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Specifications of the octupole magnets required for the ATF2 ultra-low β^* lattice*

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Abstract

The Accelerator Test Facility 2 (ATF2) aims to test the novel chromaticity correction for higher chromaticity lattices as the one of CLIC. To this end the ATF2 ultra-low β^* lattice is designed to vertically focus the beam at the focal point or usually referred to as interaction point (IP), down to 23 nm. However when the measured multipole components of the ATF2 magnets are considered in the simulations, the evaluated spot sizes at the IP are well above the design value. The designed spot size is effectively recovered by inserting a pair of octupole magnets. In this note we addressed the technical specifications required for these octupole magnets.

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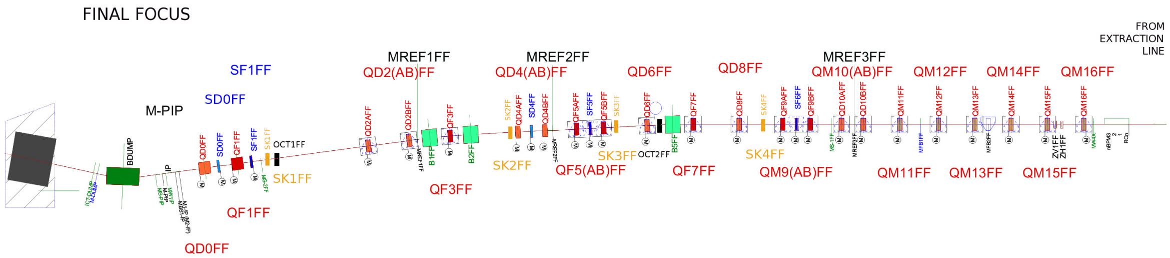

FIG. 1. Scheme of the FFS of ATF2. Octupole magnets namely OCT1FF and OCT2FF are shown in dark gray. Beam travels from right to left.

I. INTRODUCTION

The ATF2 ultra-low β^* lattice [1] is a proposal of a challenging optics with a value of vertical beta function at the IP (β_y^*) of 25 μm. The expected σ_y^* is equal to 23 nm if an error-free lattice is considered in simulations. The goal of the ATF2 ultra-low β^* lattice is to experience with high chromaticity optics. In this sense the chromaticity of ATF2 ultra-low β^* lattice is comparable to the one of the final focus system (FFS) of CLIC.

As shown in Ref. [2] the field quality of the ATF2 magnets increases the vertical spot size at the IP above 30 nm, well above the designed value of 23 nm. Simulations have shown that the detrimental effect of the multipole content of the ATF2 magnets is effectively compensated by a pair of octupole magnets located at high and low dispersion areas, see Ref. [2]. Optimization of the sextupole and octupole magnets permit to reach a σ_y^* equal to 21 nm. Additional benefits of inserting a pair of octupole magnets are; minimisation of the effect of the fringe fields of the last two quadrupoles, usually referred as Final Doublet (FD), see Ref. [**?**] and improve the tuning capabilities of the ATF2 beam line under real error conditions of the ATF2 magnets [4].

II. DESCRIPTION OF ATF2

The ATF2 beam line extends over about 90 m from the beam extraction point in the ATF Damping Ring to the IP. It comprises two different sections, the extraction line and the final focus system. The ATF2 FFS beam line extends over 40 m and is responsible for transporting and transversely focusing the beam at the IP. It consists of a matching section composed

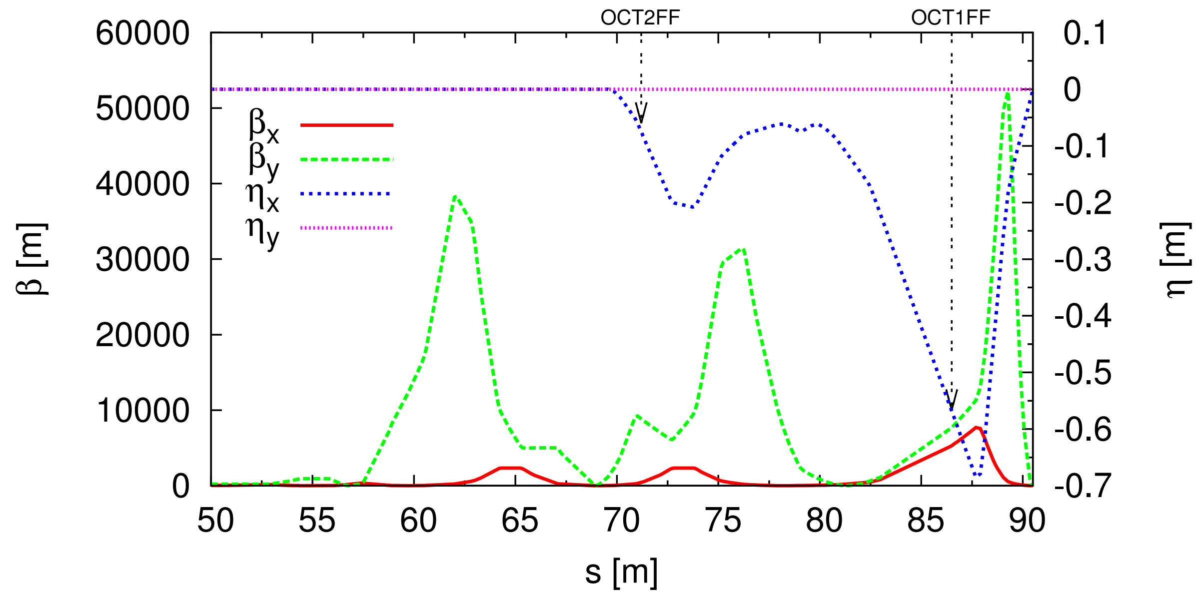

FIG. 2. The $\beta_{x,y}$-functions and the $\eta_{x,y}$-functions of the ATF2 ultra-low β^* lattice throughout the ATF2 final focus line. Beam travels from left to right.

of 6 quadrupole magnets (denoted by QM16FF, QM15FF, QM14FF, QM13FF, QM12FF and QM11FF) whose function is to match the incoming β-functions. In addition there are 14 quadrupole magnets which transport the beam to the FD meant to focus the transverse beam size at the IP. Three bending magnets, namely B1FF, B2FF and B5FF, generate the required dispersion to correct the chromaticity introduced by the FD by means of the 5 normal sextupoles, namely SF6FF, SF5FF, SD4FF, SF1FF and SD0FF. Additionally 4 skew sextupoles namely SK1FF, SK2FF, SK3FF and SK4FF are distributed along the FFS. The considered locations for the octupole magnets, labelled as OCT1FF and OCT2FF, are respectively upstream of the SK1FF (high dispersion region) and upstream of the QF6FF magnet (low dispersion region), as shown in Fig. 2. These locations offer available free space to allow for the installation of the new octupole magnets.

Figure 1 shows a layout of the FFS of the ATF2 beam line. Figure 2 shows the $\beta_{x,y}$ and $\eta_{x,y}$-functions along the FFS of ATF2.

The characteristics and tolerances in terms of alignment, power supply tunability and stability and magnet field quality are described in the following.

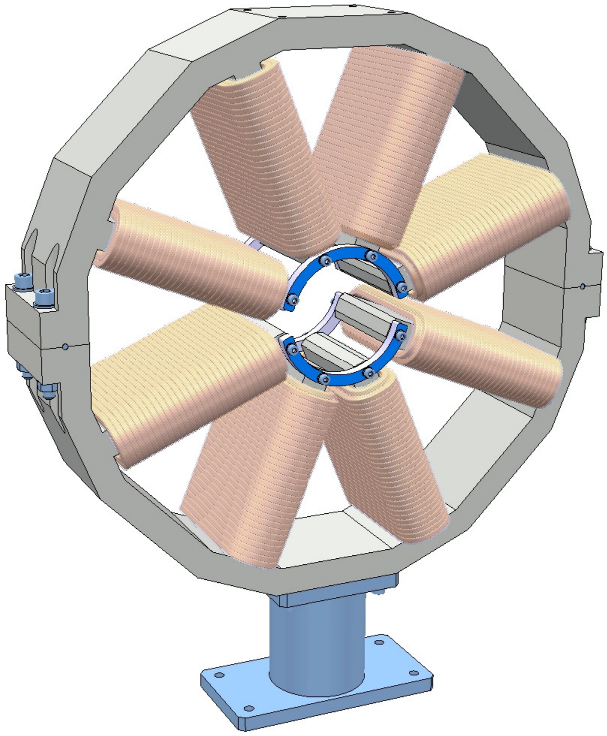

FIG. 3. Preliminary design of the octupole magnet.

III. CHARACTERISTICS OF THE OCTUPOLE MAGNETS

A conceptual magnetic and mechanical design of an octupole magnet has been developed by the magnet team at CERN [5]. Figure 3 shows a sketch of the proposed octupole design. The number of yoke parts is intended to be the minimum (possibly two half-yokes) to get the highest mechanical precision and so the best field quality. The magnet aperture is relatively big, about 50 mm, for the following reasons:

- to low saturation (when operating at -75% of nominal),
- assembly reasons (insertion of the coils in the two half-yokes),
- to improve the field quality at a radius of 20 mm.

Table I summarises the most relevant parameters.

TABLE I. Parameteres of the octupole magnets OCT1FF and OCT2FF.

	Units	OCT1FF	OCT2FF
Nominal Gradient	[T/m^3]	5753	-2109
Required tunability	[%]	-75, +20	-75, +20
Integrated gradient	[T/m^2]	610	-224
Aperture radius	[mm]	50	50
Iron length	[m]	0.1	0.1
Magnetic length	[m]	0.106	0.106
Coil number of turns		61	61
Conductor size	[mm x mm]	5 x 5	5 x 5
Ampere-turns	[A]	1200	1200
Current	[A]	19.7	19.7
Resistance (per coil)	[mω]	14	14
Yoke mass	[kg]	56	56
Total mass	[kg]	92	92

IV. ALIGNMENT TOLERANCES OF THE OCTUPOLE MAGNETS

The alignment tolerances in the transverse plane for the OCT1FF and OCT2FF octupoles are summarized in Table II. Each tolerance represent a $\Delta\sigma_y^* = 2\%$. Relaxed tolerances are found for OCT2FF while the vertical alignment of OCT1FF is the most critical alignment. In order to satisfy the OCT1FF alignment, we foresee to mount OCT1FF on a mover † with micrometer resolution and practise beam based alignment. Taking advantage of the sub-micron resolution beam position monitors installed at ATF2 we expect to reach an alignment resolution below 25 μm, however further studies are required in order to demonstrate its feasibility. OCT2FF will be placed on a support provided by ATF2 since it is not required to be mounted on a mover in terms of alignment tolerances.

† currently available at ATF2.

TABLE II. Transverse alignment tolerances for octupoles OCT1FF and OCT2FF.

	Unit	OCT1FF	OCT2FF
X-offset	[mm]	>0.1	>0.1
Y-offset	[mm]	0.025	0.09
Z-Tilt	[deg]	0.1	1.4

V. POWER SUPPLIES

The two octupoles magnets would required independent power supplies and a tunability range of -75% +25%. The required stability for OCT1FF and OCT2FF power supplies are 2.8% and 21%, respectively. Each percentage represents a $\Delta\sigma_y^*$ of 2%. The power supplies would operate in slow DC and will be remotely operated from the ATF control room. The power supply would require an ON/OFF switch and an interlock system for regular and safety operation.

The required voltage of the magnet is ≈2 V, in order to operate at higher values we plan to install a resistor in series with the magnet at expenses of losses and over-dimensioning but keeping these counter-effects under reasonable values. Commercial power supplies should meet the specifications required by the octupole magnets.

VI. MAGNETIC FIELD QUALITY

The required stability of the individual power supplies of the octupoles magnets are 2.8% and 21% for OCT1FF and OCT2FF respectively. Each tolerance represents a $\Delta\sigma_y^*$ of 2%. The relative quadrupole, sextupole, decapole and dodecapole components have been evaluated at a radius equal to 2 cm for both octupole magnets. Each component represents a $\Delta\sigma_y^*$ of 2%. Table III summarises the obtained tolerances. The quadrupole and sextupole tolerances are not limiting factors since the quadrupole and sextupole magnets of ATF2 can be optimised for accommodating the measured errors. The field quality obtained in preliminary designs is less than 10^{-4} at a radius of 20 mm for the permitted harmonics (12-pole, 20-pole, 28-pole and 36-pole), which satisfies the tolerances for the normal dodecapole component shown in Tab. III. Figure 4 shows the preliminary computation of field quality

TABLE III. Relative magnetic tolerances at a radius of 2 cm of the octupole magnets. 4P, 6P, 10P and 12P refer to quadrupole, sextupole, decapole and dodecapole component respectively.

OCT1FF	Normal				Skew			
	4P	6P	10P	12P	4P	6P	10P	12P
	0.001	0.013	0.4	1.7	0.001	0.007	0.2	0.7
OCT2FF	Normal				Skew			
	4P	6P	10P	12P	4P	6P	10P	12P
	0.002	0.01	1.5	2.4	0.0006	0.008	0.9	4.8

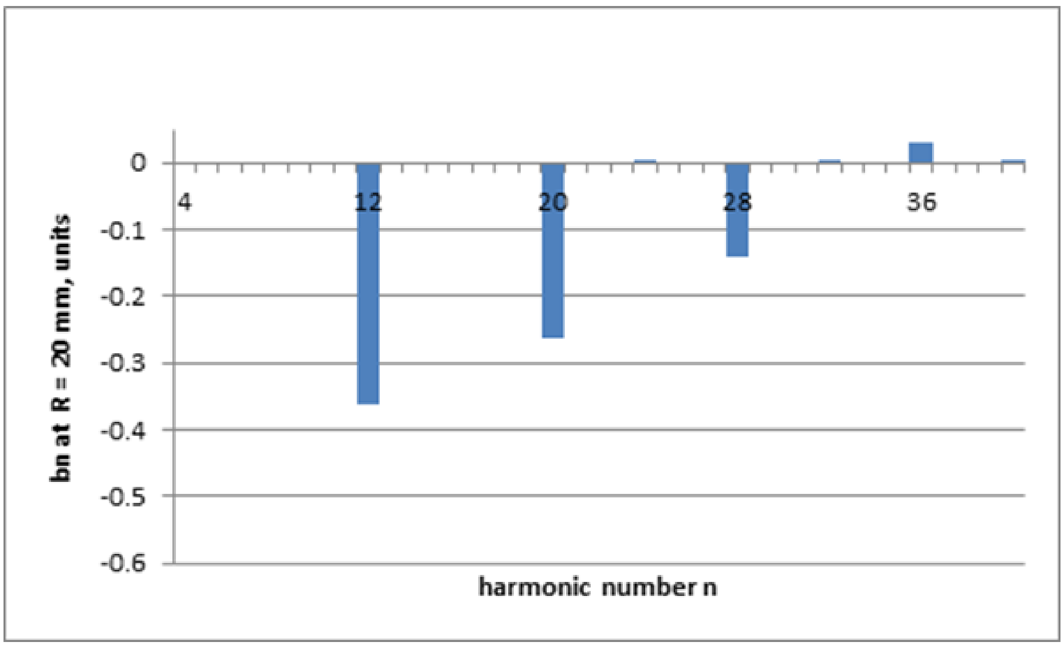

FIG. 4. Computed field quality in units of 10^{-4} at a radius of 20 mm for the permitted harmonics (12-pole, 20-pole, 28-pole and 36-pole) of OCT1FF at nominal gradient.

for the permitted components of the octupole magnet.

VII. SUMMARY

The installation of the octupoles allows to pursue the exploration of lattices with ultra-low values of the beta function. ATF2 is providing a unique experience to assess the effect of field errors in FFS which is of special interest for the future generation of linear colliders.

The results of the calculations reported in this note do not show any major difficulties for designing and installing the octupole magnets.

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