CONSTRUCTION OF ELLIPTICAL UNDULATORS FOR ELETTRA

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Abstract

The construction of a series of six new undulators for ELETTRA is underway. Each device is optimized for a different photon energy range and can provide linear, circular and elliptically polarized radiation. One of the magnets will use a novel quasi periodic structure in order to reduce the contamination from high order spectral harmonics. We present the status of the magnetic design, and the results of magnetic tests on a short prototype of a 6 cm period device.

1 INTRODUCTION

The three new beamlines presently under design and construction for ELETTRA will take significant advantage from the flexibility offered by variable polarization undulators. For this reason, the APPLE type device [1] was chosen for the magnetic structure of the next series of undulators to be built for our facility [2]. Table 1 gives the main design parameters of the devices for a magnetic gap of 19 mm.

Table 1: Main parameters of the new undulators

period (mm)	Np	Horizontal Polarization		Circular Polarization		Vertical Polarization	
		B_0	ε_1	B_0	ε_1	B_0	ε_1
46	48	0.54	224	0.28	344	0.32	426
60	36	0.77	62	0.43	93	0.51	123
76	29	0.86	25	0.50	37	0.61	49
100	21	1.05	8	0.66	10	0.83	12
125	17	0.78	8	0.48	10	0.63	12

The 60 mm period undulator (EU6.0) is presently under construction, and is described in some detail in section 2. First results obtained on a short prototype are given in section 3. The 125 mm period undulator (EU12.5) is in an advanced design phase, and its predicted performance is illustrated in section 4. These two magnets will be placed in the same straight section. Simultaneous use of the two sources is made possible by a chicane-like steering of the electron beam. For this reason a small dipole electromagnet will be placed between the two undulators, producing a 2 mrad deflection angle. EU4.6 and EU7.6 will be also accommodated in a single straight section, but no chicane is foreseen in this case. Finally, the two EU10.0 devices will be used for a combined SR beamline plus storage ring FEL experiment, with the possibility of adding a modulator magnet between the two modules in order to implement an optical klystron system.

2 EU6.0 UNDULATOR

The magnet structure consists of four rows of permanent magnets, two of which can be shifted longitudinally with respect to the other two. The magnet blocks are cut on two opposite edges and clamped onto individual holders, which in turn are attached to four base plates by pins and bolts (see figure 1). A small horizontal separation of 1 mm is left between the arrays to allow for the translation while marginally affecting the magnetic field. Square cross section blocks are used in order to reduce the number of different block types required in the structure.

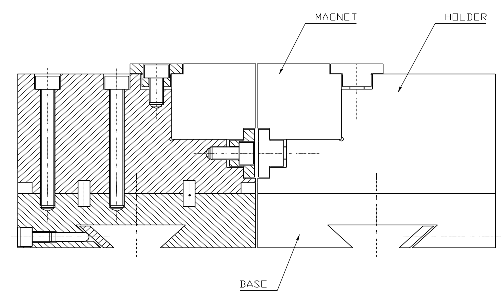

Figure 1: Cross section of the two lower arrays showing the mechanical clamping system of the magnet blocks.

A new kind of termination has been developed which, in addition to producing a displacement-free trajectory, has a reduced fringe field level compared to the standard scheme. The chosen solution (see figure 2) uses half size blocks of only two types (horizontally and vertically magnetized).

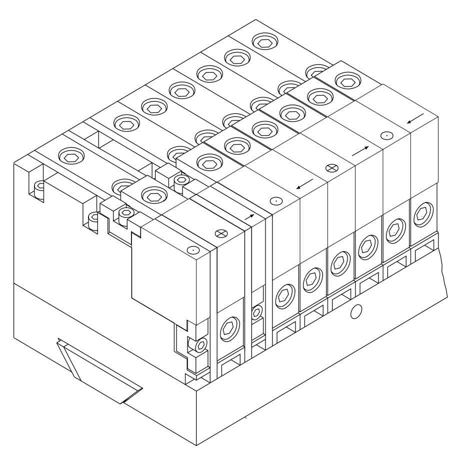

Figure 2: Termination of one magnet array, using half size horizontally and vertically magnetized blocks.

A total of 652 NdFeB blocks (Neomax-44H) has been purchased from Sumitomo Special Metals Co., having an average remanent field of 1.33 T. Dimensions are 35 x 35 x 15 mm for the full size blocks. The magnetization vector of each block has been measured after delivery with a Helmholtz coil system in a temperature stabilized environment. Results show a maximum variation of ±0.5% in magnetization strength and ±0.7° in angle. Homogeneity of the magnetization was found to be good, giving a typical difference in field at 10 mm above and below two opposite faces of each blocks of 0.5%.

Based on magnetization data, an optimization of the magnetic field quality is performed by appropriately selecting and sorting the magnet blocks within the structure. A simulated annealing algorithm is used to minimize a merit function which includes rms optical phase error as well as first and second field integral multipoles.

3 EU6.0 PROTOTYPE RESULTS

To gain some experience with the new undulator scheme, a short seven period prototype has been constructed and tested (see figure 3). Correct termination is included on both ends.

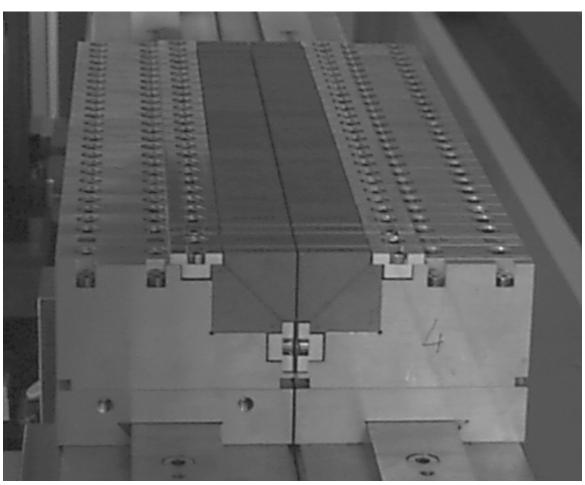

Figure 3: Lower half of the undulator prototype.

The prototype has been mounted on the final support structure (see section 5) and characterized using our new combined Hall plate and flipping coil measuring bench [3]. The main results are listed in the table below. All of the following results were obtained at a gap of 19 mm without any field correction.

Table 2: Measured performance of the prototype undulator

Phase (mm)	Pol. mode	Bo (T)	Phase Error (deg)	Ix (G m)	Iy (G m)
0	Horizontal	0.79	1.9	-0.36	0.07
19	Circular	0.43	2.3	-0.52	-0.23
30	Vertical	0.51	1.9	-0.47	-0.99

It can be seen that the design field has been exceeded and that the phase error and field integral values are small. Figure 4 shows the measured field in the linear and circular polarization modes.

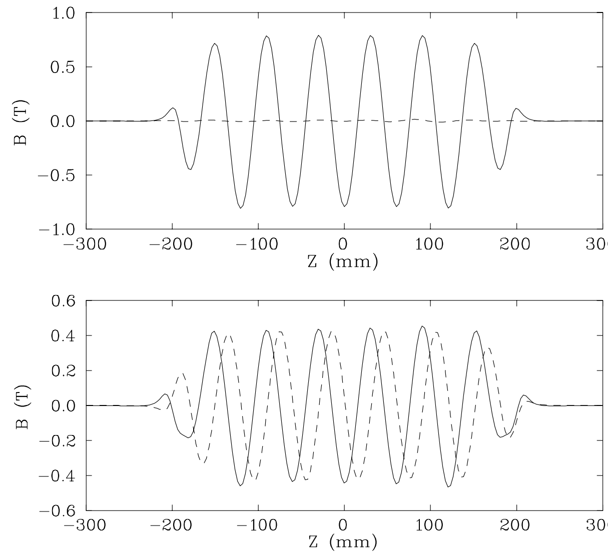

Figure 4: Measured field distribution at 19 mm gap in the linear (upper graph) and circular (lower graph) polarization modes. Solid line = By, dotted line = Bx.

The computed trajectory is shown in figure 5 for the circular mode. Note that displacement free oscillation occurs in both the horizontal and the vertical plane.

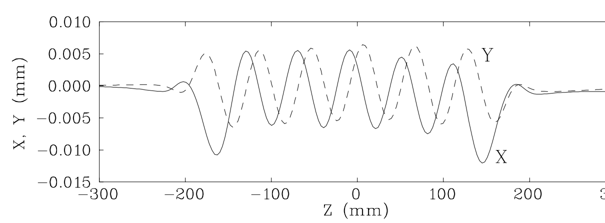

Figure 5: Computed 2 GeV electron trajectory (gap = 19 mm, circular polarization mode).

The transverse variation of the first field integrals (figure 6) is contained within ±1 Gm relative to the centre value over a distance of ±20 mm at all gaps.

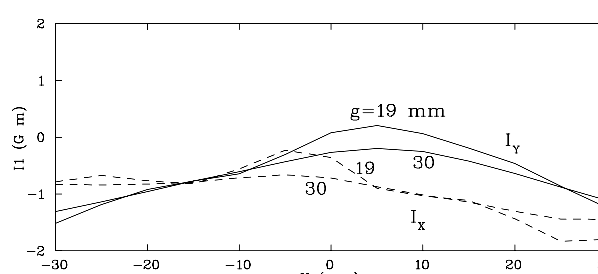

Figure 6: Transverse distribution of the field integrals at two different gap settings in the linear polarization mode.

A variation of the vertical field integral occurs when changing the polarization mode. This can explained as the effect of non unit permeability of the magnetic material, as shown in figure 7 where the measured variation is compared with a calculation assuming typical permeability for NdFeB of 1.06 and 1.15 in the two orthogonal directions.

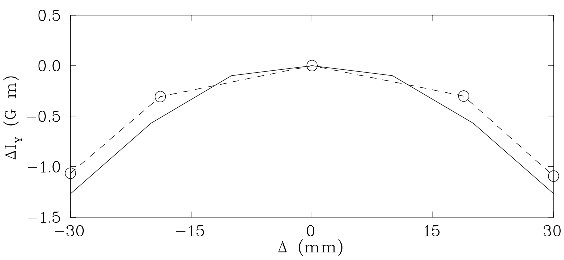

Figure 7: On-axis field integral as a function of the phase Δ at 19 mm gap. Solid line = computed, dotted line = measured.

4 EU12.5 UNDULATOR

This undulator is designed to provide a high flux of photons in the 10-70 eV spectral interval. A special requirement for this device is to limit as much as possible the contamination coming from high order harmonics which are difficult to filter by optical methods. A modification of the original quasi-periodic structure [4] has therefore been developed, in which the period is maintained constant while the field amplitude is modulated along the length of the device by selectively removing a few of the horizontally magnetized blocks (see figure 8). This has the effect of reducing the field on the two adjacent poles. The sequence which specify the blocks to be removed is generated according to a modified prescription compared to the conventional quasi periodic undulator [5,6].

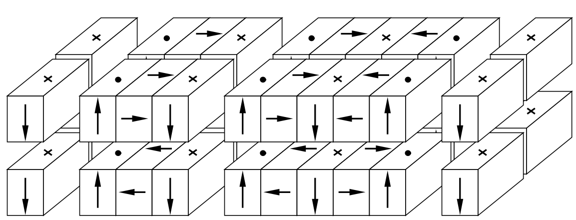

Figure 8: Schematic of the new variable polarization quasi-periodic undulator.

The new structure is simple to implement, requiring no modifications to the standard block holders. Figure 9 shows the computed spectra in the linear and circular polarization modes. It can be seen that flux at integral multiples of the fundamental are significantly reduced. In particular the intensity of the second, third and fourth harmonics, which occur in a wavelength range in which optical rejection is very poor, are below 10% of the fundamental peak. It should be noted that performance remains good also in the circular and elliptical polarization modes.

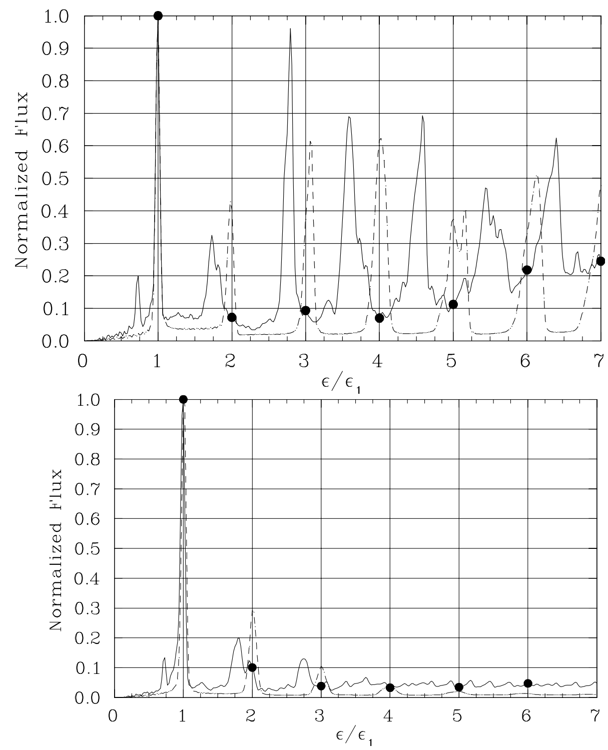

Figure 9: Computed EU12.5 spectra with the fundamental at 10 eV in the linear (upper) and circular (lower) polarization modes. The 0.7 x 0.7 mrad angular acceptance is included in the calculation. The result for the periodic case is shown as a dotted line.

5 SUPPORT STRUCTURE

A new support structure has been designed and constructed according to our specification by EOTECH S.r.l. The C-shaped structure is based on the design used for all 13 presently installed modules but with an increased length to accommodate the change from 3 to 2 ID modules per straight section and the inclusion of longitudinal motion on two arrays. Between the 2 m long stainless-steel I-beams and magnetic arrays two Al base plates are used, with a length that can be adjusted for each ID type, 2.15 m for EU 6.0. The longitudinal motion is performed using dc motors and linear encoders, and is integrated into the same control system as for the gap control.

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