STATUS OF THE MIR FEL FACILITY IN KYOTO UNIVERSITY

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Abstract

We have constructed a mid-infrared free electron laser (KU-FEL: Kyoto University Free Electron Laser) facility in Institute of Advanced Energy (IAE), Kyoto University. The wavelength tunable laser in mid infrared (MIR) region will be used for basic research on energy materials.

The first FEL power saturation at 13.2 μm was achieved in May 2008 and optical characterization was performed in 2009. Development of a laser beam transport system to an experimental hall was finished in 2009. Application of the tunable MIR-FEL in the energy researches at IAE will be started soon.

INTRODUCTION

The MIR wavelength region (5 – 25 μm) are called "fingerprint" region of molecular, because every molecules have individual vibration spectra in MIR region. Thus a MIR tunable laser is powerful tool for advanced application research which controls specific molecular chemical bond [1]. Since renewable energy resource in the future is expected to reduce environmental load, researches on energy-related material which convert solar energy or bio-energy into electricity or chemical energy are becoming more important. Thus, in the Institute of Advanced Energy, Kyoto University, we have developed an MIR Free Electron Laser (KU-FEL) facility. On the occasion of designing the KU-FEL, we regarded compactness, cost, and simplicity such that the MIR FEL can be widely used for energy-related research in many laboratories and companies.

KU-FEL FACILITY

The KU-FEL consists of an S-band 4.5 cell thermionic RF gun driven by a 10 MW klystron, a 3 m travelling wave accelerator structure driven by a 20 MW klystron, a Halbach undulator of 1.6 m, and an optical resonator. Fig. 1 shows a schematic drawing of the KU-FEL accelerator system. We have finished construction of the KU-FEL in 2007 [2]. We stated commissioning of the KU-GEL from 2007 and have achieved the first lasing at wavelength of 12.4 μm and FEL power saturation at wavelength of 13.2 μm in March and May 2008 respectively [3, 4]. The FEL beam transport line from the accelerator hall to a users application room has been designed [5] and constructed in 2009. Schematic drawing of the FEL beam transport line is shown in Fig. 2.

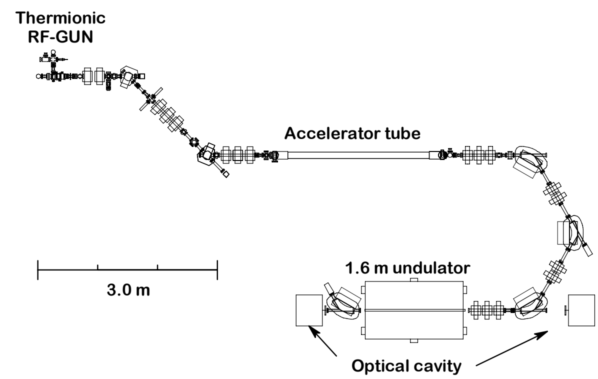

Figure 1: Schematic drawing of KU-FEL.

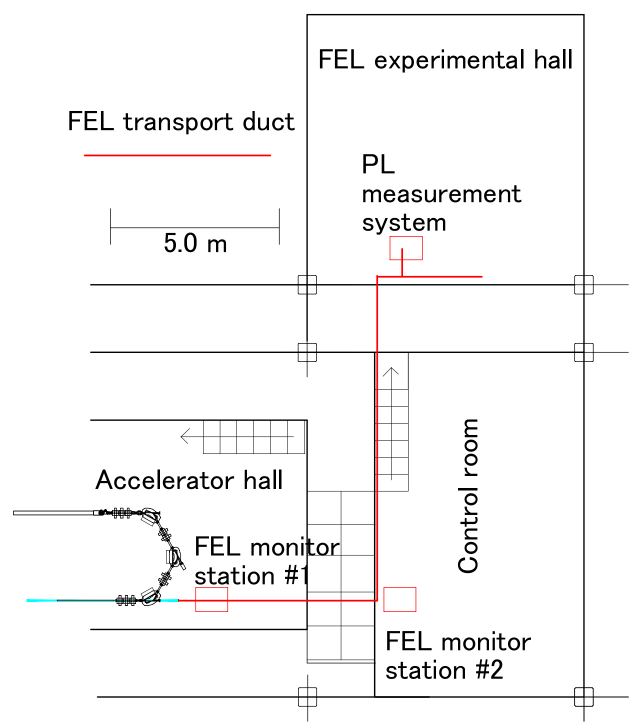

Figure. 2: A diagram of MIR-FEL Beam Transport System.

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OPTICAL PROPERTIES OF FEL

The optical properties of FEL were evaluated at the FEL monitor station located in the accelerator hall. A fast MCZT IR detector (HgCdZnTe, PDI-2TE-10.6, Vigo System) was used to measure the temporal properties of the FEL in the time scale of μsec. Fig. 3 shows the typical output signal and temporal profile of the electron beam. FEL gain and cavity loss were estimated to be 22 % and 10 % from the slope of the exponential growth and decay of the output signal.

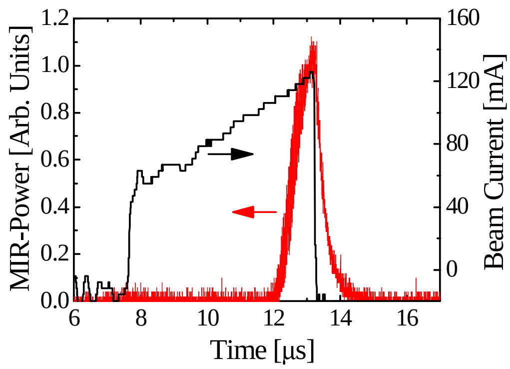

Figure 3: Power evolution of the FEL output and current profile of the electron beam at the undulator section. Around the end of electron beam macropulse, exponential growth of the FEL output was observed.

A pyroelectric detector system (818E-20-50S and 1835C, Newport) was used to measure the optical energy per pulse. The pulse energy was 4.6 mJ/macropulse. The wavelength spectrum was measured by a monochromator (Digikrom, Dk240) and high-sensitive MCT detector (J15D12-M204-S01M-60, Judson technology). The central wavelength was 13.2 μm and the line width was 240 nm in FWHM. Since the micro-pulse duration was estimated to be shorter than 1 ps by an interferometric measurement, expected peak power was greater than 2 MW.

MIR-FEL APPLICATION IN THE ENERGY SCIENCE

As for an application of MIR- FEL to energy science, we have been developing a new approach of material evaluation. We are focusing on the wide gap semiconductors such as SiC, TiO_2, and ZnO since these are widely applied for the eco energy related materials such as next-generation power semiconductor, solar cells, and functional material for ultraviolet optoelectronic devices. Since a phonon plays an important role to the photo-absorption, recombination, electric conduction, and band structure of the semiconductor material, we have been developing an MIR-FEL assisted photoluminescence (PL) measurement system which consists of He-Cd laser (Kinmon, IK5451R-E), and monochromator (NOS-Omini-λ3008) as shown in fig. 4.

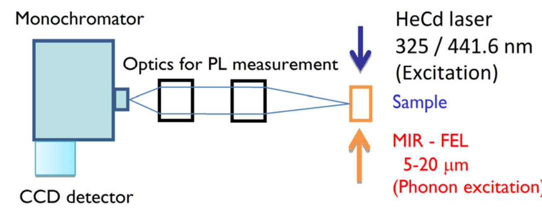

Figure 4: Schematic drawing of the FEL assisted PL measurement system.

FUTURE UPGRADE

In order to conduct future researches related to energy science, we have been considering improving and upgrading the KU-FEL facility.

Improve stability

Improvement of FEL stability is an important issue for application using FEL. Even a small change of room temperature, cooling water temperature, and cathode surface temperature, introduces large changes of electron beam energy and trajectory at the undulator position. In order to stabilize beam energy and trajectory, we have installed 6 non-destructive button beam position monitors (BPM). We are developing a beam position and energy stabilization system using amplitude information from the BPMs and a bunch phase stabilization system using RF phase information form the BPMs [6].

Extend tunable range

To extend the wavelength range, we are preparing to install a 1.8 m undulator [7] which was used in JAEA super conducting linac based FEL system. Main parameters of the present and the JAEA undulator are shown in table 1.

A preliminary calculation of the FEL gain has been performed by using GENESIS. The expected FEL gain is increased by factor 2. The wavelength tunable range will be extended to be from 5 to 21 μm.

Table 1: Parameters of the Present Undulator and JAEA 1.8 m Undulator

	Present Und.	JAEA Und.
Period Length (cm)	4.0	3.3
Period	40	52
Gap Range (cm)	2.6-4.0	1.5-10
Maximum K-value	0.99	1.5
Peak Field (T)	0.25	0.5

Recent progress of photocathode RF gun technology realize ultra high brightness electron beam [8]. A design study for the system upgrade of our FEL system was performed. The calculated FEL gain in wavelength of 9.8 μm is 810% [9]. We have prepared a 1.6 cell RF gun and are designing a multi-bunch laser system to generate high brightness photoelectron. The JAEA undulator and the photocathode RF gun are expected to the key devices for the future upgrade of the KU-FEL in MIR region.

Recently, we have proposed the table top THz FEL amplifier [10] consisting of a photocathode RF gun, a focusing solenoid, a planer undulator, and an is-TPG [11] THz seeding system. The expected THz peak power exceeds 5 kW/pulse. The table top THz FEL amplifier has a potential for tunable, compact, and high-power radiation source in THz region. Schematic drawing for the future upgrade design of the KU-FEL is shown in fig. 5.

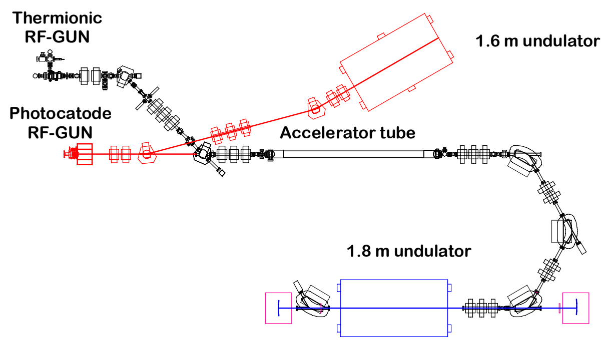

Figure 5: Schematic drawing of future upgrade design of the KU-FEL. A 1.8 m undulator and a photocathode RF gun will extend wavelength tenability, and the photocathode RF gun will be used also for FEL THz amplifier.

CONCLUSION

We have constructed a MIR FEL facility to conduct research on future renewable energy resources. The first lasing and power saturation of the KU-FEL at wavelength of 12-13 μm have been performed in 2008, and development of an FEL transport system for application experiment was finished in 2009. The first application experiment on energy rerated material research will be started soon at the KU-FEL

Future upgrade programs to improve stability of the FEL and extend tunable range are planned in parallel to the application experiment. A simple beam stabilization system using beam position monitors will improve FEL stability. Introduction of a photocathode RF gun and a 1.8 m undulator will extend FEL tunable rage from 5 to 21 μm. A new scheme for a THz FEL amplifier will introduce a new research field using high-power THz laser.

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