Mesoscale Dynamics in Complex Systems

— Pump-probe techniques using coherent X-ray

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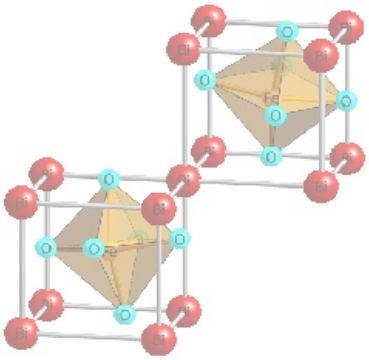
Motivation

Interrogating mesoscopic dynamics in the time domain

Macroscopic

Atomistic



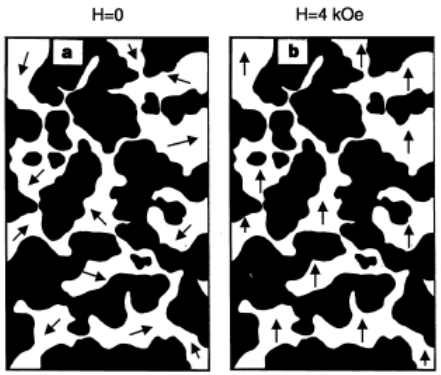
$F=ma$

$$H(t)\,|\,\psi(t)\rangle = i\hbar\frac{d}{dt}\,|\,\psi(t)\rangle$$

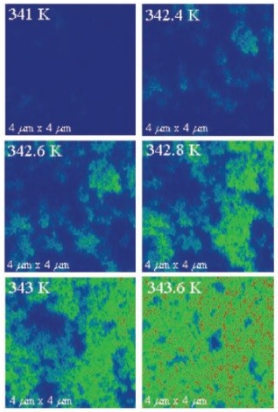
mm um nm pm

esoscale rules

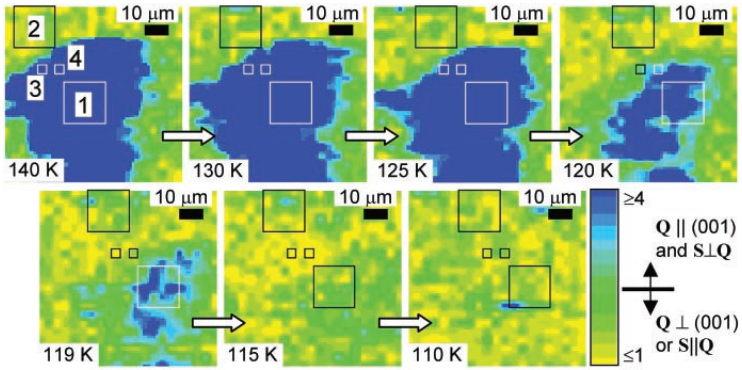
intrinsic inhomogeneity (physics)



CMR: ferromagnetic domains
Uehara, et. al Nature (1999)

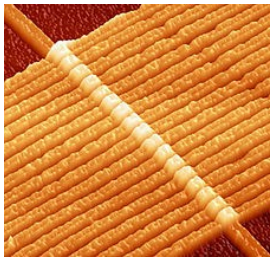


Phase percolation in VO2
Qazilbash, et. al Science (2011)

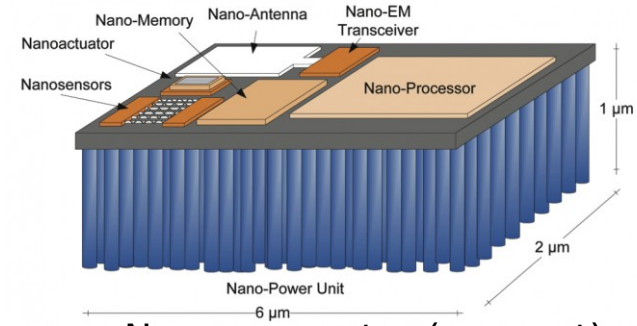


Spin density wave in Cr
Evans, et. al Science (2002)
Shpyrko, et. al Nature (2007)

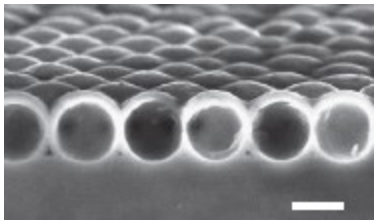
artificial inhomogeneity (device)



Memristor, HP (2008)

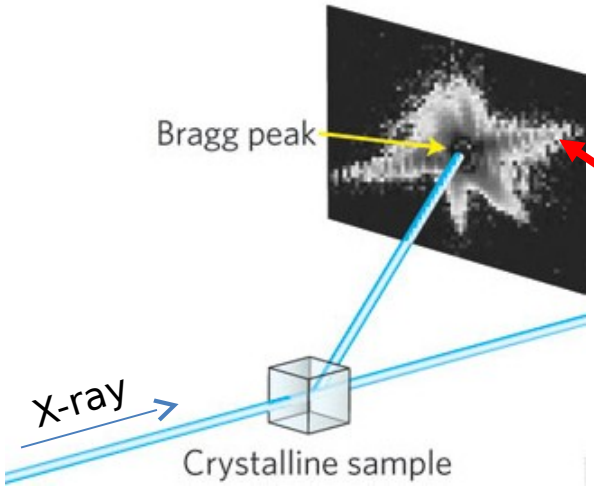


Nano computer (concept)



Light harvesting in nanoshells
Yao, et. al, Nature Comm. (2011)

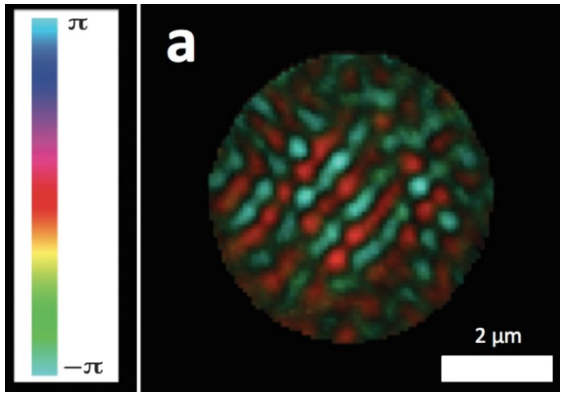
w can coherent x-ray help us?



X-ray Coherent imaging

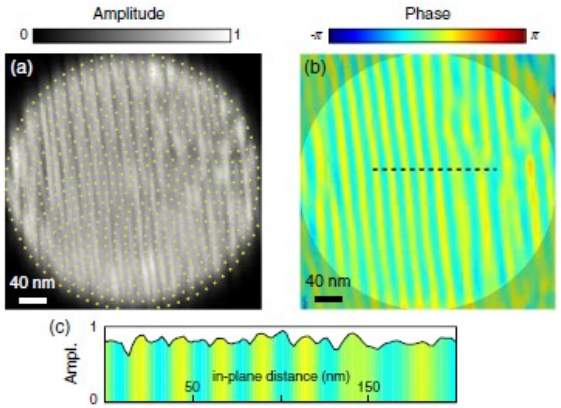
Speckles reveal long range order

TbCo, magnetic domains



Turner, PRL, 107, 033904 (2011)

PbTiO3, ferroelectric domains



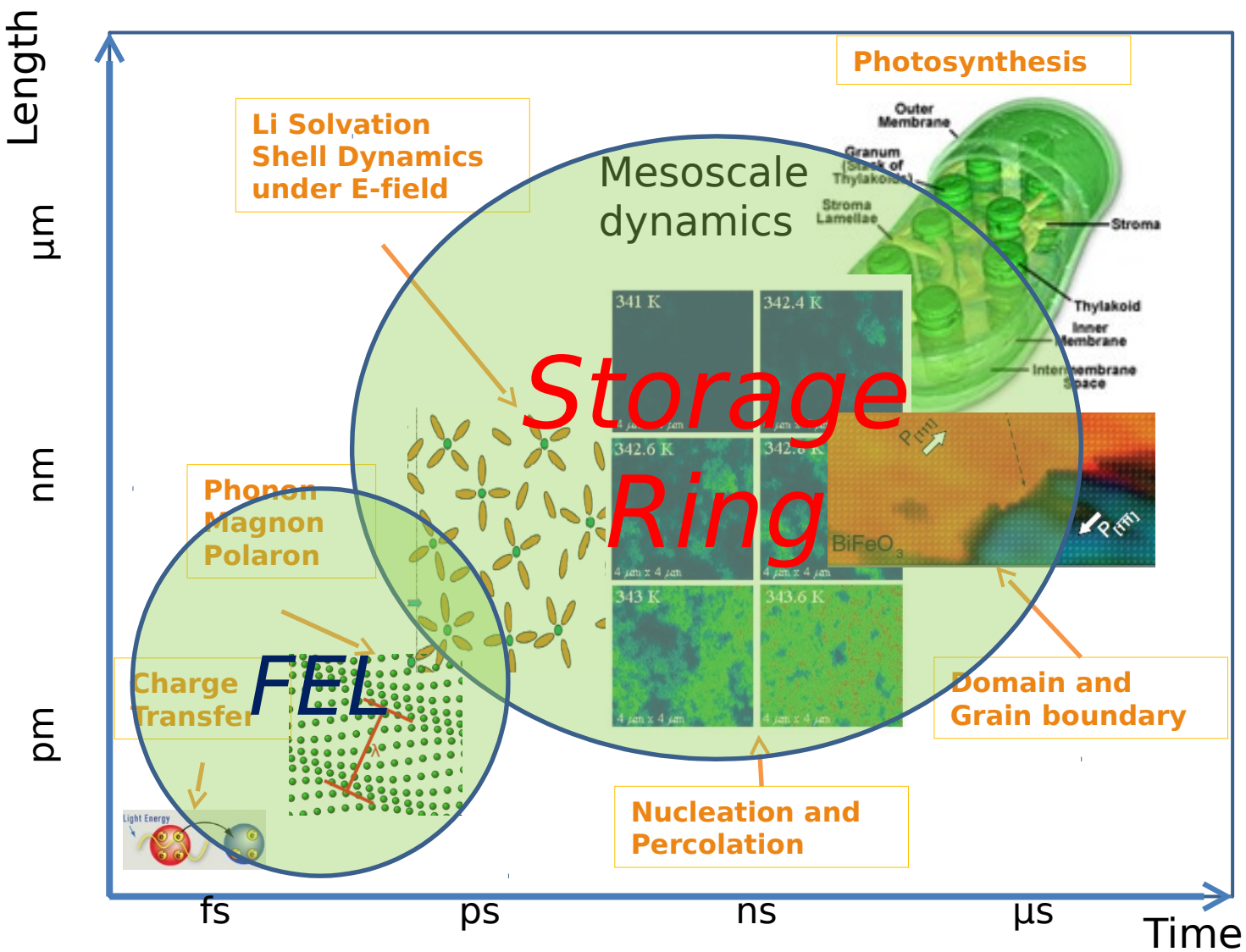
Hruszkewycz, PRL, 110, 177601 (201

Different machines for different science

FEL	v.s	DLSR
probe before destroy		*tickle and probe*
• Dynamics beyond static radiation damage limits		• minimal sample damage
• ~100 fs temporal resolution (atomistic processes)		• ~100 ps temporal resolution (mesoscopic processes)
• single shot data collection		• repetitive data collection

DLSR is suitable for studying mesoscopic dynamic

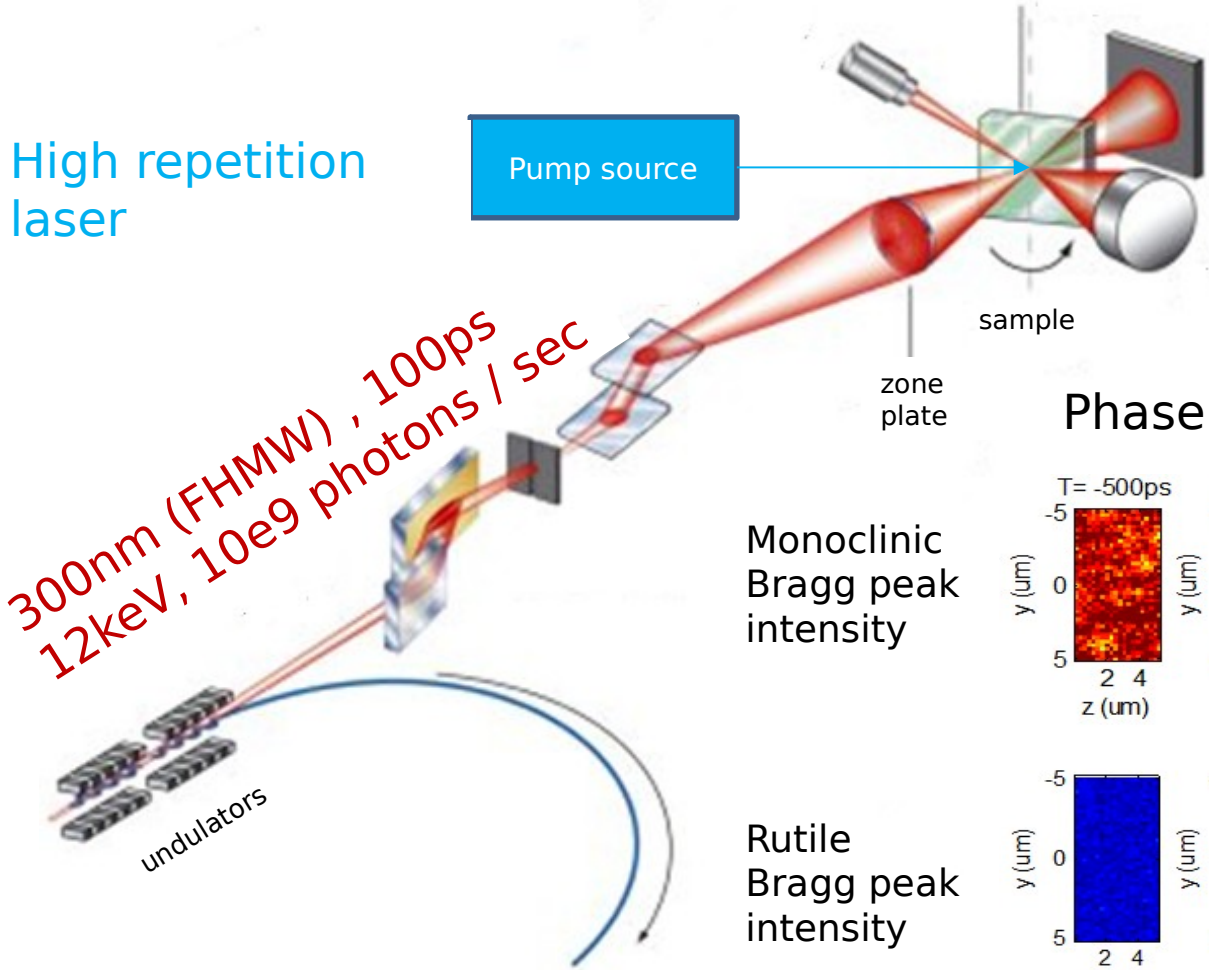
hat is the time scale?



here are we now?

Time-resolved hard x-ray nanoprobe @ Sec7

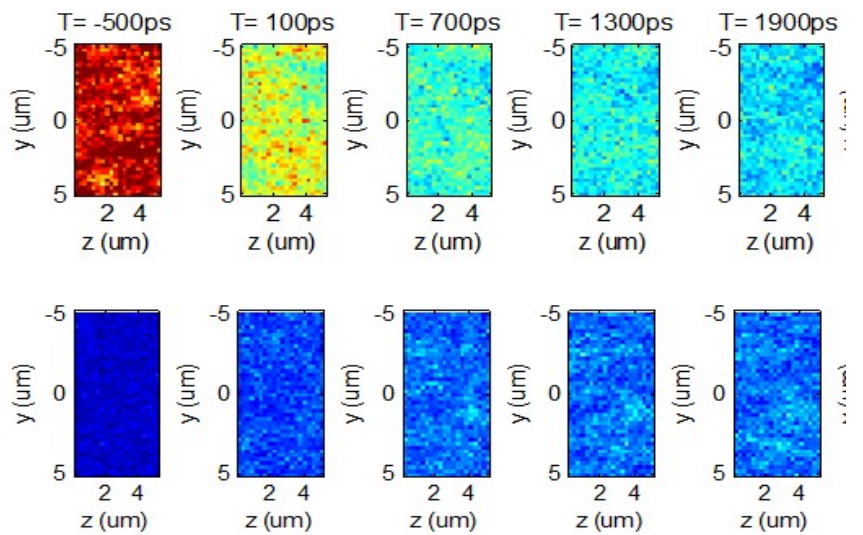
High repetition laser



Phase transition dynamics in VO2

Monoclinic Bragg peak intensity

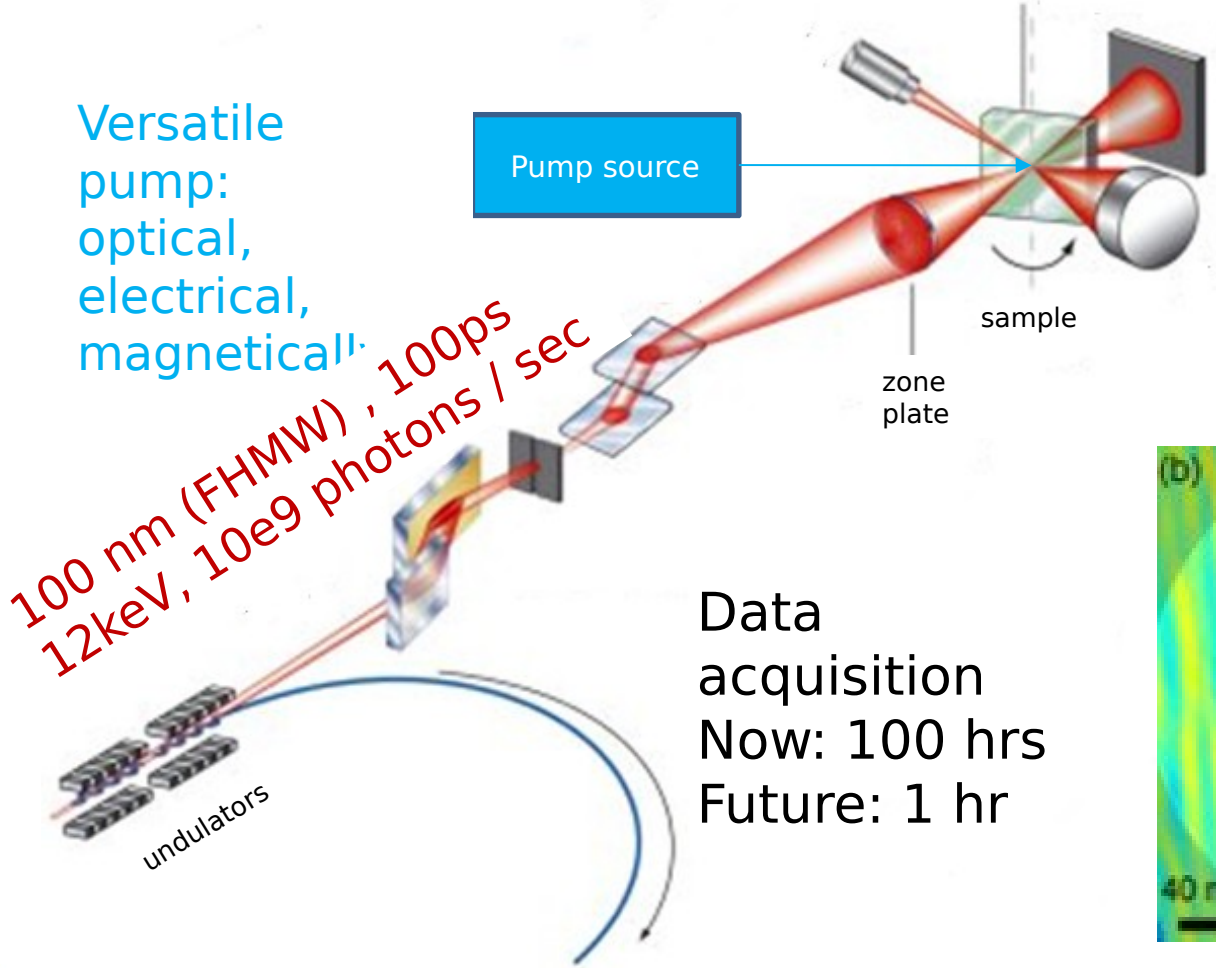
Rutile Bragg peak intensity



dream experiment

Imagining domain dynamics by time-resolved X-ray ptychography

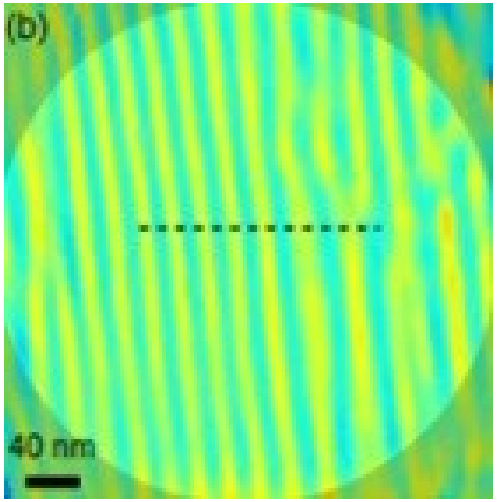
Versatile pump: optical, electrical, magnetically



100 nm (FHMW) , 100ps
12keV, 10e9 photons / sec

Data acquisition
Now: 100 hrs
Future: 1 hr

t=0.2ns



ew Science thrust

DLSR enables direct structural probe of mesoscopic dynamics: real materials and devices operating at their intrinsic length and time scales.

In-situ, In-operando
Real materials, Real time
Spatial resolution <10nm
Temporal resolution ~100ps