Nematicity, Ferromagetic Superconductivity and Quantum Paraelectricity : *In-Situ* Uniaxial Strain & X-Ray Scattering.

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In this talk I will review how deploying single crystal *in-situ* uniaxial strain deepens our understanding of complex quantum phenomena. An array of X-ray techniques including high resolution diffraction and resonant magnetic polarized scattering have facilitated the exploration of several exciting emergent quantum behaviors.

I will discuss the control of nematicity and magnetic superconductivity in pnictides and chalcogenides (1-4) Regarding the former, electronic or structural nematicity is coupled to both the lattice and conducting electrons making structural and transport measurements sensitive to the underlying fluctuations. While FM order is uncommon in superconducting systems, when present it offeres a rich playground to study the nature of their adversarial relationship. The opportunity to investigate such phenomenona make x-ray scattering coupled with electrical measurements indispensable tools in this field.

Additionally, in the rare earth tri-tellurides, structural instabilities in the form of charge density waves (CDW) emerge. For the first time we showed that through uniaxial strain we could control the orientation of these modulations The coexistence of orthogonal CDWs further creates a strain-variable bicritical phase space, offering a rich terrain for investigation and discovery (5).

Lastly, I will discuss insights into our ongoing studies in strain-based quantum devices and offer a glimpse into our future plans, which include integrated Raman and PL spectroscopy at 1K with *in-situ* strain capabilities harnessing the power of combined x-ray techniques for both QIS and an array of condensed matter questions.

1. Strain-Switchable Field-Induced Superconductivity, Joshua J. Sanchez, Gilberto Fabbris, Yongseong Choi, Jonathan M. DeStefano, Elliott Rosenberg, Yue Shi, Paul Malinowski, Yina Huang, Igor I. Mazin, Jong-Woo Kim, Jiun-Haw Chu, Philip J. Ryan*, Science Advances 9, eadj5200(2023). DOI:10.1126/sciadv.adj5200

2. Suppression of superconductivity by anisotropic strain near a nematic quantum critical point, P. Malinowski, Q Jiang, JJ Sanchez, J Mutch, Z Liu, P Went, J Liu, P.J. Ryan, J-W. Kim, Jiun-Haw Chu, Nature Physics, 1-5, (2020)

3. Joshua J. Sanchez, Paul Malinowski, Joshua Mutch, Jian Liu, J.-W. Kim, Philip J. Ryan, Jiun-Haw Chu, The transport–structural correspondence across the nematic phase transition probed by elasto X-ray diffraction. *Nat. Mater.* (2021).

4. "Spontaneous orbital polarization in the nematic phase of FeSe." Connor A. Occhialini, Joshua J. Sanchez, Qian Song, Gilberto Fabbris, Yongseong Choi, Jong-Woo Kim, Philip J. Ryan and Riccardo Comin, Nature Materials 22, 985 (2023). doi:10.1038/s41563-023-01585-2

5. Emergent tetragonality in a fundamentally orthorhombic material, Anisha G Singh, Maja D Bachmann, Joshua J Sanchez, Akshat Pandey, Aharon Kapitulnik, Jong Woo Kim, Philip J Ryan, Steven A Kivelson, Ian R Fisher, Science Advances, 23 May 2024, Vol 10, Issue 21DOI: 10.1126/sciadv.adk3321