Time-resolved Studies of Coupled Dynamics in CER and CMR Manganites

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Introduction
Colossal Electro/Magneto Resistance (CER/CMR) describes exotic phase transitions that result in a large decrease of material resistivity. The phenomena arise from a complex interplay of the charge, spin, and lattice, and we are studying these coupled dynamics, especially the dynamics of charge anisotropy due to orbital order in Mn-O plane, using time-resolved optical methods. The samples are a Ferromagnetic insulator La$_{1-x}$Ca$_x$MnO$_3$ (LCMO) at x~0.16 and an Antiferromagnetic insulator Pr$_{1-x}$Ca$_x$MnO$_3$ (PCMO) at x~0.5.

Experimental
We have grown single crystal samples of LCMO and PCMO using a zone furnace in collaboration with Prof. Wiebe’s group. The materials are characterized by x-ray, magnetization, Laue backscattering, and transport measurements. We have performed temperature, electric and magnetic fields-dependent simultaneous transient reflectivity and optical anisotropy measurements in SCM3, an optics-dedicated 17.5T superconducting magnet, and in the Cell 5 31T resistive magnet. Measurements of transient reflectivity and optical anisotropy are simultaneously taken from room temperature down to 4K and from 0T and 31T. To eliminate small contributions of the magnetic moment (i.e. magneto-optical Kerr effect), measurements taken under applied magnetic fields are reported as the average at positive and negative fields. For LCMO sample, we have also attempted optical measurements in the presence of an applied electric field.

Results and Discussion
For LCMO (just below $T_{\text{orbital order}}$), the electric and magnetic field dependence of transient reflectivity and optical anisotropy at 5K up to 25V are essentially same. However, the differences are observed in transient optical anisotropy when we apply the voltage higher than 25V (just before CER threshold). Fig. 1 a) and b) show the results of transient reflectivity and optical anisotropy at 50V, respectively. Although the reflection photo-metallization grows with the magnetic field (Fig.1 a)), the optical anisotropy shows no such effect (Fig.1 b)), suggesting a rather dynamic orbital ordering. Another significant difference is the sign flip in intermediate meta-stable state. This strongly suggests the rotation of optical axis over multi-domains.

Conclusions
While the charge dynamics show a small dependence on applied electric and magnetic fields on both materials, changes in the anisotropy provide significant additional information. Together with a prior report on PCMO, these changes reveal precursors to the insulator-metal transitions (CER/CMR) and help to clarify the electronic response to photo-induced metallization and subsequent thermalization.

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