Nonlinear optics measurements and correction in the IOTA ring (NL OMC)

PERSONNEL

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PURPOSE AND METHODS

The use of resonance driving terms (RDT) as a way to characterize the linear and nonlinear motion in particle accelerators has proven to be an invaluable tool in the last decades. The resonance driving term formalism not only facilitates the design of correction systems or of accelerator blocks with an intrinsic cancellation of unwanted resonances but also allows to localize sources of strong nonlinearities from measurements and validate corrections of such. The assessment of RDTs in the IOTA ring is particularly interesting for two main reasons. First, the peculiar structure of IOTA which enables the integrable motion in the presence of nonlinear fields in the first place requires a linear transfer outside of the nonlinear channel as is illustrated in [1]. The use of sextupoles for chromaticity correction but also the presence of field errors in the accelerator magnets in the transport section for example do violate this constraint.
Second, the specific feature of the nonlinear magnet is the generation of amplitude detuning whilst not exciting resonances. As such, no change in the measured RDTs is expected when switching on the nonlinear insert.
By measuring the RDTs at all available beam position monitors (BPM), sources of nonlinearities can then be localized and absence of resonant excitation from the nonlinear (NL) insert can be validated. The measurement results can also be used to refine the tracking model and, provided reliable results, a correction could be attempted.
The measurement procedure consists in exciting the electron bunch to large amplitudes using both the horizontal and vertical kickers while capturing turn by turn data with the beam position monitors. From the spectral composition of the captured signal the RDTs for specific resonances can then be inferred. In addition, the data can be used to assess the status of the linear beam optics. The measurement accuracy is limited by the BPM noise and the available number of turns due to decoherence. As shown in [2], the amplitude of some spectral lines decoheres faster than the main tune line thus making measurements of certain RDTs even more challenging. In general, sufficient resolution for analysis can be expected for a decoherence time over a thousand turns. To partly circumvent this problem, the strength of the NL insert, being the major source of amplitude detuning, at which RDT measurements can be conducted might be severely limited and a chromaticity correction using the sextupoles to near zero chromaticity might be necessary during the measurements. Another option to overcome the problem of rapid decoherence would be the use of an AC-dipole to excite a coherent betatron oscillation, however additional hardware is required in this case. In addition its use also affects (non-)linear observables, requiring careful disentangling to conclude also on the status for the case of free oscillations. Lastly, nonlinearities in the BPM response could also potentially have a large effect on the measurement accuracy.

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A. Measurement Procedure

- Initially, measurements with the NL insert depowered are foreseen. Multiple measurements sets at different bunch currents and chromaticity corrected close to zero using the sextupoles to establish optimal conditions for the following points. Here, one measurement set consists of a minimum of 3 large amplitude excitation in both planes simultaneously. This initial step can potentially be skipped provided previous experiments have already concluded on safe baseline.
- In the following the measurements are to be repeated at different working points to enhance sextupolar and octupolar RDTs.
- Optionally, based on the previous measurements, a correction of coupling or an alternative sextupole powering scheme could be tried, either followed by a reevaluation.
- The RDT measurements are then repeated with the NL insert or octupole channel powered on. Here, a working point enhancing the octupolar RDT is of greater interest. Kicks at different levels of strength of the NL insert are to be conducted.

BEAM CONDITIONS

- Species: e^-
- Energy: 100 MeV-150 MeV
- Potential orbit modifications
- Bunch current: > 1 mA
- Transverse emittance: <0.04 µm
- No. of bunches: 1
- Changes in optics and NL insert strength foreseen

APPARATUS

Given the availability of the hardware prior to experimental studies, the option of reconfiguring the transverse damper to excite a driven betatron motion of the beam could be considered.

RUN PLAN

In case the transverse damper is to be used for beam excitation and depending on the readiness and prior testing experience of this device, an additional shift for the setup before the experimental program may be required. The experimental program itself ideally takes up 3 shifts, each roughly 5 hours long. These shifts are preferably scheduled on non-consecutive days. No special decommissioning is expected after the experimental studies. Parts of the proposed studies can potentially share beam time with other proposed experiments on the NL insert. These experimental studies would preferably be conducted between mid and end of October 2019.

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