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Sat-Mo-Po.05-06: Coherent-Phase Optical Time Domain Reflectometry for Monitoring High Temperature Superconductor Magnet Systems

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High temperature superconductor (HTS) magnet systems, especially those designed for fusion reactors, require effective and reliable monitoring to avoid damaging anomalies. In tokamaks, some of the magnetic coils are time dependent, which cause additional strain and electromagnetic effects within the magnet system. Ionizing radiation can also lead to non-uniform degradation of conductors. The resulting decrease in critical current uniformity across the magnet, along with manufacturing defects, failure of structural materials or cooling systems, can all potentially initiate a quench. HTS have a lower normal zone propagation velocity than low temperature superconductors, and this causes normal zones to be localized and hard to detect, increasing the risk of permanent damage. Fiber optic sensors have several qualities that are essential in fusion systems; above all they are immune to electromagnetic fields, which would overwhelm voltage-based detection systems.

In this study, the efficacy of a novel optical fiber interrogation technique to monitor superconducting magnets is tested. This solution focuses on the use of optical fibers interrogated by coherent-phase Optical Time Domain Reflectometry (cpOTDR), which is capable of long-range interrogation (tens of kilometers) at high acquisition rates (tens of kilohertz), as well as separation of strain and temperature. Although there is limited data on temperature sensitivity and cross sensitivities of this technique at cryogenic temperature, interrogation range and acquisition rates are potentially superior to conventional Rayleigh backscattering interrogation based on Optical Frequency Domain Reflectometry (OFDR), motivating research in this area. The cpOTDR interrogation method has been well demonstrated in geophysical applications at room temperature, as well as under low magnetic fields. This study characterizes its ability to detect temperature variations at temperatures as low as 4 K. Additionally, the response to highly localized heating that is smaller than a fiber gauge length was evaluated to determine the viability of this interrogation technique for detection of hot-spots within HTS magnets. Results showed that the technique holds promise for this application and highlighted the current technical challenges that have to be addressed by further research.

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