Japan Aerospace Exploration Agency		ISR.35-GNL.11

Test Plan for Magnetic Shielding of Polarization Modulator

approved by	reviewed by	authors Yuki Sakurai Tomotake Matsumura data Nov. 26, 2016

Purpose

In this document we report on our reply to the action item ISR.35-GNL.11, which is identified with following information:
ID: ISR.35-GNL.11
ITEM: Set a test plan to check if magnetic shielding is sufficient.
SOURCE (REPORT): DEAD LINE: Aug. 2016
SECTION IN PHASE-A1 PLAN DOCUMENT: Aug. 2016,
WBS ID: WBS A1.02.06.03.08
EXPECTED OUTPUTS: Establish test plan for Magnetic Shielding of Polarization Modulator.

Introduction

The LiteBIRD polarization modulator unit (PMU) employs a superconducting magnetic bearing (SMB) in the rotational mechanism. The SMB is a contactless bearing.It employs an array of high temperature superconductor tiles as a stator and a permanent magnet as a rotor. The inner diameter of the rotor magnet is 400 mm and 200 mm for the Low Frequency Telescope (LFT) and the High Frequency Telescope, respectively. The half-wave plate is mounted inside of the rotor magnet. Figure 1 shows the position of the PMU and the detector with their distance. The effect of the magnetic field from the large magnet on the TES detector and the SQUID board can not be ignored. Thus, a magnetic shield for the PMU must be considered. We must design and evaluate it if necessary. In this document, we report a test plan for the magnetic shield of the polarization modulator following the action item from the International Science Review.

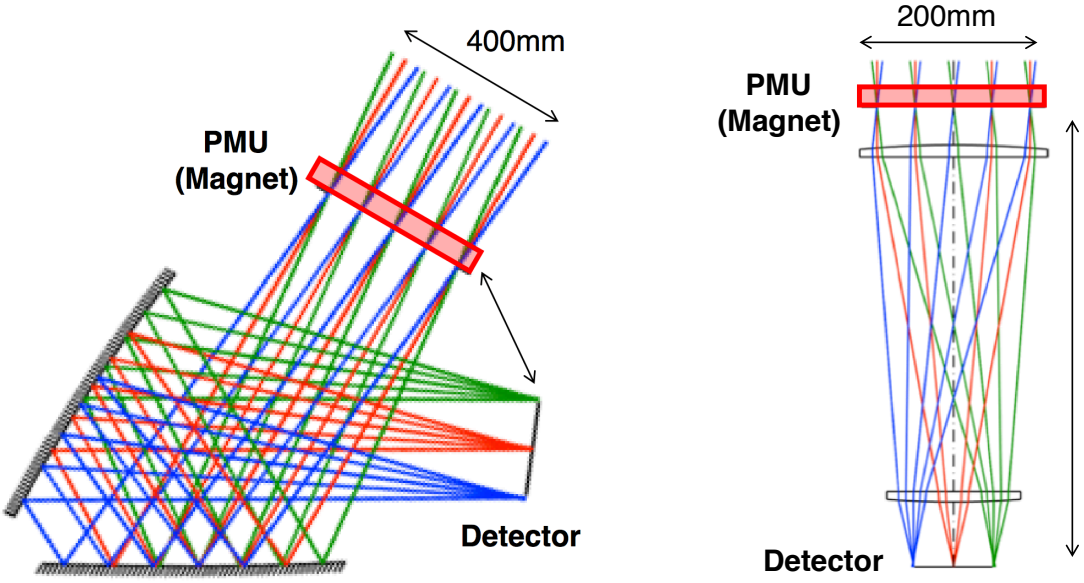

Figure 1:

Description

The design and the evaluation of the magnetic shield are carried out by a electromagnetic field simulation. The software package is a finite element method (FEM) based simulation called "JMAG". The JMAG has an advantage of a high-speed computation and containing numerous application packages of the electromagnetic field analysis. The magnetic shielding is also included in the application packages. It has several achievements such as a design of a magnetically shielded room and so on.

At first, we must study the necessity of the PMU magnetic shield. Figure 2 shows the decision tree for the PMU magnetic shield. The magnetic shield is to be installed by default for the detector and its readout (detector magnetic shield). However, it does not take into account the magnetic field from the PMU magnet. The first decision point is whether the detector magnetic shield is sufficient or not. We estimate the magnetic field due to the PMU magnet at the detector position by the JMAG simulation. In this simulation, the PMU magnet is formed into a ring shape with ϕ=400 mm and magnetized in the axial direction. The detector magnetic shield, whose specifications (a shape and a material) are already designed, are given to the simulation. From the simulation result, we determine the first decision point. If it is sufficient, there is no necessity of the PMU magnetic shield.

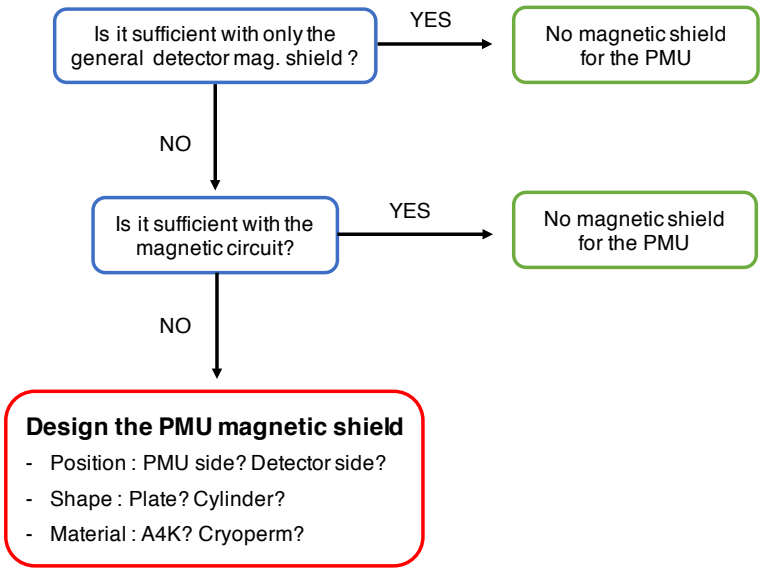

Figure 2: Decision tree and design items for the PMU magnetic shield.

Then, we investigate the magnetic circuit of the PMU magnet. The magnetic circuit is a combination of the magnetization and the yoke. It has a possibility to reduce the magnetic field at the detector position. We currently studying the following magnetic circuit: radial magnetization, two iron yoke on inner and outer side. Figure 3 shows the magnet with axial magnetization and the alternative magnetic circuit. It improves both the performance of the SMB and the magnetic shielding. We perform the same simulation as above with this magnetic circuit. Then, we decide to the necessity of the PMU magnetic shield.

If the two decision points are passed, the PMU magnetic field must be constructed. In order to design it, we must determine mainly three design parameters as following,

- Position: PMU side, detector side
- Shape: plate, cylinder, cylinder + bottom plate

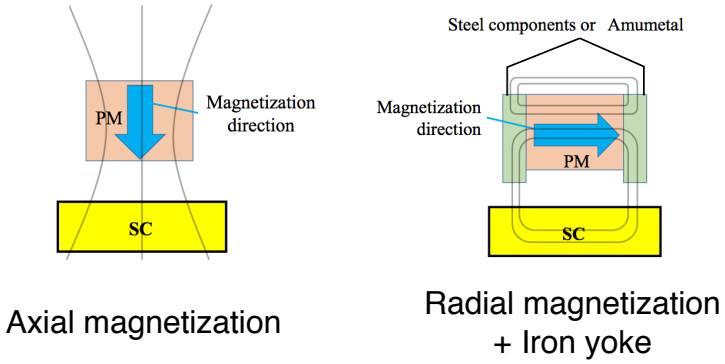

Figure 3:

- Material: A4K, Amunickel, Cryoperm10, e.t.c.

There is a trade-off between a shielding power and a weight. We perform the simulation with their all combinations in order to select the best parameters. Finally, final design of the PMU magnetic shield is determined with including an interface with other equipments.

Simultaneously designing the magnetic shield by the simulation, we also compare the simulation with the actual measurement. Since it is difficult to perform the comparison with the diameter of ϕ=400 mm, the SMB system with with the ϕ=60 mm is used. This small prototype is already constructed for the development of the PMU itself.

Summary

We describe the test plan for the magnetic field for the PMU. The JMAG electromagnetic simulation is employed to design and evaluate it. At first, the necessity of the magnetic shield is investigated with considering the detector magnetic shield and the magnetic circuit of the PMU magnet. Then, we design the magnetic shield by the simulation with several combinations of design parameters. The final design is determined by a trade-off study between the shielding power and the weight of the magnetic shield. Simultaneously, the comparison between the simulation and the measurement is performed with a small prototype.

Comments from Reviewers