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Design specification of IOTA injection Lambertson

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Introduction

IOTA is going to operate with a beam of 150 MeV electrons, and later with protons of 70 MeV momentum. An injection Lambertson septum is required to provide lossless beam injection from the FAST injector beamline to the ring.

Key Assumptions, Considerations, and Constraints

- The size of injected beam in the septum is chosen to be 13 mm (diameter) to be able to inject protons with unnormalized emittance 3 mm-mrad (rms beam diam. of about 4 mm).
- The presence of septum limits the physical aperture available for circulating beam inside the Lambertson magnet. Since the ring aperture is already reduced to 40 mm in diameter at the horizontal and vertical kickers, it makes sense not to reduce it further. Thus minimum opening for the circulating beam is chosen to be 40 mm diameter.
- The diameter of aperture outside of Lambertson is constrained by physical aperture of quadrupole magnets of 71 mm on one side and the beam pipe diameter of the horizontal

kicker, equal to 70 mm, on the other side. This value sets the upper limit for the separation of injected and circulating beams.

- Lambertson stray fields will produce beam displacement in the horizontal plane. It will be compensated using dipole correctors. Without correction, the maximum amplitude of resulting oscillation should not exceed 5 mm.
- The gradient of stray magnetic field should not change the beta-functions by more than 1% and the betatron tunes by more than 10^{-3}
- Lambertson magnet will be connected in series with IOTA dipole magnets to use the same power supply. Therefore coil current must be the same as in the dipoles.
- Possible dipole error resulting from field nonuniformity in the gap should not exceed that resulting from stray field in field-free region. Maximum amplitude of resulting oscillation should not exceed 5 mm.
- In order to compensate for possible errors on the stages of design, manufacturing, and final assembly the magnet should have a corrector coil capable of carrying the total current (in terms of A-turns) of at least 0.02 of that of the main coil.
- Pumping speed has to be sufficient to support desirable vacuum (2×10^{-8} Torr) in the injection straight. It is advantageous to have a flange for pumping combined with the Lambertson for the sake of saving space.
- To avoid hitting the plates of vertical kicker (located downstream) by injected proton beam it should be injected with 16 mrad angle to the horizontal plane. This angle is achieved by rotating Lambertson septum along its axis.

Design and Specifications

Preliminary design of the magnet was done by A. Makarov, TD. Its top view is depicted in Fig. 1. The device was then numerically modelled using Comsol Multiphysics software, and its parameters were optimized to meet the requirements mentioned above. Then the design was complemented by bellows on both ends to allow for the creation of a small (< 1 deg) injection angle and a special pickup at the exit, integrated with a flange (under development). Figure 2 presents two views of a precursory 3D model of the magnet prepared by A. Didenko.

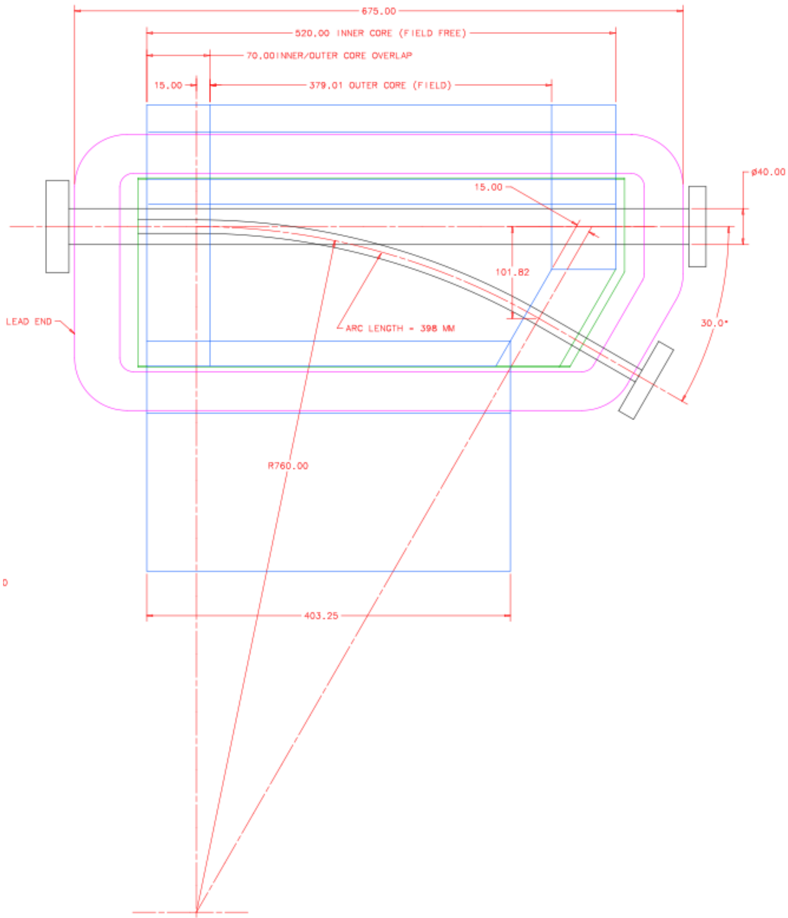

Figure 1: Preliminary design. The purpose of this picture is just to give a clue what the device looks like. The final design will differ: flanges, pole width, length of the septum, etc.

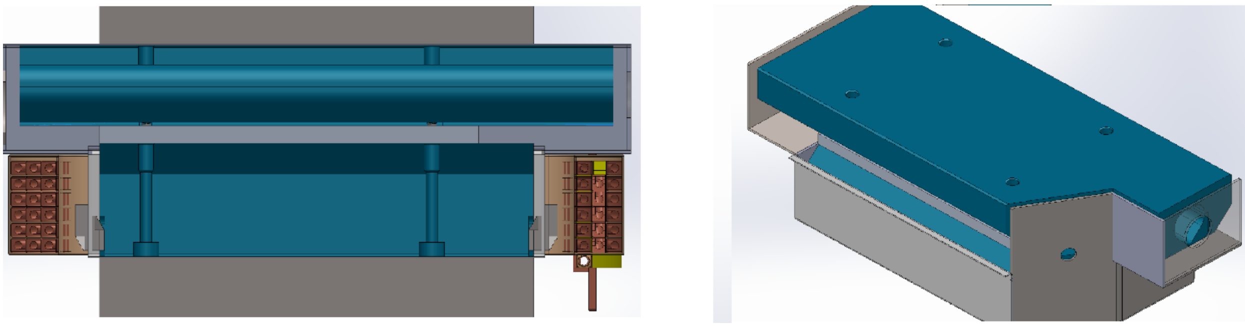

Figure 2: Left - longitudinal cross-section of the magnet; right - pole assembly inside the vacuum chamber. Not a final version. Pictures provided by A. Didenko.

Table 1: Summary of main design parameters. Fields in yellow are may change or to be confirmed

Main parameters of the Lambertson

1	Beam diam. of injected beam in the septum (protons)	13 mm (3 rms)
2	Circulating beam size	40 mm
3	Shape of the beam in the septum	Approximately circular
4	Beam separation	30-35 mm
5	Height of the gap	15 mm
6	Bend plane	Horizontal
7	Position of injected beam relative to circulating	Below
8	Bend angle	30 deg
9	Magnetic length	40 cm
10	Integrated field	263 kG-cm
11	Stray field, integrated	< 800 G-cm
12	Stray field gradient, integrated	< 50 G
13	Field uniformity in the gap	3×10^{-3} or better

Main coil

14	Coil current	520 A
15	Voltage drop	2 V
16	Dissipated power	1 kW
17	Required flux of cooling water	1 L/ min
18	Number of coil turns	18
19	Coil wire	12x12 mm, ○ 6 mm hole

Corrector coil

20	Corrector coil current	8 A
21	Corrector coil voltage	5 V
22	Number of corrector coil turns	40
23	Wire	Round, 1.45 mm diam.

Hardware

24	External beam pipe diameter, circulating beam	70 mm (same as in kickers)
25	External beam pipe diameter, injected beam	1”
26	Physical length, including flanges	70 cm
27	Steel	Upper pole – 1008, rest - 1010
28	Vacuum chamber	Stainless steel, 1.5 mm thick
29	Spacers in the gap	Al
30	Flanges with bellows on both sides	
31	Integrated pickup	Part of a DS flange assembly
32	Flange for pumping	