DESIGN OF TWO VARIABLE POLARIZATION UNDULATORS FOR THE ALBA PROJECT

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Abstract

This paper summarizes the main aspects of the magnetic, mechanical and control system design of two APPLE-II type undulators presently under construction in the framework of a collaboration between CELLS and Sincrotrone Trieste.

INTRODUCTION

Two variable polarization undulators with a period of 71 and 62 mm have been designed and are under construction. These undulators will be of the APPLE-II type, providing elliptical as well as rotatable linear polarization in the Soft X-Ray spectral domain (down to 99 eV in horizontal polarization for EU62 and 80 eV in circular polarization for EU71).

MAGNETIC DESIGN

The period length and the transverse block dimensions of the undulators were chosen to cover the required tuning range while maintaining the magnetic forces below safe limits [1]. The end sections comprise one full-size and two half-size blocks with optimised longitudinal spacing in order to limit the variation of field integrals while changing the gap and the phase. As a precaution against accidental demagnetization caused by electron beam losses, a high coercivity grade of NdFeB was chosen for the magnetic material. The main geometrical and magnetic parameters of the two devices are summarized in Table 1.

Table 1: Main parameters of the two undulators

Device	EU62	EU71
Period length λ_0	62.36 mm	71.36 mm
Number of periods	27	22
Maximum horizontal field	0.62 T	0.70 T
Maximum vertical field	0.87 T	0.93 T
Magnetic Material	VACODYM 655 TP	
Intrinsic Coercivity H_{CJ}	21 ÷ 24 kOe	
Remanence B_R	1.22 ÷ 1.26 T	
Transverse block size	32 x 32 mm	
Minimum vertical gap	15.5 mm	
Horizontal transverse blocks separation	1 mm	

MECHANICAL DESIGN

The mechanical design proposed for the two AppleII Undulators for ALBA-CELLS, is based on a similar construction made for SOLEIL - France [2]. Figure 1 shows the front and rear views of the complete undulator. Figure 2 shows a detail of the end-section with the magnet arrays. The model was developed using Solidworks [3].

Both undulators will have solid stainless steel beams (AISI 316L) with a length of about 1.8 m, since their magnetic length is similar for the two devices (1.66 m for EU71 and 1.77 m for EU62). The selected length also takes into account the space required by two magic finger holders (about 14 mm on each side). The stainless steel beam construction does not foresee any welding. The specified planarity of the surface supporting the magnet arrays is 0.02 mm. Each backing beam with magnets and holders will weight about 11 kN, and the overall weight of the undulator is about 35 kN.

The mechanical design was optimised taking into account both magnetic forces and beam weight. These undulators will also be used to produce skew linear polarization, so they will operate in the so-called anti-parallel mode, where the two movable arrays are displaced longitudinally in opposite directions. In this mode additional longitudinal forces are present. Table 2 shows the maximum magnetic forces at minimum gap (15.5 mm) for the worst case (EU71).

Table 2: Maximum magnetic forces (in kN) acting on the magnet arrays at minimum gap of 15.5 mm for EU71 (P-Parallel mode, AP-Anti-parallel mode)

	Fixed Array		Mobile Array		Mobile+Fixed Array	
	P	AP	P	AP	P	AP
Transv.	11.5	11.5	11.5	11.5	0	3
Longitud.	1.6	13	1.6	3	0	13
Vertical	8.5	8.5	8.5	8.5	17	17

The deformation of the backing beams, the supporting brackets and the frame induced by the magnetic forces were simulated by the 3D FEM analysis code ANSYS [4]. The transverse deformation in parallel mode at minimum gap, calculated with a margin of about 30% with respect to the computed forces is shown in figure 3: the maximum observed value is 4 μm. In the vertical plane a maximum value of 7μm was calculated.

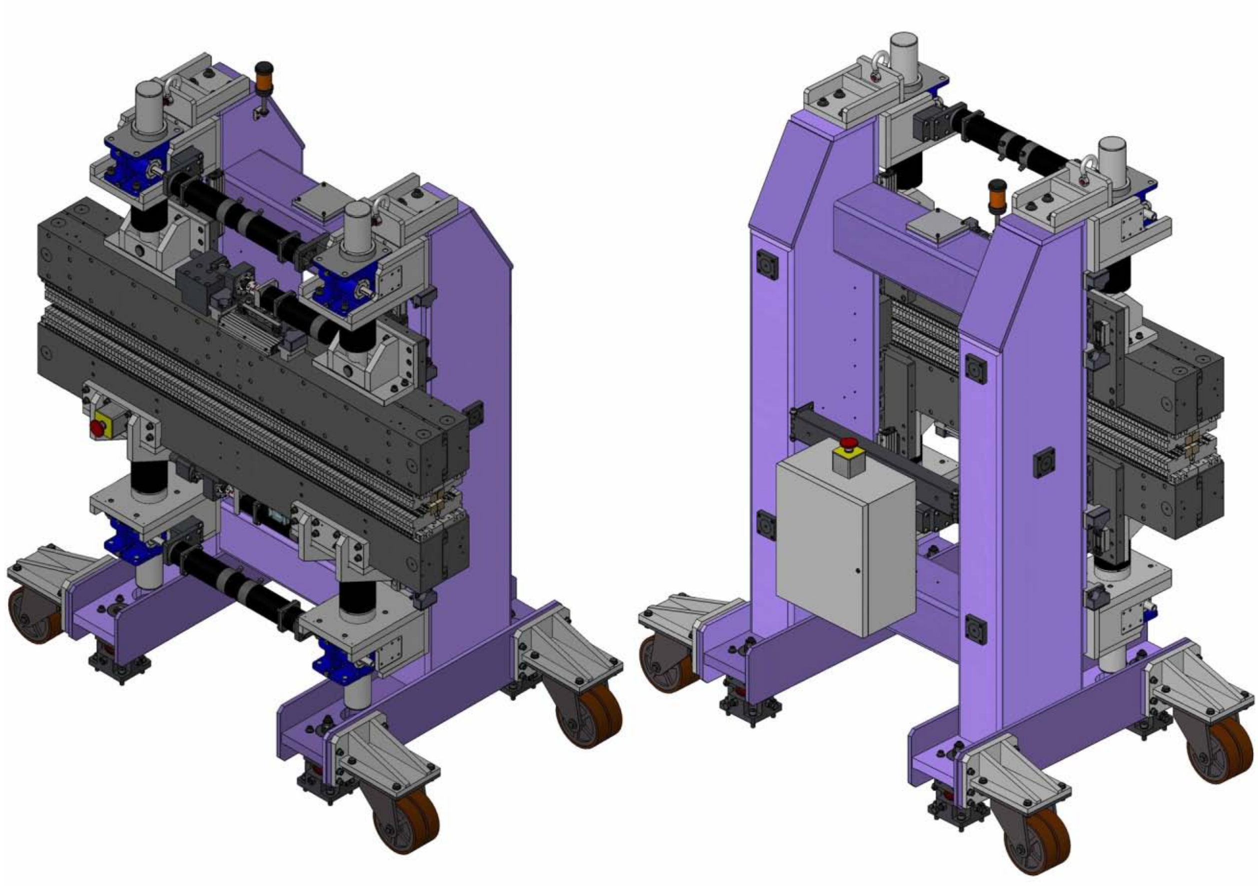

Figure 1: Front and rear views of the Apple II undulator.

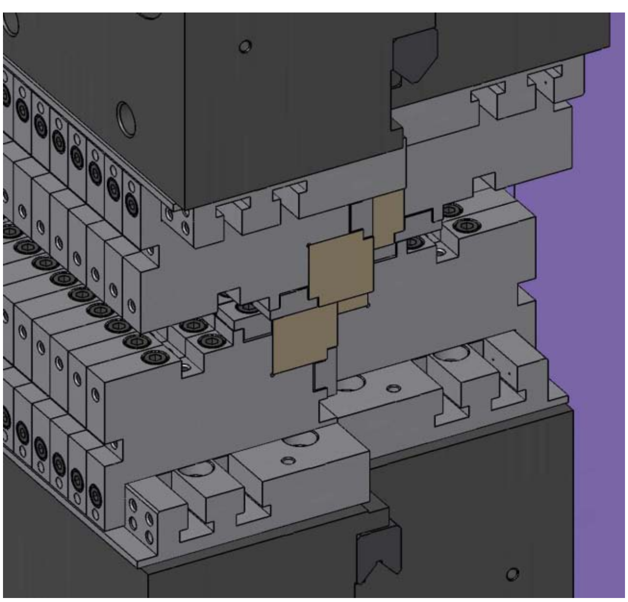

Figure 2: Undulator end-section showing the linear rails for the phase movement, magnets, holders and backing beams

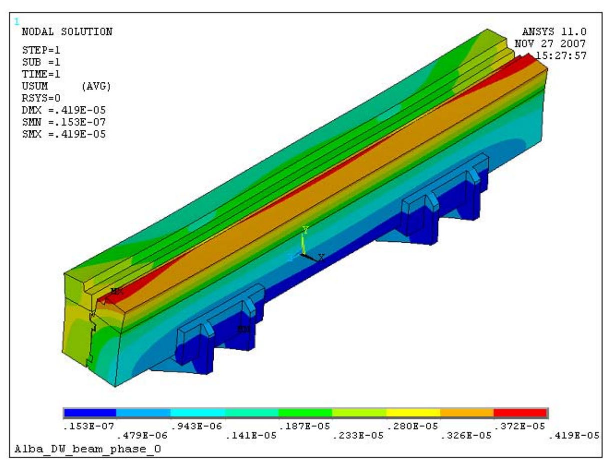

Figure 3: Stainless steel beam deformation due to a transverse force of 16 kN. Blue parts are fixed and red parts show a deformation of 4 microns maximum.

In figure 4 the vertical deformation of the frame with the phase set to zero (vertical magnetic field) is showed: the maximum value of about 0.2 mm on the upper brackets is visible (blue). This large error can be easily compensated reading the encoders and by a beam positioning adjustment.

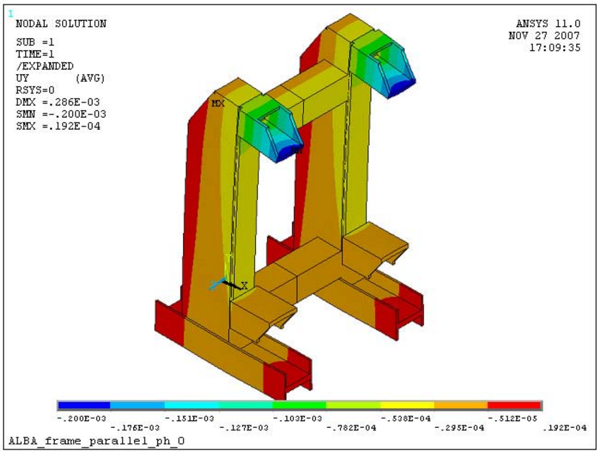

Figure 4: Vertical frame deformation with an attraction force of 34 kN (14 kN) applied on upper (lower) brackets. Red parts are fixed and blue parts show a deformation of 0.2 mm maximum

CONTROL SYSTEM

The control system is based on Tango software. Tango has first been developed at ESRF and now it is a collaboration between five institutes: CELLS, ELETTRA, ESRF, Soleil and Desy.[5].

The control of the motors is carried out via the Icepap motor controller, a new device developed at ESRF implementing a wide range of capabilities [6]. CELLS has selected Icepap as a standard for motor controller for beamlines as well as accelerators.

In the Apple-II application, six Phytron ZSH88 stepper motors, with 200 steps/revolution and six absolute encoders LT-140-S from TR electronics, with a resolution of 0.1 microns, are controlled. For each motor, an additional incremental rotary encoder can be read, just in case. Motors are provided with brakes, acting as safety actuators to prevent any movement without commanding.

The control is done via an industrial PC running Tango over a Linux platform, acting as input-output controller (IOC). Communication between IOC and the Icepap is made via Ethernet. The IOC also controls the power supplies of four correction coils installed at the ends of each girder.

Interlocking is carried out by twelve limit switches connected to the Icepap controller, to limit the travel of the girders. Twelve additional limit switches act as safety interlocks, and disable the power of the Icepap if they are overpassed. These additional switches (kill switches) are controlled via a PLC. In order to avoid dangerous taper angles, two inclinometers are also managed by the PLC. Motors have Pt1000 thermal sensors implemented in order to monitor the motor temperature. They are connected also to PLC which disables the Icepap in case an over-temperature is detected in any motor.

With respect to the control, Tango allows the definition of pseudo-motors in such a way that the user can directly drive the gap, the taper and the phase positions of the system, with a synchronous and symmetric movement of the six motors, despite each one of the six motors and encoders are totally independent from hardware point of view. The IOC, the motor controller and the PLC are connected to the network via ethernet, acting in fact as a fieldbus. Graphical user interface (figure 5) can run in the control room or in the beamline.

In order to test the control system, a full prototype including motors, encoders and interlocks has been built at CELLS.

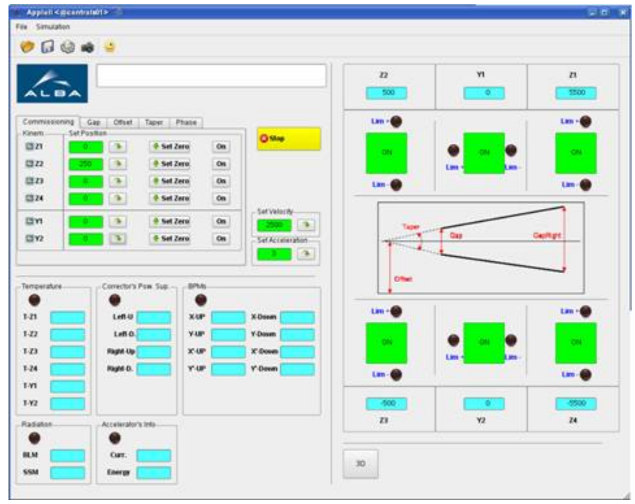

Figure 5: Screen shot of the GUI of the Tango application controlling the undulator.

CONCLUSION

The mechanical components of both undulators are now under construction. The mechanical assembly of the first Apple-II device will start this August and the first undulator will be ready at the beginning of the next year. We foresee about 3 month for the magnet assembly and magnetic field optimisation (shimming). The second one should be ready to be delivered to CELL in the spring of next year.

REFERENCES

[1] J. Campmany, Z. Martì, *Conceptual Design of APPLE-II devices for PEEM and XMCD beamlines at ALBA*, ALBA Project Document AAD-SR-ID-AN-0141; Z. Martì, Period of Apple II undulators for CELLS (third approach), ALBA Project Document AAD-SR-ID-AN-0076.

[2] B.Diviacco et al., “Design, Construction and Field Characterization of a Variable Polarization Undulator for SOLEIL”, PAC 2005, Knoxville, Tennesse, USA, p.4242.

[3] http://www.solidworks.com.

[4] http://www.ansys.com.

[5] http://www.tango-controls.org/

[6] http://www.esrf.eu/UsersAndScience/Experiments/TBS/InstrumentSupport/ISGUnits/ControlElectronics/ceudevel/icepap.