OPERATION OF INSERTION DEVICES IN ELETTRA AND PLANS FOR FUTURE DEVICES

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Abstract

Recent improvements in the technique used to minimize the effect of undulator gap change on the closed orbit in ELETTRA are presented. Plans for future devices, which include four sections with variable polarization as well as an in-vacuum device, are also summarised.

1 INTRODUCTION

Five insertion devices are presently operational in ELETTRA out of a total number available of 11. The table below summarizes the main parameters of these devices including the maximum field and K value at the operational minimum gap. The four undulators (U) have a pure permanent magnet configuration, while the multipole wiggler (W) is of the hybrid type. Each device except one (ID#7) consists of 3 separate sections based on a standard 1.5 m support structure. The design and construction of the first 3 devices has been presented previously [1-3] and the initial operation was reported in [4]. A sixth device, an electromagnetic elliptical wiggler, is presently under construction [5]. In this article we discuss recent improvements in the technique used to minimize closed orbit effects due to undulator gap changes, as well as plans for future devices.

ID#	Type	N	Gap (mm)	Bo (T)	K
2	U5.6	81	27.0	0.44	2.3
3	U12.5	36	28.0	0.51	5.9
5	W14.0	30	22.0	1.50	19.6
6	U12.5	36	26.0	0.55	6.4
7	U8.0	19	26.0	0.71	5.3

2 CLOSED ORBIT CORRECTION

Each undulator sub-section contains two sets of correction coils, one at either end of the carriage [6]. Each set of 4 coils allows either a horizontal or vertical field to be generated, depending on the inter-connections. In order to compromise on the total number of correction channels, a 4-channel power supply is used for each complete undulator. For the 3-section undulators the 4 channels are connected so as to produce a horizontal field at the entrance and the exit of the complete ID, and a vertical field at the two interfaces between sections. This allows both first and second field integrals to be compensated in both planes, with a local correction of the vertical field component that arises due to the interaction between two sections as a result of the non-unit permeability [7]. The correction capacity is up to 1.2 (1.6) Gm per channel in the horizontal (vertical) plane at 20 mm gap. In the case of the single section undulator full compensation is also possible, however in this case each channel affects both horizontal and vertical planes. The power dissipation for each coil is sufficiently small (< 2 W) to produce negligible temperature rise.

An automatic compensation of the orbit changes due to the undulators has been implemented using the correction coils. Based on a table of values of coil current as a function of gap, the VME crate controlling each ID automatically sets the required currents dynamically during gap changes. Initially the optimum coil settings were determined by manual adjustment of the sum and difference of the two coil currents for each plane, for separate correction of the first and second field integrals respectively. In this way it was possible to reduce the maximum (rms) displacement in the closed orbit at any point in the ring to about 15 μm (8 μm) in both planes.

The limitation of the original method of correction was the drift in the orbit in the time needed to perform the manual correction. Recently significant effort has gone into improving the correction with a view to giving control of ID gaps to the users. To achieve this a special program has been written to automate the correction procedure. In this way the correction is both more accurate and more rapid, thus reducing the effect of orbit drift.

The program works as follows : after recording the orbit at maximum gap, the gap is then brought to the first required value and the coils are calibrated by applying a fixed excitation (1 A) to each set in turn and recording the change in orbit. The required currents to minimize the difference orbit are then obtained using a least-squares method, either separately for the horizontal and vertical planes (ID#2, 3, 6) or for both planes simultaneously (ID#7). The program iterates the correction until a specified level of correction has been reached (2 μm rms). To eliminate non-physical changes that sometimes occur BPM's that indicate a change in difference orbit greater than 2σ are discounted from the calculation.

The new program has allowed the correction to be applied to many more gap values and in a reduced time interval : typically 10 gap values can be corrected in 25 mins. Figure 1 shows the results obtained in two cases, which are typical also of the results obtained with the other devices.

The results that are presently obtained show an rms difference orbit at the level of 2 μm horizontally, 1 μm vertically, roughly a factor of 5 better than previously obtained. The maximum displacement in position and angle at the ID location can be estimated from these values as follows :

$$\frac{\Delta_{\max,\mathrm{ID}}}{\Delta_{\mathrm{rms}}} = \sqrt{\frac{2\beta_{\mathrm{ID}}}{\bar{\beta}_{\mathrm{mon.}}}} \qquad \Delta'_{\max,\mathrm{ID}} = \frac{\Delta_{\max,\mathrm{ID}}}{\beta_{\mathrm{ID}}}$$

where the mean β values at the monitor positions are (9.2, 6.3) m and the β values at the ID location are

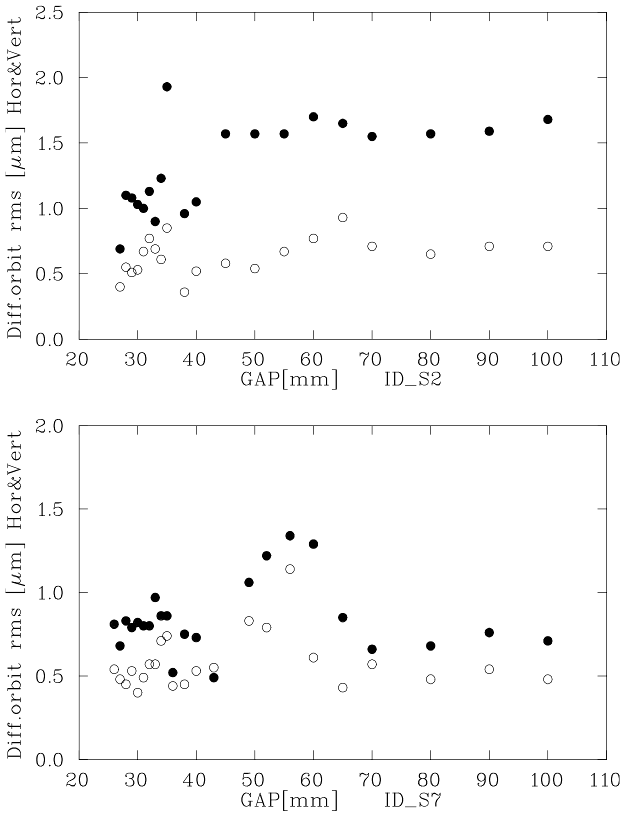

Figure 1. Residual change in orbit (rms) due to gap changes of ID#2 (upper) and ID#7 (lower) after correction coil calibration; solid circles - horizontal plane, open circles - vertical plane.

(8.2, 2.6) m in the horizontal and vertical planes respectively. The table below shows the corresponding maximum displacements and angular deviations at any ID.

ID orbit changes	horiz.	vert.
Δ_{max} (μm)	2.6	0.90
Δ'_{max} (μrad)	0.32	0.35
Δ_{max}/σ (%)	1.1	6.7

Also shown is the ratio of displacement to rms beam size (= ratio of angular deviation to beam divergence) assuming the natural horizontal emittance of 7 10^{-9} m rad and the estimated 1 % coupling. The present correction accuracy should therefore be sufficient to allow user control of the ID gaps.

3 PLANS FOR FUTURE DEVICES

A number of new beamlines are being planned for ELETTRA following a recent call for proposals by the CNR (National Research Council) and INFM (National Institute for the Physics of Materials) funding bodies. At the present time two new beamlines involving insertion devices have been approved for construction by INFM and Sincrotrone Trieste, and others may be approved in due course. Here we give preliminary details of these two devices, together with one of the other proposals for an in-vacuum undulator.

3.1 Variably polarized undulators

Two separate beamlines are proposed for advanced dichroism and photoemission studies both of which require circularly polarized as well as linearly polarized radiation. Both beamlines are designed to cover a wide photon energy range, one from 35 eV to 1.5 keV, the other from 10 eV to 2 keV. To cover such a wide range requires the use of two undulators with different period lengths in each case.

	EU4.6	EU6.0	EU7.6	EU12.5
Period (mm)	46	60	76	125
No. periods	47	36	28	17
Length (m)	2.162	2.160	2.128	2.125
K_{max} - vertical	2.4	4.2	6.3	8.8
- horizontal	1.4	2.8	4.5	6.9
- helical	1.2	2.3	3.6	5.4

A preliminary optimization of parameters has been carried out based on the APPLE-II structure [8] resulting in the values shown in the table above. Two magnets of length in the range 2.1 - 2.2 m can be accommodated in the straight section allowing sufficient margin for longitudinal displacement of the magnet arrays. A minimum gap of 18 mm is assumed for the first three devices based on a new vacuum chamber design [9]. In the case of EU12.5 a longer period and lower field than could be achieved were chosen in order to reduce the radiation opening angle and hence power loading problems.

Figure 2 shows the performance of the two pairs of devices in the circular polarization mode. For each photon energy the magnet gap and longitudinal phase have been adjusted to maximize the product of total flux and the square of the degree of circular polarization, calculated using the usual analytic approximations. Two new features can be seen with respect to standard undulator tuning curves. Firstly, the circular polarized flux drops off rapidly at low photon energies, reflecting the fact that the highest field, and hence lowest photon energies, are obtained in the linearly polarized mode. Secondly, there is a much reduced figure-of-merit for the higher harmonics compared to the fundamental, since the flux is zero for pure circular polarization, and maximum for pure linear polarization.

A particular aspect of the implementation of these devices that is presently under study is the problem of the heat load on the downstream bending magnet vacuum chamber. The large vertical divergence of the radiation means that a significant radiation power can be intercepted on the walls of the 10 mm high slot, 6.2 m downstream from the ID centre, particularly in the case of the longer period and higher K value devices. Finite element calculations show that temperatures in excess of 500 ^{o}C could be experienced (2 GeV, 400 mA) in the worst cases (EU7.6 and EU12.5) with the present method of external cooling, which is however adequate both for the present linear devices and the elliptical wiggler. Two solutions to the problem are being investigated in parallel: improving

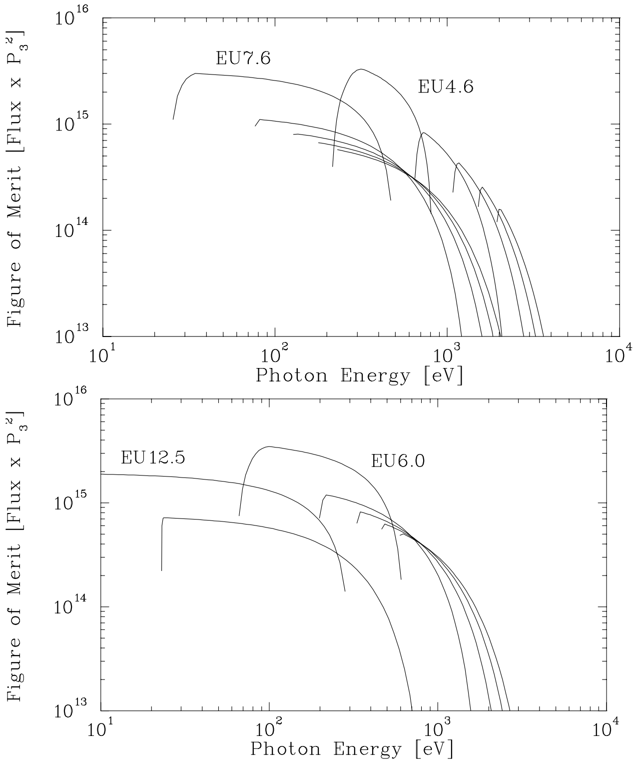

Figure 2. Performance of the proposed elliptical undulators in the circular polarization mode (2 GeV, 0.4 A).

the cooling of the existing chamber and design of a new Al chamber with integral cooling. Initial calculations show that the latter solution would eliminate completely the problem, whereas in the former case it may be necessary to relax the magnetic parameters somewhat by choosing a slightly longer period and hence smaller field value than those given in the table.

In the case of the lowest photon energy device (EU12.5) there is strong interest in the possibility of removing the rational harmonics in the linearly polarized mode. Accordingly we have made some preliminary studies [10] of a version of the APPLE-II structure which contains quasi-periodic arrays both of the type introduced in [11] as well as a new type based on a conventional 4-block per period pure permanent magnet device with vertical block displacements. The initial conclusion of this work is that it seems feasible to generate variably polarized radiation with a quasi-periodic spectrum in this way. Further calculations for a specific design will be made in due course.

3.2 In-vacuum undulator

In order to satisfy the needs of some experimenters for high brightness radiation at higher photon energies than presently available at ELETTRA a short period

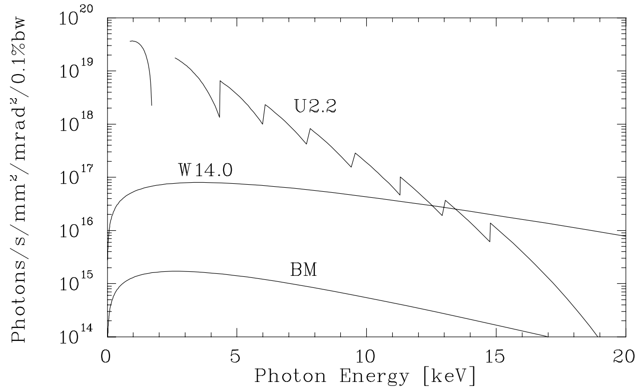

Figure 3. Performance of a mini-gap undulator in ELETTRA (2 GeV, 0.4 A, $\varepsilon_X = 7\ 10^{-9}$ m rad, $\kappa = 1$ %).

device is being studied. The in-vacuum technology is considered the most appropriate in the present case and tentative parameters for such a device are an operational gap of 7 mm, period length of 22 mm, K = 1.4, N = 136, length = 3 m. The predicted brightness of such a device is shown in fig. 3 compared to that of the W14.0 multipole wiggler at 20 mm gap (1.6 T) and a bending magnet source. The undulator brightness has been computed using the URGENT program, and includes the nominal electron beam emittances and energy spread. It can be seen that such a source would give 100 times higher brightness at 5 keV, and 6 times at 10 keV, compared to the existing multipole wiggler, and 400-3000 times higher than a bending magnet.

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