Infrared Free Electron Laser Facilities employing a 150-MeV Linac Injector for Saga 1-GeV Synchrotron

Takio TOMIMASU, Masato Yasumoto[a], Yuuji OCHIAI[b], Masahiko ISHIBASHI[b] and Tatsuhiko MURAYAMA[b]

Free Electron Laser Research Institute, Inc. (FELI)
2-9-5 Tsuda-yamate, Hirakata, Osaka, 573-0128, Japan
[a]Osaka National Research Institute, AIST (ONRI)
1-8-9 Midorigaoka, Ikeda, Osaka 563-8577, Japan
[b]Industry Promotion Division, Saga Prefectural Government
1-1-59 Johnai, Saga, 840-8570, Japan

Abstract

Free electron laser (FEL) facilities as the FELI FEL Facilities are proposed, for which a 150-MeV linac type injector for a Saga 1-GeV synchrotron is employed in FEL mode. The linac has two operating modes; short macropulse mode of 1 micron-second at 150 MeV for injection to the 1-GeV storage ring and long macropulse mode of 12 micron-second at 100 MeV for the FEL Facilities. The macropulse beam consists of a train of several ps, 0.6 nC microbunches (peak current 100 A) repeating at 22.3125 MHz or 89.25 MHz. We are aiming to supply high power level photon beams covering an attractive wavelength range from 0.05 nm (25 keV) to 200 μ m (0.006 eV) for scientific researches, bio-medical and industrial applications, using the 1-GeV SR Facility with a super-conducting wiggler and the proposed FEL Facilities.

1.Introduction

The construction of a Saga synchrotron radiation (SR) facility has been conducted by the Saga Prefectural Government in Kyushyu as a six-year project started in 1998. The project is sponsored by the Science and Technology Agency (STA) and is managed by the Saga Prefectural Government. The preliminary design study of a compact SR facility with a 150-MeV linac type injector is underway. The Saga 1-GeV SR Facility will be operated in 2004 to promote material science, bio-medical and industrial applications in Kyushyu area close to Korea and China, in collaboration with Asian SR Facilities. The location of the Saga SR Facility is shown in Fig.1.

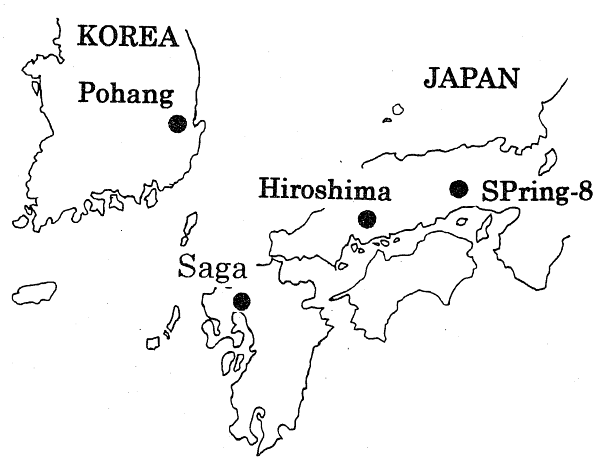

Fig.1. Location of Saga SR Facility

As one of many applications of the electron injector, the construction of free electron laser (FEL) facilities are proposed, for which the 150-MeV linac for a Saga 1-GeV SR Facility is employed in FEL mode. We are aiming to supply high power level photon beams covering a wavelength range from 0.05nm (25keV) to 200 μ m (0.006eV) for scientific researches, bio-medical and industrial applications, using the compact conventional type 1-GeV SR Facility with a superconducting wiggler and the proposed FEL

Facilities.

Two type electron linacs are considered as an electron injector supplying a low emittance and high energy electron beam suitable for FEL generations; one is of the FELI type [1] and another is of the MARK-III type [2]. The both type linacs are now available in Japan. The FELI type and the MARK-III type ones are available from the FELI group and Kawasaki Heavy Industries, Ltd.[3], respectively. The paper describes (1) electron injectors suitable for FEL generation, (2) the beam qualities of available injectors for FEL and positron generations and (3) the Saga linac as an electron injector for the Saga SR Facility and for FEL Facilities.

2. Electron beam qualities of electron injectors

An electron injector is usually used to inject a high energy electron beam into an electron storage ring two or three times a day, if the lifetime of the stored electron beam is longer than 10 hours. The total time necessary for the injection is of the order of one hour including the preparation time for the beam conditioning before and after the injection. Except the injection time, the high energy electron beam from the electron injector can be used for the generation of free electron lasers (FELs) and intense slow positron beams. FELs are useful as high brilliant, tunable photon source for studies of semiconductor nano-structures, fullerenes, proteins and single living cells and the development of methods for isotope separation, surface modification of materials, laser surgery on the other [4]. Intense slow positron beams with narrow energy spread [5] are useful for positron annihilation experiments in condensed matters etc..

The electron beams are also used for the electron injection and the generation of intense positron beams, if the electron energy is higher than 100 MeV. At the positron generation, a conversion rate does not depend on electron beam qualities such as peak current, energy spread, beam emittance, though the injection efficiency depends on the injection beam emittance at beam injection to a low emittance ring.

As mentioned before, the FELI type and the MARK-III type linacs are capable of providing a high peak current and low normalized emittance beam. For instance, the FELI type linac can supply a 155-MeV electron micropulse beam of 130 A peak current with an energy spread of 0.5 % and a normalized emittance of 26 mm · mrad and the micropulse train continues for 24 μ s (macropulse length) at 89.25 MHz and repeats at 20 Hz [6]. The MARK-III type linac can supply a 45-MeV electron micropulse beam of 40 A peak current with an energy spread of 0.3 % and a normalized emittance of 20 mm · mrad and the micropulse train continues for 6 μ s (macropulse length) at 2856 MHz and repeats at 30 Hz [7].

3. Saga Linac and FEL Facilities

The Saga linac can operate in two modes; 150-MeV electron beam mode with macropulse length of 1 μ s for the storage ring injection, and 100-MeV electron beam mode with macropulse length of 12 μ s for FEL oscillation. The 33-, 55- and 100-MeV beams are used at three FEL facilities. The schematic layout of the Saga Linac and FEL Facilities is shown in Fig.2.

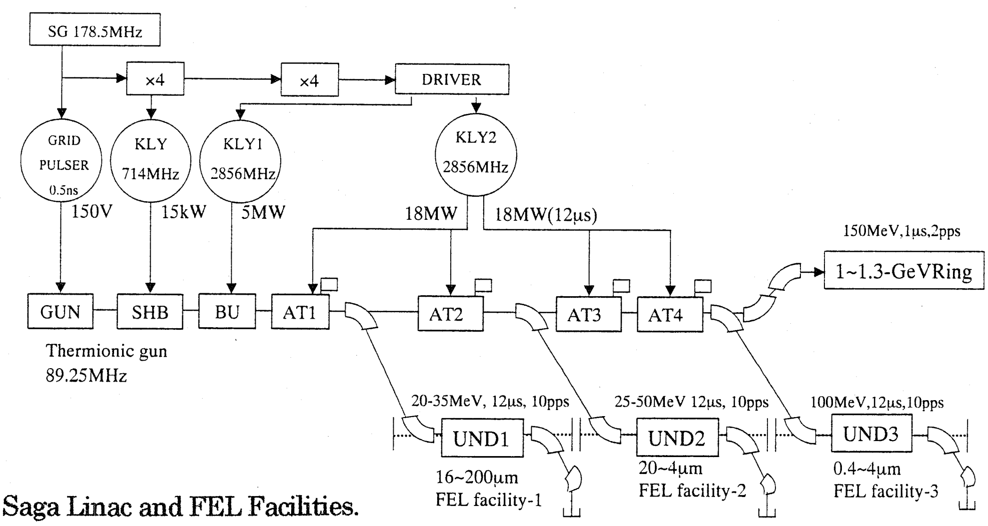

Fig.2. Layout of Saga Linac and FEL Facilities.

The Saga 150-MeV linac consists of a 120-keV thermionic triode gun, a 714-MHz prebuncher , a 2856-MHz standing-wave type buncher and four Electrotechnical Laboratory type waveguides. The four accelerating waveguides (AT-1~AT-4) with a length of 2.93 m are of linearly narrowed iris type to prevent beam blow up (BBU) effect at high peak current acceleration [8].

The gun with a dispenser cathode (EIMAC Y646B) emits 500-ps pulses of 2.3A at 89.25MHz. These pulses are compressed to 60A x 10ps by the prebuncher and the buncher. The beam focusing at the bunching process is done with two steps [9].

The electron beam at the FEL mode consists of a train of several ps, 0.6 nC microbunches (peak current 130A) repeating at 22.3125 MHz or 89.25 MHz. The train of the micropulse continues for 12 μ s (macropulse length). The repetition rate of the macropulse ranges from 1 to 10 Hz. The rf sources at the 12 μ s operation are a 714-MHz klystron (1VA88R, 15 kW) for the prebuncher, a 2856-MHz klystron (E3776, 10 MW) for the buncher and a 2856-MHz klystron (E3729, 36 MW) for the four accelerating waveguides. The rf outputs of E3776 and E3729 type klystrons are 20 MW and 70 MW, respectively, at the 1 μ s operation of the injection mode. The electron beam is accelerated up to 33 MeV at the end of the AT-1 and up to 100 MeV at the end of the AT-4. With the aid of beam transport systems and beam position monitors, the 33-, 55- and 100-MeV beams pass through the FEL Facility-1, the FEL Facility-2 and the FEL Facility-3, respectively. An expected micropulse FEL energy is 30 μ J and an average power is 2.6 kW per macropulse at the FEL Facilities-1 and -2. An expected shortest wavelength oscillation is at 130~193 nm on the third harmonics at the FEL Facility-3.

We are aiming to supply high power level photon beams covering an attractive wavelength range from 0.05 nm (25 keV) to 200 μ m (0.006 eV) for scientific researches, bio-medical and industrial applications, using the 1-GeV SR Facility with a super-conducting wiggler and the proposed FEL Facilities.

References

[1] T. Tomimasu, T. Takii, T. Suzuki, E. Nisimura, S. Ogino, A. Nagai, M. Yasumoto, Nucl. Instr. Meth. A407(1998)494.

[2] S. V. Benson, J. Schultz, B. A. Hooper, R. Crane, J. M. J. Madey, Nucl. Instr. Meth. A272 (1988) 22.

[3] H. Kuroda, presented at the 46th Spring Meeting of The Japan Society of Applied Physicsand Related Societies (Tokyo Science University, March 28-31, 1999) 28p-YG-9.

[4]"Free Electron Laser Facilities and Application" edited by H. Schwettman and T. Tomimasu, Nucl. Instr. Meth. B144 (1998)1~268.

[5] R. Suzuki, Y. Kobayashi, T. Mikado, H. Ohgaki, M. Chiwaki, T. Yamazaki, T. Tomimasu, Jpn. J. Appl. Phys. 30(1989)L532.

[6] T. Tomimasu, E. Oshita, Y. Kanazawa, A. Zako, Presented at FEL'98 International Conference (CEBAF, Aug.17-22, 1998).

[7] N. H. Tolk, C, A. Brau, G. S. Edwards, G. Margaritondo, J. T. Mckinley, Proc. Conf. on Short-Wavelength Radiation Sources, San Diego, 1991, SPIE Proc. Ser. Bellingham, Washington, USA (1991), Vol. 1552, p.7.

[8] T. Tomimasu, IEEE Trans. NS-28(3) (1981) 3523.

[9] T. Tomimasu, Y. Morii, E. Oshita, S. Okuma, S. Nishihara, T. Takii, Nucl. Instr. Meth. A407(1998) 370.