Tunable High-power Terahertz Free-electron Laser Amplifier

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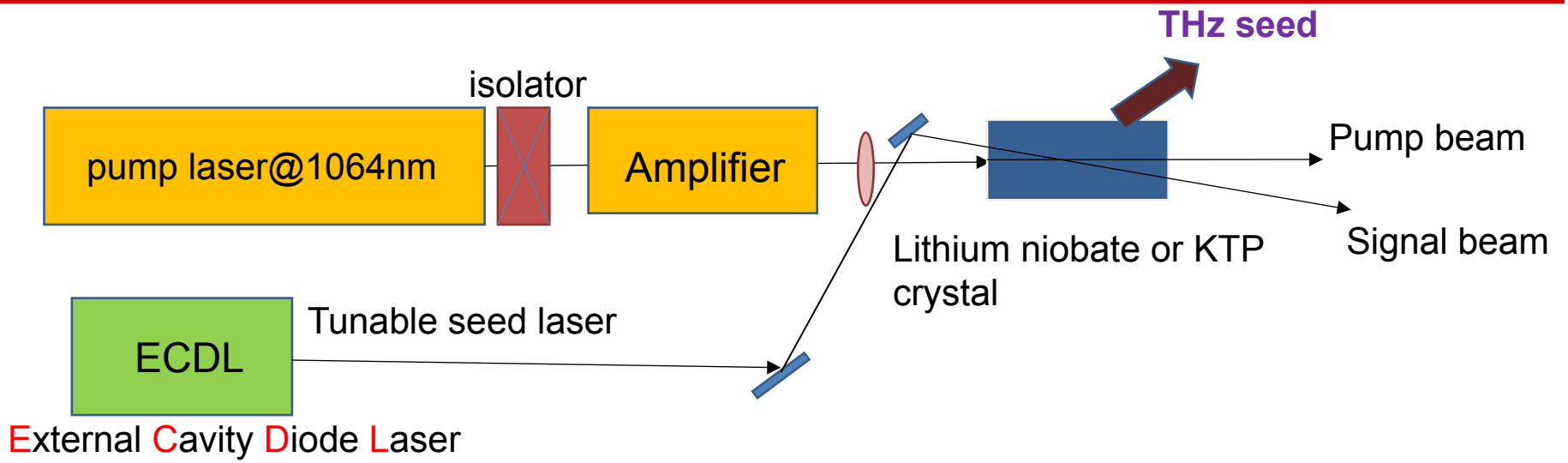
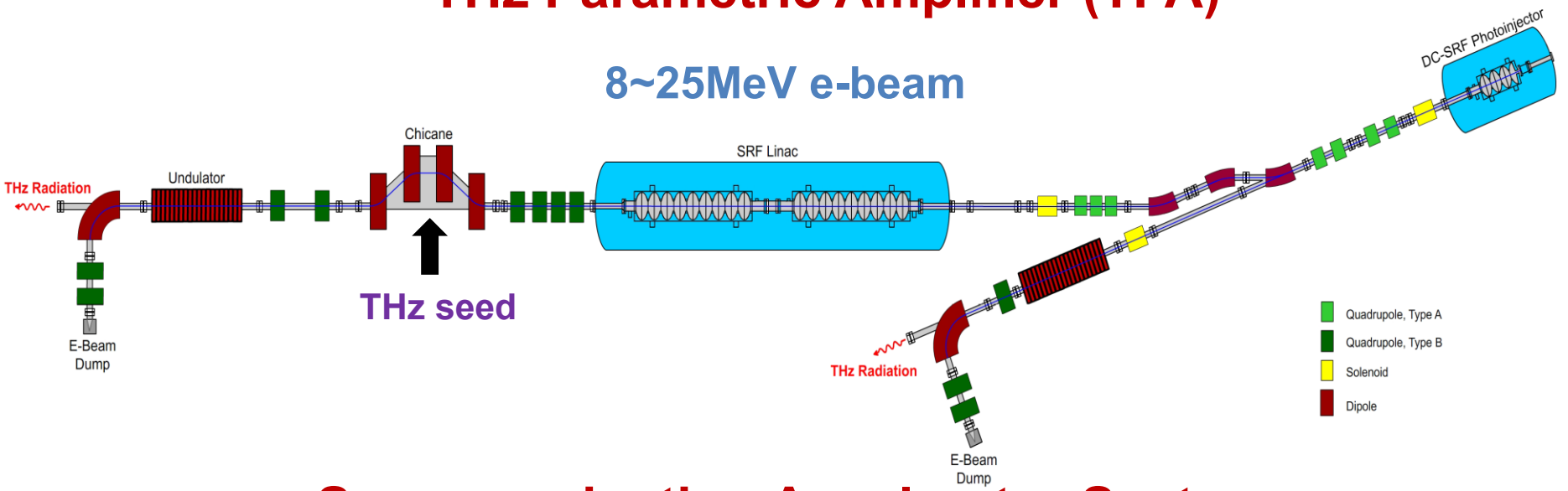
Outline

- The Plan of THz FEL Amplifier
- FEL Simulation
- Preliminary Research on THz seed
- Summary

The Plan of THz FEL Amplifier

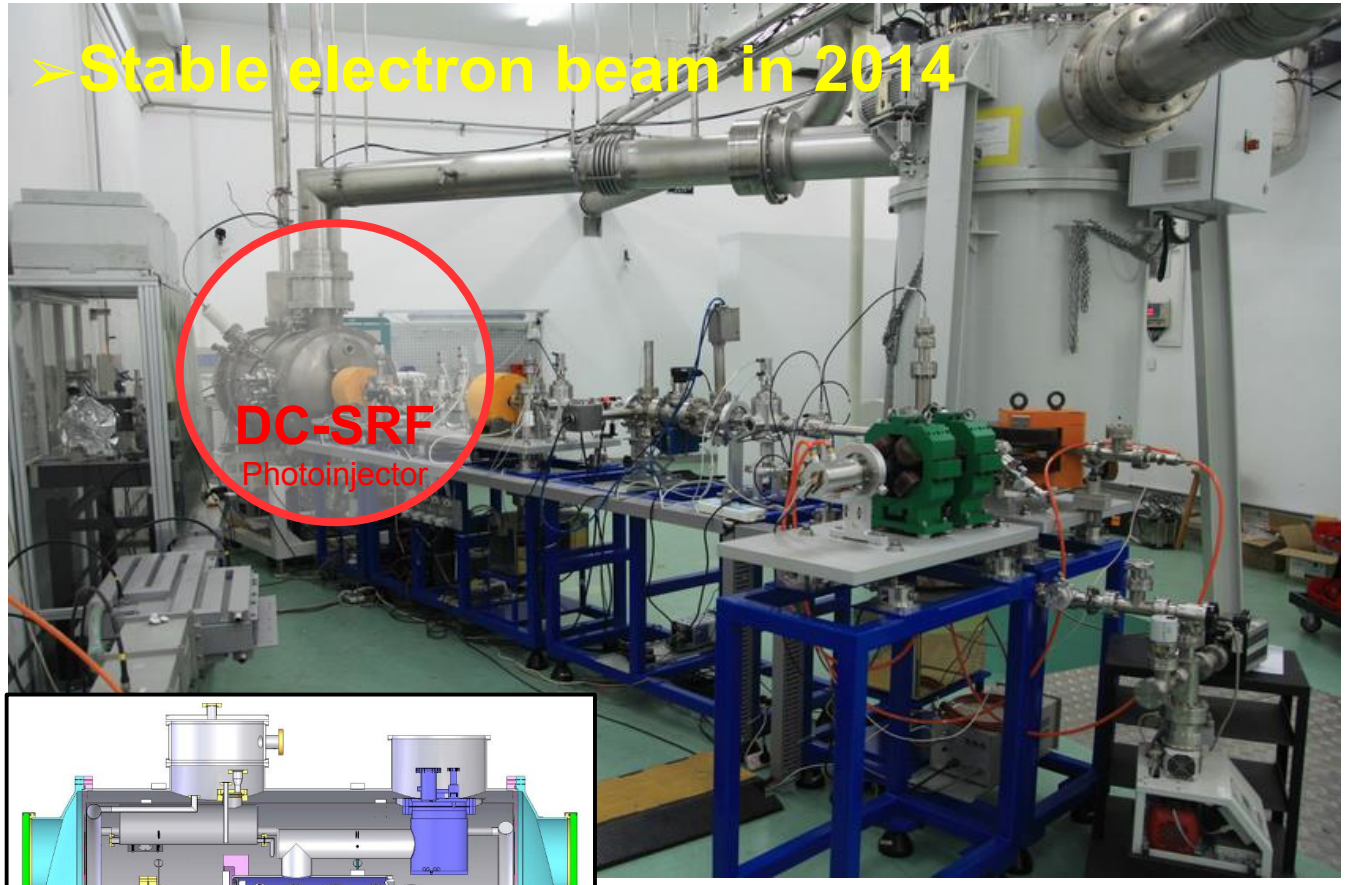


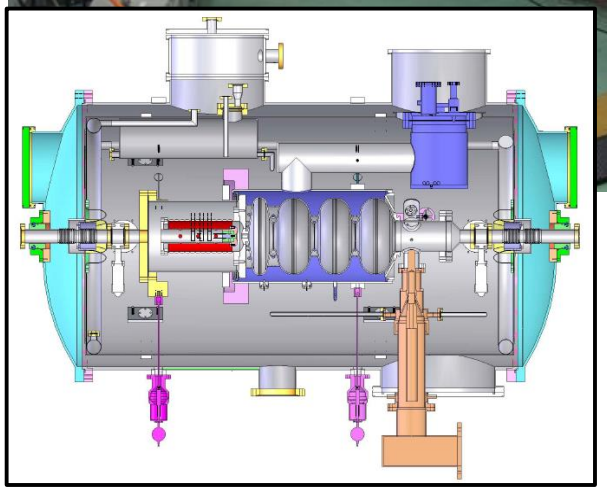
THz Parametric Amplifier (TPA)

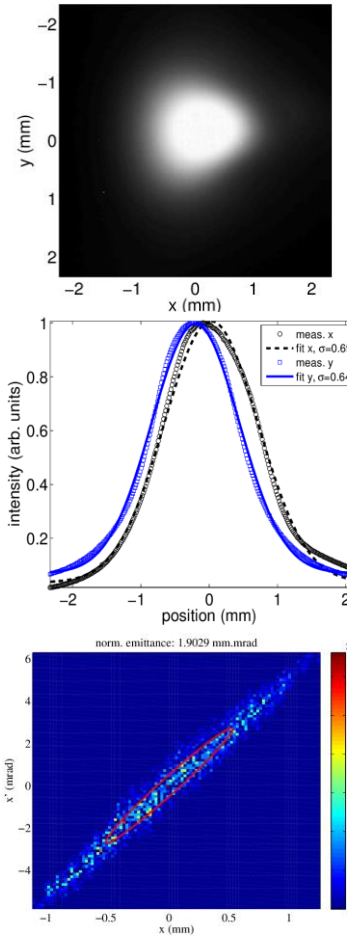


Superconducting Accelerator System

DC-SRF Photoinjector at Peking University



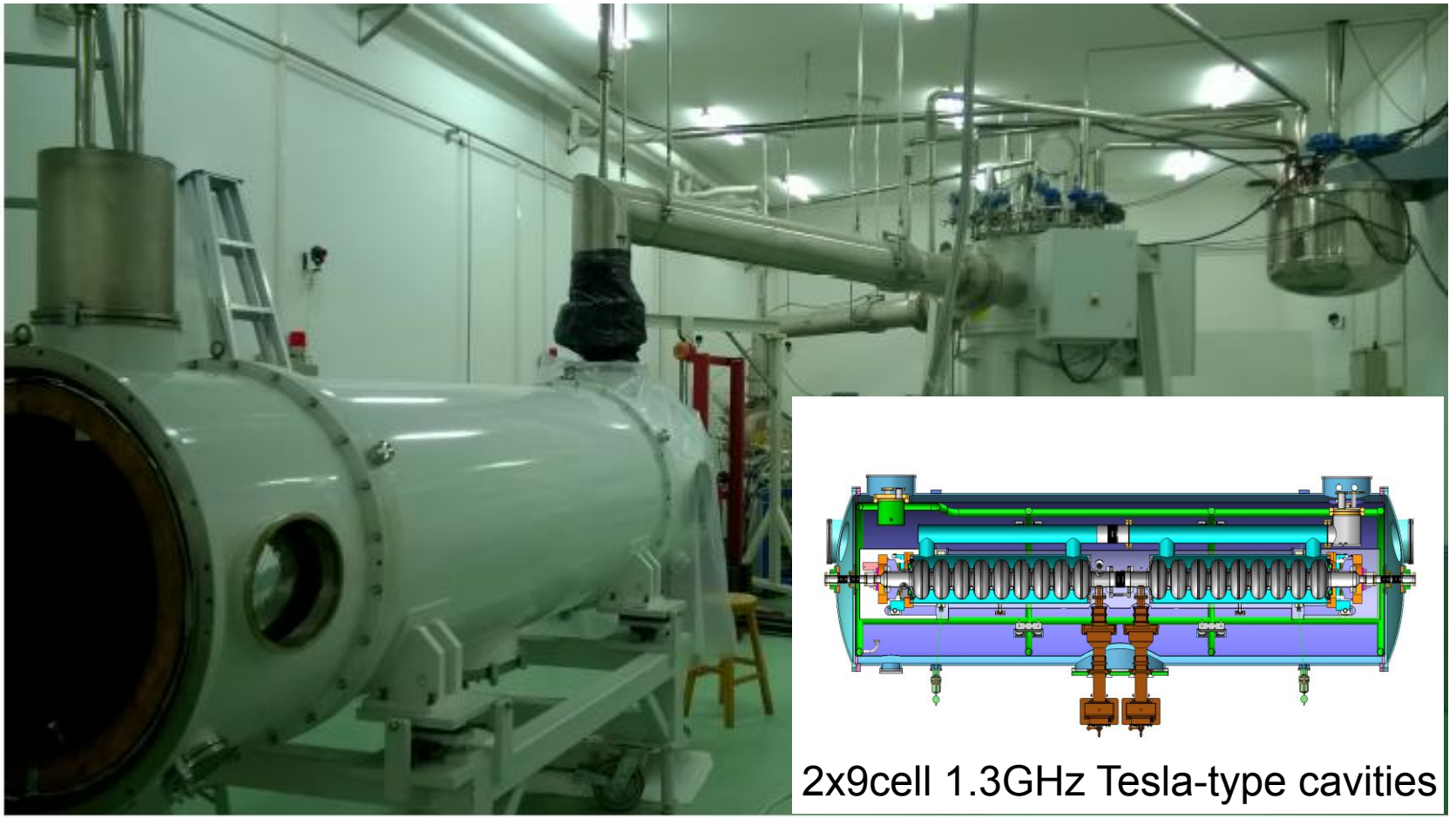




◀90 KV Pierce DC gun with Cs_2Te cathode matched with SRF cavity

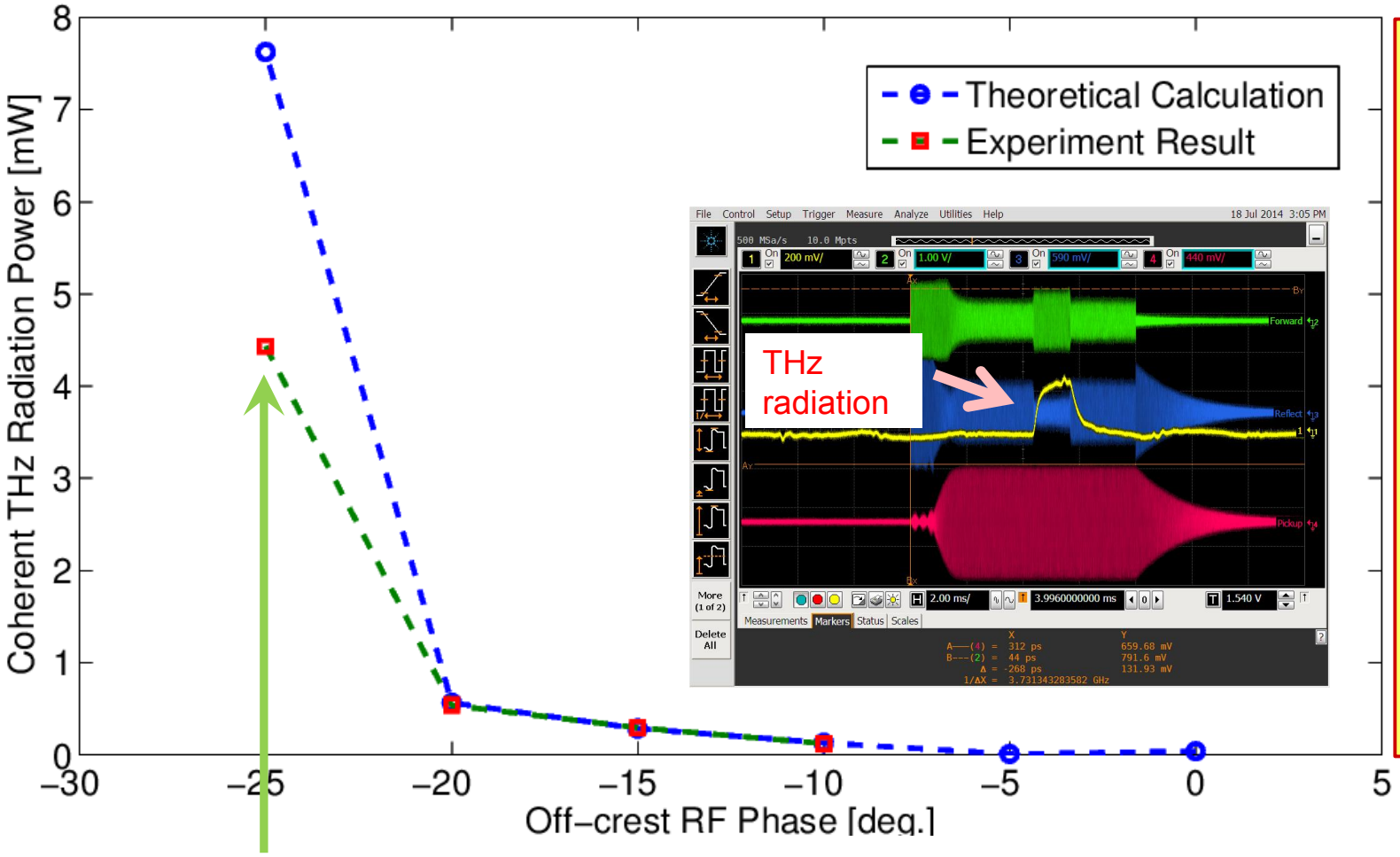
◀Providing 3-5 MeV electron beam with bunch charge up to 60 pC and repetition rate up to 81.25 MHz

Superconducting Linac



- The superconducting linac is under installation and will be operated in this autumn.

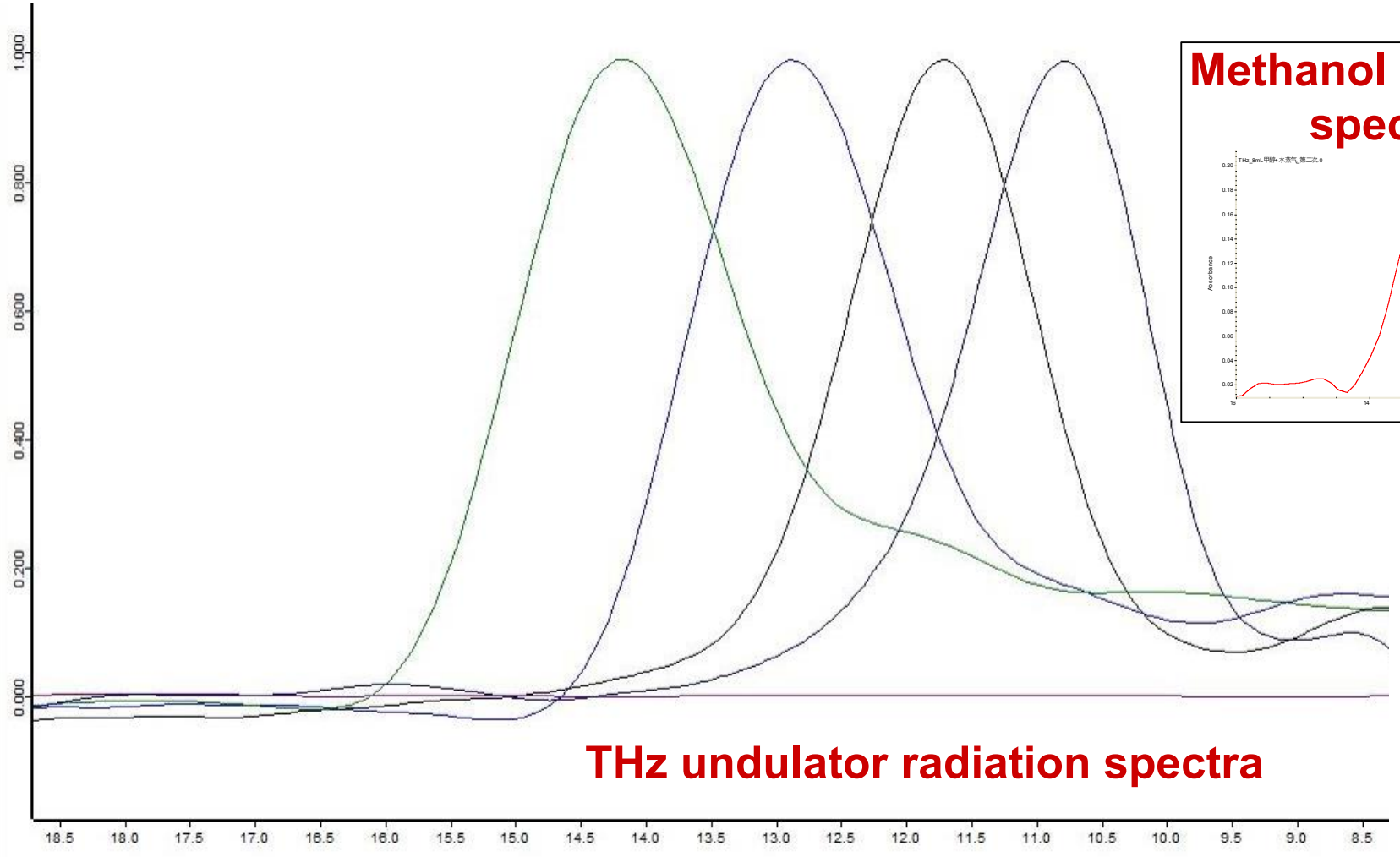
THz Undulator Radiation with DC-SRF Photoinjector

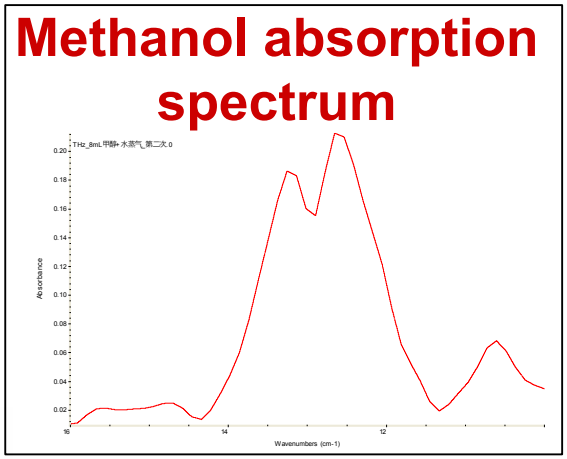


Calculation shows that our current THz transport tube introduces a **diffraction loss of 7-8**.
THz radiation power at the undulator exit is **about 30 mW (avg.)**

E-beam energy @ 3 MeV, repetition rate @ 16 MHz; undulator radiation ~ 0.5 THz

Measured THz radiation spectra

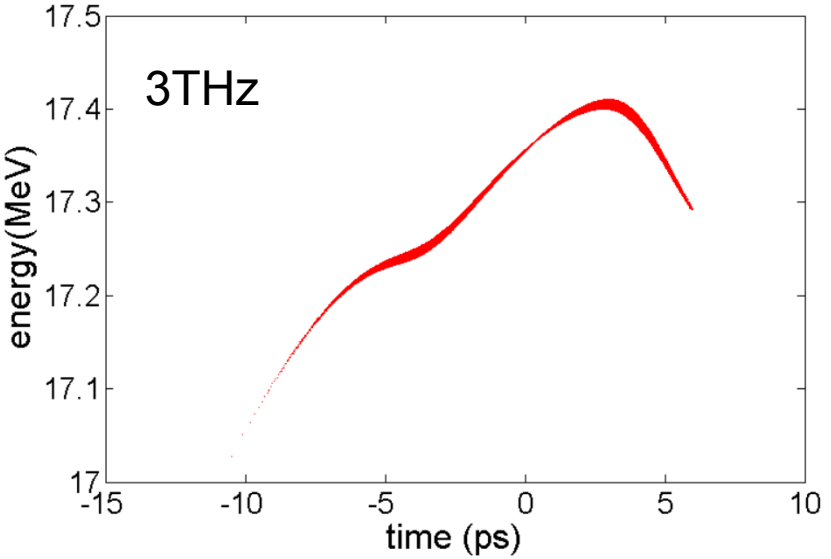




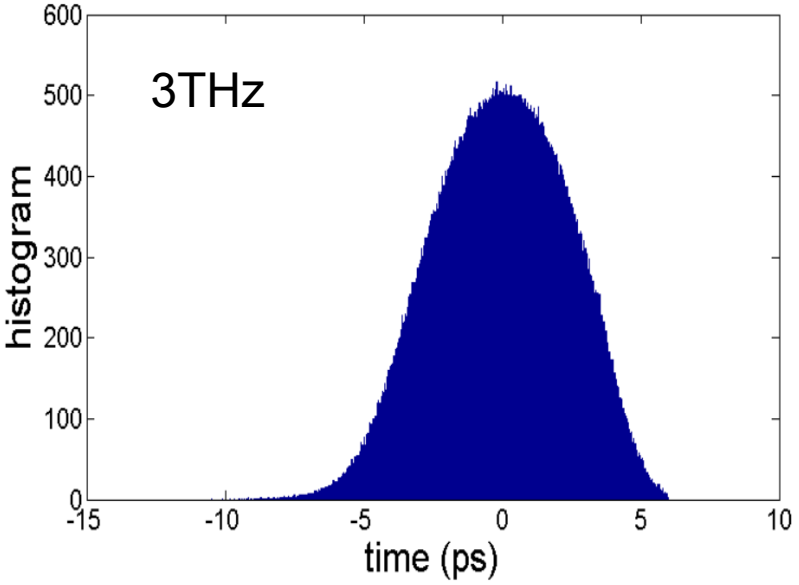
Demonstration of central wavelength adjustment

Parameters for FEL Simulation

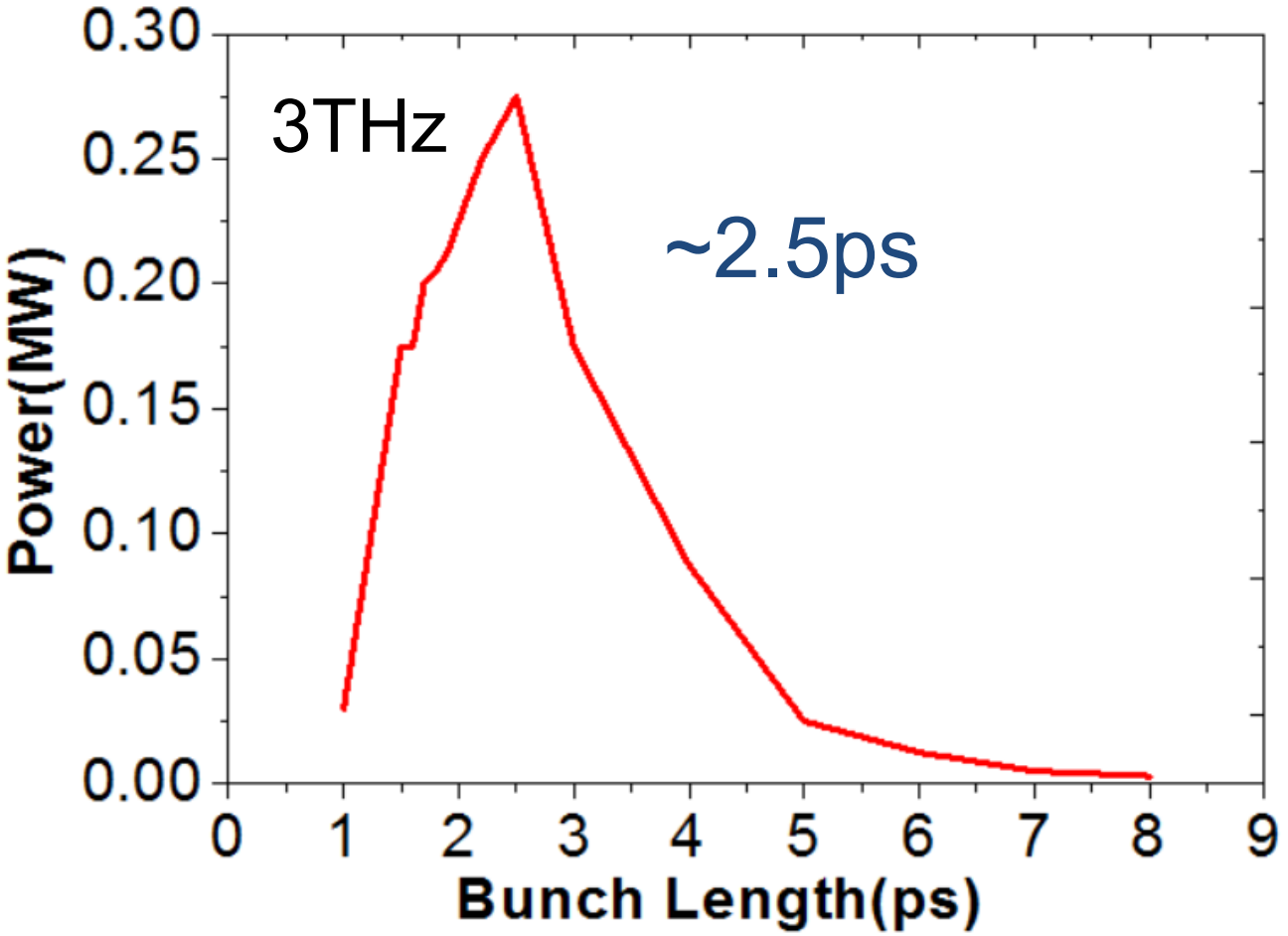
Electron beam parameters before undulator	
Charge, Q (pC)	200
Beam energy (MeV)	8 ~ 25
Energy spread (rms)(%)	~0.5
Emittance, ε_{nx} (πmm-mrad)	~2
Beam size, σ_x (μm)	~200



undulator	
Type	Planer
Period length (cm)	4
Period number	100
K(rms)	2.3

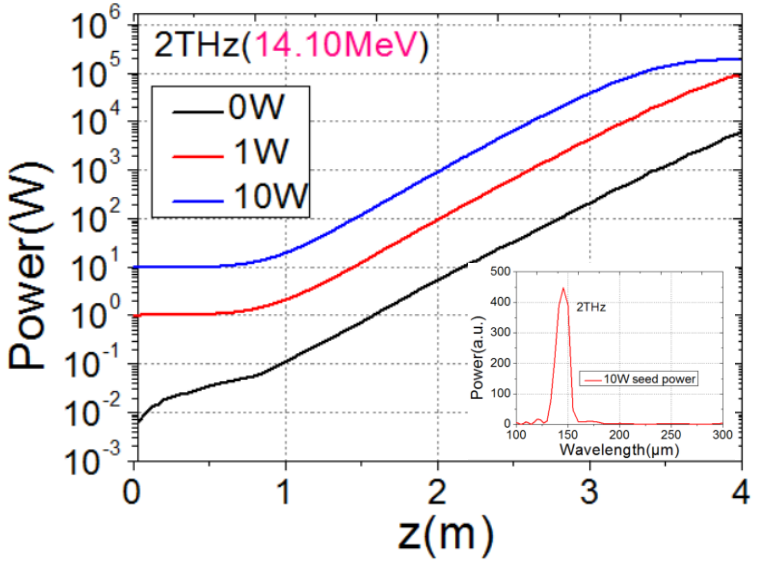


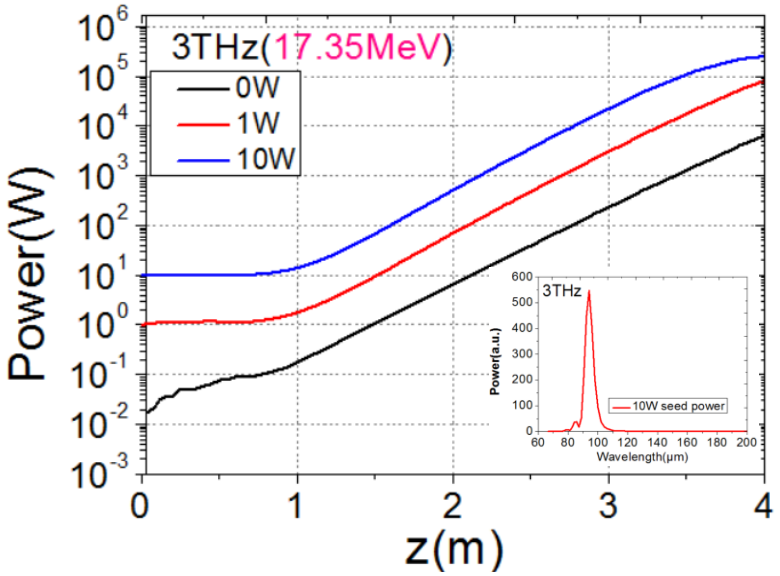
FEL Power VS Bunch Length

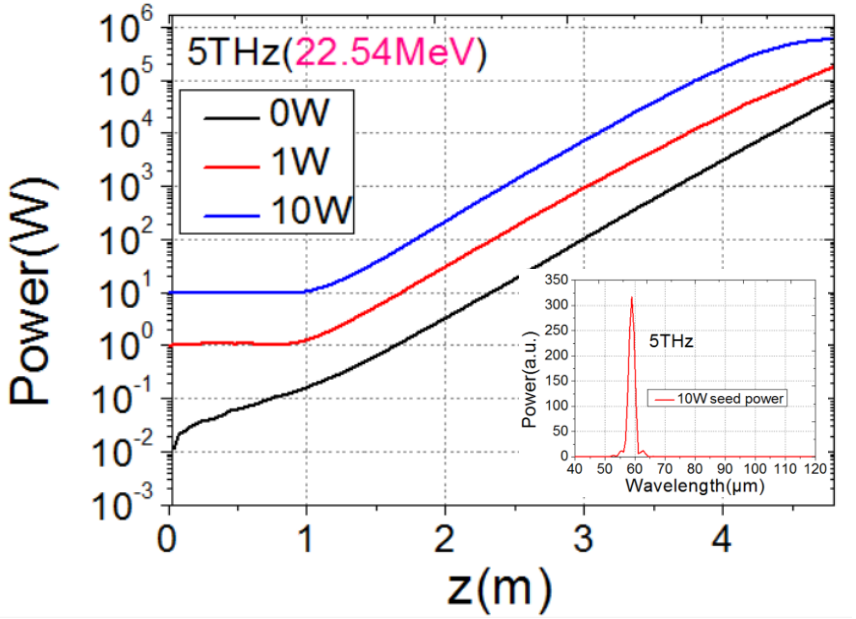


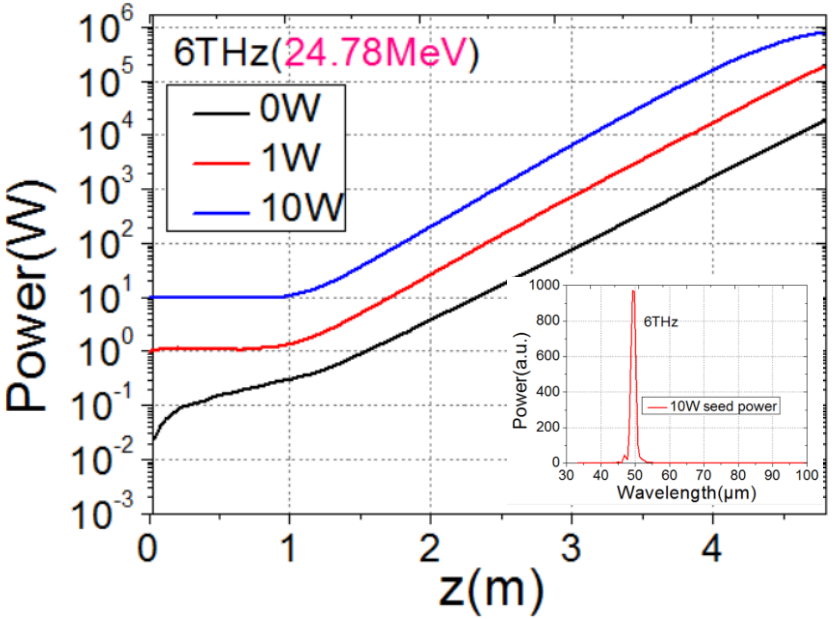
Slippage effect and low peak current

FEL Power along Undulator







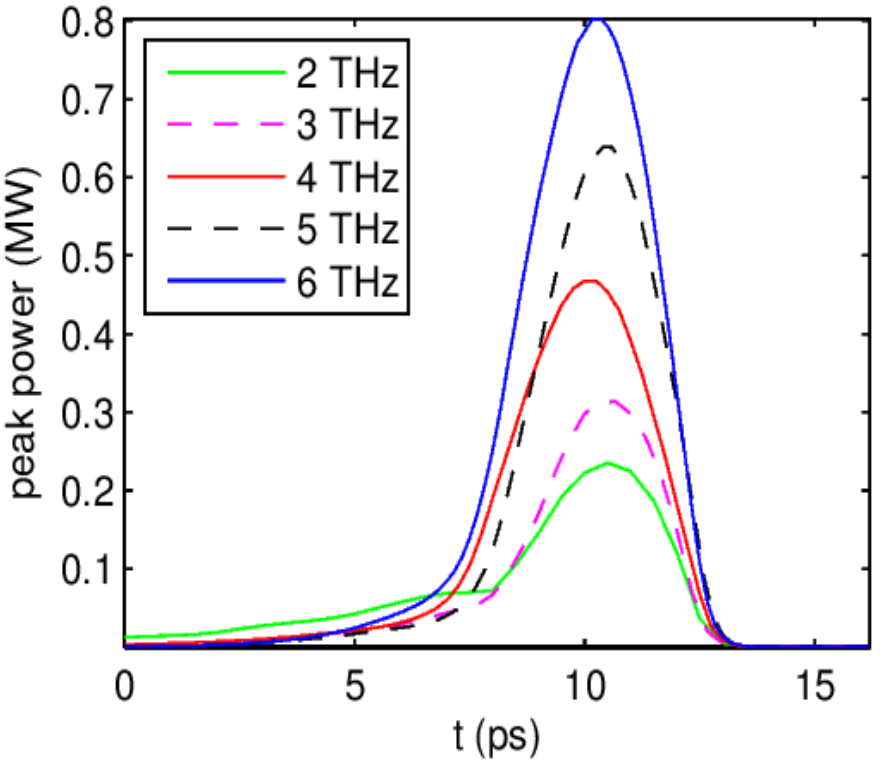


FEL Power Summary

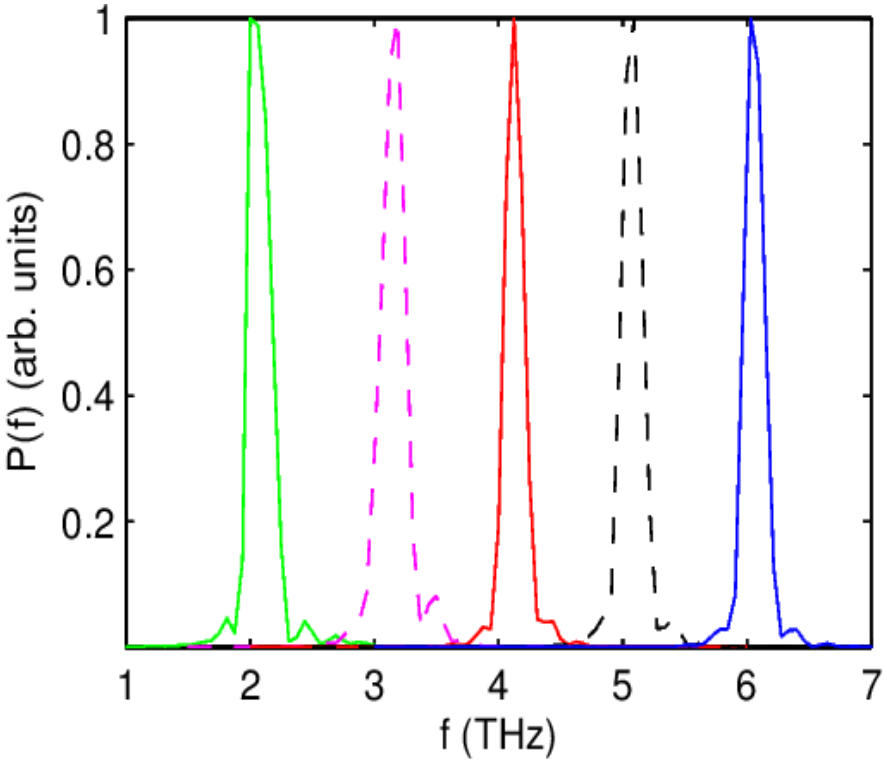
Frequency(THz)	E-beam Energy(MeV)	Peak Power(MW)
1	**9.88**	**0.1**
2	**14.10**	**0.2**
3	**17.35**	**0.25**
4	**20.19**	**0.45**
5	**22.54**	**0.6**
6	**24.78**	**0.8**

With the repetition rate is 1MHz, the average power is from 0.3W to 2.4W.

FEL Power Profiles and Spectra



power profiles, fwhm ~ 3 ps



power spectra, fwhm ~ 0.18 THz

$$\Delta f \cdot \Delta t \sim 0.54 \ \left[1.2 \times Limit(Gaussian)\right]$$

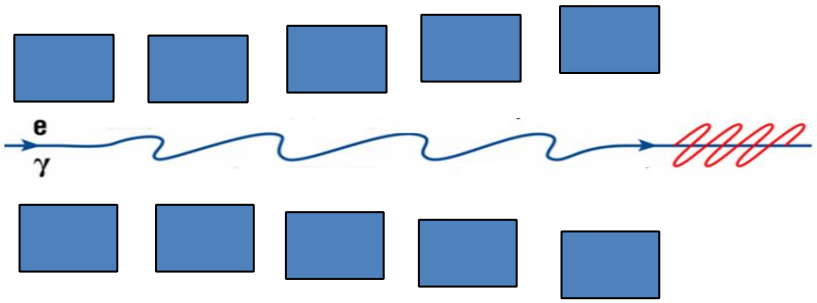
Undulator tapering

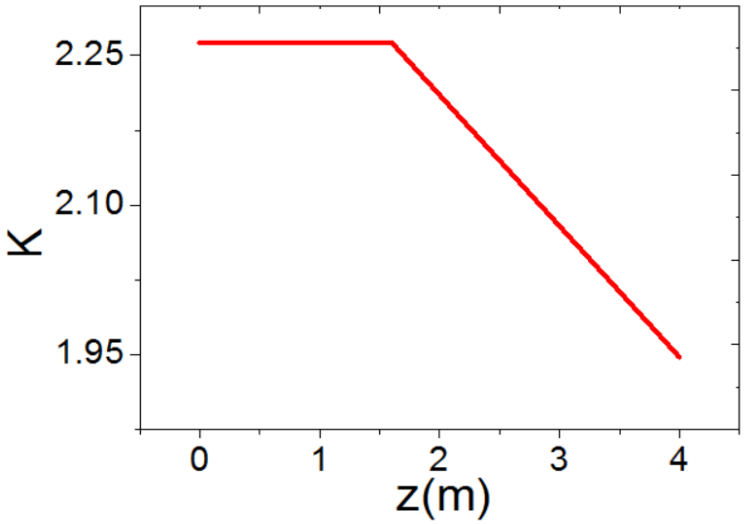
- FEL resonant condition

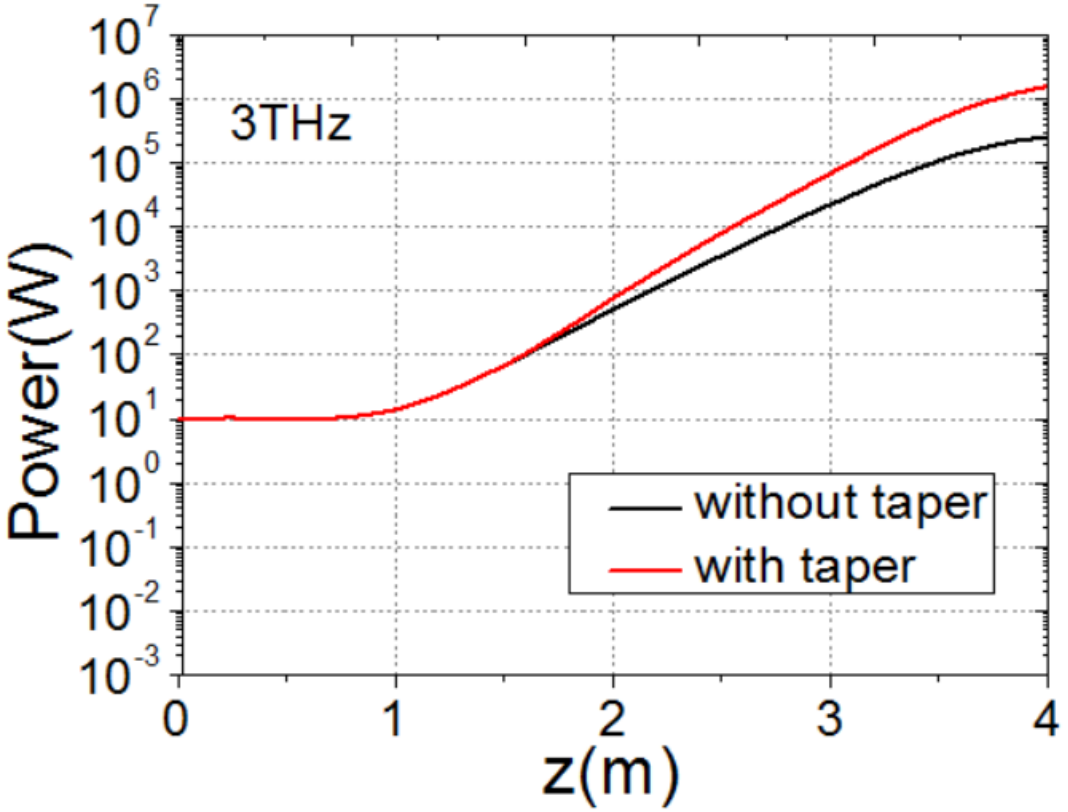
$$\lambda_r = \frac{\lambda_u}{2\gamma_0^2}\left(1 + \frac{K_0^2}{2}\right)$$

- Lower the resonant energy to a value of the decelerated electrons

$$K(z) = \alpha(z)\, K_0$$

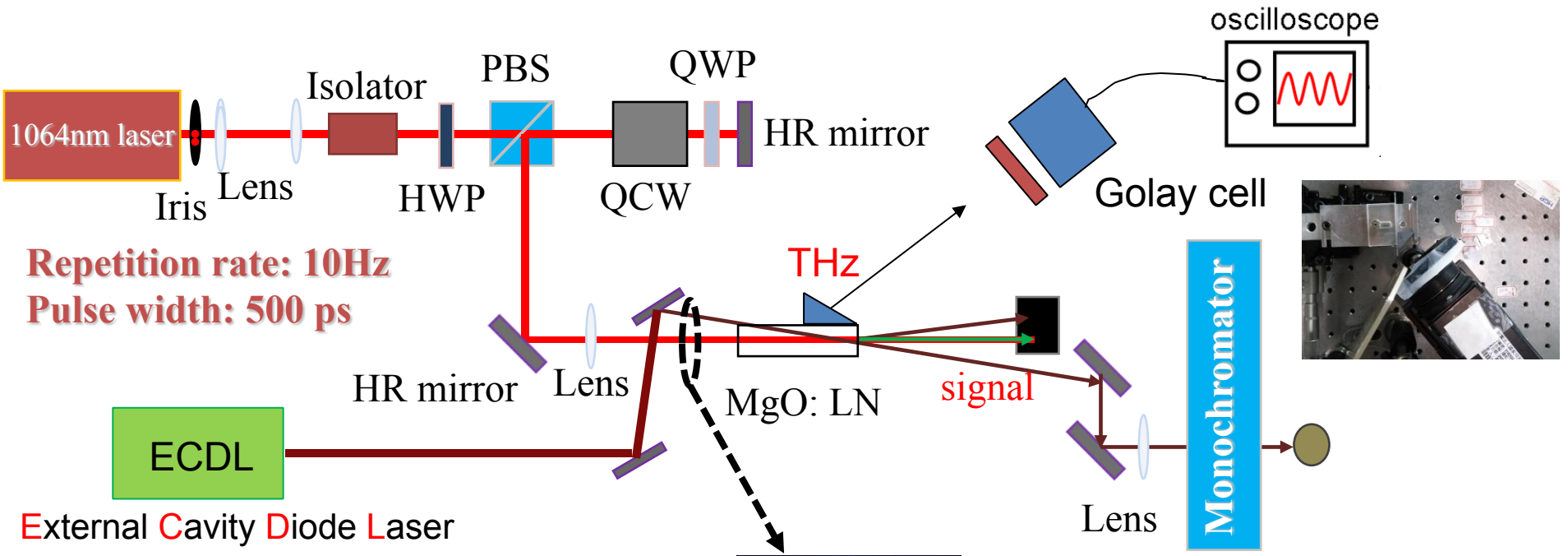


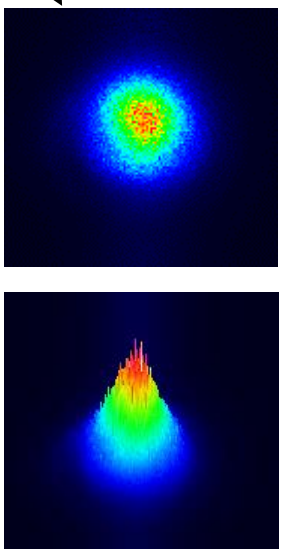


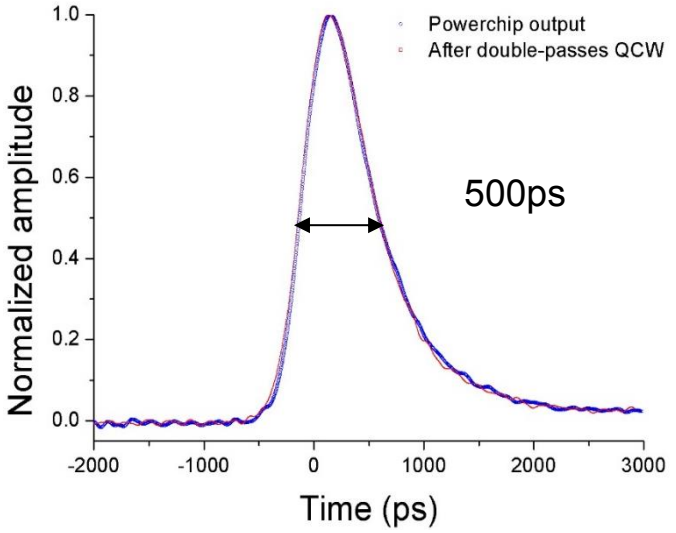


Peak Power: 0.25MW ⟶ 2MW

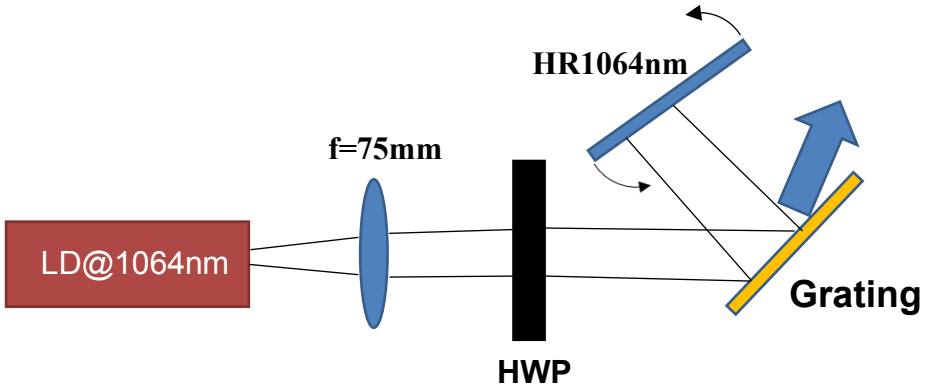
Preliminary Research on THz seed – the system





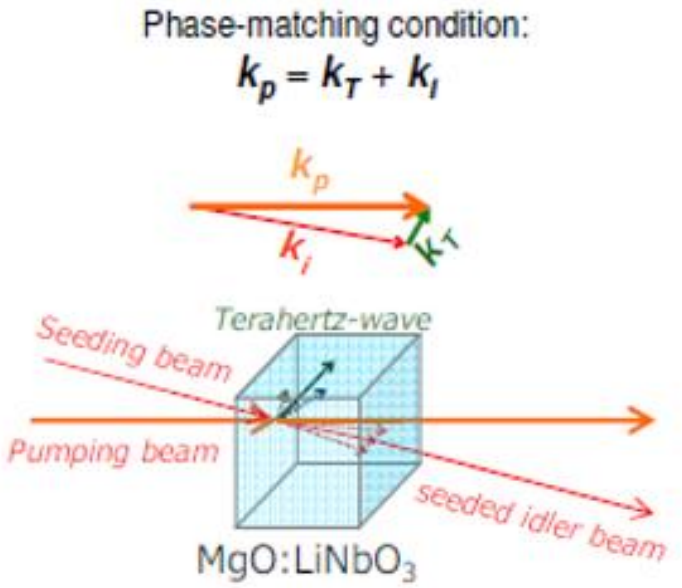


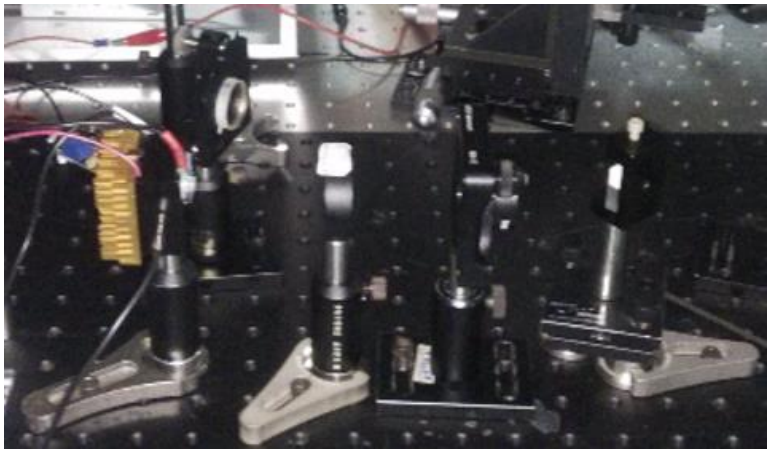
Preliminary Research on THz seed – the system



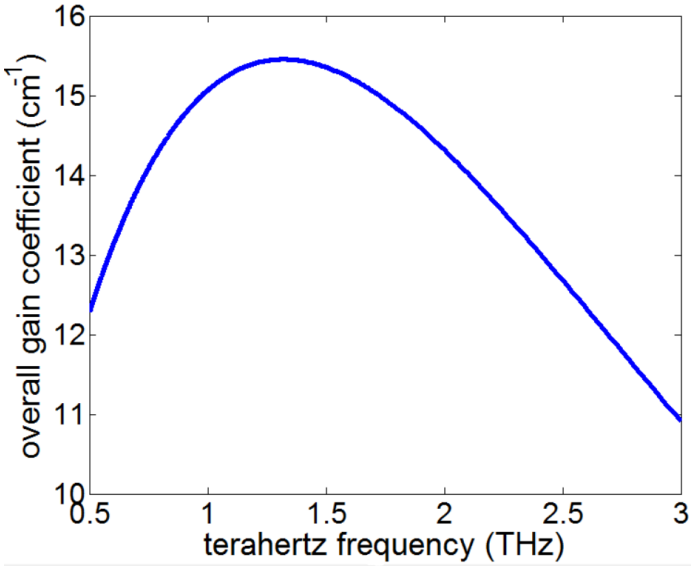
Mode : CW Power: 600mW

Tunable Range: 1066nm~1082nm





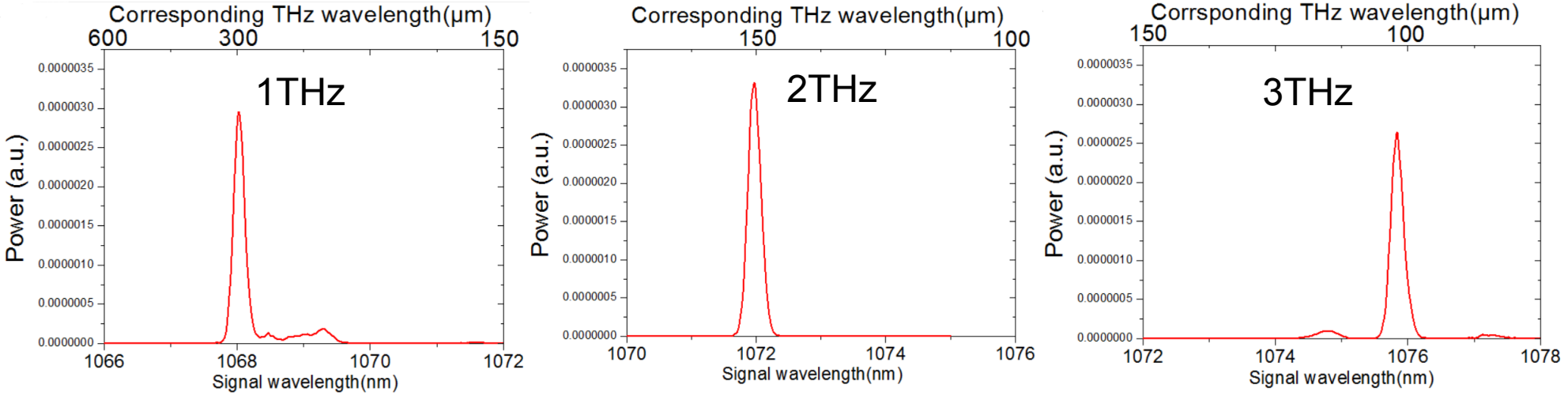
ECDL System

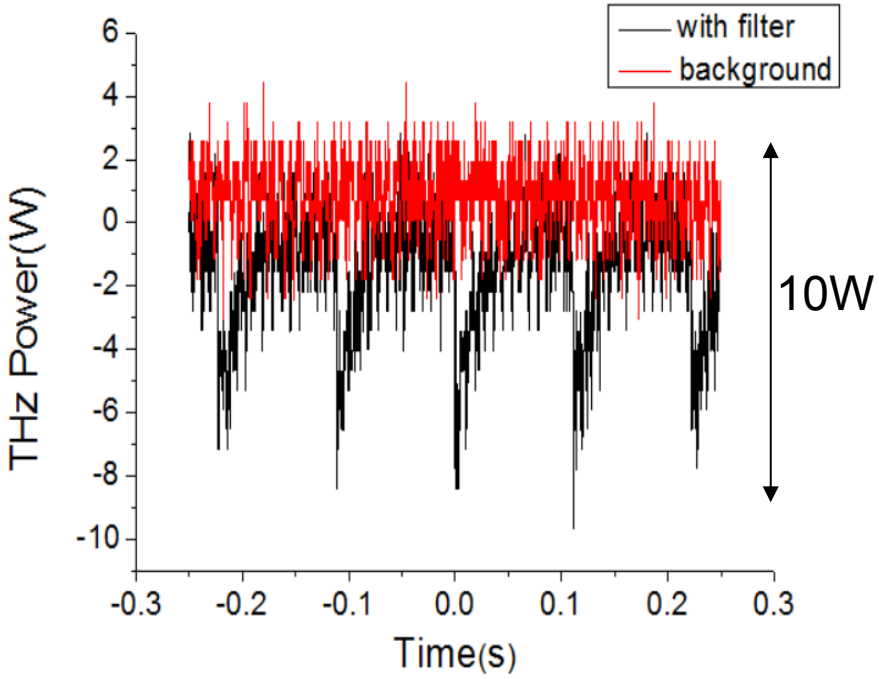


LN gain spectrum

LN: 0.5~3 THz
KTP: 3~6 THz
(for seeded FEL)

Preliminary Research on THz seed - experiments





The bandwidth of THz spectrum mainly depends on the resolution of ECDL.

Summary

- A plan of THz FEL amplifier based on TPA seed and 8~25MeV superconducting accelerator was proposed by PKU and NTHU.
- Simulation results show that THz radiation with tunable frequency from 1 to 6THz, peak power higher than 0.8MW and average power of several watt can be generated.
- On the test system of THz seed, we have obtained narrow-band, frequency tunable THz radiation with about 10W peak power.
- Further optimization for better FEL performance is ongoing.

Thank You!