COMMISSIONING OF TWO NEW INSERTION DEVICES AT ELETTRA

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Abstract

Two new insertion devices have recently been installed in the ELETTRA storage ring: a 3.5 Tesla superconducting multipole wiggler and a Figure-8 permanent magnet undulator. The first is the radiation source for a future X-ray diffraction beamline, while the second is designed to generate photons in the 5-11 eV range for inelastic UV scattering experiments. The impact of these devices on the electron beam dynamics was already studied at the design stage [1]. In this paper initial commissioning results are presented and discussed, including the measured effects on the closed orbit and tune.

SUPERCONDUCTING WIGGLER

The superconducting multipole wiggler (SCW) fabricated at Budker Institute of Nuclear Physics, BINP (Novosibirk, Russia) was successfully tested in presence of Sincrotrone Trieste personnel in August 2002. After being disassembled and delivered to ELETTRA, it was reassembled and tested again to confirm the performance measured at Novosibirsk. In November 2002 it was installed (see fig. 1) and the commissioning started.

The main parameters of the wiggler are listed in table 1. It is equipped with a special cold copper liner (20 K) to reduce the heat flux generated by the electron beam; more details about this device can be found in [2].

Table 1: Main parameters of wiggler.

Maximum field on beam axis (T)	3.5
Pole gap (mm)	16.5
Period length (mm)	64
Internal liner gap (mm)	10.7
Critical photon energy at 2 GeV (keV)	9.3
Total radiated power at 2 GeV, 100 mA (kW)	4.6

Figure 1: The SCW installed in the storage ring.

The magnet can be operated both in power mode (with the power supplies connected) and in persistent mode (power supplies disconnected). The minimum tested ramping up time from 0 to 3.5 T is about 300 seconds. The ramping down time with (without) field integral control is about 460 (300) seconds.

The liquid Helium (LHe) consumption measured at 3.5 T was 0.9 (0.5) l/h in power (persistent) mode. With the electron beam the LHe consumption increases by a large factor: at 2 (2.4) GeV with 300 (140) mA we measured a LHe consumption of 5 (1) l/h. In order to overcome this anomalous consumption, which is believed to be due to the beam interaction with the liner slots [3], the liner itself will be removed next November and replaced with a modified version.

The SCW as initially installed in the storage ring had a vertical misalignment of about 2 mm, caused by an extra force of about 7000 kN on the magnet vessel created after pumping the insulating chamber, which had not been taken into account at the design stage. The closed orbit distortion at 2 GeV before and after the realignment is shown in fig. 2. The horizontal distortion will be further reduced by recalibrating the current table [2]. With the SCW set in persistent mode at 3.5 T we measured a maximum horizontal beam (angle) position variation of 20 μm (1 μrad) and 2 μm and 5 μrad in the vertical plane in an hour of operation. These values also include the machine's thermal drift.

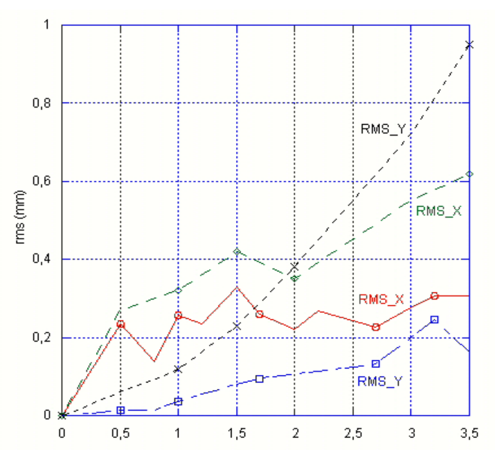

Figure 2: Closed orbit distortion (RMS) as a function of the magnetic field (dotted line are measured with a vertical misalignment of 2 mm).

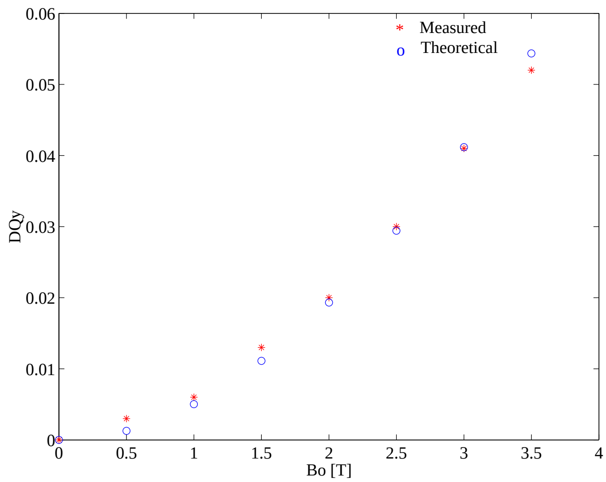

Figure 3: Measured and theoretical vertical tune shift as a function of magnetic field at 2 GeV.

Figure 3 shows the good agreement between the theoretical and measured vertical tune shifts as a function of the magnetic field at 2.0 GeV. In the horizontal plane the tune shift is only 0.003 at 3.5 T, as expected.

Dynamic aperture and lifetime variation could not be measured at this stage, but will be measured before the replacement of the liner.

FIGURE-8 UNDULATOR

Linear effects

A twin Figure-8 undulator has recently been constructed and installed in the storage ring. Details on its design and characteristics can be found in [4,5]. Following assembly, the magnetic field properties were measured and found in good agreement with the design parameters. Table 2 shows the measured peak field intensity, optical phase error and residual normal and skew quadrupole for three representative gaps (average values of the two undulator modules). The small phase error implies that the spectral intensity will be close to the theoretical limit, and the low quadrupole content shows that no significant perturbation to the linear beam dynamics will be introduced.

The most important parameter governing the interaction with the electron beam is therefore the field roll-off, which determines the undulator focussing potential. The measured transverse field variation was found to be in excellent agreement with that predicted by 3D field calculations, as can be seen in figure 4.

Table 2: Main measured magnetic field parameters.

Gap (mm)	Bxo (T)	Byo (T)	σ_Φ (°)	Q_N (G)	Q_S (G)
19	0.14	0.75	1.5	-11	26
30	0.13	0.56	1.5	3	11
50	0.12	0.33	1.7	0	-23

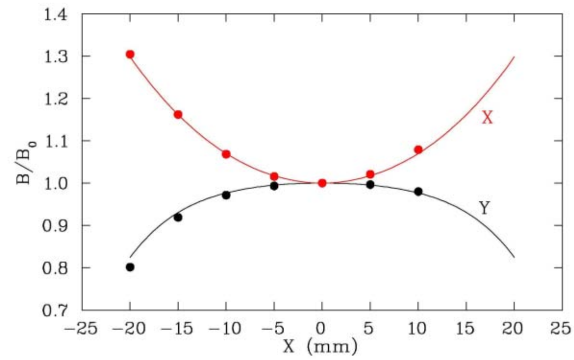

Figure 4: Measured (dots) and computed (solid line) transverse field distributions at minimum gap.

Based on the above results, we expect the undulator to behave as an ideal device. This is demonstrated in figure 5, where the measured tune shift is compared with that predicted from the ideal magnetic field. The effect is fairly small, and of the same order of that of the other conventional undulators in operation at ELETTRA.

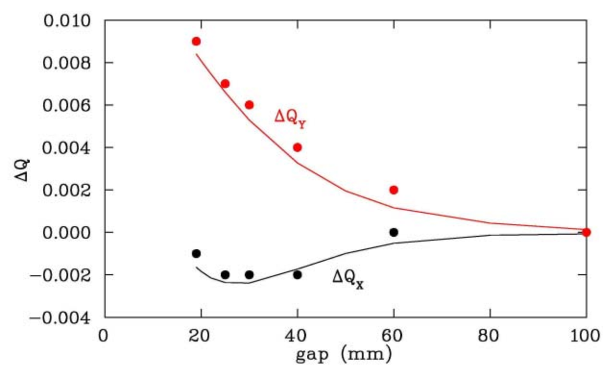

Figure 5: Measured (dots) and computed (lines) tune shifts as a function of the gap for one undulator segment at 2 GeV (black=horizontal plane, red=vertical).

Non linear effects

Due to the temporary absence of scrapers in the machine, it was not possible to confirm the dynamic aperture studies which had been carried out prior to the construction of the devices [1]. In order to study non-linear effects, phase space measurements have been performed at 2.0 GeV with the Figure-8 undulator set to minimum gap. Turn by turn data was acquired with the transverse multibunch feedback system [6] which uses only one beam position monitor. While the horizontal motion was excited using the injection kickers, the vertical one was induced with the vertical kicker of the system in antidamping mode. The method used to extract the conjugate momenta from the data is the one proposed in ref. [7], in which a Hilbert transformation is performed on the beam positions. This transformation introduces a 90° phase rotation in the data, allowing the representation of the motion in the two conjugate variables:

$$x = (\beta\cdot J)^{1/2}\cos(\phi) \quad \text{and} \quad p_x = (\beta\cdot J)^{1/2}\sin(\phi).$$

A characteristic of non-linearities is the decoherence of particles within a bunch which results in the damping of the centre of mass motion with a rate proportional to the strength of the non-linearities [8]. In phase space this is reflected as a collapse of the bunch centre of mass towards the origin [9]. Fig. 6 and 7 show comparisons of the vertical phase spaces when the device is open and when it is closed for two different values of the vertical tune (8.20 and 8.25). As the tune satisfies a resonance condition, branches which spiral towards the centre appear. In both measurements it can be clearly seen that the collapse in the phase spaces occurs more rapidly in the case in which the undulator is closed. Fig. 8 shows the comparison of the horizontal phase spaces for a horizontal tune of 14.250. Whereas the branches are clearly seen when the device is closed, those when it is open are hidden by the longer time required to collapse and the number of turns. The number of turns required to collapse with the device closed have been found to be 0.67 (horizontally) and 0.5 (vertically) times of those when it is open.

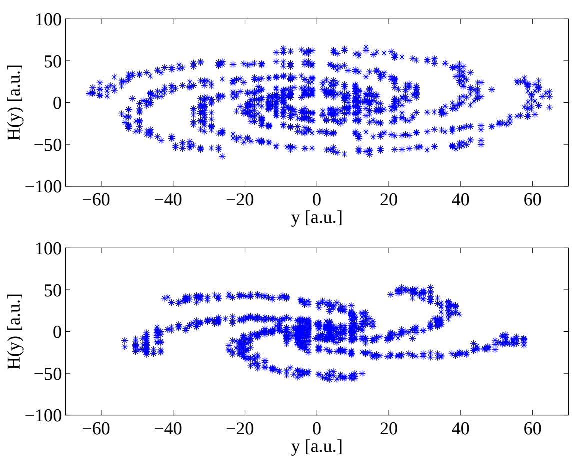

Figure 6: Comparison of the vertical phase spaces with the undulator open (top) and closed (bottom) with Q_y = 8.20.

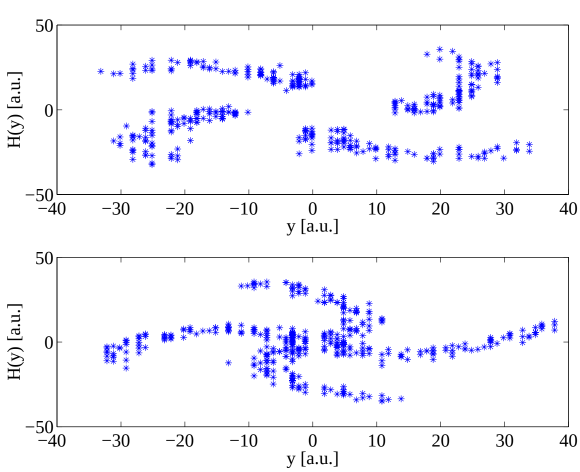

Figure 7: As figure 6 but with Q_y = 8.25.

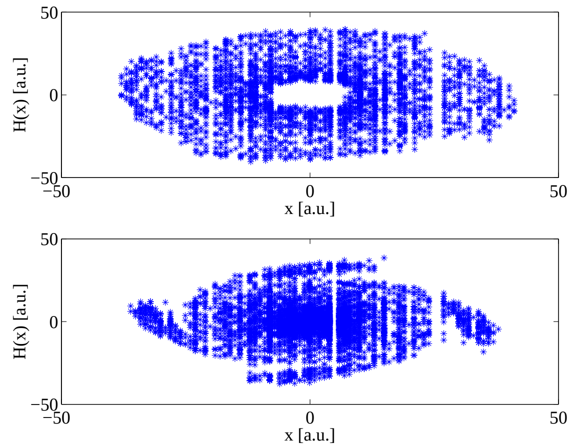

Figure 8: Comparison of the horizontal phase spaces with the undulator open (top) and closed (bottom) with Q_x=14.25.

Theoretical computations of the amplitude dependent tune shift coefficients as well as the chromaticities with the distorted optics due to the undulator revealed a too small variation to explain the difference in the collapse rate. Thus, the intrinsic non-linearities of the device may be the cause.

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