THE RF SYSTEM OF FELI

Y.Morii, Y.Miyauchi, A.Koga, H.Abe, T.Keishi, I.Bessho, and T.Tomimasu

Free Electron Laser Research Institute, Inc.(FELI)
2-7-4 Kyoumachibori Nishi-ku Osaka city 550

Abstract

FELI (Free Electron Laser Research Institute, Inc.) is constructing a Free Electron Laser facility covering from 20 μm (infra red region) to 0.35 μm (ultra violet region), using an S-band linac. The building will be completed in November 1993 and installation of the linac will start in December 1993.

The linac consists of a thermoionic 0.5ns-pulse triggered gun, a 714MHz SHB (subharmonic buncher), a 2856MHz standing wave type buncher, and 7 ETL (Electrotechnical Laboratory) type accelerating sections.

An RF system of the linac for FELs is required of long pulse duration and high stability. S-band klystrons (TOSHIBA E3729) are operated in three pulse operation modes (pulse width and peak RF power); 24 μs-24MW, 12.5 μs-34MW, 0.5 μs-70MW. Each klystron modulator has the PFN consisting of 4 parallel networks of 24 capacitors and 24 inductors, and it has a line switch of an optical thyristor stack. These equipments are manufactured now, and an S-band klystron and modulator will be combined to test their performance at the works of NISSIN ELECTRIC Co. in October 1993.

Introduction

The electron beam of linac for high quality FEL should satisfy following requirements.

(1) Long pulse duration
(2) High peak current
(3) Low energy spread
(4) Low emmitance
(5) Period of micro pulse should be highly stabilized

So the RF system of linac for FEL is required of long pulse duration, high stability in RF power, RF phase.

A laser performance data at FELIX[1] illustrated in Fig. 1 is very instructive. It shows that it takes about 3 μs from electron beam rising to laser's saturation at the wave length of 35 μm. It should take longer at shorter wave length laser because gain of undulator decreases. On the other hand the typical pulse duration of most of S-band linacs in Japan are a few micro seconds. So it is difficult to saturate the FEL in such a short pulse linac. The pulse duration of FELI is 24 μs for shorter wave length laser (visible or ultra violet), 12.5 μs for infra red region laser, and 0.5 μs for injection mode to a storage ring with an FEL resonator.

The beam energy gain T is

$$T = \sqrt{(1-e^{-2\tau})RPL} - \frac{RLI}{2}\left(1 - \frac{2\tau e^{-2\tau}}{1-e^{-2\tau}}\right), \quad (1)$$

where R denotes shunt impedance, P denotes RF power, L denotes the length of the accelerating structure, and τ denotes an attenuation parameter. Second term at the right side is beam loading effect and somewhat small. So the stability of energy gain is determined by the stability of RF power P. To stabilize the energy within 0.1%, the stability of P should be better than 0.2%.

The klystron output power stability $\triangle P/P$ is related to the stability of cathode voltage $\triangle V/V$ as follows,

$$\frac{\triangle P}{P} = \frac{5}{2}\frac{\triangle V}{V}. \quad (2)$$

So the stability of klystron modulator voltage should be better than 0.08%[2].

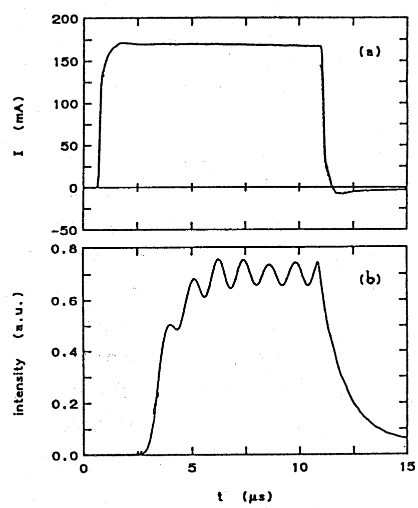

Fig. 1 Beam current and laser intensity in FELIX[1]
(a) is beam current, and (b) is laser intensity.

The layout of RF system are shown in Fig. 2. Main signal generator oscillates 22.3125MHz, and the frequency is multiplied to 178.5MHz, 714MHz and 2856MHz. The pulser for thermoinic gun uses 178.5MHz for 5.6ns micropulse repetition or 22.3125MHz for 44.8ns one. The micropulse width from the gun is 0.5ns, which corresponds to 130° for 714MHz. So the SHB uses a 714MHz. As an SHB cavity is made of stainless steel, the shunt impedance of cavity is about 0.7MΩ. Therefore the SHB cavity needs comparatively large RF power 15kW.

The first main klystron of S-band supplies RF power to a buncher and three accelerating sections, and the second main klystron supplies RF power to four accelerating sections.

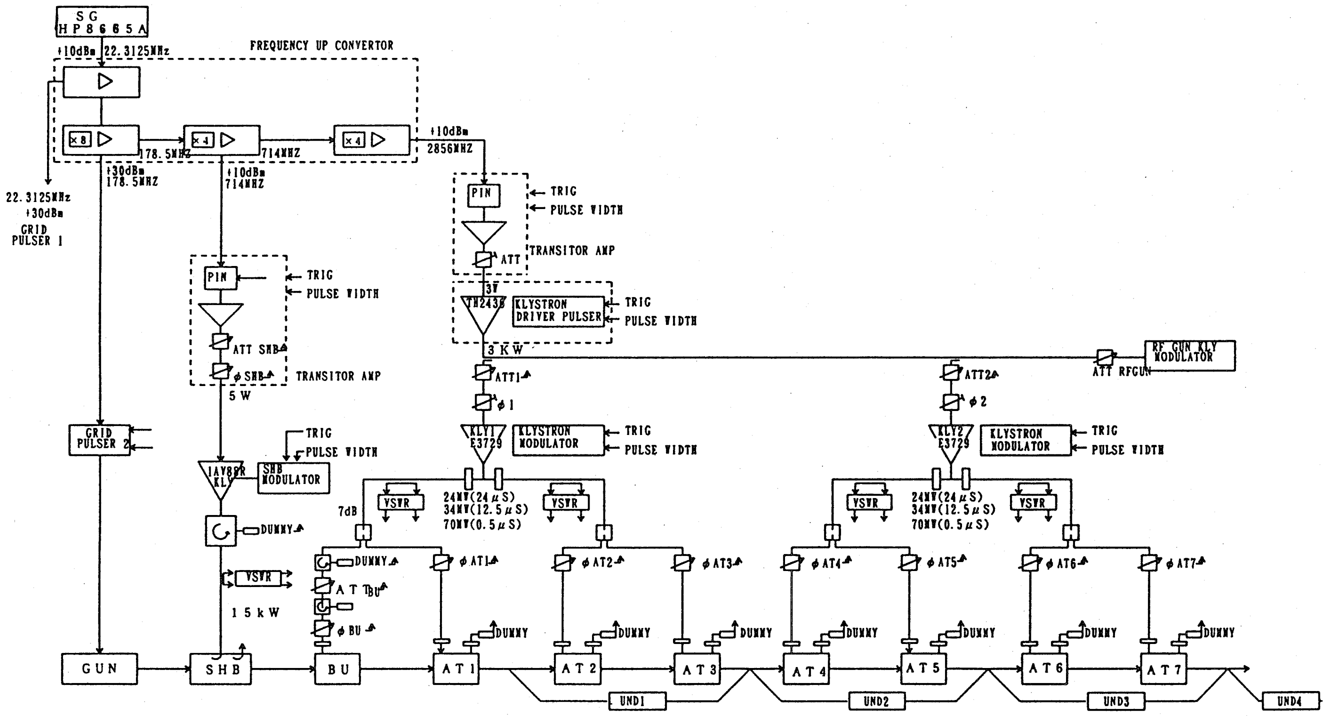

Fig. 2 The layout of RF system of linac

S-band klystron

As the klystron of our linac for FEL should be available for long pulse operation, we chose the klystron E3729 (TOSHIBA) which was modified from the type of E3712 (4 μ s -80MW, 50pps). In long pulse operation (24 μ s-24MW, 10pps) it is no problem for the cathode and collector of E3712 in the thermal point. So E3729 uses same body of E3712, but the tuning of cavity is changed so as to improve the efficiency at long pulse and low power operation. But the efficiency at short pulse and high power operation is sacrificed a little. The properties of E3729 are shown in Table 1.

a

Pulse width(μ s)	24	12.5	0.5
Cathode voltage(kV)	285	304	390
Cathode current(A)	308	333	477
RF output power(kw)	24	34	70

Table 1 Characteristic properties of klystron(E3729)

Klystron Modulator

In order to satisfy the requirement of 24 μ s pulse duration and 0.08% output voltage stability, our klystron modulator has following measures. The block diagram of klystron modulator is shown in Fig. 3 and its properties are shown in Table 2.

PFN (pulse forming network) consists of 24 sections 4 parallels in 24 μ s operation, 14 sections 4 parallels in 12.5 μ s operation, and 3 sections 8 parallels in 0.5 μ s operation. Each section contains a inductor (11.4 μ H) and a capacitor (37nF). The inductors are equipped with a motor drive plunger tuner to vary the inductance. A computed wave form of output voltage in 24 μ s operation is shown in Fig. 4.

A charging power supply consists of not IVR and De-Q circuit but an inverter and converter for high stability. It can deliver 3A at 50kV with an output voltage stability within $\pm$ 0.01% with input voltage stabilized within $\pm$1% by a motor generator.

The line switch consists of not thyratron but 30 optical thyristors of type SLG1500GX22 (TOSHIBA) in series. An saturable inductor is placed in series in order to protect the each thyristor from overvoltage because of time lag of each thyristor's turn on.

The voltage drop across thyratron lies 100～250V, and this voltage varies about 10%. If the output voltage of PFN is 20kV, this variation of voltage means an uncertainty of 0.1%. The stability of final out voltage should be within 0.08%, so thyratron is not acceptable. For this reason, we choose thyristor. Though the pulse rise time of our modulator is comparatively small (about 2 μ s), the specification of operation of thyristor's stack (42kV, 10000A) is difficult. So the life time test of thyristor was done when we chose thyristor.

Flat top duration (μ s)	24	12.5	0.5
Output voltage (kV)	285	304	390
Output current (A)	308	333	477
Output stability (%)	0.08	0.08	1.5
Repetition frequency (Hz)	10	10	10

Table 2 Characteristic properties of klystron modulator

S-band driver amplifier

An S-band driver amplifier has a klystron TH2436 (THOMSON). Its peak power is 3kW and the RF power is delivered to three klystrons. Two of them are klystrons E3729 and one is klystron for an RF Gun. This modulator uses a commercially available MOS-FET modules (BEHLKE), switching 1.1A at 10kV.

A preamplifier is a class C type transistor amplifier with a pin diode switch. This switch is used for deciding input RF pulse width and protecting for these klystrons.

SHB amplifier

The amplifier for SHB contains a klystron 1AV88R (TOSHIBA), which is widely used for UHF TV. Its maximum output power is 15kW (714MHz). The modulator uses MOS-FET modules (PULSE ELECTRIC ENGINEERING) switching 2.1A at 16kV.

A preamplifier is a class C type transistor amplifier with a pin diode switch.

Acknowledgment

The authors would like to express thanks to H. Yonezawa of TOSHIBA Co. for the klystrons of E3729 and 1AV88R, Y. Miyai, H. Ooshita, I. Ito of NISSIN ELECTRIC Co. for the S-band modulator, S. Miyake of DAIHEN Co. and H. Matsumoto of NIHON KOSHUHA Co. for the S-band driver amplifier, M. Yuura of PULSE ELECTRIC ENGINEERING CO. for the SHB modulator, and T. Suzuki, S. Nishihara of MITSUBISIHI ELECTRIC Co. for the injector and accelerator tubes.

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[2] B. J. H. MEDDENS "A 50MW Pulse forming network with a voltage stability within 0.03%." The FELIX project report 1992.

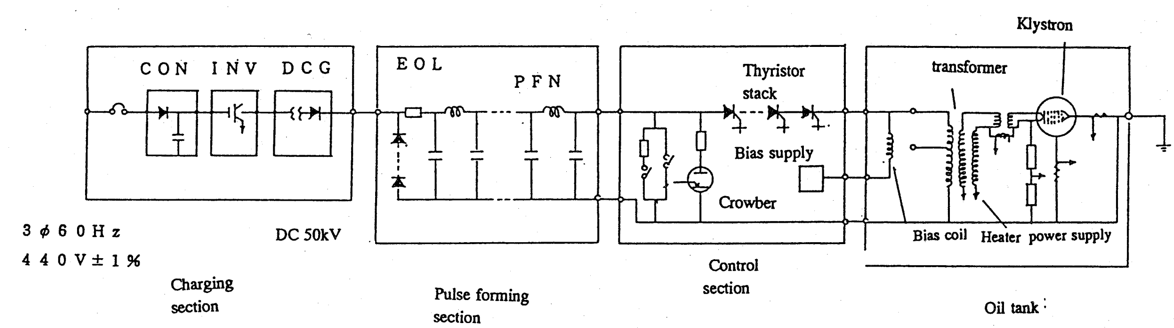

Fig. 3 The Block diagram of S-band klystron modulator

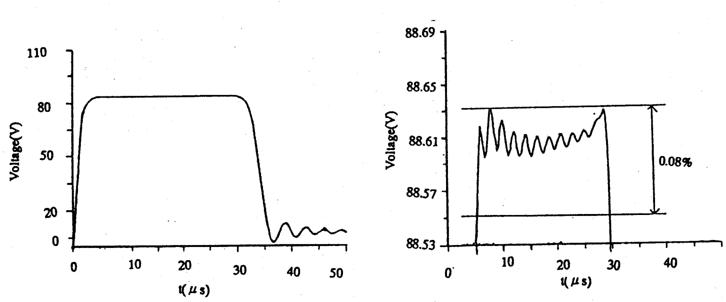

Fig. 4 A cumputed wave form of output voltage of PFN
Right side view is expanded view of flat top of left side.