MAGNETIC FIELD MEASUREMENT REQUIRED FOR HIGH LUMINOSITY ACCELERATOR

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Abstract

The KEKB is a high luminosity accelerator, which has achieved the highest luminosity record of $2.1\times10^{34}cm^{-2}s^{-1}$. It requires the precise and stable beam control to keep its high luminosity continuously. Slight change of the magnetic field may easily deteriorate the performance of the collisions of the very small and thin beams. The field measurement accuracy better than 10^{-4} has been already achieved. The resolution of the measurement has reached to a few$\times10^{-5}$. But it is known by the beam studies that the field change less than 10^{-4} may cause deterioration of the luminosity. The requirement on the stability of magnetic field will be stricter for future nano-beam colliders. We have studied the effects of the following conditions on the magnetic field by using some KEKB magnets: changes of the magnetic field due to air or cooling water temperature, changes due to initialization conditions, effect of excitation of the adjacent magnet and behaviour of the magnetic field under polarity change have been measured. These studies are not only useful for the existing KEKB but also important for future nano-beam accelerators.

INTRODUCTION

In KEKB the luminosity deterioration sometimes occurred after beam aborts even if the machine parameters were restored as same as before. The initialization of the magnet system could recover the luminosity in some cases. So slight changes of the magnetic fields were thought to cause some of these luminosity deteriorations. Hence we studied magnetic field changes caused by some possible sources using the KEKB magnets.

MEASUREMENTS

The measurement systems and the mass measurements of the KEKB magnets were described in the contributions [1], [2], [3]. After the mass measurement we investigated magnetic field changes caused by some sources: air and/or cooling water temperature, variation with time, adjacent magnet effects and polarity change. Some of them are presented in this paper.

Resolution of the measurement system

A histogram of normalized integrated field of a LER dipole magnet, which had been used as a standard during the mass measurement, is shown in figure 1. The measurement was continued over 15 hours. The good resolution better than a few$\times10^{-5}$ was achieved. This resolution is good enough to discuss magnetic field changes discussed in this paper.

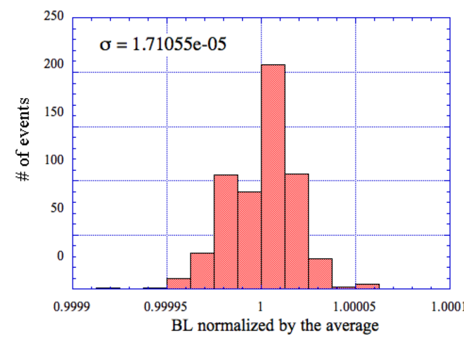

Figure 1: Normalized integrated field of the LER dipole magnet used as a standard.

Magnetic field variation due to air and cooling water temperature

Magnetic field is affected by air and/or cooling water temperature. It depends on thermal design of each magnet in general. The variations of normalized field strength of the LER dipole magnet caused by air and cooling water temperature change are shown in figure 2 and figure 3, respectively. Those for other magnets are summarised in Table 1.

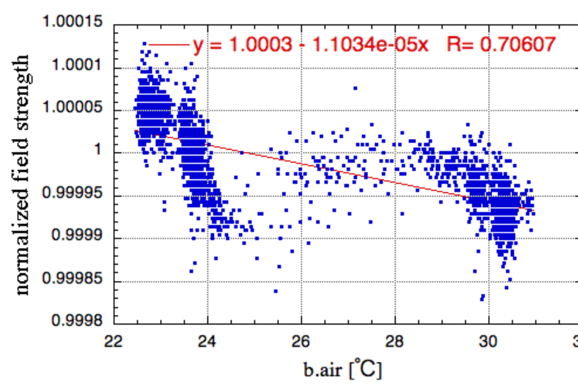

Figure 2: Change of the normalized field strength of the LER dipole with respect to air temperature.

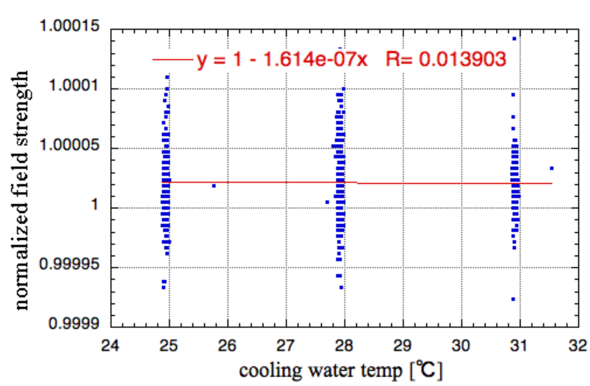

Figure 3: Change of the normalized field strength of the LER dipole with cooling water temperature.

Table 1: Change of the normalized integrated field due to air or cooling water temperature.

Magnet	Air temp.	Cooling water temp.
LER dipole	-1.1×10^{-5} /deg.	-1.6×10^{-7} /deg.
HER dipole		1.8×10^{-6} /deg.
LER Q	-2×10^{-5} /deg.	

Variation after excitation

Variation of the normalized integrated field of the LER dipole is shown in figure 4 for 50 hours after excitation. The temperature of the pole surface and the yoke near the coil raised about 2.5 and 3.5 degree for the first 20 hours, respectively. The central field decreased with time according to the expanding of the magnet core due to the temperature rise. On the other hand, the integrated field BL stayed almost same. It seems that the increase of the effective length due to the temperature rise traded off the decrease of the central field.

The long-term variation is shown in figure 5. The measurement was continued for nearly 100 days. The normalized dipole field increased gradually with time up to 4×10^{-4}.

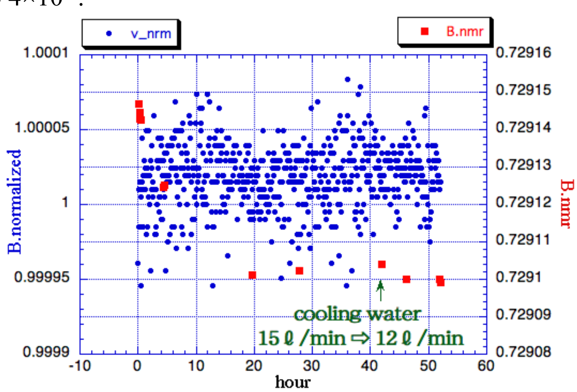

Figure 4: Variation with time after excitation. The blue circles show the normalized integrated field of the LER dipole and the red squares show the central dipole field measured by NMR.

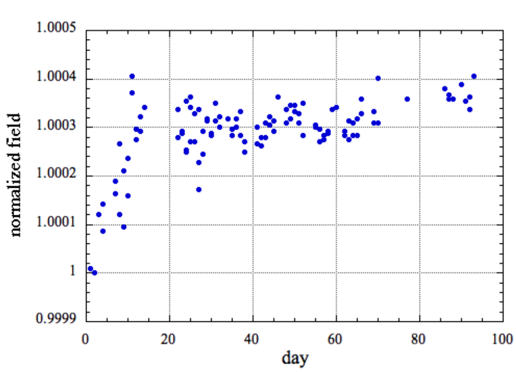

Figure 5: Long-term variation

Initialization condition

The fields of the LER dipole magnet were measured on the different initialization conditions. The initialize process was five cycles of current ramp up and down with fixed ramp speed, I_{max} and duration of the flat top as parameters. The usual I_{max} was 1250A and the dipole field at 1050A (usual operating point) was measured on the different initialization parameter. Figure 6 shows the magnetic field measured by NMR for different I_{max}. The difference depending on the current ramp speed is shown in figure 7. The difference due to the flat top duration was less than 2×10^{-6} T.

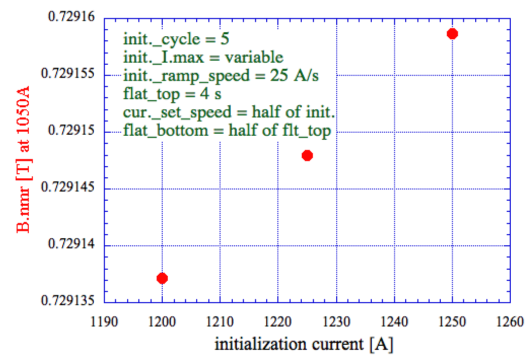

Figure 6: Magnetic field of the LER dipole measured by NMR for difference I_{max}.

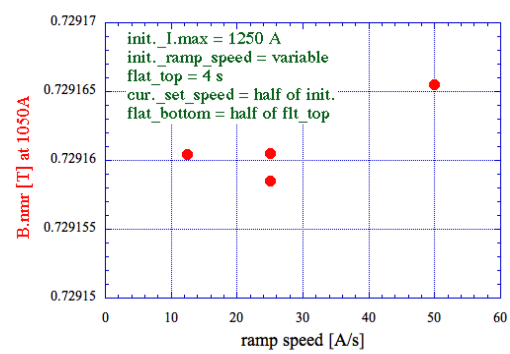

Figure 7: Magnetic field of the LER dipole measured by NMR for difference current ramp speed.

Effects of adjacent magnet excitation

Both horizontal and vertical dipole correctors are located adjacent to a quadrupole magnet in KEKB lattice. The integral of each magnet field is reduced due to the iron yoke of the other magnet. These effects were measured and reported [3]. Furthermore the central magnetic field of the corrector could be changed due to excitation of the adjacent quadrupole magnet. The measurements were done at some currents for +/- polarity of the corrector, while the quadrupole polarity was fixed. The variations of the magnetic fields of the corrector at 0A and 4A are shown in figure 8 and figure 9, respectively.

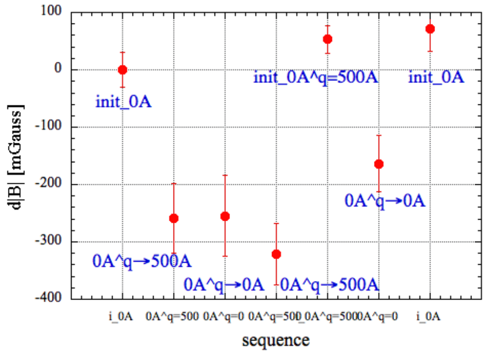

Figure 8: Variation of the corrector field caused by adjacent magnet excitation. A term 'init_0A' means to set the corrector current 0A after an initialization cycle, five times ramp up to 4.2A and down. '0A^q→500' means to excite the adjacent quadrupole up to 500A keeping the corrector current 0A. 'init_0A^q=500' means to initialize and set the corrector 0A keeping the quadrupole current 500A.

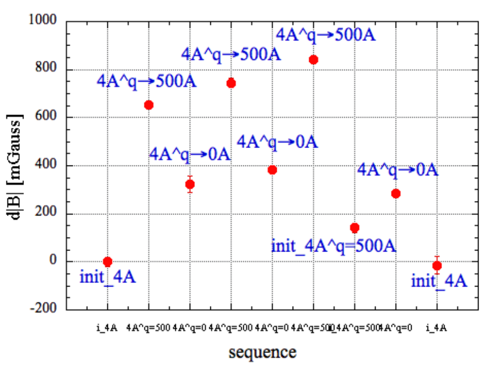

Figure 9: Variation when the corrector current is 4A.

Polarity change (effects of external fields)

Polarity switching of the LER was once considered to cure photoelectron problem. Hence the magnitude of the LER dipole field was measured in both polarities. The differences of integrated dipole field Δ|BL| between the original and reversed polarity are shown in figure 10. The polarity was switched at the magnet electrodes or at the current leads of the power supply. The LER nominal energy 3.5GeV corresponds to 1058.6A, where Δ|BL| due to polarity change is about 2 gauss·m. At lower currents, Δ|BL| remains 1 gauss·m, which means that the terrestrial magnetism over the used long flip coil is about 0.5 gauss·m. At higher currents, the Δ|BL| becomes larger due to saturation of the iron core.

The polarity switching also makes the difference of the central dipole field shown in Figure 11. At lower currents, as the iron core is not saturated, the external magnetic field (terrestrial magnetism) passes through the return yoke. Hence no difference is observed. On the other hand at higher currents, as the iron core is saturated, some of the external field passes through the air gap of the magnet. At 1058.6A, the difference Δ|B| is about 1 gauss. This difference is well reproduced by Poisson calculation.

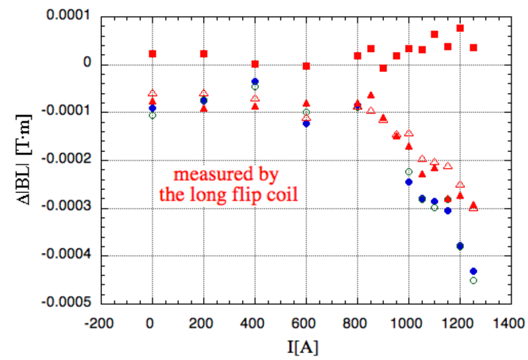

Figure 10: Δ|BL| caused by polarity change. The blue and green circles show the Δ|BL| when polarity was reversed at the magnet electrodes. The red thick and open triangles show the Δ|BL| when polarity was reversed at the current leads of the power supply. The red squares show the Δ|BL| when polarity was restored.

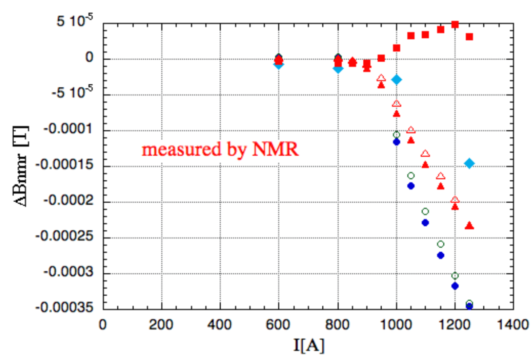

Figure 11: Δ|B| caused by polarity change. The marks are as same as Figure 10. The light blue lozenges show the Poisson calculation.

SUMMARY

We described some examples of possible changes or variations of magnetic fields. At 10^{-4} level, magnetic fields could easily vary due to environmental conditions or adjacent magnet effects. The changes caused by polarity switching, power cables and external fields including terrestrial magnetism are not negligible. As well as precise mass measurement, these careful measurements are necessary for future nano-beam accelerator.

REFERENCES

[1] K. Egawa and M. Masuzawa, "Field measurements of the KEK B factory dipole and wiggler magnets", PAC 99, New York, 1999, THP165, p. 3357 (1999).

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