Studies of Light-Induced Magnetization Using a Commercial SQUID Magnetometer

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Certain classes of materials exhibit changes in their magnetization or magnetic state in response to *light*. Observation of these effects is most convincingly demonstrated by measuring the optically-induced changes in the real magnetic moment – for example, in a SQUID magnetometer. Coupling *unpolarized* light into a commercial SQUID is relatively simply accomplished via a multimode optical fiber, and fiber-coupled probes of this type are readily available from vendors. However, if light with *tunable polarization* at the sample is required, then considerably more effort and a custom-built apparatus is required.

Here we demonstrate a system to deliver (and tune) circularly polarized light to an *in situ* sample of $SrTiO_{3-\delta}$ in a Quantum Design MPMS SQUID magnetometer. 405 nm light was coupled to the sample via a standard single-mode UV optical fiber (0.13 NA), using a three-axis fiber launcher with piezoelectric actuators. It was critical to produce and maintain circularly polarized light at the output of the fiber (at the sample) while the sample and probe were *in situ*. We used a linear polarizer and a variable waveplate (a Soleil-Babinet compensator on a rotation mount) to launch circularly polarized light into the fiber. We adjusted the polarization state of the light within the fiber by straining it and inducing birefringence with a manual fiber polarization controller. This is essential to correct for unwanted birefringence in the fiber (due to bends, etc.) to ensure circular polarization of the light at the output of the fiber.

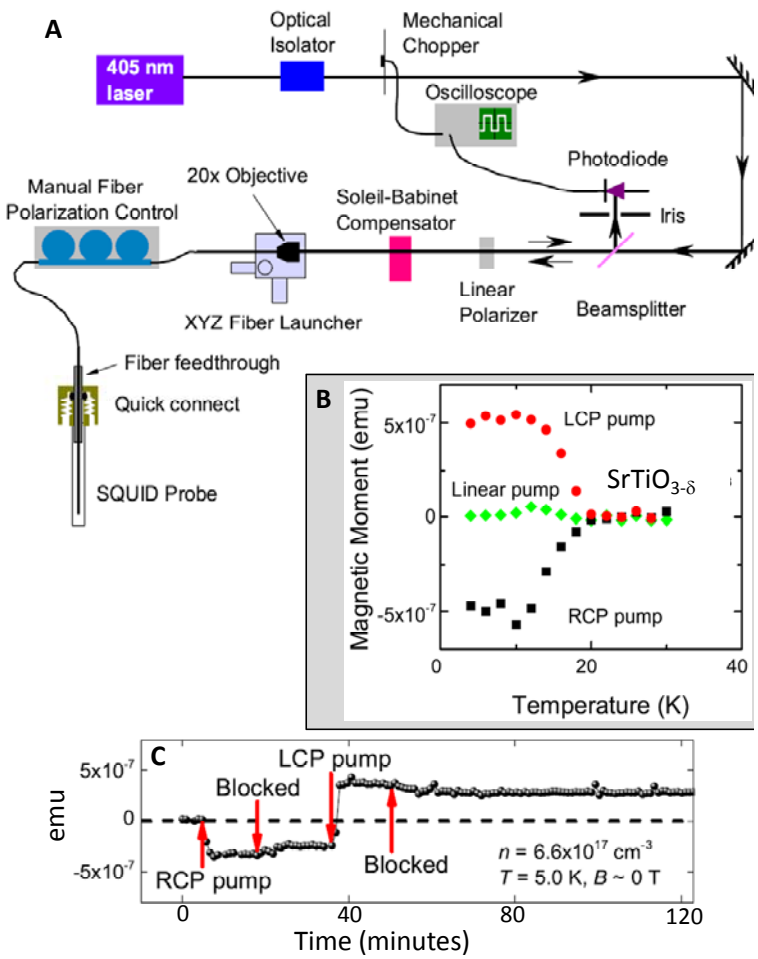

Fig. 1 A) Schematic: how circularly-polarized light is coupled into a commercial SQUID magnetometer. B) Optically induced magnetic moment at B=0 in $SrTiO_{3-\delta}$. C) The induced signal persists long after the pump illumination is turned off.

Circular polarization of the light at the output of the fiber was confirmed and continuously monitored by measuring the intensity of the light that was back-reflected from the end cleave of the fiber. Upon back-reflection, RCP light (for example) changes to LCP light, which is then nulled upon traversing the time-reversed path back through the Soleil-Babinet and the linear polarizer. A perfect null is achieved only when the light is perfectly circularly polarized at the end of the fiber. An iris (to block other reflections), photodiode, chopper and oscilloscope make this back-reflected light easy to monitor. More broadly, this monitoring scheme effectively turns the back-reflected intensity into a polarization sensor. To switch from (say) RCP light to linear or LCP light at the sample, the Soleil-Babinet is then rotated by 45 or 90 degrees.

The data reveal that magnetization can be induced in oxygen-deficient $SrTiO_{3-\delta}$ below 18K, and that the magnetization direction is reversed upon switching from RCP to LCP light. Moreover, the induced magnetization persists long after the pump light is turned off – evidence for a longlived persistent magnetization in this nominally nonmagnetic material. This work is supported by the Los Alamos LDRD program.

[1] W. D. Rice *et al*, *submitted*.