MIR-FEL Oscillator Lasing by Photocathode Operation of LaB_6 Thermionic Cathode in KU-FEL

H. Zen, S. Suphakul, T. Kii, K. Masuda, H. Ohgaki : IAE, Kyoto University

R. Kuroda, Y. Taira : AIST

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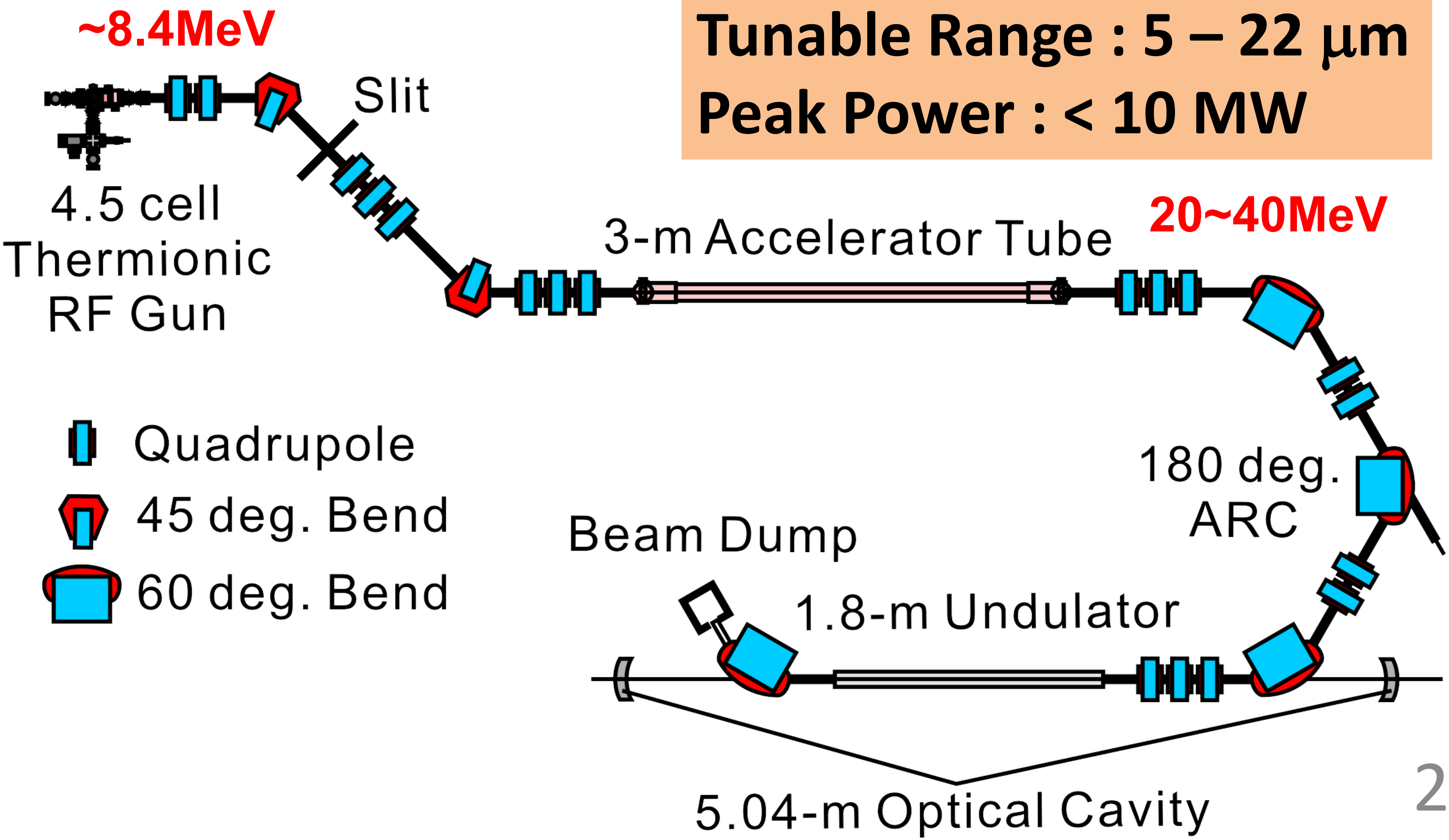
Introduction

KU-FEL = Compact MIR-FEL using thermionic RF gun

Tunable Range : 5 – 22 μm
Peak Power : < 10 MW



KU-FEL Upgrade Project
Thermionic Cathode → Photocathode

Thermionic RF Gun
- Simple and Low cost
- Back-bombardment Effect
- Low bunch charge
- Good for high Ave. Power

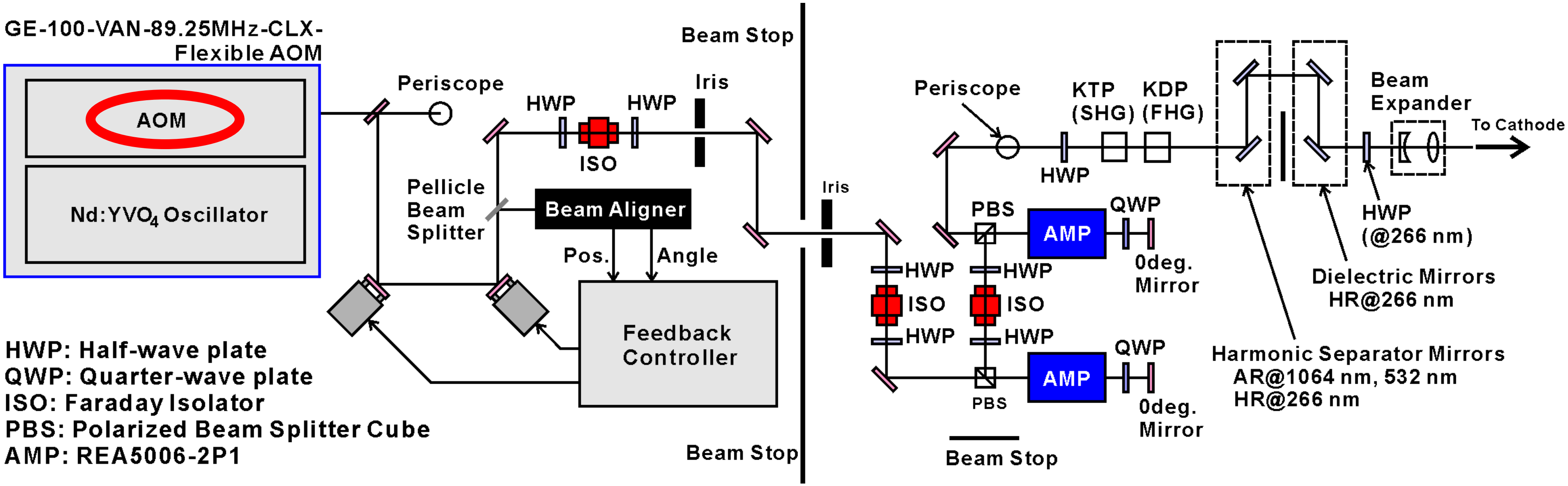
Photocathode RF Gun
- Need Expensive ps-Laser
- No Back-bombardment
- High bunch charge
- Good for high peak Power

Our Upgrade Project
- Use same RF gun
- Use same cathode (LaB_6)
- Use same beamline, undulator and optical cavity
- **Develop multi-bunch UV-laser for photoemission**

➡ **Increase peak power of KU-FEL**

Multi-bunch UV-Laser

2010 : Start development ➔ 2014 : Completed



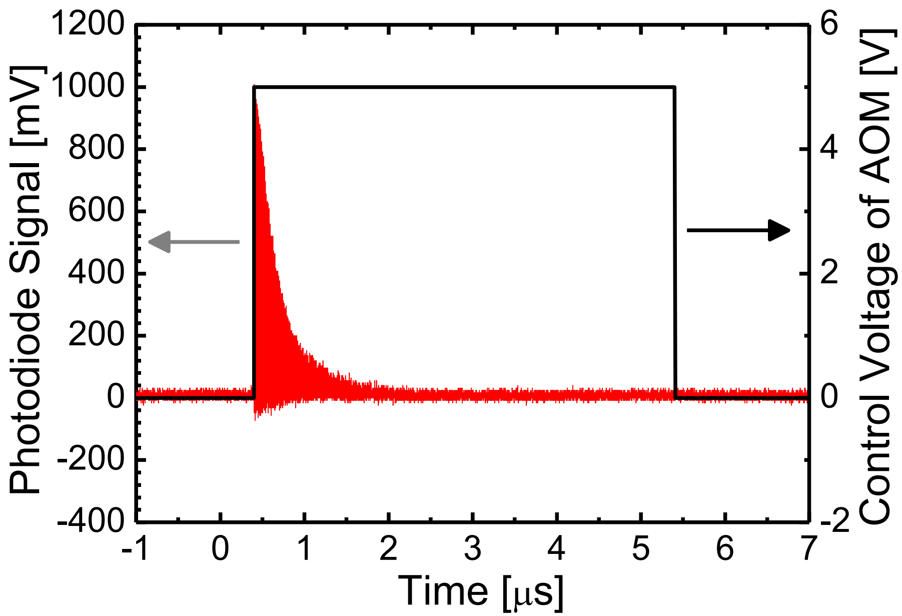
Main Component

- $Nd:YVO_4$ Mode-locked Oscillator & **Integrated Acousto-Optic Modulator (AOM)**
  (89.25 MHz, 7.5 ps-FWHM) (Pulse picker)
- Beam Position Stabilizer
- Two-pass Nd:YAG Amplifier x 2
- Nonlinear Crystals (SHG & FHG)

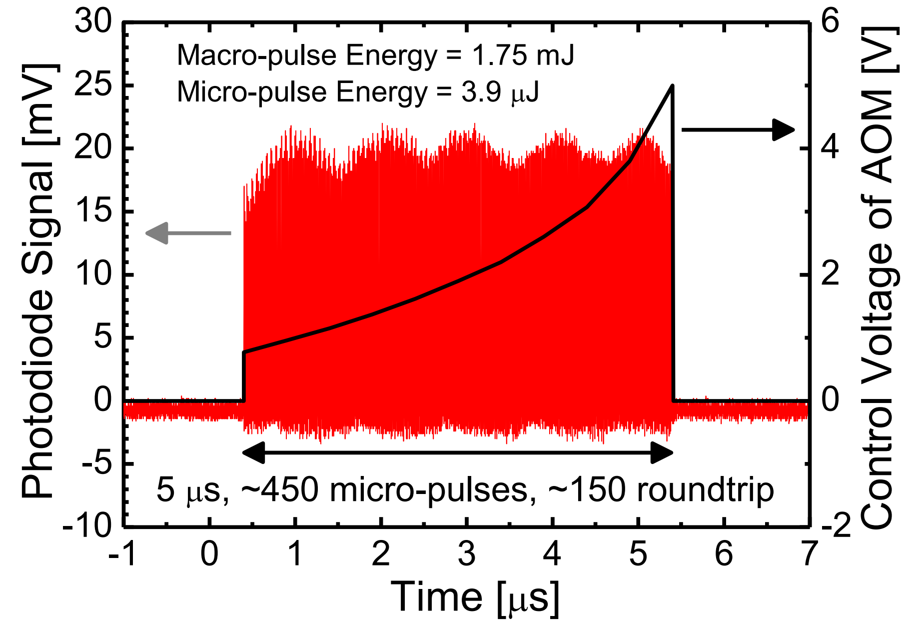
The AOM is key component for multi-bunch UV-laser generation

Compensation of Gain Drop

W/O Compensation



With Compensation



Stored energy in Nd:YAG amplifier rapidly decrease when amplified micro-pulse energy is high.

➔ High gain at the beginning of macro-pulse and low gain at the end.

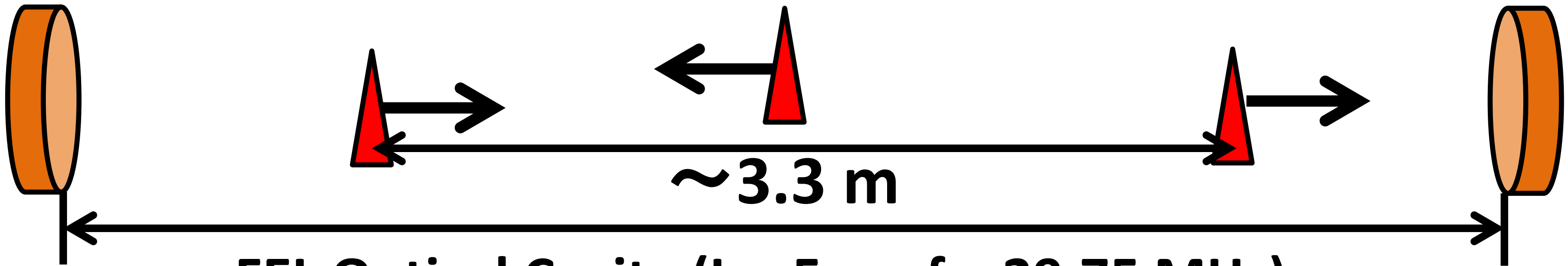
The gain drop can be compensated by modulating input laser pulse by AOM.

➔ Weak input laser pulse at the beginning of macro-pulse and strong at the end.

Multi-bunch UV-laser pulse with rectangular macro-pulse structure can be realized.

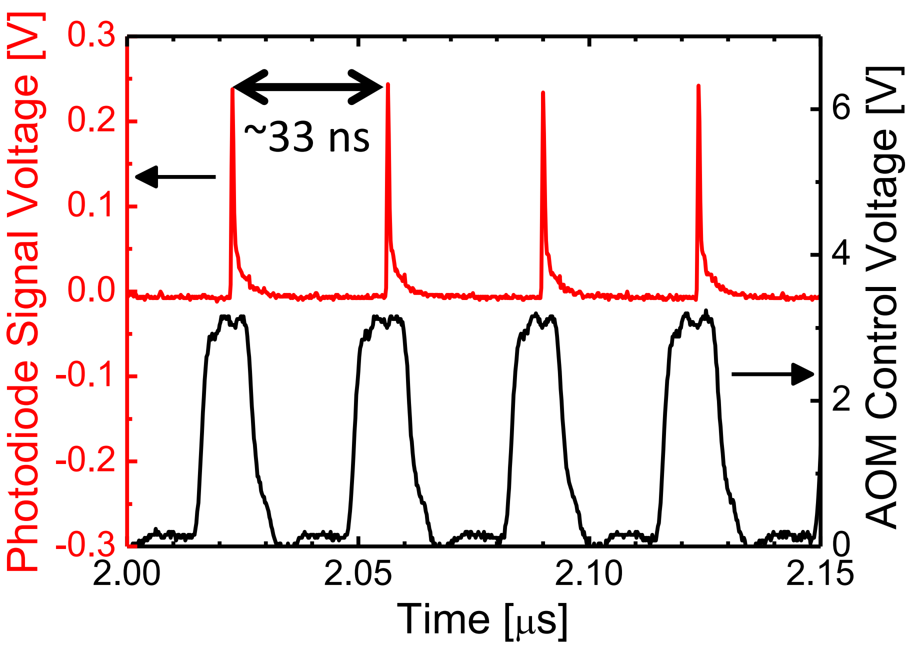
Reduction of Micro-pulse Frequency

In case of e-beam repetition rate = 89.25 MHz



Three independent optical pulses can be amplified.

➔ Use AOM to reduce micro-pulse frequency from 89.25 to 29.75 MHz.



When macro-pulse duration is 5 μs,

89.25 MHz operation

Micro-pulse energy : **~ 4 μJ**

29.75 MHz operation

Micro-pulse energy : **~ 20 μJ**

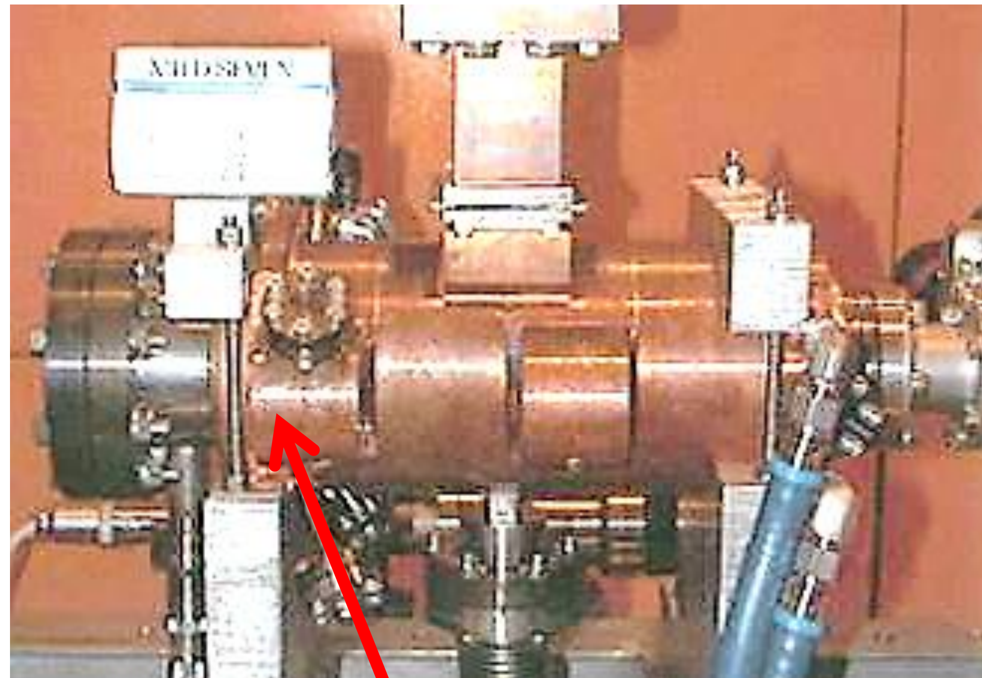
Cathode & RF Gun

Cathode

LaB$_6$ Single Crystal
(100) Surface, 2 mmϕ

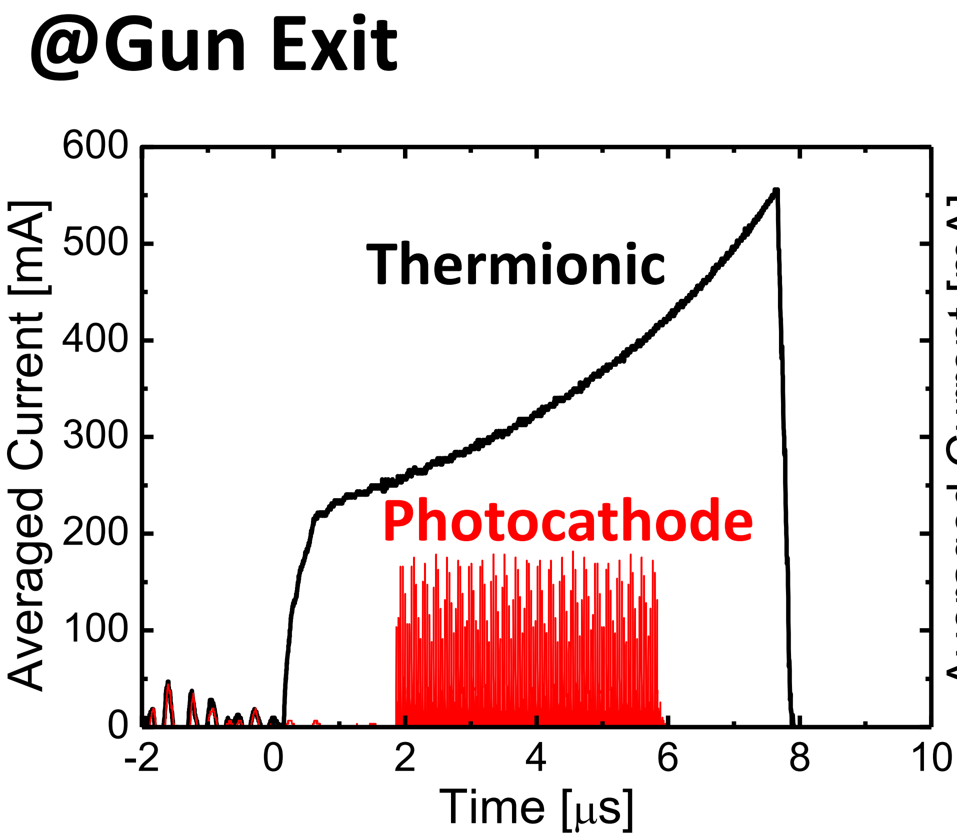
Cathode Temperature
- Thermionic : 1700 deg. C
- Photocathode : 1100 deg. C
  ➔Negligible thermal emission

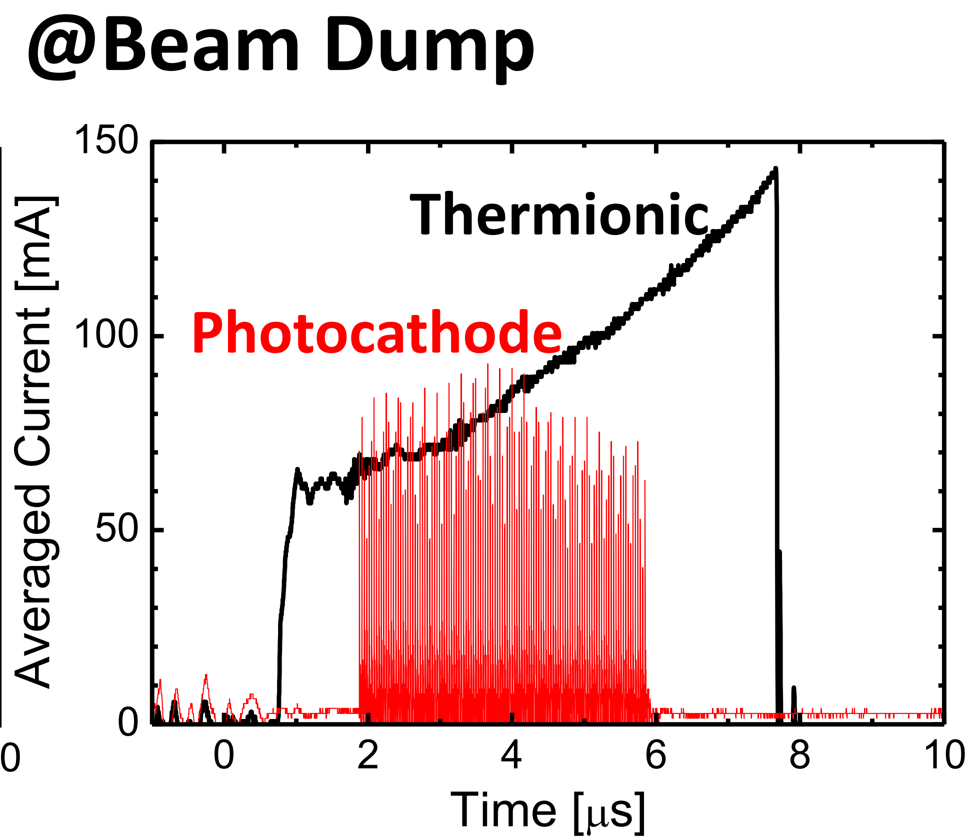
RF Gun : side coupled 4.5-cell, S-band



Laser injection from 70 deg.
Polarization was adjusted to have highest QE.
The measured highest QE was ~0.01%.

Multi-bunch Photoelectron Beam Generation

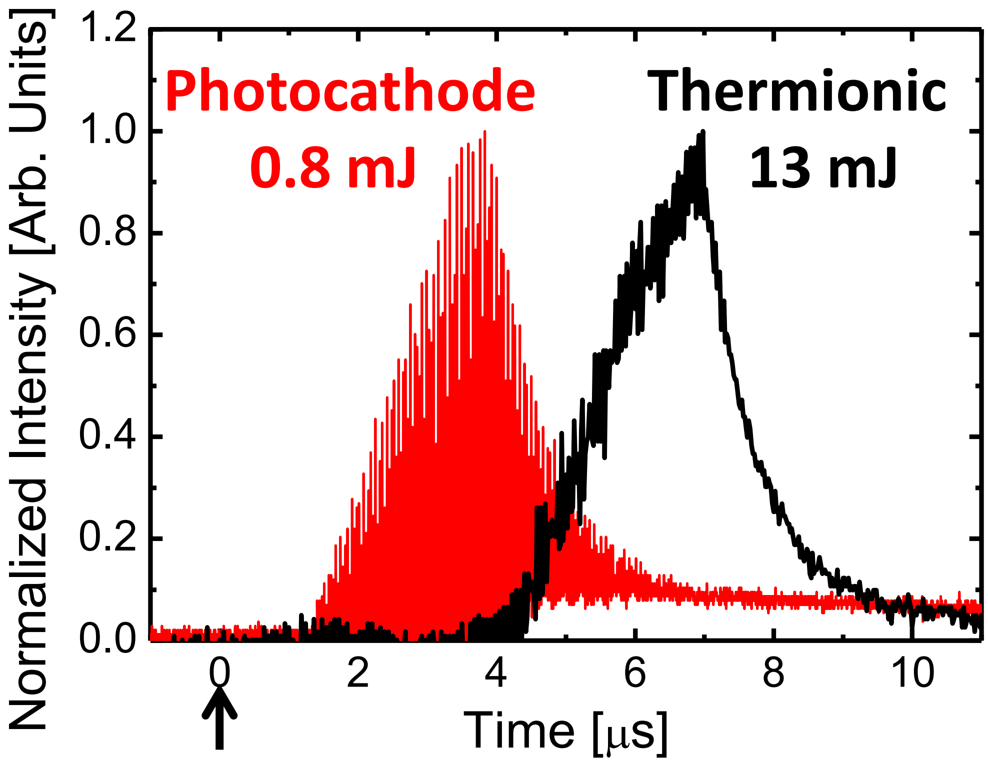




- Flat top Macro-pulse generation with 4-μs macro-pulse duration.
- Bunch charge at beam dump was measured by Faraday Cup.
    - **Thermionic : < 50 pC**
    - **Photocathode : ~ 150 pC**

> 3 times

First Lasing with Photocathode Operation



Starting time of e-beam macro-pulse

Same condition of Undulator and FEL Optical Cavity

e-Beam Energy : ~ 23.8 MeV
Undulator K-value : ~ 1.1
FEL wavelength : ~11.7 μm

Linac was adjusted to have maximum macro-pulse energy.

Micro-pulse Energy Evaluation

Thermionic Operation :

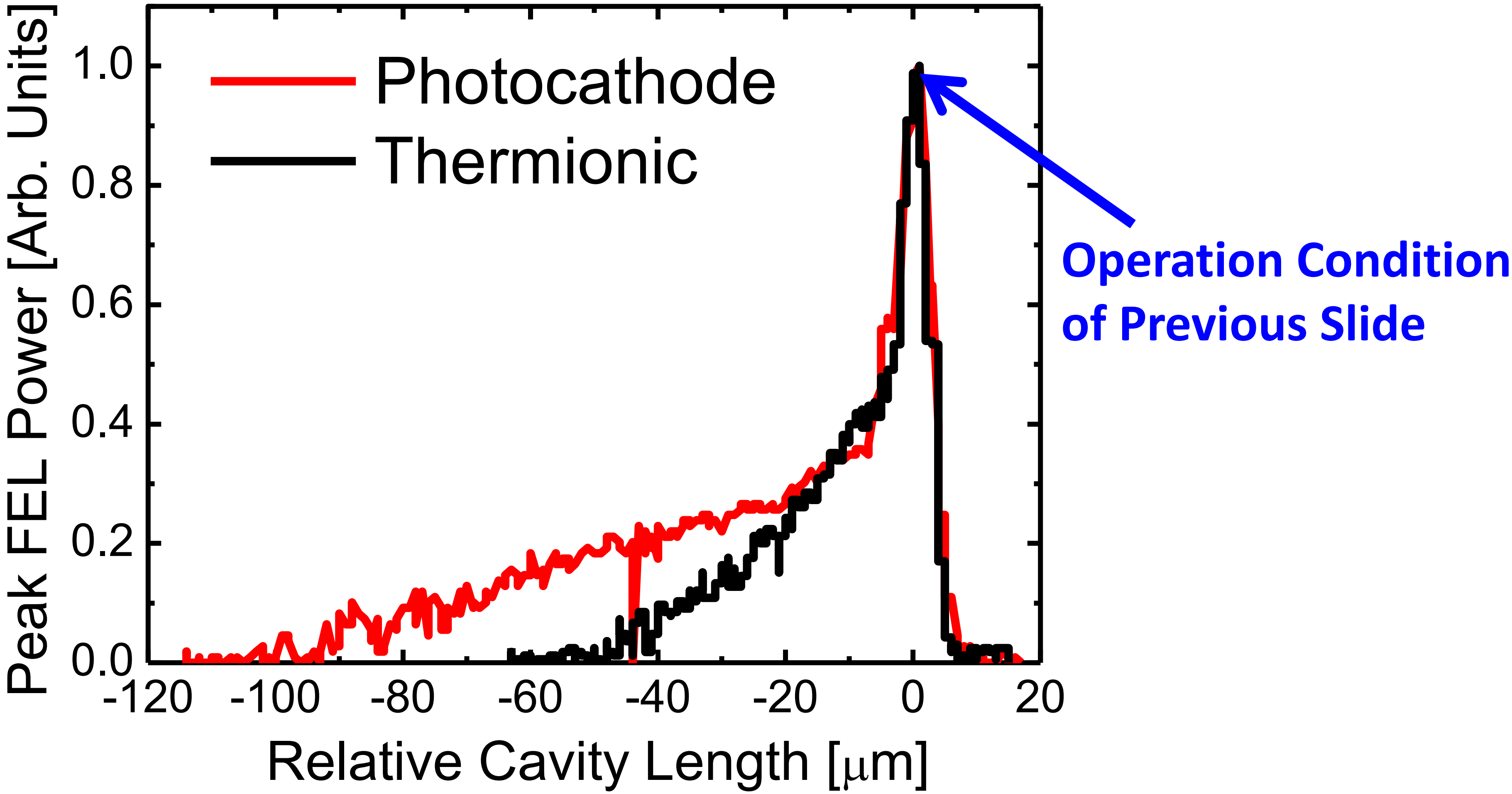
13 mJ / (2856 MHz x 2 μs) = **2 μJ**

Photocathode Operation

0.8 mJ / (29.75 MHz x 2 μs) = **13 μJ**

~ 6.5 times

Detuning Curve



Wider detuning width ➔ Much Higher Gain

Summary

- First Lasing of KU-FEL with photocathode operation of LaB_6 cathode has been achieved.

- Bunch charge @undulator :
  Thermionic < 50 pC ➔ Photocathode 150 pC

- Micro-pulse Energy of FEL : 2 μJ ➔ 13 μJ

- Wider detuning width imply higher gain.

Future Work

- Measurement of basic properties of FEL under the photocathode operation
  - Spectrum
  - Tunable range
  - Temporal structure

- Optimization of coupling hole of FEL optical cavity

- Apply to user experiment require higher peak power of FEL

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Thank you for your attention !