SEPTUM MAGNET BASED ON PERMANENT MAGNET FOR HALF

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Abstract

This paper presents a DC septum magnet based on permanent magnet designed for the Hefei Advanced Light Facility (HALF). Compared with conventional electromagnet, the permanent septum magnet offers better stability, significantly lower power consumption, and occupies less space [1]. The physical design of the permanent septum magnet was developed, and its feasibility in terms of gap field strength and leakage field was verified using the OPERA software.

INTRODUCTION

A few years ago, we designed and fabricated a type of eddy current septum magnet, which played a key role in the injection system of the HALF accelerator complex. Due to the HALF low emittance lattice the beam acceptance of the machine is reduced, the deflecting field generated by our septum magnets reaches unprecedented strength and speed, made possible by one of the most essential components: a high-power pulsed magnet supply. However, the cabinets of these devices make the entire injection section bulky and complex and result in substantial power consumption. For this reason, we designed a permanent-magnet-based solution to replace the thick eddy-current septum magnet. In this paper, we present the materials used for the permanent septum magnet, simulate and calculate the deflection field of the magnet, redesign the vacuum chamber in the injection section, and evaluate the leakage field.

MAGNET DESIGN

Injection Setup

The layout of the septum magnets developed in this study is shown in Fig. 1. The upstream permanent septum magnets provide the majority of the deflection for the injected beam, and the final injection deflection is delivered by a thin pulse septum magnet. The corresponding main parameters are summarized in Table 1.

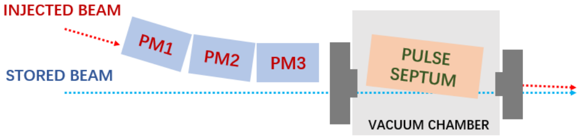

Figure 1: Schematic of the injection setup of a storage ring with septum magnets.

Table 1: Target Specifications for DC Septum Magnets

Parameter	**PM 1**	**PM 2**	**PM 3**
Gap height [mm]	10.0		
Gap width [mm]	17.0	20.0	17.0
Yoke length [mm]	200.0	190.0	200.0
Permanent-magnet length [mm]	92.5	87.5	92.5
Permanent-magnet type	Sm_2Co_{17}		
Yoke material	DT4		
Gap field [T]	1.47		

Magnet Materials

For accelerator magnets, two types of rare-earth magnetic materials are widely used at present: Samarium–Cobalt and Neodymium–Iron–Boron. Taking into account the complex electromagnetic environment in the injection section, we selected samarium–cobalt (Sm_2Co_{17}) due to its superior resistance to radiation [2, 3]. DT4 soft iron was selected as the magnet yoke material. As an industrially pure iron, it is widely used in magnetic flux-guiding components.

Magnet Structure

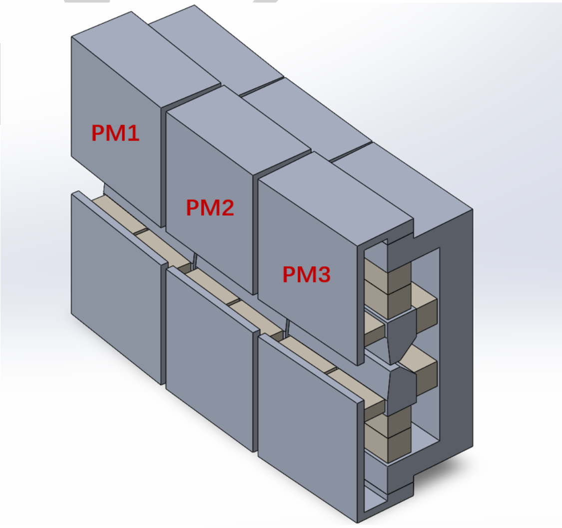

Figure 2: Magnet structure. The brown regions represent Sm_2Co_{17}, whereas the gray regions correspond to $DT4$ soft iron.

Due to the current manufacturing size limitations of permanent magnets, relatively short permanent magnet blocks were adopted and assembled to form the entire permanent magnet. Injection requirements are met by a combination of three permanent magnets, PM1, PM2, and PM3. This scheme allows a smaller gap width to be used, which is beneficial to meeting good-field region requirements. PM1, PM2,

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and PM3 have an identical structural configuration, differing only slightly in their dimensions, as illustrated in Fig. 2.

MAGNETIC FIELD DISTRIBUTION

The gap field generated by the permanent magnets was calculated using OPERA. Because it is difficult to achieve high-precision agreement between the actual magnetic field and the design value under practical cost constraints, an additional magnetic field adjustment mechanism was introduced into the magnet design [4], as shown in Fig. 3.

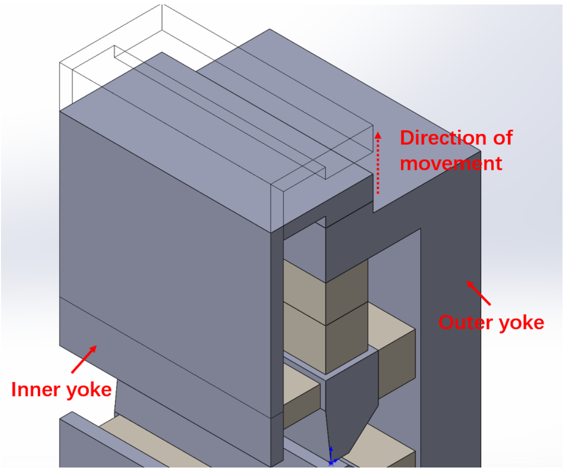

Figure 3: Magnet adjusts the gap field strength by moving the inner yoke.

The inner yoke on the storage-ring side of the permanent magnet was designed to move within a certain range. As the inner yoke approaches the outer yoke, the gap field strength decreases, as shown in Fig. 4.

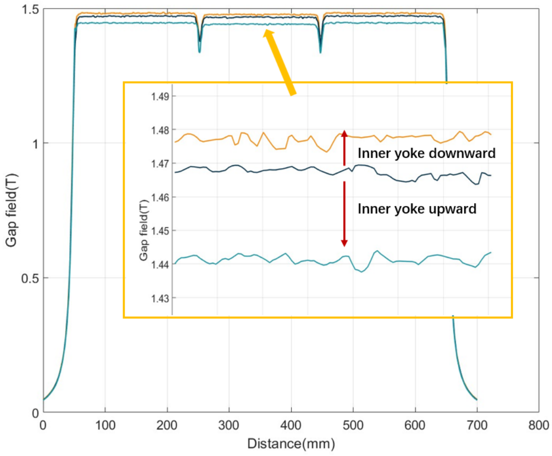

Figure 4: Gap field calculation and its variation induced by inner yoke.

The movement of the inner yoke is restricted to a range of 0 to 40 mm, which can induce a gap field variation of approximately 300 Gauss. Drawing on our prior magnet operation experience and data from other light sources, we consider this capability adequate to compensate for engineering errors and time-dependent demagnetization.

LEAKAGE FIELD

Another key issue is the reduction of the leakage field within the stored beam tube. Due to the constraints of the injection conditions, the PM3 is located close to the stored beam trajectory. If a septum is used to shield the leakage field, the high-permeability material septum has to be placed very close to the gap, which would distort the gap field. Therefore, the stored beam tube was wrapped with a layer of mu-metal to suppress the leakage field. The mu-metal shielding reduces the leakage field inside the stored beam tube from 0.1 T to a few Gauss, as shown in Fig. 5.

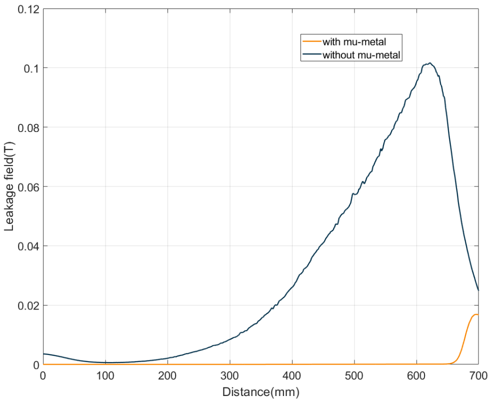

Figure 5: Leakage field inside the stored beam tube.

CONCLUSION

This paper presents the basic design of a permanent septum magnet for the HALF, with emphasis on the calculated gap field and leakage field performance. Future work will investigate the influence of manufacturing and assembly tolerances of the permanent magnets on the gap field as well as the demagnetization effect on the permanent magnets induced by radiation in the injection section.

ACKNOWLEDGMENT

Work supported by the Fundamental Research Funds for the Central Universities (WK2310250134) and National Natural Science Foundation of China (No. 12205293)

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