DIAMOND-BASED BEAM HALO MONITOR EQUIPPED WITH RF FINGERS FOR SACLA*

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Abstract

The diamond-based beam halo monitor has been developed by the Safety Design Group with the collaboration of the Insersion Devise Team for SPring-8 Angstrom Compact free electron LAser (SACLA). This monitor can be used as an interlock sensor to protect the undulator magnets against radiation damage. To reduce the degradation of electron beam due to installation of the halo monitor into the beam duct, new RF fingers with aluminium windows has been designed and improved. The RF fingers are made of beryllium copper, and having the aluminum windows, which is low-Z material, in front of active areas of the diamond detectors. To evaluate influence on the output signal of the diamond detector by changing the finger material, both the simulations and the measurements have been carried out. Feasibility tests of this monitor, which is equipped with the RF fingers, have also been demonstrated at the SCSS test accelerator.

INTRODUCTION

It is important for not only electron accelerators but also proton and heavy ion accelerators to measure the halo part of the beam because of the prevention of radiation damages and the reduction of induced activities. Especially in X-ray free electron laser facilities and storage ring-based synchrotron radiation facilities, where undulators are used, a demagnetizing of undulator permanent magnets is a crucial problem [1]. Up to now, there were measurement methods such as OTRs. But the detection limits are insufficient.

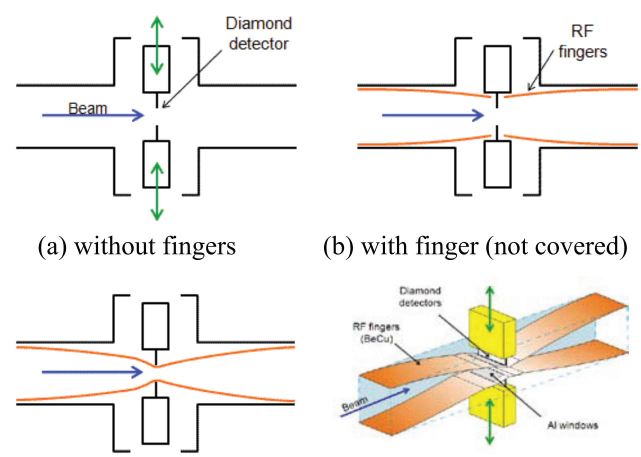
Therefore, we have developed a beam halo monitor, which measures the intensity of the halo of the electron beam directly by installing the diamond detectors [2] into the beam duct as shown in Figure 1 (a), and we have demonstrated the feasibility of the monitor [3, 4].

A wake field that originates from the core part of the beam generates a high frequency component in unipolar pulse signal. This component may cause to obstruct the oscillation of XFEL when the detectors are inserted in the vacuum chamber, and also cause to grow the noise level of output signals of the detectors.

In order to remove the high frequency component, RF fingers were introduced to the halo monitor [5]. Using the RF fingers, we succeeded in the reduction of the wake field generated by the resonance in the vacuum chamber of the monitor. In this configuration of the RF fingers, the active areas of the diamond detectors project between RF fingers to measure the beam halo directly as shown in Figure 1(b).

In order to prevent the irradiation of the intense wake field from ultra short pulses of SACLA to the diamond detectors, the RF fingers have been improved to cover the detectors fully as shown in Figure 1(c). The schematic view of the RF fingers with aluminum windows is shown in Figure 1(d). The upper and lower diamond detectors are covered by four RF fingers. Outside edges of four fingers, which are made of BeCu, are fixed on the top and bottom walls of the vacuum chamber, and inner edges overlap behind the diamond detectors. To avoid the influence of the fingers as much as possible, the windows made of aluminium were set up.

In this paper we report the experimental and the simulation results of the influence of the fingers on output signals of diamond detectors by electron irradiation, and the beam tests of the halo monitor equipped with the RF fingers using SCSS prototype FEL facility..



(a) without fingers (b) with finger (not covered)

(c) with finger (fully covered) (d) Schematic view of (c)

Figure 1: Configuration of the RF fingers.

RADIATION FROM RF FINGERS

Beryllium copper alloy (BeCu), which has high spring characteristics, is used for RF fingers usually. But BeCu is a material with high atomic number. So if the RF fingers are placed in front of the detectors, the secondary electrons and bremsstrahlung are generated at the fingers, and may influence the detection efficiency. Therefore, we adopted aluminum window, which has a small atomic number, on the RF fingers.

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The beam tests have been carried out at the beam dump area of 8GeV booster synchrotron in SPring-8. The influence on the diamond detector was measured, and the results were compared with the simulation result.

Experimental Setup

Figure 2 shows the setup of the experiments. The RF finger is placed as a radiator in front of the diamond detector, and the inclination of the finger is about 1/3, which is assumed in actual use. That means the effective thickness triples. The silicon detector for calibration of incident electron was placed on the upstream side. An increase of the signal of the diamond detector due to the irradiation of the silicon detector is negligibly small.

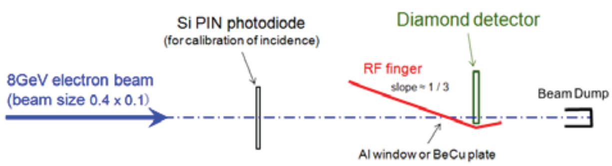

Figure 2: Setup of experiment at synchrotron beam dump.

Experimental and Simulation Results

Figure 3 shows the results of the experiments and the simulations. Measurement data were normalized as the value without fingers corresponds to the energy deposition of 0.16MeV/e. EGS5 [6] was used for the simulations. The vertical axis is the energy deposition within the diamond crystal (t=0.3mm). The experimental results and the simulation results are in good agreement within the measurement errors. A few percent of signal increment is expected due to the installation of Al window (t=0.1mm), but there is no obstacle in our use.

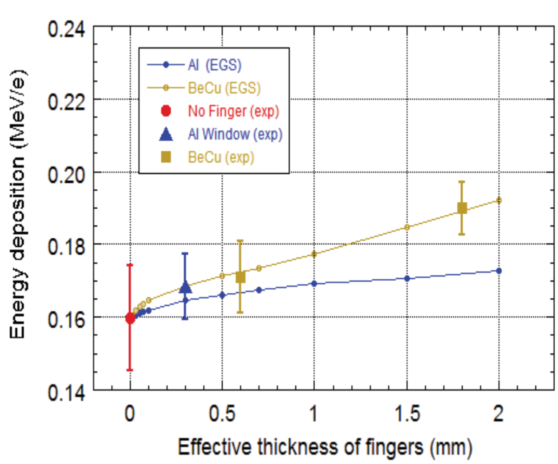

Figure 3: Experimental results and simulation results.

FEASIBILITY TESTS AT SCSS TEST ACCELERATOR

Installation of the Halo Monitor

Figure 4 shows the mechanical design of the halo monitor equipped with RF fingers for SACLA. The beam pipe adaptors are connected to the upstream and downstream of the halo monitor, and the round section of the vacuum ducts is gradually transformed into a square section of the vacuum chamber of the halo monitor. The diamond detectors can be actuated from the upper and lower ports. The electrodes for the signals of the diamond detectors and for the bias voltage are connected to the SMA feed through connectors [7] of the ICF70 flanges by introducing the microstripline structure as shown in Fig. 5(a), so as not to deform a unipolar pulse shape. The RF finger is pushed toward the beam pass with metal fittings attached beside the diamond detectors as shown in Fig. 5(b). The halo monitor (Fig. 4) that has the finger type shown in Fig. 1 (d) had been installed at the upstream of the undulators of the SCSS test accelerator. The experimental data of this monitor were compared to those of the monitors as shown in Fig.1 (a) and (b).

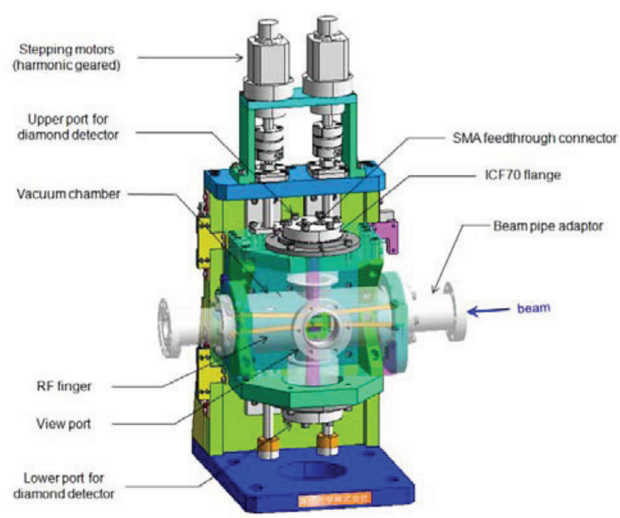

Figure 4: The mechanical design of the halo monitor.

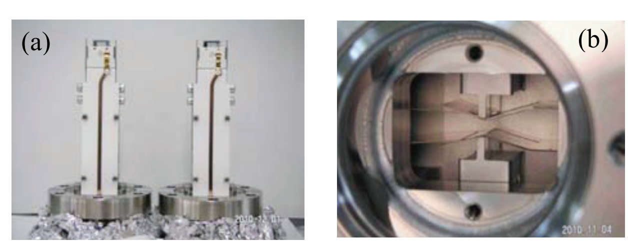

Figure 5: Photograph of (a) detectors with microstripline structure, and (b) RF fingers with Al windows (beam direction: from left to right).

Experimental Results

Figure 6 shows output signals with the high frequency component by the influence of the wake field generated when the beam core is passed between the diamond detectors. The high frequency component is drastically decreased by covering fully with the RF finger, and duration has also shortened. Figure 7 shows the result of the FFT analysis. It decreases especially in the band of 2GHz or wider.

The pulse shape has been observed on the condition of decreasing influence of the wake field by inserting the OTR screen and diffusing the beam, as shown in Fig. 8. The unipolar pulse signal was observed clearly even when the diamond detector was covered fully with the RF fingers. A shoulder in the pulse shape disappeared because high frequency SMA feedthrough connectors have been introduced.

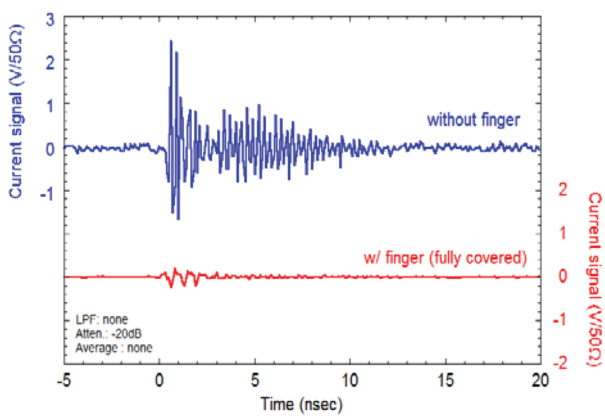

Figure 6: The suppression of effect of wake field.

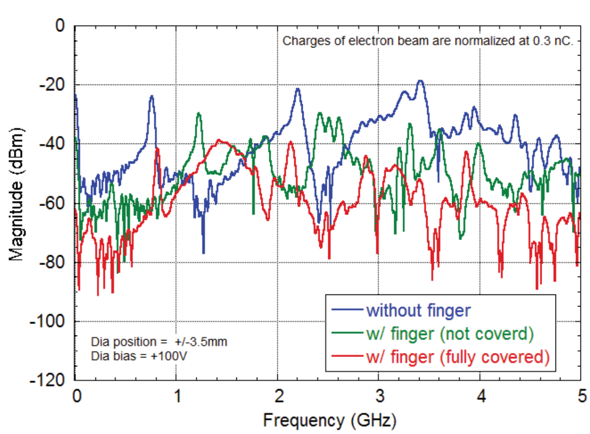

Figure 7: FFT analysis of output signals.

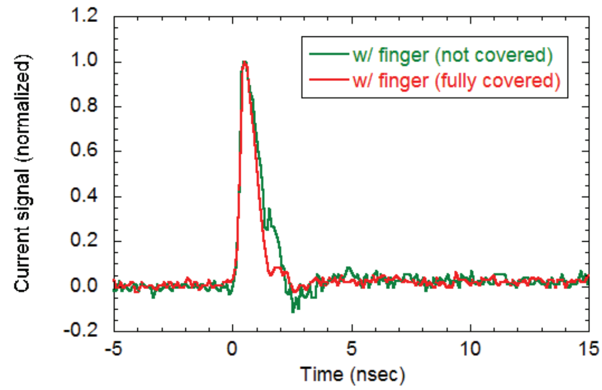

Figure 8: Pulse shape without influence of the wake field. The pulse heights are normalized at the peak.

SUMMARY

The RF fingers of the halo monitor have been redesigned for the diamond detectors to be covered fully. The merits of this configuration are (1) decreasing the impedance against the beam, and reducing the influence to the FEL oscillation, (2) suppressing the high frequency components that mix with the signal output of the diamond detector, and (3) preventing the diamond detectors from being irradiated directly with intense wake field. We have evaluated the influence on the signal output by radiation from the Al windows, and confirmed that the influence is negligibly small for our use. We have also carried out the beam tests of the halo monitor at SCSS test accelerator. We think that the halo monitor equipped with RF fingers will be feasible for SACLA.

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