PULSE OCTUPOLE MAGNET SYSTEM AT THE PHOTON FACTORY STORAGE RING

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Abstract

In order to study a dynamical property of a vertical instability, we have developed a pulse octupole magnet system. The magnet can be operated with magnetic field rise and fall time of around 1.2msec, respectively. The maximum integrated field strength reach up to 2600T/m^2. We measured the dynamical behavior of the vertical instability using the pulse octupole magnet for a multi-bunch beam of 400mA. We found that the growth time of the instability was longer than the suppression time.

INTRODUCTION

In the Photon Factory Storage Ring, a vertical instability is observed in a multi-bunch operation mode. The instability can be suppressed by DC octupole magnetic field in routine operation. It seems that the instability is caused by ion trapping effect, the operating parameters in routine operation are near the threshold of it, and Landau damping caused by octupole filed is suppressed the instability [1].

In order to study the dynamical behavior of the instability, we developed a pulse octupole magnet system which can produce the octupole field with rise and fall time of around 1.2msec. We installed the magnet system in the PF-ring, and have made a detailed study. In this paper, we describe the design performance, the results of magnetic filed measurement and preliminary results of a measurement for the behavior of the instability.

PULSE OCTUPOLE MAGNET SYSTEM

The pulse octupole magnet system can provide a octupole magnetic field with rise and fall time of around 1.2msec, respectively. The principal parameters are given in Table 1. It consists of a magnet, a ceramic duct and a power supply.

Table 1: Principal parameters of the pulse octupole magnet system.

Parameter	Value
Maximum field gradient (peak)	11700 T/m^3
Maximum peak current	±100A
Maximum peak voltage	±285V
Bore diameter	80 mm
Core length	0.20 m
Effective length	0.22 m
Self inductance	3.34 mH

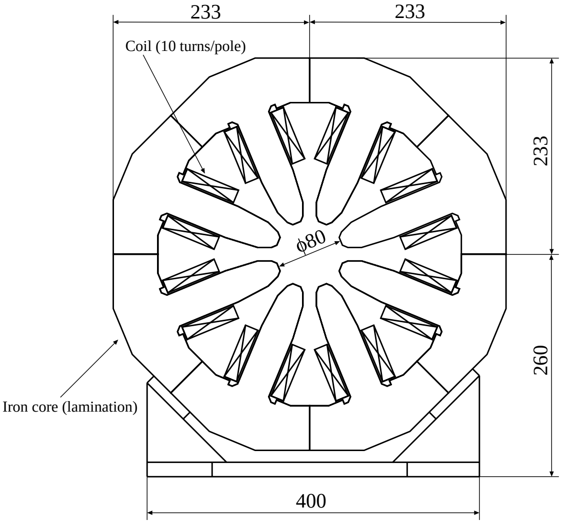

Figure 1: Cross sectional view of the pulse octupole magnet.

Pulse Octupole Magnet

The pulse octupole magnet was designed by the use of a computer code POISSON to realize the maximum field gradient of 11700 T/m^3 at the excitation current of 1000A·turns and the self inductance of about 3mH. In order to realize the high field gradient, the bore diameter of the magnet was designed to be 80mm. To reduce the in-

Figure 2: Photograph of the pulse octupole magnet installed in the PF ring.

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ductance, it was determined that the turn number of the coil was 10 turns/poles, then the calculated inductance was 3.24mH, and the measured inductance was 3.34mH.

Cross sectional view and photographs of the pulse octupole magnet are shown in Fig. 1 and 2. The iron core is made of the 0.5mm thick silicon steel lamination and the length of the iron core is 0.2m.

Ceramic Duct

A ceramic duct, as shown in Fig. 3, was adopted to avoid problems of the eddy currents. In order to reduce a beam coupling impedance, inner-side of the duct was coated with Ti of 5μm thick. The coating was connected with the both ends of Fe-Ni-Co flange(see Fig. 3). The duct caused no problems in both single and multi bunch operation. The temperature of the duct was not raised practically, when a single bunch beam of 70mA was stored.

An absorber was placed at upper side of the pulse octupole magnet in order to prevent the synchrotron radiation from impinging on the duct.

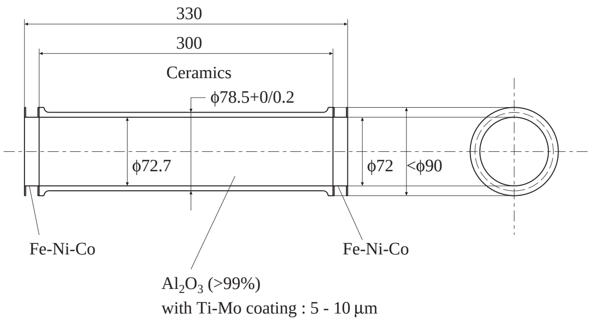

Figure 3: Ceramic duct coated Ti-Mo.

Power Supply

Since the inductance of the magnet is about 3mH, to excite the magnet with 1.2msec to maximum current of 100A, the power supply must output maximum voltage of about 280V. In order to realize the magnetic field rise and fall time of around 1.2msec, the power supply was designed to be maximum current of 100A and maximum voltage of 285V.

FIELD MEASUREMENT

The field measurement of the pulse octupole magnet was performed using two method: a harmonic coil method for static magnetic field and hall sensor for pulse magnetic field.

DC Octupole Field

The static field measurement of the pulse octupole magnet was performed using DC power supply and a harmonic coil that consisted of the long coil to measure integrated field and the short coil to measure center field. Fig. 4 shows the excitation curves of the integrated octupole field. The maximum integrated field was 2623T/m^2 and the maximum field gradient of the magnet center was 11695T/m^3 at the excitation current of 100A. The effective magnetic length, which was calculated from the measured value of the center and the integrated field, was 0.22m.

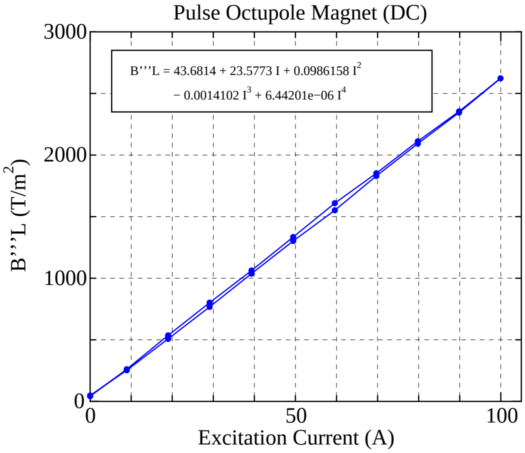

Figure 4: Excitation curve of pulse octupole magnet.

Pulse Octupole Field

The response of the pulse magnetic field was measured using a hall sensor. The sensor was set at $x = -30$mm(horizontal plane) and $y = 0$mm(vertical plane) inside the magnet. The pulse signal of set current consists of the magnetic field rise up time of 1.2msec, flat top time of 2.4msec and fall down time of 1.2msec. In order to investigate the effect of eddy current, the field measurement was performed under two conditions: with a test aluminum duct of 15μm thick inside the magnet and with out the duct. The response of the magnetic field at the excitation current

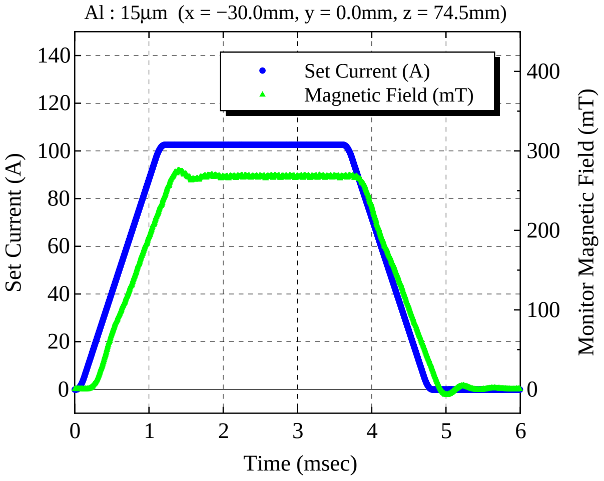

Figure 5: The response of the pulse octupole magnet.

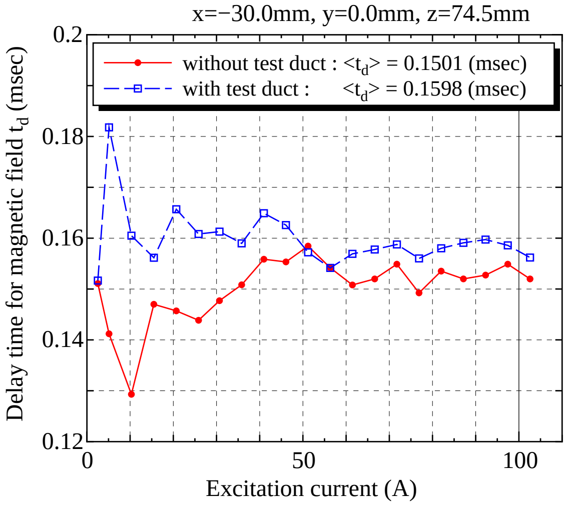

Figure 6: Measured delay time of the pulse octupole filed from the set current signal with and without the test aluminum duct of 15μm thick. The set current signal is shown in Fig. 5.

of 100A with the test aluminum duct is shown in Fig. 5. The measured magnetic field was delayed about 0.16μsec form the set signal. The delay time with and without the test aluminum duct is shown in Fig. 6.

MEASUREMENT OF BEAM INSTABILITY

In order to measure the behavior of the beam instability when the pulse octupole field is excited, we measured the beam spectrum from a button-type electrode using realtime spectrum analyzer. We set the ring parameter in the vicinity of the threshold of the instability suppression. Under this condition, the instability was suppressed when only the pulse octupole magnet was excited.

Fig. 7 shows the beam spectrum in the vicinity of the second harmonic of the rf frequency $f_{\rm rf}$ when we excited the pulse octupole magnet at 100A. The beam current was 400mA with 280 bunches. Fig. 8 shows power of the vertical instability at $2f_{\rm rf} - f_{\rm rev} + f_{\beta y}$, where $f_{\rm rev}$ and $f_{\beta y}$ are the revolution and the vertical betatron frequency, respectively. After excitation of the magnet, the power spectra of the instability decreased, namely, the instability was suppressed. After 50msec, the instability was grown slowly compared with to suppress it.

SUMMARY

We developed the pulse octupole magnet system at the Photon Factory storage ring. The magnet system satisfied design performance: the rise and fall time of the magnetic field was 1.2msec and the maximum integrated octupole field strength reached 2600T/m^2. We obtained preliminary results of a measurement for the dynamical behavior of the instability. We will study the dependence of the instability on beam current and fill pattern of the bunch train.

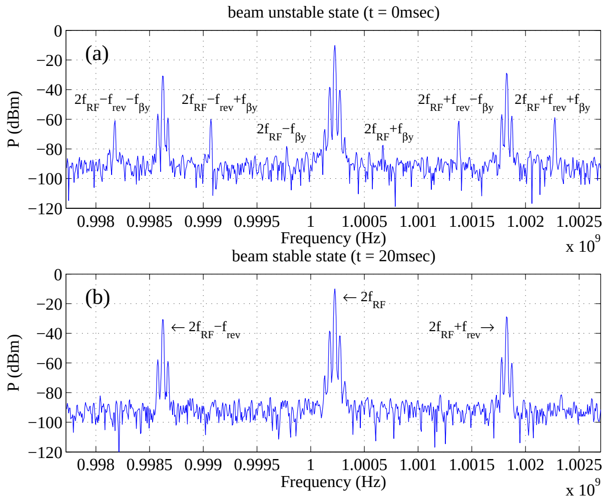

Figure 7: Beam spectrum from a button-type electrode when the pulse octupole magnet was excited at 100A. The beam current was 400mA with 280 bunches. (a) The spectrum when the vertical instability was excited at t = 0msec in Fig. 8. (b) The spectrum when the instability was suppressed at t = 20msec.

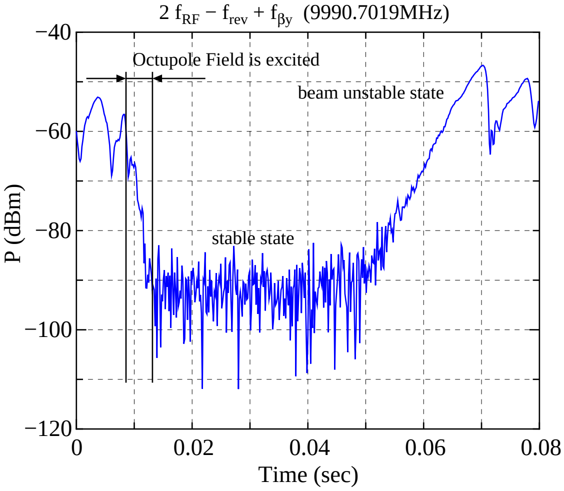

Figure 8: Power of the vertical instability at $2f_{\rm rev} - f_{\rm rf} + f_{\beta y}$. The pulse octupole magnet was excited at 100A from t = 8msec to 12.8msec.

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