FIRST LASING OF THE JAERI FEL DRIVEN BY THE SUPERCONDUCTING RF LINAC

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Abstract

First and strong laser oscillation has been obtained in the wavelength ranging from 24 to 28μm using the JAERI (Japan Atomic Energy Research Institute, Tokai) 500MHz superconducting rf linac based FEL driver and far infrared FEL device. Electron beam energy and resolution are around 16MeV and 0.6%, respectively, the beam current between 2 and 4mA, and pulse width between 0.1ms and 0.9ms, respectively. A near-concentric optical resonator with a 52 period of 33mm length hybrid planer undulator (K=0.7) is 14.4m long, and uses Gold-coated Copper mirrors of 120mm diameter. The optical axes and distance of the mirrors are precisely adjusted by remotely controlled actuators in order to coincide with the electron beam and micro pulse repetition rate, respectively, before the oscillation. The power has been measured and scattered from 10^7 to 10^8 times higher than that of the spontaneous emission. During the first successful operation, the highest FEL power was measured to be about a hundred watts in average. The FWHM of the FEL spectrum is around the Fourier-transform limited value, and less than 0.09 μm, which corresponds to $\Delta\lambda/\lambda$=0.37%. The detuning curve of the cavity is asymmetrically-peaked over about 3 μm in the longer side, and spanned over about 15μm.

1 INTRODUCTION

A prototype for a quasi-cw or very long-pulse, and high-average power free electron laser(FEL) driven by the 15 MeV superconducting rf linac has been developed, and constructed at Tokai, JAERI (Japan Atomic Energy Research Institute) since 1989 [1-4]. Both high performances of cryogenic stand-by loss<3.5W at 4.5K and accelerating fields' Eacc < 8.3MV/m and Q < 2 $\times10^{+9}$ in the JAERI superconducting rf linac modules have been successfully realized as a so-called zero-boil-off and world-first transportable capabilities without any serious vibrational problem in the JAERI FEL accelerator vault.

Since modification and related maintenance of the cryogenic refrigerator system for the driver were completed in the middle of October 1995, the system has run with no trouble, and the driver has been continuously run very successfully up to now. The optical resonator system and related electron beam transport system were modified to realize larger acceptance than the old for both of the undulator radiation and energetic electron beam. An alignment and distance measurement system was newly developed, and successfully applied to actual preparatory measurement for lasing in the JAERI FEL. A far-infrared light transport line and detector room was built to realize a low-loss and low-noise measurement near the accelerator vault in April, 1996.

In order to realize the quasi-cw and very long-pulse operation, we have improved the electron gun grid-pulsar and high voltage power supply, and rf amplitude and phase control systems for the JAERI superconducting rf linac. The improvements in the electron gun and the related with the rf system are still under way.

A beam test and commissioning of the JAERI superconducting rf linac as an FEL driver was successfully performed to get an electron beam ranging from 10 to 23 MeV with a nearly full transmission and a full current, and relatively short macro pulse of 0.01ms. Strong and stable oscillation in the wavelength of around 24 μm have been observed by using the Ge(Cu) detectors with a home-made fast current amplifier system, commercially-available MCT detectors and thermopiles. As shown in Fig. 1, a sudden increase of the light signal were observed after a few tens of microseconds later from the onset of beam current pulse.

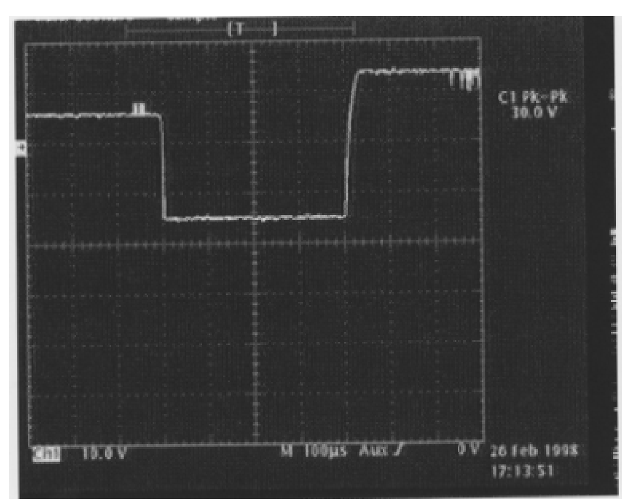

Figure 1: Stable oscillation in the wavelength of around 24 μm. The pulse duration is continued over 0.4ms, the beam current ranging from 2 to 4mA, and the maximum laser power about a hundred watts in average.

2 EXPERIMENT

Fig. 1 shows the first and stable laser oscillation with the JAERI superconducting rf linac based FEL. The average current for a macro pulse is measured to be around 4mA. The lower trace of the figure is a far-infrared light signal waveform of a Ge-Cu detector. The total cavity loss and the FEL gain are scattered between 1.1 and 1.9%, and estimated to be from 10% to 30%, respectively, which were obtained from decay and rising times of the output pulse.

Fig. 2 shows the e-beam current signal of the lower part and FEL light output signal of the upper over a half millisecond. As shown in Fig. 3, the FEL spectrum was measured with a grating spectrometer and a commercially-available pyroelectric line-sensor of 64 channels located at the focal plane during the operation.

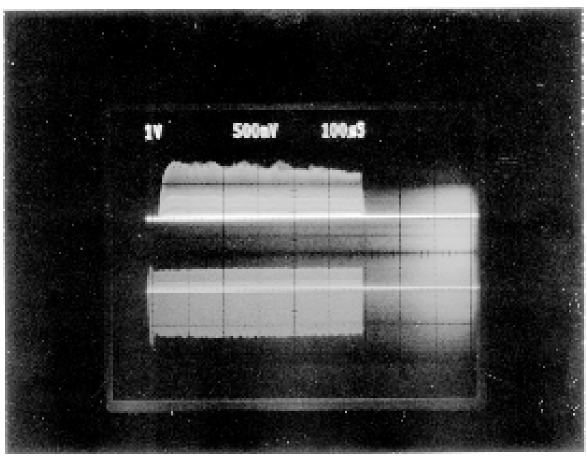

Figure 2: Electron-beam current signal of the lower part and FEL light output signal of the upper over a half millisecond.

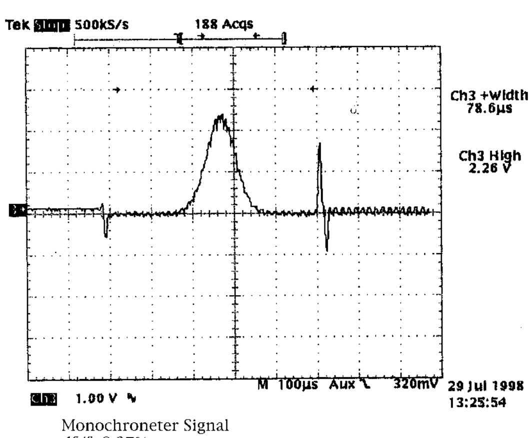

Figure 3: The FEL spectrum was measured with a grating spectrometer and a commercially-available pyroelectric line-sensor of 64 channels fixed at the spectrometer focal plane during the operation. The FWHM of the FEL spectrum is less than 0.09 μm, which corresponds to $\Delta\lambda/\lambda$=0.37%.

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The detuning curve was measured reliably to be asymmetric, long-tailed in the shorter cavity-length side, and short-tailed or quickly-disappeared in the longer.

An FEL beam spot was observed using a pyro-camera fixed in the optical measurement room neighboring the FEL accelerator vault.

Divergence of the beam is estimated to be the same order of a diffraction limit value in the figure 4.

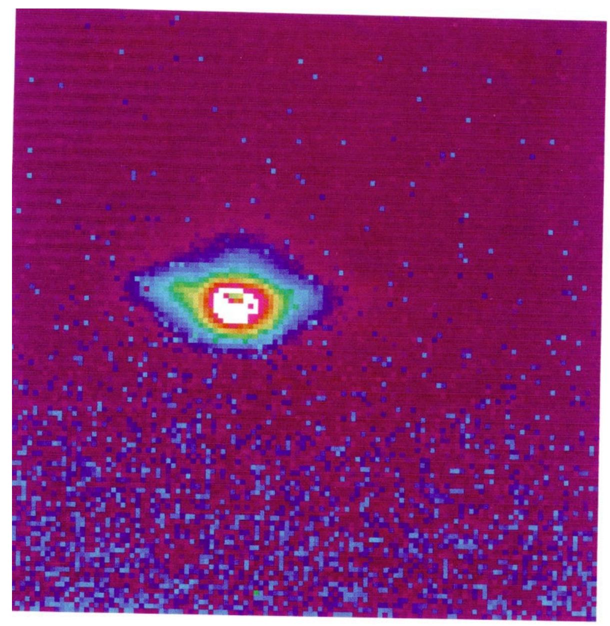

Figure 4: FEL beam spot observed using a pyro-camera fixed in the optical measurement room neighboring the FEL accelerator vault.

Stable laser oscillation has been obtained at a wavelength of 24μm using the JAERI superconducting rf linac based FEL driver. During the first successful operation, the highest FEL power was measured to be about a hundred watts in average. The JAERI superconducting rf linac operational parameters are summarized in the following; 1) Electron Beam Energy of 15.8 MeV from 0.1 to 0.9ms, 4) Beam current ranging from 2mA to 4mA, 5) Energy resolution around 0.6%, and 6)Repetition Rate 10.4125MHz.

A near-concentric optical resonator with a 52 period of 33mm length hybrid planer undulator (K=0.7) is 14.4m long and uses Gold-coated Copper mirrors of 120mm diameter. The optical axes and distance of the mirrors is adjusted by remotely controlled actuators in order to coincide with the electron beam and micro pulse repetition rate, respectively, before the oscillation. The power has been measured and scattered from 10^7 to 10^8 times higher than that of the spontaneous emission.

3 REFERENCES

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