CHARACTERISTICS OF THE ELECTRON LINACS OF OSAKA UNIVERSITY AND THEIR APPLICATION TO LIGHT SOURCES

S. Okuda, K. Tsumori, J. Ohkuma, T. Sawai, N. Kimura, T. Yamamoto,
T. Hori, S. Takamuku and S. Suemine*
The Institute of Scientific and Industrial Research, Osaka University
Mihogaoka, Ibaraki, Osaka 567, Japan
*Unicom System

Abstract

In Osaka University electron beams from a 38 MeV L-band linac and a 150 MeV S-band linac are available for experimental research. Each component and the beam characteristics of these linacs have been investigated for developing new light sources using radiation from the high-energy electron beams. From the results of the present work the applicability of the linacs to realizing the intense light sources are discussed.

Introduction

One of the advanced applications of high-energy electron beams is to light sources. A 38 MeV L-band linac in our institute[1] is equipped with three subharmonic prebunchers (SHPB's). A single-bunch beam generated by this linac has electrons as much as 70 nC in total charge, which has been availed for studying ultrafast phenomena induced in liquid or solid materials. The peak current of the beam is about 3 kA in maximum, which is sufficient for the high-gain free electron laser (FEL) experiments.

Electron beams passing through a bending magnet emit synchrotron radiation. In the case of bunched beams the radiation becomes far more intense at wavelengths longer than the bunch length. This phenomenon has been recently confirmed in experiments.[2] The single-bunch beam seems to be applicable to this experiment.

The SHPB system installed in the linac makes micropulses of high peak-current in a macropulse. Such function has been applied to some FEL systems with rf linacs.[3,4] The present SHPB system can be applied to the oscillator-type FEL experiments.

We have newly constructed a 150 MeV S-band linac.[5] The beam energy is high enough for visible FEL experiments and a positron source being prepared.

The present work has been made to investigate the each component and the beam characteristics of the linacs for applying the beams to developing new light sources.

Two electron linacs and the beam characteristics

The main components of the L-band linac and the S-band linac are schematically shown in Fig. 1. The beam characteristics for typical three modes are shown in Table 1.

The SHPB system of the L-band linac consists of two 12th SHPB's and a 6th SHPB. In order to generate a single-bunch beam a pulsed beam of a duration of 5 ns is injected from the gun to the 1st SHPB. The pulse shape of the cherenkov lights from a radiator, which is corresponding to the shape of the single-bunch beam, has been measured with a streak camera of a time resolution of 2 ps (Fig. 2). The shape and the peak current of the beam can be controlled.

When a long-pulse beam of a duration of 1.5 us are injected under operating the SHPB system micropulses are generated in the macropulse at an interval of 9.2 ns corresponding to the 12th subharmonics of 1300 MHz rf used for acceleration. The pulse shape has been monitored by measuring cherenkov lights with a phototube of a time resolution of 60 ps, as shown in Fig. 3. This figure shows that the SHPB's work well over the macropulse and that satellite pulses are comparatively small. The charge in the micropulse is evaluated from the pulse shape measured with a streak camera to be 0.65 nC.

The S-band accelerator consists of three

Table 1 Beam characteristics of the two linacs.

	L-band Single	L-band Long	S-band Long
Energy(max.)	38 MeV		150 MeV
Accelerator Freq.	1.3 GHz		2.86 GHz
Micropulse spacing	9.2 ns		0.35 ns
Charge/micropulse	70 nC	1 nC	0.2 nC
Peak current	3 kA	50 A	10 A
Macropulse length	>20 ps	2.5 μs	4 μs
Repetition rate	720 pps	360 pps	60 pps
Energy spread	1%		1%
Emittance(norm.)	<200 πmm.mrad		<30 πmm.mrad(gun)

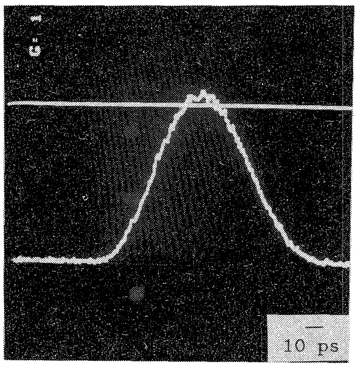

Fig. 2 Pulse shape of the single bunch beam monitored with a streak camera.

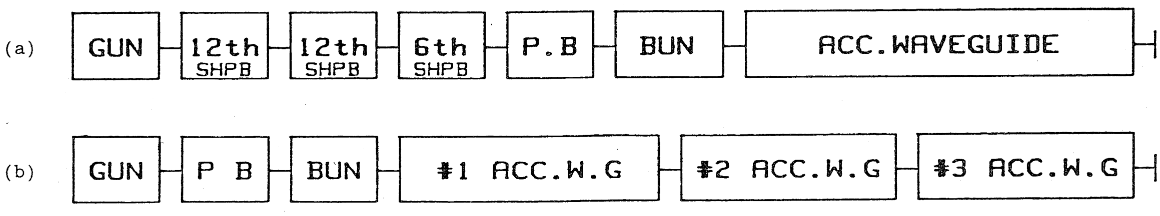

Fig. 1 Accelerator system of (a) the 38 MeV L-band linac and (b) the 150 MeV S-band linac.

(a)

(b)

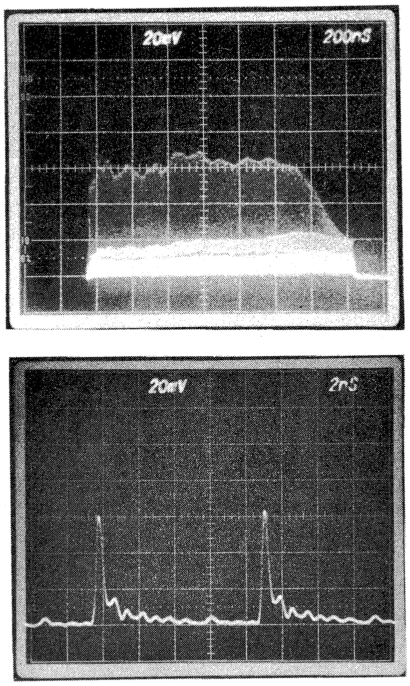

Fig. 3 Pulse shape of the multi-bunch beam monitored with a phototube: (a) 1.5 us macropulse; and (b) micropulses at a 9.2 ns interval.

Table 2 Wiggler parameters.

	Long	Short
Length	198 cm	48 cm
Period	6 cm	4 cm
Number of periods	33	12
K parameter	1-2	1-2

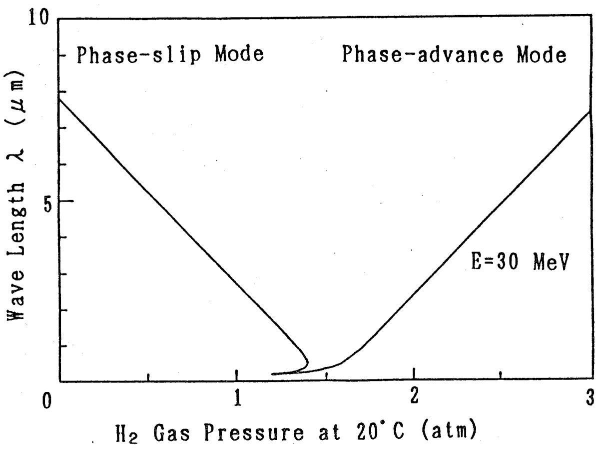

Fig. 4 Pressure dependence of the wavelength of radiation for gas loaded FEL.

accelerating waveguides to which rf is supplied from three 35 MW klystrons. The overall length of the linac has been made relatively short, according to the relatively small area of the linac room. The accelerating gradient of 19.3 MV/m could be achieved.[5] The electron gun is a main component determining the final beam emittance. The normalized emittance of the beams generated by the gun was measured with a beam profile monitor and a multi-whole beam mask and was about 30 πmm.mrad which should be much improved for FEL experiments.

Radiation from the single bunch beams

The single-bunch beam generated by the L-band linac is available to produce coherent pulsed lights.

The peak current of the single-bunch beam is comparable to those of the induction linacs used for FEL experiments:[6] The energy spread and beam radius are comparable; the present beam emittance shown in Table 1 is about one order of magnitude lower than that of the latter; and the pulse duration (about 20 ps) is about 3 orders of magnitude shorter. By using the present beam high-gain FEL experiment will be made to obtain intense pulsed lights and to investigate the interaction of the beam and the radiation in an optical cavity. In Table 2 the wiggler parameters for the present experiments are listed. The wavelengths of the radiation is calculated to be 10-40 μm for the beam energy of 25-35 MeV.

When an electron beam passes in gas through a wiggler the wavelength of the FEL can be shortened.[7] By using the single-bunch beams and a relatively short wiggler, whose parameters are shown in Table 2, the effect of gas has been investigated. The relation between the hydrogen gas pressure and the wavelength theoretically evaluated is shown in Fig. 4. At a pressure of 1.3 atm visible lights have been observed at an intensity comparable to cherenkov lights radiated at the same time. This method will be applied to the FEL experiment with the single-bunch beam described above, after relatively intense infrared lights being obtained.

When a single-bunch beam passes through a bending magnet the synchrotron radiation of relatively long wave lengths compared with the bunch length becomes coherent, and the intensity of the radiation becomes about N times of the ordinary radiation: N denotes the number of electrons in the beam; and is 5×10^{11} for the present beams. The radiation strongly depends on the shape of the bunch. It is advantage of this system that the shape can be controlled. The high-current single-bunch beams are effective for the experiments generating intense pulse lights of submillimeter-millimeter wavelengths by bending magnets.

FEL experiments with the long-pulse beams

In the ordinary FEL experiments with rf linacs, the pulsed lights radiated is amplified by each electron micropulse repeatedly in an optical cavity because the intensity of the radiation for the single passage of a micropulse is not sufficient. Such FEL requires low-emittance and high peak-current beams. For the long-pulse beam from the L-band linac the SHPB system works well for bunching beams but the gun should be replaced by a low-emittance gun. The S-band linac doesn't have an SHPB system and the beam emittance measured is relatively high. We should develope a new injector system such as an rf gun generating low-emittance beams with some bunching process. We have started the improvement of the gun system of the L-band linac and are planning to make a new injector system for the S-band linac.

Conclusions

The each component and the beam characteristics of the two linacs have been investigated for developing the sources of FEL and intense pulsed lights. The results have shown that the single-bunch beams from the L-band linac are effective for obtaining intense pulsed lights. These also have shown the effectiveness of applying the two linacs to FEL experiments under the improvements of the electron gun or the injector system.

References

1. S. Takeda et al., IEEE Trans. Nucl. Sci. NS-32 (1985) 3219.
2. T. Nakazato et al., to be published in Proc. 14th Int. Conf. on High Energy Accelerators, Aug. 22-26, 1989, Tsukuba, Japan.
3. R. W. Warren et al., Nucl. Instr. Meth. A259 (1987) 8.
4. K. E. Robinson et al., Nucl. Instr. Meth. A259 (1987) 49.
5. K. Tsumori et al., to be published in Proc. 14th Int. Conf. on High Energy Accelerators, Aug. 22-26, 1989, Tsukuba, Japan.
6. T. J. Orzechowski et al., IEEE J. Quantum Electron. QE-21 (1985) 831.
7. A.-M. Fauchet et al., IEEE J. Quantum Electron. QE-20 (1984) 1332.