Demonstration of Giant Faraday Rotation in Terbium Glass Using a Table-Top Pulsed Magnet

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Magneto-optical spectroscopy began with the original experiments of Michael Faraday in 1845. Since then, advances in magnet technology have provided high magnetic fields for optical measurements with a variety of approaches, all of them requiring either liquid helium for superconducting magnets up to 20 T or access to large scale facilities for non-destructive pulsed resistive magnets up to 70 T. Here, we present and demonstrate the operation of a 10-T portable pulsed magnet appropriate for magneto-optics. The magnet and its power supply are readily prepared for an optical table measurement setup. The coil sits in liquid nitrogen in a simple polycarbonate transparent cryostat with horizontal optical access to a bore diameter of 6 mm for the sample. The pulse lasts for 5 ms and can be periodically repeated every 5 s up to 5 T. Given this setup, we demonstrated a giant Faraday rotation in terbium glass referenced as M18 Faraday glass [http://www.kigre.com]. The sample temperature was set at 110 K, and the sample was placed between two parallel polarizers and illuminated by a red laser-pointer beam. We found that the output beam displays a periodic sinusoidal intensity as a function of magnetic field, as $I = I_m(\cos\frac{\pi B}{B_F})^2$. We obtained up to six periods as the magnetic field was swept up and down from 0 to ±5 T. The data evidence a giant Faraday rotation that follows the Malus law ($= I_m \cos\theta^2$), and therefore, the rotation angle is given by the expression $= \frac{\pi B}{B_F}$. On the other hand, since the Faraday angle is proportional to the sample length L, according to the Verdet law, $\theta = CLB$, the material Verdet constant is directly obtained as $C = \frac{\pi}{LB_F}$. Here, L = 1 cm, and thus, the Verdet constant C = 160 rad/Tm. The Verdet constant in this paramagnetic material becomes larger at lower temperatures, exhibiting the Curie law ($\propto 1/T$). Another advantage of the portable setup is the very high signal-to-noise ratios achievable simply by using the repetitive pulsed mode and averaging. In this situation, one does not need to implement modulation techniques. A final and unique advantage of the repetitive mode is to allow a step-scan recording mode of magneto-spectroscopy. This mode of operation provides a three-dimensional plot of spectra as a function of magnetic field. This mode was recently demonstrated in the THz frequency range [IRMMW-THz 2011].