Present Status of LEBRA at Nihon University

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Abstract

Free electron laser (FEL) of Nihon university has based on a 125MeV electron linac. These construction were started in 1994 and were completed in 1997. The linac was commissioned at January of 1998. An observation of spontaneous emission (SE) from electrons pass through an undulator was performed and the qualities as the SE spectrum, an emittance, an energy spread and a shape of bunched beam were successively measured

The beam achieved at a current of 210 mA with an energy of 87 MeV. However, when the beam is transported to the FEL system, it decreased to about a half. What is worse it was unstable. In order to beam stability, improvements for the rf system have been attempted.

The linac met with various accidents since its first commissioning. Moreover, the permanent magnets of undulator was damaged by the radiation. Now, the undulator is under repair.

This report summarizes the present status and developments in the facility

1. Introduction

The FEL project in Atomic Energy Research Institute (AERI) was authorized by the board of directors in Nihon University in 1994. The project is requested to promote accelerator technologies and to progress advanced researches in physics, chemistry, biology, engineering, medical sciences and medical treatments. The project was programed to use the 35 MeV double sided microtron[1] for the FEL. Nevertheless, it is difficult to lase on the FEL because a current from the microtron is low. In the result, the accelerator for FEL was replaced an electron linac. For the purpose of extending research and application program, a minimum of wavelength on FEL was changed from infrared to ultraviolet. In this case, the tuned range of FEL corresponds to variation of electron energy from 30 MeV to 120 MeV.

At the original design[2], we intended to use a rf gun as an injector because of a good property. However, it has a serious problem that the emitted current comes back on the cathode. Consequently, we have decided to introduce a dc gun for the first commissioning. For this decision, we have come to prepare not only the dc gun system but also a bunching system. The former was recycled from some of which used for the microtron and the latter was also recycled from some of which used for the old injector in 2.5 GeV PF injector of KEK. These elements were installed in the facility as a housing for the microtron and completed in December of 1997.

We have groped for a practical use of high quality beam in the FEL, and have been programed a new project[3] for advanced research by using various radiations. These are an electron of high energy and radiation probes as SE, FEL in a range of ultraviolet, parametric X-ray[4] and a slow positron source[5]. This facility has been named Laboratory for Electron Beam Research and Application (LEBRA).

2. Operation and Commissioning

In the first stage at LEBRA, a high power test for klystron modulators was executed by using a dummy diode-tube instead of the klystron. In the next stage performance of klystron (PV-3030 A1) was tested by means of a water load in March of 1997, and we succeeded in obtaining the rf power of 16 MW with 20 μ s. Continuously, a high power test for a rf gun was performed over two months by use of this power source.

The first acceleration of electron was carried out as a test of dc gun on December 25 of 1997.

LEBRA was gone into the first commission[6] of the linac on January 28 of 1998, and then was successful in acceleration of 20 mA of 90 MeV by use of a dc gun with 60 kV. After that, the gun voltage was gradually increased. It was achieved to 100 kV on February 12 and beam transmission on the linac was improved extremely, and then the beam was increased to 56 mA at 97 MeV.

The linac was continually tuned up, it was achieved to 80 mA of 80 MeV on February 27. On the instant, the beam was transported to the FEL system and then its current decreased at 40 mA. At the same time, we could observe SE in there and also confirmed that the color visible on SE has corresponded to the gap space of undulator. Then, the transmission efficiency in this system was decreased about 60 percent because the beam line along the undulator was such a narrow pipe as the length of 3 m and the inner diameter of 7 mm.

Continuously, the radiation light was transported from the FEL system to the control room by use of several surface mirrors. In July of 1998, the spectrum[7] in SE was measured finely by using a monochromator and a photo multiplier. At a stretch, we executed the measurement of the beam qualities, the emittance and the energy spread[8]. These measurements were performed on the beam line downstream the linac and were executed by use of a profile monitor and a bending magnet.

An optical mirror system in FEL has been tuned at a wavelength of 488 nm. In December of 1998, we have tried frequently a lasing of FEL, however we could not observe its signs of showing. SE corresponding to the bunched shape of electron beam was observed by using the Steak camera. Its shape was normal, but its pulses arrayed into macro pulse was irregular as come out a tooth of a comb. On the other hand, a spectrum[9] of SE was carefully measured again by using the CCD camera in Jun of 1999. However, we could not obtain the spectrum as the previous measured one.

Recently, the beam pulse width of 10 μs has been increased gradually and achieved current of 210 mA at energy of 87 MeV. At present, the beam transmission in FEL system has kept an efficiency of about 100 percents.

The emittance was measured again in August of 1999 by using a wire scanner[10], it was estimated to be 48.5 π mm-mrad for the current of 100 mA.

The total time warmed up the klystron was over 1455 hours and just 142 days in the year since January of 1998. It involves the conditioning for the klystron. Also, the operation time for acceleration of the beam was just 39 days.

3. Trouble

On a first power test for the klystron modulator, back diodes were damaged on account of its shunt registers broke. At the high power test for the rf gun, the intention was discontinued on account of staining a vacuum chamber into the alpha magnet with grease. As the result, we were driven in haste by necessity so that an new dc gun injector system serves as a substitute for the rf gun.

On a testing for a dc gun, a high voltage generator (Cockcroft-Walton) was broken down by a breakdown on a ceramic insulator of gun.

A conditioning for klystron has been intermittently continued for its power upgrading, then we have been often experienced breakdown in an oil tank as housing a pulse transformer.

In order to generate SE of 488 nm, we attempted to increase rf power of klystron. Then, we often suffered such accidents as breakdown on surface of rf window. The window was fatally broken on stretching out a duration time of the pulsed rf power. The klystron was replaced by a new one. We also suffered a breakdown of rectifier for converting DC current to supply a heater of klystron. The accident might be caused by a surge current due to a discharge in the oil tank. After restoration, there have been slow vacuum leak from a metal packing of wave guide. Owing to the leak, the klystron have been discharged frequently at its window, reducing its performance gradually. For this trouble, we were obliged to again the klystron to a new one.

We could observe that a sparking discharge in the oil tank originated from the secondary winding of a heater transformer of klystron. Then there have been corona discharges generated always at the edge of secondary winding. It seemed that field gradient was enhanced at the edge of packed insulator sheets over the secondary winding. A solution for the trouble[9] was discussed. As a result, we have decided to install a guard rings on the secondary coil. These were reconstructed in December of 1998 and in February of 1999. After the reconstruction, we have not been experienced these trouble.

At an experiment for FEL, we could not control a gap space of undulator. The trouble was owing to breakdown of a limit switch made of a photo diode, and it was caused by a damage due to radiation.

At an up-to-date, the distribution in magnetic field strength of undulator was surveyed in a rough way. The result as shown in Fig 1 has been guide different from the previous one on account of damage due to radiation.

4. Application Program

In the near future, LEBRA will make in use of progress five radiation sources, the electron beam, the free electron laser, the spontaneous emission, the slow positron beam and the parametric X-ray. Consequently, boundaries on the application program of research are expanded from nuclear physics to material science.

LEBRA started a study of a new radiation as a parametric X-ray. This radiation has monochromatic, coherent and directive property. Moreover, the photon scheme is able to expand from ultraviolet rays to X rays.

In order to advance application studies, seven study groups were organized in Nihon University at October of 1998. Those research items were chosen as a biological reaction, a medical treatment and care, a macro-molecular structure spectroscopy, a photo-chemical catalysis reaction, a lithography and diffraction, a solid surface structure analysis and R&D as produce new material elements.

5. Radiation Source Complex

Specifications for the five radiation sources give as shown in Table 1 to Table 5.

Table 1 Electron linac

Beam energy	125 MeV
Beam Intensity	200 mA
Beam pulse duration	25 μ s
Peak currents	20 A
Beam bunch width	3.5 ~ 10 ps
Beam energy spread	< 0.5 %
Repetition rate	12.5 pps
Maximum beam power	6.25 kW
Frequency	2856 Mhz
Accelerator structure	4 m×3+0.3 m×1
rf gun	mode locked laser
Dc gun	- 100 kV
Klystron power	30 MW×2

Table 2 FEL generator

Undulator structure	Halbach
Total length of undulator	2,400 mm
Gap space of magnet pole	13 ~ 30 mm
Periodicity	24 mm
Periodic numbers	100
Ordinary k-value	0.7
Length of optical cavity	6,718 mm
Mirror	multi-coated
Photon wave length	0.5 ~ 5 μ m
Average power	0.3 ~ 5 W

Table 3 Spontaneous Emission

Wave length of radiation	0.043 ~ 5 μ m
Photon energy	0.24 ~ 29 eV
Photon energy spread	1 %
Average photon flux	2.5×10^{11}photon/s

Table 4 Parametric X-ray

Energy of X-ray	3 ~ 30 keV
Energy spread	1 %
Average flux	1.2×10^{9} photon /s
Directional angle	~ 4 mrad

Table 5 Slow Positron Source

Supplied electron power	6.25 kW
Supplied beam pulse duration	20 μ s
Repetition rate	12.5 pps
Generator of positron	multi - foil
Extracted potential	1 ~ 4 kV
Positron yield	4×10^{8} /s
Positron energy	10 ~ 400 eV

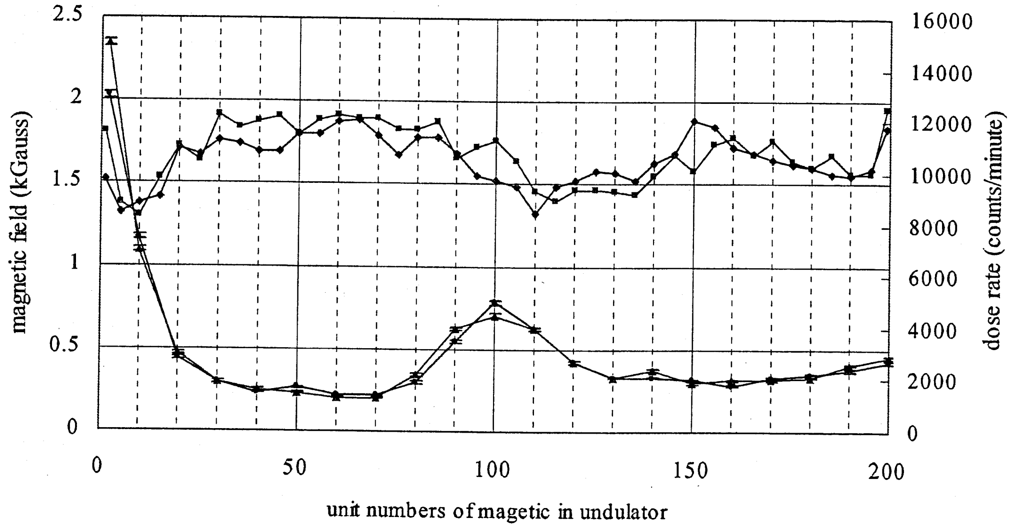

Fig.1 The distorted distribution of magnetic field on undulator on account of damage due to radiation
Upper : magnetic field strength at a position of 6 mm from surface of magnet.
Lower : dose rate from activated magnet.

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