IOTA Pre-proposal: (Non-)Linear Optics studies and correction

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To enable the next generation of storage rings at the intensity frontier various concepts to overcome current limitations are studied at the Integrable Optics Test Accelerator (IOTA) [1]. These include the study of nonlinear integrable systems using either special magnets [2] or electron lenses, optical stochastic cooling [3] or space charge compensation using an electron column [4]. Previous studies [5, 6, 7] already highlighted that especially for the study of non-linear integrable systems, good control of the linear and nonlinear optics is a prerequisite to achieve the desired bound motion of particles over a wide range of amplitudes.

A first goal of the study is assessing the status of the (non-)linear beam optics in the IOTA ring with an electron beam for a case with and without special magnetic inserts as a baseline for following studies and improving the optics model of the accelerator. Using the Turn by turn data from the BPMs and the same software suite [8] already employed for the optics commissioning of the LHC [9, 10] and other accelerators [11, 12, 13] a first assessment of the beta-beating and coupling can be made. Provided sufficient resolution in the frequency spectrum, amplitude and phase of sextupolar and octupolar resonance driving terms (RDT) around the ring can be additionally determined. To provide an optimum turn by turn BPM signal a intensity close or above the nominal bunch ($2 \cdot 10^9$) is favourable. For the excitation of the beam the stripline kicker [14] in the injection straight may be used. If available, the results could be cross-validated with previous measurements using the orbit response matrix (ORM) method. These optics measurements are then to be repeated with multiple momentum offset settings with a relative change in the order of 10^{-4} to also measure off-momentum beta-beating, chromaticity, first and second order dispersion, and chromatic coupling. Furthermore, for the case without any nonlinear insert, the amplitude detuning, likely only generated from the second order effect of the sextupoles, can be measured. These measurements can then be repeated for cases with the magnet inserts turned on and for different power settings of those. Due to the added nonlinearities, the measurement conditions are expected to worsen due to additional decoherence [15], the impact on turn by turn measurements still to be quantified. In case this proves to be the limiting factor for some measurements and provided the availability of the required additional hardware, using the kicker in an AC-dipole configuration [16] could be considered.

The second proposed part of the study concerns the impact of higher order perturbations and possible corrections. Provided sufficiently reliable and reproducible results from the preceding optics measurements a first study on the impact of (local) coupling in the nonlinear inserts on the beam stability could be attempted, similar to studies conducted at the LHC [17]. By using four properly phased skew quadrupole correctors a closed coupling bump through the nonlinear inser could be created and the impact on the amplitude detuning and dynamic aperture can be studied. Similarly, also the effect of a significant uncorrected global ΔQ_{min}, possibly leading to an amplitude dependent tune approach [18] distorting the footprint, could be studied by using all available skew quadrupole correctors. Both of these experimental studies would then eventually allow to put on realistic tolerances on the allowed coupling in future operations.

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Another part of the proposed study is to quantify the detrimental effect of sextupole on integrabilty. It has already been shown in theory [6] and simulation [7] how first order chromaticity breaks the integrability and leads to a reduction in dynamic aperture. By changing the sextupole powering settings while keeping the overall first order chromaticity constant and observing both the change of the local sextupolar RDT in the insert and the overall second order chromaticity allows to infer the criticality of good control over both distortions.

The presented study aims to assess the status and impact of linear and nonlinear optics distortion in the IOTA accelerator. It has already been shown in simulations that good control of the linear optics down to the percent level is required to allow for bound motion of particles whilst generating amplitude detuning. By exploiting to wide range of possible observables in turn by turn data tolerances on several of those can be established for future operations. In addition, by tuning the sextupolar powering scheme, the adverse effect of required chromaticity correction can be studied.

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