MAGNETIC QUADRUPOLE LENSES FOR THE IFUSP MICROTRON

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Abstract

In this work, we describe the magnetic quadrupole lenses for the IFUSP microtron. The proposed design eases the assembling of the coils around the poles and allows the installation of the lenses in the beam line without breaking the vacuum. We present the characteristics of a prototype and show that the magnetic field configuration in the region of interest is within the project specifications.

INTRODUCTION

The Instituto de Física da Universidade de São Paulo (IFUSP) is building a two-stage 38 MeV continuous wave (cw) racetrack microtron. Figure 1 shows an isometric view of the accelerator and the beam transport line [1], where it can be seen that the beam travels, from the injector to the experimental hall, about 35 m. Along this path the beam must be kept within an 18-mm diameter tube.

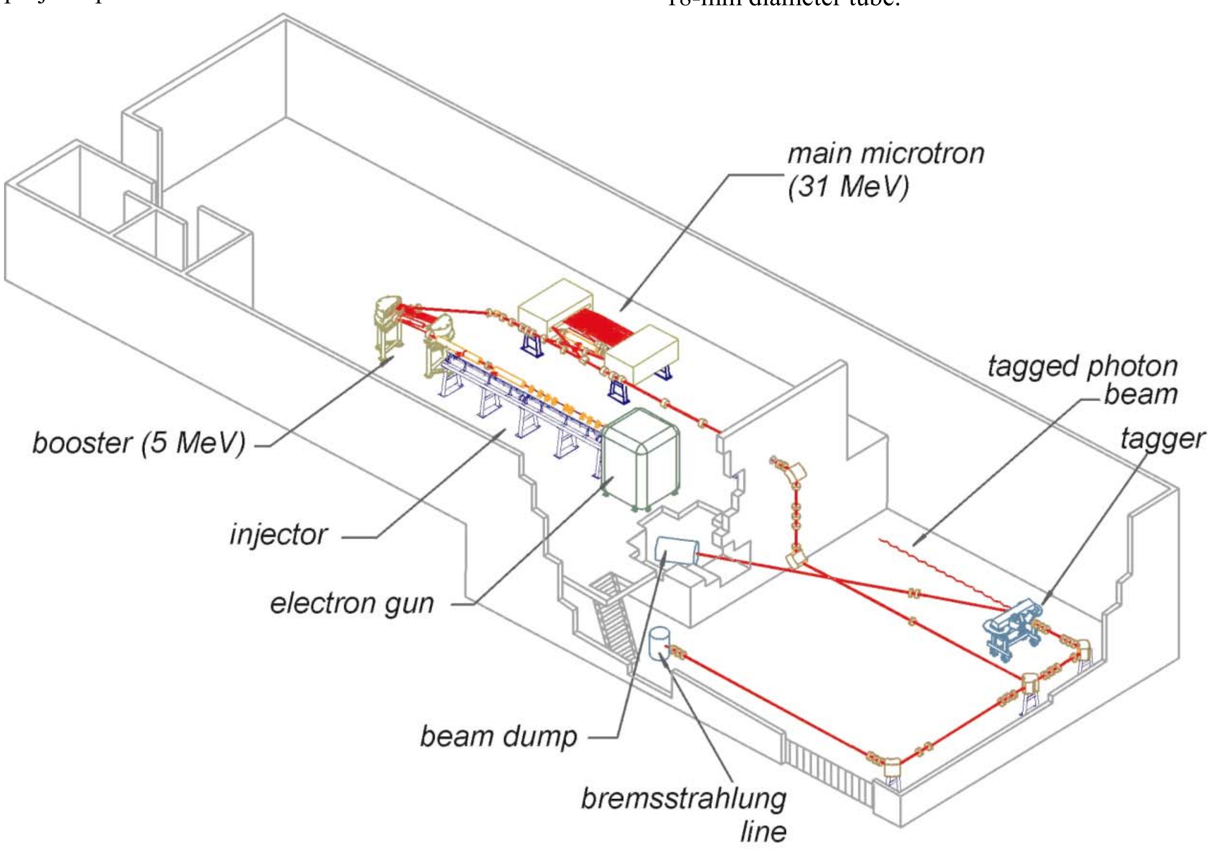

Figure 1: Isometric view of the accelerator in the accelerator building.

The beam focalization is made by magnetic elements [2, 3], like solenoids (where the beam energy is below 5 MeV) and magnetic quadrupole lenses (above 5 MeV) [4]. In this work, we describe the design and characterization of the magnetic quadrupole lenses for the IFUSP microtron.

DESIGN

We opted for a lens with a square cross section, in order to ease mounting and leveling procedures. The polar face profile is an arc of circumference, approximating the ideal hyperbolic shape with a tolerance of less than 2% [5].

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The magnetic design was made using the POISSON code [6], and the final configuration is shown in Fig. 2.

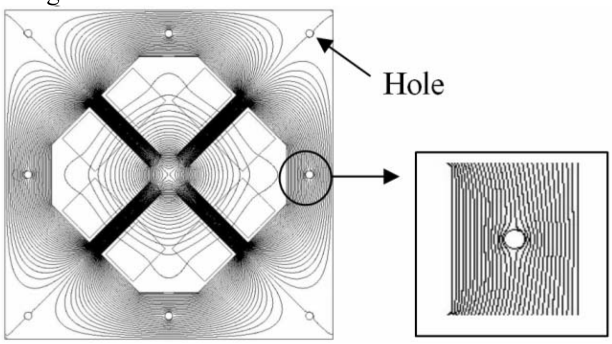

Figure 2: POISSON simulation.

For the mechanical construction we decided to use thin iron plates stacked together along the longitudinal axis. Each plate was divided in 4 equal pieces that are assembled together to form a pole, as shown schematically in Figure 3. This solution reduces the construction costs, since we have a single type of piece that can be cut with a laser tool (the plate is 1.25-mm thick). Figure 4 shows the mechanical drawing of the piece.

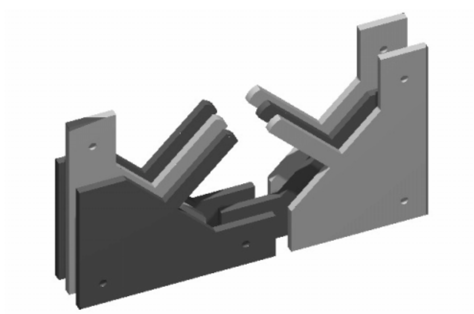

Figure 3: Assembling scheme.

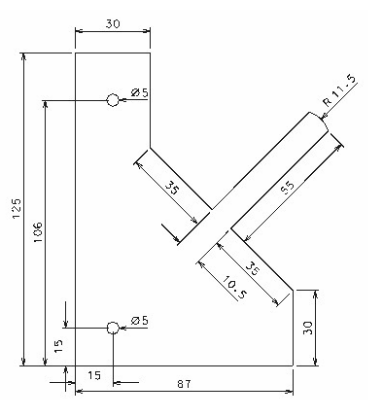

Figure 4: Mechanical design of the piece (measures in mm).

Due to the fact that the quadrupole is laminated along the longitudinal axis, it is possible to change the length of a given lens by adding or subtracting foils.

Other advantages are related to maintenance and installation procedures: the lenses can be installed in (or removed from) the transport line without breaking the vacuum; coils can be changed easily, by disassembling the respective pole.

An artistic picture of a quadrupole assembled and with the coils installed is presented in Fig. 5. Screws 1 (at the corners) hold the plates together to form an individual pole, and the screws 2 join the poles, attaching the alternating pieces (see Fig. 3).

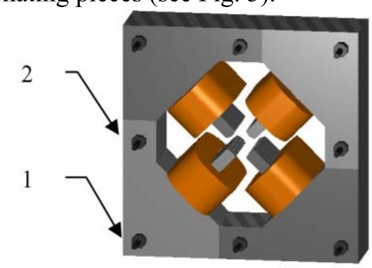

Figure 5: Artistic view of the assembled quadrupole.

THE PROTOTYPE

The pieces were cut with a laser tool, with good finishing, according to the mechanical drawing. We used 192 pieces to build a 6-cm long lens. The coils have 12 layers with 15 loops each. After the coils were installed, the lens was aligned and the screws fastened, and the assembly presented a satisfactory rigidity.

Thermal Performance

The temperature of one of the coils was monitored while the quadrupole worked for 5.5 h. The current was approximately 70% of the maximum current supported by the wire, corresponding to 50% more than the maximum current expected for the quadrupoles in the beam transport line. We observed that the temperature stabilized around 43 ºC after 3 hours, as shown in figure 6. This assured that no forced cooling was needed for the quadrupoles.

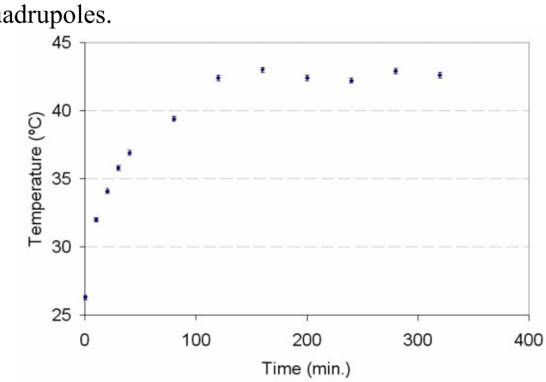

Figure 6: Coil temperature as a function of time.

Mapping

The magnetic field mapping at the mid plane† of the quadrupole was made with a digital gauss meter with a relative precision of 0,2%+0,01G on the selected mode

† The mid plane is defined as a plane equidistant to a pair of adjacent poles.

[7]. The system included a Hall probe and a computerized positioning system [8].

A typical mapping is presented in figure 7, where the X and Y axes represent the position of the probe on the mid plane.

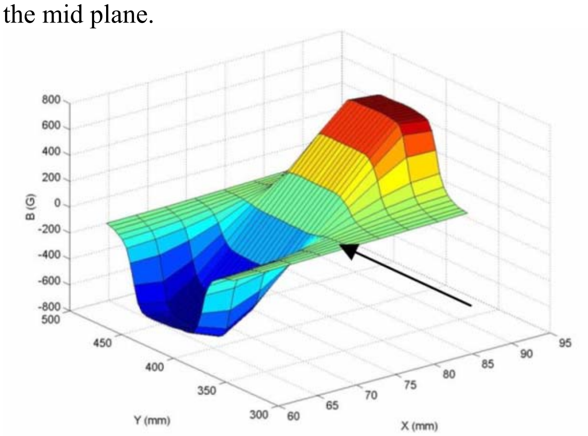

Figure 7: Magnetic field mapped on the mid plane. (The arrow indicates the beam incidence).

Figure 8 presents a comparison between the experimental data and the simulation obtained with the POISSON program, showing good agreement.

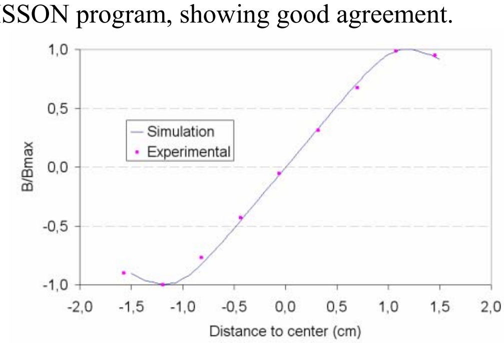

Figure 8: Comparison between the experimental results and the simulation.

The field gradient distribution along the Y-axis was obtained from the mapped field data, and is presented in figure 9. This distribution was considered adequate, since it presents symmetric fringe fields and a relative homogeneity of approximately 0.6 %.

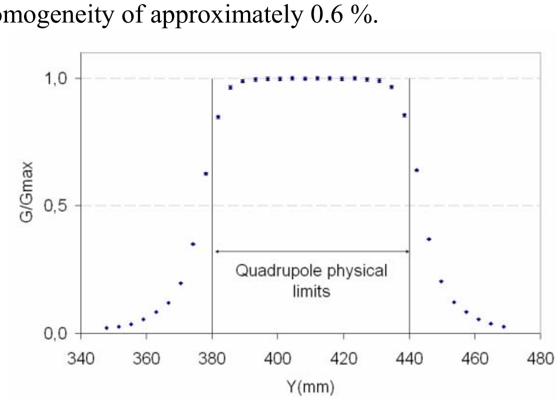

Figure 9: Gradient distribution.

CONCLUSIONS

The laser machining used on the manufacturing of the pieces, provided a good finishing, allowing for a good regularity on the polar faces, which resulted in a good configuration of the magnetic field.

The magnetic quadrupole design presented in this work eases the installation of the lens in the beam transport line, without breaking the vacuum, and simplifies the assembling of the coils. Besides, a modular iron core allows for the construction of lenses with different lengths just by adding or subtracting foils.

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