PULSE STRUCTURE MEASUREMENT OF NEAR-INFRARED FEL IN BURST-MODE OPERATION OF LEBRA LINAC

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Abstract

The near-infrared free electron laser (FEL) at the Laboratory for Electron Beam Research and Application (LEBRA) in Nihon University has been provided for scientific studies in various fields since 2003. Improvement in the electron beam injector system for the LEBRA 125MeV electron linac made possible to accelerate the electron beam in three different modes, full-bunch mode, superimpose mode and burst mode. FEL lasing in the second and the third modes was achieved in 2011. In these three modes, the pulse length of the FEL of wavelength 1600 nm was measured by using the autocorrelation trace obtained from the Michelson interferometer.

LEBRA 125MEV LINAC

The LEBRA has supplied the infrared free electron laser (FEL) and parametric X-ray (PXR) for various user experiments since 2004 [1].

Table 1 lists the parameters of the LEBRA 125MeV linac. The linac uses the conventional 100kV DC electron triode gun. The grid of this DC gun is fed pulse from two grid pulsars, the conventional macro grid pulsar and the high-speed grid pulsar. The emitted electron beam is accelerated to maximum 125MeV in three 4m accelerator tubes. Two klystrons, PV-3040 and PV-3040N manufactured by Mitsubishi Electric amplify to approximately 20MW each. RF is generated from the master oscillator and fed to each klystron. The amplified RF is fed to the pre-buncher, the buncher and three accelerator tubes. The accelerated beam is transported to the FEL undulator line by two 45-degree bending magnets. Table 2 lists the specification of the undulator. The round trip time of the undurator is 44.8ns.

Table 1: Specification of the LEBRA 125MeV Linac

Accelerating RF Frequency	2856 MHz
Klystron peak output power	30 MW
Number of klystron	2
Electron beam energy	30-125 MeV
Energy spread	0.5 $\sim$ 1 %
Macro pulse beam current	200 mA
Macro pulse duration	20 μs
Maximum Repetition Rate	12.5Hz

The output of the high-speed grid pulsar is superimposed on the output of the macro grid pulsar by the grid pulse coupler, and fed to the grid of the electron gun. Thus, there are three beam modes, the full bunch mode, the burst mode and the superimpose mode, as illustrated in Figure 1.

Table 2: Specification of the LEBRA Undurator

Resonator length	6720 mm
Undurator length	2.4 m
Undurator of period	48 mm
Number of periods	50
Maximum K value	1.36 rms

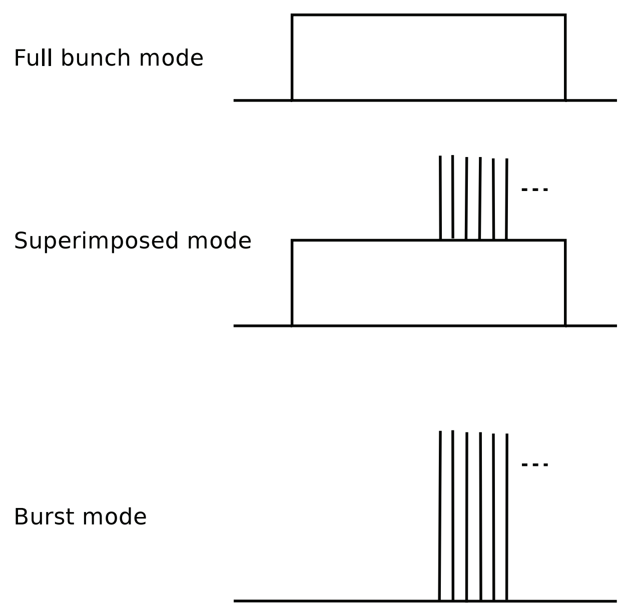

Figure 1: Illustration of pulse structure in full bunch Mode, Superimpose Mode and Burst Mode.

BURST MODE AND SUPERIMPOSE MODE BEAM

RF generated from the master oscillator is fed to the frequency divider. The high-speed grid pulser is driven by the 89.25MHz sine wave output from the frequency divider as a master clock input. The clock input is divided internally by 2 or 4. The gated output of the pulsar is a train of short pulses with a period of 22.4ns or 44.8ns and a pulse width of 600ps FWHM.

In the full-bunch mode, only the macro grid pulsar is used. When the superimpose mode is selected, both of grid

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pulsars are used. When the macro grid pulsar set up in output voltage lower than the threshold which emits electrons, and a high-speed grid pulsar are used, beam mode turns into a burst mode.

On April 19th, 2011, it succeeded in the first laser oscillation in the burst mode. The wavelength of the FEL was approximately 1800nm, FEL power was approximately 2.3mJ per macro pulse and burst pulse period was 44.8ns, at that time [2].

Figure 2 shows time structure of FEL wavelength 1600nm in the burst mode. In this figure the horizontal axis shows time and the vertical axis shows output voltage of the detector. It was detected by an InGaAs PIN photo diode (Hamamatsu G6854-01) and measured by Tektronics TDS5104 oscilloscope (sampling frequency up to 5GHz and band width 1GHz). The burst pulse period was 22.4ns and the macro grid pulse voltage was 35V and the high-speed grid pulse voltage was 160V. It is shown that FEL was oscillated in the burst mode beam because in this figure high peaks are in each 22.4ns.

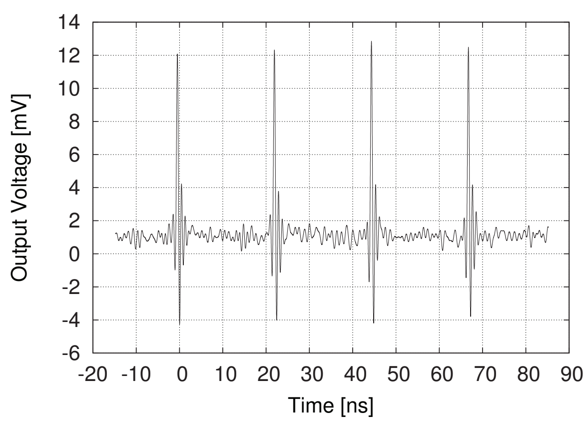

Figure 2: Time structure of burst mode FEL

PULSE WIDTH MEASUREMENT WITH MICHELSON INTERFEROMETER

Since the FEL pulse is a coherent wave packet, the approximate pulse length can be deduced from autocorrelation measurements. The shape of the autocorrelation trace in each beam acceleration mode was measured at a wavelength of 1600nm with a Michelson interferometer [3].

Table 2 shows output voltage setting of the macro grid pulsar and the high-speed grid pulsar. A grid bias voltage was 53V at that time. The peak current in the superimpose mode is larger than burst mode and burst mode is larger than the full bunch mode.

The autocorrelation trace measured in the burst mode, the superimpose mode, and the full beam mode is shown from Figure 3,4 and 5. In these figures, the horizontal axis shows the position of the movable mirror of the Michelson interferometer, and the vertical axis shows relative strength detected with the InGaAs PIN photodiode. This PIN photo diode has sensitivity from the wavelength from 600nm to 1700nm.

Table 3: Output Voltage Setting of Grid Pulsars.

Mode	Macro G.P.	High-speed G.P.
Full-beam	60 V	0 V
Superimpose	60 V	160 V
Burst	35 V	160 V

(G.P.: Grid Pilser)

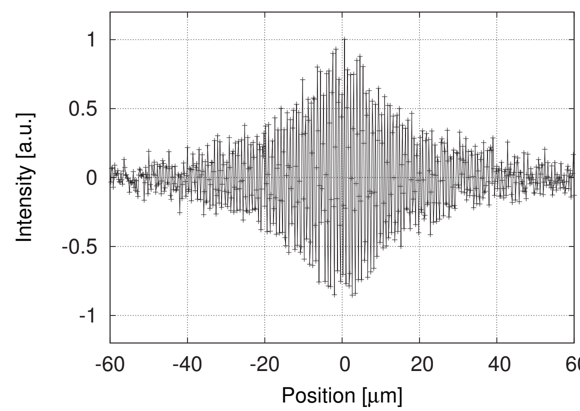

Figure 3: Autocorrelation trace in the burst mode.

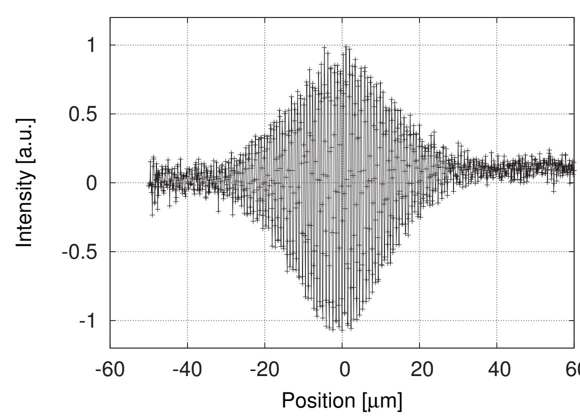

Figure 4: Autocorrelation trace in the superimpose mode.

From these autocorrelation traces, the pulse length of FEL was 0.09ps FWHM in the burst mode and 0.11ps FWHM in the superimpose mode and 0.09ps FWHM in the full-beam mode. In these modes, the substantial change was not seen by the FEL pulse length though the peak current of the electron beam was different.

CONCLUSION

It succeeded in the FEL lasing in the burst mode and superimpose mode in last year. The FEL pulse length was

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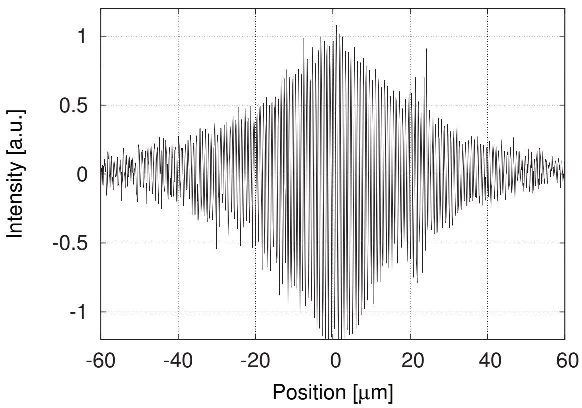

Figure 5: Autocorrelation trace in the full-bunch mode [2].

measured with each mode with a Michelson interferometer, and the result was approximately 0.1ps, and did not have the substantial change in each mode.

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