Burst-Mode Electron Gun Pulser for FEL with the ISIR Linac

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Abstract

Infrared free-electron lasers (FEL's) are being developed at The Institute of Scientific and Industrial Research (ISIR). For a FEL oscillator, a burst-mode electron gun pulser with short pulse widths and high repetition rates is effective to obtain multi bunch beams of high peak currents. In order to produce narrow pulses at a 36.9ns interval, rf of two different frequencies, 27 MHz (fundamental) and 81 MHz (the third harmonic), has been combind with a 3 dB hybrid coupler. The pulses have been directly supplied to the cathode of a high-current electron gun (Model-12, ARCO). The electron beam from the gun at an energy of 100keV has a peak current of 440 mA in a micropulse with a width of 4.5 ns (FWHM), whose frequency is 27MHz for a macropulse duration of 4micro second. After acceleration at an energy of 23MeV, the charge of an electron bunch and energy spread have been measured to be 1nC and 0.9%, respectively, which shows good performance of the present pulser for FEL oscillator experiments.

The grid pulser will be improved to make the repetition rate of the micropulse changeable.

1. INTRODUCTION

The ISIR L-band linac was constructed in 1978. After the improvement of the subharmonic prebuncher (SHPB) system the charge of the single bunch beam was remarkably increased from 7 to 67 nC. [1], [2] The beams have been applied to various studies for analyzing the transient phenomena in the fields of radiation physics and chemistry. Recently, the FEL project has started to realise an oscillator and an amplifier at 10-60 micrometer wavelengths.

For a FEL oscillator, an electron gun pulser with a very high repetition rate (more than 10 MHz) and a short pulse width (less than 5 ns) is effective. Such a high frequency is not realized with the ordinary grid pulsers using the avalanche transistors nor the discharge tubes. For time-of-flight experimens at SLAC [3], the burst-mode grid pulser which consists of a V-MOS transistor and a snap diode has been developed: a pulse width is less than 1 ns and a repetition rate is above 20 MHz during a 1.6 micro-second rf macropulse. For the FEL experiments with an S-band linac at CLIO,[4] a grid pulser using a very fast frequency divider and a wideband solid state amplifier of 10-500 MHz has been developed: The pulser with a 0.9 ns width at 4-32 ns intervals drive a Y646B(EIMAC) cathode.

In this work, a new bursut-mode pulser having a simple circuit and the same performance as above system have been developed.

2. ISIR LINAC

The ISIR linac consists of a 120 kV electron gun (Model-12,ARCO), three SHPB's (two twelfth SHPB's and one sixth), a prebuncher, a buncher and an accelerating waveguide 3m long. The accelerating waveguide is driven by a 20 MW L-band klystron (TV-2022B,THOMSON) and both the buncher and the prebuncher are driven by a 5 MW klystron (E3775A,TOSHIBA). The SHPB has a coaxial single-gap cavity at one end of the inner conductor. To SHPB's pulsed rf of 20 micro-second duration and 20 kW peak power is supplied. Beam characteristics at the single bunch mode

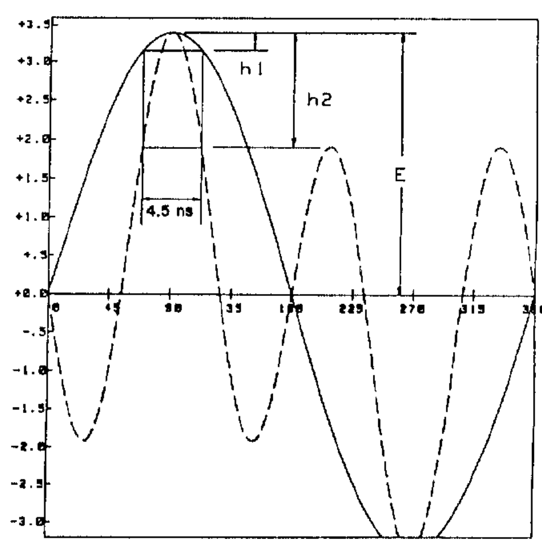

Figure 1. A wave form given by calculation. Solod line: Fundamental wave form of 27 MHz. Dotted line: combind wave form of 27MHz and 81MHz(third harmonic).

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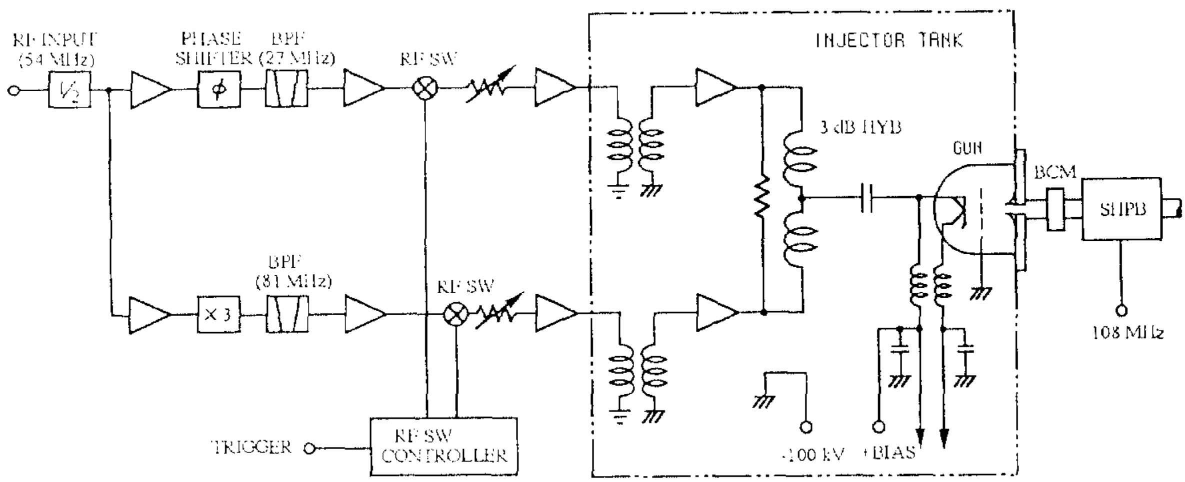

Figure 2. Schematic diagram of the burst-mode gun pulser.

operation, the energy, the energy spread and the charge per single bunch, are 38 MeV, 0.9% and 67 nC, respectively.

3. BURST-MODE GUN PULSER

For the FEL oscillator experiments, the interval between the micropulses of the accelerated beam can be determined by the round-trip time of light in an optical resonator. In the present case, the interval is 36.9 ns(27 MHz), corresponding to four rf periods at the first SHPB. The maximum pulse width of the beam from the gun acceptable for the first SHPB (108 MHz) is 4.5 ns. In order to produce such narrow pulses by the gun pulser, rf of two different frequencies, 27 MHz (fundamental) and 81 MHz (the third harmonic) have been combined.

The schematic diagram of the present grid pulser system is shown in Fig. 2. The pulser consists of rf processing circuits on the ground potential and the gun-cathode driver which is installed in a high voltage deck in an injecter tank. In the processing circuit, 54 MHz rf from the master oscillator of the linac is converted to rf at two frequencies, 27 and 81 MHz. The pulsed rf which modulated by a PIN diode switch is amplified to about 10 W and then fed to coupling coils working over a voltage diffrence of 100 kV in the injector tank filled with Freon gas at a pressure of 5 PSI. The width of the gap between these coils is 85 mm. An attenuation of rf power between the coils is about 20 dB.

For driving the gun cathode, the two pulsed rf of 27 and 81 MHz are independently amplified up to 300 W and combined by using a 3 dB hybrid coupler. In this case a phase shifter and attenuaters placed in the rf processing circuit are adjusted. A wave form given by calculation is shown with a dotted line in Fig 1. The combined rf is supplied to the cathode through a dc-cut capacitor. The bias supplied to the cathode to avoid emission due to the small peaks shown in Fig.1 decreases the injection current to some extent. The driving voltage at the cathode is measure rate of 400 V peak to peak as shown in Fig.3.

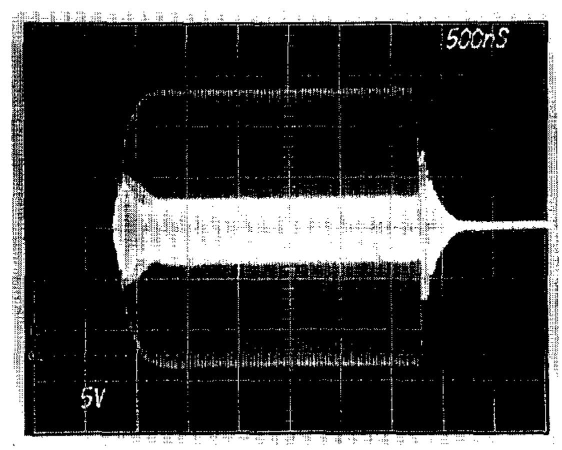

Figure 3. Pulse shape of the combined rf at the cathode voltage is measured of 400 V peak to peak.

The electron beam generated by the gun at an energy of 100 kV has a peak current of 440 mA for a 4.5 ns pulse width. For an electron beam accelerated at an energy of 23 MeV, micropulses having a repetition rate of 27 MHz (36.9 ns interval) over a 4 micro-second macropulse duration is shown in Fig. 4. This measurment has been made with a bi-planar phototube (60 ps rise time) by observing Cherenkov radiation from the electron beam in the air atmosphere. Measurements have also been made with an ultrafast streak camera. The charge per micropulse is 1 nC.

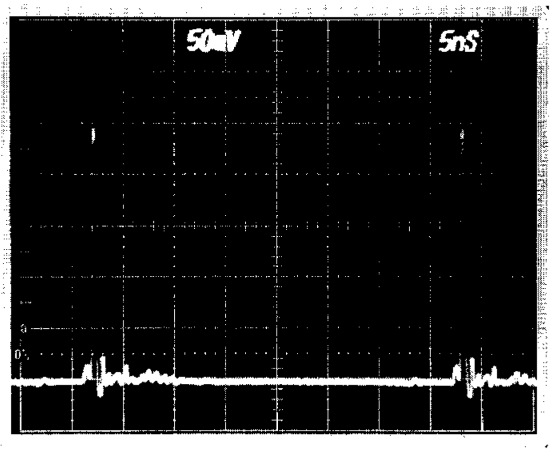

Figure 4. A part of the accelerated micropulses having a repetition rate of 27 MHz (36.9 ns interval).

4. GUN PULSER UPGRADE

On the burst-mode operation for common use of electron beams, the repetition rate of the micropulse is desired to be changeable. In order to realize this feature a micropulse-elimination circuit will be added to the present gun pulser. Fig.5 shows the schematic diagram of the main part of the new circuit.

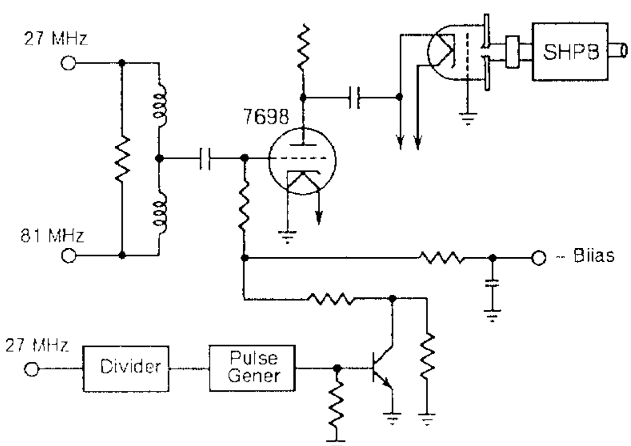

Figure 5. A pert of the micropulse-elimination circuit a gun control triode is added to the present gun pulser.

The plana triiord 7698 (EIMAC) is inserted between the hybrid coupler and the gun cathode. Only when positive short pulse which has the same width as the micropulse is imposed on the dc bias, the triode works. The rate of elimination can be determined by the rf frequency divider. This system will be tested by November in 1993.

5. ACKNOWLEDGMENTS

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