Transversal Magnetostriction to 60 Tesla with an Optical FBG Technique

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Introduction

Magnetostriction, the strain response of a material to an external or internal magnetic field, is a thermodynamic tensor quantity that is closely related to the magnetization. Additionaly, the volumetric coefficient of thermal expansion $\alpha_v(T) = \partial V/\partial T$ is related to the specific heat, which in turn is often used to identify elementary excitations and ground-states in materials. Pulsed field facilities provide the highest available magnetic fields for research purposes. However, electrical and vibration-related noises are significantly higher than in steady fields, and the short timescales make noise cancellation challenging. In this demanding environment, fast optical techniques which are immune to electromagnetic interference have significant advantages. Inspired by the above motivations and challenges Daou et al. developed an optical fiber Bragg grating (FBG) technique that demostrated to perform fantasticaly in pulsed fields environments [1,2]. As initially developed, however, the technique could not be used to measure lattice changes perpendicular to the applied fields, and the sample volume could not be computed.

Experimental

We expanded and improved an optical FBG technique to include measurements of the magnetostriction in the configuration $\Delta L \perp H$ in the NHMFL 60T motor generator-driven long pulse magnet, with the goal of determining the volumetric magnetostriction of materials. The modifications consisted in (a) building a fiber guide to bend the 125 μm optical fiber in the shape of a cork screw, such that the FBG sensor at the end of the fiber is placed perpendicular to the axis of the magnet, and (b) the addition of a light polarization scrambler to further randomize the light source polarization state and in this way reduce the polarization rotation artifacts [3].

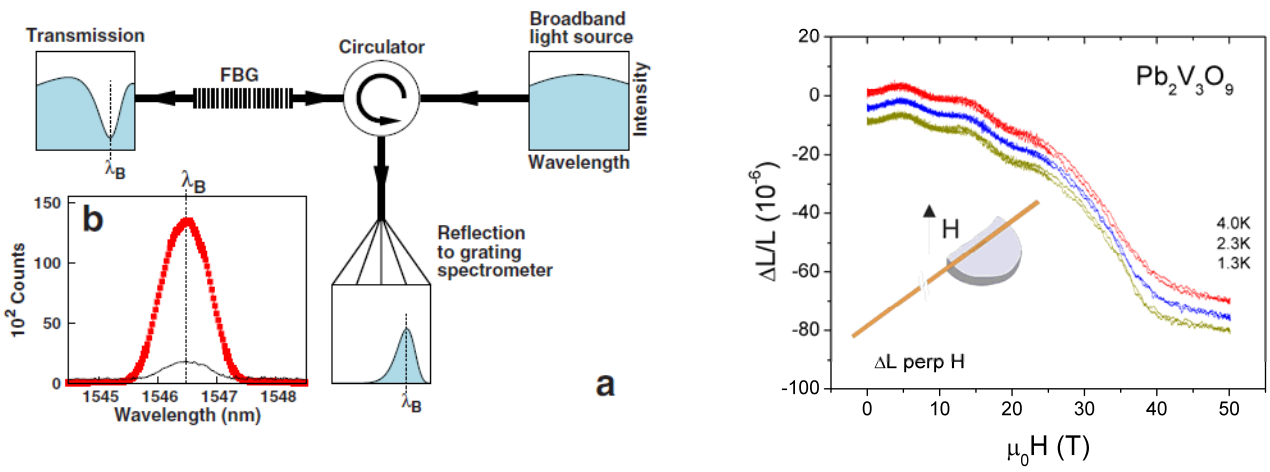

Figure 1.(a) Schematics of the optical FBG technique described by Daou et al. **(b):** Typical reflection spectrum recorded at a frequency of 46kHz with an line array InGaAs camera. **(left panel):** Strain $\Delta L/L$ vs. magnetic field in a $Pb_2V_3O_9$ single crystal in the $\Delta L \perp H$ configuration measured in a 60 T motor-generator-driven long pulse magnet. The contraction observed in the lattice parameter at $\mu_0 H$ ~37T is due to the suppression of a low temperature XY-AFM phase. The small and broad apparent oscillations observed at fields $\mu_0 H$ < 25T are an artifact caused by light polarization rotation in the magnet fringe field. The amplitude of these oscillations was reduced by a factor of five (resulting in what is seen in this figure) by the addition of a polarization scrambler in the original setup, making it possible to observe the magnetic phase transition more clearly.

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References

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[2] M. Jaime et al., *Proc. Natl. Acad. Sci* **109**, 12404 (2012).
[3] M. Jaime, manuscript in preparation.