Improvement in High-Frequency Properties of **Beam Halo Monitor using Diamond Detectors** for SPring-8 XFEL

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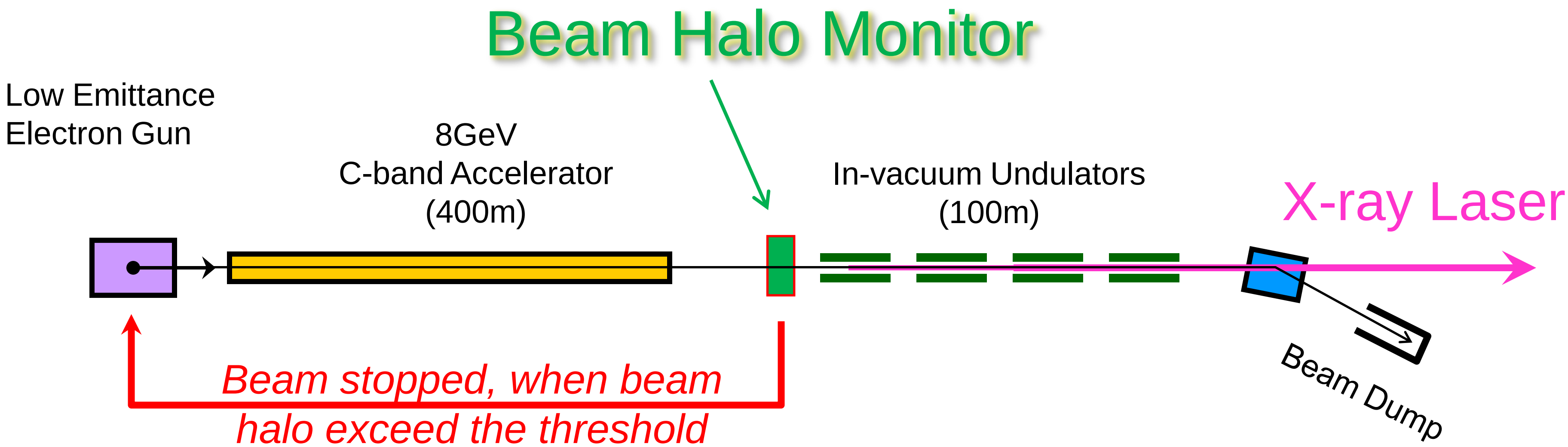
Motivation of this Work



We are planning to install a **beam halo monitor** in front of the in-vacuum undulators.

Demagnetization of the permanent magnets will be occurred under electron irradiation. The halo of electron beam may be broadened by some changes of beam conditions, and may hit the magnets.

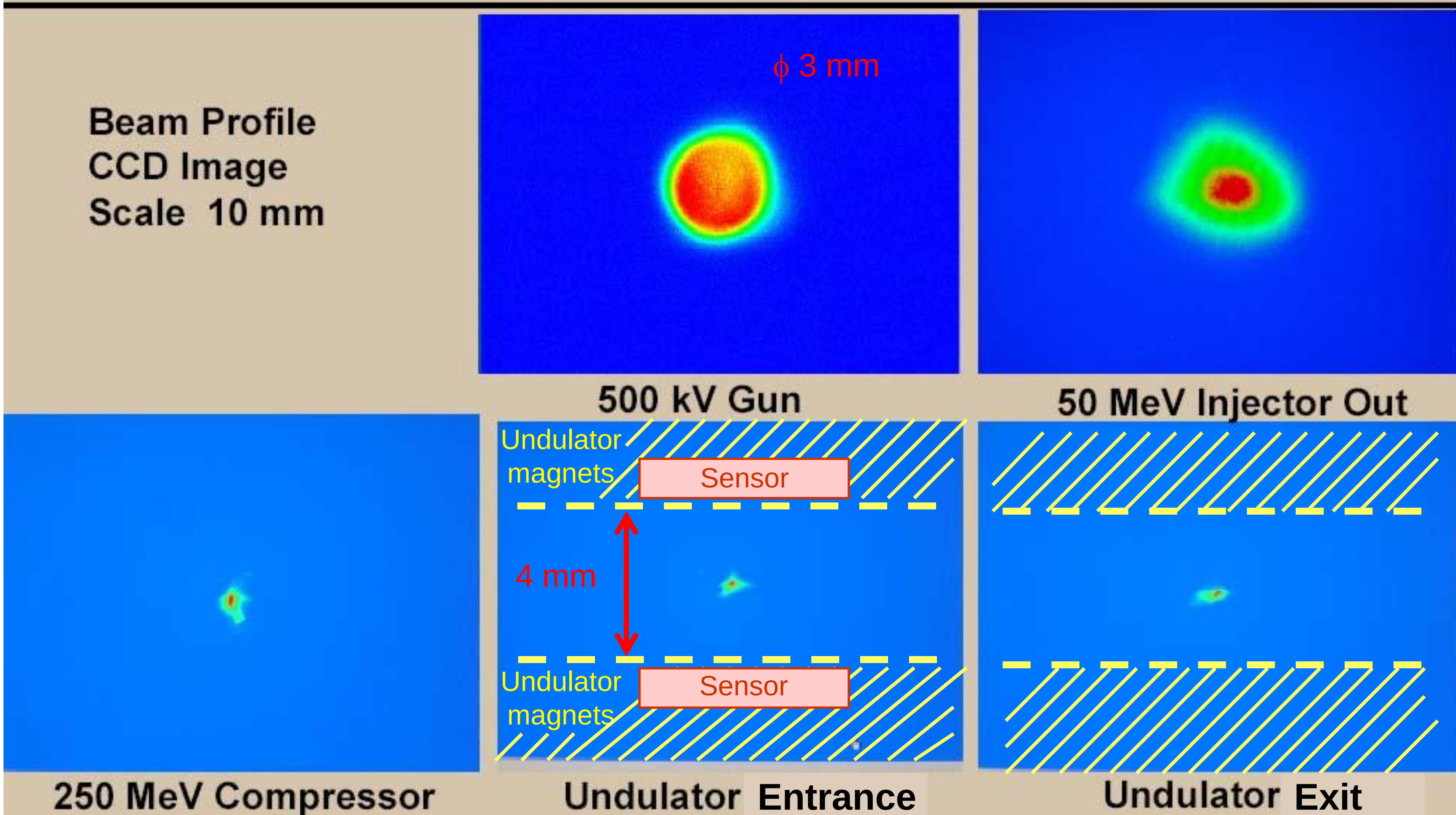
The intensity of the halo of the electron beam must be monitored during machine operation, and an electron injector must be halted when the intensity of the halo exceeds a threshold.

Sensors in front of the undulator magnets

Profile of electron beam emitted from a thermionic gun at 250 MeV SCSS Test Accelerator.

加速器学会2006

T. Shintake



Beam halo is existing and the profile is asymmetric.

Required Detection Limit

Tolerance of demagnetization rate of undulator magnets

1 % / 10 year

→ Tolerance of incident electron on the magnets

4×10^{14} e^- / 10 year (based on the experimental results)

→ Required detection limit $< 2 \times 10^{4}$ e^- / pulse

(60Hz × 24hrs × 365day × 10 year ⇒ 1.9×10^{10} pulse)

cf. Number of electron through undulators

2×10^{9} e^- / pulse (0.3nC/pulse)

→ Tolerance of electron loss rate $< 10^{-5}$

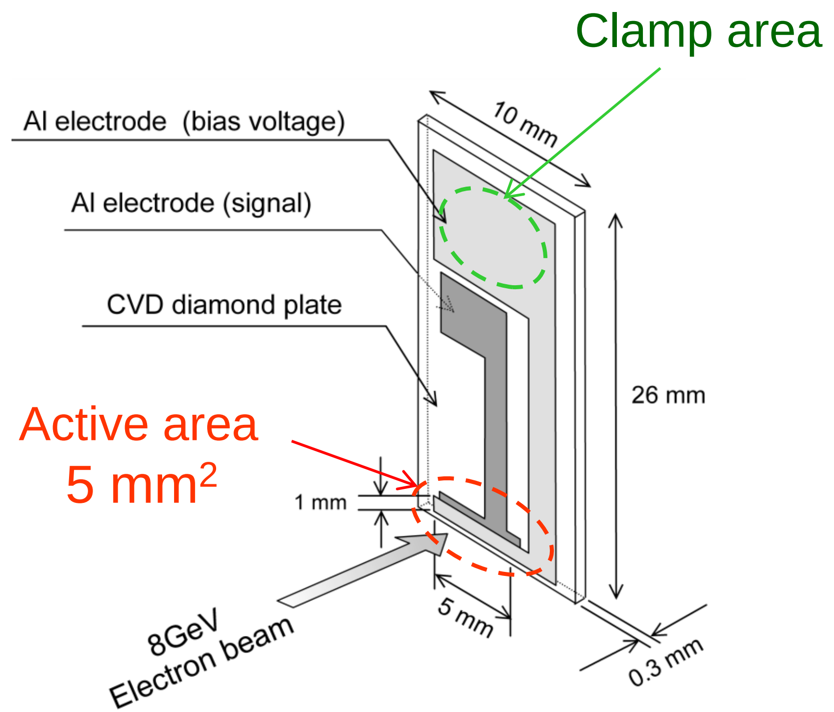
2. Prototype of Beam Halo Monitor

The Diamond Detector and the beam tests at 8GeV Booster Synchrotron

The Prototype and the beam tests at 250MeV SCSS Test Accelerator

Diamond detector as semi-conductor detector

Aoyagi et al., SRI2003



Manufactured by Kobelco

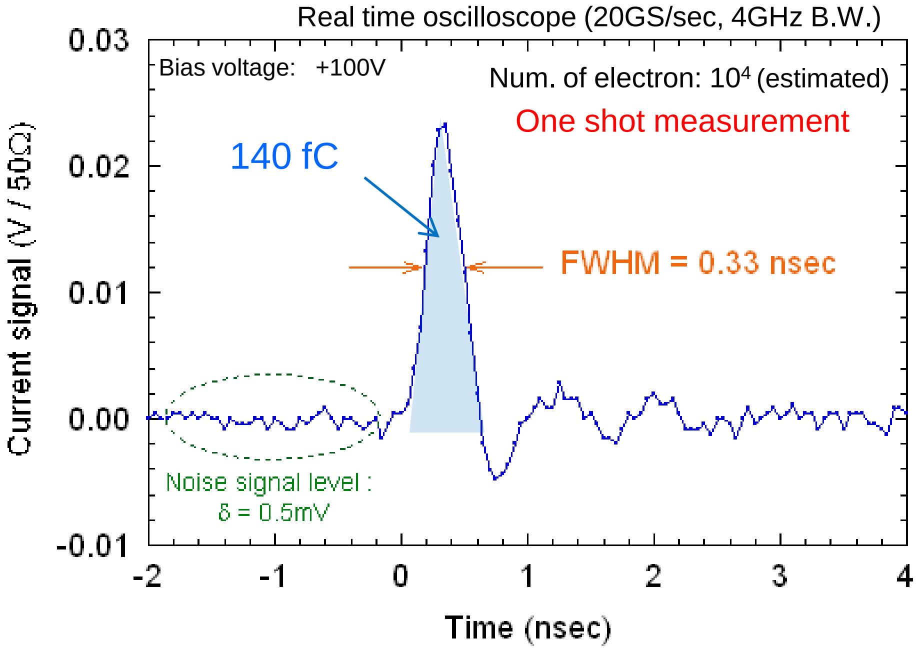
Properties of diamond

- High radiation hardness (durable)
- Sufficient heat resistance (bakable)
- High insulation resistance (low dark current)

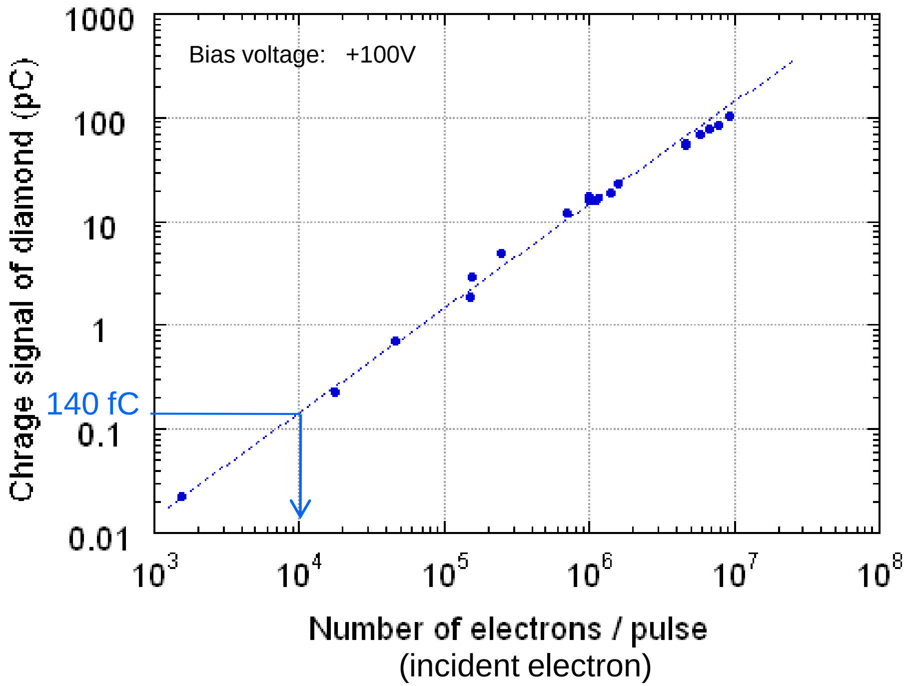
Pulse-by-pulse measurement suppresses the background noise efficiently, especially in the facilities having extremely high intense beam but low repetition rate, such as X-ray free electron lasers.

Beam test of the diamond detector at 8GeV booster synchrotron

Unipolar Pulse shape



Linearity



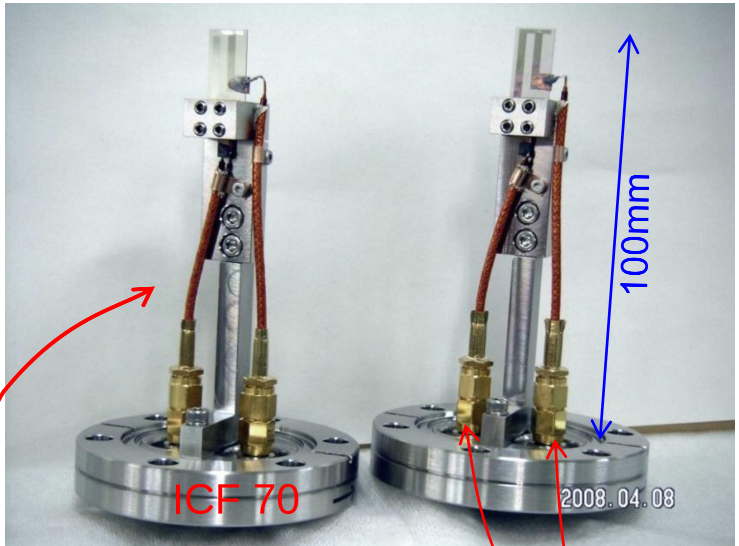
FWHM=0.33nsec

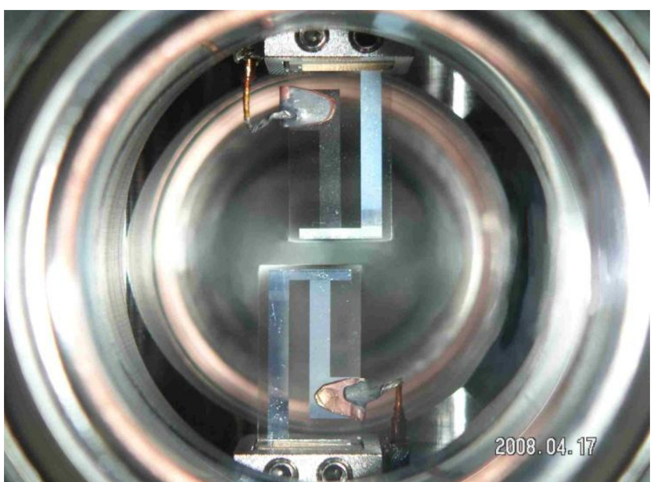
Charge signal is 140 fC at the incident of 10^4 electrons.

Charge from the diamond detector is proportional to the number of electrons in the range of from 10^3 to 10^7 /pulse.

For use as an interlock sensor, practical detection limit is about 2×10^3 /pulse.

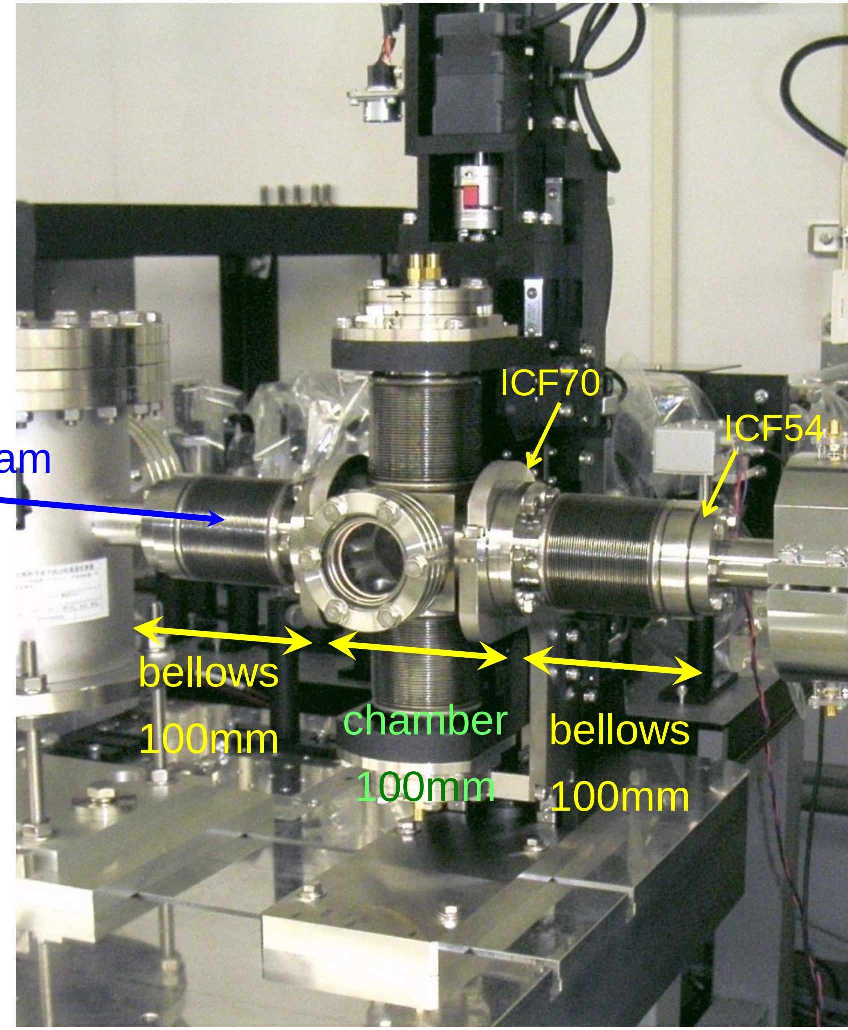
Photographs of the Prototype





Seen from on the axis

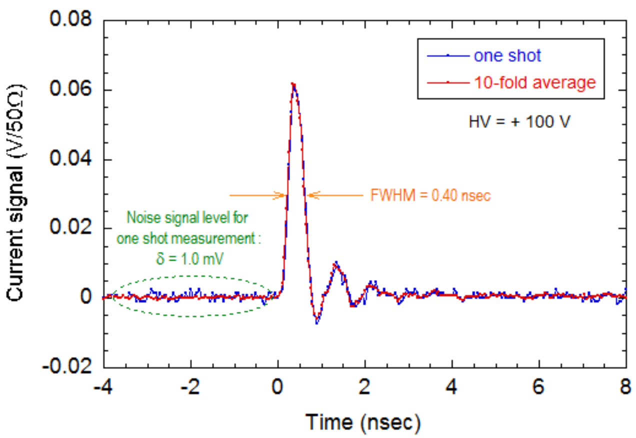
Installed at 250MeV SCSS Test Accelerator



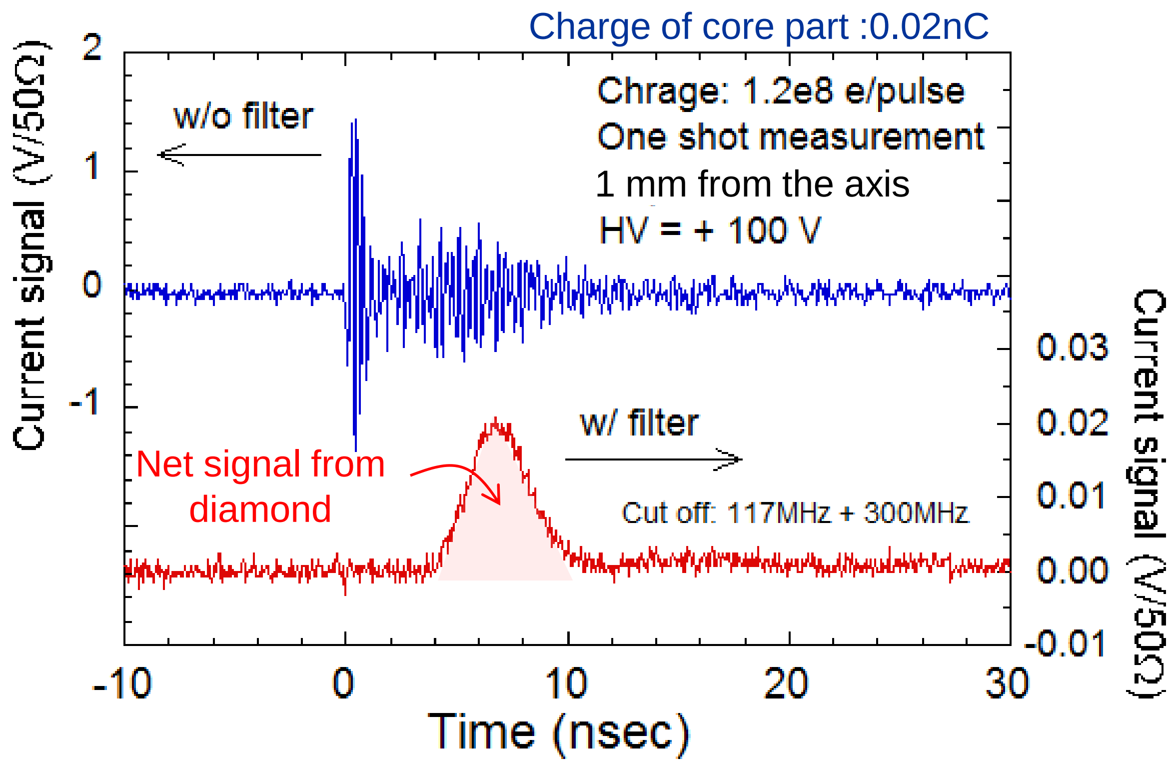
Effect of Wake Field and their suppression

The beam core passes through near the edge of diamond detectors.

The active area of the diamond detector was irradiated directly with the beam core (3×10^4 e).



The unipolar pulse shape can be observed clearly.

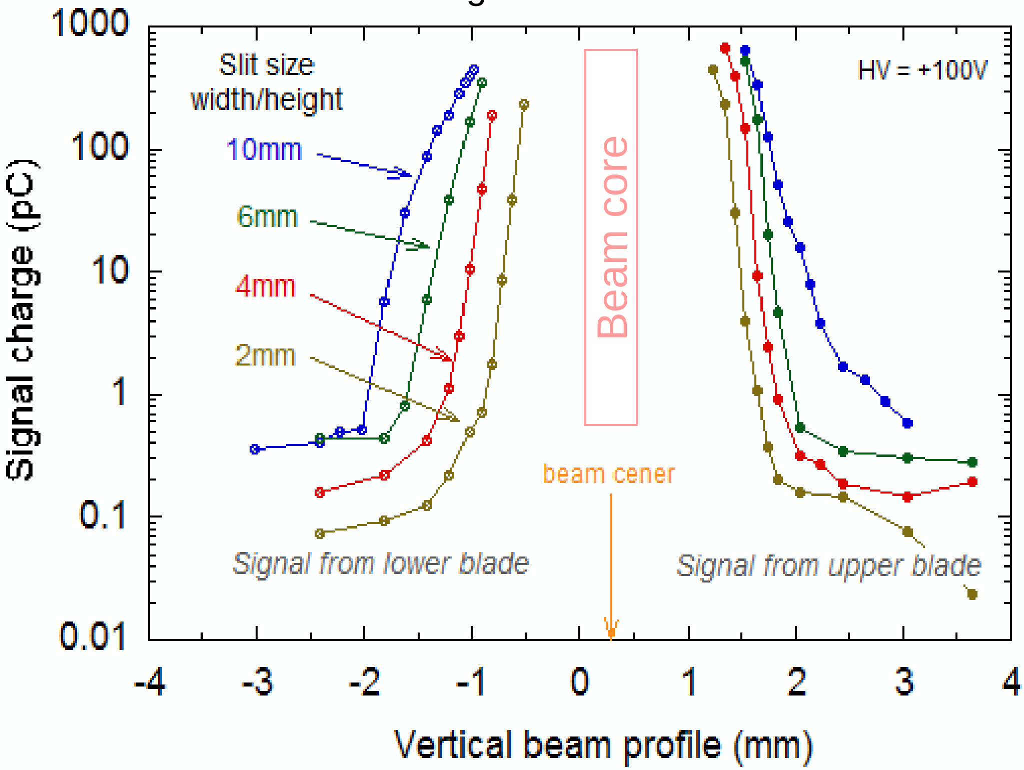


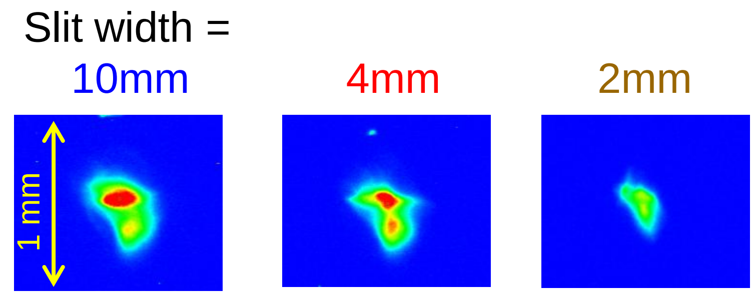
The effect of induction current can be smeared by using Low Pass Filters, so the net signal from e-h pairs that is created by the halo part of the electron beam can be measured.

Effect of secondary electrons and radiation

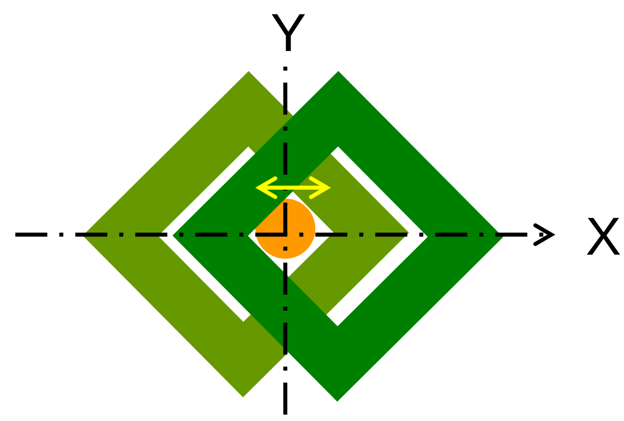
Profile measurements

Scanning in the vertical direction





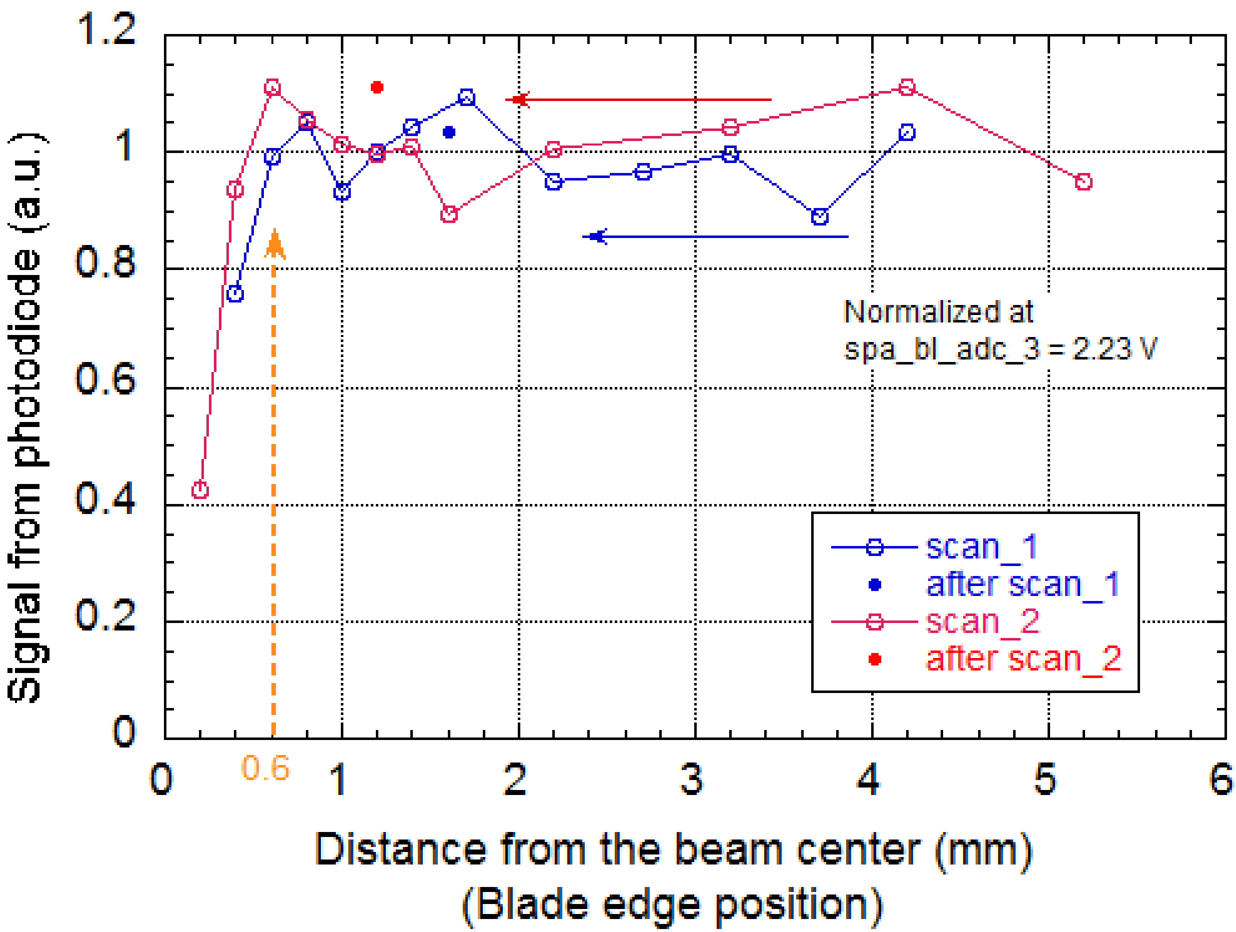
Images of OTR screen just after beam halo monitor



Spacial slit
after 50 MeV Injector

The profiles of electron spread by bremsstrahlung and electron scattering is assumed to be broad. On the contrary, the amount of signal charge at the vertical position over +/-2 mm is lower than the detection limit. So we think that the signal cause of bremsstrahlung and secondary electrons is negligibly small.

5. Effect on the oscillation of FEL



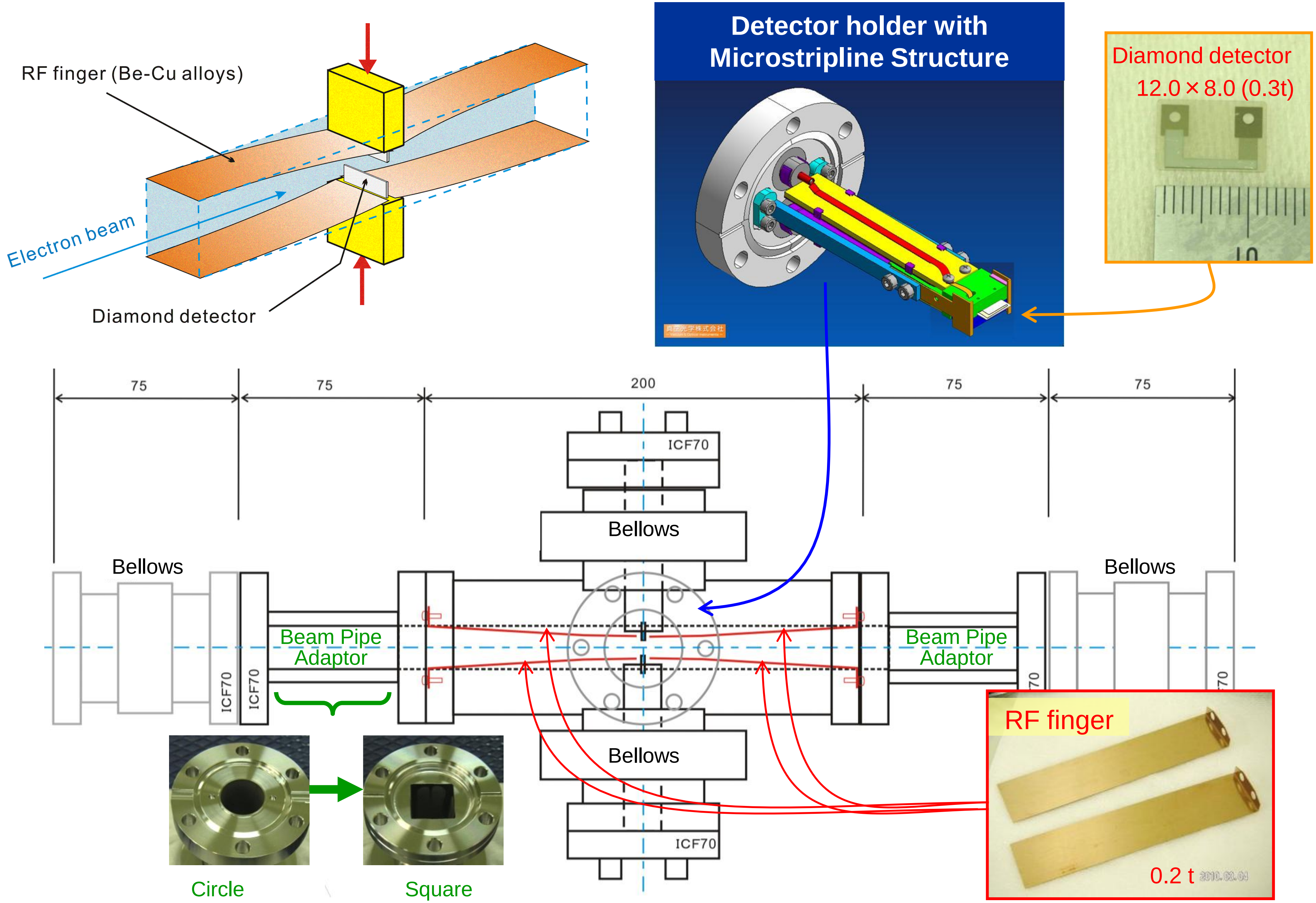
The intensity of laser oscillation is not to be effected if the distance from the beam center and the diamond detector is more than 0.6 mm.

3. Improvement in High-Frequency Properties

Structure of RF fingers and other devices

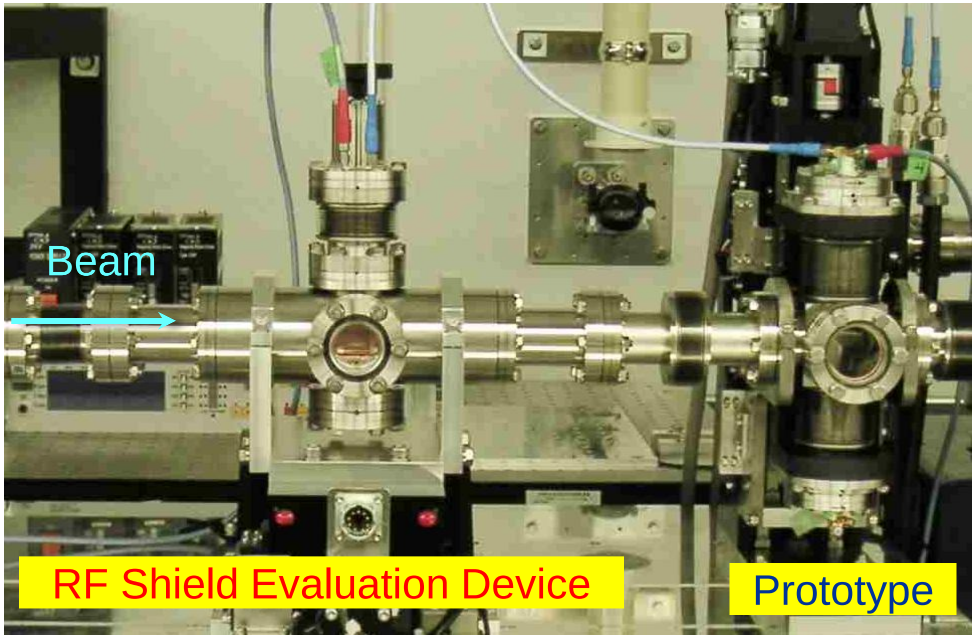
Beam Test of the RF Shield Evaluation Device (test chamber)

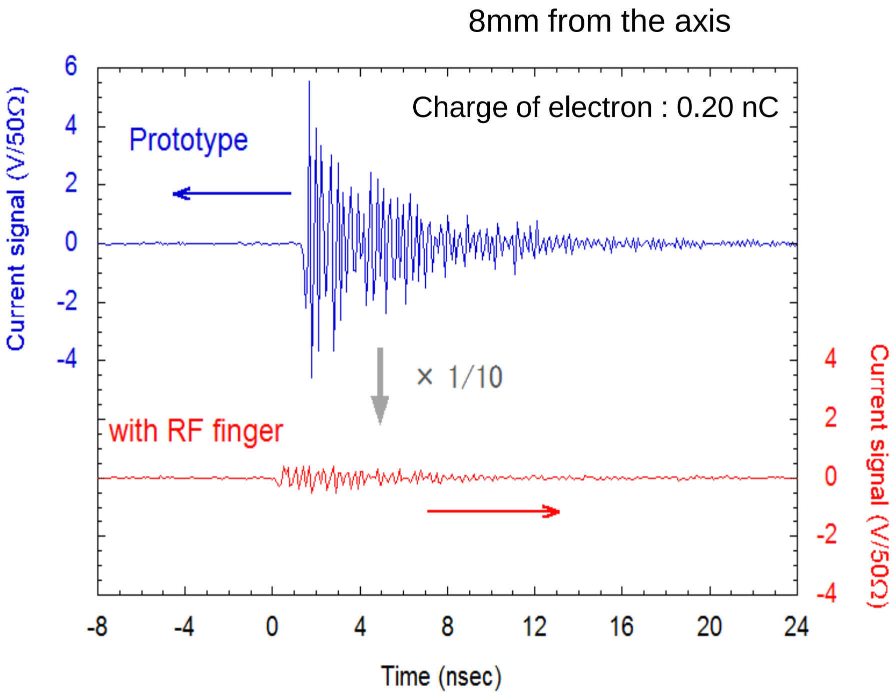
Structure of RF finger and other devices



Beam Test with RF Shield Evaluation Device

The beam tests of the RF shield evaluation device, which adopts the above-mentioned items, have been performed at 250 MeV SCSS test accelerator.



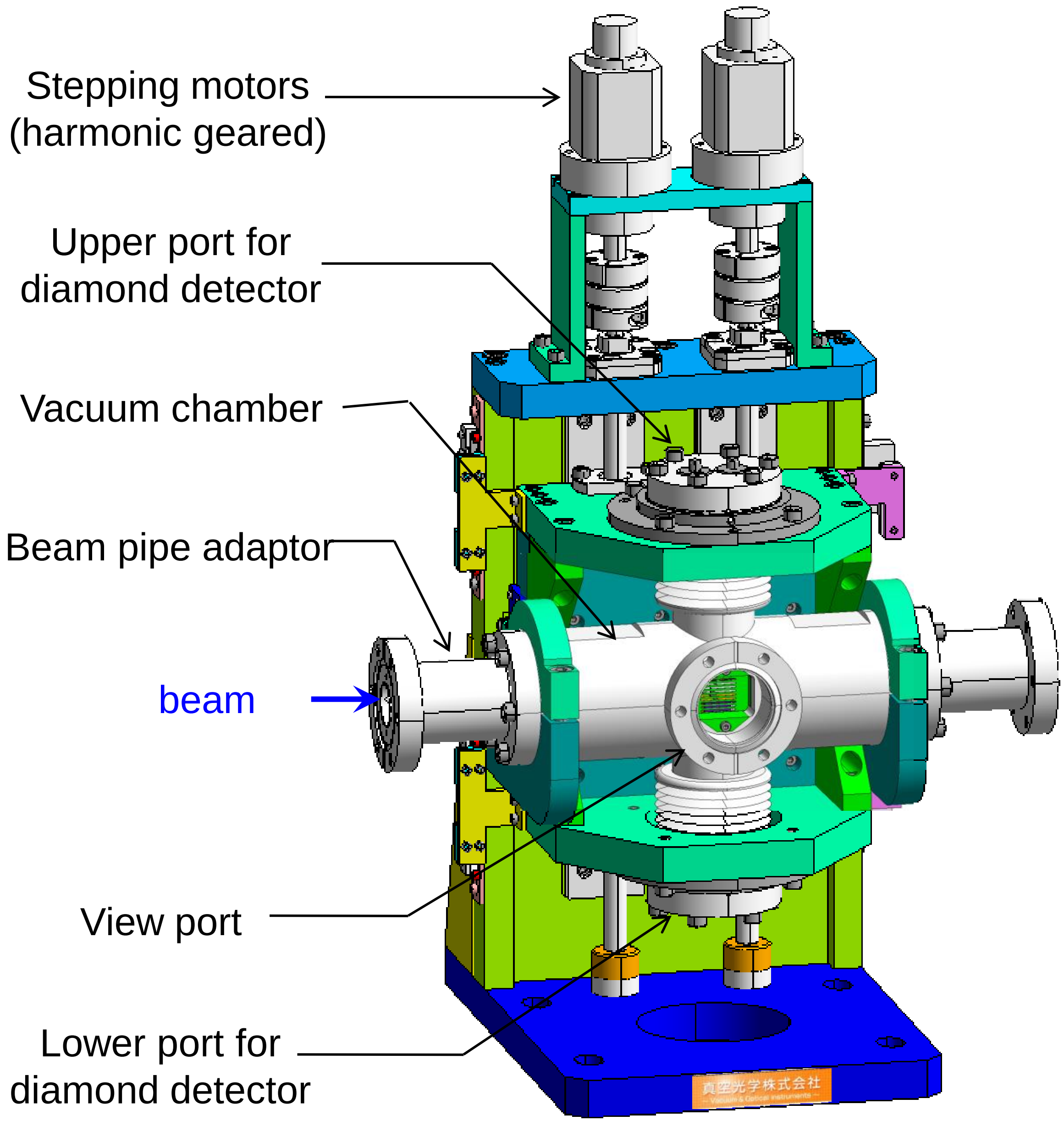


The effect of wake field is reduced by of 1/10.

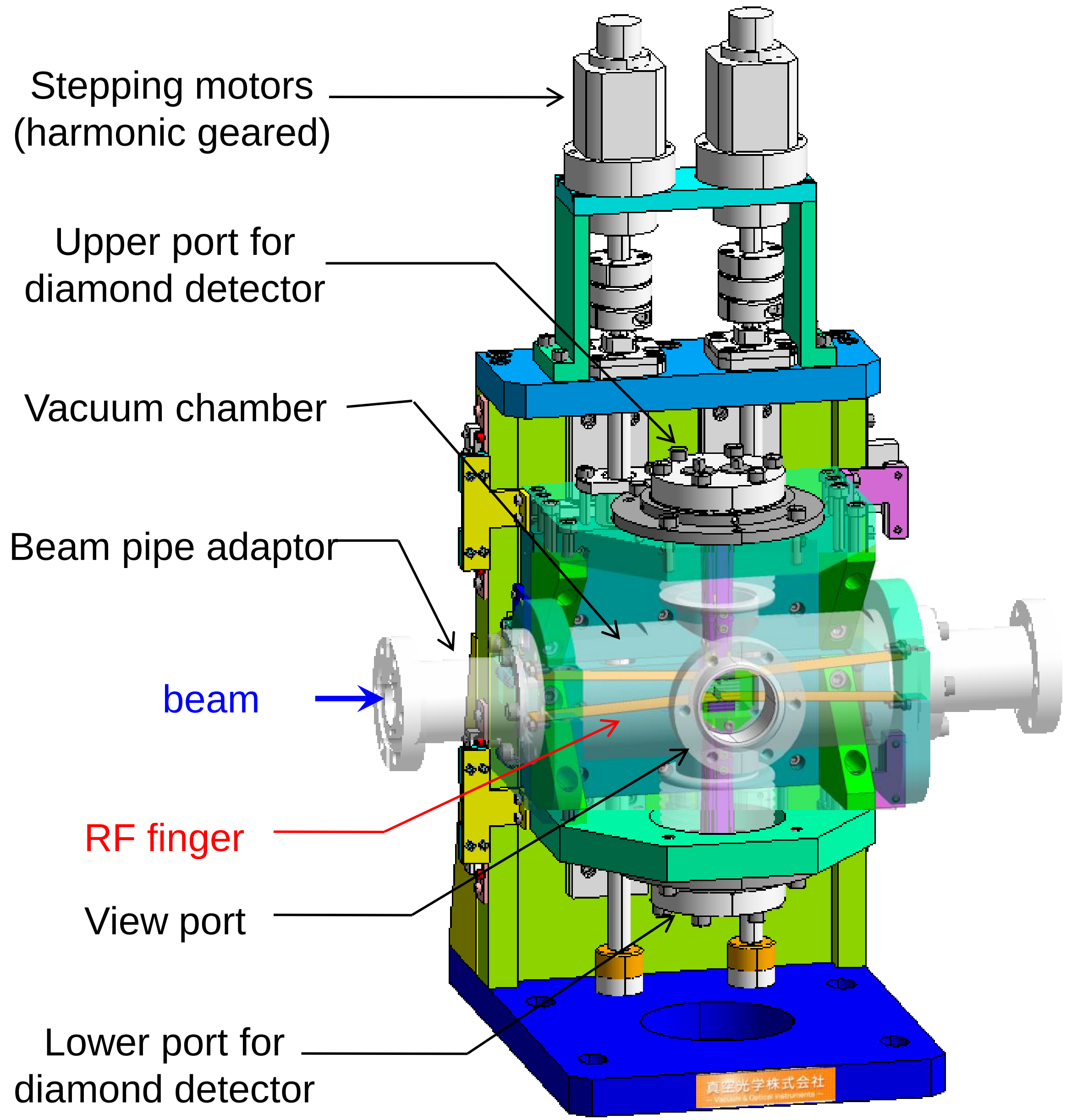
The induced current can be reduced further by improving the shape of the RF fingers.

4. Mechanical Design of Beam Halo Monitor

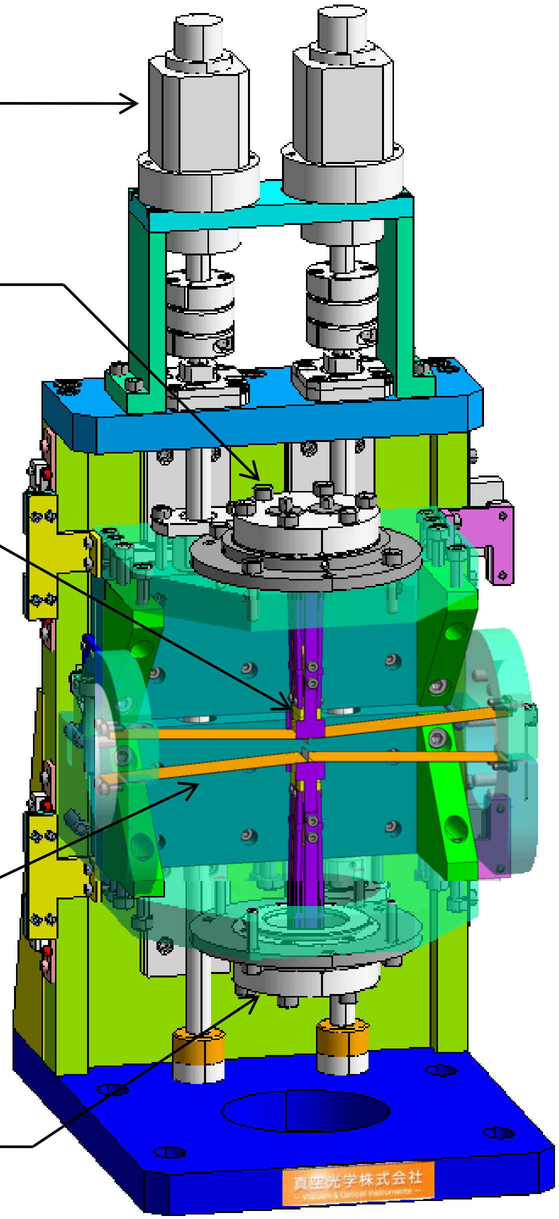
Mechanical Design of the Practical Monitor 1



Mechanical Design of the Practical Monitor 2



Mechanical Design of the Practical Monitor 3



Mechanical Design of the Practical Monitor 4

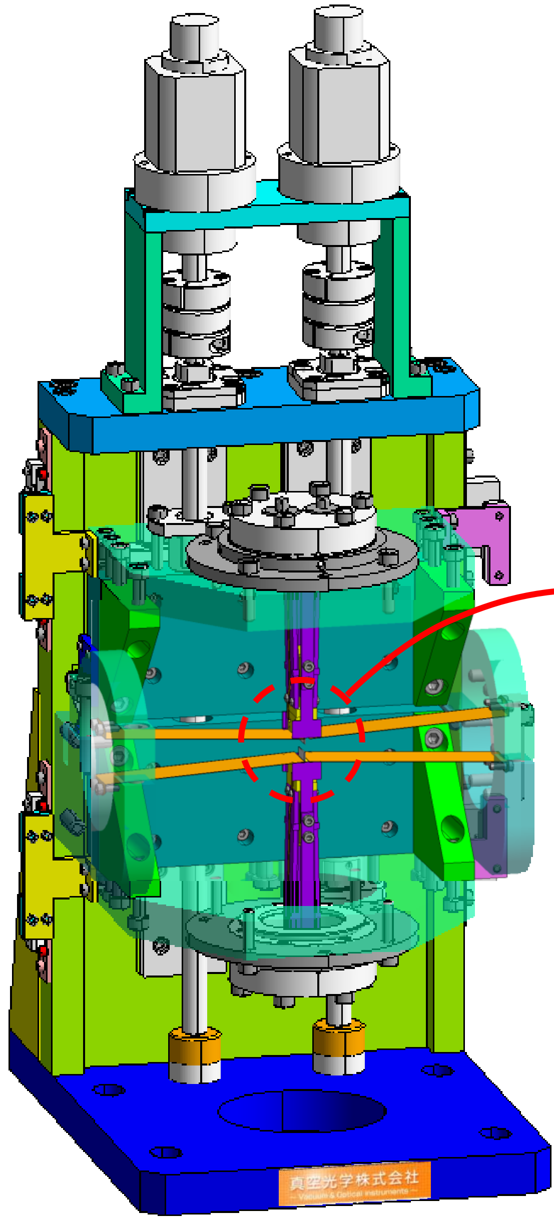
Next step:

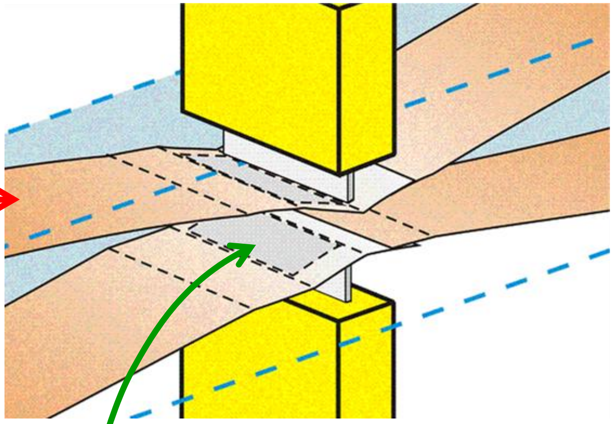
The diamond detectors will be covered by RF fingers.

- Reduce the wake field for preserving beam quality.

- Mute the induction current that emerges in the signal of the diamond detector.

- Protect the diamond detector from the intense wake field.





The aluminum window will be adapted to prevent secondary electrons and radiation.

5. Summary

1. Purpose of this work

- to protect undulator magnets against radiation damage
- using the beam halo monitor equipped with the diamond detectors
- adopting pulse measurement for enhancing S/N ratio

2. Prototype of Beam Halo Monitor

- Practical detection limit is about 2×10^{3} /pulse. (10^{-6} of 0.3nC)
- Feasibility had been demonstrated at 250MeV SCSS Test Acc.

3. Improvement in High-Frequency Properties

- RF fingers and other devices were applied.
- Beam test was carried out with the RF Shield Evaluation Device.
- The induced current was reduced by a factor of 1/10.
- Mechanical design has been completed.

4. Next step

- Further modifications on RF fingers will be added, and will be tested soon.