OPERATIONAL RESULTS OF THE DIAMOND-BASED HALO MONITOR DURING COMMISSIONING OF SPRING-8 XFEL (SACLA)*

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Abstract

Measurement of electron beam halo is a very important issue for X-ray free electron laser and synchrotron radiation facilities, because the beam halo may cause radiation damage of undulator magnets. Furthermore, it may cause degradation in quality of electron beam, and radio activation of beam ducts and components. In order to prevent these situations, a diamond-based halo monitor (HM) has been developed for the SPring-8 Angstrom Compact free electron LAser (SACLA). The commissioning of the HM, which was installed at the upstream of 90m undulator, has been carried out, and it has been figured out that the intensity of the beam halo can be measured very nicely since secondary electrons and bremsstrahlung that are emitted in the accelerator components have not been observed. We describe operational results of the HM during the commissioning of SACLA.

INTRODUCTION

The construction of SPring-8 Angstrom Compact free electron LAser (SACLA) has been completed since FS2010, and the commissioning of the electron linear accelerator and the X-ray beam line has started since March, 2011. The first beam of the X-ray laser was observed in June, 2011. The diamond-based electron beam halo monitor (HM) was installed at an upstream of 90m undulator, and start-up tuning of the HM has been carried out during the commissioning of SACLA. The HM was developed for the first time at SPring-8 as a sensor to prevent the demagnetization of the undulator permanent magnets [1] by irradiation of the beam halo. The feature of the HM is to measure intensity of the electron beam halo directly by installing diamond detectors [2] in a vacuum duct. The output signal is unipolar pulse with the pulse length of 0.6ns FWHM, so an effective lower detection limit can be improved. The beam test of the diamond detectors was carried out at the beam dump area of the 8GeV booster synchrotron in SPring-8 [3]. We have achieved an excellent detection limit of 0.3 fC/pulse for single-shot measurement, which corresponds to the ratio of 10^{-6} to the beam core, and a dynamic range of 10^{4}. A prototype of the HM was manufactured, and its feasibility test was carried out at the 250MeV SPring-8 Compact SASE Source (SCSS) [3, 4]. The diamond detectors can be actuated from the top and bottom of the beam duct. Therefore, the intensity of the beam halo that irradiates to undulator magnet arrays on the upper and lower side can be measured. When the electron beam core passes near the diamond detectors, intense high-frequency component is generated by an influence of a wake field. We demonstrated that the high-frequency component can be reduced by using low pass filters (LPFs), and that net signal can be detected. Moreover, we confirmed that there is no influence on the laser oscillation by degradation of the electron beam, even if the diamond detectors were approached to the electron beam core. We carried out profile measurements and stability tests of the prototype, and we concluded that it is possible to put it to practical use at SACLA.

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DESIGN AND FABRICATION OF HALO MONITOR FOR SACLA

The HM actually used at SACLA was designed based on the above-mentioned prototype as shown in Fig. 1. The RF fingers were introduced into the prototype to suppress an influence of a wake field [5, 6]. By covering the diamond detectors with the RF fingers entirely as shown in Fig. 2, the influence of the wake field is not received directly and the degradation of the electron beam can be suppressed. Beryllium copper alloy (BeCu), which has high spring characteristics, is used for RF fingers usually. But BeCu is a material with high atomic number, Z. A RF finger with an aluminum window, which is a low-Z material, is introduced to suppress an increase of an output signal by scattering at an edge of the RF finger. The HM was installed at the upstream of the undulators as shown in Fig. 3. The HM is covered by the geomagnetic shield box, and the magnetic field on the beam axis is attenuated [7].

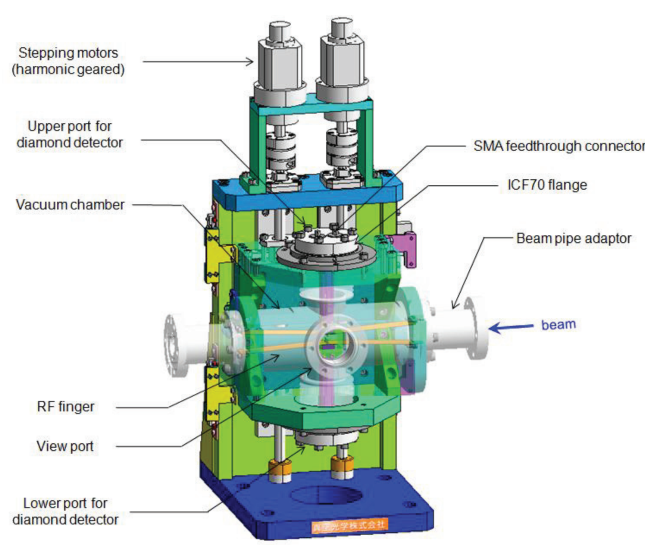

Figure 1: Structure of the HM for SACLA.

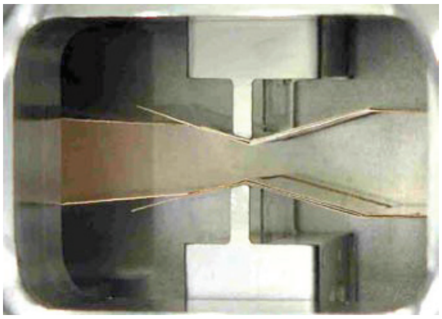

Figure 2: Photograph of diamond detectors and RF fingers with aluminum windows. Thickness of aluminum windows is 0.1mm.

Figure 3: Installation of the HM that is covered with the geomagnetic shield box.

OPERATIONAL RESULTS AT SACLA

In order that the halo monitor is continually used at SACLA, the degradation of the electron beam must be avoided, even when the diamond detectors covered with the RF fingers approach the beam axis. Figure 4 shows the behaviour of the laser power when the distance from the edges of the RF fingers to the beam axis were changed. The laser power did not receive a significant change even when the minimum gap of the RF fingers in this measurement was 0.4mm, where the vertical position of the upper (lower) finger edge V_U (V_L) was at +0.3mm (-0.1mm). We conclude that this is an effect of reducing the wake field by the RF fingers.

The RF fingers with aluminum windows were adopted for the halo monitor used at SACLA. When the edges of the RF fingers are irradiated by the beam core, scattering radiation is generated resulting in increase of the output signal of the diamond detectors. In order to evaluate this influence, we observed the output signal of the diamond detectors when the one side of the upper and lower diamond detectors was expanded from 0.4mm in the gap between the upper and lower RF fingers (Fig. 5). L1 and L2 (U1 andU2) indicate that only the lower (upper) finger was moved. The output signal of the upper (lower) detector was also changed at L1 and L2 (U1 and U2). This result suggests that the core of the beam was scattered at the edge of the RF finger.

Figure 6 shows the output signal of the diamond detectors when the distance between the RF fingers was changed. A horizontal axis is a vertical position of the edges of the RF fingers. The output signals of diamond detectors increase because of scattering when the edge of the RF finger is near the beam core. However, the output signal decreases below the detection limit when the

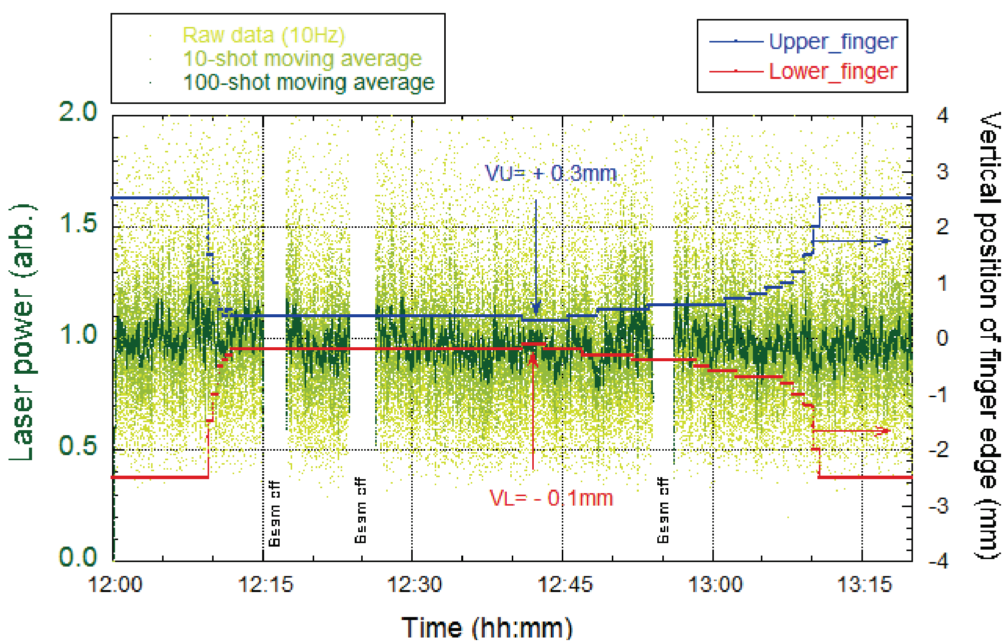

Figure 4: Trend graph of laser power (left axis). A right axis is a vertical position of edges of RF fingers during this measurement. The minimum gap is 0.4 mm around 12:42.

distance from the beam axis to the edges of the RF fingers were 1mm or more. Therefore, we conclude that the beam halo with the distance from the beam axis of 2mm or more is below the detection limit. This result means the undulator permanent magnets will not have demagnetization by irradiation of the beam halo. Moreover, the dashed lines in Fig. 6 were measured during the early stage of the commissioning of the accelerator, and the influence of scattering is seen in the larger area than the measurement after XFEL lasing. This observation suggests that the beam size became to be small with improvement of the commissioning.

During the commissioning of SACLA, the gap between the diamond detectors was fixed to 7mm, and the intensity of the beam halo was always monitored using a data acquisition system. We found that the intensity of the beam halo was always below the detection limit. In the other words, there are no influences of dark current, secondary electrons and bremsstrahlung generated in the accelerator.

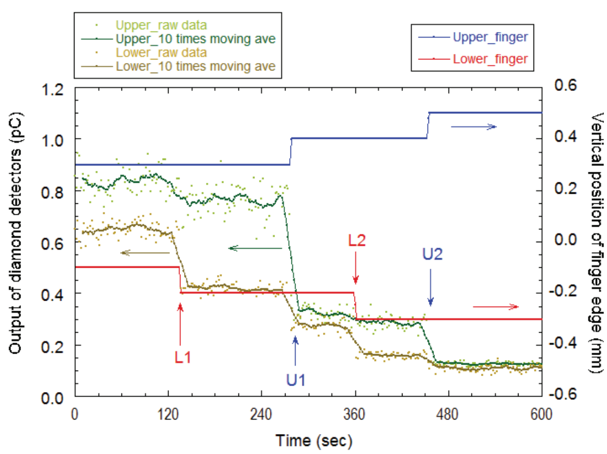

Figure 5: Behaviour of output signal of diamond detectors when a vertical position of the finger edge is changed.

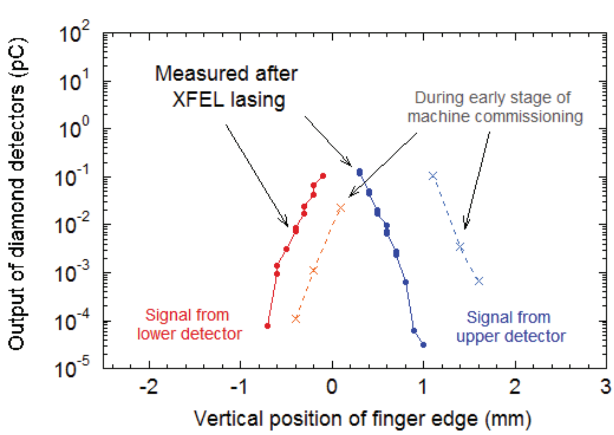

Figure 6: Influence of RF finger edges on output signal of diamond detectors. Solid lines were measured after XFEL lasing. Dashed lines were during early stage of machine commissioning.

SUMMARY

A halo monitor (HM) actually used at SACLA, which has RF fingers with aluminum windows, was designed and fabricated. The HM was installed at an upstream of the undulators to prevent undulator permanent magnets from demagnetization by irradiation of the beam halo. During a commissioning of SACLA we demonstrated the performances of the HM. We figured out that the laser power has not received a significant change even when the minimum distance between the edges of the fingers was 0.4mm and that the beam halo with the distance from the beam axis of 2mm or more is below the detection limit. No dark current, secondary electrons and bremsstrahlung generated in the accelerator were observed. Profile measurements suggest that the beam size became small as the commissioning advanced. As for the next step, we think the RF fingers can be improved in order that the edge of the RF finger will not to be irradiated by the beam core.

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