

# Time-Resolved Spectroscopy of Multifunctional Materials in Collaborations with the NHMFL

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This talk will summarize three time-resolved optical measurements as part of collaborations with the NHMFL, focusing on three classes of multifunction material systems for developing concepts for new device functionalities. **(1)** Organic-inorganic halide perovskites (OIHP), where perovskite layers are separated by an organic spacer material, **(2)** Multiferroic BaTiO<sub>3</sub>-BiFeO<sub>3</sub> films and nanorods, and **(3)** GaMnAs, a ferromagnetic semiconductor.

In the first materials system, we focused on probing the photoluminescence (PL) and time resolved PL of quasi-2D BA<sub>2</sub>PbI<sub>4</sub>, and provided new insights on the temperature dependence of their excitonic dynamics and fine structures of their PL emissions. Furthermore, we observed long lifetimes which can result from the formation of large polarons; screening the Coulomb interactions of the charge carriers, and reducing the scattering of the carriers with charge defects. **[1]**

Focusing on a different materials system, using several magneto-optical techniques at high fields, we probed multiferroics BaTiO<sub>3</sub>-BiFeO<sub>3</sub> with strong magneto-electric (ME) properties. Specifically, by detecting coherent phonons (CP) we provided detailed spectroscopy information on coherent states in this material system. Our results provide new insights into the ME signatures in these heterostructures. **[2]**

Finally, we present our experimental and theoretical studies on the generation and propagation of longitudinal coherent acoustic phonons by ultrafast laser pulses in a ferromagnetic GaMnAs film at high external magnetic fields. Our observation provides new information, reporting an extremely large increase in the amplitude of the CP when an external magnetic field is applied. The ability to control and manipulate coherent vibrational degrees of freedom on a nanoscale length and picosecond time scale promises to be revolutionary in the fields of quantum phononics. **[3]**

[1] Brenden A Magill, Kai Wang, Stephen McGill, Christopher J Stanton, Shashank Priya, Giti A Khodaparast, AIP Advances, **12**, 015114 (2022).

[2] Rathara R. H. H. Mudiyansele, Brenden A. Magill, John Burton, Moira Miller, Joseph Spencer, Kiara McMillan, Giti A. Khodaparast, Han-Byul Kang, Min-Gyu Kang, Deepam Maurya, Shashank Priya, Jade Holleman, Steve McGill, and Christopher J. Stanton, J. Mater. Chem. C, **7**, 14212 (2019).

[3] Brenden A. Magill, Sunil Thapa, Jade Holleman, Stephen McGill, Hiro Munekata, Christopher J. Stanton, and Giti A. Khodaparast, Phys. Rev. B **102**, 045306 (2020)