

COMMISSIONING OF FELI FACILITY 5 COVERING THE WAVELENGTH FROM 50 TO 100 μm

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ABSTRACT

The FELI facility 5 (50-100 μm) of the compact facility, including a 2.24-m long undulator (λu=8 cm, N=28) and a 5.04-m long optical cavity, was installed at the 20-MeV beam line of the 20-MeV S-band linac with an RF-gun in the Laser Instrument Room in March 1996. An FEL beam will be delivered from the upstream optical cavity to the Laser Experimental Room through a pipeline. The operation of the compact facility including final RF aging was begun in May and the beam acceleration was started in the middle of June. The beam current of 150-200 mA was obtained from the linac in the middle of October and the spontaneous emission was measured in the end of October. The FEL oscillation experiment is continued.

1. Introduction

The FELI facility 5 is an RF linac based facility designed to extend our FEL applications to semiconductor devices at the far-infrared wavelengths from 50 to 100 μm [1]. This paper will review the design, construction and status. The distinguishing characteristics of the FEL facility 5 are the use of a thermionic-cathode RF gun, a PV3020 klystron driven by a 10 μs modulator with a PFN of two parallel by 24 sectors, and a 2.24 m long, 28 periods NdFeB Halbach undulator. The design work of the FELI facility 5 was began in 1995, and the system was installed on the present site in March 1996. Since then, the system has been under continuous improvement. Spontaneous emission was firstly observed in October 1996.

2. Description of the machine performance

The general layout of FELI facility 5 is shown in Fig. 1. The system parameters are shown in Table 1. These values are present operating values.

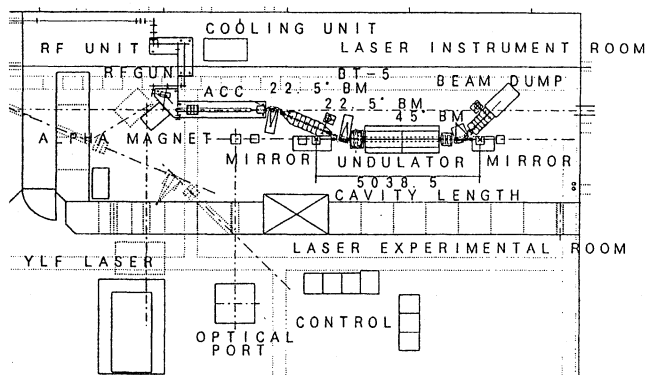


Fig. 1 Schematic view of the FELI facility 5

Table 1 FELI facility 5 system parameters

Electron beam	
Macropulse length	4-5 μs
Macropulse repetition rate	10 Hz
Micropulse length	3-5ps
Micropulse repetition rate	2856 MHz
Beam energy	18 MeV
Macropulse current	150-200 mA
Undulator	
Period	8 cm
Number of periods	28
Gap	30-150 mm
K-value	1-2.3
Optical cavity	
Cavity length	5.04 m
Operating wavelength	50-100 μm
Mirror radii upstream	2.662 m
down stream	2.662 m
Mirror reflectance	99 %
Rayleigh length	0.6 m

2.1 The thermionic RF gun

As an injector, the RF gun consists of two parts, the gun cavity and the alpha magnet. The electrons are emitted by a 3 mm diameter LaB6 cathode. They are accelerated across a 3 cm gap by the RF field in the cavity.

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The electrons emerge from the cavity through steering and triple quadrupole magnets and then pass through the alpha magnet. This magnet selects most of the electrons in some energy range, and bunches them for injection into the accelerator. Since the electron energy is not very high, the emerging bunches will lengthen as they pass through the drift sections before and after the alpha magnet. The alpha magnet is configured to have a positive momentum compression factor, and the debunching of the drift sections must be compensated by the overbunching in the magnet. Since the dimension of the alpha magnet and the length of the drift sections are fixed, in order to increase its bunching effect we must increase the electron energy emerging from the gun cavity while increasing the magnetic field to keep the electron path unchanged in the magnet. This indicated that electron bunches were compressed to a few picoseconds at the entrance of the linear accelerator.

It is known that the back-bombardment effect could cause beam current to increase within macropulse. This beam is generally not suitable for acceleration because of beam loading. This is the main reason we do not use the full  $10\mu\text{s}$  pulse length of the klystron. However, the photo-cathode RF gun will be used the full  $10\mu\text{s}$  pulse length.

## 2.2 The high power RF system

The RF system consists of a 20 MW high power klystron driven by a 10 kW klystron, TH2436. This PV3020 klystron was developed for a  $10\text{-}\mu\text{s}$  pulse operation from the PV3030A3 klystron. A modulator for the PV3020 klystron consists of 2 parallel networks of 24 capacitors and 24 variable reactors, and it has a line-switch of the F-241 thyatron. The flatness of our klystron modulator for PV3020 is 0.3% at  $10\mu\text{s}$  pulse operation.

## 2.3 Linac section

An ETL type 2 m long accelerator section is used for acceleration. This accelerator section with a length of 2 m is of linearly narrowed iris type to prevent beam blow up (BBU) effects at high peak current acceleration. Fig. 2 shows the electron beam macropulses before and after the accelerator section.

The measured energy spread is 0.6% at FWHM. The bunch width after acceleration, was measured with a streak camera with 2 ps time resolution. It gave an FWHM value of about 3-5 ps.

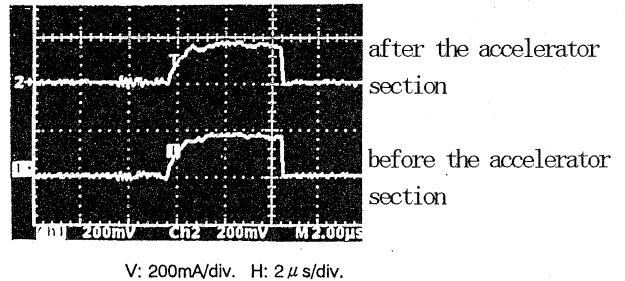


Fig. 2 Electron beam macropulses before and after the accelerator section

## 2.4 The beam transport line

Along the electron beam line, seven screen monitors are prepared. The electron beam size and position are always monitored and controlled to pass through the center of accelerator section using screen monitors installed at the inlet and outlet of accelerator section. Further, using five screen monitors installed in the S-type BT line for the FEL facility, the beam size and position are adjusted along axis so as to pass through the center of a narrow vacuum chamber inserted into the undulator. The system of first and second  $22.5^\circ$ -bending magnets are satisfied achromatic condition, and parallel beam is transported between them. As a result of achromatic transport, the focused electron beam passes through the undulator. The beam passing through the undulator is focused and sent to a beam dump using a  $45^\circ$ -bending magnet.

## 2.5 The undulator

The undulator is of the Halbach type with NdFeB permanent magnets of 28 periods of 8 cm. The dimensions of a component permanent magnet is  $10 \times 20 \times 170\text{ mm}^3$ . The peak magnetic field and the corresponding K-value cover the ranges of 1300-3100 G and 1-2.3, respectively, according to the gap range of 38-60 mm. While, the range of the gap

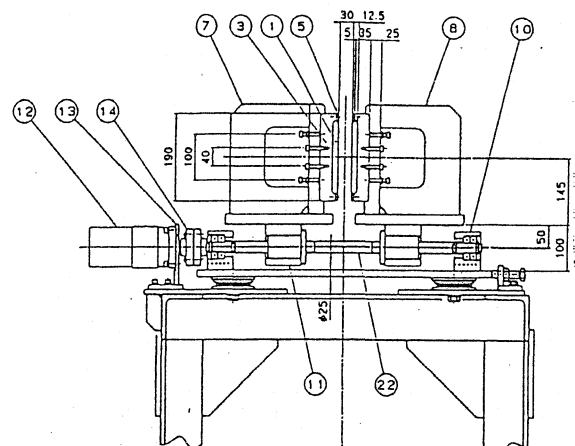


Fig. 3 Assembly plan of the undulator

distance can be set to cover 30–150 mm. Fig. 3 shows the assembly plan of the undulator.

## 2.6 The optical cavity

The optical cavity is a Fabry-Perot cavity which consists of two mirror vacuum chambers. The cavity mirrors are spherical and gold coated on copper substrate. An aperture of 3 mm diameter in the upstream mirror provides outcoupling of a fraction of the optical radiation. After extraction from the upstream mirror, the laser beam passes through a vacuum pipe and sent to the diagnostic room. The optical window between low and high vacuum is used diamond, while the output window is used polyethylene. Fig. 4 shows a bird's eye view of the FELI facility 5.

Same way as the other FELI facility was used to align the cavity[2]. The optical axis of two mirrors is adjusted to coincide with the electron beam position. The electron beam position is detected using three profile monitor in the undulator and images of profile at the plate are observed by CCD cameras. The reference He-Ne laser was used to monitor the position of the two mirrors by observing the shift of the laser spot reflected from the two mirrors. First, the reference laser beam is reflected to the optical axis by a beam splitter, and is reflected by the downstream mirror. Then, images of the laser profile is observed to reflect by a beam splitter with the upstream stopper of a beam splitter. Secondly, the laser beam through a beam splitter is reflected by the upstream mirror without the upstream stopper of a beam splitter, is reflected by the downstream mirror, and then images of the laser profile is observed to reflect by a beam splitter. The secondly observed laser spot is adjusted to coincide with the firstly observed laser spot by the tilt of the upstream mirror.

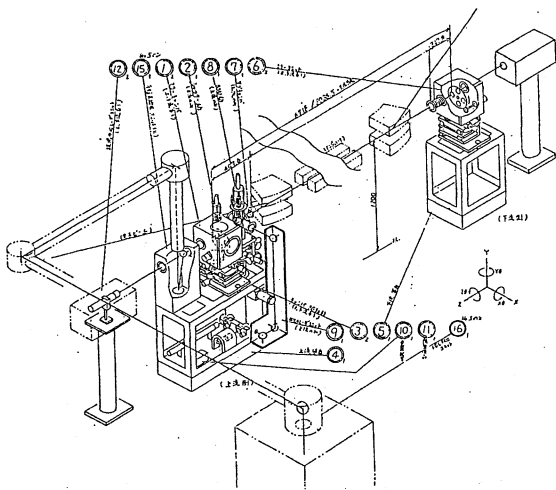
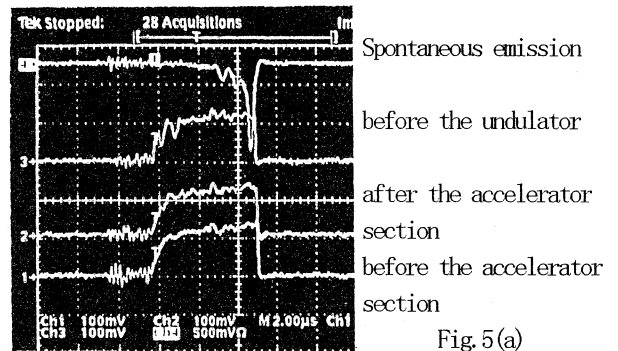


Fig. 4 Bird's eye view of the FELI facility 5

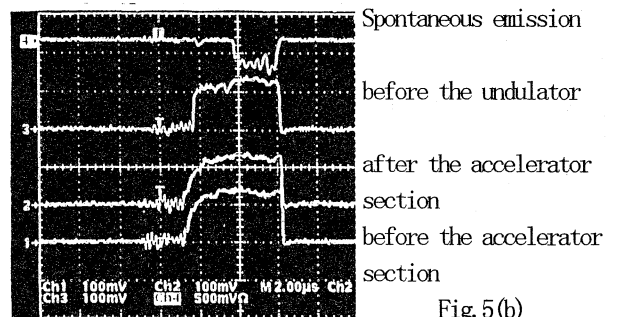
## 3. Spontaneous emission

The Ge-Ga detector cooled by liquid helium is used for detecting the spontaneous emission. The detector spectral response is provided by 52 micron cut-on filter installed at the cone entrance aperture. The measured parameters are shown below. The signal at preamplifier output at 1000 Hz of this detector is 0.6 V. The chopped power falling on detector of  $0.455 \mu\text{W}$ . The noise reference to the detector is  $1.82 \mu\text{V}/\sqrt{\text{Hz}}$ . The S/N ratio is  $3.30\text{E}+05$ . The constant background power is  $2.17\text{E}-06 \text{ W}$ . The measured NEP is  $1.38\text{E}-12$ . The quantum efficiency is  $1.05\text{E}-02$ . The current responsibility is  $1.32 \text{ E}+02 \text{ A/W}$ .

Fig. 5 shows both the electron pulses (lower 3 parts) and the spontaneous emission (upper part). The electron pulses 1–3 are of before and after the accelerator section and before the undulator, respectively. The experiment at the beam current of 200 mA is not measured because of the RF breaking in the gun cavity. After this breaking, the beam current of 200 mA is not obtained from the accelerator. Therefore, it will need more RF aging for the linac to achieve the more beam current operation.



1~3 V: 100mA/div. H: 2 µs/div.



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Fig. 5 Spontaneous emission measured with a Ge-Ga detector at  $80 \mu\text{m}$

## References

- [1] T. Tomimasu, et al, Nucl. Instr. and Meth, A375 (1996) 626–631.
- [2] K. Saeki, et al, Nucl. Instr. and Meth, A375 (1996) 10–12.