§51. Development of Fiber-Optic Diagnostic on Vacuum Vessel Current of QUEST

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A magneto-optic polarimeter is being developed for the measurements of the toroidal currents on the vacuum vessel of QUEST. The toroidal current is measured in the same way as an optical current transformer with a poloidal loop of an optical fiber wound around the vacuum vessel as shown in Fig. 1. 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 current. 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.

The Verdet constant of a flint glass fiber is about six times that of a silica glass fiber and the photoelastic constant of the former is much smaller than that of the latter, which enable us to wind the optical fiber 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 QUEST tokamak is normally operated with bake-out temperature of the vaccum vessel at about 100°C. We measured the temperature distribution along the planned route of the loop with thermocouples. An example result of the temperature measurement is shown in Fig. 2. The temperature was highest near the PF2 coil while thermocouples inside the CS coil indicated temperatures around 20°C presumably because the temperature of the cooling water of the CS coil was about 20°C. The integrity of the optical fiber was found to be preserved since the highest temperature does not exceed 50°C.

The temperature dependence of the Verdet constant of the flint glass fiber, however, is slightly stronger than that of silica fibers. Figure 3 shows an evaluation result of the Verdet constant by setting the optical fiber in a thermostatic chamber. The fitted line indicates that the Verdet constant varies by about 0.2% in the temperature range from 20°C to 50°C. The temperature control of the optical fiber within 15°C difference is required to assure the applicability of Ampere's theorem to measure the current with an accuracy of three digits. The averaged value agrees with the catalog value when the dependence of inversely proportional to the square of the wavelength is taken into account.

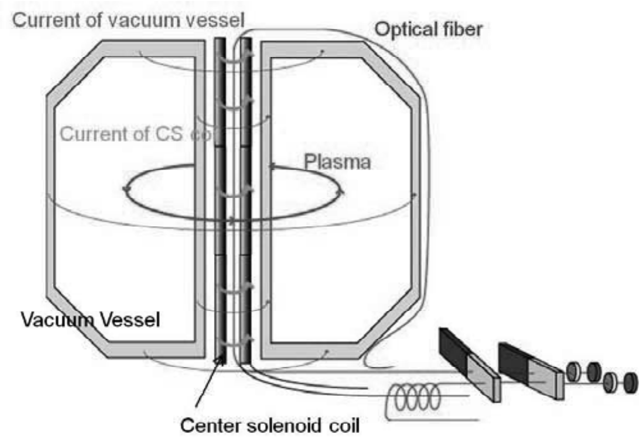

Fig. 1 Schematic illustration of the optical fiber poloidally wound around the vacuum vessel of QUEST. A coil of optical fiber is used to numerically cancel the Ampere-turns of the CS-coil current. Two plates at the bottom right indicate PEMs.

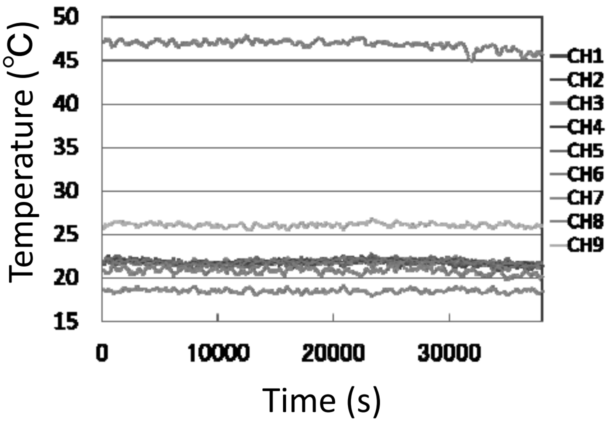

Fig. 2 Time traces of temperatures along the planned route of the loop measured with thermocouples.

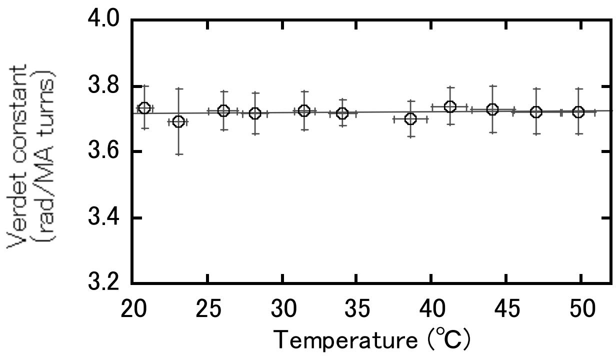

Fig. 3 The Verdet constant of the single-mode flint glass fiber evaluated as a function of the temperature inside a thermostatic chamber. A straight line was fitted.