

# THE VIBRATION MEASUREMENTS AT THE PHOTON FACTORY STORAGE RING BUILDING

K.Haga, Photon Factory, High Energy Accelerator Research Organization (KEK), Tsukuba, Japan  
M.Nakayama, K.Masuda, H.Ishizaki, M.Kura and L.Meng, Fujita Corporation, Japan  
Y.Oku, Kawasaki Heavy Industries, Ltd., Japan

## 1 INTRODUCTION

The synchrotron light sources, especially newly constructed low-emittance third-generation light sources, have to be operated in good stability in order to give full scope to their ability. Movements of the synchrotron radiation (SR) axis will reduce the effective brilliance of the SR from the design value.

The Photon Factory is a 2.5 GeV electron storage ring and has been operating since 1982 as a dedicated SR source. The PF ring was upgraded to reduce its emittance from 130 nm-rad to 36 nm-rad in order to be equal to the third-generation light sources [1]. From October 1997, the PF ring has been operating in the new low-emittance optics and the necessity for the beam stability in usual operation has been required.

At the Photon Factory, we have been pursuing the various sources of the beam instabilities which deteriorated the SR beam quality in the wide frequency range. Some of the sources were the vibrations of magnets and floor of the ring tunnel, temperature change of the cooling water and the elongation of the storage ring building roof due to sunshine that induced the diurnal motion of the SR beam axis [2].

It was suggested from the data regarding the SR axis vibration that the magnets of the storage ring vibrate together with the light source building. In 1986, the vibration of the ring tunnel floor was measured and the vibration sources were identified [3]. The main causes of the ring tunnel floor vibration were the air-conditioners installed in the light source building as well as the refrigerator used for the superconducting wiggler.

In order to reconfirm the vibration sources and to know the mechanical vibration of the storage ring magnets and the experimental hall, we have planned the detailed measurements of the vibrational states of the storage ring building. The effect of the mechanical vibration on the electron beam motion are also measured.

## 2 VIBRATION MEASUREMENTS

The vibration measurements were performed for three days. On the first and second days PF ring was stopped, and on the third day PF ring was operated as usual in the users time and stored 400 mA electron beam. Measured data of each day are compared in order to know the effects of the storage ring operation. Cooling water of the magnets and the vacuum chambers are flown same in three days.

### 2.1 Vibration measurement system

The measurement system consists of the vibrational gauges, amplifiers and the digital data recorder. Small vibration was detected by twelve sets of seismometers by Shindou Giken Co. Ltd. and six piezoelectric accelerometers by PCB Co. Ltd. Each signal generated in gauges was amplified and sent to the digital data recorder that performs analog-to-digital transformation and data storage. Data sampling rate was 500 Hz. Measured acceleration data are analysed in FFT and represented as frequency spectrum.

We represent the magnitude of the vibration using the root mean square (RMS) displacements converted from the measured acceleration in the frequency range of 1-100 Hz.

### 2.2 Vibration of the air-conditioner

The vibrations of the ground and of the air-conditioner have been recognized as the two main sources of the beam motion. In the light source building, there were eight air-conditioners above the storage ring tunnel and around the experimental hall that surrounds the storage ring tunnel. Before measuring the vibrations of various parts of the light source building, the vibration of eight air-conditioners itself were measured, in order to identify the frequency components of the measured data. Figure 1 shows the vibrational output power of the air-conditioner No.2 (AC2). The rotational frequency of the fan in the AC2 was 890 rpm and the fundamental mode of vibration was 14.8 Hz. The several frequency peaks originated from this fundamental mode were seen in figure 1.

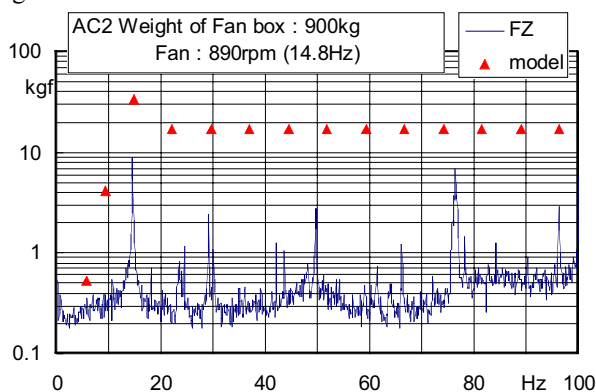


Figure 1: The output power spectrum of the air-conditioner No.2(AC2)

Each air-conditioner has its fundamental mode of vibration in the frequency range from 14.8 to 22.5 Hz. Because there are only thin viscoelastic damping pads under these air-conditioners, these vibrations propagated around the light source building.

### 2.3 Vibration of the storage ring tunnel floor

The vibration of the storage ring tunnel floor was measured at twelve points using the twelve sets of probes situated along the storage ring. We measured the three components of the vibration with one set of the probes. Displacement of the vertical direction is larger than the displacement of other two direction, but the magnitude of its displacement is only about  $0.04 \mu\text{m}$  on the average. At measuring point No.9, vertical displacement measured with all air-conditioners working is about five times larger than the displacement measured with all air-conditioners being stopped.

Effects of the air-conditioners are evident from the Fourier spectrum of this data. Figure 2 presents the Fourier spectrum of the vertical ring tunnel floor displacement at the measuring point No.9. One peak at 14.65 Hz corresponds to the fundamental vibration frequency of the AC2, and another peak at 20.26 Hz also arises from the fundamental vibration frequency of the AC4 (20.3 Hz). The magnitude of the 20.26 Hz peak amounts to  $0.1 \mu\text{m}$ . This displacement is equivalent to  $0.07 \mu\text{m}$  RMS displacement. So the vibration arising from the air-conditioners exhaust almost all of the RMS displacement measured at point No.9.

### 2.4 Vibration of the quadrupole magnets

The vibration of the quadrupole magnet (Q-magnet) of the storage ring affects mostly the behavior of the stored electron beam motion. Then, the vibration of the twelve Q-magnets selected equally from all storage ring Q-magnets were measured. Twelve sets of the probes were situated on top of the Q-magnets. After the lattice change of the PF ring for reducing the beam emittance,

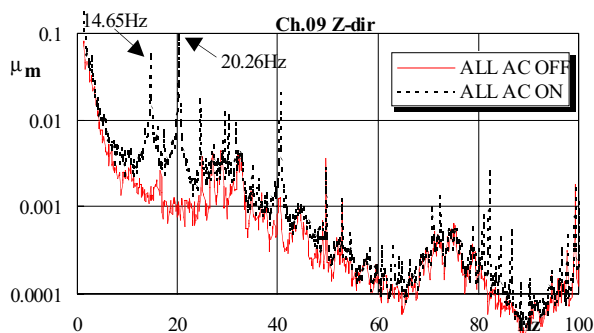


Figure 2: Fourier spectrum of the vertical displacement of the ring tunnel floor at the measuring point No.9. Solid line shows the vibration with all AC are stopped, and dotted line shows the one with all AC are working.

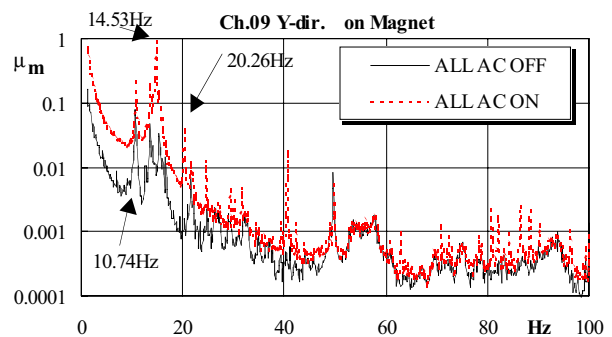


Figure 3: Fourier spectrum of the Q-magnet vibration

two quadrupole magnets and two sextupole magnets in a normal cell have been settled on a common girder.

The magnitude of RMS displacement of the Q-magnet vibration in lateral (y) direction exceeds those in other two directions. In case of ring floor vibration, we showed previously that the displacement in the vertical (z) direction was prominent. On the contrary, the vibration of the Q-magnet in the lateral (y) direction was ten times as large as the lateral (y-directional) vibration of the floor. The displacement at the measuring point No.9, especially in y-direction, was affected mostly from the nearby air-conditioners.

The Fourier spectrum of the Q-magnet displacement at the point No.9 is shown in the figure3. Two major peaks at 14.53 and 20.26 Hz already seen in the spectrum of the floor vibration are also seen in this spectrum. Adding to these two peaks arising from the vibration of the air-conditioners, a new peak at 10.74 Hz appears. Because this peak can be seen when all air-conditioners have stopped, it can be estimated that this peak arises from the fundamental resonant vibration of the girder and the Q-magnet.

### 2.5 Vibration of the girder and the Q-magnets

To investigate the vibrational properties of the girder and the quadrupole magnet, we have performed the hammering test and measured the fundamental resonant frequencies. In figure 4, the Fourier spectrum of the Q-magnet vibration is presented with the spectrum of the floor for comparison. The vibration of the Q-magnet was

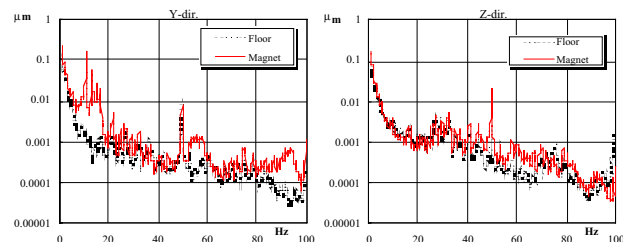


Figure 4: Fourier spectrum of the Q-magnet vibration in the lateral (y-) direction and the vertical direction

amplified at frequencies between 10 and 20 Hz. There were many peaks in this frequency range. The peak at 10.38 Hz, already seen in figure 3, arises when the Q-magnet swayed on the girder in the lateral direction. Another remarkable peak at 13.18 Hz arises from twisting the girder's leg. The picture of the vibrational state of the Q-magnet and the girder is presented in the figure 5. This picture shows that the top of the Q-magnet vibrates heavily comparing to other part of the magnet and girder.

## 2.6 Vibration of the stored electron beam orbit

The sixty-three beam position monitors (BPMs) are installed in the PF storage ring in order to measure the electron beam orbit. But if the detection units of the BPMs themselves vibrate or displace, the resolution of the beam position measurement gets worse and incorrect beam position data are detected. The vibration of the detection unit of the BPM was measured and the vibration of the position of the stored electron beam was also measured.

The piezoelectric accelerometer was settled on a vacuum tube of the detection unit of the BPM, and beam position data was collected using the data taking system of the BPM. Sampling rate of the BPM data was restricted within 83 Hz and maximum number of the beam position data was 101, owing to the program of data taking system.

The vibration of the BPM detection unit was thought to be same as the Q-magnet vibration, because the BPM detection unit was fixed directly to the end of the Q-magnet yoke. But we found that the Fourier spectrum of

the BPM detection unit was amplified in the frequency range below 3 Hz. It was supposed that the vibration due to the cooling water flow was added to the vibration coming from the air-conditioners.

In the Fourier spectrum of the vertical beam position vibration at the BPM No.52, the effects of the air-conditioners appear as the broad peak around 15 Hz, and its magnitude is about 3  $\mu\text{m}$ . It is necessary to measure the electron beam motion with finer sampling to resolve the each contribution of vibration sources.

## 3 SUMMARY

We summarize the results of the vibration measurements at the Photon Factory below.

- (1) The vibrations of the ring tunnel floor and the experimental hall floor, comparing with the vibration of the ground surrounding the storage ring building, are same order in the 1 ~ 5 Hz range, and 1/3 ~ 1/5 in the 5 ~ 100 Hz range, in the vertical and the horizontal direction.
- (2) The effects of the vibration arising from the operating eight air-conditioners can be seen in the Fourier spectrum of the vibration of the ring tunnel floor, experimental floor, Q-magnets and BPM vacuum duct.
- (3) The vibrations of the Q-magnet and girder at frequencies near their fundamental resonant frequencies have been amplified 100 times in the lateral direction comparing to the floor vibration.

The obvious cure for the propagation of the air-conditioner vibration is the installation of the thick viscoelastic damping pad beneath the air-conditioner. From the simulation of this damping pad, the reduction of the propagated vibration amounts to -20 dB.

We will plan to measure the vibration of the stored electron beam and the synchrotron radiation beam more accurately, together with the vibration of the Q-magnets, in order to know the correlation between these vibrations.

## REFERENCES

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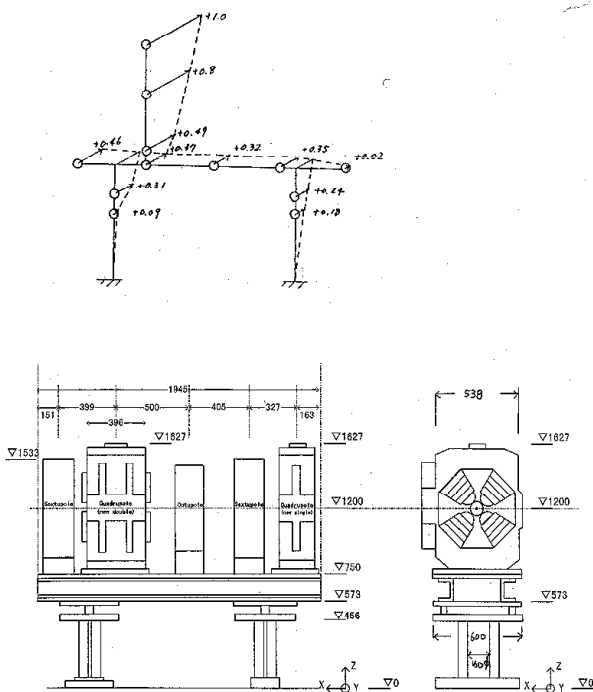


Figure 5: Vibrational state of the Q-magnet and girder