Opportunities for Advanced Materials and Nanotechnology

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UK X-ray FEL Science Case
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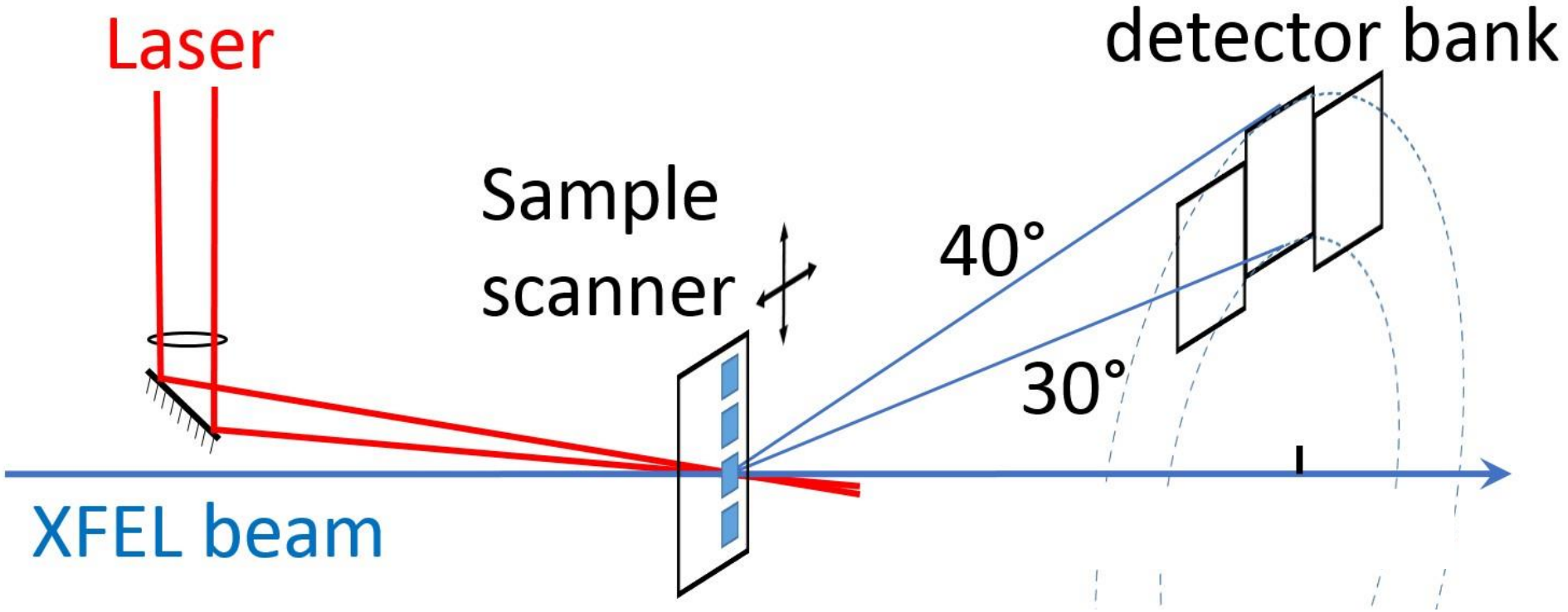
Outline

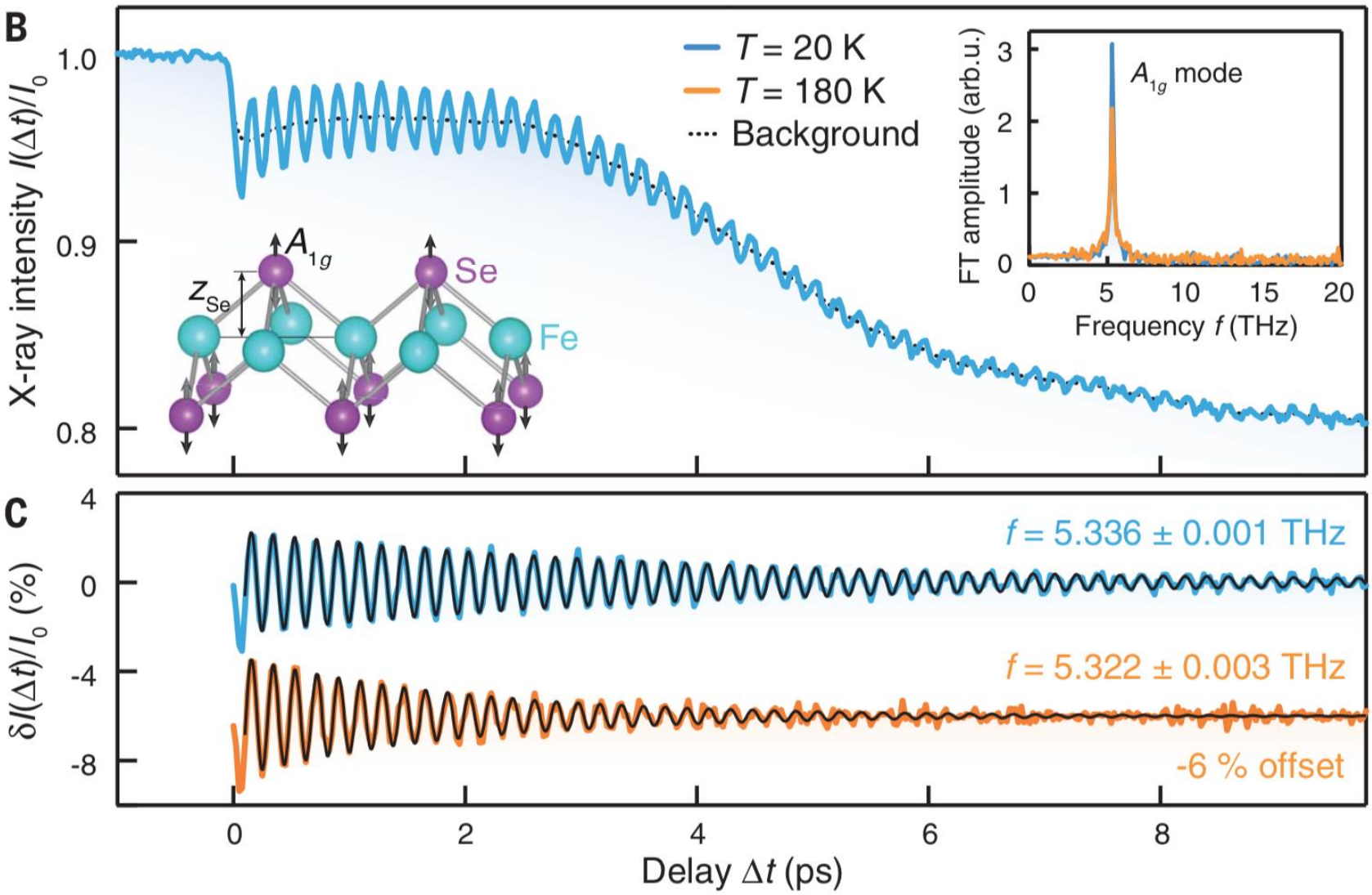
- Pump-probe method
- Excitations in the time domain
- Bragg Coherent Diffraction Imaging
- Evolution of nanoparticle strain
- Ultrafast melting of gold films

Pump-probe Method using Sample Scanner



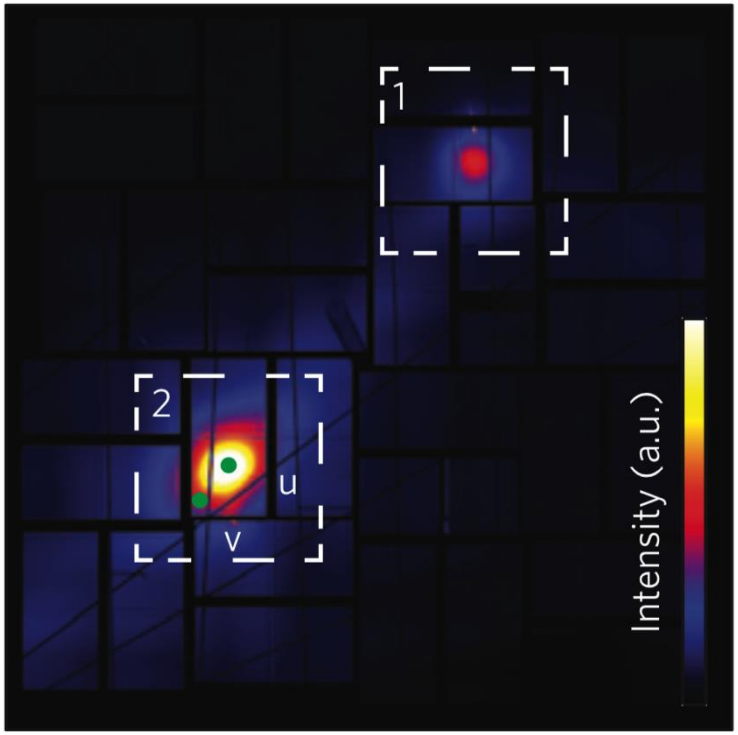
Zone-Centre Optical Phonon in FeSe

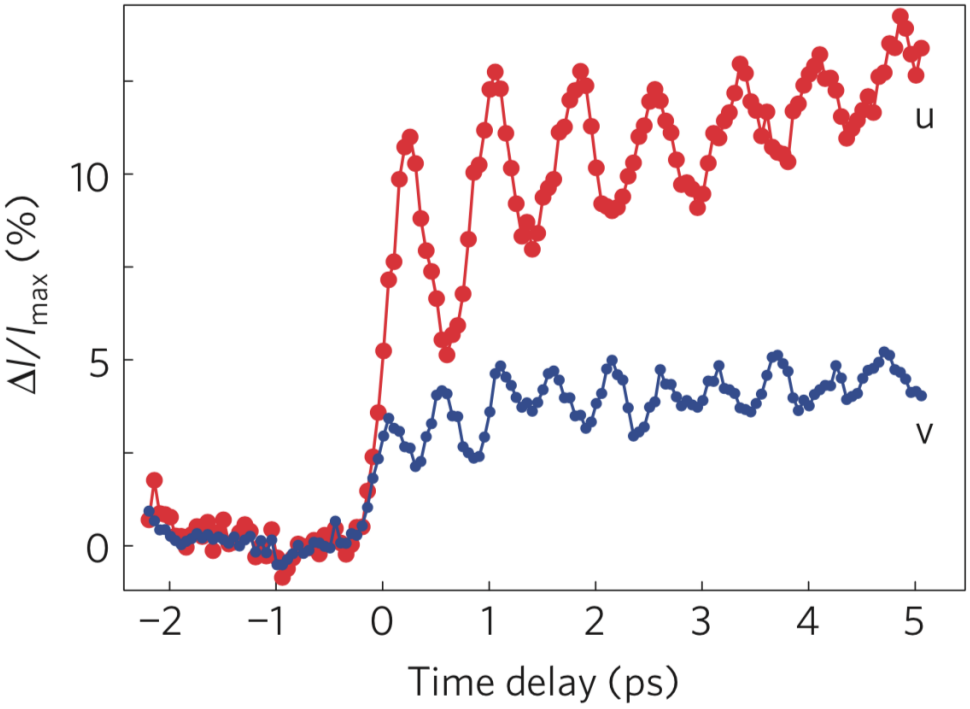
S. Gerber et al., Science **357** 71–75 (2017)



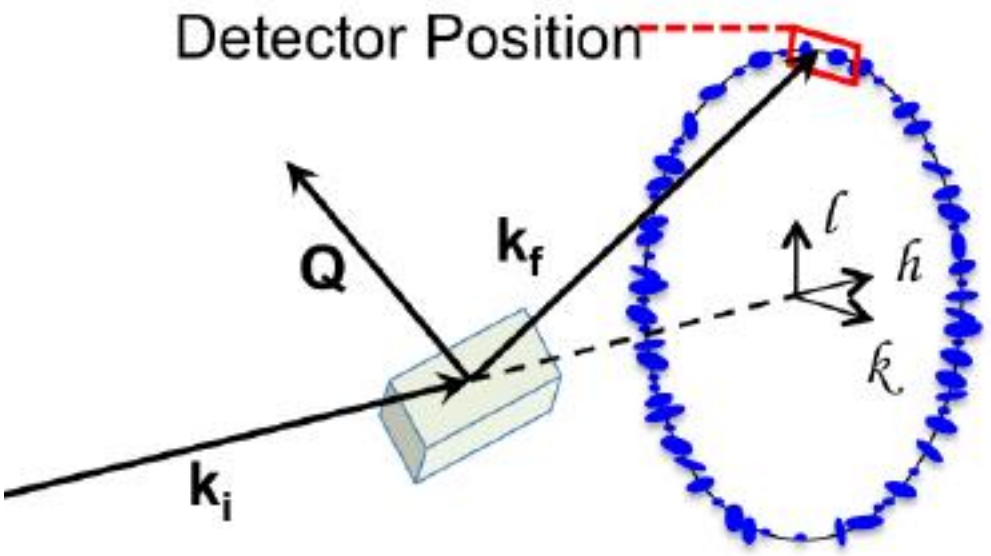
Phonon Dispersion in Ge by FT-IXS

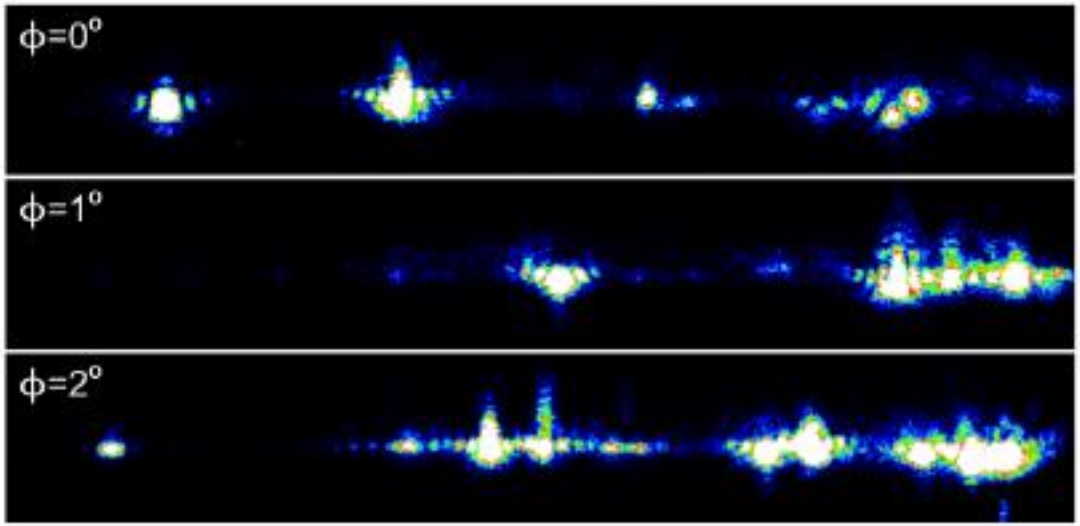
M. Trigo et al, Nat. Phys. **9** 790 (2013)





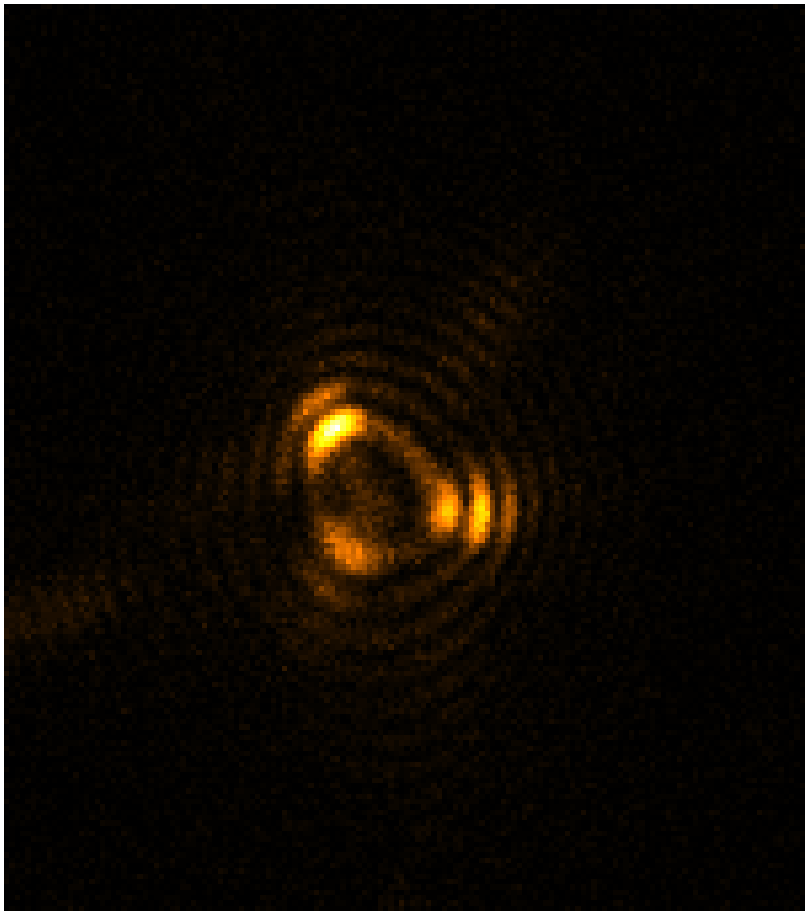
Bragg Coherent Diffraction Imaging (BCDI)

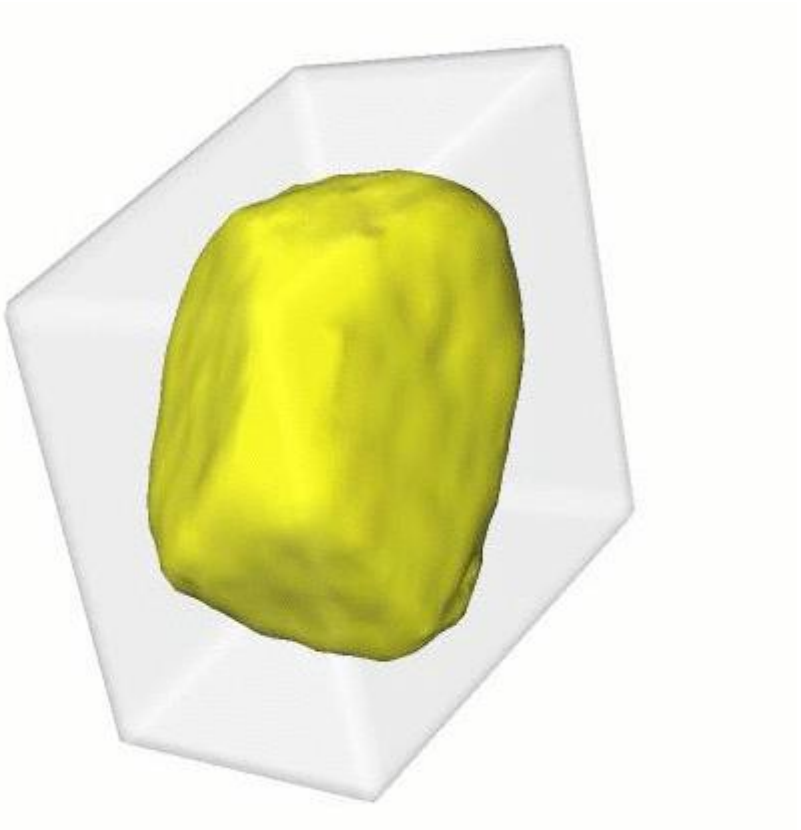




Gold nanocrystal reconstruction

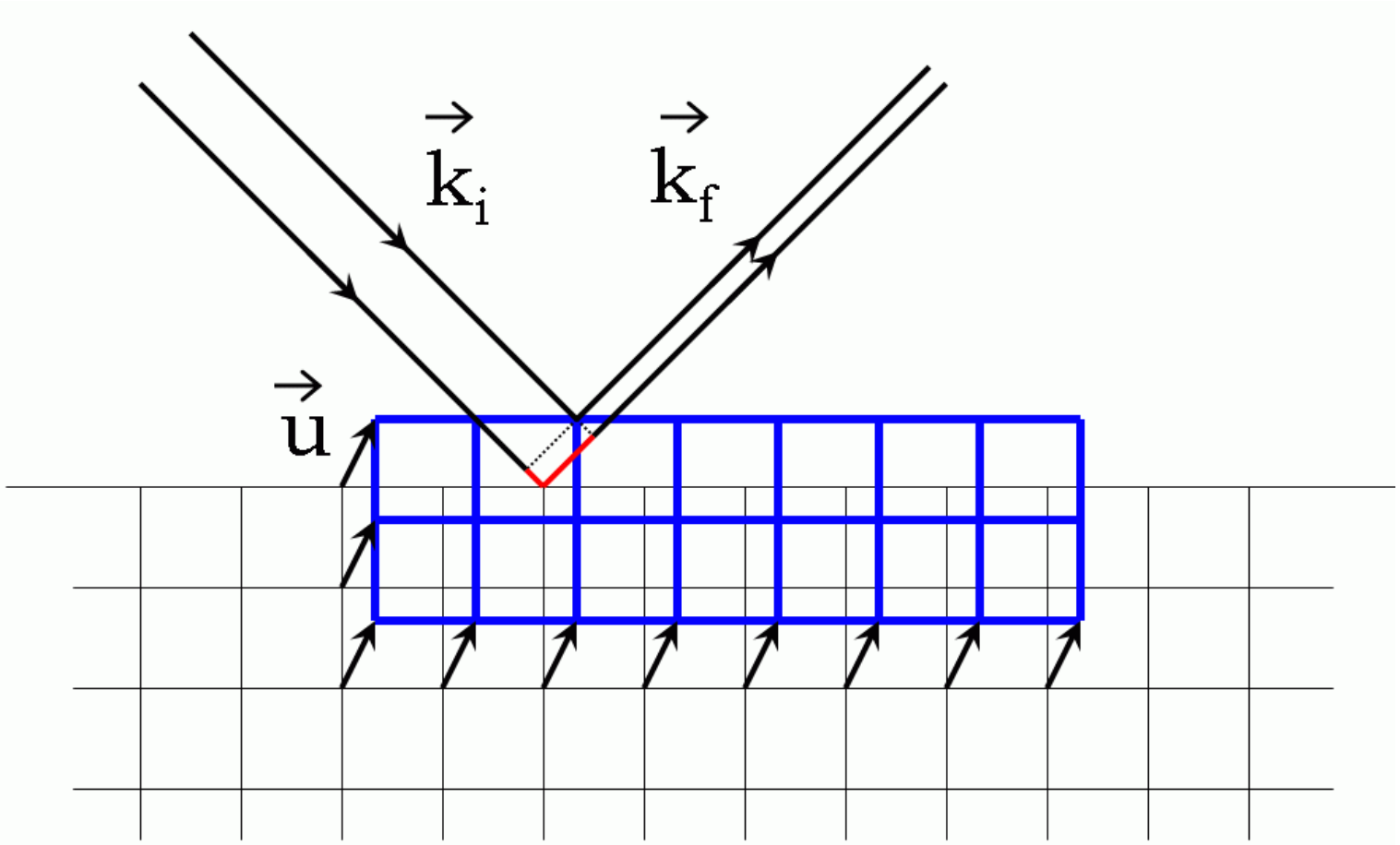
showing support used for 20 HIO followed by 10 ER





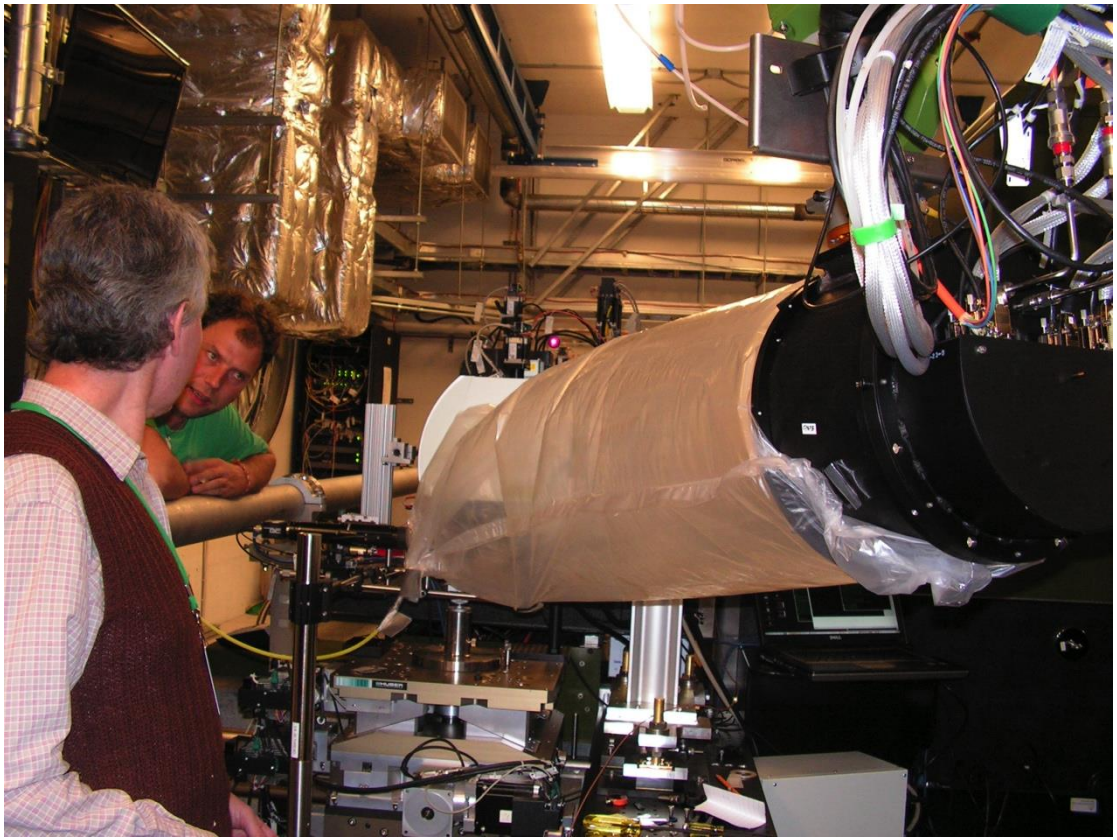
Sensitivity to strain

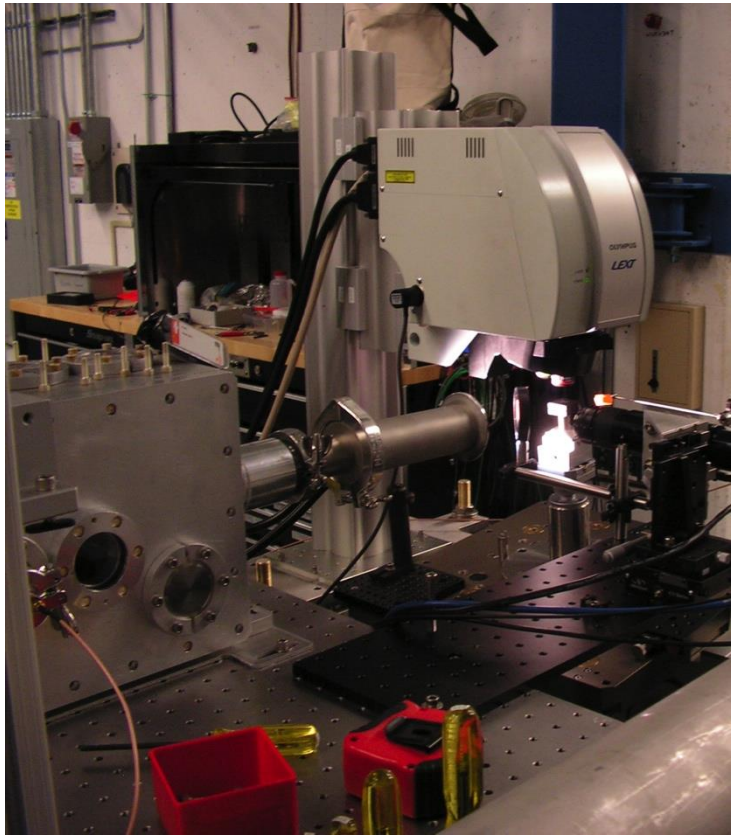
$$\Delta\varphi = \mathbf{k}_f \cdot \mathbf{u} - \mathbf{k}_i \cdot \mathbf{u} = \mathbf{Q} \cdot \mathbf{u}$$



Pump-probe at LCLS (XPP)

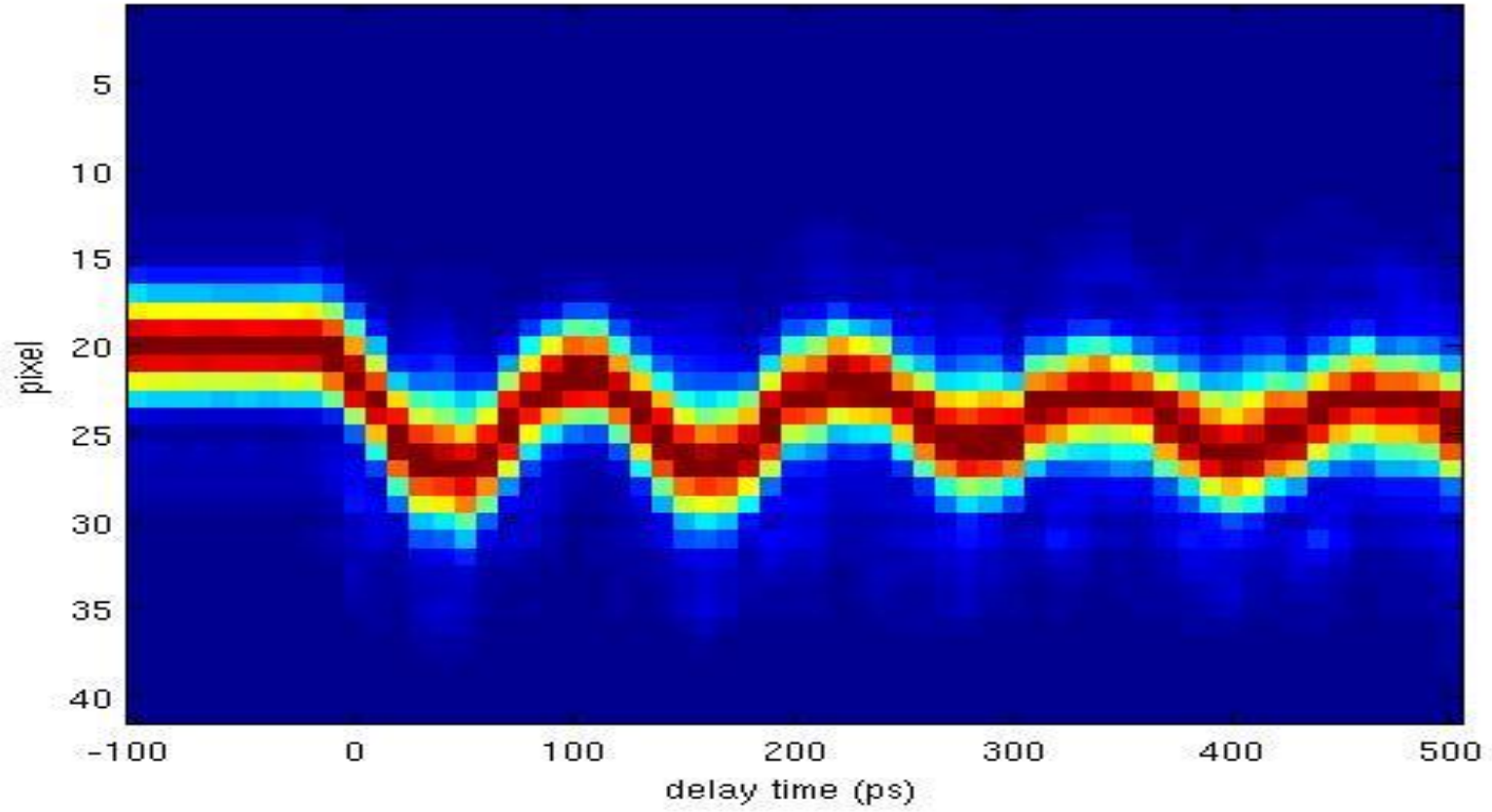
J. N. Clark, L. Beitra, G. Xiong, A. Higginbotham, D. M. Fritz, H. T. Lemke, D. Zhu, M. Chollet, G. J. Williams, M. Messerschmidt, B. Abbey, R. J. Harder, A. M. Korsunsky, J. S. Wark and I. K. Robinson, Science **341** 56 (2013)





Pump-probe at LCLS (XPP)

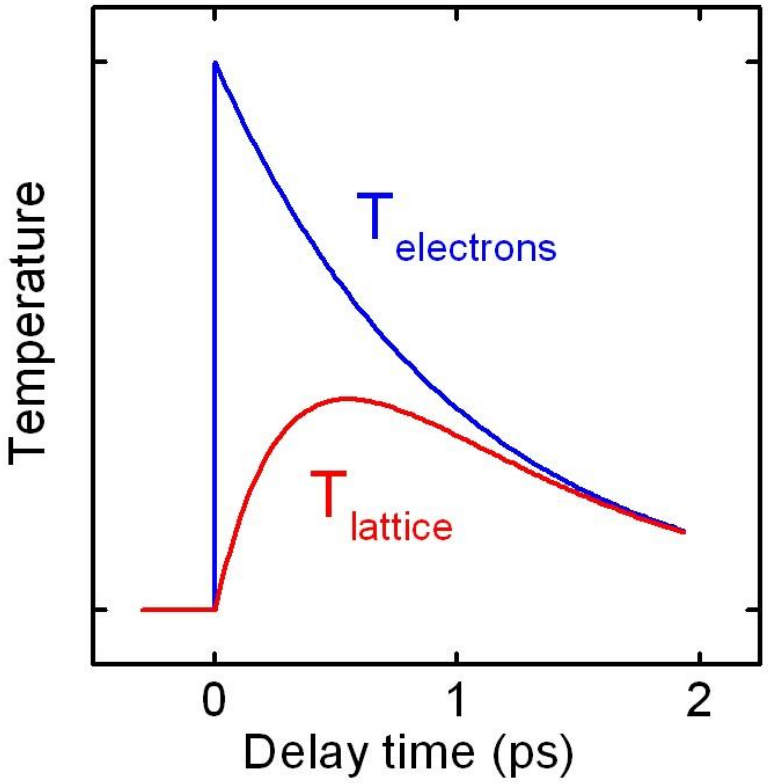
Justin Wark, Loren Beitra, Alexander Korsunsky, Ross Harder, David Fritz , Sebastien Boutet, Jesse Clark, Garth Williams, Brian Abbey, Andy Higginbotham, Diling Zhu, Henrick Lemke, Mattieu Chollet, Marc Messerschmidt



“Two-temperature” model

I.K. Robinson et al, Journal of Optics **18** 054007 (2016)

J.K. Chen et al, Int J. Heat Transfer **49** 307 (2006)



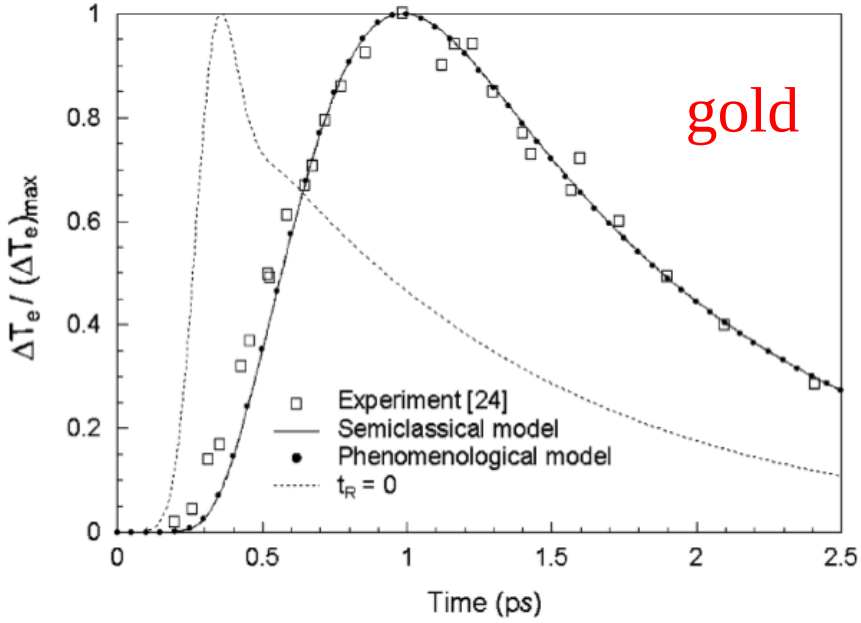
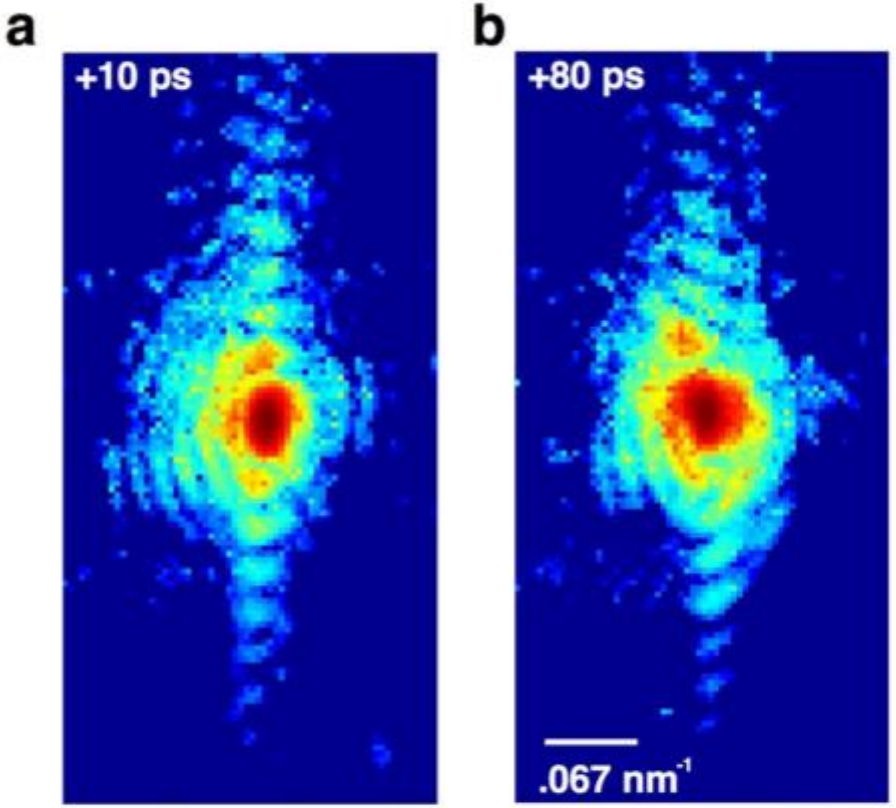
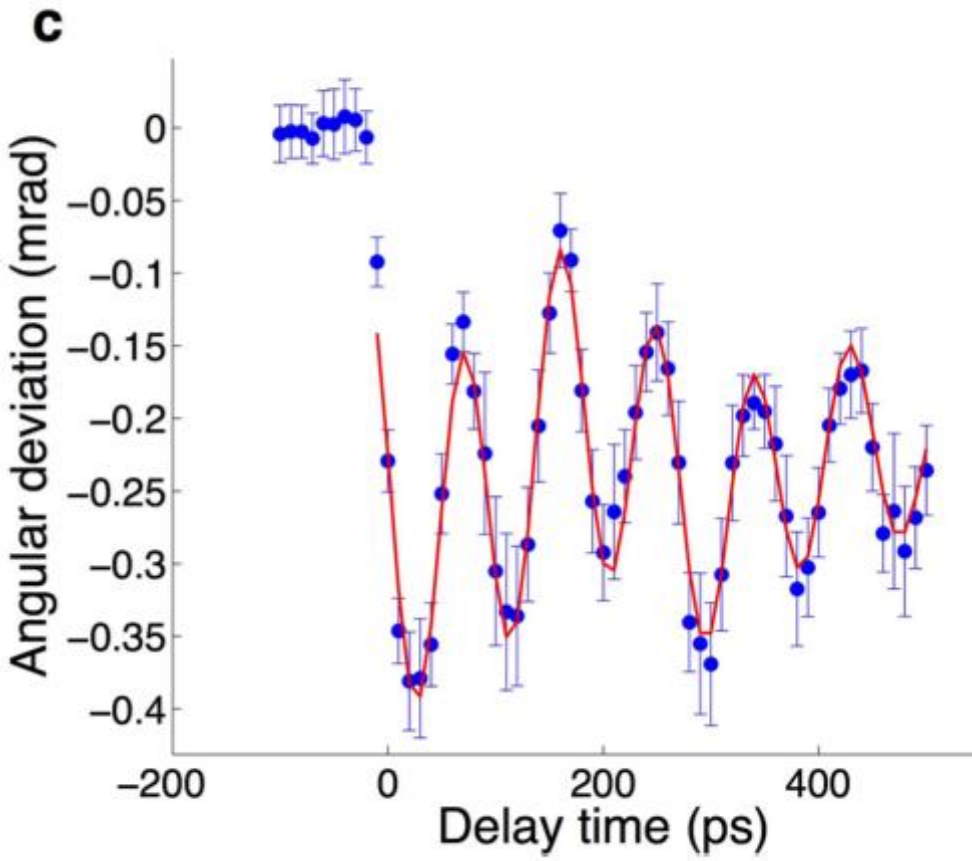


Fig. 2. Comparison of the change in electron temperature at the front surface of an 80-nm gold film irradiated by a 2.8 mJ/cm^2, 800 nm, 150-fs laser pulse.

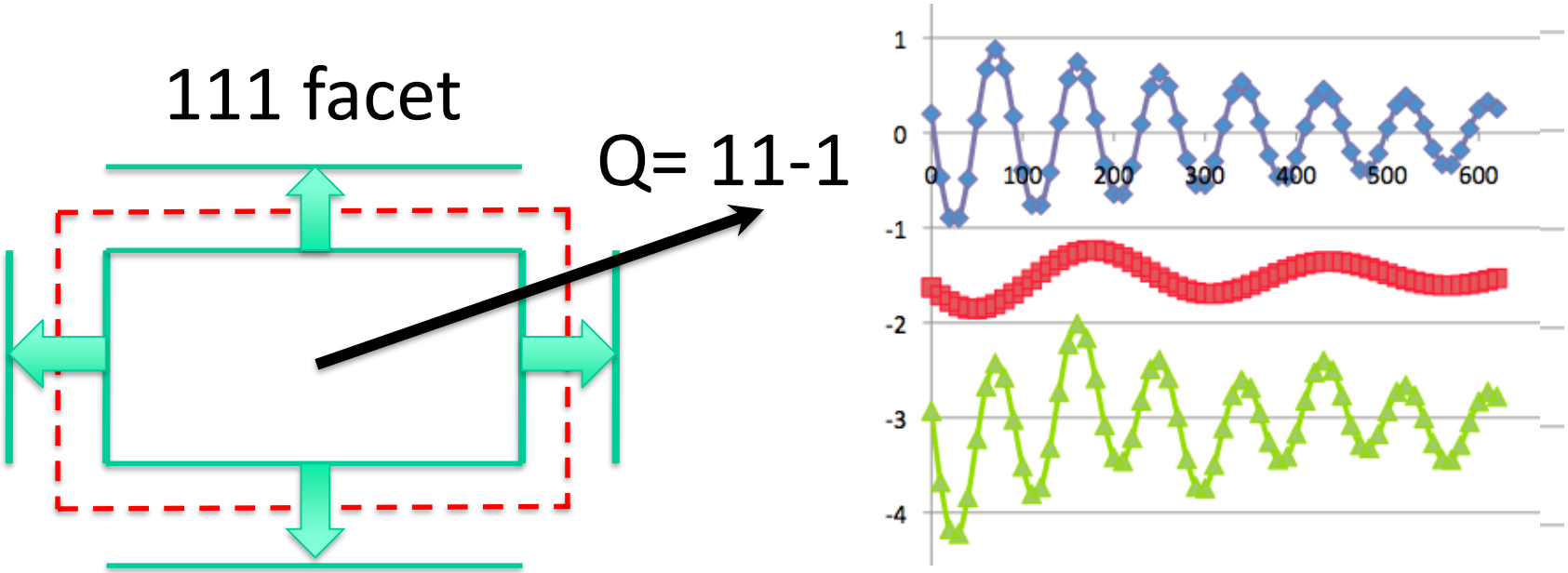
Time resolved Bragg peak position





Two Normal Modes of Vibration

$$S(\tau) = \sum_{n=1}^{N} A_n \exp\left[-(\tau/\tau_{d,n})^2\right] \cos(\omega_n \tau + \varphi_{0,n})$$



T_1 = 90ps h_1 = 145nm c_S = 3240 m/s

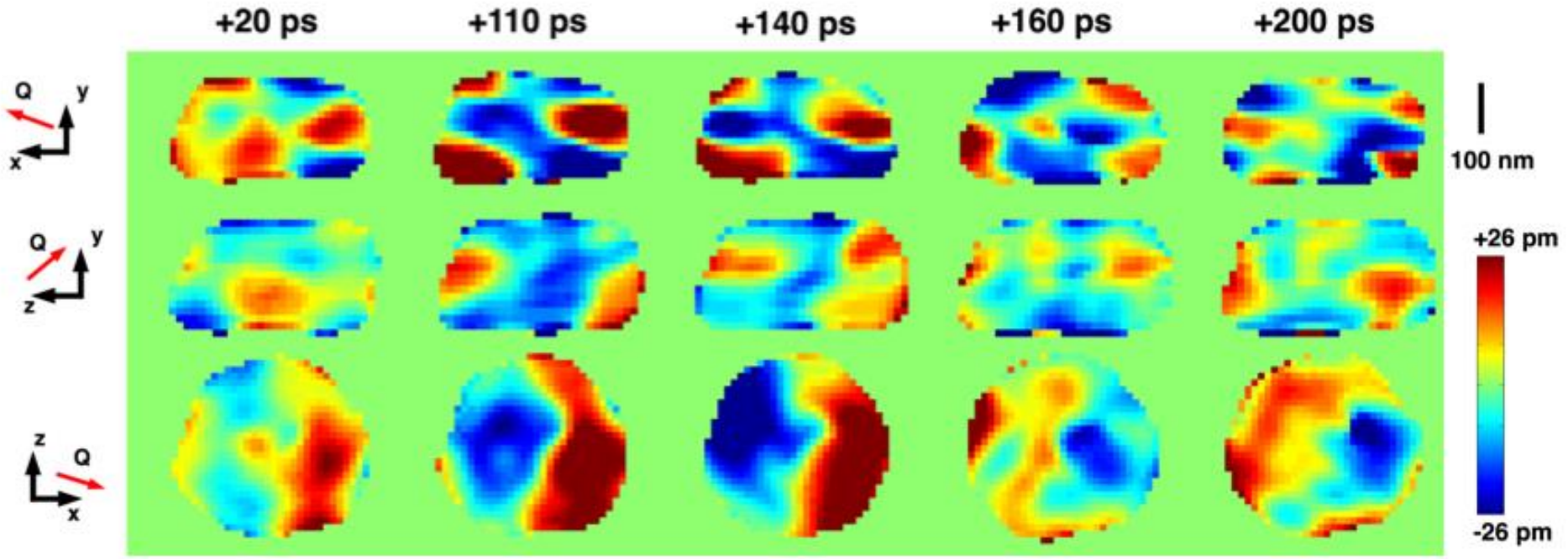
T_2 = 259ps h_2 = 420nm

Dynamic imaging of displacements

CDI inversion of 3D diffraction patterns

1000 frames averaged at each point of rocking curve

Jesse Clark et al, Science **341** 56 (2013)

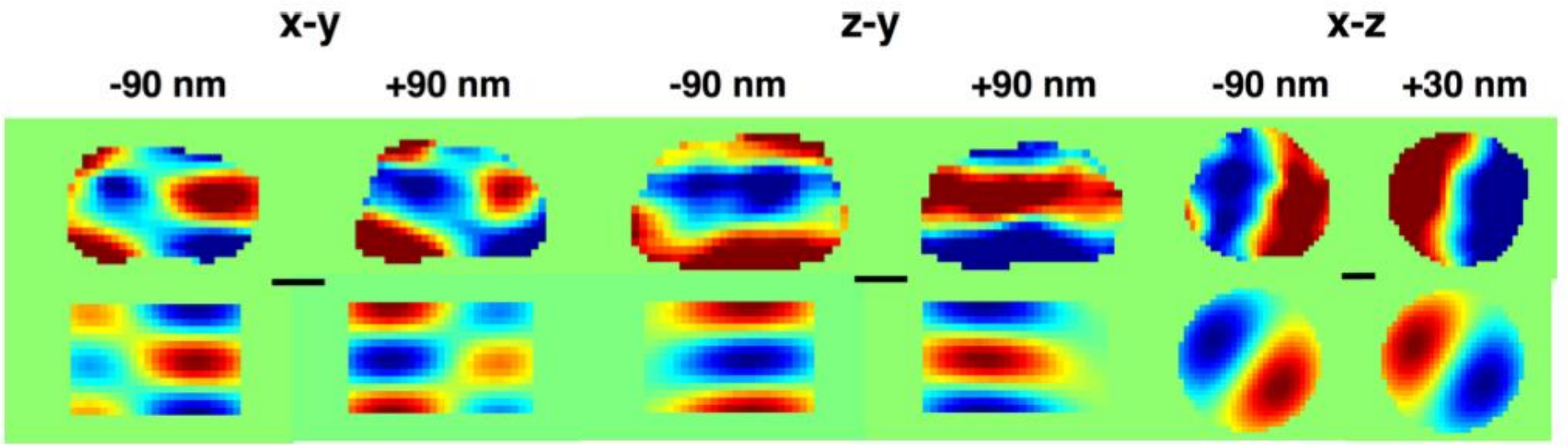


Dynamic imaging of displacements

CDI inversion of 3D diffraction patterns

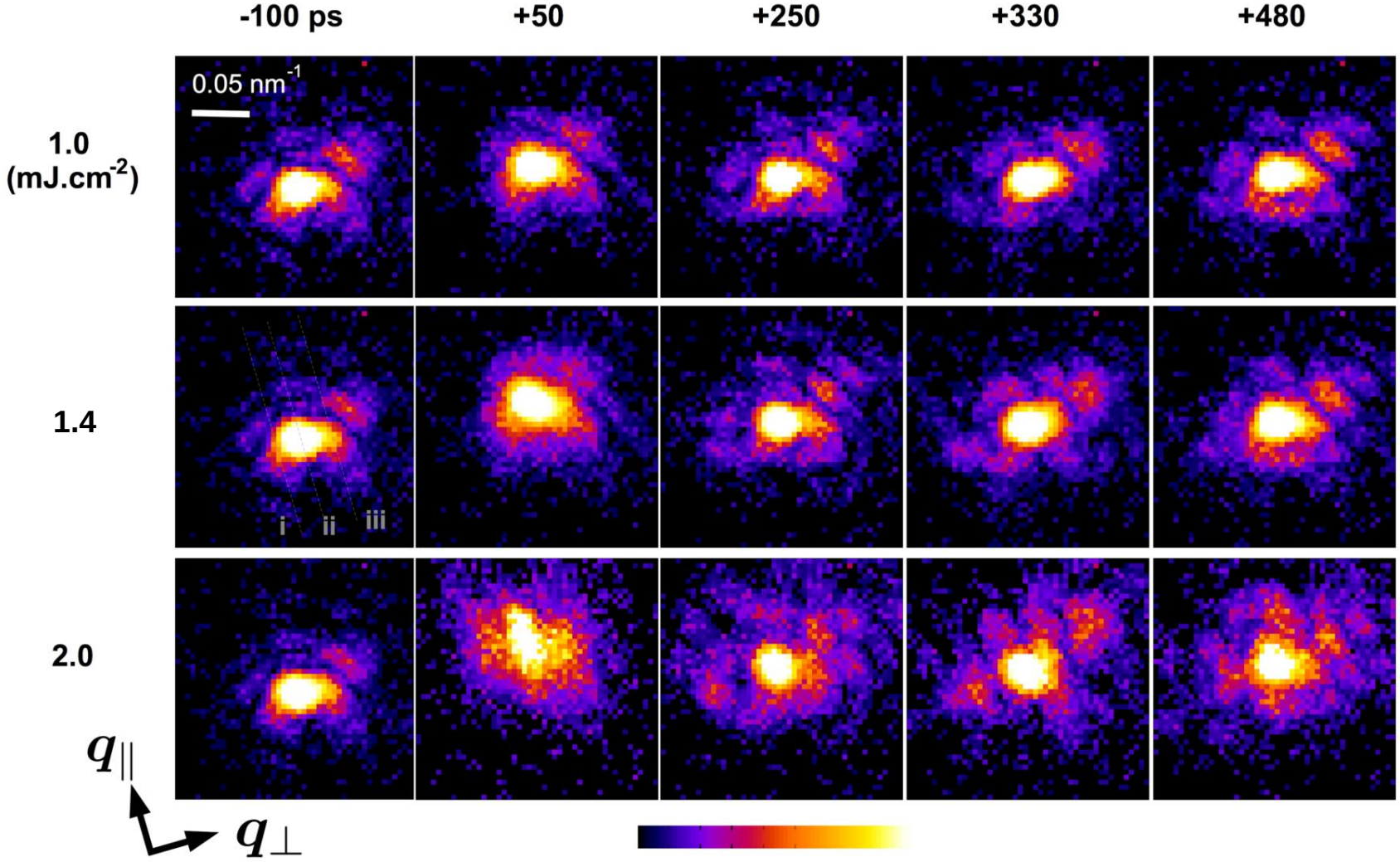
Comparison with (1,1) normal mode of cylinder

Jesse Clark et al, Science **341** 56 (2013)



Dependence on Laser Fluence

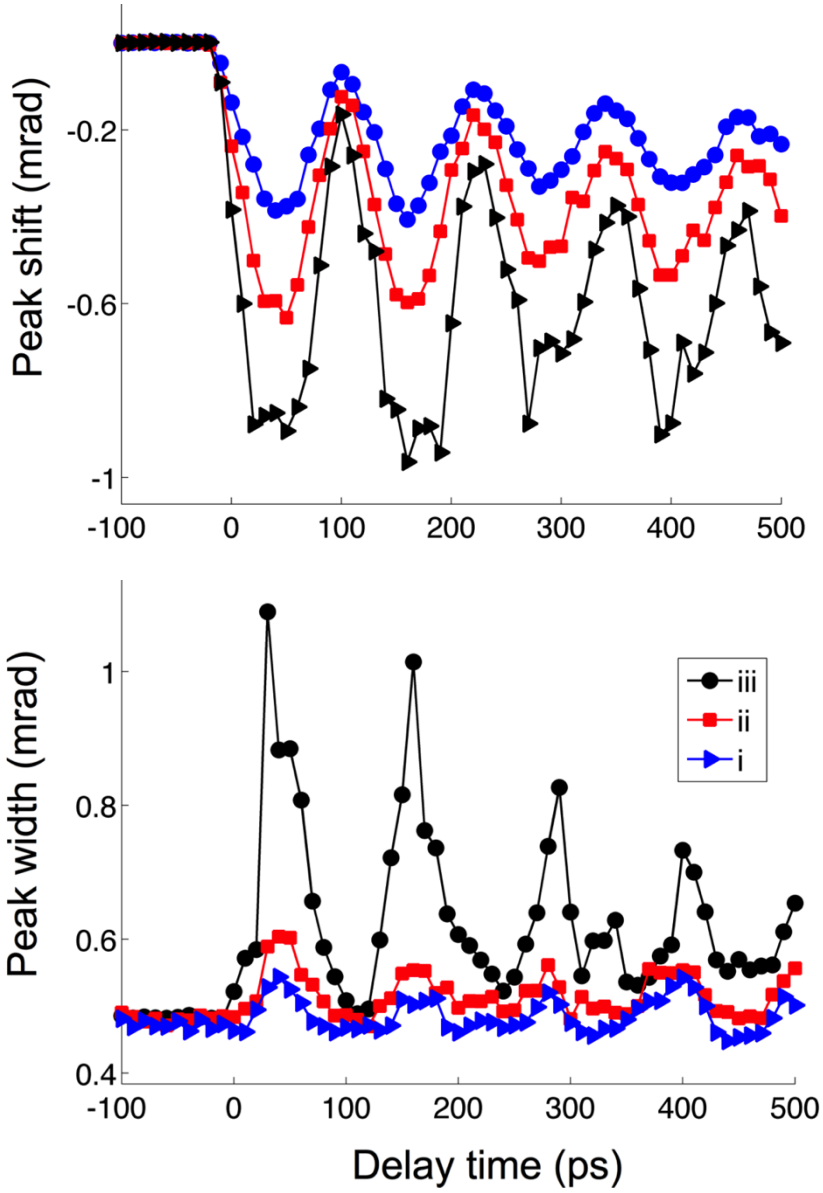
Jesse Clark et al, PNAS **112** 7444-8 (2015)



Dependence on Laser Fluence

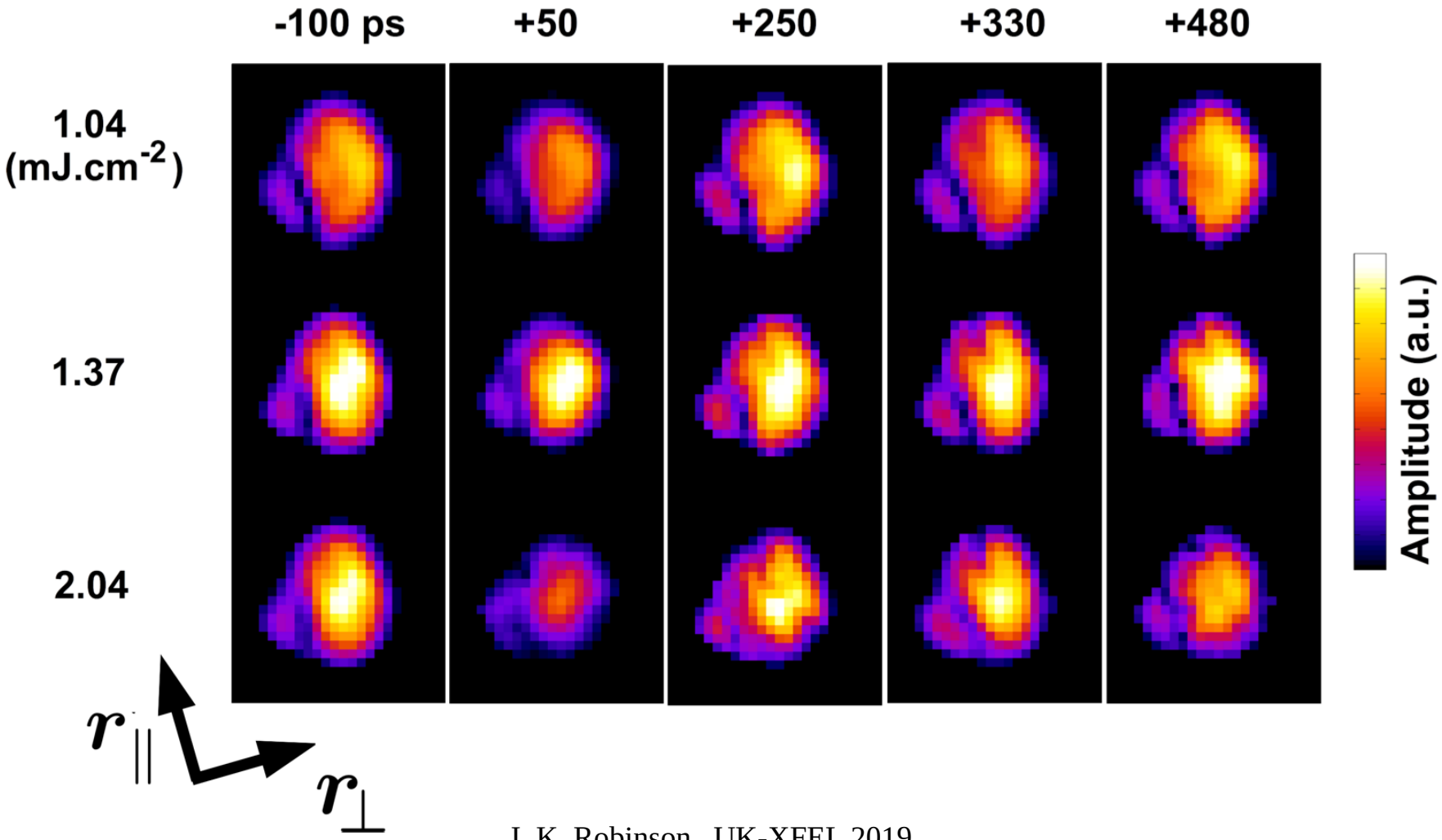
Jesse Clark et al, PNAS **112** 7444-8 (2015)

1.0 mJ cm^{-2}
1.4 mJ cm^{-2}
2.0 mJ cm^{-2}

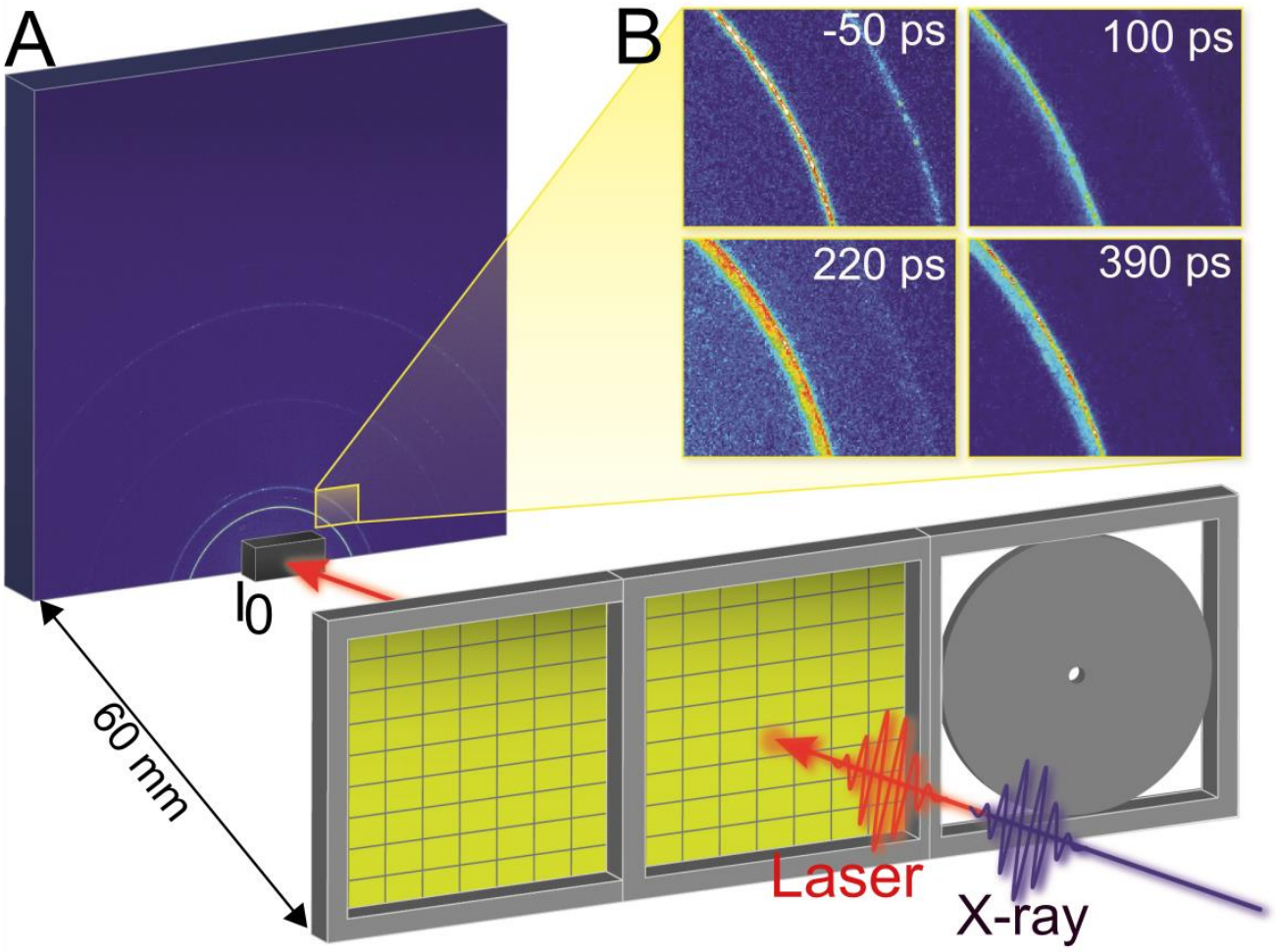


Dependence on Laser Fluence

Jesse Clark et al, PNAS **112** 7444-8 (2015)

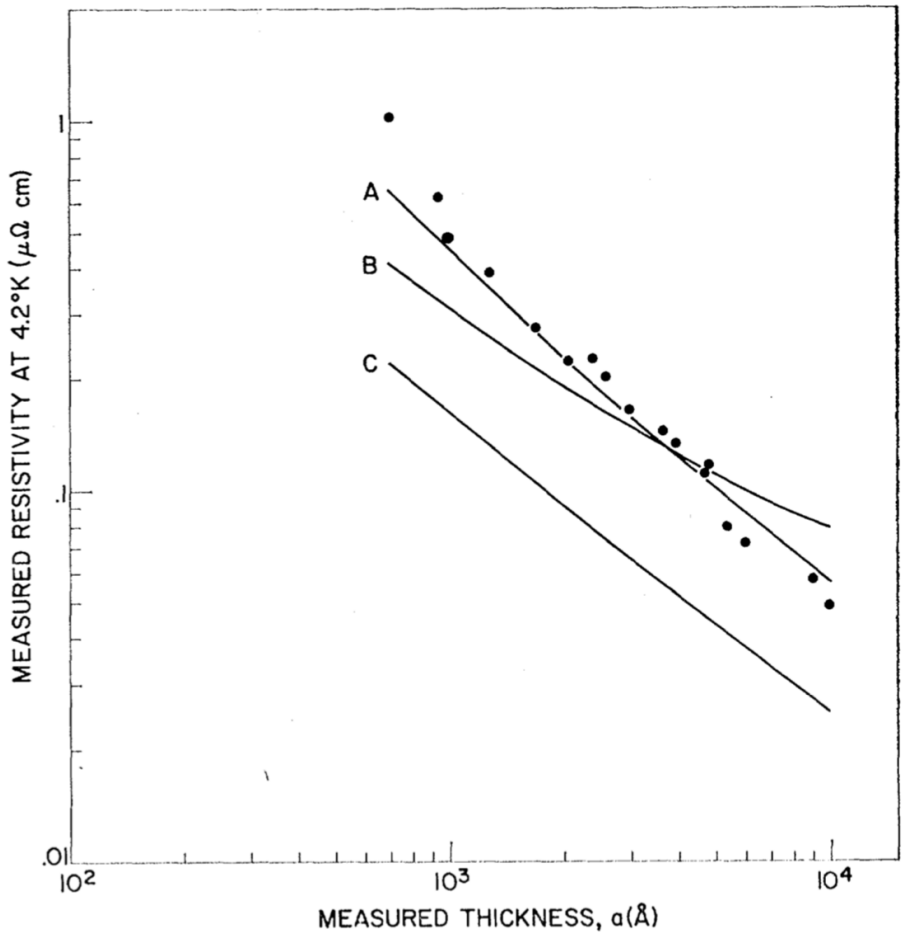


Melt-front Dynamics in Gold Thin Films using PAL-XFEL

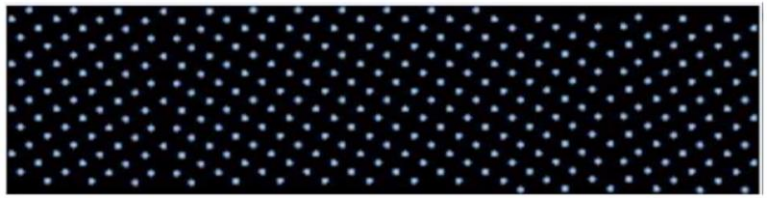


Resistivity of Al Thin Films

A. F. Mayadas and M. Shatzkes, PRB **1** 1382 (1970)

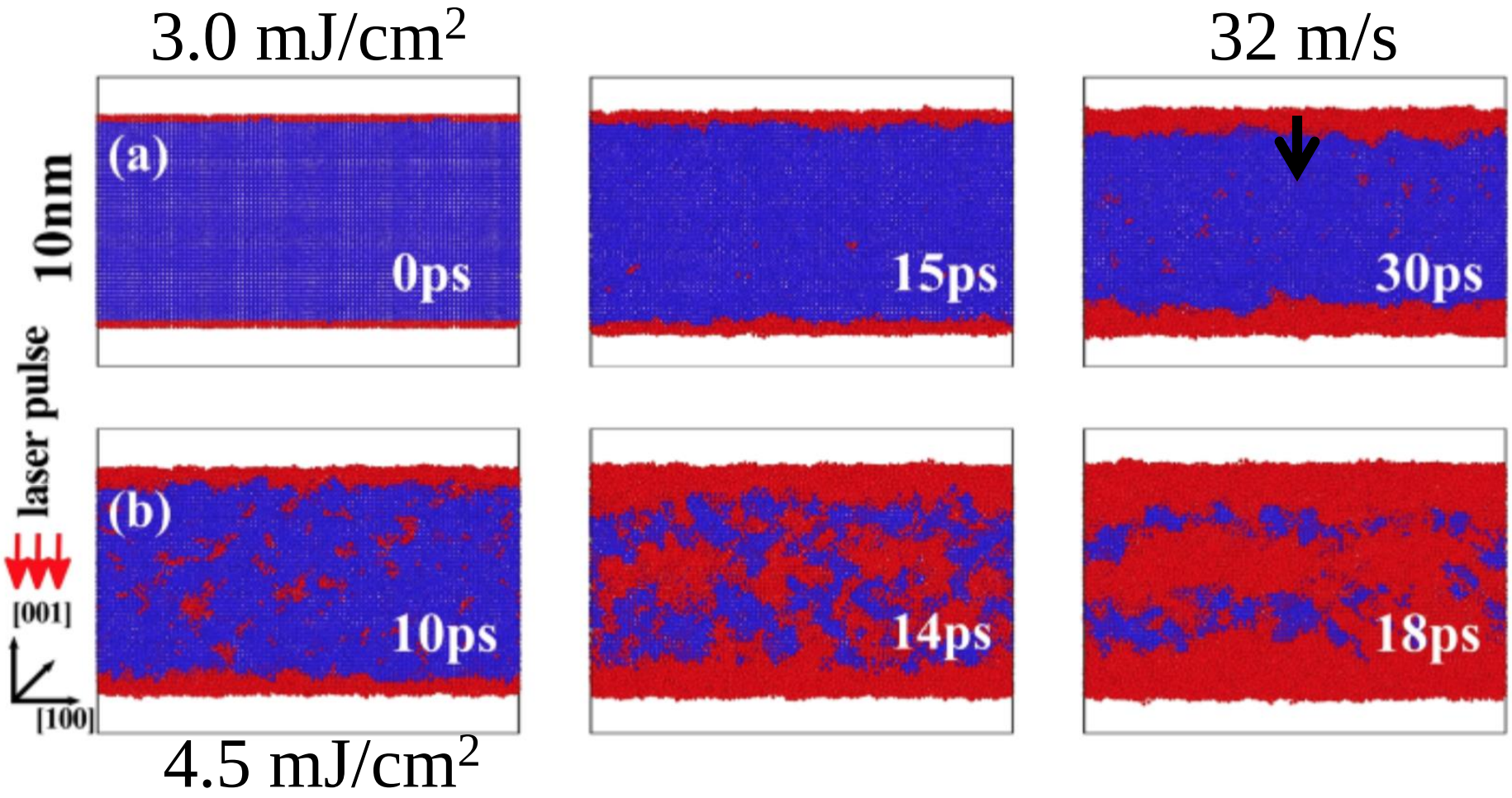


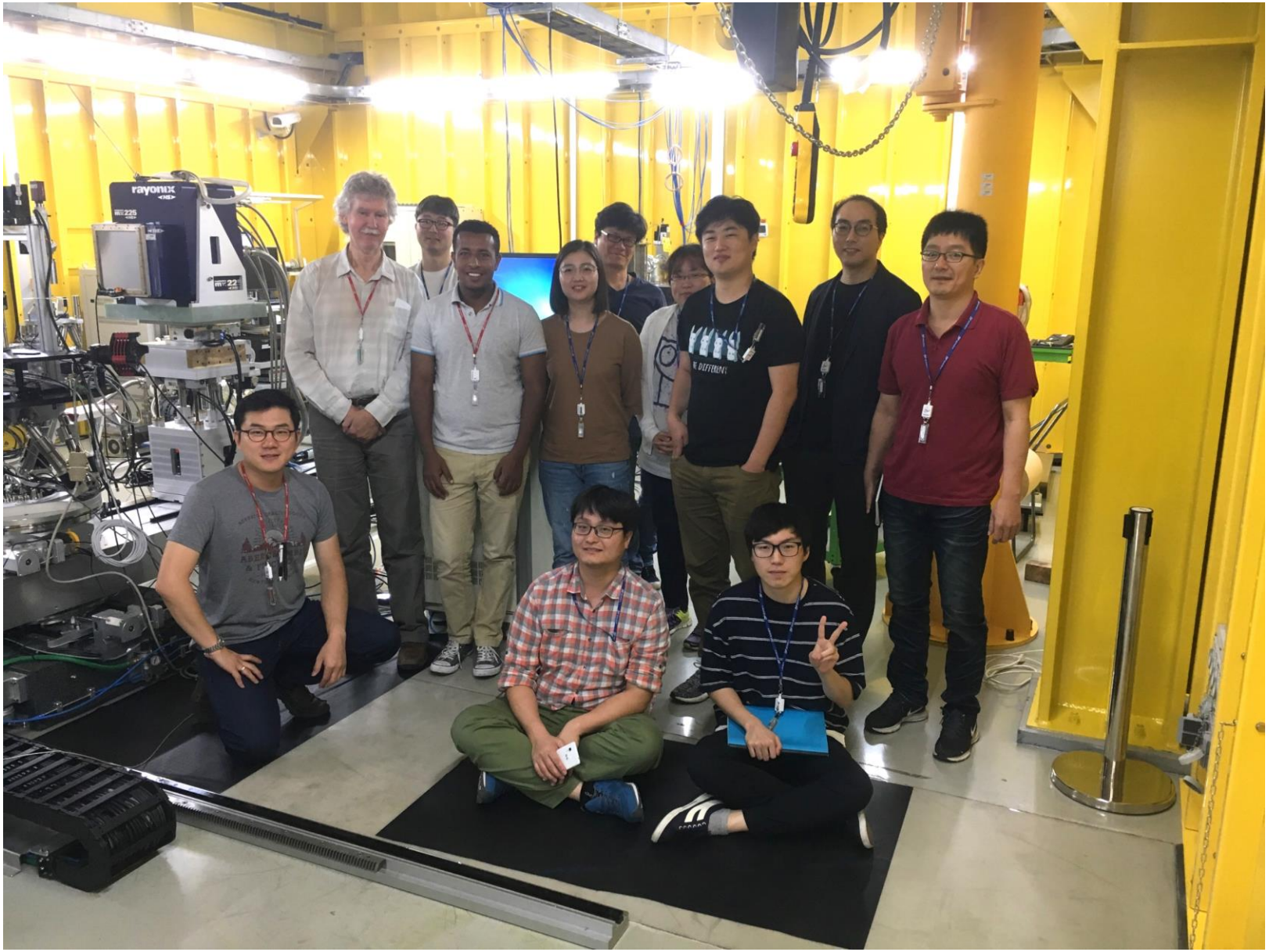
- "Universal curve" of MFP vs electron energy
- Thermal MFP removed at low temperature
- Grain size proportional to thickness (model)



2TM-MD (EAM) simulation Au slab

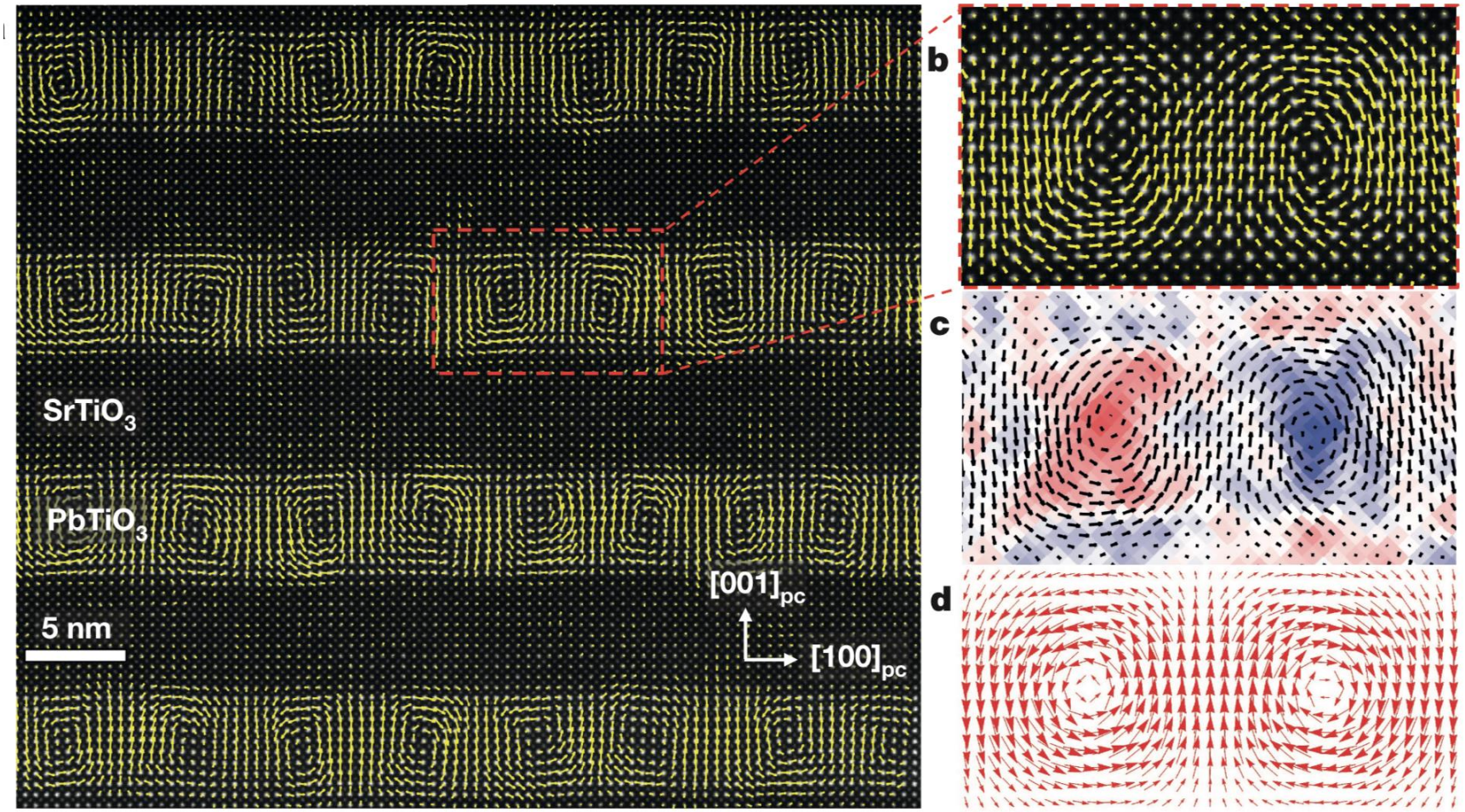
Giret et al, APL **103** 253107 (2013)



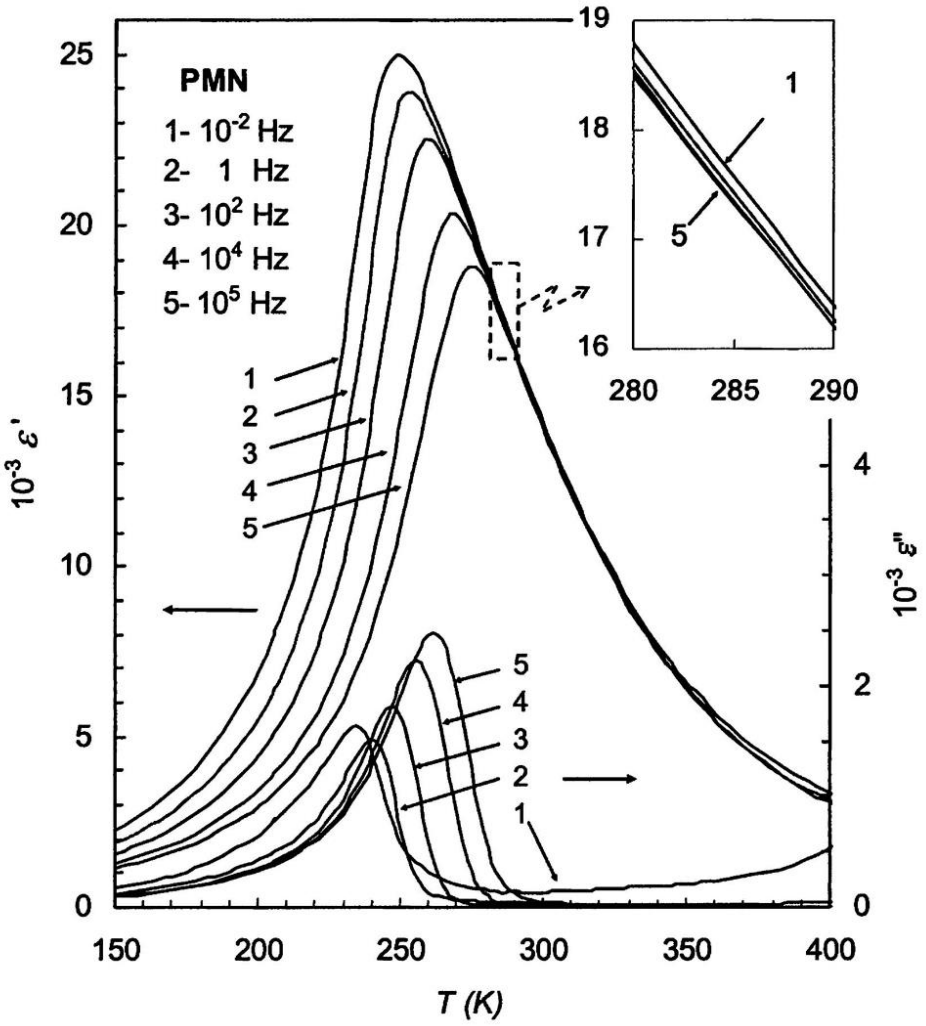

rayonix

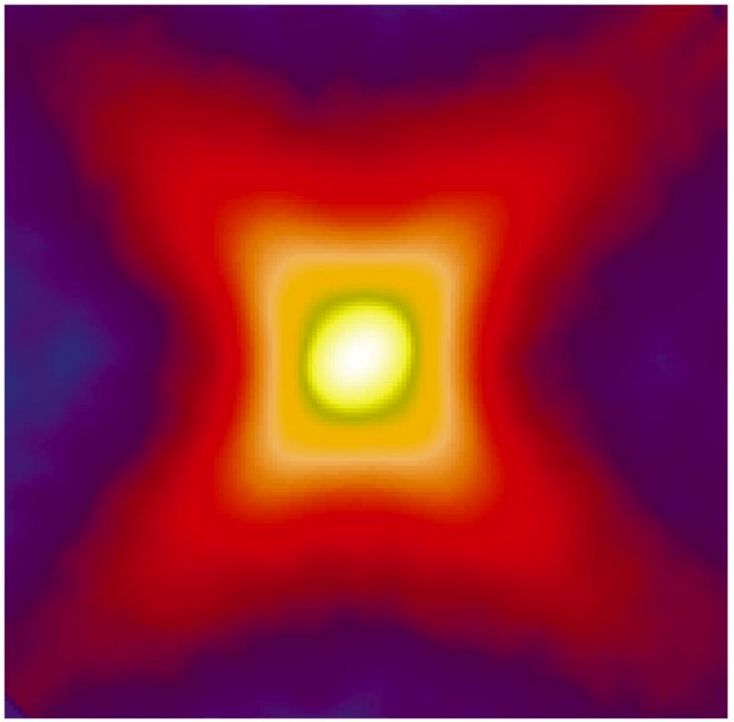
Ferroelectric Polar Vortices

A. K. Yadav et al Nature 530 198 (2016)



$PbMg_{1/3}Nb_{2/3}O_3$ Relaxor Ferroelectric





A. A. Bokov et al J. Mat. Sci. 41 31 (2006)
G. Xu, G. Shirane, et al PRB 69 064112 (2004)

Advanced Materials and Nanotechnology

- Pump-probe approach to excitations
- Bragg Coherent Diffraction Imaging (BCDI)
- New vibration mode of Au Nanoparticle
- Surface melting of Au Nanoparticle
- Melt-front picture of Ultrafast melting

Acknowledgements

Jesse Clark
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Ming Lu
Changyong Song
Hyunjung Kim
Simon Billinge

Sunam Kim
Sungwon Kim
Dongjin Kim
Heemin Lee
Jae Hyuk Lee
Sang-Youn Park
Intae Eom
Jaeku Park
Daewoog Nam
Sangsoo Kim
Sae Hwan Chun
Hyojung Hyun
Kyung sook Kim