# STUDY OF THE PHOTON BEAM STABILITY IN COMPACT STORAGE RING HiSOR

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*Abstract*

The rf cavity of the HiSOR is known to have the higher order mode (HOM) which induces a longitudinal coupled bunch instability (LCBI). We have found that the quadrupole bunch oscillation due to the LCBI contributes to a considerable increase in the beam life time. However, there remains the question that the LCBI has an influence on the photon beam stability. The photon bean position and flux measurements were made to see how it depends on the LCBI and the results showed an effect of the LCBI should not be neglected. For the measurement of the photon beam position, different types of monitors were independently used to mutually examine the error included in the measured value.

## INTRODUCTION

The photon beam stability is an important demand for synchrotron radiation experiments. The photon beam position monitoring is made in many synchrotron radiation facilities[1-3]. In the HiSOR ring the beam diagnostic beamline (BL8) has been constructed and a preliminary studies for the photon beam stability were made by the conventional two-wire monitor [4,5]. In addition, an alternative method has been developed by our group and used independently for ..

The compact electron storage ring HiSOR, manufactured by Sumitomo heavy industries [6], was installed at Hiroshima University in 1997 and it has been operated successfully as a synchrotron radiation source for the research and the education since then [7-10]. It is of a racetrack type with one rf accelerating cavity system ($f_{rf}$ = 190.244 MHz) and two undulators at straight section. The normal operating ring energy is 0.7GeV and the initial stored beam current is 200 mA in the orbit of 0.8 m in the radius. The other basic machine parameters are described in ref. 8.

The rf cavity of the HiSOR is known to have the higher order mode (HOM) which induces a longitudinal coupled bunch instability (LCBI) [11]. When the quadrupole bunch oscillation have appeared over several hours in an operation, the beam life time has founded to be appreciable increased. However, photon beam flux fluctuation has been observed at almost all the beamlines. There are possibility that the electron beam instability due to the excitation of the longitudinal HOM has an influence of the photon beam stability. The photon beam position and flux measurements were made to see how it depends on the electron beam instability.

## EXPERIMENTAL PROCEDURES

### *Photon beam stability measurements*

Two kind of monitor can be used independently in the BL8. The first is the conventional two-wire monitor [4]. It was placed at the position of 6300 mm from the source point. In the analysis, the photon beam position measured P can be expressed in a simple form

$$P = C\eta = C\frac{(I_u - I_d)}{(I_u + I_d)} \qquad (1),$$

where C is the coefficient to be calibrated, $\eta$ is the response of the monitor, $I_u$ and $I_d$ are the currents generated from upper and lower wire, respectively. The second is the two beam type monitor using vertical polarized quasi-monochromatic beams. Figure 1 shows schematically the structure of this monitor.

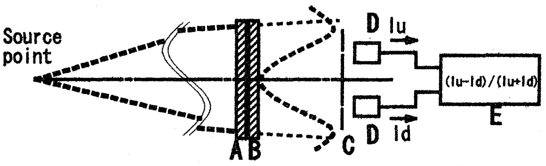


Figure 1: Schematic structure of the polarized two-beam monitor
A) Cylindrical lens; B) Band-pass filter; C) Slit; D) Photodiode.

The cylindrical lens is used to focus the photon beam in the horizontal direction. The band-pass filter cantered at 650 nm ($\lambda$=10 nm) is inserted in the beam path and polarization filter is used to exclude the vertically polarized component of the photon beam. The slit aperture is rectangular with 1 mm (vertical) × 1.8 mm (horizontal). The photodiode (IRD UVG-20BNC) is put at the position 8515 mm from the source point. The currents from the photodiodes are measured by electrometer (ADVANTEST R8240). The photon beam position in the vertical direction can be calculated from the data referring to the eq. (1). The response $\eta$ calculated against the beam displacement is shown in Fig. 2. It shows a linear relation within ±1mm.

On the other hand, the flux fluctuation of the incident beam was recorded in the VUV Beamline 9 (BL9). The flux monitoring device has been put on the focusing mirror, the photoemission current generated can be measured in unit of volts.

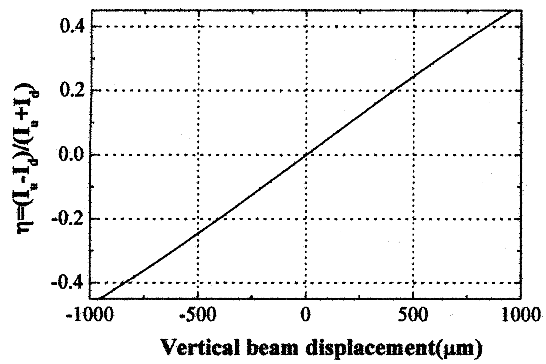


Figure 2: Calculated response η against the beam displacement.

## *Observation of the electron beam instability*

In order to see the influence of the excitation of the HOM on the electron beam, the longitudinal and transverse beam profile measurements were made by using the streak camera (Hamamatsu C1587) and the standard profile monitor using a focusing lens, respectively. By observing the beam signal from the RF cavity pick-up using a spectrum analyzer (HEWLETT PACKARD 8561E), the magnitude and the frequency of the excited bunch oscillation mode were measured. In addition, the rf cavity pick-up voltage and the temperature of the rf cavity wall were recorded because these quantities have a close relation to the thermal deformation of the rf cavity. All of them were measured as a function of time.

## RESULTS

An experiment was carried out in the usual operation of the ring. Figure 3 shows the example of the results of observation. At the top in Fig. 3 shows the measured photon beam position $P_{ver}$ and the flux $V_{flux}$, in which the compensation has been made for the reduction of the $V_{flux}$ depending on the stored beam current. They represented that the drastic changes of beam position give the flux reduction and fluctuation. The middle in Fig.3 shows the change in the magnitude $P_{HOM}$ and frequency $F_{HOM}$ of the observed bunch bunch oscillation mode due to the LCBI. We see the mode changes between dipole ($f_{HOM,d} = 6f_{rf} + 13f_{rev} + f_s = 1.325163$ GHz) and quadrupole oscillation ($f_{HOM,q} = 6f_{rf} + 13f_{rev} + 2f_s = 1.325278$ GHz) arising from a frequency shift of the longitudinal HOM. The bottom in Fig. 3 shows the rf cavity pick-up voltage $V_{cav}$ and the gradient of the increase in the temperature of the rf cavity wall dT/dt. It is seen that the change in $V_{cav}$ depends on the dT/dt, suggesting that thermal load of the cavity wall induces the deformation of its shape. Since the considerable changes in all measured quantities have been occurred at the almost equal time, these measured quantities are strongly related to each other. When no bunch oscillation mode appears, the photon beam position was somewhat disturbed, showing the other possible sources of instability are dominant.

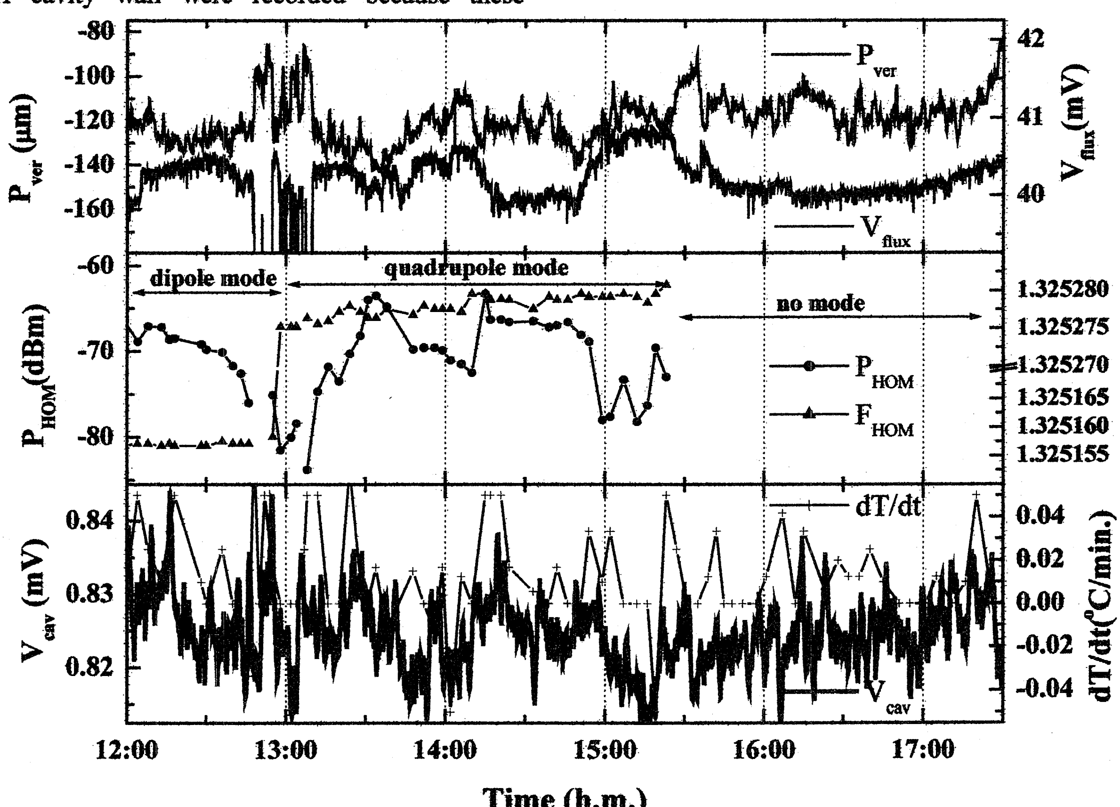


Figure3: Example of the observation of the photon beam stability.

In the streak camera measurements, the quadrupole bunch oscillation was observed as shown in Fig. 4. It acts to increase the effective bunch length resulting in an increase in the beam life time and the result is shown in Fig. 5.

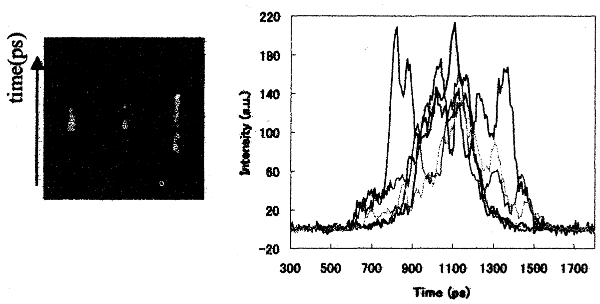


Figure 4: Streak camera image (left side) and profile (right side).

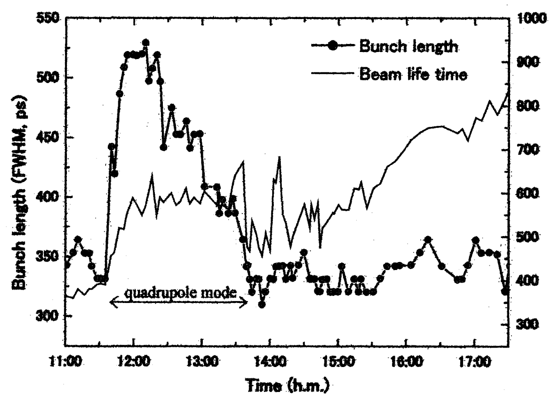


Figure 5: Average bunch length and beam life time.

In the vertical direction, we observed the beam profile change at different bunch oscillation mode as seen in Fig. 6.

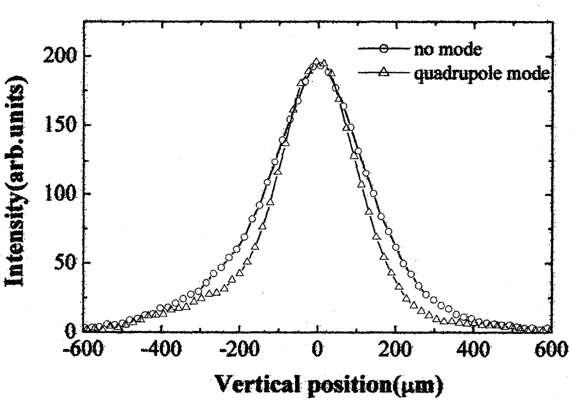


Figure 6: Vertical beam profile when quadrupole mode and (Δ) no mode was observed.

## DISCUSSION

Our results show that the stability of the photon beam is considerably disturbed by the excitation of the longitudinal bunch oscillation due to the LCBI. In the observation of the LCBI, it seems that the frequency of the longitudinal HOM shifts with a thermal deformation of the rf cavity and the LCBI is excited. New rf cavity are now being installed to overcome the thermal load of it and reduce the effect of higher order modes.

For the change in the vertical beam profile measured, it is necessary to take into account the effect of the ion trapping or the ring vacuum, resulting in a more reduction of the photon beam quality. Simple analysis showed that the error arising from the beam profile change is included in the measured beam displacement and it is roughly estimated to be over 30%.

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