# Status of Free Electron Laser Project at the JAERI

M.Ohkubo, Y.Kawarasaki, N.Shikazono, K.Mashiko, E.Minehara
M.Sugimoto, M.Sawamura, M.Takabe and J.Sasabe*

Dept. of Physics, Tokai Establishment
Japan Atomic Energy Research Institute
Tokai-mura, Ibaraki-ken, 319-11 Japan
* Hamamatsu Photonics

## Abstract

Design and construction of the JAERI FEL system based on a superconducting linac are continued aiming at FEL oscillation in 10～20 μm infrared wavelength. A part of vacuum system, a sub-harmonic buncher and a buncher have been fabricated.

## Introduction

As a tunable and high power laser light source, the free electron laser(FEL) is very attractive to basic researches and applications. We are continuing the design and construction of the FEL system to prove the feasibility of the FEL. At the primary stage of the JAERI FEL program(Phase I, 1987-'92), an FEL system for infrared region is to be constructed based on a superconducting linac. At the succeeding stages, efforts will be focused at shortening of the FEL wave length to visible light, and upgrading of the quality of output light (power, stability and spectral purity).

Outline of the JAERI FEL program in Phase I has been reported elsewhere [1,2,3,4,5]. We have already fabricated beam transport tubes with focusing coils, a sub-harmonic buncher(SHB), a buncher, and an RF power supply for the SHB.

In this article, an overview of the JAERI FEL program and the status are described briefly.

## JAERI FEL System Design

For the first step to the FEL study, it was considered that the oscillation in the infrared region will be easier than in the region of the visible wave length. The FEL wave length was selected to an infrared 10.6 μm, which is a strong line of the $CO_2$ laser. A high quality electron beam of about 25 MeV, with an energy homogenity less than 0.2%, with a beam emittance less than the wave length of the laser light, is needed to the FEL oscillation. To obtain this electron beam, a superconducting accelerator was adopted which will produce an electron beam satisfying the above requirments. Also suitability to a long pulse or CW operation of the superconducting cavity is considered, which will be useful for high power FEL operation in future. Average beam current is determined to be 4 mA considering the accelerating RF power required, which is limitted about 100 kW during operation. Pulse operation ( 1 ms, 10 pps ) with duty factor 0.01 was adopted, because of the maximum power capacity of the building, and the mass of radiation shielding required, which is probably over-weight the floor strength of the building. However, the pulse operation contradicts to the merit of the superconducting accelerator, and requires extra cost in the pulsed power supplies for the RF drivers and the controll system.

The injector system consists of a 250 kV electron gun, a subharmonic buncher(84.8 MHz), a buncher (508MHz), two-cell superconducting pre-accelerating cavity(508MHz), and an energy selection magnet. Beam focusing is made by an array of focusing coils. The main accelerator is a 10-cell superconducting cavity (508 MHz) with helium reservoirs and small refrigirators. In addition, the auxiliary focusing and steering coils, beam diagnostics, RF sources, the control system, the vacuum system and the radiation shielding are included.

The bird's eye view of the FEL system to be constructed is shown in Fig.1.

## Electron Gun

A thermionic cathode with a grid structure(Eimac Y646B) emits pulsed beam of a 100 mA in peak, 4ns in width, and of 10.6 MHz repetition rate during macropulses of 1ms width. The cathode anode structure has been designed to emit beam with a diameter 2 mm or less at 250 kV.[6,7] The grid is driven by a grid pulser, in which microwave triodes are utilized. The timing pulses are sent, through an optical fiber, from an optical pulser at the ground potential. The high voltage equipments are contained in a tank in which $SF_6$ insulation gas is filled at 2 atms.

## Sub-Harmonic Buncher and Buncher

A quater wave resonator (84.8 MHz, 1/6 of 508 MHz)is used for the sub-harmonic buncher, whose cavity length is 90 cm and inner diameter 40 cm. The maximum gap voltage of 60 kV can be obtained by feeding a 5 kW maximum RF power. The buncher is a re-entrant cavity(508MHz), whose length is 15 cm and inner diameter 25 cm. The maximum voltage of 10 kV can be obtained by a 1.5 kW RF power. In a rather long drift space, the electron beam from the gun is compressed to 40 ps at the entrance of the pre-accelerator cavity.[8] The beam focusing is made by an array of focusing coils along the drift space. The ring cores of permanent magnets are also used for the same pourpose.

## Pre Accelerator Cavity

With two superconducting pre-accelerator cavities of $\beta$ =1.0, the electron bunches are accelerated to 2 MeV. Each cavity is fed by an RF power of maximum 4 kW from a solid state amplifier. To keep the synchronism between the electron bunches and the phase angle of the accelerating field, the grid trigger pulses, the RF sources of 84.8 MHz and 508 MHz are produced from a same 10.6 MHz standard source, by minimizing the time jitter in frequency multiplication processes.

## Main Accelerator

The main accelerator is a 508 MHz superconducting accelerator which is same as that of TRISTAN main ring installed at KEK, developped by Kojima et al.[9] at KEK and fabricated by Mitsubishi Heavy Industry Co.. The accelerator are composed of 2 sets of 5 niobium cells, contained in a 4.4 m long cryostat. The operating temperature is 4.2 K. A couple of small liquid helium refrigirators will be used to condense the evaporated helium. The maximum field strength in the cavity is limited by the field emission of electrons from the surface. Right now the average field strength of 6 -8 MV/m can be obtained typically. Then a 15 - 20 MeV energy gain will be expected through the 10 cells accelerator.[10] An RF power of maximum 40 kW each is fed from two klystrons through two RF ports, and the $\pi$-mode is excited in these cavities.

Status

The sub-harmonic buncher and the buncher cavities have been fabricated by Nihon Koshuha Co.. The RF characteristics, resonance frequencies, and Q-values have been measured. The focusing coils along the drift space and some vacuum components were fabricated by the Tokin Co.. The beam focusing in the SHB is made by placing permanent magnet rings in the central conductor. A suitable arrangement of these magnet rings are designed by calculating the beam focussing effects. In the next year, the electron gun, a low power RF system, and the vacuum system will be completed, and the low emittance electron beam experiments will be started. The fabrications of the superconducting pre-accelerator and the main accelerator will be started next year. Design studies of the beam transport system, the undulator and the optical system are in progress.


1) Y.Kawarasaki et al. Free Electron Lasers '87, North Holland p206, Proceedings of the 9th Int.FEL Conf. Williamsburg, VA, USA, Sept 1987
2) Y.Kawarasaki et al. to be published in proceedings of 10th FEL Conf. Jelsalem, Israel, Sept.1988
3) M.Ohkubo et al. to be published in proceedings of 1988 Linac Conf. Williamsburg, VA, USA, Oct.1988
4) M.Ohkubo et al. to be published in Proceedings of 11th Int.FEL Conf. Naples,Florida,USA, Aug.1989
5) M.Sawamura et al. to be published in proceedings of 7th Int.Conf. High Energy Accelerators Tsukuba, Japan, Aug.1989
6) M.Sugimoto; Proceedings of 13th Linac Meeting in Japan(1988)
7) H.Yoshikawa and K.Mashiko; ibid. p115
8) M.Sawamura; ibid. p161
9) Y.Kojima ; OHM No.1(1988) p38 (in Japanese)
10) T.Furuya, K.Asano, Y.Kojima, S.Mitsunobu, H.Nakai, T.Nakazato, S.Noguchi, K.Saito and T.Tajima; Proc. of 3rd Workshop on RF superconductivity, Argonne (1987) p95


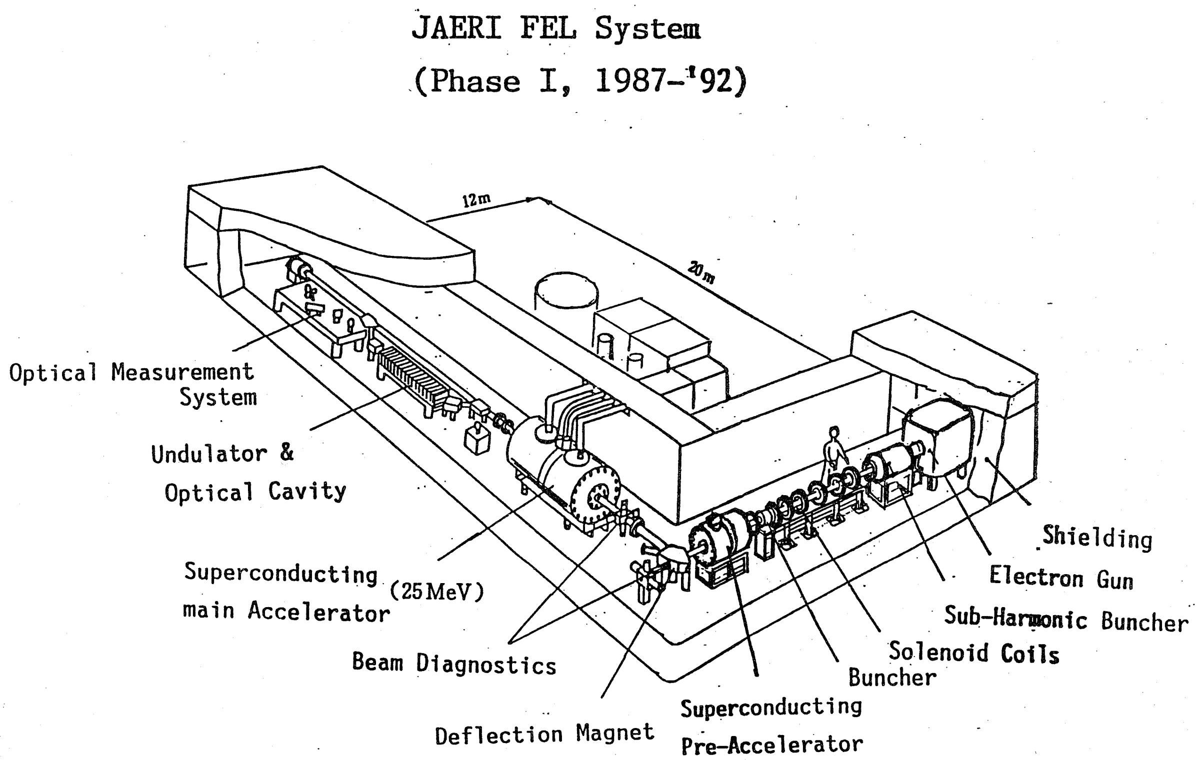


Fig.1 The bird's eye view of the JAERI FEL system.