A PROPOSED FAST LUMINOSITY FEEDBACK FOR THE SUPER-B ACCELERATOR*

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Abstract

We present a possible design for a fast luminosity feedback for the SuperB Interaction Point (IP). The design is an extension of the fast luminosity feedback installed on the PEP-II accelerator. During the last two runs of PEP-II and BaBar (2007-2008), we had an improved luminosity feedback system that was able to maintain peak luminosity with faster correction speed than the previous system. The new system utilized fast dither coils on the High-Energy Beam (HEB) to independently dither the x position, the y position and the y angle at the IP, at roughly 100 Hz. The luminosity signal was then read out with three independent lock-in amplifiers. An overall correction was computed based on the lock-in signal strengths and beam corrections for position in x and y and in the y angle at the IP were simultaneously applied to the HEB. With the 100 times increase in luminosity for the SuperB design, we propose using a similar fast luminosity feedback that can operate at frequencies between DC and 1 kHz, high enough to follow any beam motion from the final focusing magnets.

INTRODUCTION

The SuperB design attains ~100 times higher luminosity than PEP-II due to smaller beam sizes and a crab waist at the IP. The spot size (1σ) at the IP is expected to be about 10 μm by 0.04 μm. These small beam sizes will make the luminosity very sensitive to mechanical vibration and electrical noise. Mechanical motion is expected at low frequencies due to ground motion and to diurnal variations. Electrical noise is expected at harmonics of power line frequencies (e.g. 50, 150, 300, and 600 Hz).

Two different feedback approaches were implemented in PEP-II. The older approach drove correctors to implement a sequential dithering of x, y, and y' for the HEB at the IP. The effects of each dither excitation were detected on the luminosity signal and beam corrections were applied. This was slow (~1 Hz) due to the slow response of the correctors.

The newer "fast dither" system used dedicated air core Helmholtz coils for beam excitation and drove all three motions simultaneously, each at a slightly different frequency near 100 Hz [1,2]. Lock-in detection of the luminosity signal allowed separation of the three responses. A beam correction was applied at 1-10 Hz.

For SuperB, we have the advantage of including a fast feedback system in the original design rather than trying to retrofit one later. We propose a similar system to PEP-II, but with dithering of the Low-Energy Beam (LEB) rather than the HEB and use of a higher frequency (1-3 kHz). Simultaneous excitation with lock-in amplifiers should allow corrections to about 300 Hz. We will also investigate sequential excitation, which may allow faster corrections of the more critical y position. The best feedback approach will be dependent on the noise environment, which will not be known until the machine is commissioned, so the system must be flexible.

DITHER COILS

Coil Locations

We need to dither x, y and y'. For this, we would like to have dither coils for both the x and y planes at a location near the IP where $\sqrt{\beta}\sin\psi$ is large, and another set of coils near the IP at a location where $\sqrt{\beta}\cos\psi$ is large. We propose to place an x and a y coil as close to the IP as we can reasonably get (about 3.5 m from the IP, just outside of the detector solenoid field), and a second coil set between the final two bend magnets (B1), and preferably between the quad (QD2) and sextupole (SDM2) which are between these two bend magnets (see Fig. 1).

Dither Amplitudes

Under normal operation, the dither amplitude should be large enough to be detectable but small enough to have minimal impact on the luminosity. A luminosity modulation of about 1% worked well for PEP-II; this requires shifting the beam by about 0.2 σ (see Table 1). A larger dither amplitude will be helpful during commissioning and for diagnosing problems.

Table 1: Dither coil excitations for a shift of 0.2 σ, giving a 1% luminosity reduction

Parameter	Deflection	Coil 1 Excitation	Coil 2 Excitation
X	2 μm	7 G-cm	7.4 G-cm
Y	8 nm	0.36 G-cm	-0.06 G-cm
Y'	200 μrad	-2 G-cm	-60 G-cm

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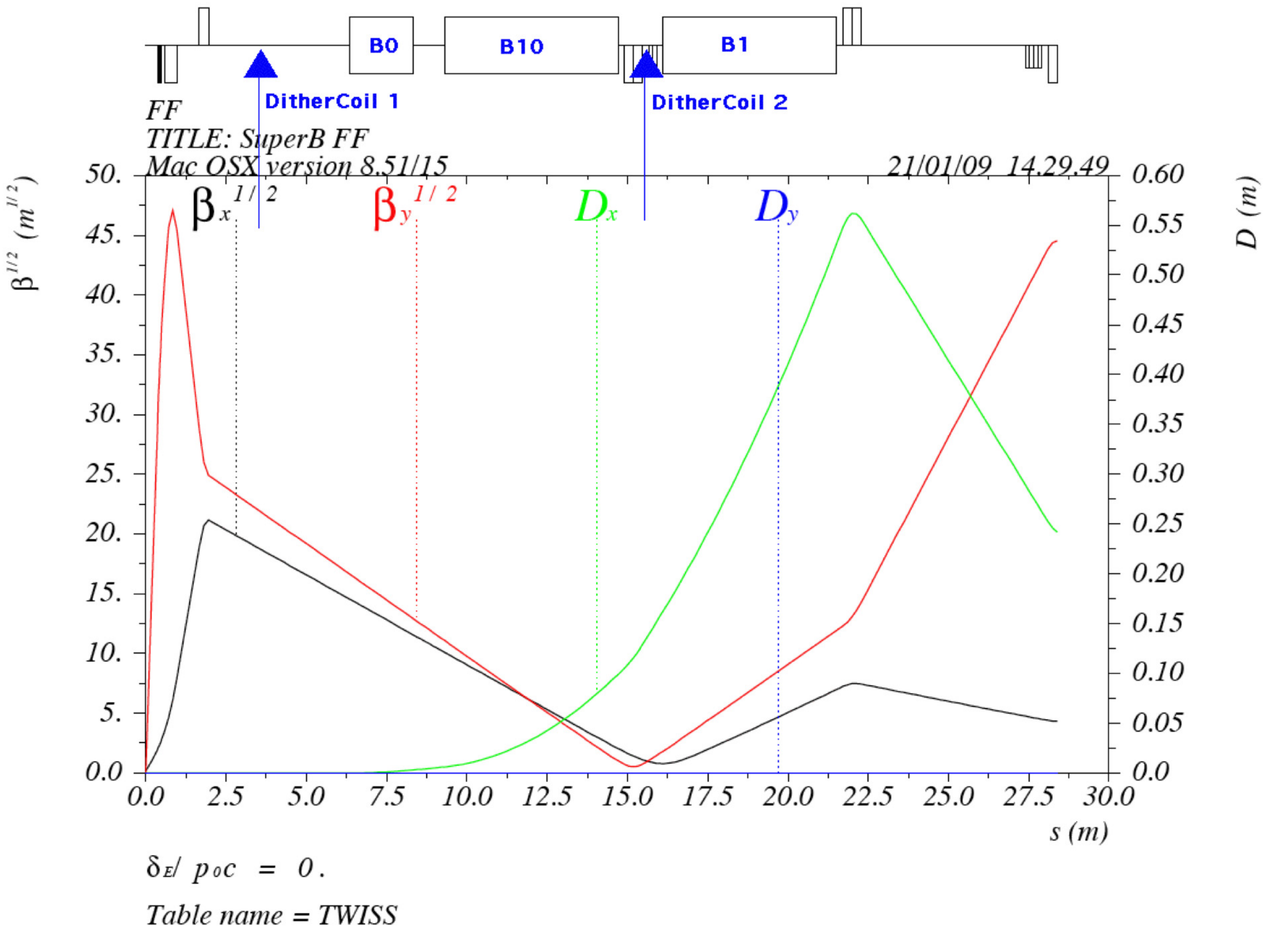

Figure 1: Dither coil locations in SuperB LEB lattice

The entries in Table 1 are somewhat idealized. Coupling will mix the excitations together to some extent. The beam y-position is extremely sensitive to the magnetic field strength at the Coil 1 location, and even more sensitive to the magnetic field strength at the end of the –I insert about 28 m from the IP. Careful shielding and attention to power supply noise will be required at these high-β locations.

Beam Pipe

The beam pipe needs to provide good conductivity for beam HOMs, but poor shielding at dither frequencies. Assuming a 6 mm bunch, the inside of the beam pipe should provide multiple skin depths at frequencies above 8 GHz. The beam pipe conductivity should be poor enough that induced eddy currents at 1-3 kHz do not induce phase shifts of more than a few degrees.

A ceramic pipe with a 1-2 μm Cu coating fits these requirements well. The skin depth of Cu is about 2 μm at 1 GHz. The phase shift induced in a 5 cm diameter, 1 μm thick Cu pipe at 3 kHz is about 0.6 degrees. The electrical resistance of this pipe is about 0.1 Ω/m, causing about 0.4 W/m power dissipation with a 2 A beam.

Coil Design

We propose curved "saddle" coils with a $\cos\theta$ current distribution and an outer ferrite cylinder to act as a shield and flux return. This design is similar to CRT deflection coils, and provides much better shielding and efficiency than the open Helmholtz coil design used in PEP-II.

Estimated coil parameters are about 1 Ω, 2 mH, and 10 cm length, with either a 9 cm ID (coil 1) or a 5 cm ID (coil 2). Coil sensitivities would be about 50 and 150 G-cm per amp for coils 1 and 2 respectively, with maximum currents of about 2 A and nominal currents (for deflections in Table 1) of less than 400 mA. Custom coil sets with these parameters can be purchased from commercial vendors for about $1200 per coil location.

SYSTEM ISSUES

Luminosity Monitor

A luminosity monitor similar to that used in PEP-II will be fine. The luminosity signal is subject to statistical noise, which depends on the luminosity. The feedback system will thus need to change its correction bandwidth as a function of luminosity; corrections at low luminosity operation will be slowed down.

Correction Scheme

The corrections will be divided between a slow and a fast component. The slow corrections (slower than about 1 Hz) will be made through normal dipole correctors. Faster corrections will be made through the dither coils, as the dipole correctors will not pass these frequencies. The coil design described above allows plenty of headroom for these corrections, especially in the y-position.

Additional Applications

These fast dither coils will have other applications in addition to fast luminosity feedback. Their high frequency capability will provide a useful diagnostic for identifying sources of electrical noise.

They can also be used to scan or raster the beam at larger amplitudes to find collisions. The coil design described above will allow rapid scanning of the collision point by about 25 μm in x and 2 μm in y in just a few milliseconds. A larger search range can be achieved by superposing a slower scan with correctors.

Design Constraints

A fast dither system as proposed here imposes some minor but important constraints on the design of the system. To allow a 10 cm coil length and a special ceramic beam pipe, about 20 cm of free space must be allowed at each coil location. This will require a slightly larger gap between the B1 bends than would otherwise have been chosen. Free space also has to be reserved as close as possible to the end of the detector solenoid, about 3.5 m from the IP.

The extreme sensitivity of the IP position (especially the y-position) to electrical noise also imposes design constraints. Electrical noise needs to be carefully considered in the specification of power supplies. The current lattice has quadrupole and sextupole lenses located –I apart in high β regions near the IP; it may be important to operate these lenses from a common main power supply so that their electrical noise is cancelled to first order.

SUMMARY

The small beam sizes at the IP of SuperB will be challenging to achieve and to hold in collisions. Based on experience at PEP-II, a fast luminosity feedback system will be essential. We have presented a design which is more than 10x faster than the system used in PEP-II. Given the small SuperB spot sizes we may need active mechanical damping of magnets in the interaction region as a supplement to the fast dither feedback. This fast dither system will also be helpful in diagnosing noise problems and in scanning beams to find collisions.

REFERENCES

[1] A.S. Fisher et al, “Commissioning the Fast Luminosity Dither for PEP-II”, Proceedings of PAC 07, Albequerque, NM, 4165-4167; SLAC-PUB-12608, July 2007.

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