APS-U: Frontier Experiments in Condensed Matter Physics

Held May 20-21, 2015

Chairs

John W. Freeland (APS)

Oleg Shpyrko (UCSD)

SRI Satellite Workshop July 14, 2015

Workshop Goal

Articulate 2-3 high-impact experiments to make the science case for X-ray science with a new APS **10 years** from now

Frame of Mind

Imagine you can dynamically visualize not only where the atoms are but also their electronic and magnetic state with high-precision over a macroscopic sample across a wide range of time-scales from nsecs to hours

The Agenda

9:00 am: **Coherent X-ray Studies of Materials Synthesis**
G. Brian Stephenson – Materials Science Division, Argonne National Laboratory

9:30 am: **Opportunities at Oxide Interfaces: Using the Synchrotron to Open New Scientific Directions**
Steve May - Materials Science and Engineering, Drexel University

10:00 am: **TBA**
Chris Marianetti - Department of Applied Physics, Columbia University

10:30 Break

11:00 am: **XPCS: Beyond time correlations**
Mark Sutton – Department of Physics, McGill University

11:30 am: **Tracing spatiotemporal dynamics in flowing solids?**
Robert Maass - Materials Science and Engineering, Univ. of Illinois, Urbana

12:00 pm: **Let's make the synchrotron an indispensable tool for materials physics**
Rafael Jaramillo - Department of Materials Science and Engineering at Massachusetts Institute of Technology

12:30 pm Working lunch

1:30 pm: **Where have all the ions and electrons gone? The case for observations of heterogeneity as descriptors of function**
Jordi Cabana – Department of Chemistry, University of Illinois, Chicago

2:00 pm: **The dynamics of ordering processes in condensed matter: the past, present, and future**
Richard Averitt – Department of Physics, University of California, San Diego

2:30 pm: **Opportunities for probing topological phenomena out of equilibrium**
Greg Fiete – Department of Physics, University of Texas, Austin

3:00 pm Break

3:30 pm: **Disentangling Spin, Charge, Orbital and Lattice Order Parameters: A Key for understanding Complex Materials**
Luc Patthey, Swiss Light Source, Paul Scherrer Institute

4:00 pm: **The unreasonable irrelevance of quantum mechanics in condensed matter physics (and what to do about it)**
N. Peter Armitage – Department of Physics and Astronomy, The Johns Hopkins University

4:30 pm: **Frontier Materials: Spin-Orbit Effects in Iridates**
Gang Cao - Department of Physics, University of Kentucky

5:00 pm Wrap-up

Complexity

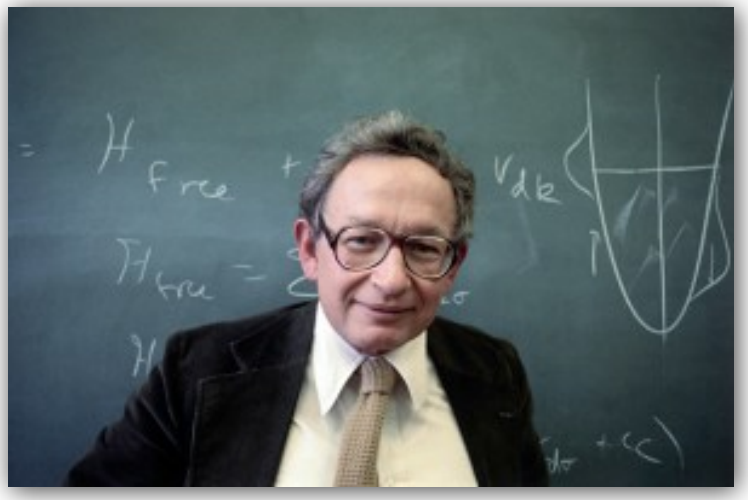
More Is Different

Broken symmetry and the nature of the hierarchical structure of science.

P. W. Anderson

SCIENCE

4 August 1972, Volume 177, Number 4047



...indeed, complex cooperative behaviour can arise with even very simple individual units and very simple interactions.

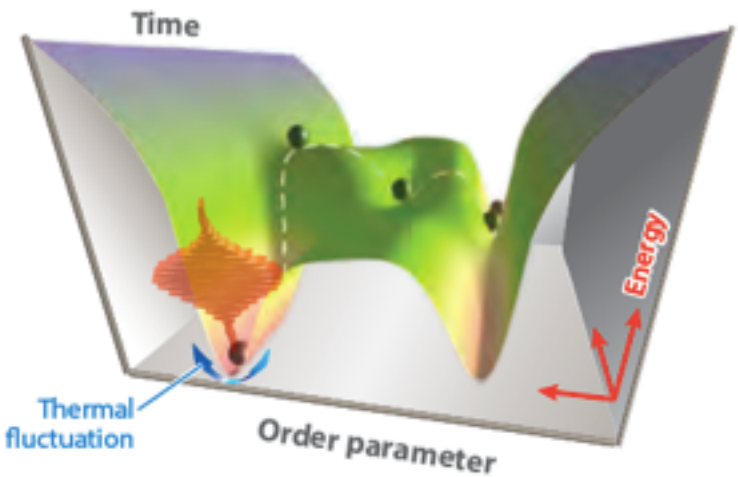
D. Sherrington

Phil Trans Roy Soc **368**, 1175 (2010)

Complexity in Condensed Matter

Non-equilibrium

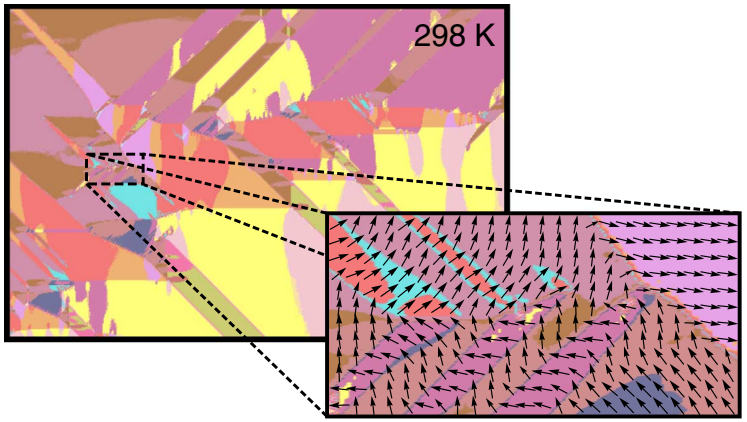
e.g. Optical Excitation



R. Averitt (UCSD)

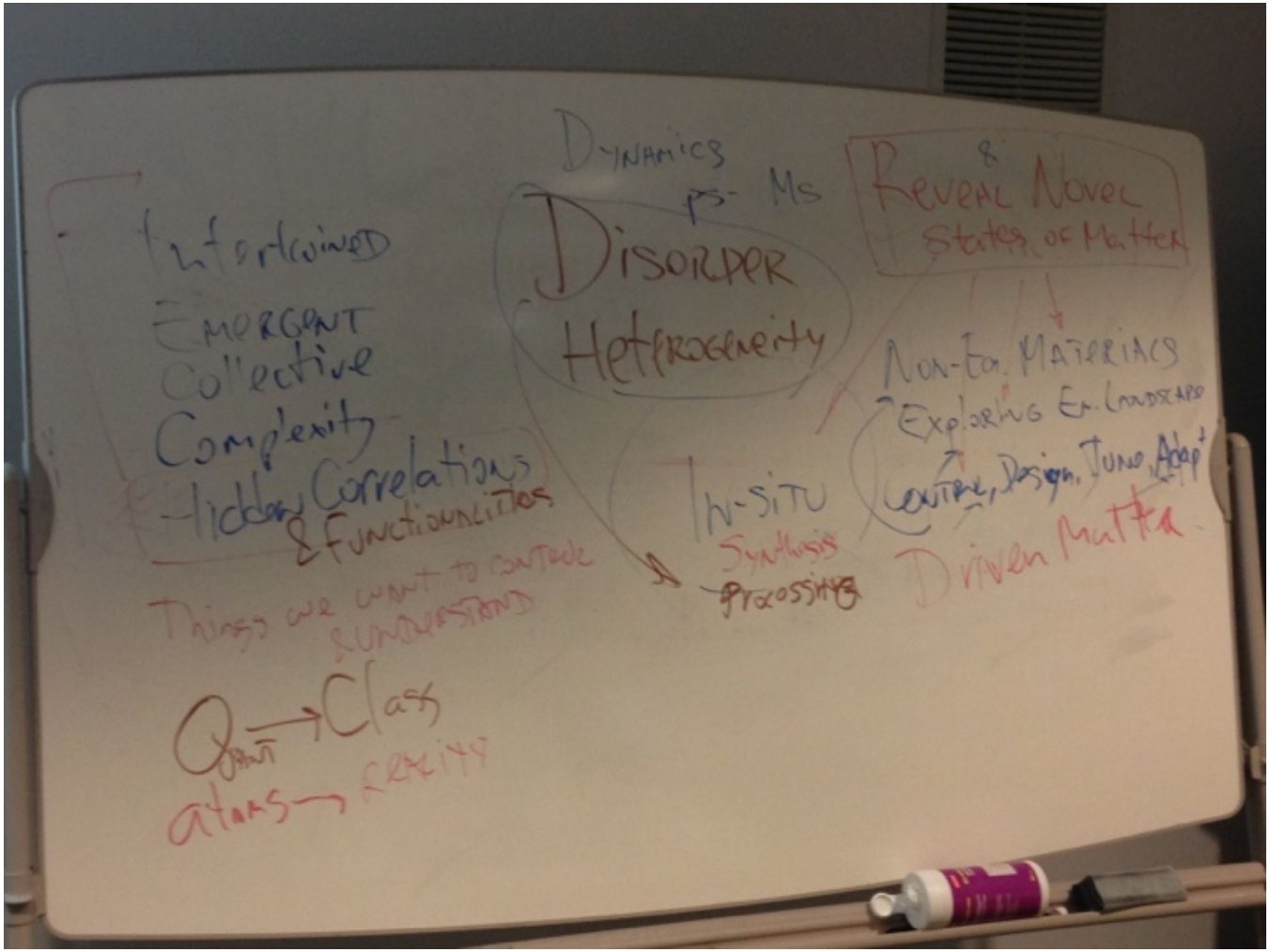
Non-homogeneous

e.g. BaTiO3 phases



V. Gopalan (PSU)

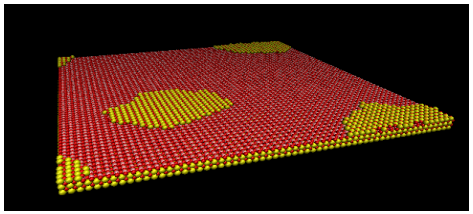
Brainstorming



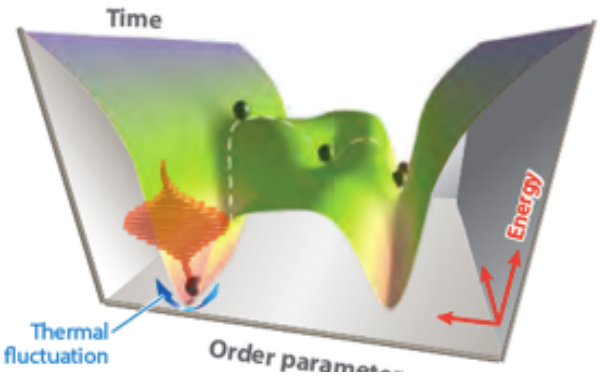
Target Areas

Hidden Correlations and Functionalities

Linking Disorder/Inhomogeneities to Properties



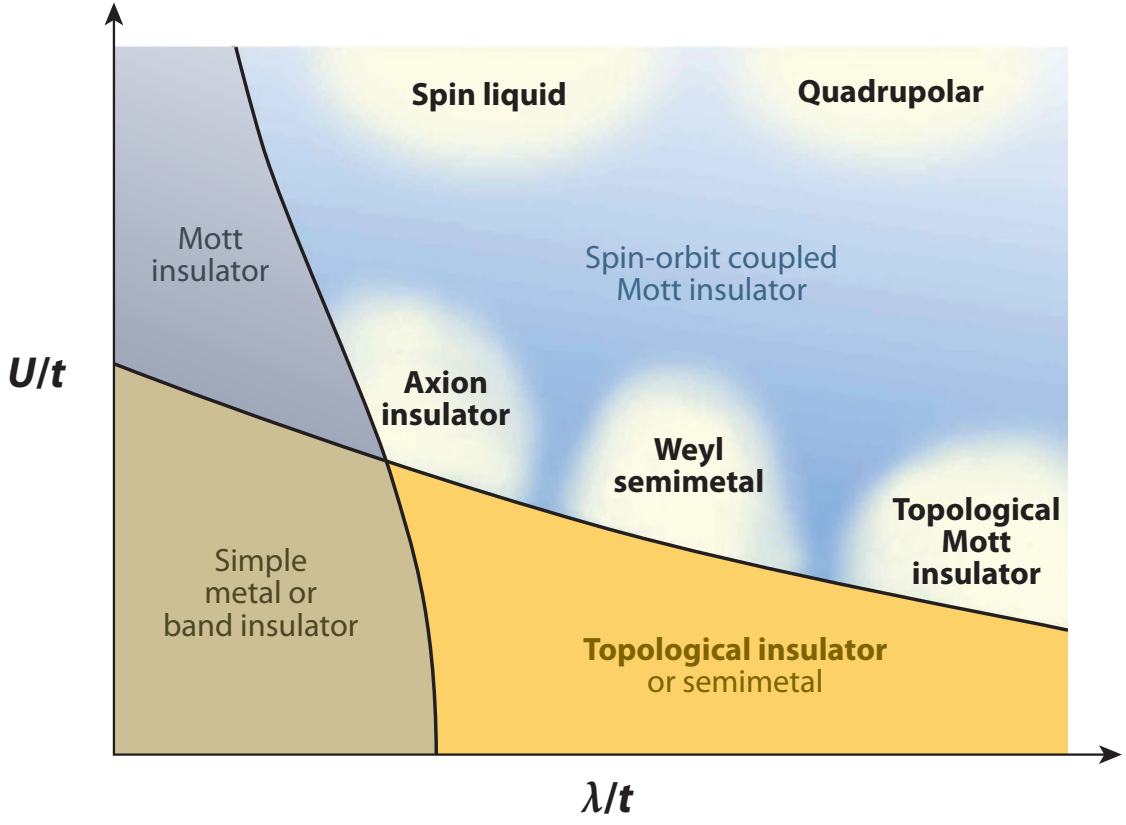
Creating New Dynamic States of Matter



Quantum Spin-Liquids

Novel States of Matter

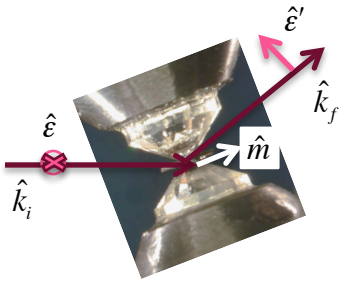
Theoretical phase diagram for new materials

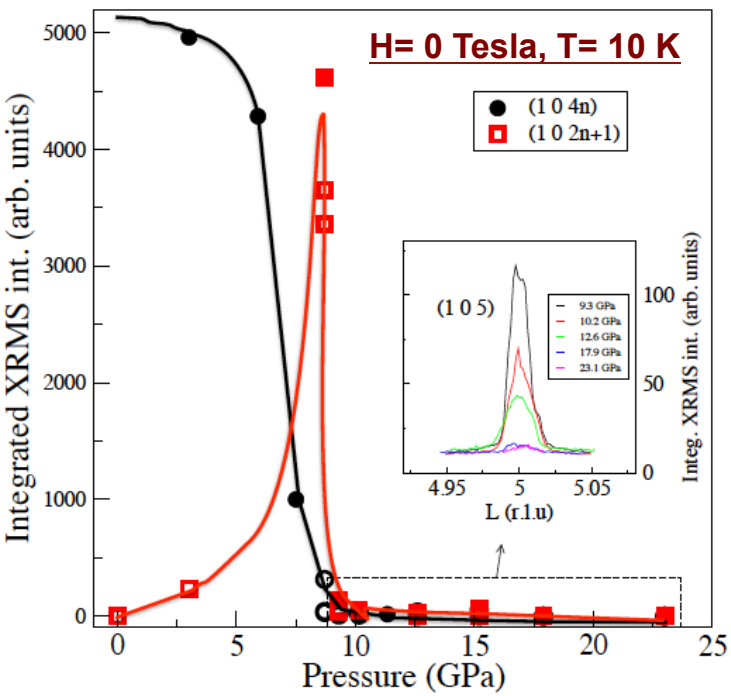


W. Witczak-Krempa, G. Chen, Y. B. Kim, and L. Balents, Annual Review of Condensed Matter Physics **5**, 57 (2014).

High-Pressure with Coherent X-rays

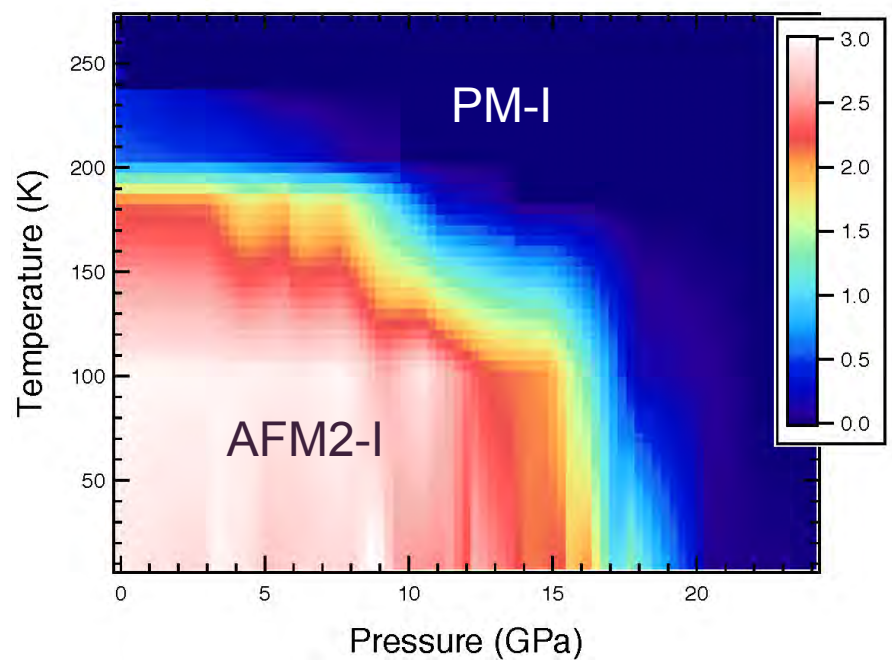
Pressure induced collapse of magnetic order in layered Iridates





D. Haskel, J.-W. Kim (APS)

P-T diagram (H=0.5 T)



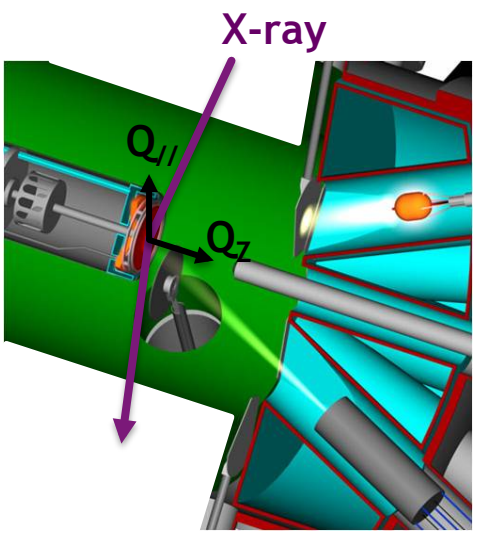
Use coherence source to measure fluctuations in region of quantum critical point!

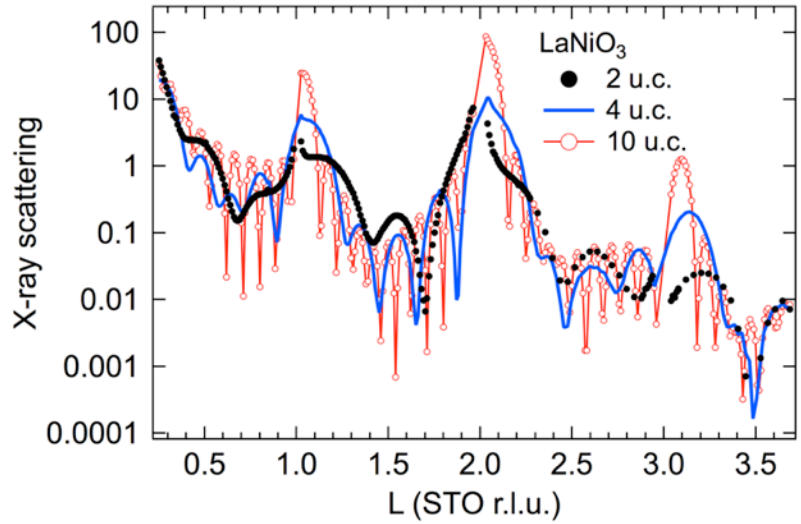
Unravelling Synthesis

in-situ Oxide MBE

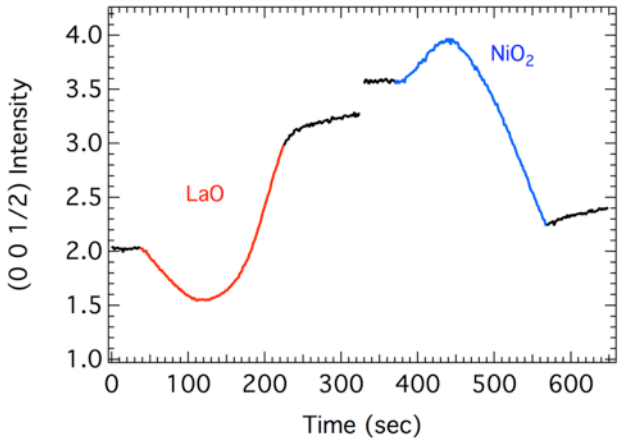
X-rays provide quantitative information!

T = 590° C
P = 5e-6 Torr O_3



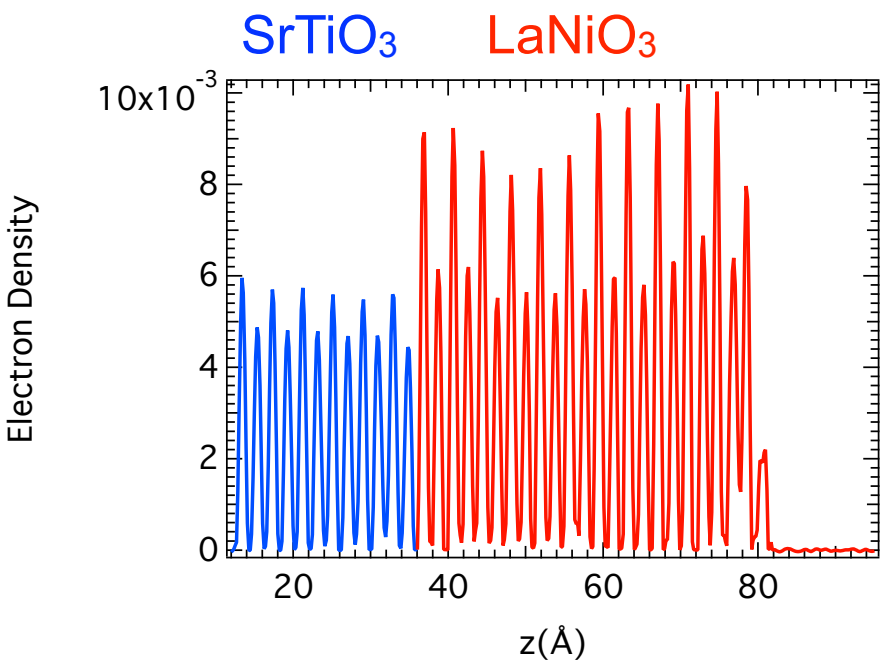


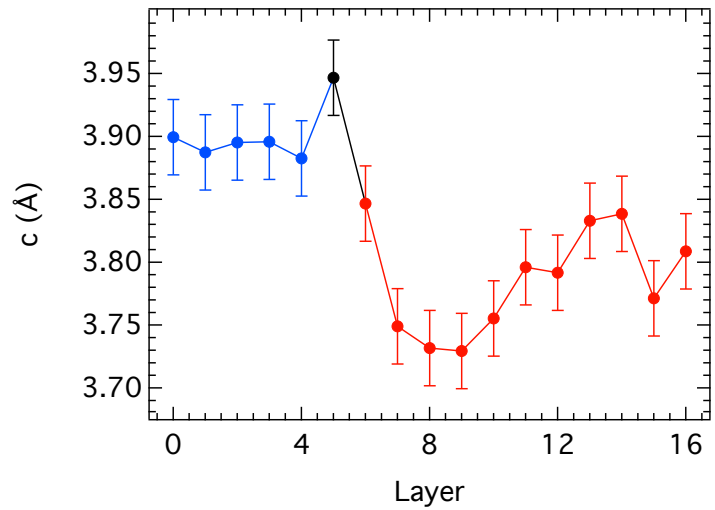
- Film thickness
- Unit cell size
- Lattice symmetry
- Composition
- Dynamics of growth

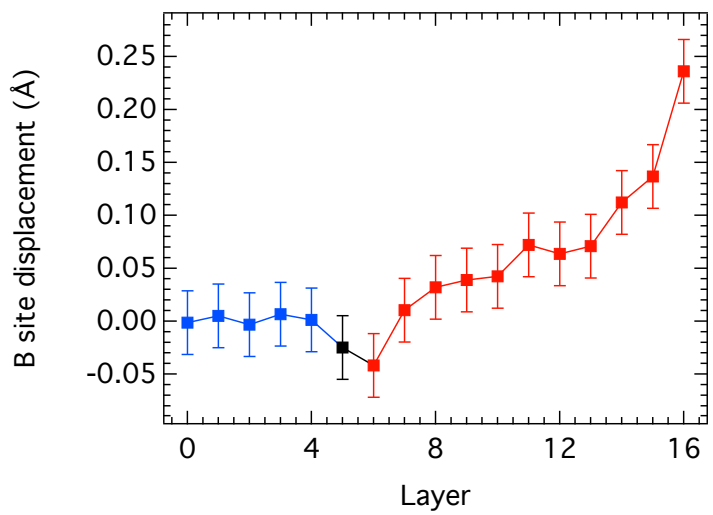


Lattice Structure

Use COBRA to analyze the diffraction data and extract electron density



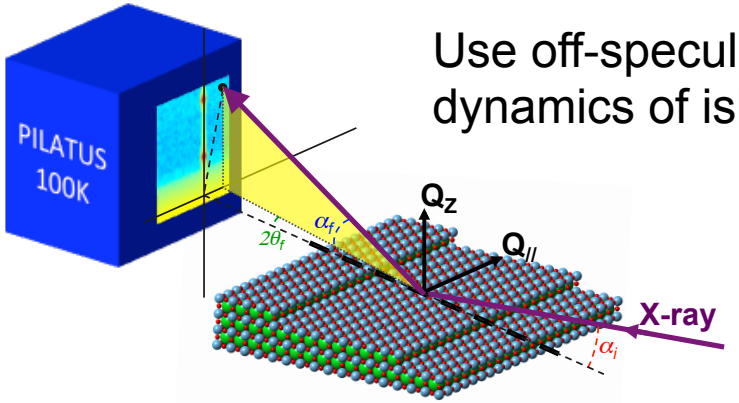


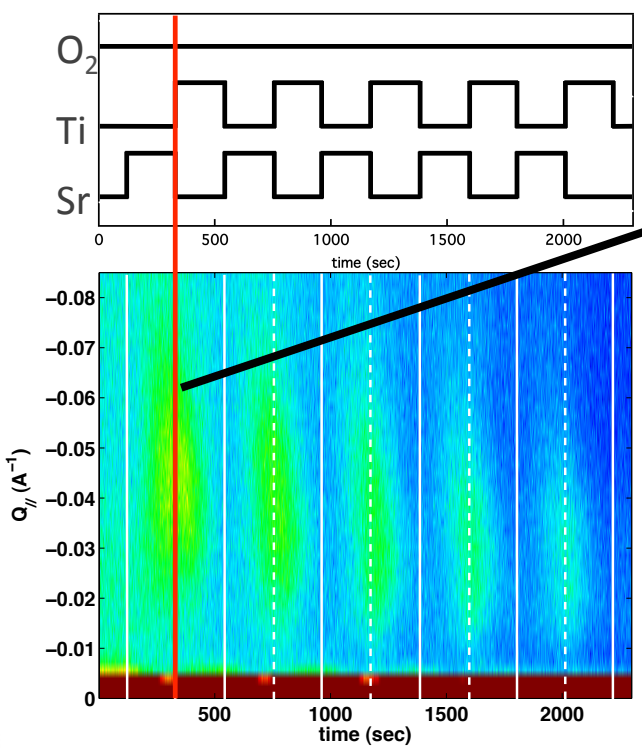


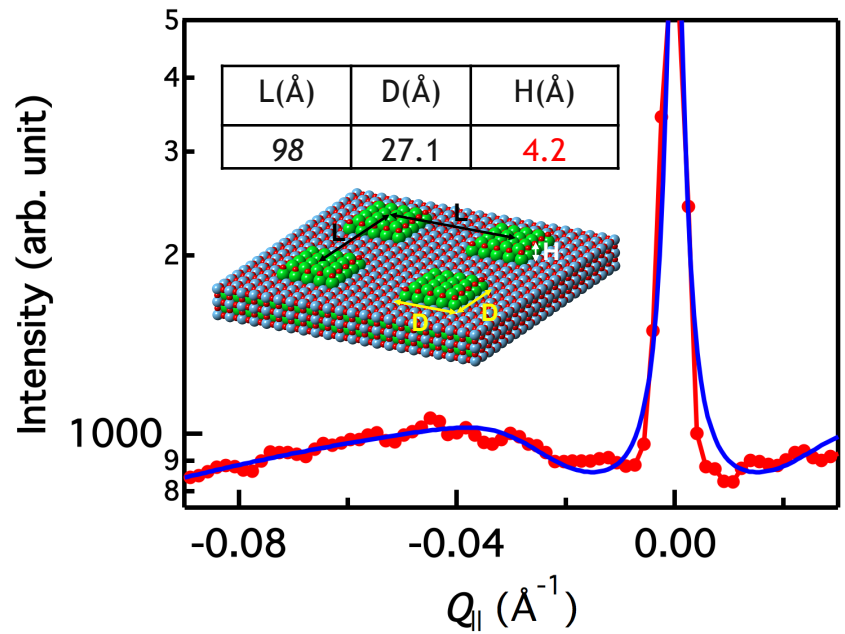
Need to understand complex lattice structure!

Tracking Layer Formation

Use off-specular scattering to follow the dynamics of islands during growth





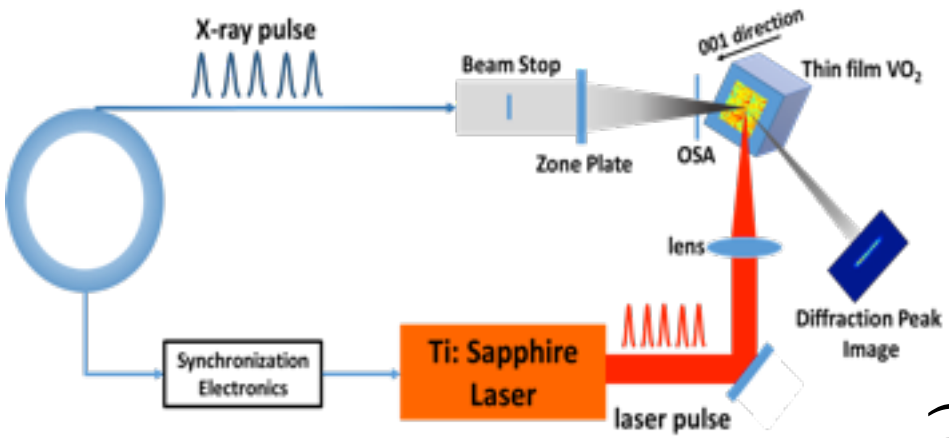


L(Å)	D(Å)	H(Å)
98	27.1	4.2

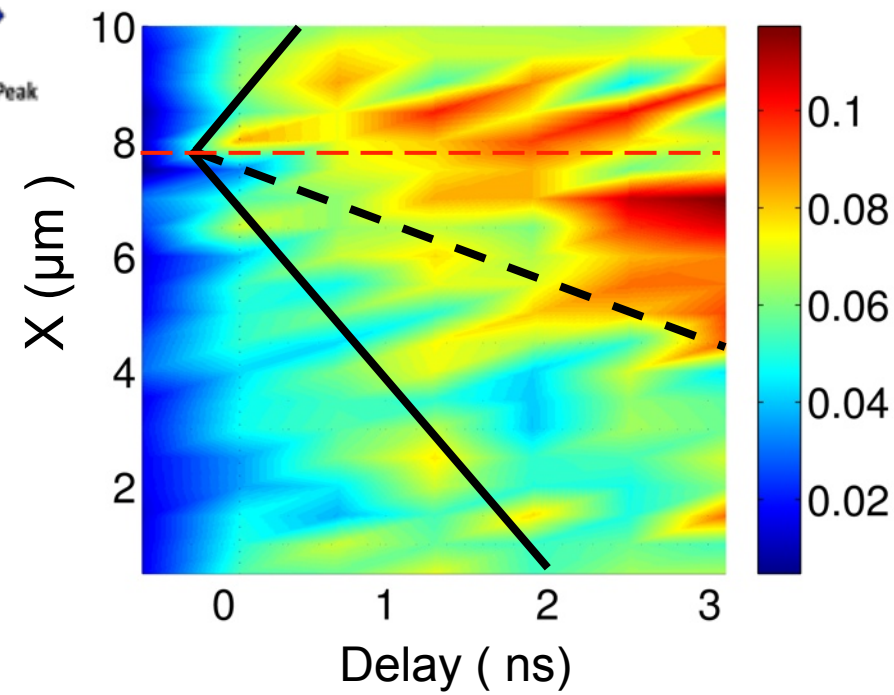
Island morphology during growth coupled to theory is provide a framework to understand how dynamic process control quality of synthesis

Driven Matter

Spatio-Temporal Diffraction Microscopy



Driven phase transition in VO_2



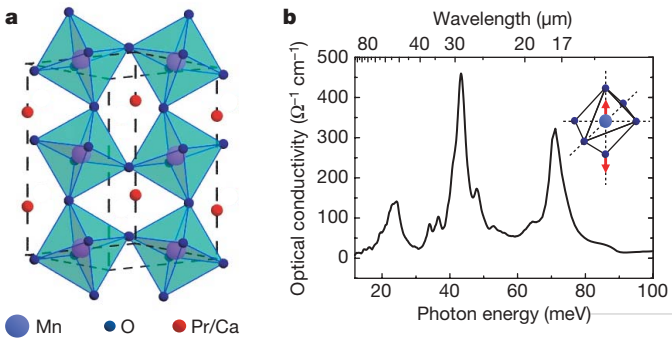
Thz pumps available
Mid-IR under development

H.Wen, Y. Zhu (APS), P.G. Evans (UW Madison)

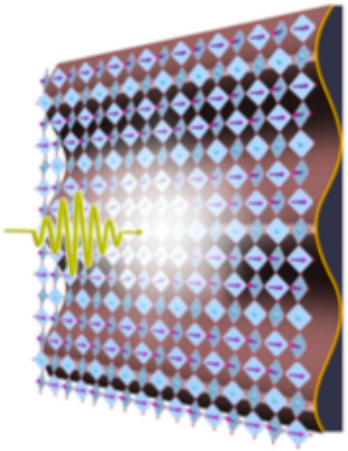
Phonon Control

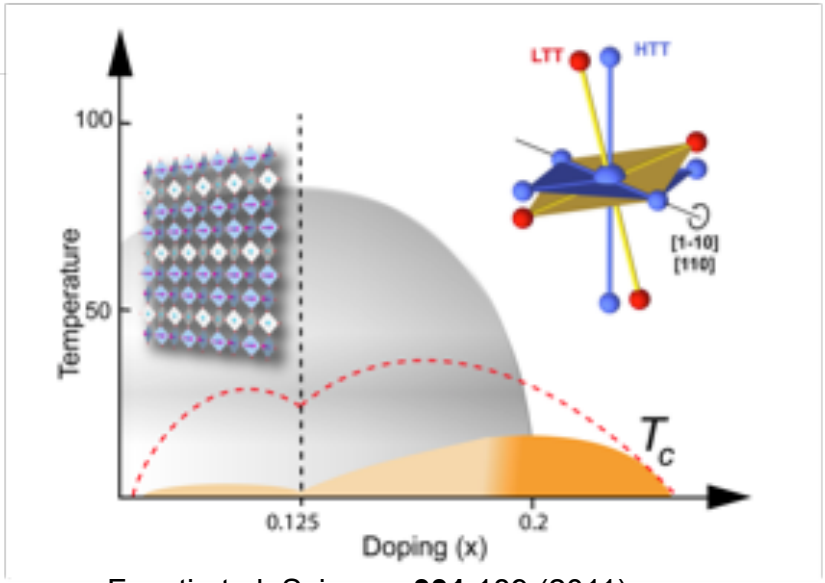
Control of the electronic phase of a manganite by mode-selective vibrational excitation

Matteo Rini[1], Ra'anan Tobey[2], Nicky Dean[2], Jiro Itatani[1,3], Yasuhide Tomioka[4], Yoshinori Tokura[4,5], Robert W. Schoenlein[1] & Andrea Cavalleri[2,6]



Rini et al. Nature **449**, 72 (2007)





Fausti et al. Science **331** 189 (2011)

Other Suggestions?

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