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Development of Fiber-Optic Diagnostic on Vacuum Vessel Current of QUEST (2)
QUESTにおける光ファイバーを用いた真空容器電流計測器の開発 (2)

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In spherical tokamak QUEST at Research Institute for Applied Mechanics, Kyushu University, the vacuum-vessel current makes the error magnetic field. It influences the start-up of the current of plasma. We are planning the current measuring instrument using Faraday rotation in the optical fiber. We adopted the dual photo elastic modulator polarimetry. The measurement accuracy is required to be not less than three-digits under ambient temperature variation. By bench testing, we evaluated the accuracy of the optical system and the temperature dependence of optical fiber sensors. The temperature dependence of the optical fiber and the measurement accuracy were confirmed to be within tolerance.

1. Introduction

This study is intended to measure the vacuum-vessel currents of spherical tokamak at Kyushu University, QUEST [1]. Error-magnetic fields generated by vacuum-vessel currents obstruct the ramp-up of the plasma current in QUEST since there is no toroidal gap to avoid to toroidal currents on the vessel parallel to the plasma current.

Measurements of the total current flowing through the vacuum vessel are required for the confirmation of the accuracy of the calculated eddy current with evaluation models. The QUEST is normally operated with bake-out temperature of the vaccum vessel at about 100°C. Requirements for this measurement are long-term stability and high sensitivity ao that we adopt polarimetry to avoid integration drift in the case of commomly used Rogowski coil. We measure the Faraday rotation angle along an optical fiber in this study. And, we evaluate the electric current from the faraday rotation angle. Optical fiber current sensor has advantages, which are wide dynamic range, fast response, high sensitivity, strong inductive noise, compact, lightweight, low-loss optical transmission and electrical insulation. The most important issue at present is the temperature dependence of the fiber sensor. This paper provides an overview of the device configuration, and the required accuracy, about the results of bench testing.

2. Fiber Sensor Instrumentation Overview

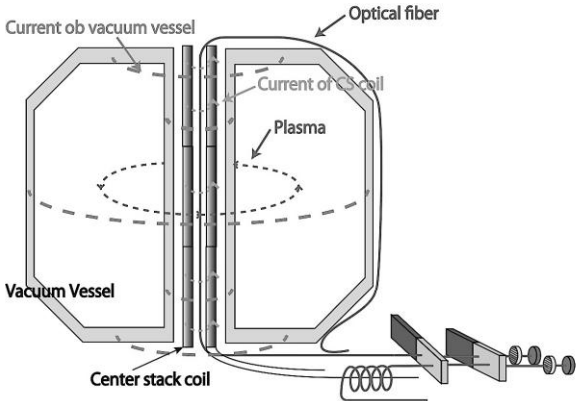

Fig. 1. Illustration of the measurement setup on QUEST

We will wind a poloidal loop of an optical fiber around the vacuum vessel as shown in Fig. 1 and measure the toroidal current in the same way as an optical current transformer. The loop must go through the torus center since there is no room between the center stack (CS) coil and the vacuum vessel so that the vacuum-vessel current must be evaluated under significant background signals up to 1.73 MA·turns by the CS–coil currents. The Ampere-turns of the CS-coil current will be separately measured with a coil of optical fiber wound at the coil feeder and it will be numerically subtracted from the total Ampere-turns measured with the loop. In order to measure the vacuum current in accuracy of less than 1 kA, the required measurement accuracy is not less than three digits. We measured the temperature distribution along the planned route of the loop with thermocouples and found that the integrity of the optical fiber is preserved since the highest temperature does not exceed 50°C.

3. Optical Test Bench

The Verdet constant of a flint glass fiber is about six times that of a silica glass fiber and the photo elastic constant of the former is much smaller than that of the latter, which enable us to wind the optical fiver with smaller bending radii. We tested a single-mode flint glass fiber for 1550 nm with a SLD (super-luminescent diode) of wavelength 1545 nm as light source. We adopted the dual photo elastic modulator (HINS Instruments, Inc., PEM-90 I/FS50 and II/FS42) polarimetry. The modulator axes of the two modulators are at 45 degrees with the polarizer passing axis at 22.5 degrees with each modulator. The second harmonic amplitudes of the photodiode output are measured with two lock-in amplifiers.

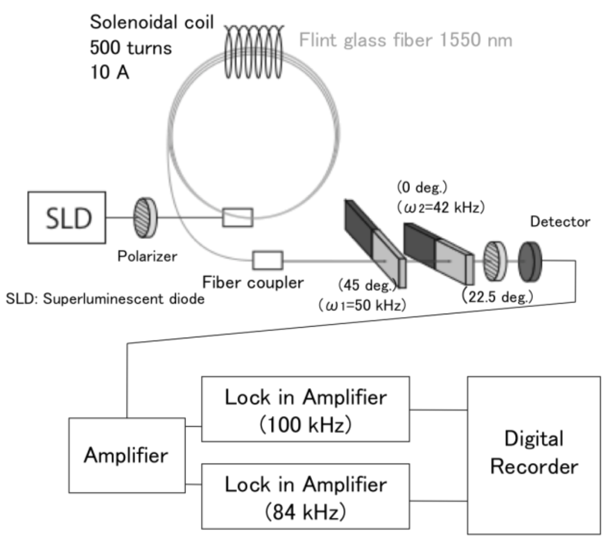

fig.2. Optical setup of bench testing

3. Results of bench tests

An example result of bench testing of current measurements of a solenoid is shown in Fig. 3. The standard deviation of the measured polarization angle was confirmed to be well below a required accuracy of the Faraday rotation angle measurement of 0.37 degrees.

The temperature dependence of the Verdet constant of the flint glass fiber, however, is slightly stronger than that of silica fibers. Figure 4 shows a preliminary evaluation result of the Verdet constant by varying the room temperature. The weak dependence may become a problem to assure the applicability of Ampere's theorem to measure the current. The averaged value agrees with the catalog value when the dependence of inversely proportional to the square of the wavelength is taken into account [2,3].

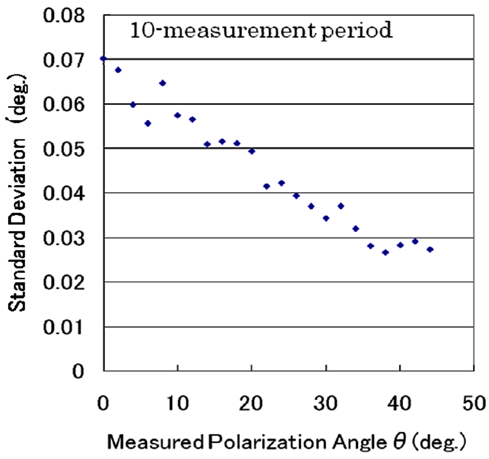

fig.3. Polarization angle dependence of the measurement errors.

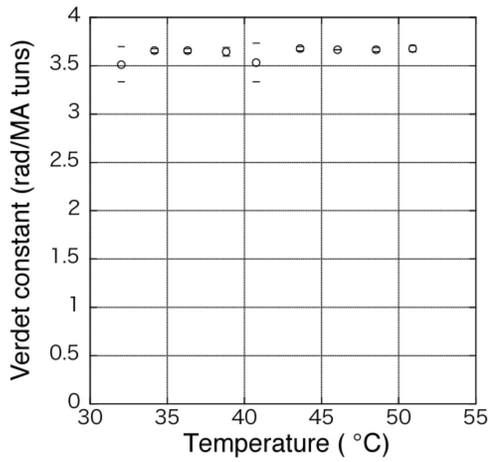

fig.4. The Verdet constant evaluated as a function of the room temperature.

4. Summary

Standard deviation of measured polarization angle is within target resolution ($\Delta\theta \le 0.37$ deg.). Uniform temperature along the optical fiber is required not to be affected by the weak temperature dependence of the Verdet constant of the fiber.

References

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