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SPECIAL ELETTRA CORRECTOR MAGNETS

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Abstract

To fully control the beam position source point for the dipole beam lines additional correctors are needed. The space available however is minimal and no alternative solution (e.g. additional coils on quadrupoles or sextupoles) is possible making the design of such a magnet very challenging. The design, installation and performance of those special magnets is presented and discussed.

INTRODUCTION

Located on the outskirts of Trieste, Elettra operates for users since 1994 being the first third generation light source for soft x-rays in Europe. During those 20 years many improvements were made in order to keep the machine updated and therefore competitive with the other more recent and modern light sources.

Elettra originally was not supposed to have dipole beam lines and the original corrector magnets (seven combined water-cooled correctors 400 mm long per section for eleven sections and five in the injection section) configuration did not allow simultaneous control of position and angle there. To control both position and angle of the electron beam in a certain location four corrector magnets are needed in pairs before and after the source point, a condition fully satisfied for the insertion devices source point while for the dipoles there are only 3 correctors available. After Elettra came into operation in 1994 dipole beam lines started being added and functioning well although at the source point only the position or the angle could be controlled but not both due to the fact that one corrector after the dipole was missing. In general most dipole beam lines have a large acceptance and just fixing the vertical angle is enough, however some beam lines like SYRMEP and MCX are very sensitive to both angle and position and therefore a better control of their source point is necessary otherwise the required reproducibility is obtained by moving the beam line optics, a time consuming procedure. Adding an 8th corrector after the dipole magnet so that the correctors before and after the dipole source point come in pairs could solve the problem [1]. This however proved to be complicated due to the lack of space, there was only a maximum of 120 mm available where a NEG pump was positioned, so the magnet had to be <120 mm long and to provide some 100 Gm or a kick of about 1.5 mrad at 2 GeV in both planes while the NEG pump had to be installed somewhere nearby resulting in changing also that part of the vacuum chamber. Note that an alternative solution adopted by other storage rings namely using additional coils in the sextupoles cannot be realised in the case of Elettra because their poles do not create a closed magnetic circuit.

Overcoming the difficulties, additional combined air cooled correctors were home designed, produced by Kyma s.r.l. and three are already installed while three more are expected to be installed within the next year. Dipole beam lines already equipped with the additional corrector report an excellent reproducibility.

MAGNET SPECIFICATIONS, DESIGN AND REALIZATION

Several types of air-cooled combined correctors were studied in order to satisfy the most important constraint that of the available longitudinal space and the maximum integrated fields both horizontal and vertical. The feasibility study led to the choice of a combined corrector composed by a window shape with 6 poles. Four coils for each channel (CH & CV) are organized in order to obtain the required independent magnetic fluxes with a maximum excitation current of 16 Ampere. Figure 1 show the models used in the simulations.

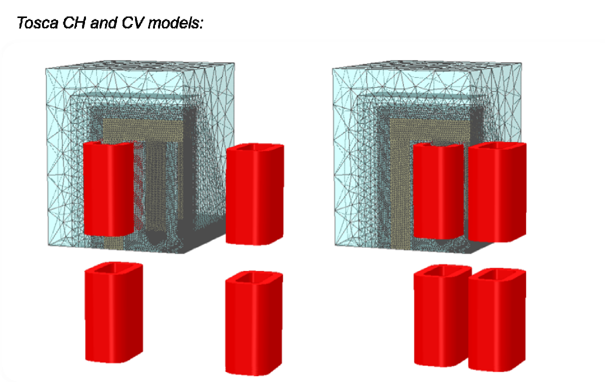

Figure 1: Horizontal and vertical models meshing.

The pole shapes have been optimized in order to maximize the efficiency and the field homogeneity in the requested good field region (<1% at a radius R=10 mm). The last optimization produced pole surfaces horizontally parallel to the Elettra vacuum chamber (Fig. 2).

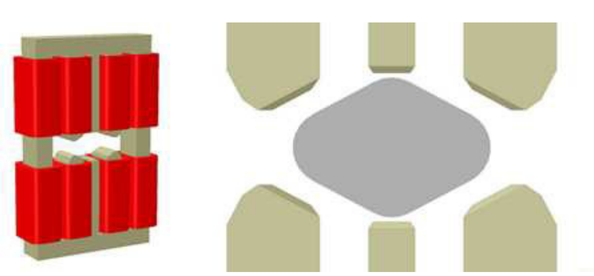

Figure 2: Final model and optimized pole surfaces.

This solution was preferred for facilitating the installation and alignment.

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The next figures show the simulated field distribution on the transversal plane studying the yoke saturation and the cross talk effects.

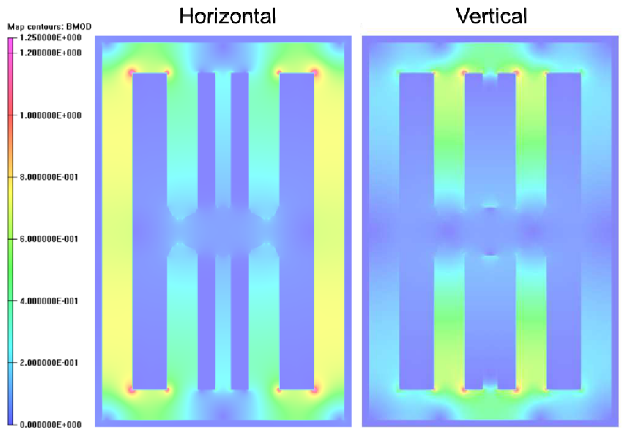

Figure 3: Magnetic flux module distribution.

In order to study the yoke efficiency for both channels, the integrated fields were calculated at different coexistent excitations (Fig. 4 and Fig. 5)

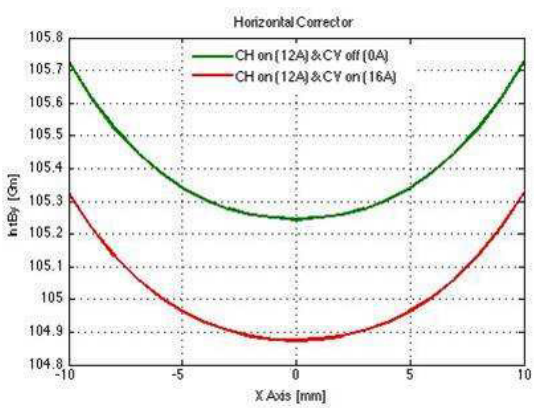

Figure 4: Integrated By on X axis.

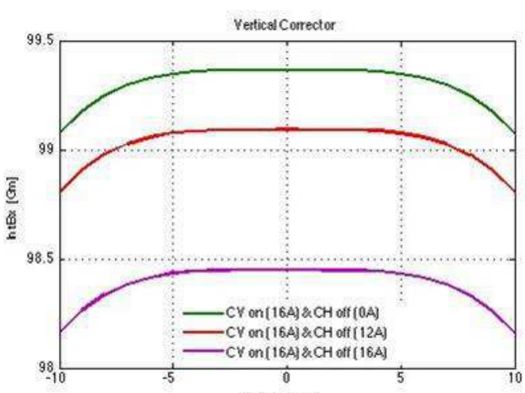

Figure 5: Integrated Bx on Y axis.

Based on our specifications and design, the magnet prototype was realized and measured by Kyma s.r.l. and delivered in April 2012. The magnet support parts were developed at Elettra and realized by P.M.L. Trieste.

The final version of the special corrector magnet realized by Kyma s.r.l. was measured at Elettra. This version is 14 mm shorter than the prototype in order to facilitate the installation. The magnetic measurements at Elettra have showed a lower efficiency due to the shorter yoke and maybe a different iron BH curve. The calculated and measured longitudinal field distributions are shown in Figure 6. The very similar curves indicate that there are no saturation effects on the pole edges (e.g. the same field quality), but only a greater reluctance of the magnetic circuits.

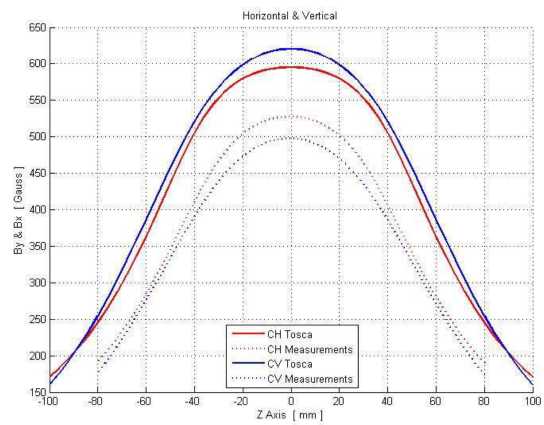

Figure 6: Magnetic flux module distribution.

MAGNET INSTALLATION AND MEASUREMENTS

At the time being three magnets are installed in sections S6 for SYRMEP, S7 for MCX and S11 for XAFS beamlines. In order to change the NEG pump location, the installation of the magnet was done after changing part of the vacuum chamber with a new one designed by Elettra and realized by CINEL s.r.l. Figure 7 shows the magnet before and after the installation.

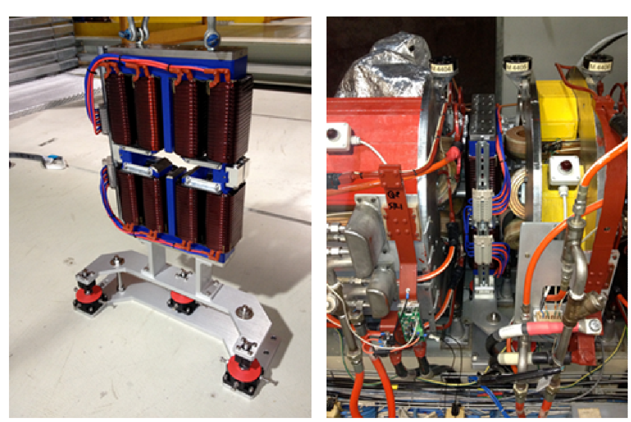

Figure 7: The special corrector magnet before and after the installation.

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In the next figure the position of the special corrector is shown with an arrow. Dipoles are depicted with green, quadrupoles with red, sextupoles with yellow and correctors with blue colour. The long vertical blue line indicates the source point in the dipole magnet.

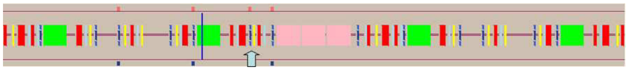

Figure 8: The position of the special corrector in the Elettra magnetic lattice.

Tests with the beam confirmed the magnetic simulations, the correct power supply polarity and the symmetry of the magnet on the horizontal and vertical plane. The offset between the mechanical and the magnetic centre was also checked. The orbit rms distortion introduced by the corrector was calculated for different current settings. The average rms distortion confirmed the mechanical symmetry; an rms of 0.39 (0.15) mm in the horizontal (vertical) plane was measured with the power supply set at ±0.5A. Doubling the power supply settings also the distortion doubled. As expected no noticeable tune shift was observed.

In the next two figures the reproducibility of the position and divergence of the electron source point at the SYRMEP dipole beam line after re-injecting due to beam losses is shown for the situations before and after the installation of the additional special (8^{th}) corrector.

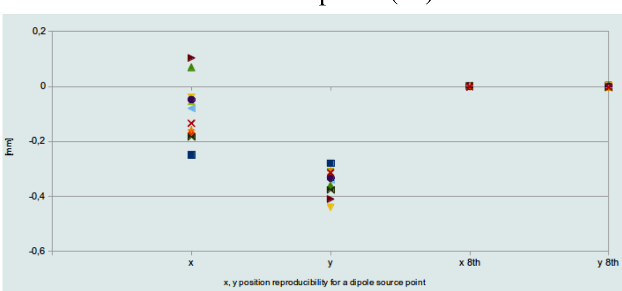

Figure 9: Beam position reproducibility at dipole before and after the introduction of the special corrector (8th).

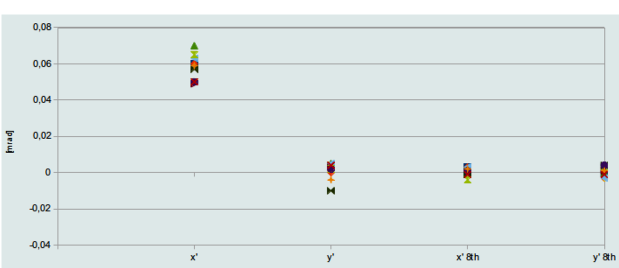

Figure 10: Beam divergence reproducibility at dipole before and after the introduction of the special corrector.

Before the installation of the additional special (8^{th}) corrector only the vertical angle was set by a vertical 3-bump while the horizontal plane was left uncorrected since the horizontal acceptance of the (dipole) beam line is large. The spreads refer to source point position/angle after re-injecting to the machine file. To reach then the required vertical source point position at dipoles using local bumps was time consuming and always within ±25 µm accuracy. Very often a position adjustment from the beam line was also necessary. After the installation of the additional corrector both position and angle in both planes are kept at their set values. Dipole beam lines, already equipped with the additional corrector, report an excellent reproducibility.

CONCLUSIONS

Special air-cooled correctors satisfying the main request for an overall longitudinal length shorter than 120 mm were designed at Elettra, manufactured by Kyma s.r.l. and installed in the machine. Their performance is comparable with the much longer (400 mm) water-cooled nominal Elettra correctors.

With the help of those special correctors at the dipole beam line sections it is possible through four corrector bumps to control both beam position and angle of the dipole source point with an excellent reproducibility. The four corrector bump consists of three old (nominal) correctors and one new (special) corrector. Furthermore the beam position at dipoles and the beam position at the insertion devices are now completely decoupled.

Until the end of the next year three more special correctors will be installed in the remaining dipole beam line sections (in total six special corrector magnets) rendering the source points of all dipole beam lines fully reproducible.

REFERENCES

[1] E. Karantzoulis, "A generalized orbit correction scheme", EPAC 2002, Paris, France (2002), p 1142.