Experimental methods for study of collective electronic, structural and magnetic behavior

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(Invited)

Three experimental methods with applications in the study of collective properties and dynamics will be discussed. The first is an approach to femtosecond time-resolved measurements that allows a complete dynamical measurement in just one laser shot, enabling the study of phase transitions and other rearrangements even when they are irreversible or only slowly reversible [1-4]. In recent work, we have made direct observations of photoinduced phase transitions in bismuth and other semimetals and in LCMO, in all cases conducting measurements well beyond the thresholds for transitions into long-lived nascent phases or for irreversible sample damage. Observations of the dynamics yields insights into the phase transition mechanisms.

The second method is the use of strong THz-frequency fields to induce electronic and structural phase transitions. THz excitation pulses were used to drive the insulator-to-metal phase transition in VO_2. The resulting change in electrical conductivity was measured with THz probe pulses [5], and the associated structural phase transition was monitored by time-resolved x-ray diffraction from the two crystalline structures [6].

Finally, a recent demonstration of THz-driven nonlinear magnon responses will be discussed. We have measured 2D electron spin resonance (ESR) spectra of the ferromagnetic and antiferromagnetic magnon modes of $YFeO_3$ [7], extending modern magnetic resonance to the THz frequency range. We also have demonstrated strong coupling between THz phonon-polariton waves and magnons in a hybrid waveguide structure, clearly observing magnon-polariton modes. Both results open new avenues for coherent control over collective spin dynamics.

References:

[1] "Irreversible organic crystalline chemistry monitored in real time," P. R. Poulin and K. A. Nelson, *Science* **313**, 1756-1760 (2006).
[2] "Dual echelon single shot femtosecond spectroscopy," T. Shin, J.W. Wolfson, S.W. Teitelbaum, M. Kandyla, and K.A. Nelson, *Rev. Sci. Instru*. **85**, 083115 (2014).
[3] "Invited Article: Single-shot THz detection techniques optimized for multidimensional THz spectroscopy," S.M. Teo, B.K. Ofori-Okai, C.A. Werley, and K.A. Nelson, *Rev. Sci. Instru*. **86**, 051301 (2015).
[4] "Cooperative photoinduced metastable phase control in strained manganite films," J. Zhang, X. Tan, M. Liu, S.W. Teitelbaum, K.W. Post, F. Jin, K.A. Nelson, D.N. Basov, W. Wu, R.D. Averitt, *Nature Materials* 4695 (2016). DOI: 10.1038/nmat4695. *arXiv*:1512.00436 (2015).
[5] "THz-field-induced insulator-to-metal transition in vanadium dioxide metamaterial," M. Liu, et al., *Nature* **487**, 345-348 (2012).
[6] "Ultrafast THz field control of electronic and structural interactions in vanadium dioxide," A. X. Gray, et al., *arXiv*: 1601.07490 (2016). Submitted for journal publication.
[7] "Two-dimensional terahertz magnetic resonance spectroscopy of collective spin waves." J. Lu, X. Li, H. Y. Hwang, B. K. Ofori-Okai, T. Kurihara, T. Suemoto, and K. A. Nelson, *arXiv*:1605.06476 (2016). Submitted for journal publication.