INITIAL OPERATION OF THE ELECTROMAGNETIC ELLIPTICAL WIGGLER IN ELETTRA

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Abstract

An electromagnetic elliptical wiggler for the generation of circularly polarized light has been installed in the 2.0 GeV synchrotron light source ELETTRA. This paper presents the results of measurements of the effects of the wiggler on the electron beam, which include tune shifts, effects on the closed orbit and dynamic aperture in the static operational mode. Comparisons with theory and simulations are also presented.

1 INTRODUCTION

In January of this year, a novel electromagnetic elliptical wiggler (EEW) has been installed in the 2.0 GeV third generation synchrotron light source ELETTRA. The device is designed in order to provide a source of circularly polarized light in the VUV/Soft X-ray region with a variable helicity up to 100 Hz switching rate in the horizontal field. The device is formed by 15 periods of length 0.212 m each and the vertical and horizontal fields are generated by two power supplies, capable of generating currents up to 200 A and ± 300 A respectively. The nominal working point of the EEW forsees a maximum vertical on-axis field of 0.5 T and a horizontal one of 0.1 T, corresponding to 160 A and 275 A in the power supplies. Further details of the design may be found in [1, 2].

In the stage of designing the pole shapes for the EEW, extensive beam dynamic simulations had been carried out in order to study the non-linear effects of the device and to optimise their impact on the performance in ELETTRA [3]. Furthermore, magnetic measurements of the maximum on-axis fields and of the first and second field integrals were performed on the device prior to the installation in the storage ring [2, 4]. In this paper, we present the results of the measurements of the effects of the EEW on the electron beam and compare them with those expected from magnetic measurements and simulations. While section 2 deals with the linear effects and the distortions on the closed orbit, section 3 reports on dynamic aperture issues.

2 CLOSED ORBIT DISTORTIONS AND LINEAR TUNE SHIFTS

Insertion devices, in addition to the intrinsic linear effects induced on the optics, introduce perturbations of the closed orbit due to magnetic field errors. These manifest themselves as non-zero field integrals along the axis of the device. While the first field integral results in an angle perturbation of the closed orbit, the second integral is equivalent to a displacement error. It is therefore of great importance for the operation of a third generation light source to understand and to correct for the first and second field integrals.

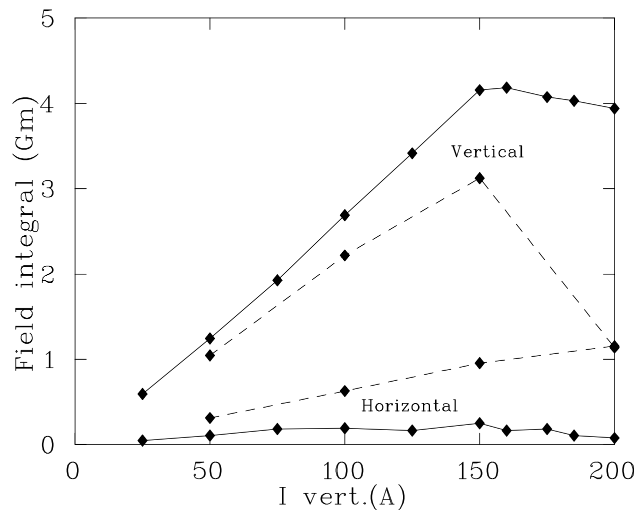

Figure 1: Horizontal and vertical first field integrals measured on the electron beam (solid lines) and in the magnetic measurement laboratory (dotted lines).

Figure 1 illustrates the horizontal and vertical first field integrals obtained by magnetic measurements in the laboratory [2, 4] and those measured on the electron beam as a function of the vertical current I_V. The values measured on the electron beam were obtained via the method described in [5,6], taking into account the measured tunes and assuming the nominal beta functions. It can be observed that there is a good agreement (within 1.0 Gm) in both planes up to the nominal working point of the device. The large discrepancy in the vertical plane at maximum current has not yet been understood.

The effect of the horizontal current on the beam is to produce horizontal and vertical first field integrals within 1.0 and 2.0 Gm respectively for a current variation of ±300 A. The agreement between the first field integrals measured on the beam and in the laboratory as a function of the horizontal current is very good (within 0.5 Gm) in both planes.

Figure 2 shows the horizontal and vertical second field integrals obtained in the laboratory and those measured on the electron beam, referred to the center of the EEW, as a function of the vertical current. It can be seen that the agreement is good within 1.0 and 2.0 Gm^2 in the vertical and horizontal planes respectively. The horizontal and vertical second field integrals induced on the electron beam

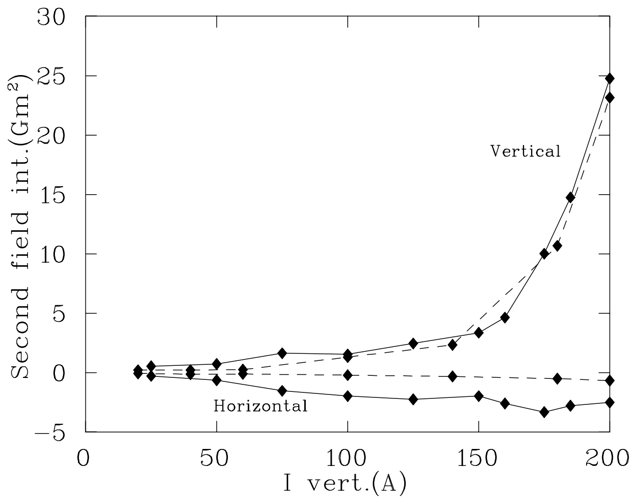

Figure 2: Horizontal and vertical second field integrals measured on the electron beam (solid lines) and in the magnetic measurement laboratory (dotted lines).

by the horizontal current were found to be of about 1.0 and 2.0 Gm^2. The agreement with the magnetic measurements is within the same values as for the vertical current.

Without any compensation scheme for the first and second field integrals, the maximum vertical field (200 A) of the device induces a difference orbit with 280 μm rms horizontally and 16 μm rms vertically. The maximum horizontal field (300 A) instead gives rise to a difference orbit with 122 μm rms horizontally and 19 μm rms vertically.

The EEW, however, is provided with external correction coils designed to compensate for the first and second field integrals of the device and thus to eliminate the distortion generated in the closed orbit. At present a preliminary manual closed orbit correction has been performed in d.c. mode only, which showed that cancellation of the closed orbit errors can be achieved for all possible wiggler field settings. The residual orbit distortions for this preliminary correction was found to be less than 50 μm peak to peak in both planes. A more accurate finding of the settings for the coils using the method described in [6] should further reduce the residual distortion.

As for the linear distortions induced by the device, the major effect is seen on the horizontal tune and it is caused principally by the vertical field. In contrast to other devices with vertical fields, the EEW presents significant transverse variations in both planes [3], giving rise to a stronger linear tune shift in the horizontal plane than in the vertical one, due to the larger beta value at the device location (8.2 m horizontally against the 2.6 m vertically). Figure 3 shows the tune shifts as a function of the square of the maximum on-axis vertical field. The contributions to the tune shifts due to the horizontal field are small (< 0.002). At the nominal working point of the device, the tune shifts are of -0.007 horizontally and 0.002 vertically. The measured data agree very well with the model. A measurement of linear coupling was also performed, with the result that the device does not increase the difference resonance stopband.

3 DYNAMIC APERTURE MEASUREMENTS

Previous computations [7] have always shown reductions in the dynamic aperture when non-planar insertion devices were included into the ELETTRA lattice. The reduction always manifested itself mainly in the horizontal plane due to the presence of non-linear coupling terms, which are absent in the case of planar devices. Thus, it is essential to check the validity of the models used for the computations by measuring the influence of the device on the dynamic aperture and comparing the results with the simulations.

Dynamic aperture measurements were carried out with the wiggler set to its nominal working point and lifetime was recorded as a function of the position of the blades of the horizontal and vertical scrapers in steps of 1 mm. The data for both blades are shown separately. The results are presented under the form of $\ln(\tau^{-1})$ versus $\ln(A^{-2})$, where τ

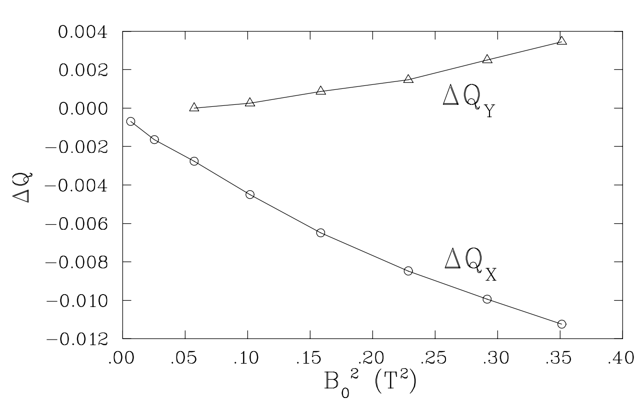

Figure 3: Measured tune shifts as a function of the square of the maximum on-axis vertical field.

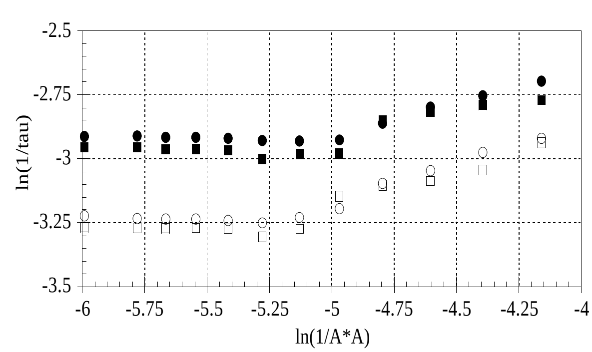

Figure 4: Comparison of the horizontal dynamic aperture measurements between the bare lattice with sextupoles only (white markers) and with the EEW set to its nominal fields (solid markers).

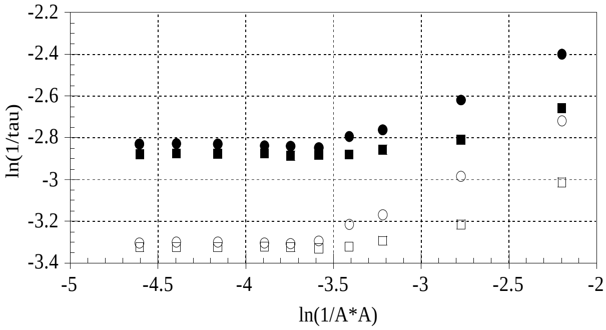

Figure 5: Comparison of the vertical dynamic aperture measurements between the bare lattice with sextupoles only (white markers) and with the EEW set to its nominal fields (solid markers).

is the lifetime in hrs and A is the position of the blade of the scraper in mm.

Figures 4 and 5 illustrate the comparisons of the horizontal and vertical dynamic aperture measurements between the bare lattice with sextupoles only and with the EEW fields set to their nominal values. In the horizontal plane it can be seen that there is a reduction of 1 mm, whereas no reduction is observed in the vertical plane. Simulations using the field model described in [3] and including the physical full aperture of 40 mm in the horizontal plane at the injection point and of 15 mm in the vertical plane at the location of the EEW, agree very well with the measured data, giving a reduction of 2 mm in the horizontal plane and no reduction in the vertical plane. The difference in the values in the lifetime between the case with sextupoles only and with the EEW included was noted only in the first days of operation of the device and is probably due to outgassing.

Figure 6 on the other hand shows the additional effect of the EEW on the horizontal dynamic aperture when all of the existing planar insertion devices are energised. In this case no reduction can be seen.

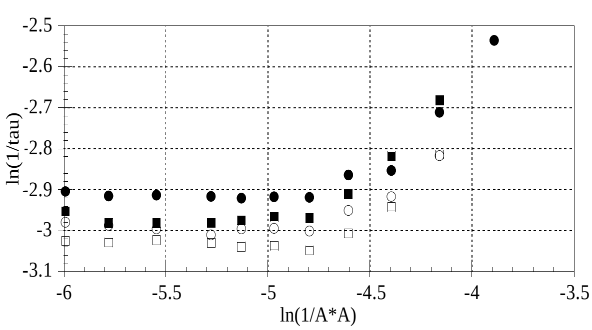

Figure 6: Comparison of the horizontal dynamic aperture measurements between the scenario with all the existing planar devices energised (white markers) and with also the EEW included (solid markers).

4 CONCLUSIONS

The measured effects induced on the electron beam by the electromagnetic elliptical wiggler have been presented and compared with both the magnetic measurements and the model used for simulating the device in optics and non-linear computations. The results show that overall there is a very good agreement. In the near future, the external correction system for the first and second field integrals will be fully calibrated for all current settings of the device in the d.c. mode. Subsequently, the a.c. modes of operation will be commissioned.

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