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Status of Free Electron Laser Project at the JAERI

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Abstract

Constructions of the JAERI FEL system based on a superconducting linac are continued. The injection system including the electron gun, timing and RF system are in test operation. The superconducting accelerators, the refrigerators and the main RF amplifiers are under fabrication. The radiation shielding for the accelerators are to be constracted.

1. Introduction

As a tunable and high power light source, the free electron laser(FEL) will be an useful tool for basic researches and applications. We are continuing 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-'94), an FEL system is to be constructed based on a superconducting linac aiming at lasing at the infrared region 10-30 µm. At the succeeding stage (Phase II), the purpose are the lasing at visible light, and upgrading the quality of output light (power, stability and spectral purity).

Outline of the JAERI Phase-I FEL program has been reported elsewhere [1,2]. All the system is composed of an injecter system, the superconducting pre- and main-accelerators, the RF sources, the helium refrigerators, an undulator and the optical measurement system, with vacuum, control, and the radiation protection system.

The system is to be constructed partly year by year due to budgetary schedule. This year, we are at about midpoint of the project.

We have already assembled the injection system, and the beam tests have been made at an voltage 180 - 200 keV. The superconducting accelerators, composed of two pre-accelerators and two main accelerators, are under fabrication, and will be installed in 1992. The closed loop helium gas refrigerators are under construction, and will be installed in 1992. For the main accelerators two all-solid state RF amplifiers are under construction, and will be installed in 1992. A semi-underground shielding room for FEL experiments is under construction in which the accelerators will be installed.

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

2. Electron Gun

Design of the electron gun was already reported eleswhere.[3,4] A ceramic insulation column with eight metallic stages was fabricated by the Kyoto Ceramic Co. An inner electrode, a cathode-anode assembly with a wehnelt, and a pressurized tank were fabricated by the Kishikawa Special Valve Co.. In the pressurized tank, are confined a grid pusler made by the Iwatsu Electronics Co., and a Cockcroft-Walton type high voltage power supply made by the Pulse Electronics Co..

The vacuum aging was started from November 1990, and the electron beam was accelerated in December with an acceleration voltage 70 kV. To overcome the break down at higher voltage, the amelioration in the vacuum conductance near the Y646B grid-cathode assembly, and the fine polishing on the cathode-anode electrode surface, and lapping the grid pulser with metallic mesh were made. Then the acceleration voltage was able to rise up to 250 kV without break down in April 1991. After some initial troubles on the grid pulser, the electron beam of 4ns pulse width, 100 mA peak current was emitted with a repetition rate 1 kHz, and with a burst mode of 10 MHz repetition rate in a duration of 100 µs macropulse.

3. Timing and RF System

The timing and the RF system of the accelerator is shown in Fig.1. The system is based on a master oscillator of 10.4125 MHz sinusoidal wave. For the electron gun the timing pulses are made by shaping the master frequency, where time jitter is reduced less than 0.5ns. The timing pulses are delivered to the grid pulser at high DC voltage through one of the optical fibers. By pulsing the Y646B, the pulsed electron beam was emitted with a width 4ns and a repetition rate 10.41MHz during macropulse.

For the subharmonic buncher(SHB), the master frequency is multiplied to 83.3 MHz, and through a phase and amplitude control circuits, it is amplified to maximum 5kW to feed the SHB cavity. Phase locking is available to compensate phase error in the cavity during macropulse. The anglular spread of the the 4ns electron beam corresponds to 120 deg. of the 83.3 MHz, and a good bunching is expected for the proper timing between the electron injection and the RF field in the SHB.

The 83.3 MHz is again multiplied to 499.8 MHz for the buncher and the superconducting accelerators. Through phase and amplitude control circuits, the RF is fed to power amplifiers, maximum 1.5 kW power for the buncher, each 4kW for the two pre-accelerator cavities independently. For the two main accelerators, RF powers of maximum 50 kW each are fed from two RF amplifiers.

Through the subharmonic buncher and the buncher, the electron beam is compressed to less than 40 ps, which correspond to 7.2 deg. for 499.8MHz. By the two pre-accelerators the electron beam is accelerated to have energy 2-3 MeV. The final beam energy is expected to be 10-15 MeV, depending on the maximum available field strength in the cavities.

The macropulse modulate these grid pulser and the RF amplifiers to 1 and 2 ms width and 10 Hz repetition rate. There is no phase correlation between the master frequency and the macropulse.

These RF amplifiers are the all-slid-state type, and are already fabricated by Nihon Kousyuha Co. except those of 50 KW.[5] The 50 kW amplifieres are now under fabrication.

4. Superconducting Accelerators

The superconducting accelerators are composed of two pre-accelerators and two main-accelerators. A pre-accelerator is a single cell cavity of 499.8 MHz installed in a single cryostat. A main accelerator is a five-cells cavity of 499.8 MHz installed in a cryostat. So the total number of cavity cells is 12.

For the liquid helium cooling system, the closed loop helium gas refrigerators are used. These refrigerators keep the level of liquid helium in the cryostats by the condensation of evaporated helium gas. Between 4K and 300K environmental region, two thermal anchors at 20K and 80k are fabricated to reduce input heat into the 4K region.

These accelerators are now under construction at the Interatom GmbH in Germany, and will be delivered in middle of 1992. These refrigerators are under construction at the Sumitomo Heavy Industry Co.. Details of these accelerators and cooling system are to be reported in this meeting.[6,7]

5. Radiation Shield

All the system is installed in a retired Van de Graaff accelerator target room. Gamma rays and neutrons from the beam transport line and a beam dump was estimated for several operating conditions. The source of radiation are assumed by the beam stop in the beam dump, by the constant beam spill of 10^{-4} of the maximum beam current, and by the beam clash due to unexpected change of the parameters.

In order to keep permissible radiation level in the office rooms of the VDG building, the shield of 1-1.5 m thick concrete equivalent is required around the accelerators and the FEL experimental area. However, the floor strength of the VDG target room is insufficient to pile up the concrete shielding on it. As a result, a semi-underground shilding room is to be constructed connecting to the VDG target room.

6. Beam Experiments

The measurements on the electron beam have been started, and the preliminary results of emittance measurements are described in the following. The subsequent bunching experiments are reported in this symposium.[8]

In Fig.2 the experimental setup are shown; the electron gun, a solenoid coil, a fluorescent ceramic plate viewed by a TV camera/monitor, and a Faraday cup. The fluorescent plate (Desmarquest AF995R) was movable, and inserted into the beam by the pneumatic pressure. For the acceleration voltage 120, 150 and 180 kV, the spot diameter of the electron beam was observed by changing the solenoid coil current, as shown in Fig.3. Using focal length of the solenoid coil, optical parameters of the beam were analyzed. At a some solenoid current, the spot diameter showed a minimum. The beam emittance was calculated from the gradient and the minimum value in Fig.3. If we took bottom curves in Fig.3, the emittance was less than 10 pai mm.mrad. Space charge effect on the minimum spot size was estimated by a TRACE program, but no appreciable difference was expected for this case, except that somewhat large solenoid current was required to focus the beam in the same dimension.

The emittance measurement by this method was very sensitive to the minimum diameter at the focal point. However, it was rather difficult to determine the minimum diameter correctly, because of possible halation on the fluorescent plate, non-linearity of the TV camera/monitor, and in the process of digitization of spot size through human eyes. If we take a upper curve in Fig.3, the emittance is about 70 pai mm.mrad.

To solve these uncertainty problem, the beam current measurements using a slit system are in progress.

[1] M.Ohkubo et al. Nucl.Instr.Methods. A296(1990)270
Proc. 11th Int.FEL Conf. Florida, USA,1989

[2] M.Sawamura et al. Proc.13th Int.FEL Conf. Santa Fe, USA, 1991, to be published.

[3] M.Sugimoto, Proc.13th Linac Meeting in Japan, 1988, p118

[4] K.Mashiko :Proc.of Meeting ,"Linac and related Technology for FEL", Radiation Laboratory, The institute of Science and Industial Research, Osaka University, Tsumori ed. 1990. p7

[5] K.Nakamura, K.Satoh, N.Nagatsuka, H.Matsumoto, H.Baba and K.Shinohara:Proceedings of 16th Linear Accelerator Meeting in Japan (Sept. 1991), p 87

[6] E.Minehara et al. presented in this symposium.

[7] N.Kikuzawa et al. ibid.

[8] M.Sawamura et al. ibid.

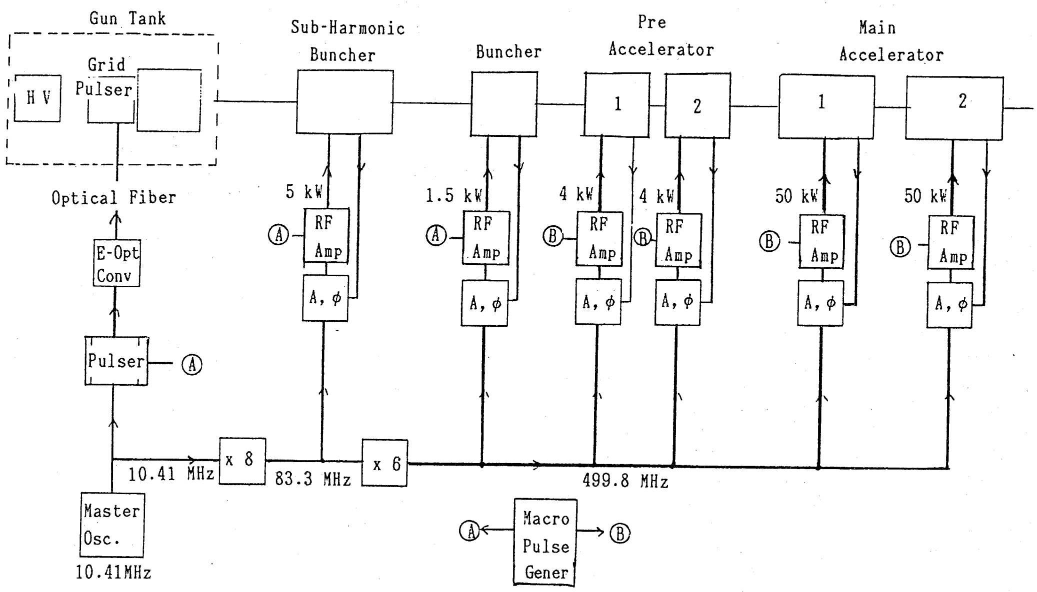

Fig.1 Timing and RF system

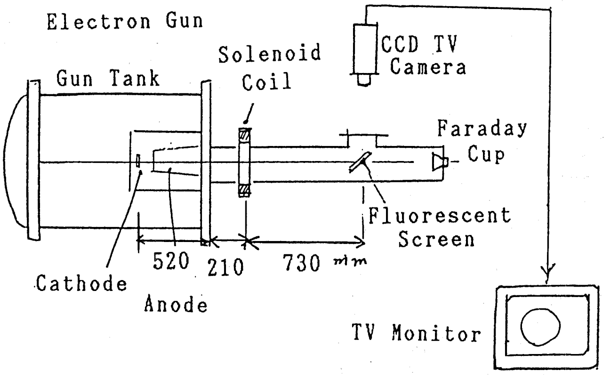

Fig.2 Arrangements of the Beam Spot Measurements

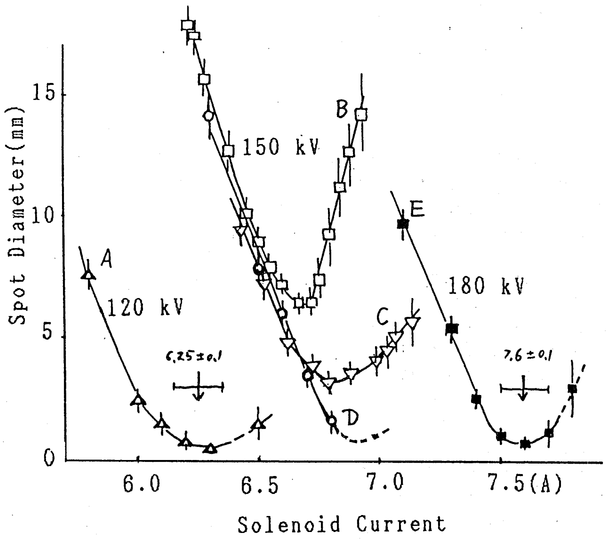

Fig.3 Beam Spot Diameter vs. Solenoid Current