COMMISSIONING OF ELLIPTICAL UNDULATORS IN ELETTRA

L. Tosi, B. Diviacco, F. Iazzourene, R. Roux, R. P. Walker, D. Zangrando
Sincrotrone Trieste, 34012 Trieste, Italy

Abstract

Six 2 m long elliptical undulators have been constructed for the generation of linearly and circularly polarized light. Of these, five have been installed in the ELETTRA storage ring. In this paper, the first results of the commissioning are presented.

1 INTRODUCTION

There has been an increasing interest on behalf of the users for the utilization of circularly polarized light for experiments, like circular dichroism or magnetic scattering. For this purpose, during the past year five elliptical insertion devices have been introduced in the ELETTRA lattice and a sixth one will be located in the ring by early autumn. The insertion devices are of the APPLE-2 type, made of two double arrays of permanent magnet blocks which are schematically shown in figure 1. By shifting longitudinally one of the upper arrays with respect to the lower one diagonally opposite to it, the phase of the magnetic fields changes, hence generating light which goes from linearly polarized horizontally to vertically polarized, passing through circular polarization. This renders the insertion device extremely flexible, permitting various types of experiments to be carried out, according to the polarization of the light. While the main parameters of the insertion devices introduced in the lattice are listed in Table 1, technical details on their construction may be found in the references [1, 2]. The insertion devices are 2 m long and situated in couples, in the order in which they appear in the table, symmetrically around the center of three straights. EU12.5 and EU6.0 are rotated by 1.0 and -1.0 mrad with respect to the machine axis and a central chicane bump is set to place the beam on their axis. This will allow the radiation to be supplied

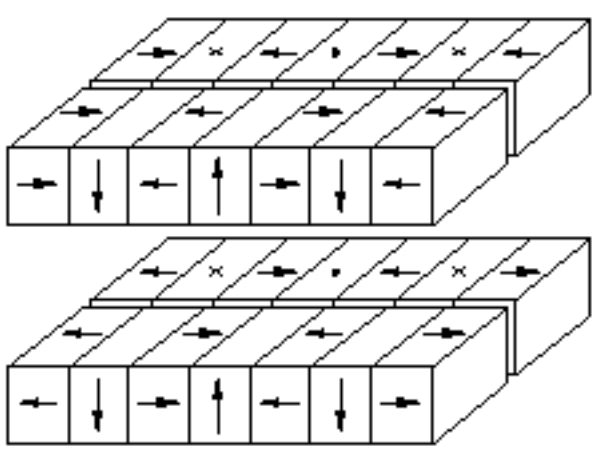

Figure 1: Schematic layout of an APPLE-2 undulator

Table 1: Main parameters of the insertion devices

Period [mm]	No. Periods	Hor. Polariz.	Circular Polariz.	Vert. Polariz.
		B_0 [T]	B_0 [T]	B_0 [T]
48	44	0.58	0.29	0.34
77	28	0.92	0.53	0.64
60	36	0.78	0.42	0.51
125	17	0.77	0.48	0.59
100	20	1.02	0.63	0.77

to two beamlines simultaneously. EU10.0 consists of two identical modules, which are separated by an electromagnetic phase adjustment magnet. The two insertion devices serve both for a conventional synchrotron radiation beamline as well as for a storage ring FEL [3], operating at 1.0 GeV. EU4.8 will be installed in the ring in early autumn in combination with EU7.7.

In this paper, the first results of the commissioning of the devices are presented. The main effects of the devices are on the closed orbit and on the tunes, which will be compared in section 2 to predictions based on the magnetic measurement data. Section 3 deals with dynamic aperture and lifetime aspects. In particular, in the latter section the effects of EU10.0 at 1 GeV will be presented, together with various matching schemes which have been investigated by simulation and practical tests in order to reduce these effects.

2 CLOSED ORBIT DISTORTIONS AND TUNE SHIFTS

In addition to the intrinsic linear effects induced on the optics, insertion devices perturb the closed orbit due to magnetic field errors. Non-zero first and second field integrals result in an angle perturbation and a displacement error of the closed orbit respectively. For all of the devices, a field quality optimization was performed by the method of block sorting, followed by a magnetic field fine-tuning consisting in displacing selectively some blocks. With this method it was possible to minimize the first and second field integrals, which for all of the devices present values less than 2.5 Gm and 3.0 Gm^2 respectively at any gap and phase. The perturbations of the single devices on the closed orbit are shown in Table 2, where the maximum horizontal and vertical rms of the difference orbit for any gap and phase are reported. The measured values showed a good consistency with the expected values corresponding to the measured first and second field integrals. The elliptical devices, however, are provided

Table 2: Maximum closed orbit perturbations (rms of the difference orbit) and tune shifts at 2.0 GeV

ID	x_{rms} [µm]	y_{rms} [µm]	$\Delta\nu_x$	$\Delta\nu_x$
EU6.0	130	30	-0.005	0.004
EU7.7	70	15	-0.013	0.006
EU10.0*	115	70	-0.025	0.012
EU12.5	100	65	-0.023	0.015

* One module

with external correction coils designed to compensate for the two field integrals and thus to eliminate the residual distortions generated in the orbit. Calibration of the coils for the devices EU12.5, EU6.0 and for one module of EU10.0 has been performed for several phases at different gaps. The calibration method of the coils consists in minimizing the rms of the difference orbit with respect to the previous calibration at a certain gap and phase; details of the method can be found in [4]. For the calibrated devices, it was possible to reduce the rms of the difference orbit to 1 µm in both planes for all gaps and phases for which the calibration was performed, with currents on the power supplies of the coils well below the maximum applicable value.

As for the linear distortions induced by the devices, the major effect is seen on the horizontal tune, which is caused principally by the horizontal fields and by the larger beta value at the devices' locations (8.36 m horizontal against 3.32 m vertical). Figure 2 illustrates the comparison between the measured tune shifts and the theoretical ones for EU10.0, as a function of the longitudinal phase with the device set at its minimum gap. For the theoretical tune shifts, the focusing strengths of the devices [5], calculated from the magnetic field distribution, were assumed and the same very good agreement was found also for the other devices. It is interesting to note in figure 2 that the horizontal tune shift produced by the closure of the gap, i.e. the shift shown for zero phase, is positive. This reflects the effect of the small gap existing between the arrays of blocks on the magnetic fields of the devices. Since the tune shifts

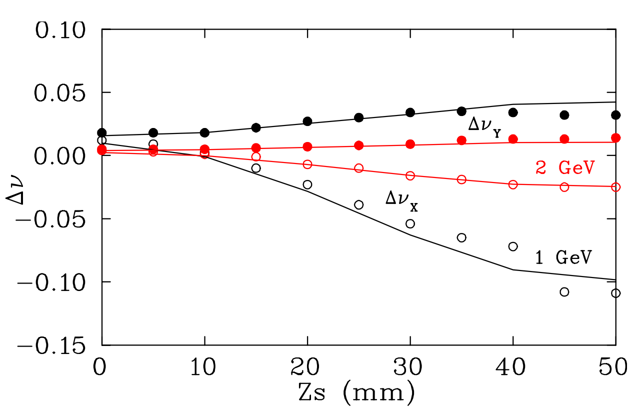

Figure 2: Horizontal and vertical tune shifts induced by EU10.0 at 2.0 and 1.0 GeV

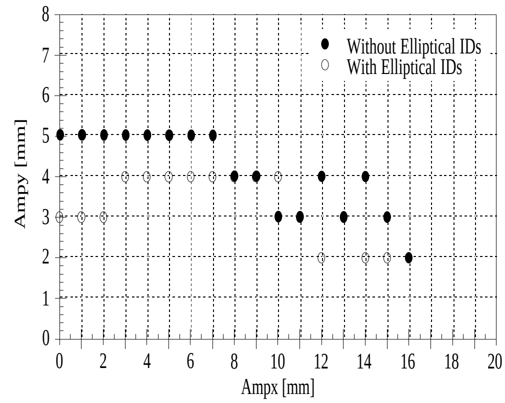

Figure 3: Comparison of dynamic aperture simulations at 2.0 GeV with and without the elliptical undulators in circularly polarized mode.

induced by a device are sensitive to the trajectory of the beam in it, the comparison between the theoretical and the measured tune shifts was particularly useful for EU6.0 and EU12.5, confirming that the bump on the chicane is properly set and the alignment of the devices is good.

3 COMMISSIONING OF EU10.0 AT LOW ENERGY

Prior to the installation of the devices in the machine, dynamic aperture computations were performed in order to see the additional effects of the elliptical devices with respect to the planar ones already installed in ELETTRA. As can be seen from the results shown in figure 3, the new devices have quite a strong impact on the dynamic aperture. The computations were performed at 2.0 GeV and with all the elliptical undulators listed in table 1 set to the circularly polarized mode at their minimum gap. Furthermore, the physical aperture of the vacuum chamber was included and the tunes were adjusted to the nominal ones of 0.3 horizontally and 0.2 vertically. Confirmation of the simulations with dynamic aperture measurement still have to be carried out, but for the moment no noticeable change in lifetime was observed when singly the devices were closed at 2.0 GeV and their phase was changed.

Different is the impact of EU10.0 when it is set to circularly polarized light at 1.0 GeV as required for FEL operation. First of all due to the strong tune shifts induced by the device at this energy, it was not possible to pass to the circularly polarized mode without correcting the tunes as the phase was being set. However even with the tunes set to the nominal values, a drastic reduction in lifetime was observed. It was observed that correcting the tunes locally with a quadrupole pair improved the lifetime by over a factor of two with respect to a global tune correction. For this purpose the program TOCA [6] was modified. Theoretical computations revealed that the horizontal beta beat with respect to the nominal optics is much less for the local tune correction than for the global tune correction (25% against 75% peak value). For the vertical beta beat, the situation was found to be inverted. Since in ELETTRA the harmonic sextupole improves the chromaticity correcting sextupoles' dynamic aperture by compensating a large horizontal sextupole harmonic [7], this induces one to think that the linear distortions introduced by the device are destroying significantly the sextupole optimization. In order to improve the situation, simulations have been carried out with a combination of local and global matching. Locally the slopes of the beta functions at the center of the straight were matched to zero with a quadrupole pair, as described in [8], leaving the beta functions outside the region unperturbed. Then globally with the remaining quadrupoles of the ring, the tunes were re-installed to their nominal values. The resulting horizontal beta beat was found to be of 15% peak value within the matching region and 5% around the rest of the ring. Dynamic aperture simulations showed an improvement when the combined matching scheme was adopted. The effectiveness of the combined correction method on the machine still has to be tried. Other methods of improving the dynamic aperture also have yet to be investigated. This includes both a re-optimization of the harmonic sextupoles and an optimization of the working point. The latter is motivated by the fact that previous resonance scans have shown the existence of wider stopbands at 1.0 GeV with respect to 2.0 GeV and this combined with the intrinsic non-linearities of the device may result in a non-optimized working point for the operation of EU10.0 at low energy. To improve the situation also a global beta beat compensation will be tried.

5 CONCLUSIONS

From the first experience with the new elliptical undulators, it certainly emerges that for their operation new procedures and application programs are needed. Until now, the tune shifts induced by the devices were not dynamically compensated. The tunes of the bare machine were set to appropriate values such that once the devices were closed, the tunes resulted in the nominal ones. Due however to the additional tune shifts that the elliptical insertion devices introduce, as well as to the effects of EU10.0 at 1.0 GeV, a software program is being developed in order to compensate the tunes dynamically with the closure of the devices and the shifting of their phase. The software will be part of a more general program which will provide various matching techniques.

As for the first results of the commissioning of the elliptical devices, orbit distortion and tune measurements have shown a very good agreement with the predictions. Although no noticeable effect on the lifetime at 2.0 GeV was observed when operating the devices singly, more measurements with combinations of the devices as well as dynamic aperture measurements have still to be performed.

REFERENCES

[1] B. Diviacco et al., “Construction of Elliptical Undulators for ELETTRA”, EPAC’98, Stockholm, June 1998.

[2] B. Diviacco et al., “Development of Elliptical Undulators for ELETTRA”, PAC’99, New York, March 1999.

[3] R.P. Walker et al., “The European UV/VUV Storage Ring FEL Project at ELETTRA”, this conference.

[4] R.P. Walker et al., “Operation of Insertion Devices in ELETTRA and Plans for Future Devices”, PAC’97, Vancouver, May 1997.

[5] B. Diviacco et al., “Development of Elliptical Undulators for ELETTRA”, this conference.

[6] F. Iazzourene, “TOCA”, PAC99, New York, March 1999.

[7] R. Nagaoka, “CATS. A Computer Code for the Optimization of Sextupoles and Linear Optics in Circular Accelerators”, Sincrotrone Trieste Machine Report, ST/M-91/3, 1991.

[8] A. Wrulich, “Effect of Insertion Devices on Beam Dynamics. Part I”, Sincrotrone Trieste Internal Report, ST/M-87/18, 1987