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IMPACT OF RF COUPLER KICKS ON BEAM DYNAMICS IN BESSY VSR

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Abstract

The expected BESSY II upgrade to BESSY VSR requires the installation of a superconducting RF system [1], consisting of four cavities. Two cavities will operate at 1.5 GHz and two at 1.75 GHz. Each of them is equipped with a Fundamental Power Coupler (FPCs) and with Higher Order Mode (HOM) damping waveguides. Dedicated simulations of these cavities and couplers have shown that at the location of the FPCs the beam will see a transverse kick [1–3], perturbing the closed orbit and affecting transverse beam dynamics. We present the results of simulations and preliminary experiments of the impact on transverse beam dynamics of these coupler induced kicks for different FPC orientations.

INTRODUCTION

The current BESSY II RF system operates at a frequency of 500 MHz, using voltages up to 2 MV, and is operated at a harmonic number of 400. This allows us to operate with two different bunch lengths, 15 ps (RMS) in standard user mode and 3 ps in low alpha mode. The downside of the current setup is that one needs to switch between operating modes to have access to a specific bunch length, making it time-consuming and limiting the users that can be provided with beam. The foreseen upgrade of the BESSY II RF system with two harmonic cavities will allow to operate with two different bunch lengths simultaneously in standard user mode, by making use of the interference patterns between the original RF cavities and the two harmonic cavities, which will operate at 1.5 GHz and 1.75 GHz with harmonic numbers 1200 and 1400 respectively [1]. Furthermore, in low alpha mode, we will have access to even shorter bunches (0.3 ps). The new harmonic cavities will be of the superconducting type [1, 4–8], with much higher voltage gradients (20 MV and 17.14 MV respectively), allowing for the possibility of shorter bunches. Figure 1 shows the voltage interference patterns and the corresponding Hamiltonian values, resulting in multiple locations where bunches can be placed. Looking at the shape of the Hamiltonian values, we can see that one can inject a long bunch (blue shaded region) and a short bunch (orange shaded region) if the correct phase with respect to the combined RF voltage pattern is chosen. This is the basis of the VSR upgrade project [1]. In this paper we discusses the impact of the new harmonic cavities on transverse beam dynamics.

FUNDAMENTAL POWER COUPLERS

In order to get the RF power to the cavities, the cavities are equipped with Fundamental Power Couplers or FPCs. Dedicated field simulations [2] have indicated that the FPCs

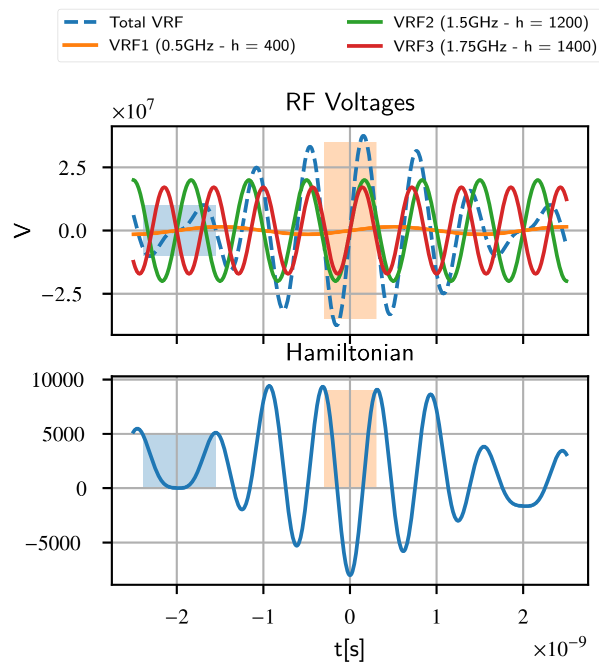

Figure 1: BESSY VSR RF Voltage interference pattern and corresponding Hamiltonian pattern.

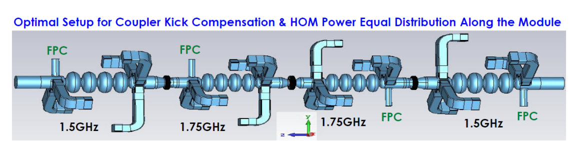

Figure 2: Possible FPC layout (PPMM).

will induce horizontal transverse kicks to the beam with amplitudes of 6.24×10^3 mπrad and of 7.06×10^3 mπrad for the 1.5 GHz and 1.75 GHz cavities respectively. The signs or directions of these kicks depend on the orientation of the FPCs and on the local RF phase when the bunch passes, resulting in various possible setups, each affecting the short and long bunches differently. Table 1 shows the signs of the transverse kicks that the beam receives at each FPC for the long and short bunches corresponding to the different FPC orientation combinations, Fig. 2 shows one such possible combination (PPMM). In the next sections, we will present the results of our study of the impact on transverse beam dynamics for the different FPC orientations.

SIMULATION

Simulations were done using MAD-X [9]. The FPC kicks were simulated by implementing four virtual horizontal kickers, of which the kick signs varied according to the combinations shown in Table 1. Figure 3 shows the current lattice

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Table 1: Possible sign for the transverse kicks seen by the different bunches corresponding to possible FPC orientation combinations.

	Long	Short
PPPP	+ - - +	+ + + +
PPPM	+ - - -	+ + + -
PPMP	+ - + +	+ + - +
PPMM	+ - + -	+ + - -
PMPP	+ + - +	+ - + +
PMPM	+ + - -	+ - + -
PMMP	+ + + +	+ - - +
PMMM	+ + + -	+ - - -

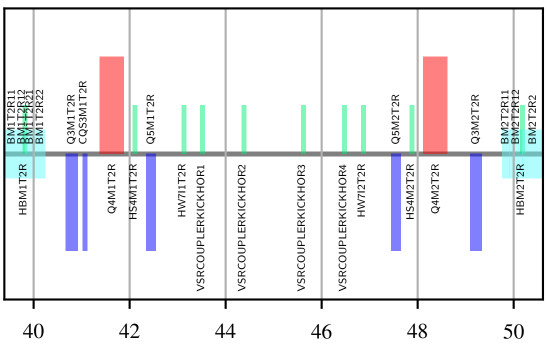

Figure 3: Lattice elements in the region where the new cavities will be installed, notice the presence of the four virtual horizontal kickers used to simulate the FPC kicks (VSRCOUPLERKICKHOR).

layout in the region where the new cavities will be installed, showing the dipoles (light blue), quadrupoles (blue and red, defocusing and focusing respectively) and horizontal kickers (light green). The virtual kickers used to simulate the FPC kicks are also included and are labelled with VSRCOUPLERKICKHORi (for i in 1,..,4). Figure 4 shows simulation results, using standard user optics (low alpha mode has not been considered yet), for the magnitude of the orbit distortions with respect to the reference closed orbit along the BESSY VSR ring in the horizontal plane. The effect for long bunches is shown in blue, for short bunches in orange. The case shown in Fig. 4 corresponds to the PPMM case from Table 1, similar behaviour is seen for the other cases. Applying an orbit correction using existing orbit correctors for the long bunches significantly improves the orbit distortions, as can be seen in Fig. 5 for this particular case. Applying the same correction for the short bunches shows (Fig. 6) that there is little improvement in the orbit distortions. This behaviour is not only limited to this particular case, but is present for all cases. Correcting for the long bunches improves the orbit distortions for the long bunches but not for the short bunches and vice versa, meaning that we can only correct for one bunch type at a time. Nevertheless, the distortions are not very large and are within an acceptable range. For all cases we also investigated the corresponding tune and chromaticity shifts, all shifts were below 0.6×10^{-3}, within the acceptable operational ranges. Comparing the different cases, it seems the PPMP and PPMP case result in the smallest maximum orbit distortions when considering both bunch types (126×10^{-6} m).

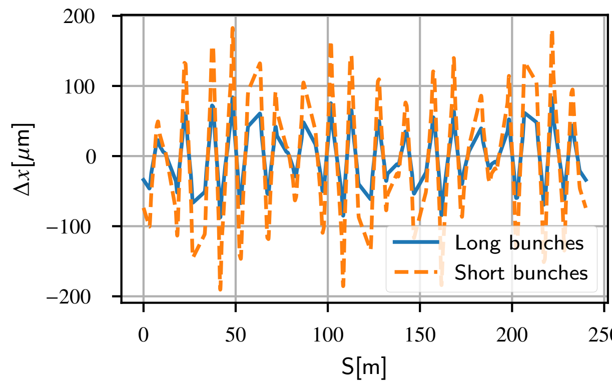

Figure 4: Orbit distortions for long (blue) and short (orange) bunches in the PPMM case.

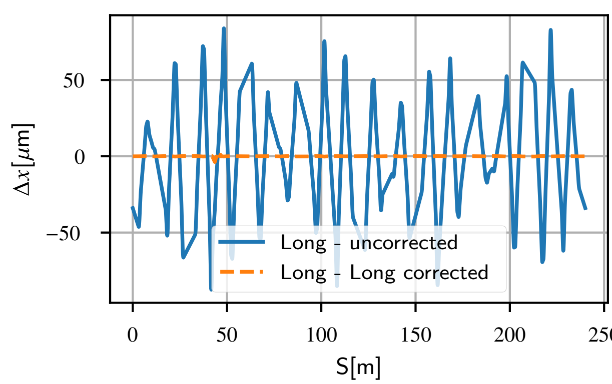

Figure 5: Orbit distortions for long bunches in the PPMM case before (blue) and after (orange) correction, where a correction for long bunches was applied.

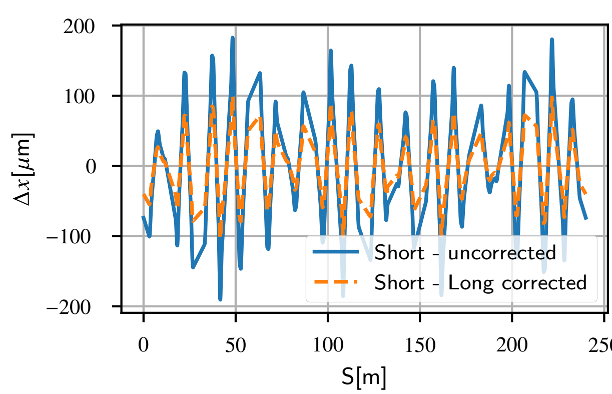

Figure 6: Orbit distortions for short bunches in the PPMM case before (blue) and after (orange) correction, where a correction for long bunches was applied.

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MEASUREMENTS

Measurement, at the BESSY II machine, were done using two different sets of existing orbit correctors (Table 2) to generate a kick to the beam that result in a distorted orbit similar to the expected distortions from the FPC kicks (see Fig. 7). The simulated settings were put in the machine and the results can be seen in Fig. 8, where the large peaks are due to residual effects of insertion devices that could not be avoided at the time of the experiment[1]. Nevertheless, there is good agreement between simulations and measurements, and as we were able to generate the orbit distortions expected from the FPCs using different sets of existing orbit correctors we can assume we will be able to correct for these distortions, at least for one bunch type as discussed before.

Table 2: Sets of orbit correctors used to simulate the effect of the FPC kicks on the orbit (see Fig. 3 for their location in the lattice).

set 1	set 2
HBM1T2R	HBM2D2R
HW7I1T2R	HBM1T2R
HW7I2T2R	HS4M2T2R
HBM2T2R	HBM2T2R

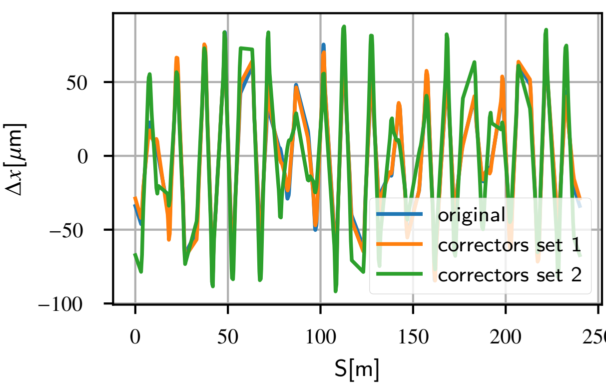

Figure 7: Orbit distortions for the PPMM case using the virtual kickers (blue), set 1 of correctors from Table 2 (orange) and set 2 of correctors from Table 2 (green).

CONCLUSION

We have studied the impact of the FPC kicks on transverse beam dynamics for different FPC orientations. It was observed that the long and short bunches transverse orbits are affected differently for all FPC orientation combinations, such that both bunches need to be considered in further studies and simulations. The simulation results presented in this paper indicate that the PMPP and PPMP orientation combinations of the FPCs lead to the smallest deviations from the reference orbit when both long and short bunches are considered. Existing orbit correctors were used to generate orbit distortions in the BESSY II machine that are similar to the expected ones from the FPCs, using simulation based settings. The fact that we were able to recreate the expected

[1] not implemented in the MAD-X model of the BESSY II machine

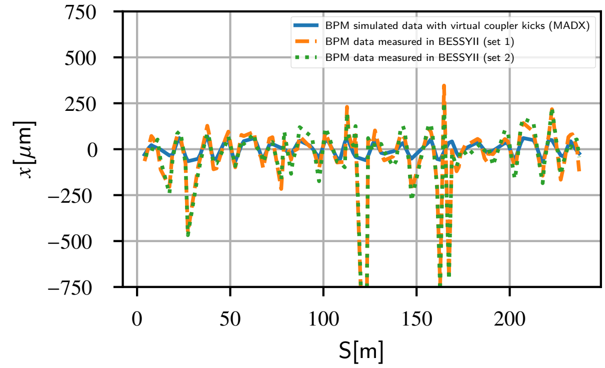

Figure 8: Comparison between simulated orbit distortion using the virtual kickers (blue) and measured orbits in the machine using the two sets of orbit correctors from Table 2 (orange and green respectively).

orbit deviations using orbit correctors, makes us confident that the existing orbit correction system is able to handle the FPC generated distortions, with the caveat that one can only correct for one bunch type at a time.

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