Chapter 6 - Conclusions

In this dissertation, a compact, highly sensitive, and well temperature compensated optical fiber magnetic field sensor system has been proposed, designed, fabricated and tested. The sensor is based on the optical detection of magnetostriction induced microdisplacement using modified extrinsic Fabry-Perot interferometry (EFPI).

Various candidate magnetostrictive materials, including Terfenol-D and Metglas materials with different geometries, were investigated and evaluated to select a material that can best support the sensor design. The obtained results indicate the Metglas with wire geometry is most suitable for weak magnetic field measurement because of its high sensitivity and the geometrical advantage. To further increase magnetstriction and straighten materials bending due to residual stress, transverse field annealing was developed and a system was implemented. One order of magnitude improvement in the magnetostriction of Metgals materials has been obtained using this method.

Since various materials with different coefficients of thermal expansion (CTEs) are involved in the sensor element, the sensor would thus show strong temperature dependence, which is unwanted in the magnetic field measurement. To significantly reduce the temperature dependence, the sensor employs a borosilicate glass tube functioning as both a mechanical alignment element to the optical fiber and the Metglas wire, and a differential thermal expansion compensator. In addition, a mathematical method has been developed to accurately measure CTE's of the key sensor materials. Based on the proposed temperature compensation scheme, precisely measured CTE values, and quality sensor fabrication, 98% suppression of temperature-induced drifts has been obtained.

Various approaches were detail investigated to minimize exertion of strain to sensor element in sensor packaging. It has been shown that even very small level of distortion to the long sensor element could increase the friction between the fiber/wire and borosilicate tube and may lead to significant reduction in sensitivity. Several methods for quality and effective sensor packaging have been developed.

Based on the magnetostrictive material, temperature compensation scheme, and sensor packaging technology optimized for highly sensitive measurement of low magnetic fields, a sensor instrumentation system for the measurement of one component of magnetic fields has been developed. In the signal processing, the Quadrature-Phase-Shift (QPS) signal demodulation was applied to ensure the accurate detection of the phase of the demodulated signal regardless of the initial phase of the EFPI sensor. Two quadrature phase shifted sensor elements yield unambiguous strain information that is correlated to the magnitude of the weak magnetic field. A single-board microcomputer is incorporated to achieve accurate signal demodulation, processing, calibration data storage and sensor signal display. The system has been shown to have a resolution of better than 100 nT over a range of 100 nT to 40,000 nT.

Furthermore, based on the results obtained from the one-dimensional field sensor system, a 3-dimensional vector magnetic field measurement instrumentation system has been developed. The instrumentation involves three pairs of EFPI sensor elements arranged orthogonal to one anther to measure the three orthogonal components of a magnetic field, which allow the determination of both vector field amplitude and direction.

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Vita

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