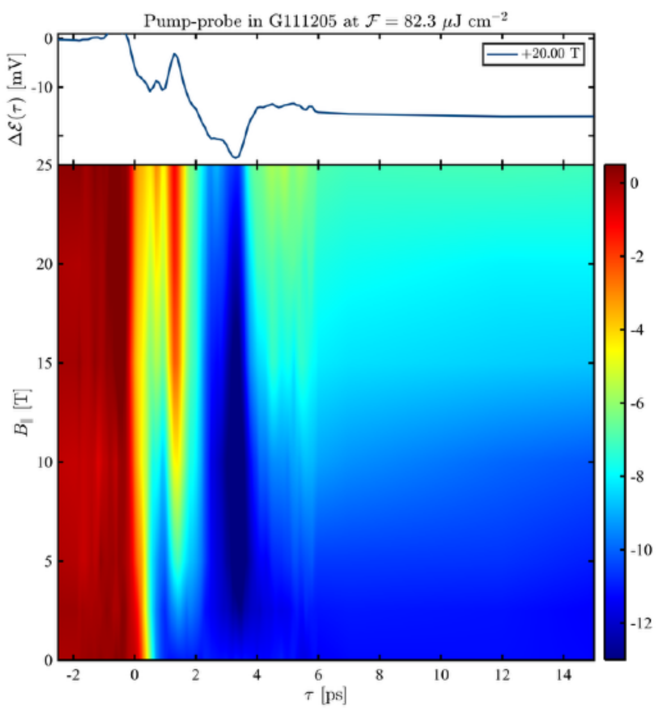
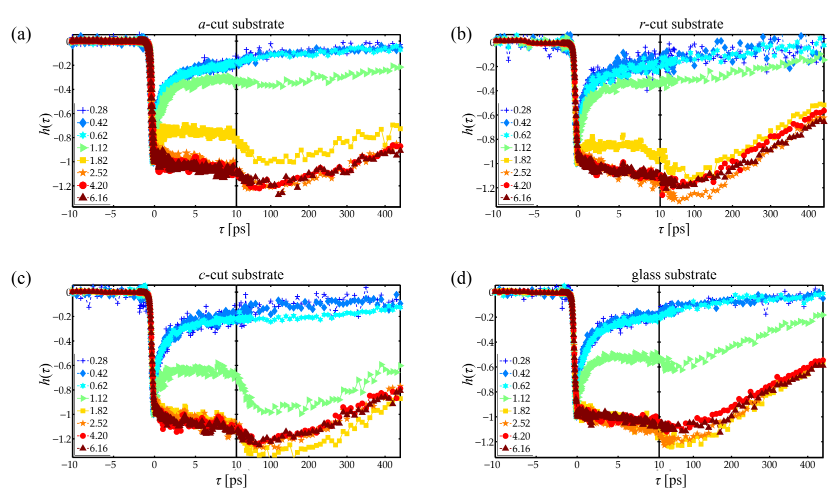
RESEARCH, DAVID J. HILTON

Our research program seeks to understand emergent behavior in materials and to develop novel experimental capabilities to demonstrate coherent control of matter. These experiments are all designed to push the forefront of condensed matter physics to help us to understand the often exotic behavior of systems that have enormous future technological importance. Our research team includes my students and postdocs at UAB as well as a broad group of collaborators that to develop entirely new experimental capabilities that allow us to perform groundbreaking new experiments. Students have run experiments both here at UAB, but also at national user facilities such as the National High Magnetic Field Lab (NHMFL), Argonne National Laboratory, NASA-Goddard, and at Los Alamos National Lab.



Ultrafast Spectroscopy in High Magnetic Fields: We have developed an entirely new experimental capability to perform time resolved far infrared and terahertz spectroscopy in unprecedented external magnetic fields (≤25 T). Our current work has focused on developing a novel pump probe spectrometer [Curtis et al., Optics Letters 39, 5772 (2014)] in which we have demonstrated the first subpicosecond dynamics measurements of condensed matter systems at 25 T. Our funding this work is through the NSF CAREER and Major Research Instrumentation Programs and two joint grants with U. South Florida (Denis Karaiskaj) that are funded by NSF and DOE. The scientific goals of this work are to study the inter- and intra-Landau level coherences in high mobility two-dimensional electron systems, which will include gallium arsenide 2DEG's as well as the novel class of layered transition metal dichalcogenides. Our terahertz experiments, along with the 2D MONSTR experiments [J. Paul, *et al.*, The Journal of Chemical Physics 141, 134505 (2014)] that will be conducted in parallel by our collaborators at the Univ. South Florida, in combination with 10 and 25 T magnet systems at NHFML (see the included figure for a sampling of our unpublished results) will allow us to perform the first direct ultrafast studies of decoherence in these systems. Future plans include expansions to other two dimensional systems, include the cuprate and pnictide superconductors in high magnetic field using a combination of ultrafast and optical frequency tools developed with my current funding.



Photoinduced Phase Transitions in Vanadium Dioxide: Our work focuses on the development of experimental methods to control the light-induced phase transition in VO_2 and to use this model system to study the competing effects of coulomb repulsions and strain on the general class of insulator-to-metal phase transitions. Our recent publication [K. Appavoo, *et al.*, Nano Letters 14, 1127

(2014)] with collaborators at Vanderbilt and LANL has demonstrated the utility of nano-engineered VO_2-Au nanoparticles, which act as heterogeneous nucleation sites to lower the overall threshold fluence of this phase transition. Our corresponding theoretical modeling has shown the strong sensitivity of this phase transition to electrically injected electrons, which rapidly destabilizes the band structure and triggers the phase transition. Our current work with VO_2 has studied this material using nondegenerate pump-probe spectroscopy (see included figure) to study the effects of sample morphology on the heterogeneous nucleation and grown dynamics of this transition near threshold, which is a manuscript in preparation. Our future work will be to use shaped optical and terahertz frequency pulses to control this phase transition by selective excitation of the structural and/or electronic pathways of nucleation, with the goal of identifying the correct thermodynamic pathway for the temperature-driven phase transition as well as the pathway that connects the two observed phases of the photoinduced phase transition upon intense photoexcitation. A secondary goal, in collaboration, is to use VO_2, CrO_2, other similar transition metal oxides, manganites, and other phase change materials to develop a new generation of metamaterials with tunable properties. Prior funding for this work has been through a GAANN grant from the US Department of Education, while our future funding goals would focus on the DOD and DARPA (metasurfaces) as well as NSF and DOE (phase transition).