FIRST LASING AT SCSS

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Abstract

On 20 June, the first lasing was observed at 49 nm in SCSS prototype accelerator for Japanese XFEL project. A challenging approach: 500 kV gun using CeB_6 single crystal thermionic cathode generates low emittance beam from 500 kV gun, followed by velocity bunching, and magnetic chicane bunch compression, the measured emittance at 50 MeV was 3 π.mm.mrad normalized. When we firstly closed undulator, we observed narrow spectrum of amplified SASE signal. Radiation energy per pulse is around 1 μJ/pulse at moment.

INTRODUCTION

Unique combination of three key technologies: the in-vacuum short period undulator, the C-band high gradient accelerator and low emittance injector using thermionic electron source make possible to realize SASE-FEL at 1 Å within available site length at SPring-8 less than 800 m. It was named as SCSS: SPring-8 Compact SASE Source [1]. From year of 2001, we have been carrying out R&D on the key components: the electron gun, injector, C-band klystron modulator with oil-filled compact design, high resolution beam position monitor, digital rf signal processing system, etc.

TEST ACCELERATOR

In order to test this challenging scheme, and check all hardware components developed in our R&D [2], we constructed prototype accelerator in 2004-2005 as shown in Fig. 1. Beam line layout is shown in Fig. 4. We use four C-band accelerating structures, 1.8 m long each, energy gain 32 MV/m maximum. With maximum beam energy of 250 MeV, the shortest wavelength of VUV-radiation at 50 nm can be obtained.

Fig. 1 Tunnel view in SCSS prototype accelerator.

We commissioned beam operation in November 2005 and spent a few months to repair some hardware and software. From May 2006, we started dedicated beam tuning to demonstrate first lasing.

FIRST LASING EVENT

Two in-vacuum undulators were installed, whose undulator period is 15 mm, minimum gap is 3.5 mm, nominal K value is 1.3 and one undulator length is 4.5 m. In the beam tuning, we firstly opened the gap to 20 mm and passed the e-beam through gap and transported into the beam dump. We tuned the beam optics upstream of the undulator. We setup the optics, in coming beta-matching and focusing Q-magnet in between two undulators.

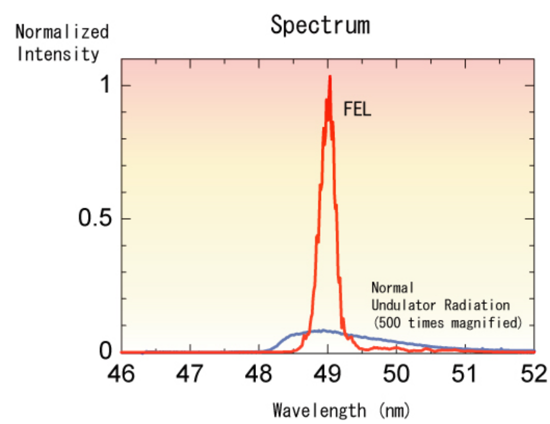

Fig. 2 Radiation spectrum at the lasing condition, 0.25 nC per bunch and 250 MeV. Peak at 49 nm is the coherently amplified signal (6000 times) from the spontaneous undulator radiation (blue line).

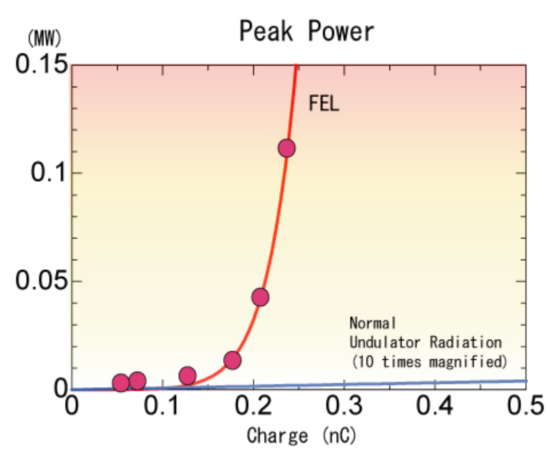

Fig. 3 Peak output power v.s. bunch charge. Using photo diode, peak height was detected from averaged pulses.

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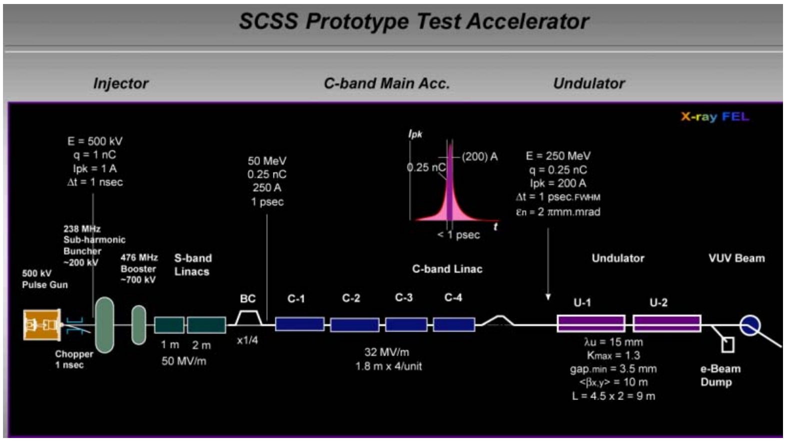

Fig. 4 SCSS prototype accelerator, two undulators of 15 mm pitch, 250 MeV e-beam, generates VUV-radiation.

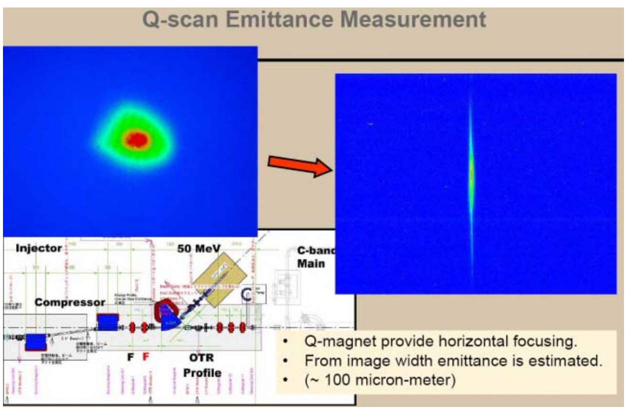

Fig. 5 Beam profile during Q-san emittance measurement. Transition radiation from Au coating of optical mirror was monitored by CCD camera.

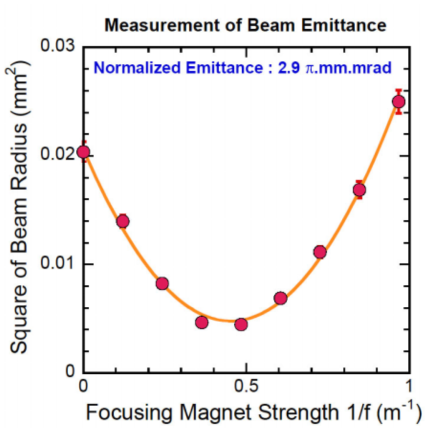

Fig. 6 Beam width as a function of focusing power. At beam energy 50 MeV, charge 0.25 nC, length <1 psec.

On 15 June, evening, we firstly closed the gap in the upstream undulator, and measured radiation spectrum, where the spectrum width was already quite narrow peaked at 49 nm, and totally different from the natural spontaneous radiation, as shown in Fig. 2. The spectrum width is around 1% FWHM, which is much narrower than the spontaneous undulator radiation, while it is dominated by e-beam energy fluctuation, at moment.

As shown in Fig. 3, when we varied the bunch charge, the lasing power drastically changed. This threshold phenomenon indicates high FEL amplification. The power has not yet reached the saturation. Further tuning is required. Detail analysis is now undertaken.

EMITTANCE MEASUREMENT

At the injector end, the velocity bunching and chicane bunch compression have been completed, where the beam energy reaches to 50 MeV, bunch charge is 0.25 nC and the bunch length is 1 psec or less, which depending on operation condition, specifically phase & amplitude tuning of 238 MHz and 476 MHz cavities.

We measured projected emittance right before the C-band accelerators, using Q-scan method. By reversing polarity of one of the Q-magnets to provided strong focusing in X- and Y-direction, and measured the minimum beam width. By varying focusing power, the beam width response was measured as Fig. 5. By fitting the beam size data as a function of the Q-magnet focusing strength as shown in Fig. 6, we found the normalized projected emittance of around 3 π.mm.mrad for both X- and Y- directions. The slice emittance was also measured at 50 MeV beam dump, it was 2 π.mm.mrad, where the measurement was limited by spatial available resolution of profile monitor. Probably, the slice emittance is still lower than 1 π.mm.mrad [3], but we do not have instrument to measure it at moment.

We repeated many measurements in this kind, always observed emittance around 3~4 π.mm.mrad. This experimental data indicates that the velocity bunching in our system does not largely deteriorate the projected emittance for compression ratio exceeding 100 times.

CONCLUSION & SCHEDULE

We measured the e-beam emittance and observed first lasing in the SCS prototype accelerator. From this experiment, superior performance of the thermionic gun and injector system has been demonstrated.

Analysing the experimental data carefully, we refine hardware design, and start XFEL construction this year.

REFERENCES

[1] T. Shintake, et. al, "SPring-8 Compact SASE Source", SPIE2001, San Diego, USA, June 2001.

[2] T. Shintake, Status of SCSS Project, 3rd Asian Particle Accelerator Conference, APAC2004, Gyeongju, Korea, March 2004.

[3] K. Togawa et.al., "Emittance Measurerment on the CeB6 Electron Gun for the SPring-8 Compact SASE Source", FEL2004, Trieste Italy.