DEVELOPMENT OF ELLIPTICAL UNDULATORS FOR ELETTRA

B.Diviacco[#], R. Bracco, D. Millo, R.P. Walker, M. Zalateu, D. Zangrando
Sincrotrone Trieste, Italy

Abstract

ELETTRA is presently operating six insertion devices, including an electromagnetic elliptical wiggler. Stimulated by the increasing interest in variable polarization sources, a series of new elliptical undulators has been designed to provide linear, circular and elliptical polarization in a wide spectral range. One of them will feature a quasi-periodic field in order to reduce contamination from high order harmonics. A chicane arrangement is foreseen in one straight section of the ring so that two experimental stations can be operated simultaneously. Two identical undulator segments, together with a phase modulation electromagnet, will be used in an optical klystron configuration for the storage ring FEL project. We present the construction, testing and magnetic measurement results of the first undulator of this kind (EU6.0). Progress with the other devices is also described.

1 INTRODUCTION

Six variable polarization undulators are presently under construction, whose main parameters are listed in Table 1 below. For the 60 mm period device (EU6.0) the actually measured field strengths are shown, which agree well with the initial design values [1].

Table 1: Field strength and K values of the new undulators

period (mm)	Np	Horizontal Polarization		Circular Polarization		Vertical Polarization	
		B_0	K	B_0	K	B_0	K
48	44	0.57	2.58	0.29	1.30	0.33	1.51
60	36	0.78	4.41	0.42	2.39	0.51	2.87
77	28	0.91	6.56	0.53	3.85	0.65	4.69
100	20	1.01	9.45	0.63	5.85	0.78	7.27
125	17	0.78	9.06	0.47	5.48	0.60	7.04

All the undulators are of the APPLE type [2], consisting of four arrays of permanent magnets, two of which can be longitudinally shifted in order to change the polarization state.

2 EU6.0 UNDULATOR

The undulator was originally assembled on a modified support structure equipped with two translation units for the polarization control. Initial measurements showed significant deflection of the supporting arrays, due to the large forces acting between the adjacent row of magnets. For this reason the I-beams were locally stiffened to reduce their deformation under magnetic load. The undulator was finally re-assembled in January this year. The measured magnetic field in the horizontal, circular and vertical polarization modes is shown in Figure 1.

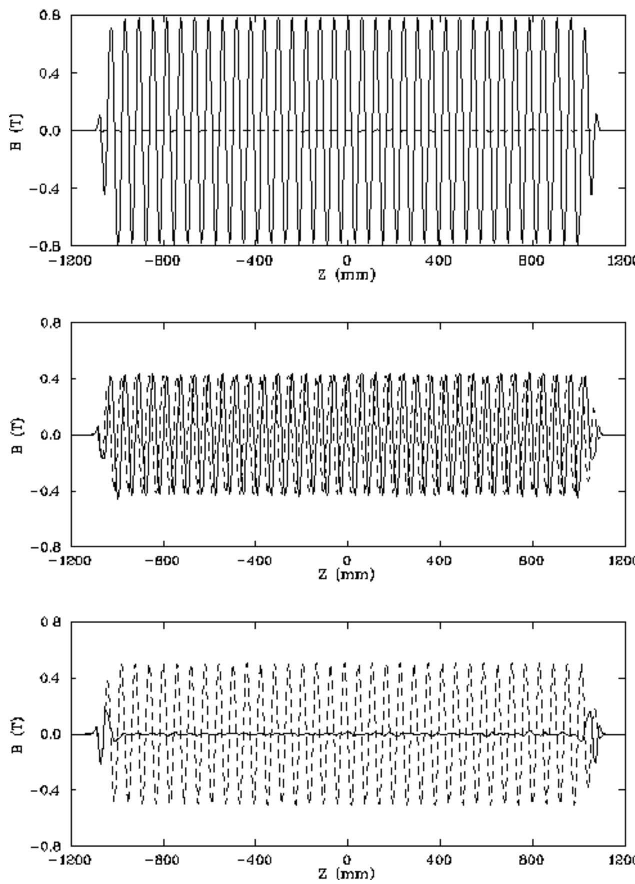

Figure 1: Measured field distribution at 19 mm gap in the horizontal (upper), circular (middle) and vertical (lower) polarization modes. Solid line = By, dotted line = Bx.

The peak field variation with gap and phase was found to be in good agreement with model calculations (see Figure 2) taking into account the actual shape of the blocks and the effect of non unit permeability of the magnetic material.

[#] Email: diviacco@elettra.trieste.it

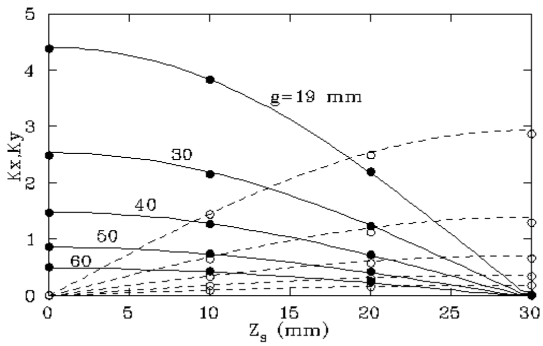

Figure 2: Measured (dots) and computed (lines) deflection parameters as a function of gap (g) and phase (Z_S). Solid lines = K_Y, dotted lines = K_X.

The transverse field distribution, as predicted by model calculations, showed a significant reduction of Bx off-axis (Figure 3). The poor homogeneity of the field introduces new problems, compared to the conventional vertical field undulators, with implications for the magnetic measurements (alignment of the measuring probes) and for the proper installation of the magnet in the storage ring (alignment with the electron beam).

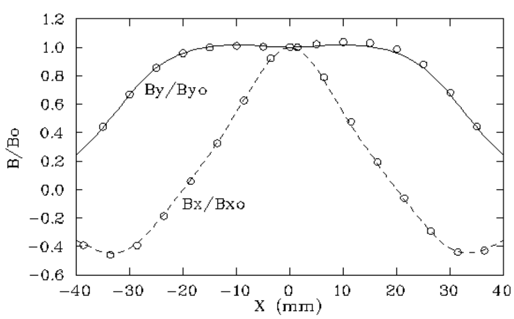

Figure 3: Measured (dots) and computed (lines) transverse field profiles.

The measured first field integrals showed a significant variation of Iy with the phase (see Figure 4), larger than for the 7-period prototype assembled last year [1]. The reason for this discrepancy is not presently understood; however, a set of correction coils placed at both ends of the device will provide compensation of the field integrals at any gap and phase.

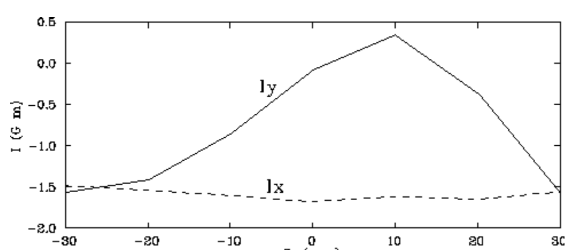

Figure 4: Measured variation of field integrals with phase at 19 mm gap, without any correction.

Multipole errors were dominated by a phase-independent integrated quadrupole of about 300 G. Attempts to use the conventional shimming method [3] to reduce it failed because of the strong dependence of the shimming effect on the phasing of the arrays. An alternative method was therefore developed, based on selective vertical displacements of a few magnetic blocks. The effect on the field integral is in this case phase-independent and could be used to effectively remove the quadrupole error. Figure 5 shows the vertical field integral distribution before and after the correction. A total of 4 blocks were moved by between 0.2 and 0.3 mm, with a corresponding reduction in useful magnetic gap of only 0.6 mm.

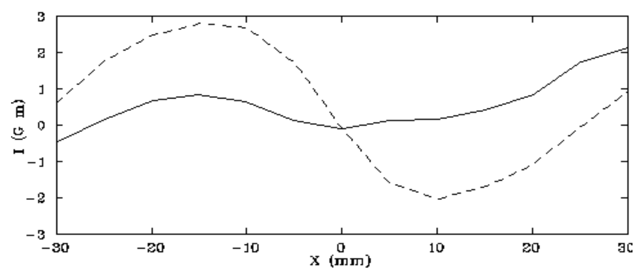

Figure 5: Measured vertical field integral distribution before (dotted line) and after correction (solid) (gap=19 mm, Δ=0).

Simultaneous reduction of the first and second horizontal field integrals was also achieved by this procedure, as can be seen in Figure 6, which shows the electron trajectory before and after the block displacement was applied.

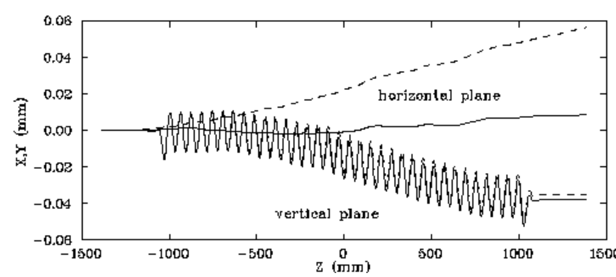

Figure 6: Computed electron trajectory before (dotted line) and after correction (solid) (gap =19 mm, Z_S =0, E=2 GeV).

The residual multipole errors, obtained by a polynomial fit of the transverse distribution of Ix and Iy over a range of ±20 mm, are shown in Table 2. The skew quadrupole component is difficult to correct with the methods described above, however its magnitude is within the maximum tolerable value specified for the ELETTRA insertion devices. Note how the errors decrease rapidly with the gap, possibly an indication of inhomogeneity of magnetization which becomes less important when the distance from the blocks is increased.

Table 2: Measured normal (N) and skew (S) integrated quadrupole and sextupole errors after correction

gap (mm)	Z_S (mm)	Q_S (G)	S_S (G/cm)	Q_N (G)	S_N (G/cm)
19	-20	-129	-9	13	206
19	-10	-105	-40	-34	150
19	0	-61	-67	-15	90
19	10	-50	-71	43	57
19	20	-104	-47	76	139
30	0	-51	-14	-7	26
50	0	-33	13	1	-1

The uncorrected rms optical phase error is shown in Table 3. Spectral performance deteriorates rapidly as we move away from the horizontal polarization mode, with a 5th harmonic reduced to 45% of the ideal intensity in the worst case.

Table 3: Rms phase error in different polarization modes at 19 mm gap, before and after phase error correction

Z_S (mm)	polarization mode	σ_Φ (°) before shimming	σ_Φ (°) after shimming
-20	circular	6.0	4.9
-10	elliptical	4.6	4.2
0	horizontal	4.5	2.3
10	elliptical	7.2	2.6
20	circular	10.0	4.8

The conventional phase shimming technique was not applicable in this case. The usual distinction between V and H shims [4] is complicated by the fact that in both types a field integral is generated which changes with the phasing between the arrays. Therefore a new method was developed, in which the basic shimming unit consists of 4 shims placed on two consecutive horizontally magnetized blocks (see Figure 7). In this way the net effect on the field integral is cancelled within the unit, and the remaining effect is a step change of the optical phase function.

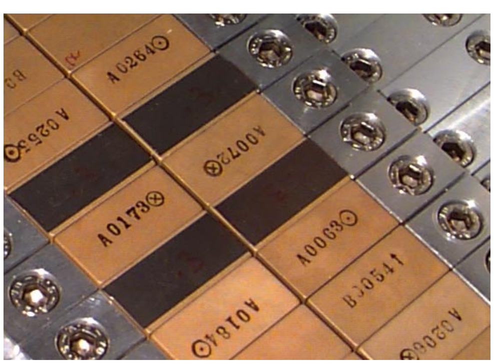

Figure 7: Shimming unit used for phase error reduction

A further complication is that, due to the varying field distribution across the shims, they move on the surface of the magnets as the phasing reaches one half-period (vertical polarization mode). For this reason the shims will be permanently glued in their final position by means of a thin layer of epoxy resin.

As usual, a simulated annealing algorithm is used to find the optimal position and thickness of the shims. The resulting rms phase error, after applying 9 shimming units of thickness between 0.2 and 0.4 mm, is shown in the last column of Table 3. Improvement is significant, bringing 5th harmonic intensity to not less than 85% of the ideal value. As expected, no change is introduced on the first field integral distributions.

3 FUTURE DEVELOPMENTS

Based on the positive results obtained in the correction of the quadrupole error of the EU6.0 undulator, a new block holder (See Figure 8) has been designed for the next devices, which will allow both horizontal and vertical displacement of the blocks from their nominal position, with increased potential for multipole error control.

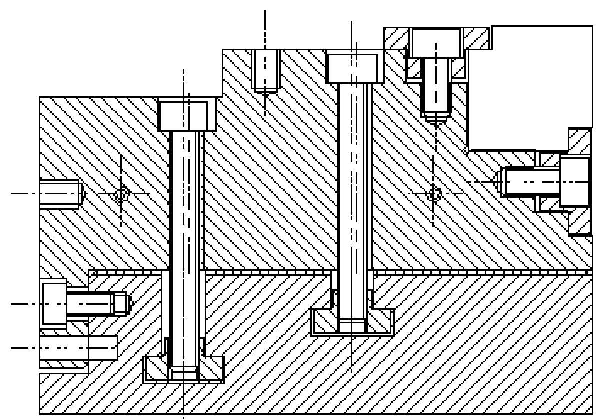

Figure 8: Block holder for the EU12.5 undulator.

At present the magnetic blocks for the EU12.5 and EU10.0 undulators are in the final manufacturing stage; the support structures are also under construction and assembly of the next magnet is due to start in a few months.

4 REFERENCES

[1] B.Diviacco et al., proc. European Particle Accelerator Conference, Stockholm, 22-26 June 1998

[2] S. Sasaki, Nucl. Instr. and Meth. in Phys. Res. A 347 (1994) 83-86

[3] J.Chavanne et al., ESRF Internal Report SR/ID-89-27 (1989)

[4] B.Diviacco, R.P.Walker, Nucl. Instr. Meth. in Phys. Res. A 368 (1996) 522-532