Ultra high-field dilatometry in UO_2 single crystals

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Introduction

Uranium dioxide is known to be a Mott insulator, and to develop first-order type non-collinear antiferromagnetic order of uranium magnetic moments below T_N = 30 K. Strong spin-lattice interactions based on oxygen Jahn-Teller modes have been proposed to account for these properties [1-3]. Despite theoretical and experimental efforts, the nature of the strong spin-lattice coupling and how it impacts the thermal properties of UO_2 are still unclear. Recently, a piezomagnetic effect was discovered in UO_2 [4].

Experimental

The axial strain $\Delta L/L(H)$ was measured along [111] on an oriented high-quality single crystal of UO_2 using an optical fiber Bragg grating (FBG) dilatometry technique adapted for the micro-second timescale of a 140T single-turn-coil magnet [5] at the NHMFL Pulsed Field Facility.

Results and Discussion

Figure 1 shows the axial strain vs time measured in the PM state, alongside the magnetic field in the single turn coil magnet. Subtraction of the H^2 component to the magneto-strain reveals ringing in the sample at 770MHz. Figure 2 shows the strain vs time in the AFM state after subtraction of 770MHz ringing. The observed magneto-elastic response is as expected for UO_2 in the positive side of the magnetic field profile. The negative field side at time stamp t >7.5 μsec, additionally, shows a 180^o phase-shift in sample ringing triggered by the AFM domain flip characteristic of piezomagnetism in UO_2. A resonant ultrasound technique (not shown) was used to confirm that 770MHz is a frequency consistent with the natural ringing spectrum of the sample in the dilatometry experiment.

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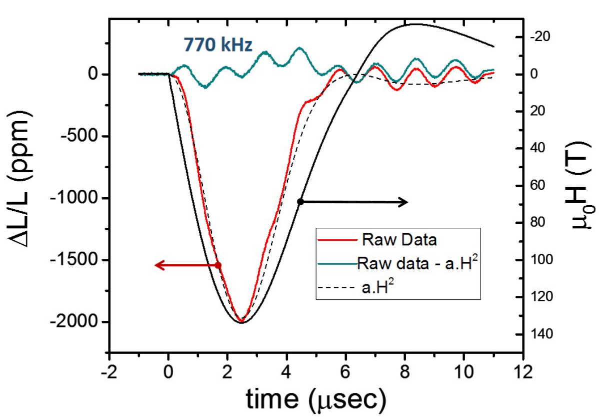

Fig.1 Strain ΔL/L (red, left y-axis), and magnetic field (black, right y-axis) vs time for UO_2 at T > T_N in the NHMFL single turn coil magnet. Sample ringing at 770 MHz (green, left y-axis) is uncovered after subtraction of a contribution proportional to -H^2 (black dashed line).

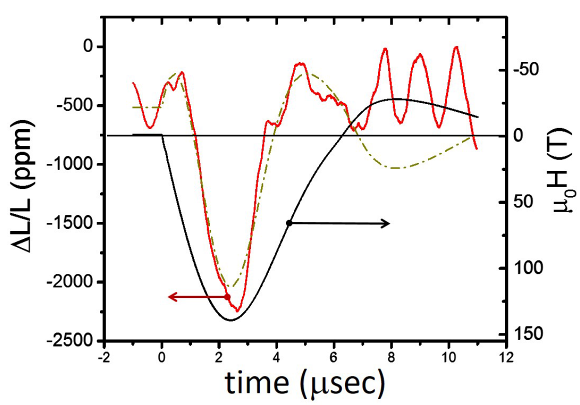

Fig.2 Strain ΔL/L (red, left y-axis) after subtraction of ringing at 770MHz frequency identified in Fig1, and magnetic field (black, right y-axis) vs time for UO_2 at T < T_N in the NHMFL single turn coil magnet. The resultant strain follows closely the expected $\alpha H-\beta H^2$ behavior displayed by the dark yellow dash-dot line.