Magnetoelectric Coupling in Frustrated Rare Earth Indium Oxides

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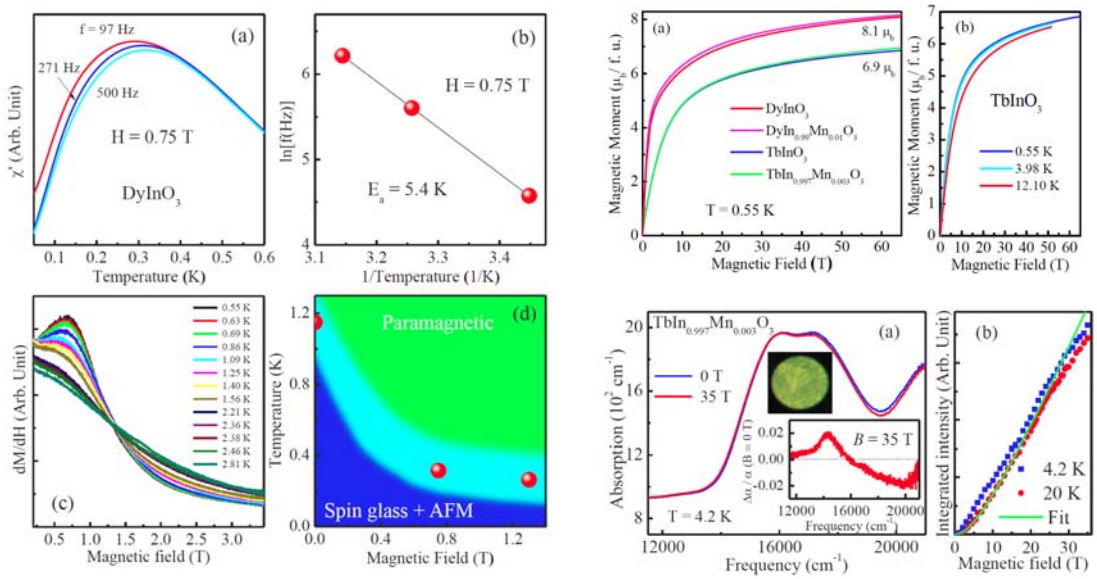
Introduction

Magnetoelectric coupling in materials like multiferroics, dilute magnetic semiconductors, and topological insulators has attracted a great deal of attention, although most work has been done in the static limit. Magneto-optical spectroscopy offers a way to investigate the dynamics of charge-spin coupling, an area where there has been much less effort. Our recent discovery that applied magnetic field drives a color change in $Ni_3V_2O_8$ is an example this effect. More recently, we extended our work to include rare earth indium oxides like R(In,Mn)O_3 (R = Dy, Tb, Gd). Here, the rare earth and indium centers bring in spin-orbit coupling, and the manganese centers function as paramagnetic impurities and chromophores. What is different is our effort to bring complementary magnetic properties work together with magneto-optical spectroscopy.



Left panel: temperature dependence of χ for $DyInO_3$ at selected frequencies and the temperature-field phase diagram; Middle panel: Isothermal magnetization of $DyInO_3$, $DyIn_{0.99}Mn_{0.01}O_3$, $TbInO_3$, and $TbIn_{0.997}Mn_{0.003}O_3$ along with the temperature dependent magnetization for $TbInO_3$; Right panel: absorption coefficient, absorption difference, and fits of the optical properties to the integrated magnetization for $TbIn_{0.997}Mn_{0.003}O_3$.

Results and Discussion

The measured moments of $TbInO_3$ and $DyInO_3$ are ~6.9 μ_B/Tb^{3+} and ~8.1 μ_B/Dy^{3+} at 65 T, respectively, although they are not saturated at this field. The values are approaching to the free ion magnetic moment of Tb^{3+} (9 μ_B) and Dy^{3+} (10.6 μ_B) and are expected to saturate at ~200 T. Mn substitution introduces isolated paramagnetic impurities into the lattice, so magnetization is slightly higher. A maximum in the dM/dB curve of $DyInO_3$ at 0.8 T is indicative of a spin glass transition, we also characterize by low temperature ac susceptibility measurements.

The temperature-magnetic field phase diagram is shown above. We are also using magneto-optical spectroscopy to prove structure-property relationships associated with charge-spin coupling in the RIn$_{1-x}$Mn$_x$O$_3$ systems. Saturation of the magnetic moment gives rise to magnetochromism as shown above for $TbIn_{0.997}Mn_{0.003}O_3$. We are also photographing this effect. This work advances our understanding of magnetoelectric coupling and motivates fundamental research on other rare-earth element materials under extreme conditions.

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