COMPENSATION OF THE BEAM DYNAMICS EFFECTS CAUSED BY THE EXTRACTION LAMBERTSON SEPTUM OF THE HIGS BOOSTER*

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Abstract

As part of the High Intensity Gamma-Ray Source (HIGS) upgrade, the booster synchrotron has been built and commissioned in 2006. It ramps the electron beam between 0.24 and 1.2 GeV for top-off injection into the Duke storage ring. The booster has vertical injection/extraction which uses symmetrical schemes with a bumped orbit. The injection/extraction kickers and corresponding septum magnets are located in the opposite straight sections of the booster ring separated by about 1/4 of the vertical betatron wave. Due to the non-ideal properties of the magnetic material, the magnetic field leaks out into the stored beam chamber, which results in orbit distortion, tune and chromaticity shifts, and change of coupling. The dynamics impacts due to the leaked septum fields have been successfully compensated to achieve good injection efficiency.

Table 1: The HIGS booster parameters.

Circumference [m]	31.902
Injection energy [GeV]	0.24-0.27
Extraction energy [GeV]	0.24-1.20
RF frequency [MHz]	178.55
Harmonic number	19
Nominal operation cycle [ms]	1.4-1.6
Energy rise time[ms]	0.59 - 0.61
Maximum$\beta_x/\beta_y/\eta_x[m]$	27.2/9.9/1.65
betatron tune ν_x/ν_y	2.375/0.425
α_c	0.158
Natural chromaticity C_x/C_y	-1.7/-3.7
Energy acceptance at 0.24 GeV	1.5-2.0%
Damping time at 0.24 GeV $\tau_{x,y}/\tau_s$	195/385

INTRODUCTION

The HIGS is driven by the Duke storage ring. The gamma-ray is produced by the collision between the introcavity FEL photon and the electron beam. For top-off operation, a booster synchrotron (Table 1) has been developed as a new injector for the storage ring and successfully commissioned in 2006 [1]. The electron beam can be injected into the booster at a energy between 0.24 and 0.27 GeV, depending on the linac configuration; the beam can be extracted between 0.24 and 1.20 GeV [2]. The injection or extraction is performed in vertical plane with only one kicker. The kicker and its corresponding septum are located in the opposite straight sections of the booster ring, separated by about 1/4 of the vertical betatron wave. Due to the use of single kicker, booster injection and extraction critically depend on the beam orbit. In the septum region, the orbit is set to -1.0 mm vertically to maximize the injection acceptance and the extraction efficiency. The orbit also needs to be optimized during the ramping.

The extraction septum, a DC Lamertson septum, was found to have a big impact on the beam dynamics, especially at high extraction energy settings. This is because the non-ideal properties of the magnetic material which makes it possible for the magnetic field to leak out into the stored beam chamber, which leads to orbit distortion, tune and chromaticity shifts, and change of coupling. Since the injection septum always works at low energy (injection energy), its effects is neglegable. Schemes have been developed for extraction septum to compensate these effects and the compensation is essential for the success of the booster commissioning [1].

ORBIT COMPENSATION FOR THE EXTRACTION SEPTUM

The most important effect of the extraction septum field leakage is the orbit distortion. It varies as a function of the extraction septum current and can not be sufficiently corrected by orbit correctors. This makes the injection very difficult. When the extraction energy is higher than 1.0 GeV the electron beam can hardly injected into the booster ring. So a local compensation aimed at redusing the orbit distortion is necessary.

The septum build-in compensation coils, symmetric and asymmetric trim coils, the so-called S-trim and A-trim in Fig. 1, are used to compensate the x and y orbits, respectively. To minimize the hysteresis effect, the orbit is corrected on the flight of a slow ramping of the extraction septum current. The singular value decomposition (SVD) is used in the correction to minimize the orbit change over the booster ring. Based upon this correction, the compensation data are integrated into the EPICS based control system as feed-forward tables. After compensation, the standard deviation of the orbit distortion can be kept within 40 μm in both directions (see Fig. 2).

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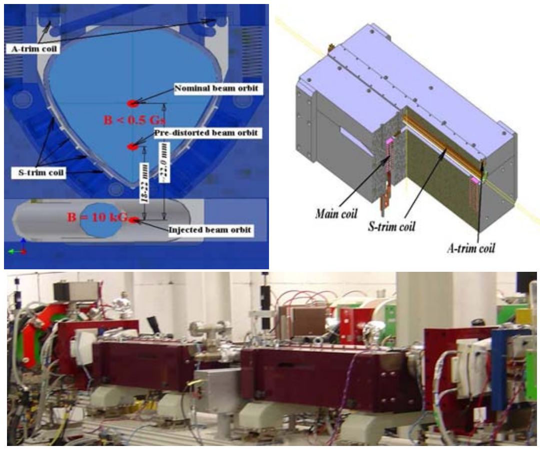

Figure 1: The septum magnets of the HIGS booster. the upper left plot) cross section of the septum; the upper right plot) 3D CAD drawing of the septum; the lower picture) extraction septum (left) and injection septum (right).

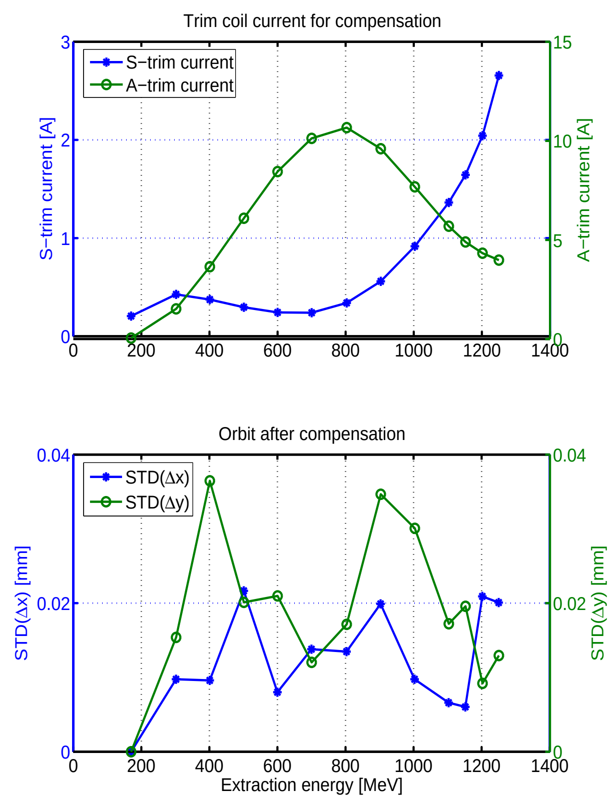

Figure 2: Orbit compensation for the extraction septum; the upper plot) S-trim and A-trim currents for orbit compensation; the lower plot) standard deviation of the orbit after compensation.

CHROMATICITY COMPENSATION

It is also found that the leaked magnetic field of the extraction septum has sextupole-like components which change the chromaticity of the booster ring. This reduces the dynamics aperture and shortens the beam lifetime. Two adjacent sextupoles, S01SD and S03SD, are used to compensate the change of chromaticity. The additional sextupole strengths for the compensation are shown in Fig. 3. The results indicate that after compensation the chromaticity changes are reduced from 1.5 in the horizontal direction and 3.5 in vertical direction to within ± 0.3 in both directions.

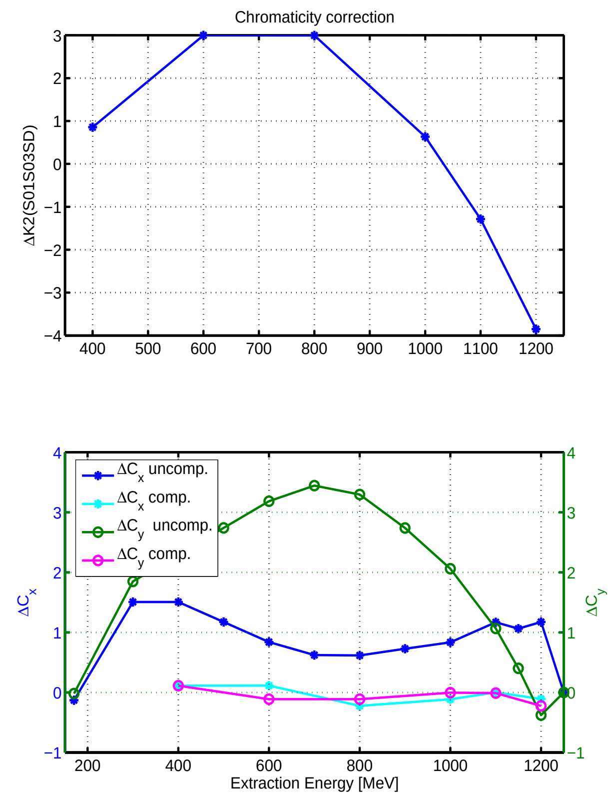

Figure 3: Chromaticity compensation for the extraction septum. the upper plot) additional sextupole strength (ΔK_2) for chromaticity compensation; the lower plot) chromaticity changes before and after the compensation.

BETATRON TUNE AND COUPLING COMPENSATION

The leaked field also changes the betatron tunes. Adjacent quadrupoles, S01QD and S03QD, are used to compensate these changes. Fig. 4 shows the additional quadrupole strengths (ΔK_1) for the compensation, as well as the tune changes before and after the compensation.

The skew terms of the leaked field modifies the coupling between horizontal and vertical betatron motion. Sextupoles with large orbit offsets, S01SF and S03SF, are used to compensate the coupling change by minimizing the η_y. The chromaticity change due to this compensation is corrected by sextupoles N01SF and N03QF which are located in the opposite straight section. Fig. 5 shows the compensation results.

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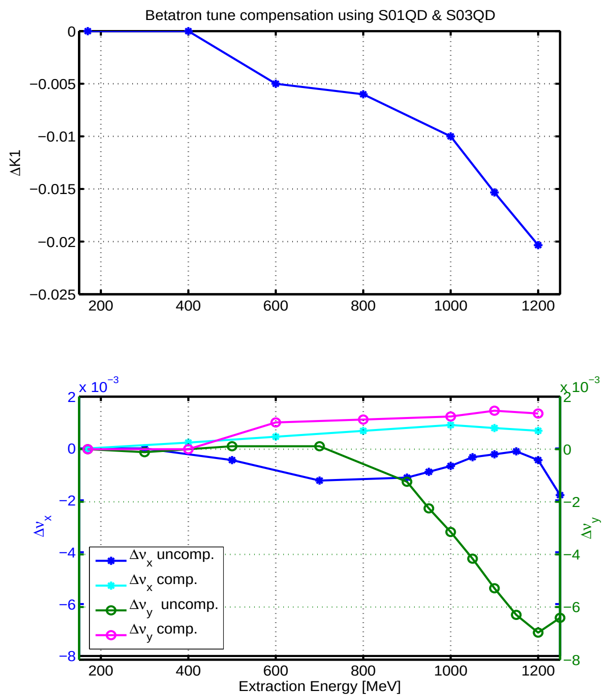

Figure 4: Betatron tune compensation for the extraction septum. the upper plot) Additional quadrupole strength for the tune compensation; the lower plot) tune change before and after the compensation

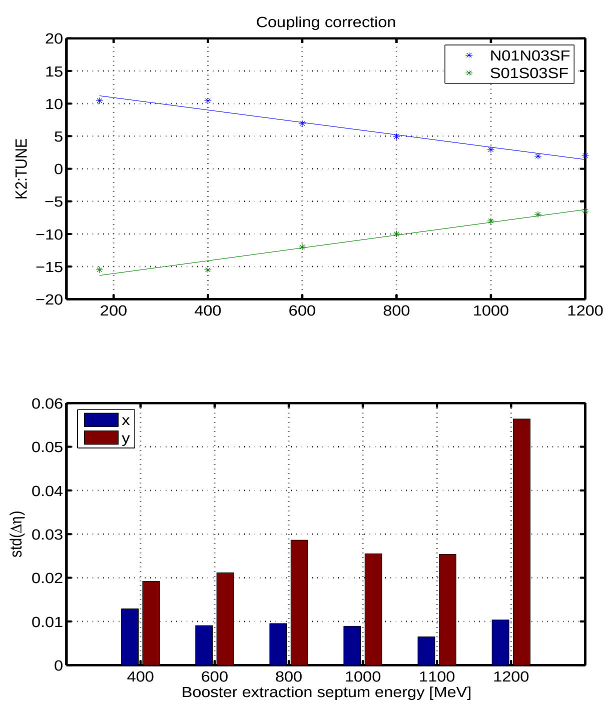

Figure 5: Coupling compensation for the extraction septum. the upper plot) additional sextupole strength for coupling compensation; down) standard deviation of η after the compensation.

SUMMARY

The orbit and chromaticity compensations are the two most critical corrections for booster injection. The compensation data have been integrated into the EPICS based control system as a feed-forward tables. These compensations have made a big contribution to the success of the booster commissioning.

ACKNOWLEDGMENTS

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