driven by a photo injector
- The experiment of the injector and the facility
- Summary and outlook

The research work of FIR-FEL in CAEP.

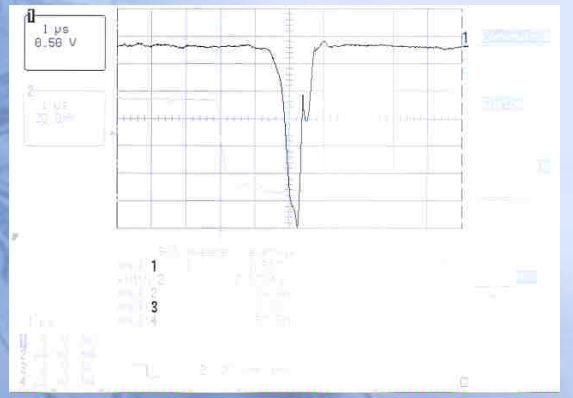




the thermionic cathode injector,1.5cells,2MeV

The parameters of the THz-FEL facility

- Electron energy 6.5MeV~7MeV
- Macro-pulse width 4 μ s,1Hz -25Hz
- Micro-pulse current ~ 4A
- Micro-pulse width 25 ~28ps
- Energy spread 1%
- Normalized emittance 20πmm.mrad

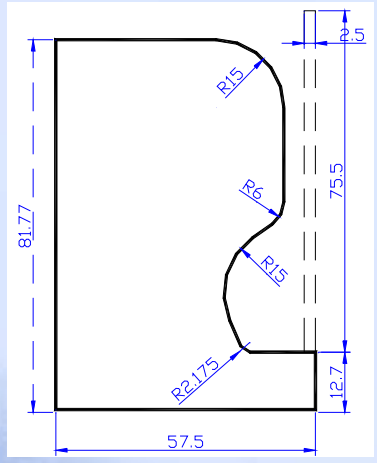


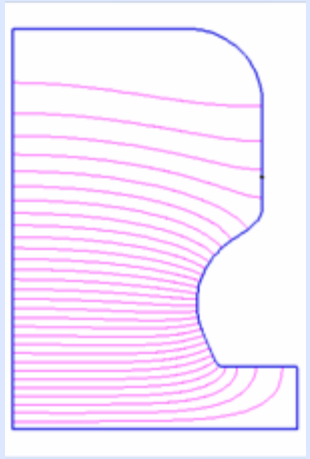
The first lasering in March ,2005,115micron
But the saturation can not be achieved.

The experiment hall

The photo cathode injector

The RF-gun

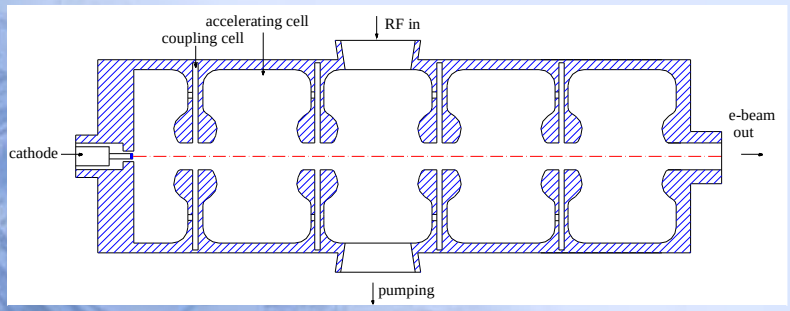




4.5cells， electron energy is about 7.5-8MeV

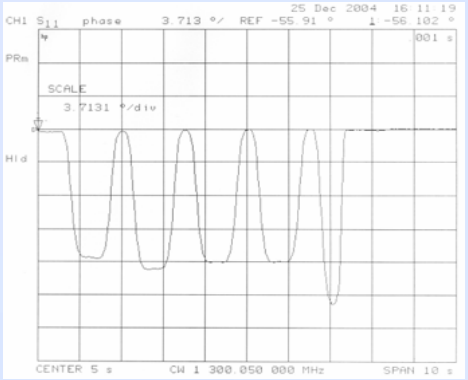
SUPERFISH and PARMELA codes were used to design and beam dynamic simulation

The cathode material is Cs2Te

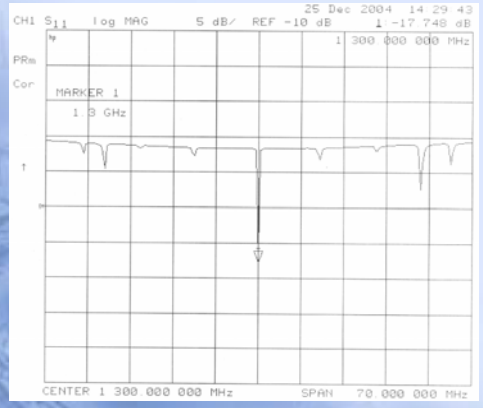


The schematic of 4.5cells cavity

The jointed cavity



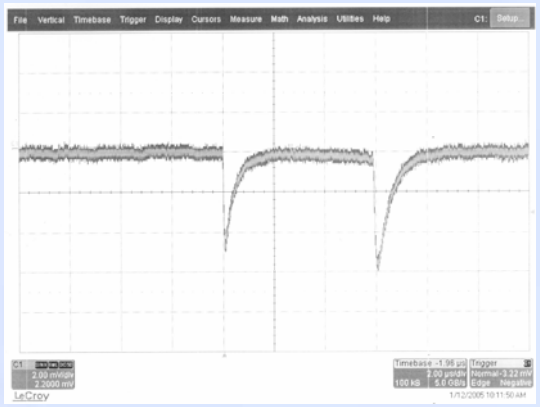
The electric field on the axis



The oscillation frequency of TM010 mode

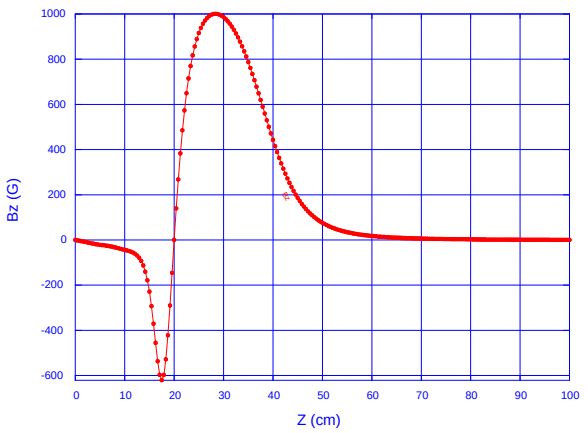
Fundamental parameters of the rf-gun

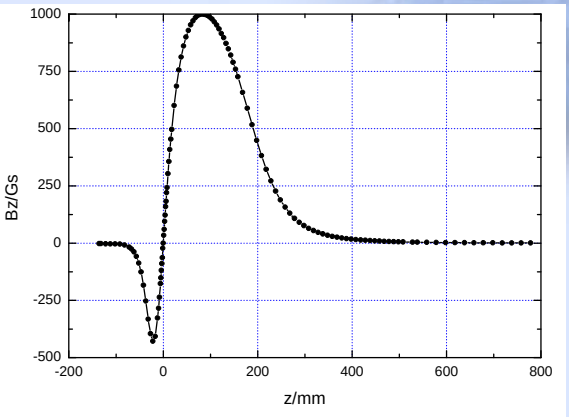
Cell number	1	2~5
Frequency/MHz	1299.95	1299.95
Stored energy/J	0.0021	0.0042
Power dissipation/W	1062	1520
Quality factor Q	16710	23346
Transit time factor T	0.79	0.79
Shunt impedance/M Ω /m	54.1	76.1
ZT2/Q/ Ω /m	2020	2020



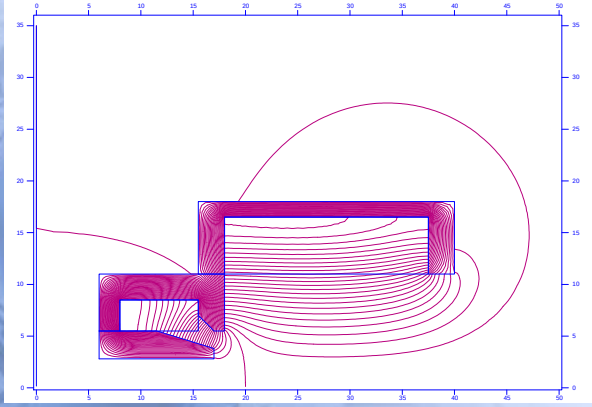
The reflected wave form of the cavity

The compensated solenoid





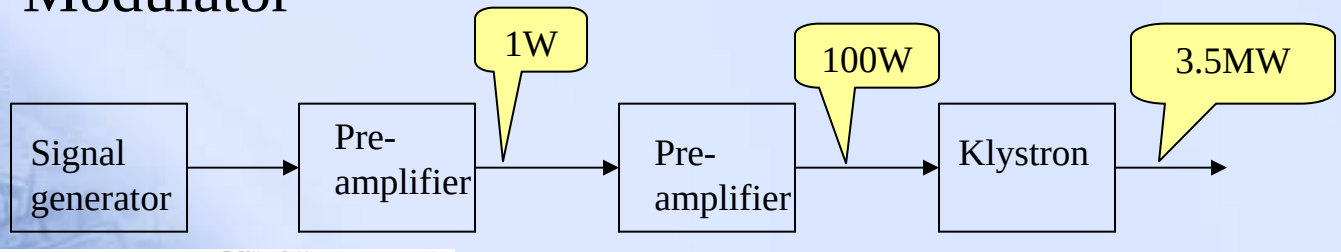
The design magnetic field

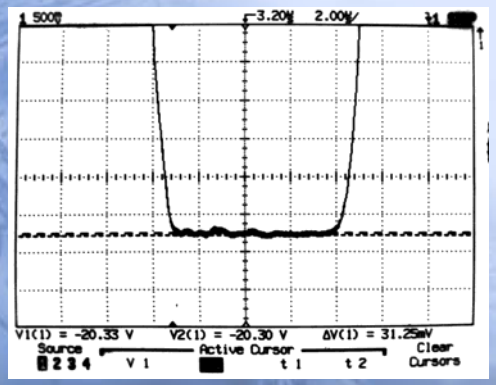


The measured magnetic field

Microwave power source

- Signal generator
- The pre-amplifier
- The klystron
- Modulator

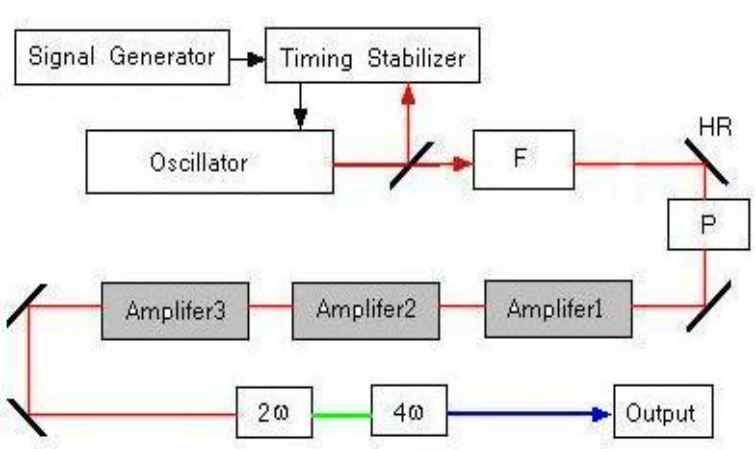


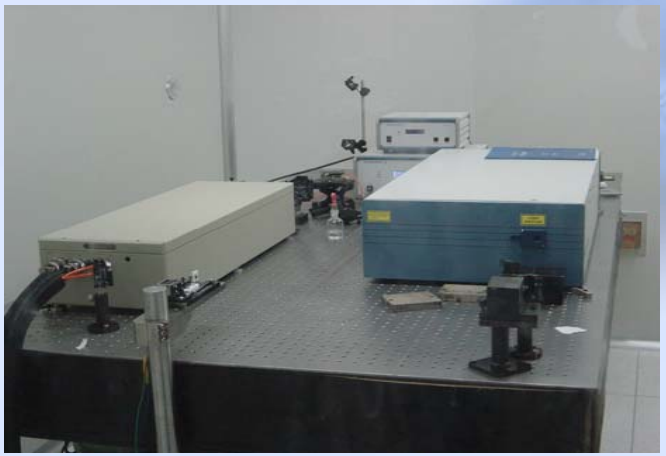


fluctuation of the modulator output

$$\frac{\Delta V_k}{V_k} \approx 0.2\%$$

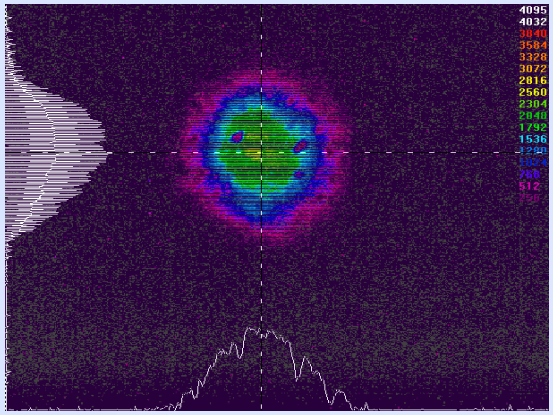
The driving laser system





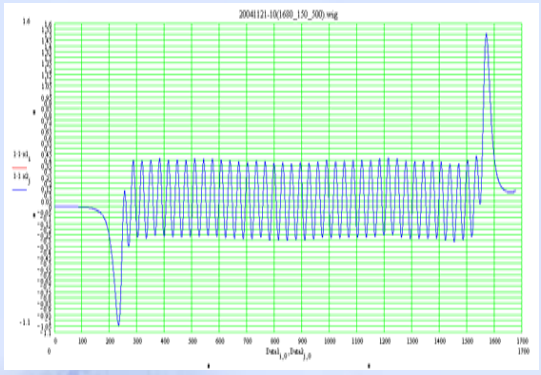
The fourth harmonic driving laser

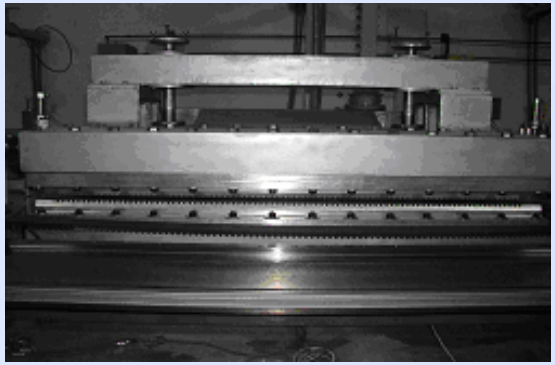
1	wavelength/nm	266
2	width/ps	11-13
3	Repetition rate/MHz	54.17
4	Pulse energy/μJ	3-5
5	Macro pulse width /μs	1-6
6	Macro pulse rate/Hz	3-6-12
7	Time jitter/ps	<2
8	Point stability/mrad	0.11



The profile of UV pulse spot

The undulator





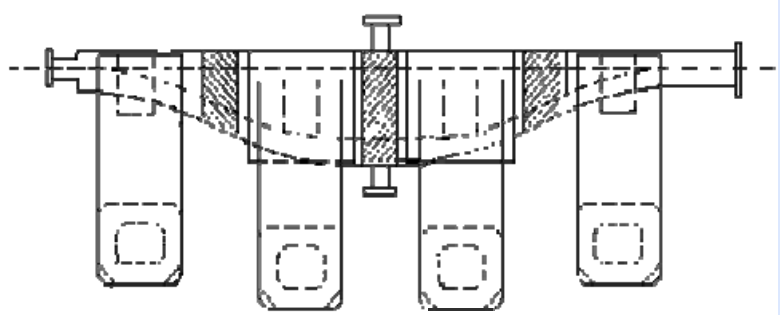
Trajectory of the electron in the undulator

Magnetic field distribution of the undualtor

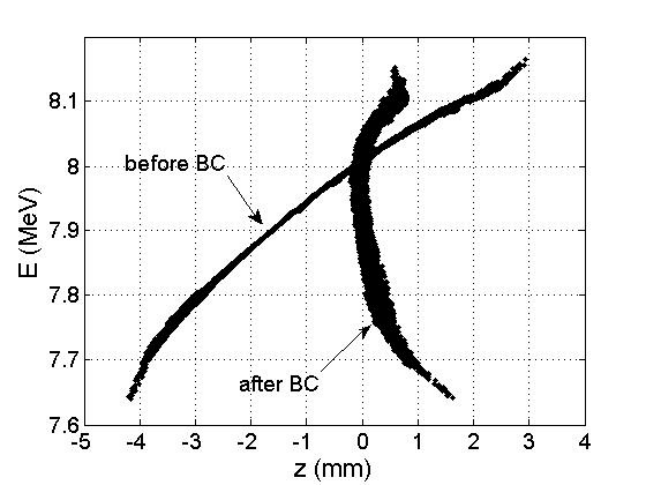
Parameters of the undulator

material	NdFeB-FeCoV
periods	44
length	32mm
gap	16mm
Magnetic value	4900Gs
good aperture	6mm

The magnetic bunch compressor



The schematic of compressor



Longitudinal phase space before and after BC

Coherent Diffraction Radiation (CDR), the rms bunch length was found to be about 0.73 ps

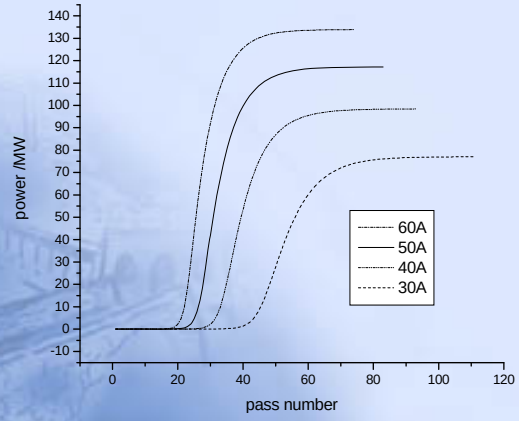
Courtesy: Xiang Dao

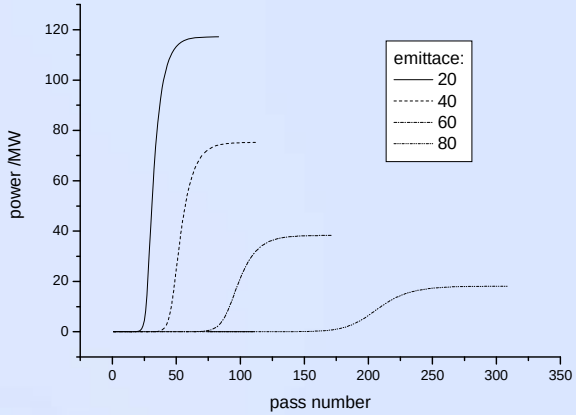
The optical cavity and the simulation

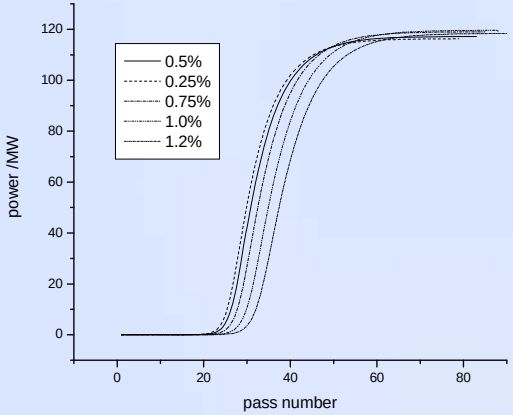
- The oscillator cavity length is about 2.767m
- The mirrors of cavity can be regulated in 5-demensions
- The mirrors are made of copper with gold coating
- The cavity is equipped with a narrow waveguide

The optical cavity and the simulation

- **The simulation of FEL was done by a three dimension code**





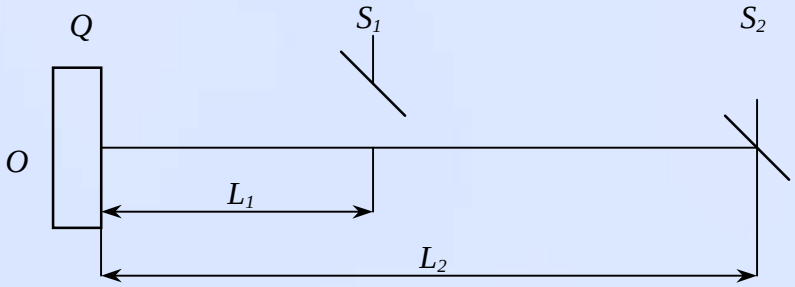


Courtesy : Xiaojian Shu and Yuhuan Dou

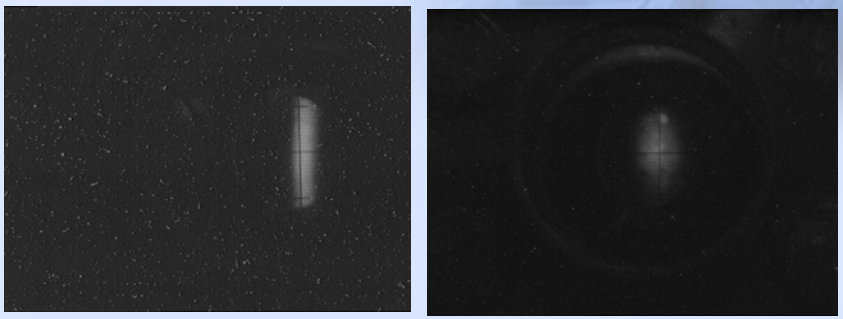
The control system and diagnostics of the beam

- The dipole magnets and quadruple magnets are drived by the high stability power source
- The modulator、the power source and the driving laser are triggered by a high precise synchronism controller
- Beam current is measured by BCT、ICT、Faraday-cup
- Micro-pulse width is measured by streak camera
- Optical cavity is adjustable by using the step motor

The diagnostics of the beam



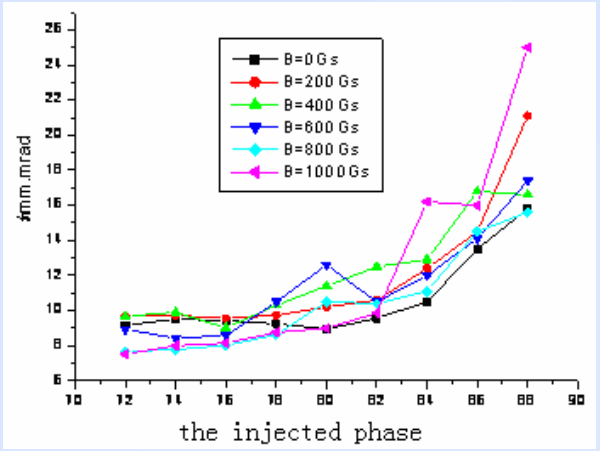
The schematic of two screen method for emittance measurement



The beam waist

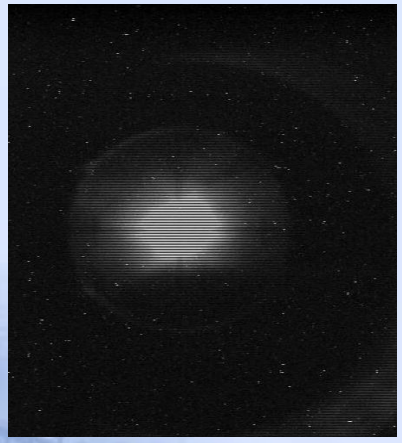
$$\varepsilon = \frac{r_2\sqrt{r_1^2 - \frac{L_1^2}{L_2^2}r_2^2}}{|L_2 - L_1|} \qquad \varepsilon_n = \beta\gamma\varepsilon$$

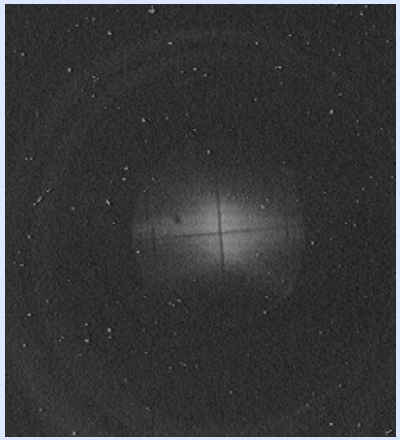
The normalized emittance is 9 π mm.mrad

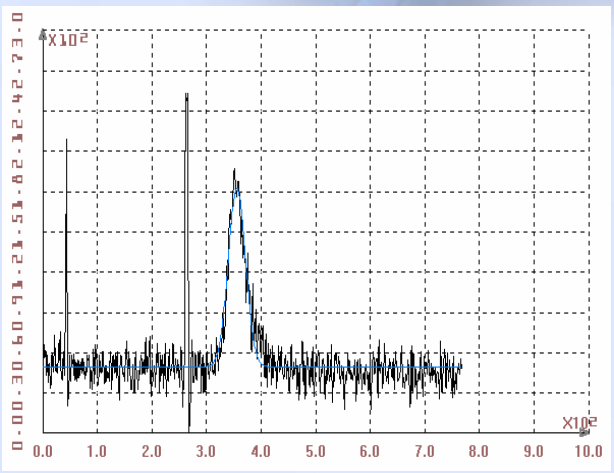


The relation of the emittance 、 the solenoid magnetic field and the injected phase

Beam size measurement



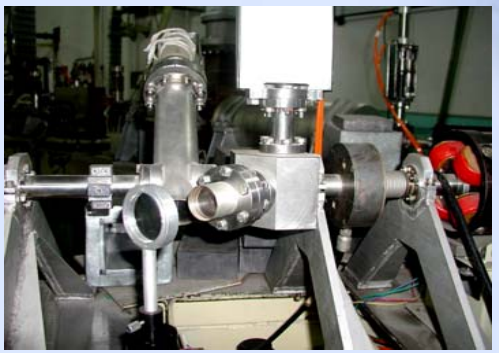




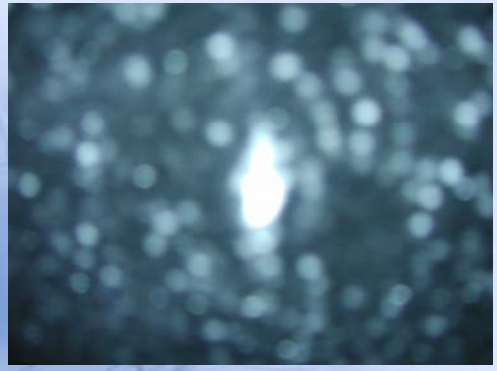
The diameter of the beam cross section is 2mm

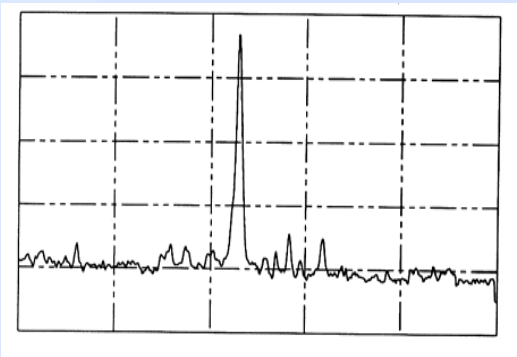
The streak camera is used to measure the micro-pulse width

The streak camera



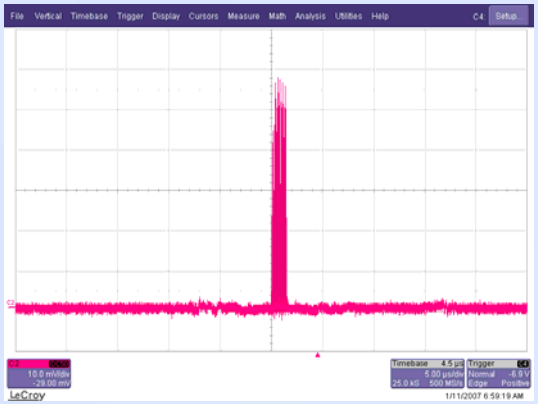
The output of the Cherenkov radiation





The micro-pulse is about 12ps
before the compressor

The diagnostics of the beam

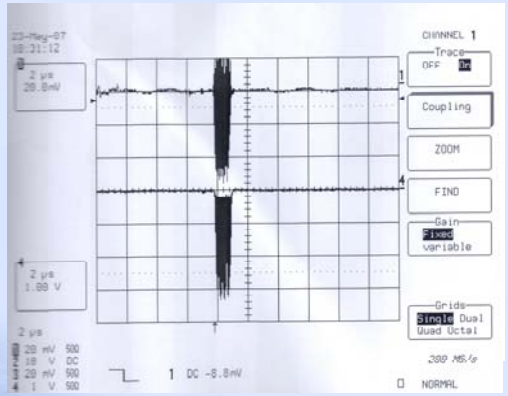


Electrons energy and energy spread were measured by using bending magnet
the energy is about 8MeV
the energy spread is about 1%

$$E = m_0 c^2 \left[\sqrt{1 + \left(\frac{eBR}{m_0 c} \right)^2} - 1 \right]$$

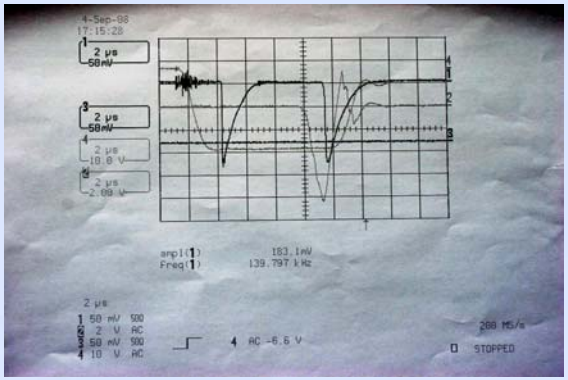
Bunch charge measurement by ICT
The charge is about 100pC and up to1nC

The spontaneous emission experiment



The Ge(Ga) detector

The FIR spectrum analyser



The spontaneous emission signal

Summary and Outlook

- **The stimulated emission experiment is undertaking and expect to achieve the saturation**
- **User lab. FEL-THz is useful to the basic science , such as semiconductor research, biology, etc**
- **The proposal of the using of superconductor**

Thank to all who contributed
to this work !
Thanks for your attention!