First Lasing at the CAEP THz FEL Facility

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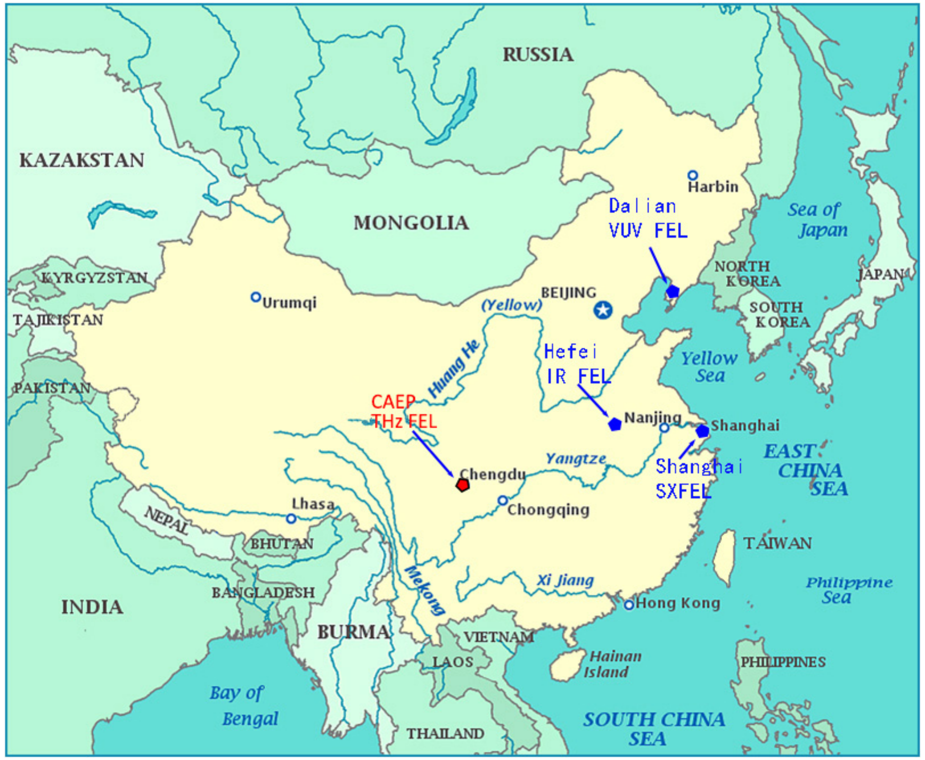
Introduction

CTFEL: CAEP THz FEL

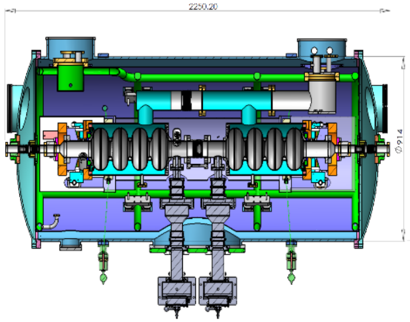
The first high average power THz FEL user facility in China.

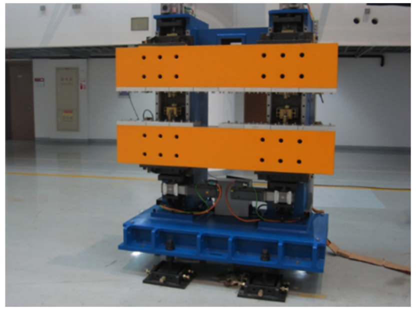
Collaborations:

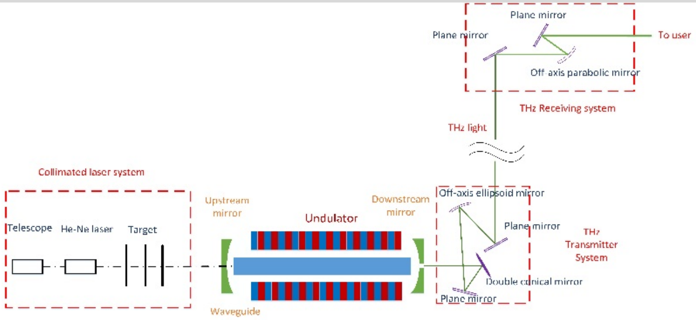
- *Institute of Applied Electronics*
- *Peking University*
- *Tsinghua University*
- *Institute of Applied Physics and Computational Mathematics*

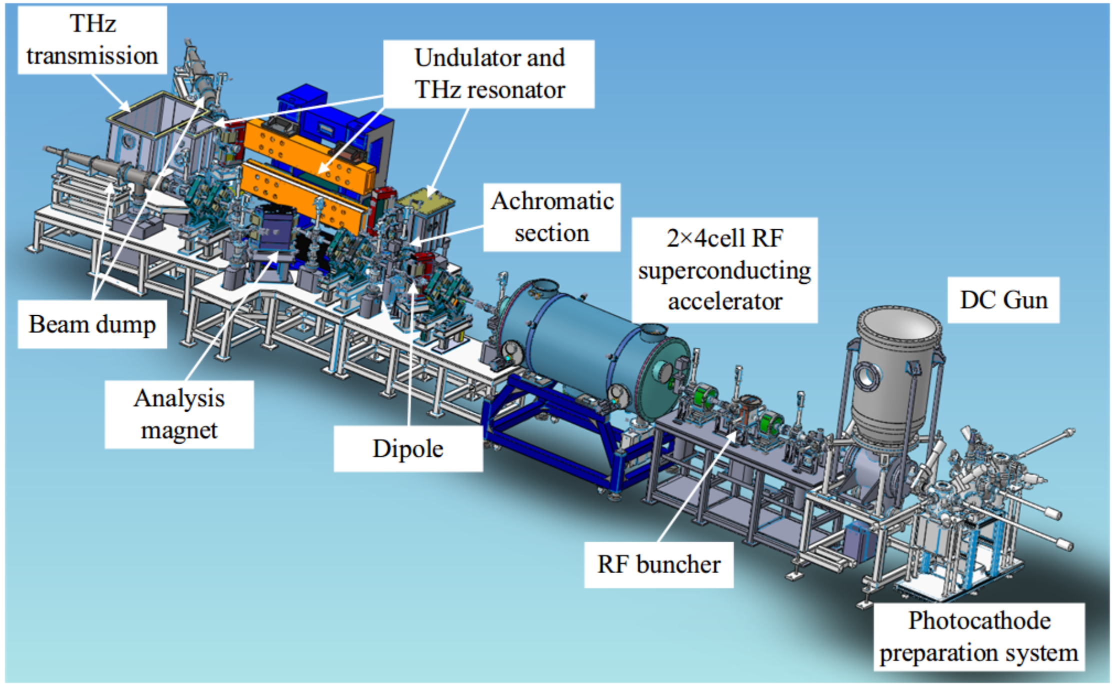


Overview of the CTFEL facility









Based on superconducting accelerator and photocathode DC gun

Componets

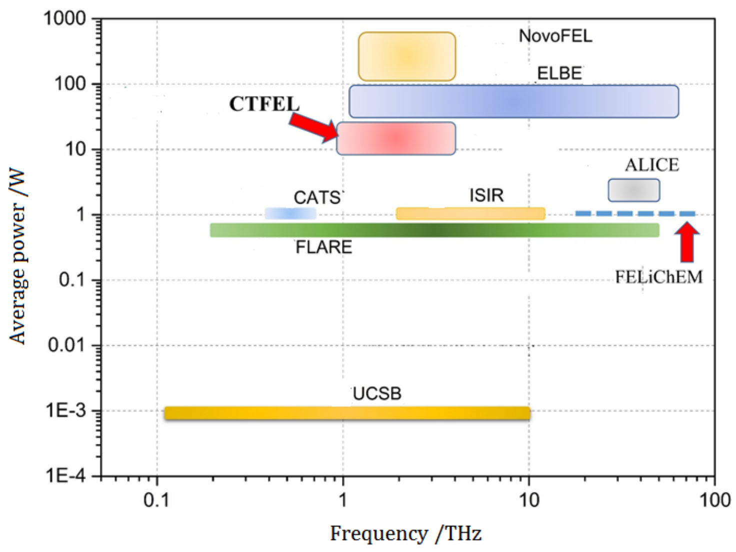
- DC gun: 350keV, GaAs
- Superconducting accelerator:
  TESLA type, 2x4-cell, 8-10 MV/m
- Undulator:
  period length 38 mm, 42 periods
- Waveguide:
  Titanium, 14mm×22mm
- Optical Cavities:
  length 2.769m, Mirror curvature 1.85m
- Microwave source system
  IOT tubes, >30kW
- Cryogenic system
- other subsystems

Electron and THz parameters

Technical route: Photocathode HV-DC injector and SRF driven Oscillator type FEL.

Designed goal: Wave length 100~300 um, THz freq. 1~3 THz, Avg. output power >10 W [1].

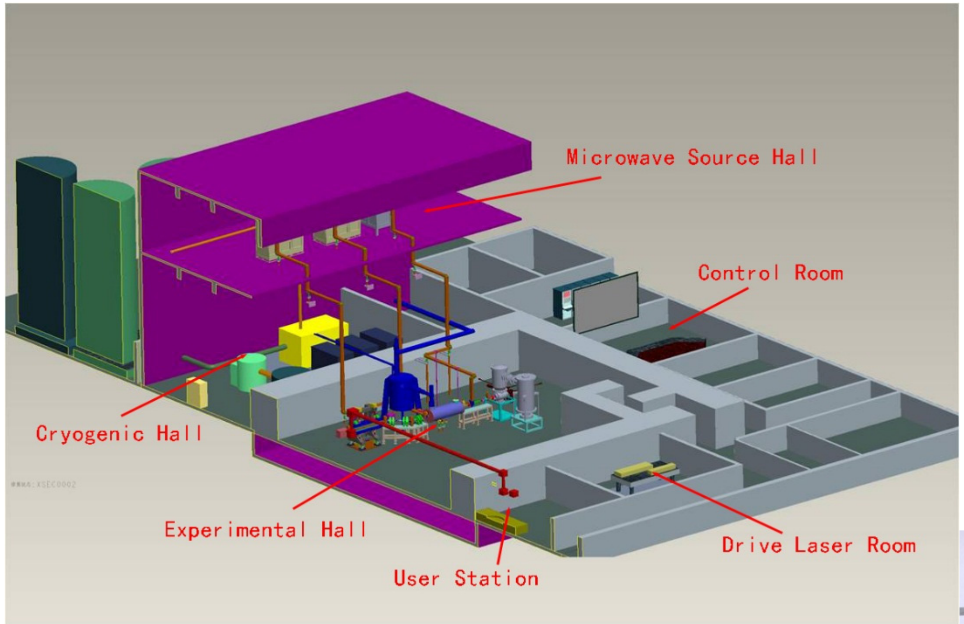
Electron beam		THz laser	
Energy /MeV	6~8	Frequency/THz	0.7~4.2
Micro bunch charge /pC	10~100	Spectral FWHM/%	2~3%
Micro bunch /ps	1.5~3	Micropulse power/MW	>0.3
Emittance /πmm mrad	< 8	Minimum transverse radius/mm	<1mm
Energy spread /%	0.2 (FWHM)	Micropulse RMS length/fs	400~500
Repetition rate /MHz	54.17	Micropulse interval/ns	18.5
Beam current /mA	1~5	Macropulse average power/W	>10
Duty cycle	10^{-5}~1	Macropulse repetition/Hz	1~20



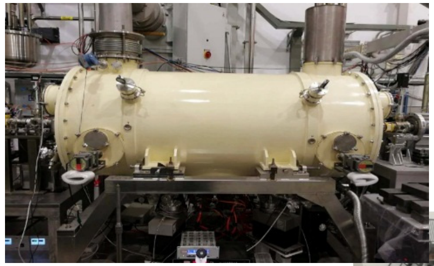
Comparison to other THz sources

[1] X. Zhou, et al., Design of high average power terahertz-FEL facility, J. Terahertz Sci. Electron. Inf. Technol. 11 (2013) 1–6.

Picture of the CTFEL Facility



Lay out of CTFEL Lab



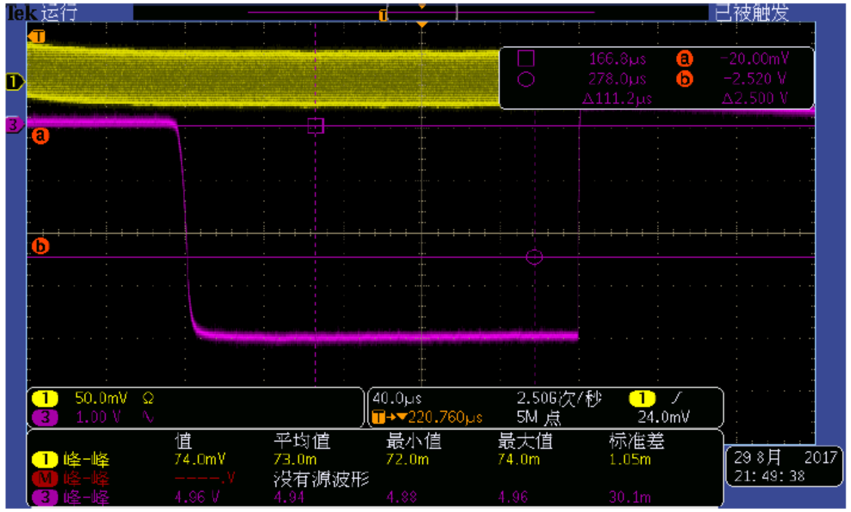
SC cavity

Transmission system

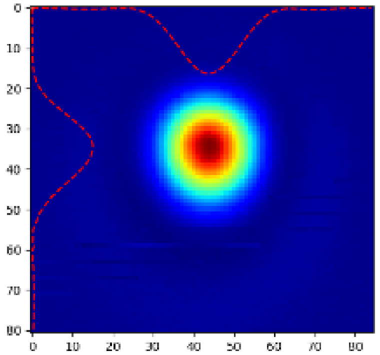
Picture of CTFEL facility

First lasing

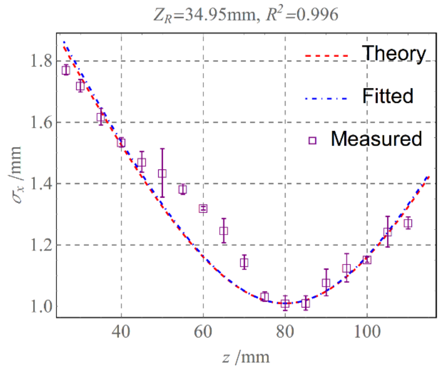
- Oscillator FEL with waveguide is difficult to do commissioning:
  - ✓ Spontaneous signal detection
  - ✓ Net gain in optical cavity
  - ✓ Energy spread between beam bunchers
  - ✓ CSR and other problems



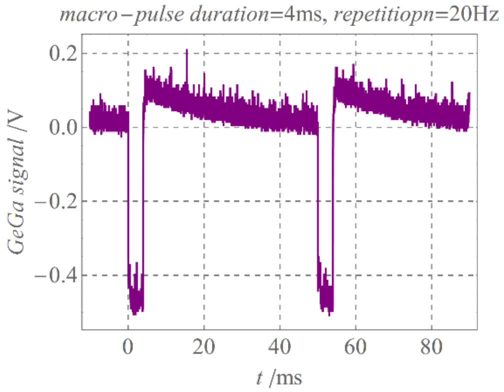
First saturated lasing signal observed on Aug. 29，2017



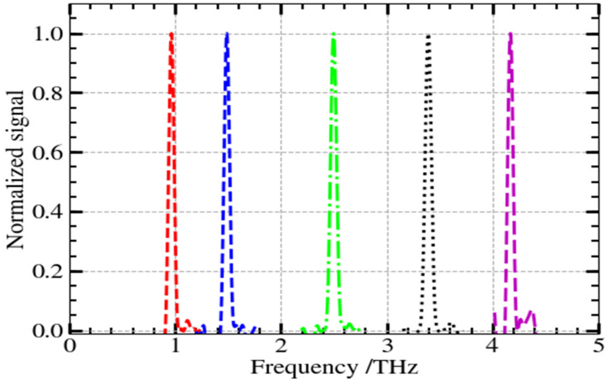
Beam size/0.1mm



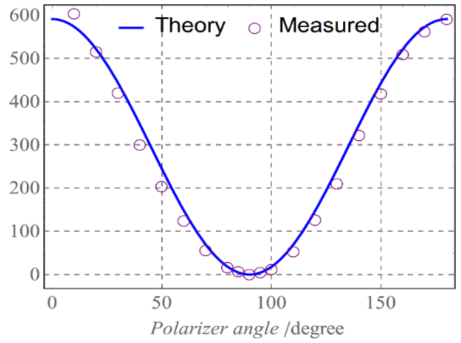
Beam quality: diffraction limit



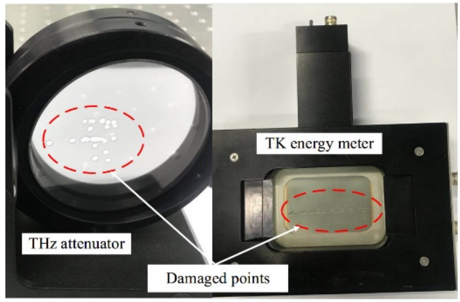
Duty factor:8% @2.85THz.
Total average power: >1.6J/s.



Frequency Scan by tuning both beam energy and undulator gap



Polarization: >99%

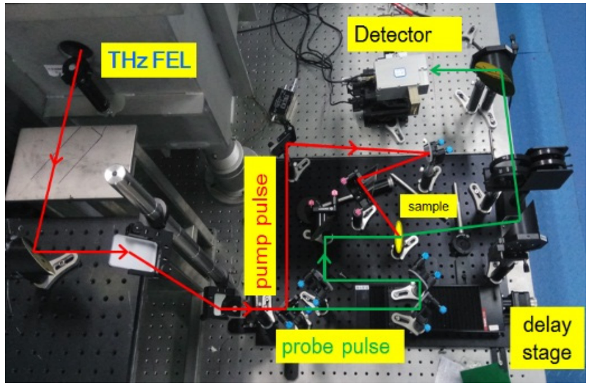


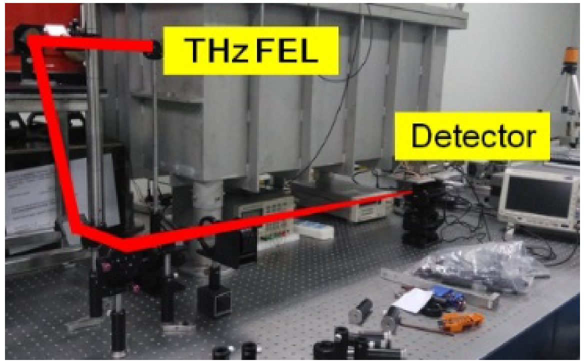
The laser damaged both the attenuator and the TK power meter

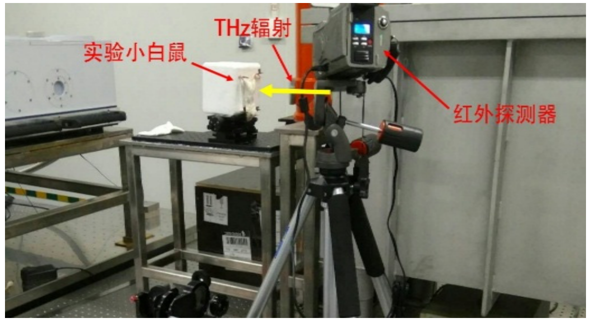
Some user experiments

Research Areas

- Coherent strong THz wave interaction with matter
- THz detection and imaging
- Biological effects and biosafety of THz radiation
- Accelerators and Free electron laser
- Application of electron beams







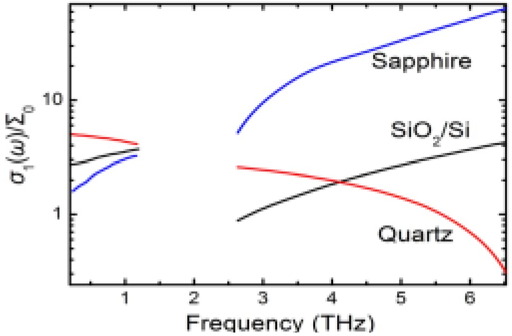
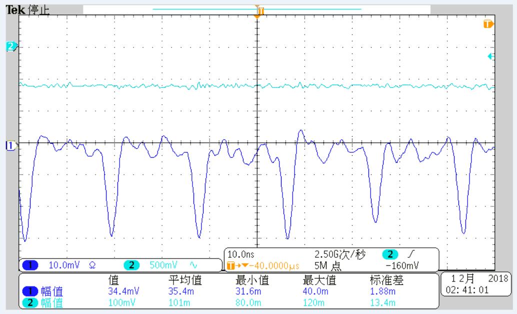


***Fig. 4.** Real part of optical conductivity for ML MoS_2 on SiO_2/Si (black), sapphire (blue), and quartz (red) substrates as a function of radiation frequency $f = \omega/2\pi$ at room-temperature, measured by THz TDS (low frequency range) and FTS (high frequency range). Here $\Sigma_0 = e^2/4\hbar$.



The CTFEL THz micro-pulses measured by Graphene detector

* C. WANG, et al. Substrate-induced electronic localization in monolayer MoS$_2$ measured via terahertz spectroscopy. Optics Letters, 2019(44), 4139

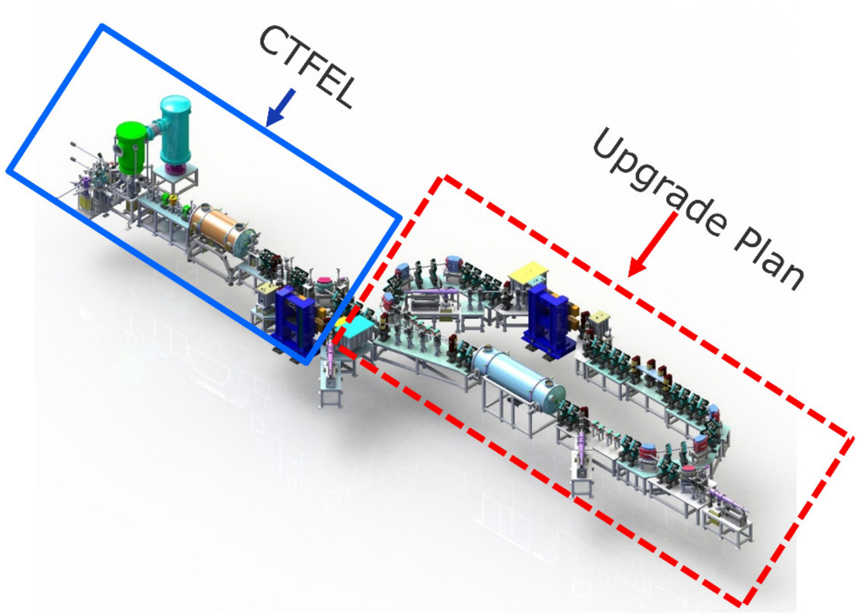
Future Plans

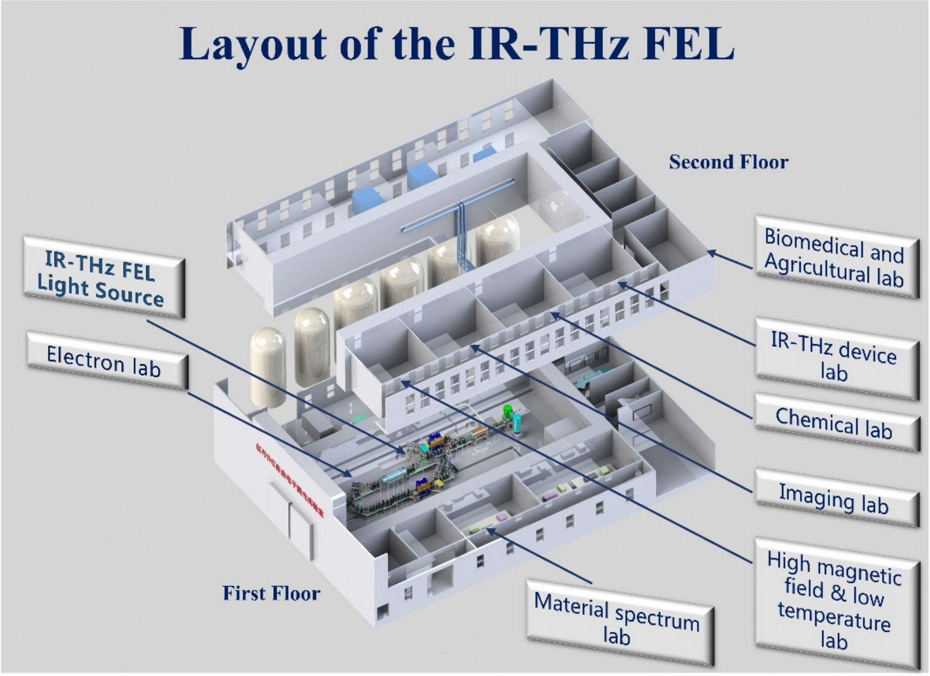
- CTFEL has realized stable operation, and Some user experiments have been carried out.
- However, there are also some places waiting for improvement or upgrade.
  - Recent plans:
    - CW operation
    - Extent the frequency range
    - pump-probe with different THz sources
  - Long term plans:
    - High magnetic field, high pressure, low temperature environment to extend experiment platform

Future Plans

- Although CTFEL has played a great role in terahertz science, its frequency band is still not too wide to meet the needs of scientific research.
- An upgrade plan is proposed. After the upgrade, the electron beam energy will be up to 50MeV, and the radiation frequency will be 0.1THz~150THz, covering the entire terahertz and infrared bands.
- The ERL technology is applied.

Parameters	Design values
Repetitions/MHz	54.17
Electron energy/MeV	~50
Beam current/mA	1~5
Averge power/W	~100
Frequency range/THz	0.1~150





Thank you for your attention!

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