PRESENT STATUS OF THE KU-FEL PROJECT 2003

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Abstract

A compact and economical FEL facility (KU-FEL) is under construction at the Institute of Advanced Energy, Kyoto University. The outline and present status of the facility are described briefly in this paper.

INTRODUCTION

The purpose of the compact and economical FEL (free-electron laser) facility (KU-FEL), which is under construction at our Institute is to establish linac-based FEL technology and explore new application fields especially in advanced energy science, e. g. researches on bio-energy, bio-chemical reactions, and materials for nuclear fusion. For these purposes the wavelength of the FEL should span a wide wavelength region from infrared (IR) to far-infrared (FIR). A conceptual view of the KU-FEL project is shown in Fig. 1. The electron beam of 20 ~ 40 MeV with macro-pulse length up to preferably 7 μs will be provided by an S-band linac with a RF (radio frequency) gun. A two stage FEL system (e. g. a MOPA (master oscillator and power amplifier) system) is planned for the future to enhance the output power without deteriorating the laser quality. Generation of quasi-monochromatic x rays of several keV by exploiting a FEL-Compton backscattering is also planned. An energy recovery system is considered to save energy and reduce shielding duty. A 4.5-cell thermionic RF gun driven by a 10-MW klystron (#1) has been constructed and an electron beam has been extracted. Measurement of beam characteristics and quantitative study of back-bombardment effect inherent to an RF gun with a thermionic cathode are underway. A 20-MW klystron and a 3-m accelerator tube have been installed and tested. A beam transport system, vacuum system, a planar undulator, an optical cavity are ready to be installed.

ACCELERATION SYSTEM

Acceleration system of the KU-FEL consists of a RF gun, a 3-m accelerating tube (linac), a beam transport system (BTS) from the RF gun to the accelerating tube, and a BTS from the linac to the undulator. The plan view of the present KU-FEL system is shown in Fig. 2, where equipments with dotted lines are going to be installed in the near future. The overall size of the whole system is about 7 m × 3 m. Numerical simulation of the electron-beam characteristics up to the entrance of the undulator [1] and measurement of the emittance and energy spectra in front of the accelerating tube [2] are under way.

RF Gun

A thermionic RF gun is used as an injector because it has features of compactness and high brightness of the output beam. The gun consists of a 4.5-cell cavity with a 10-MW RF driver, which provides an electron beam of about 4-MeV. Numerical investigation has shown that the RF gun has enough performance [3]. The parameters of the RF gun and its RF source have been described in a previous paper [4]. Measurement of beam characteristics is under way. However, the back-bombardment of electrons limits the macro-bunch length to below a few μsec at present. Temperature rise due to the back-bombardment was measured quantitatively for the first time in the world [5]. Evaluation of the heat due to the back-streaming electrons has been made using the above experimental result, results of particle simulation, and a heat transport model [6]. Use of a LaB_6 cathode of small diameter together with a sweep magnet to deflect the back-streaming electrons seems to be promising [7].

Linac

A 3-m accelerator tube and a 20-MW RF power source have been prepared and tested. The main parameters of the linac have been described in a previous paper [4]. Nominal parameters of its RF source are shown in Table 1.

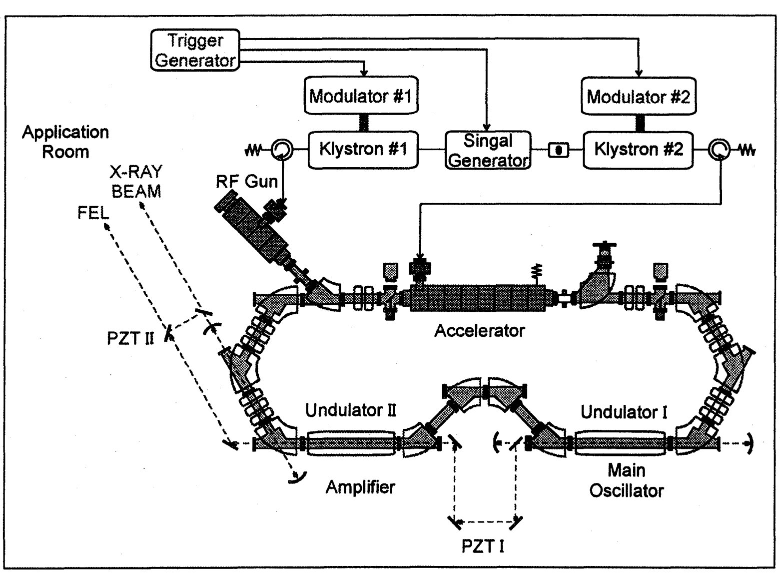

Figure 1: Conceptual layout of KU-FEL facility.

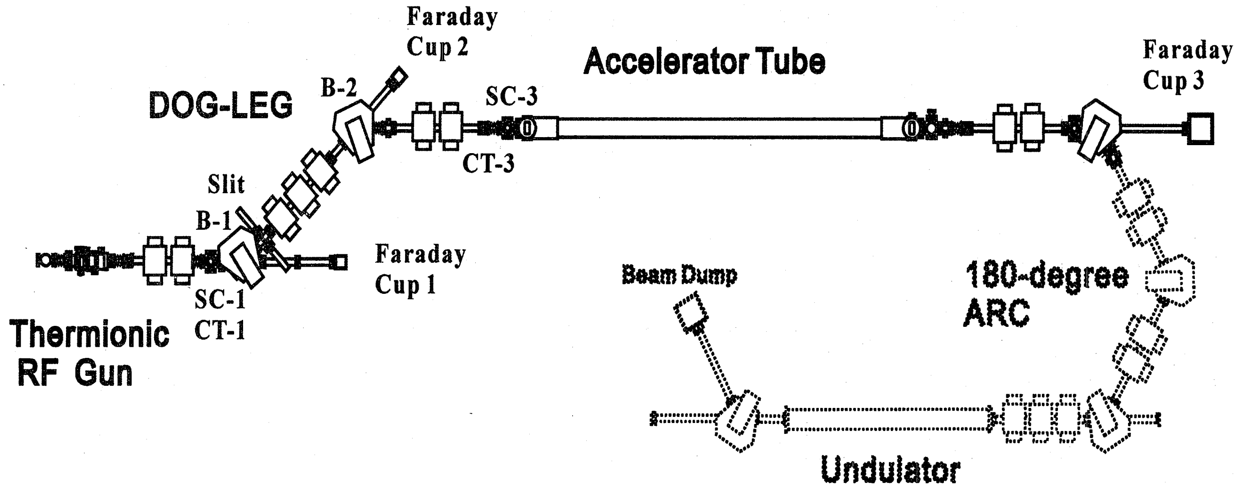

Fig. 2 The plan view of the present KU-FEL system, where equipments with dotted lines are going to be installed in the near future.

Table 1. Parameters of the RF source of the linac.

Klystron:	Mitsubishi PV3030A2
Peak Power:	20 MW
Pulse Duration:	10 μsec
Repetition Rate:	10 Hz
Modulator:	remote controlled PFN
Pulse Duration:	>10 μsec(flat-top)
Ripple:	< 0.3%p-p

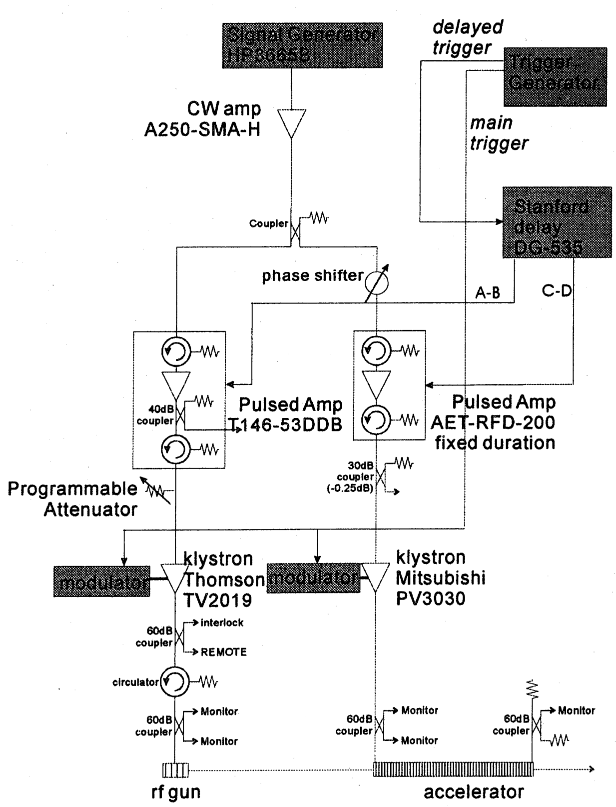

Figure 3 Circuit diagram of the RF driver and trigger system.

RF Test

The linac and its RF source have been installed. Recently, the RF test of the system was carried out.

Figure 3 shows the circuit diagram of the RF driver and trigger system. The macro-pulse duration of the electron beam generated by the RF-gun can be varied remotely by the delay module. On the other hand, the pulse duration of the accelerator is fixed to 8-10 μs. The output pulse shape can also be modified by adjusting the inductance remotely.

Figure 4 shows the output power of the klystron #2. According to the specification of the PV-3030A, the maximum output power is about 28 MW with 240 kV. However, about 15.5 MW with 240 kV was obtained in the test measurement because the klystron was rather old. We also measured the perveance of the klystron, which is shown in Figure 5, and found that the perveance was 1.82 μP, which is lower than its nominal value of 2.1 μP. During the test acceleration we will use this klystron tube for a while, and then replace it with another one.

Although we have not received permission of the final acceleration, we have carried out numerical calculation to

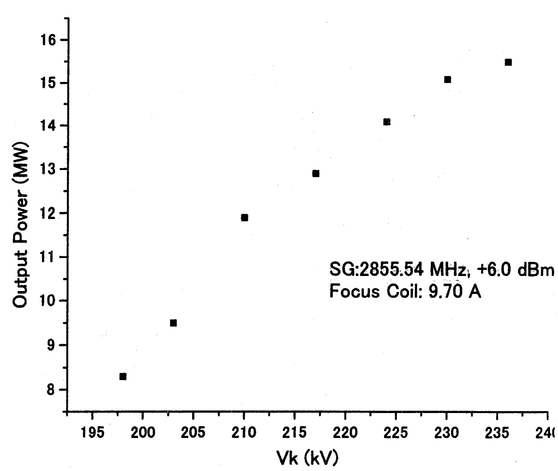

Figure 4 Output power of the klystron #2 as a function of cathode voltage.

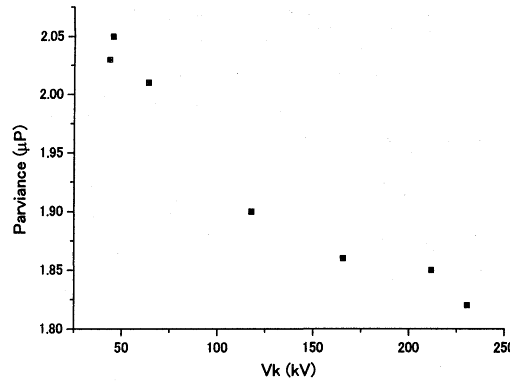

Figure 5 Perveance of the klystron #2 as a function of cathode voltage.

evaluate the electron beam parameters [1]. The calculation has been performed with PARMELA and the BTS parameters were calculated by TRACE3D.

FREE-ELECTRON LASER

A planar undulator and an optical cavity are ready to be installed after the BTS following the linac.

Undulator

A planar undulator that was used for a lasing experiment under the collaboration of the FELI (Free Electron Laser Research Institute) and the University of Tokyo will be used in our initial experiment. It has been modified from a fixed gap to a variable gap for easy handling in practical use. The main parameters of the undulator and the electron beam are listed in Table 2. The electron-beam parameters are for typical beam energy of 36.4 MeV.

The FEL gain for electron beam energies of 24.6, 30.5, and 36.4 MeV calculated with TDA3D code [8] are shown in figure 6. It was found after a successive simulation that macropulse width should be longer than 3 μs for FEL saturation [1].

CONCLUSIONS

Outline and present status of the KU-FEL project has

Table 1. Parameters of the undulator and the electron beam.

Undulator type:	Halbach (permanent magnet)
Period:	40 mm
Number of periods:	40
Gap:	26 – 56 mm
Peak magnetic field:	0.25 – 0.05T
K value	0.95 – 0.17
Energy:	20 – 40 (36.4) MeV
Peak current:	40 A
Bunch length:	1.8 ps
Energy spread:	0.40 %
Normalized emittance:	$\varepsilon_x \sim 11.3\ \pi$ mm·mrad
	$\varepsilon_y \sim 10.1\ \pi$ mm·mrad

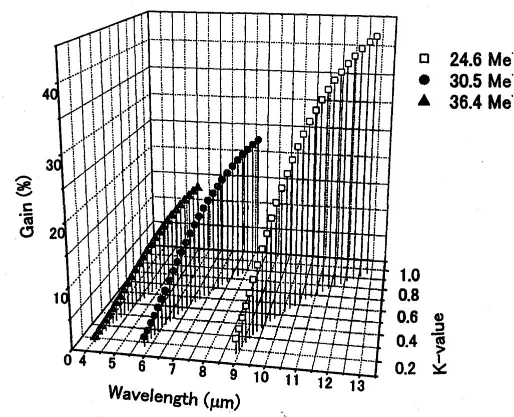

Figure 6 Expected FEL gains.

been described. Acceleration test will be begun in quite a near future after the permission of Ministry of Education and Science.

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