7th Asia-Pacific Conference on Plasma Physics, 12-17 Nov, 2023 at Port Messe Nagoya

Development of bismuth metallic Hall sensors for the HL-2A tokamak magnetic measurements

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Measurement errors will inevitably arise when using conventional inductive sensors to measure magnetic fields in future long-pulse fusion reactors. Recently metal-based Hall sensors are proposed, manufactured, and optimized for ITER and DEMO[1-3]. The sensors survive the environmental conditions corresponding to those of ITER (neutron irradiation and vacuum vessel bakeout), which demonstrates that it is prospective the metallic Hall sensors have the potential to be used in future fusion reactors.

Recently the design and manufacturing technology of metal Hall sensors has been developed in the HL-2A/M tokamak. Metal Hall sensors, involving three metals (bismuth, antimony, and copper), and two thicknesses (30 nm and 100 nm), have been manufactured and tested. The test results show that the sensitivities of the sensors are consistent with theoretical expectations approximately, and the output voltages are proportional to the magnetic field. But when the sensitive layer thickness is lower than 100 nm, the sensitivity shows a nonlinear relationship in the range of 0-10 mT. 100 nm bismuth Hall sensor offers the largest sensitivity among them, but it is temperature-dependent.

Positive results of these test experiments prompted the further installation of bismuth Hall sensor arrays on HL-2A to test the stability and reliability of the system in an actual working environment, as shown in Fig.1.

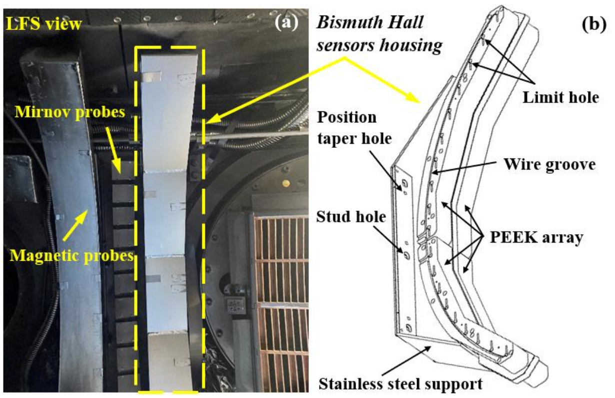

Fig. 1. (a) Specific location of bismuth Hall sensors housing on the low-field side (LFS) of HL-2A. (b) The design detail of the bismuth Hall sensors housing.

Each selected sample bismuth sensor is individually calibrated before installation, including the specific value of sensitivity K_H and stable calibration accuracy. The calibration accuracy test results show that the bismuth-based metal Hall sensor has good stability in the range of 1 T magnetic field. When the magnetic field is larger than 3 mT, the calibration accuracy is better than ±1%, as shown in Fig.2. Furthermore, the identification of advanced divertor configurations and real-time control of the high-performance plasmas in HL-2M with the optimized metallic Hall sensor is the main issues for further research and development.

This work is supported by the National Magnetic Confinement Fusion Energy R&D Program of China under Grant Nos. 2022YFE03030002, 2018YFE0301104, and 2019YFE03010002.

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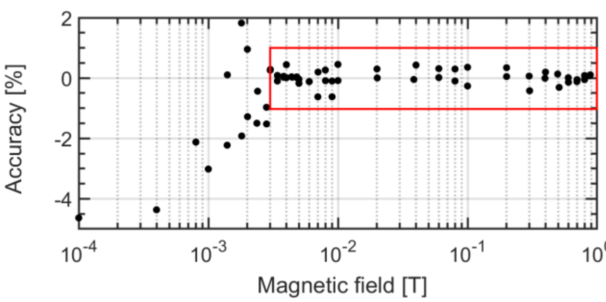

Fig. 2. The calibration accuracy of the sensors with various magnetic field strengths. Labeled by the red rectangle, the calibration accuracy is within ±1% when the magnetic field strength is larger than 3 mT.