Laser machining: what happens with ultrafast lasers?

Ian Robinson
Tadesse Assefa
Yue Cao
PAL-XFEL

London Centre for Nanotechnology
Brookhaven National Laboratory

Applied and Industrial Research with XFELs
University of Warwick
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PAL XFEL Control Room

Sunam Kim, Jae Hyuk Lee, Yongsam Kim, Jaeku Park, Sang-Youn Park, Intae Eom, Hyojung Hyun, Tae-Yeong Koo, Jaehun Park, Daewoong Nam and Sang Soo Kim

Outline

- Ultrafast Laser Machining
- Pump-probe method
- Excitations in the time domain
- Ultrafast melting of gold films

Laser Machining speed Comparison

50μm hole drilled in Alumina plate

Tatsuhiko Aizawa and Tadahiko Inohara, Book Chapter

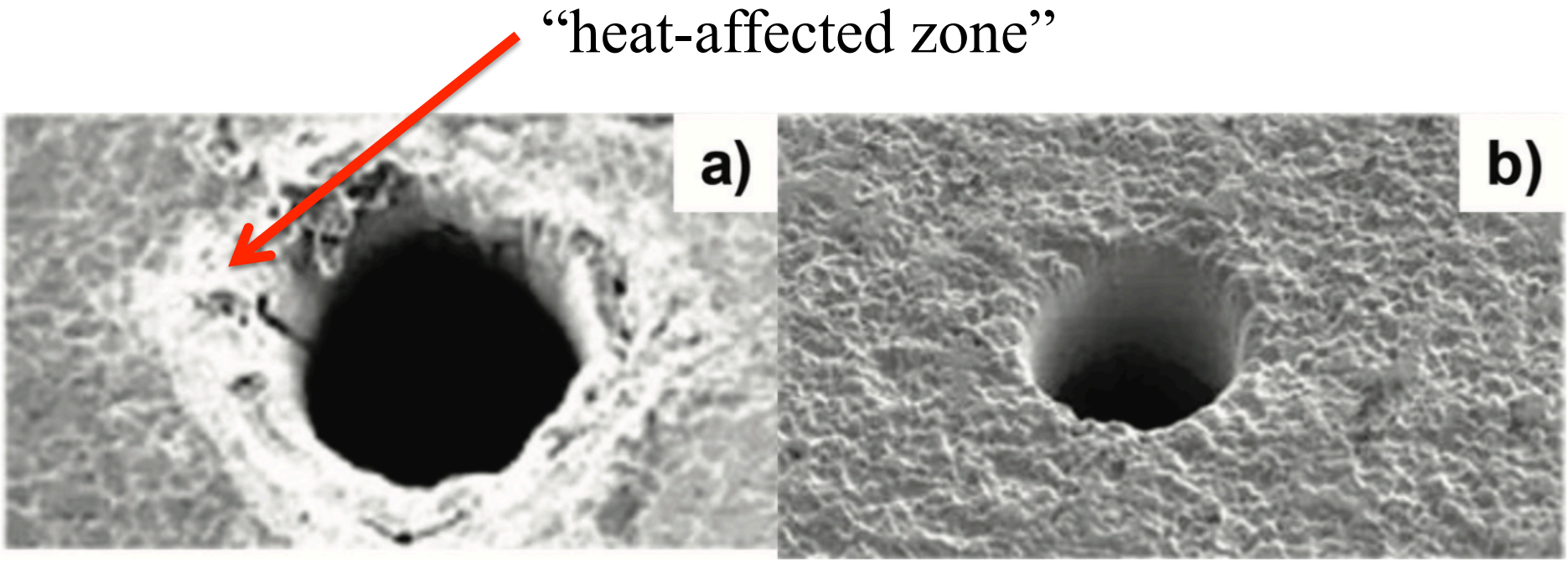


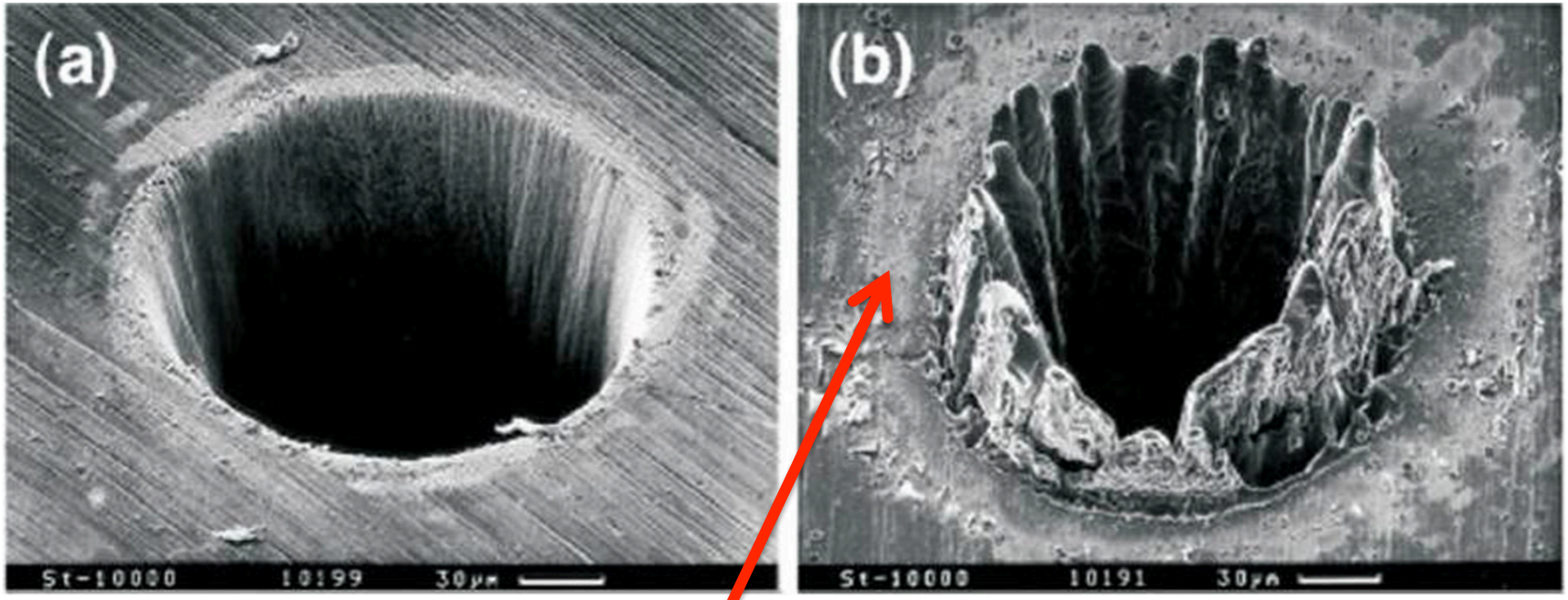
Figure 6.
Comparison of the drilled through-hole between fiber lasers and the picosecond laser. (a) Fiber laser drilling, and, (b) Picosecond laser drilling.

Laser Machining speed Comparison

100μm hole drilled in 100μm steel plate

K. Sugioka and Y. Cheng, Appl. Phys. Rev. **1** 041303 (2014)

200fs pulse, 0.5J/cm^2 3.3ns pulse, 4.2J/cm^2



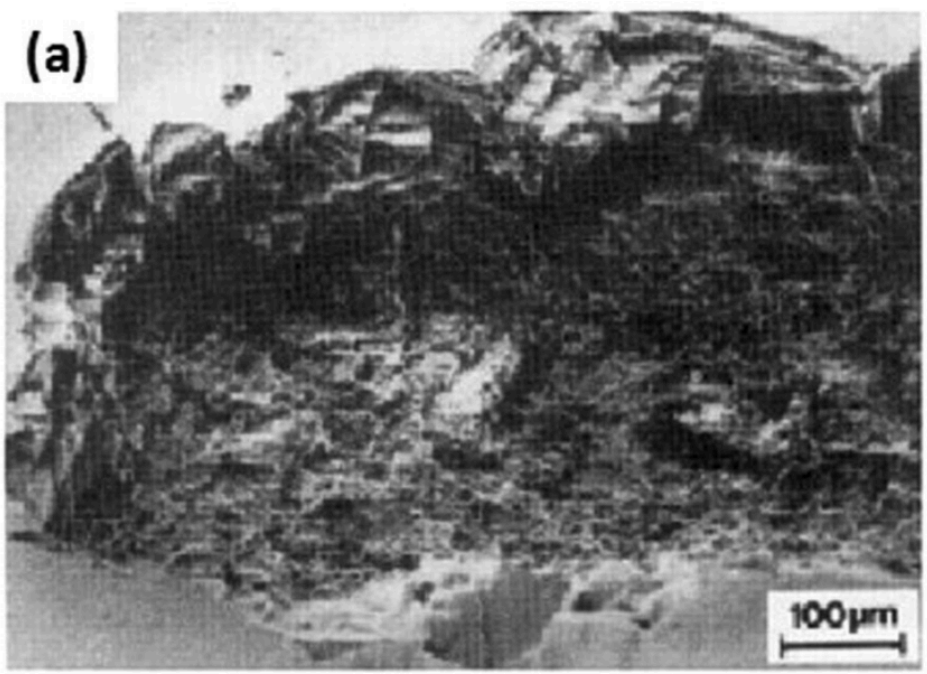
"heat-affected zone"

Laser Machining speed Comparison

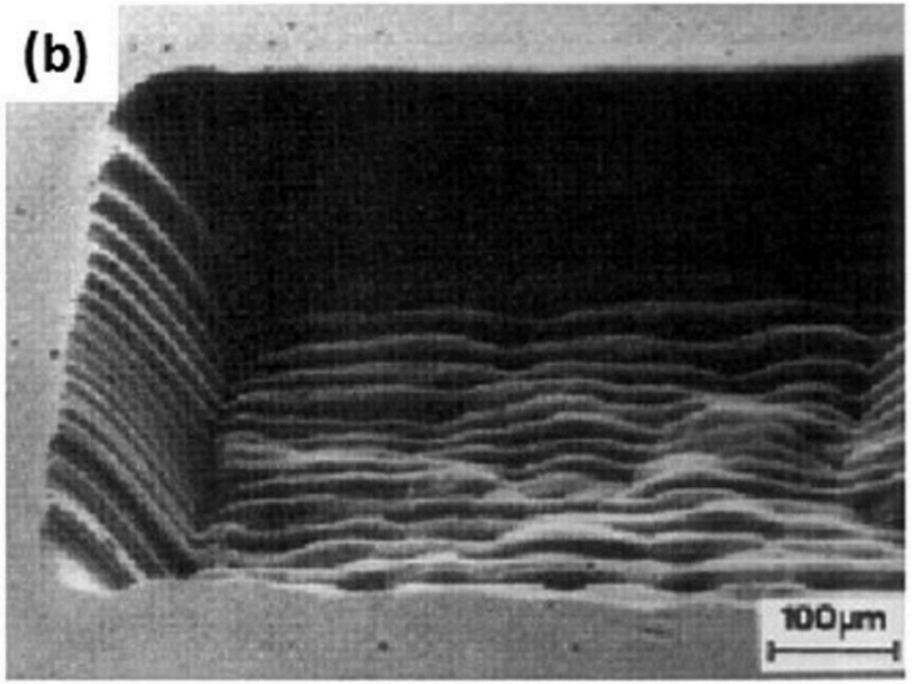
SEM of laser machined NaCl

Multiphoton Absorption of 248nm (NaCl is transparent)

K. Sugioka and Y. Cheng, Appl. Phys. Rev. **1** 041303 (2014)

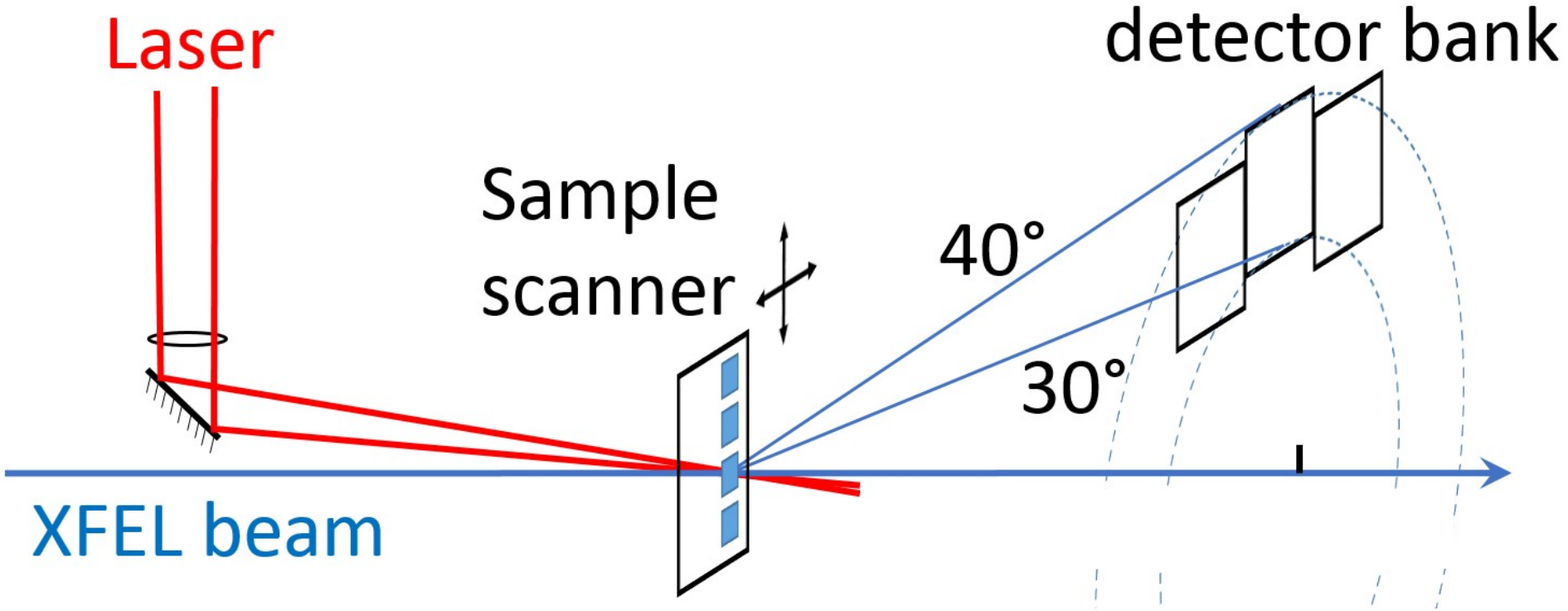


Nanosecond laser (16ns)



Femtosecond laser (300fs)

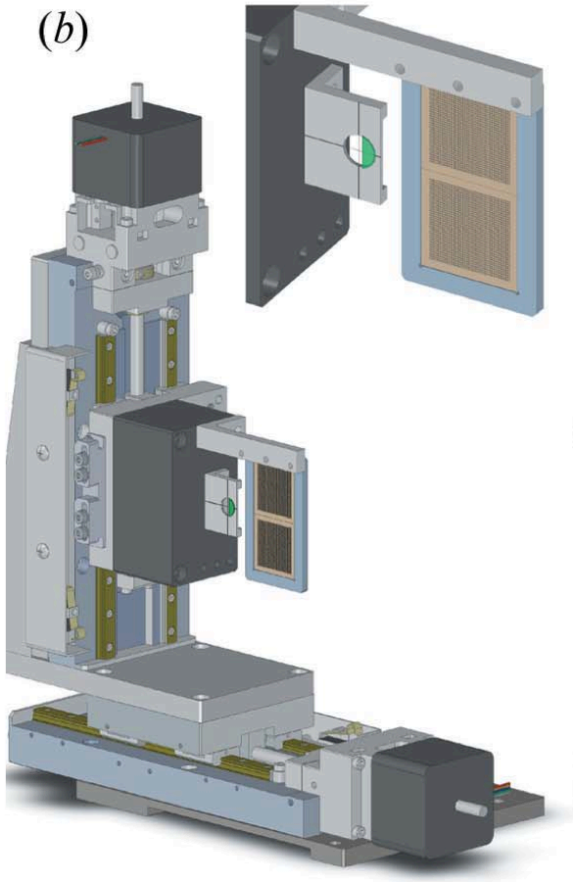
Pump-probe Method using Sample Scanner

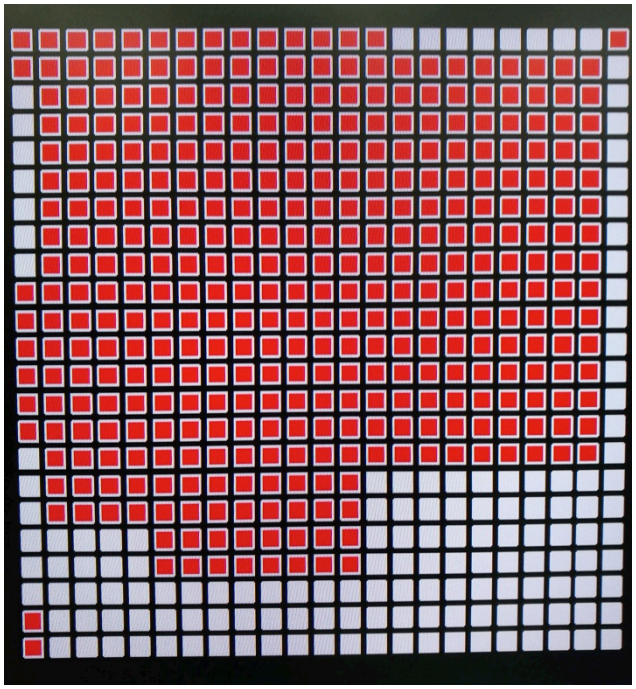


Scan Stage for MAXIC chamber

Changyong Song et al, J. Appl. Cryst. **47** 188 (2014)

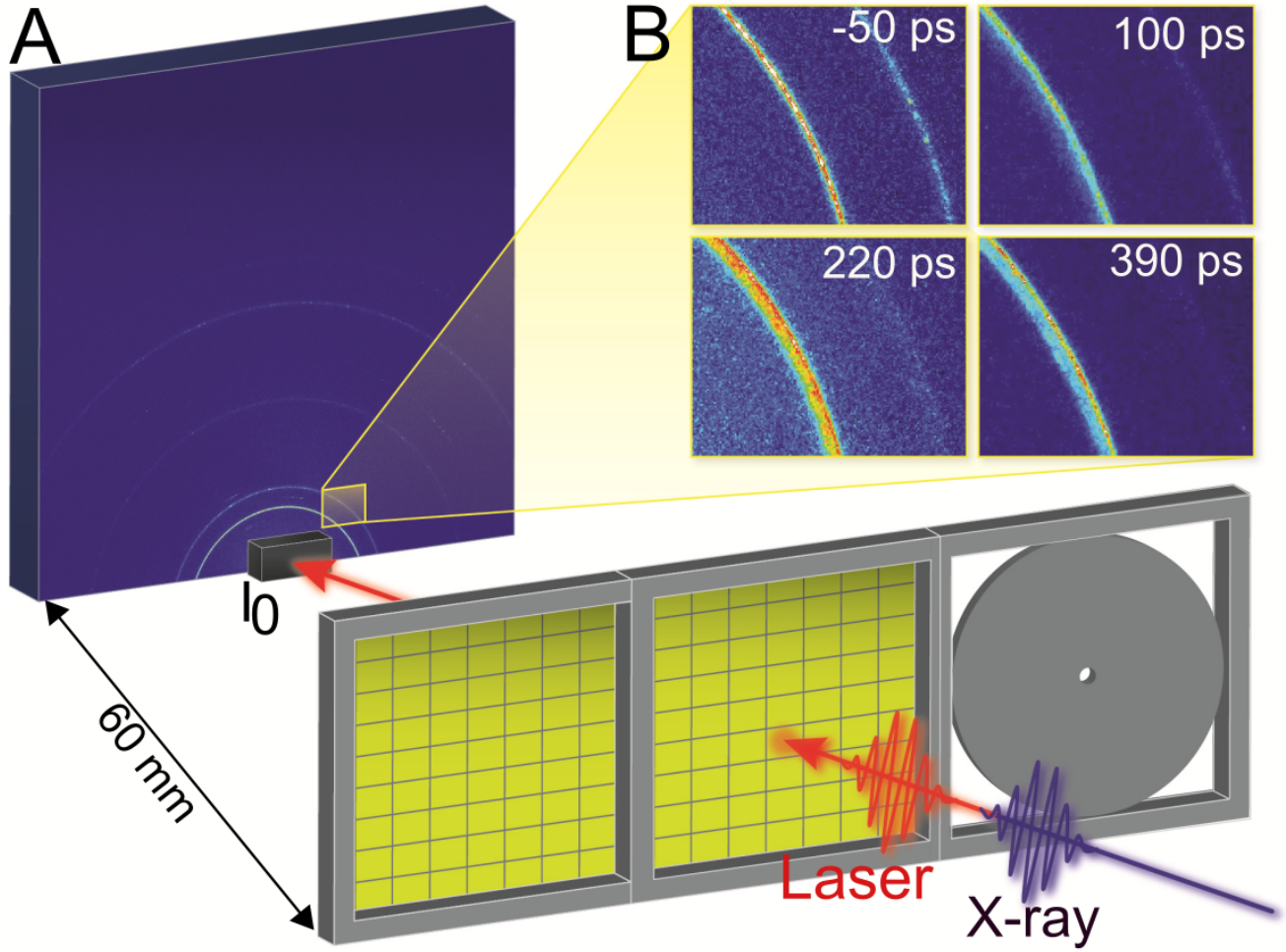
Daewoong Nam, scanning software



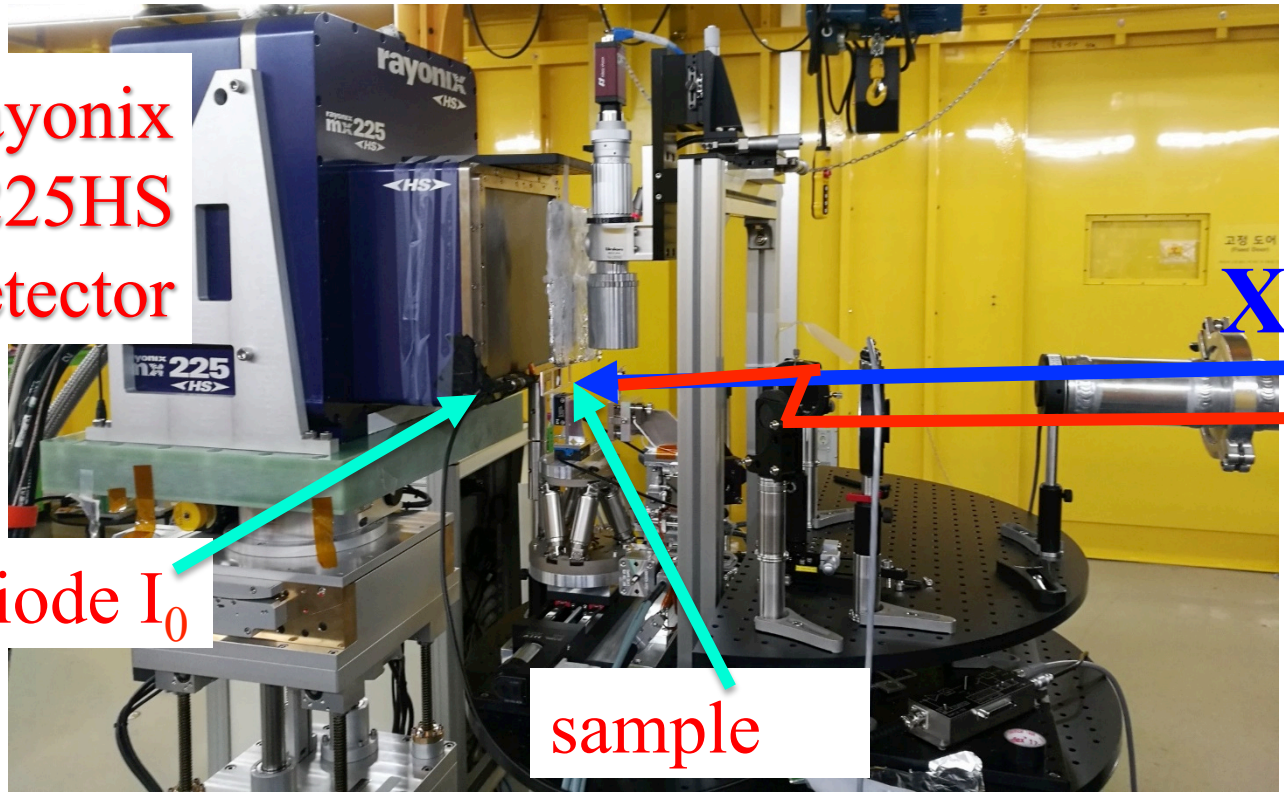


23x23 windows

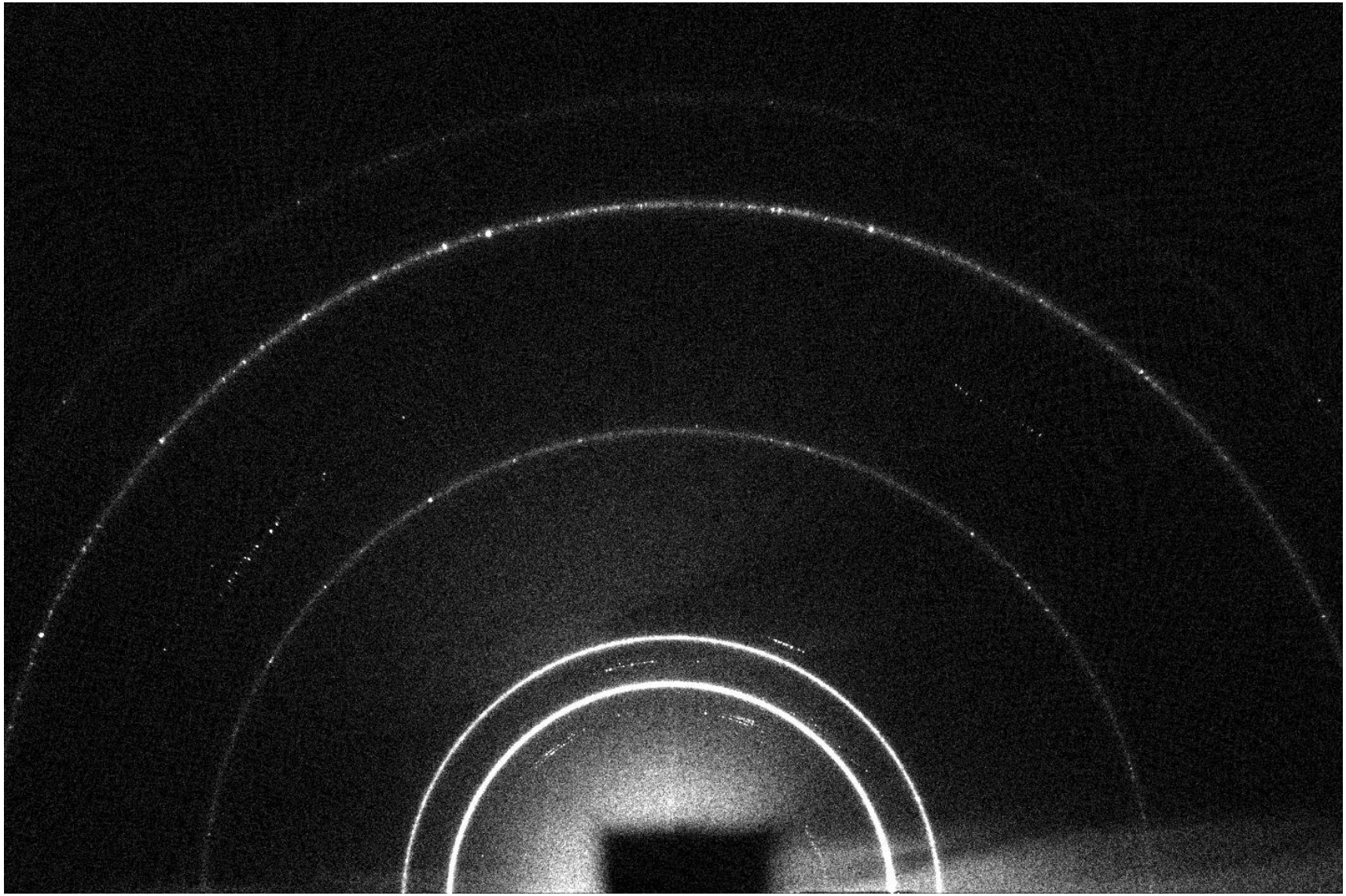
Melt-front Dynamics in Gold Thin Films using PAL-XFEL



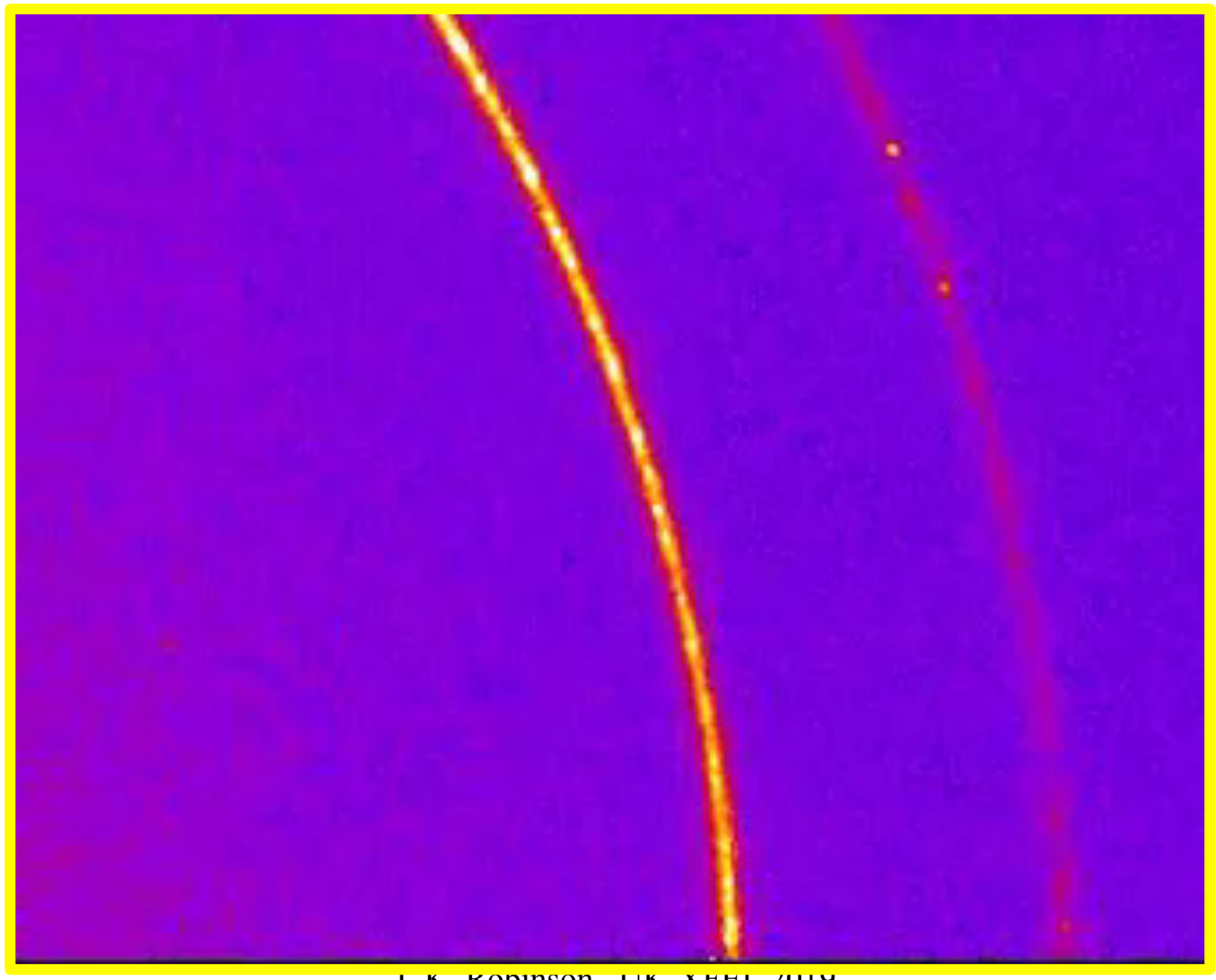
Experimental set-up at PAL-XFEL September 2017



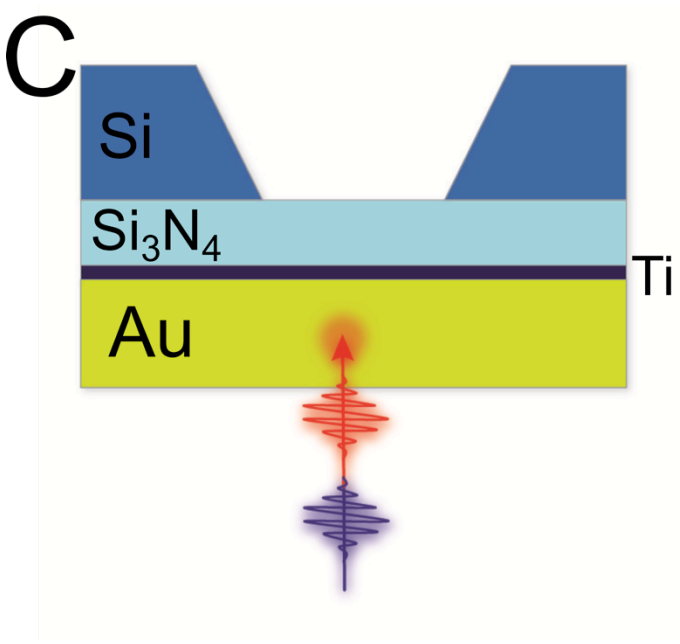
Raw data #397 300nm film

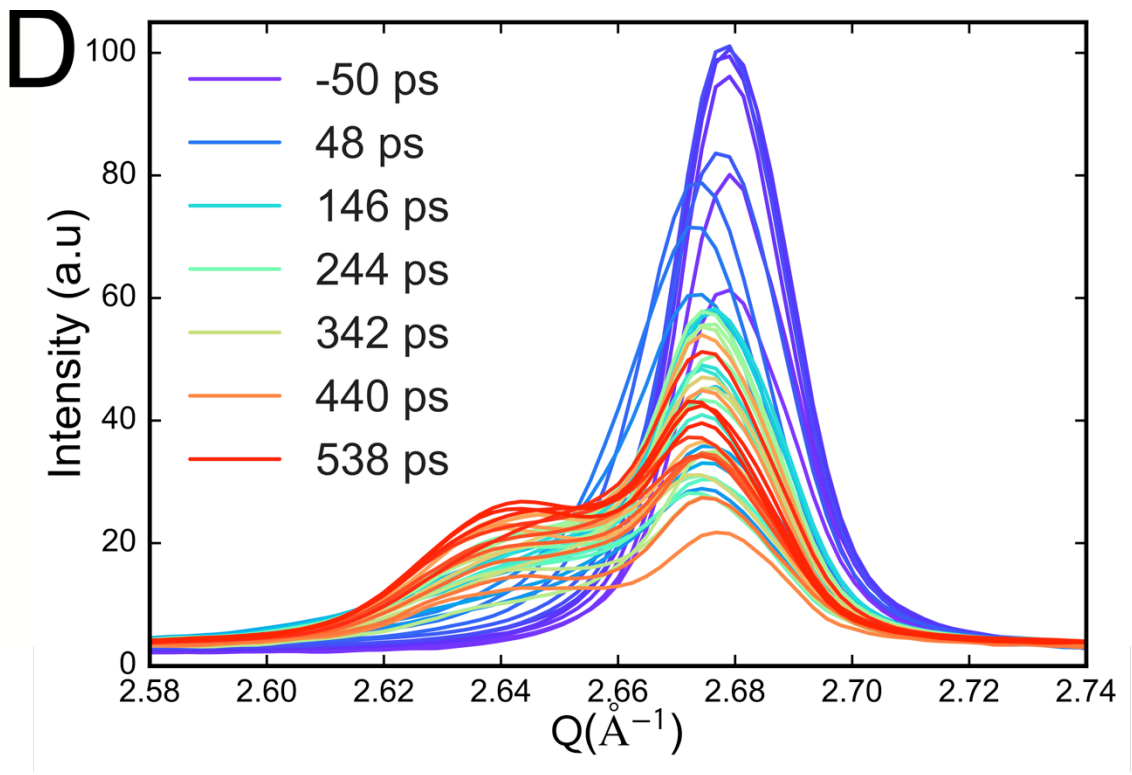


Raw data #396 300nm film, 254 mJ/cm^2



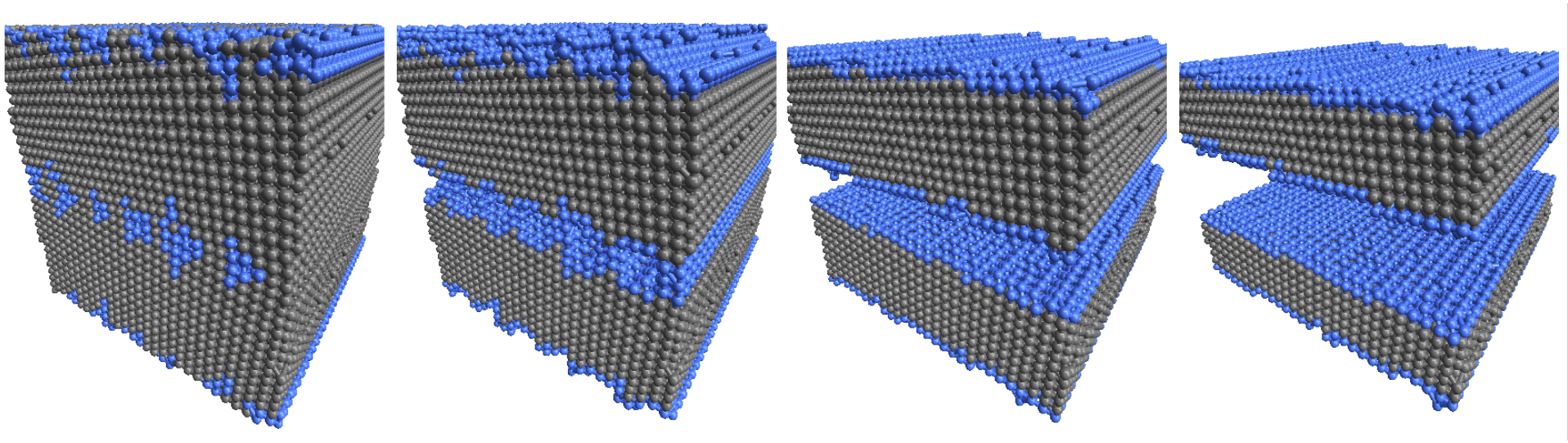
Thin Film Sample Format





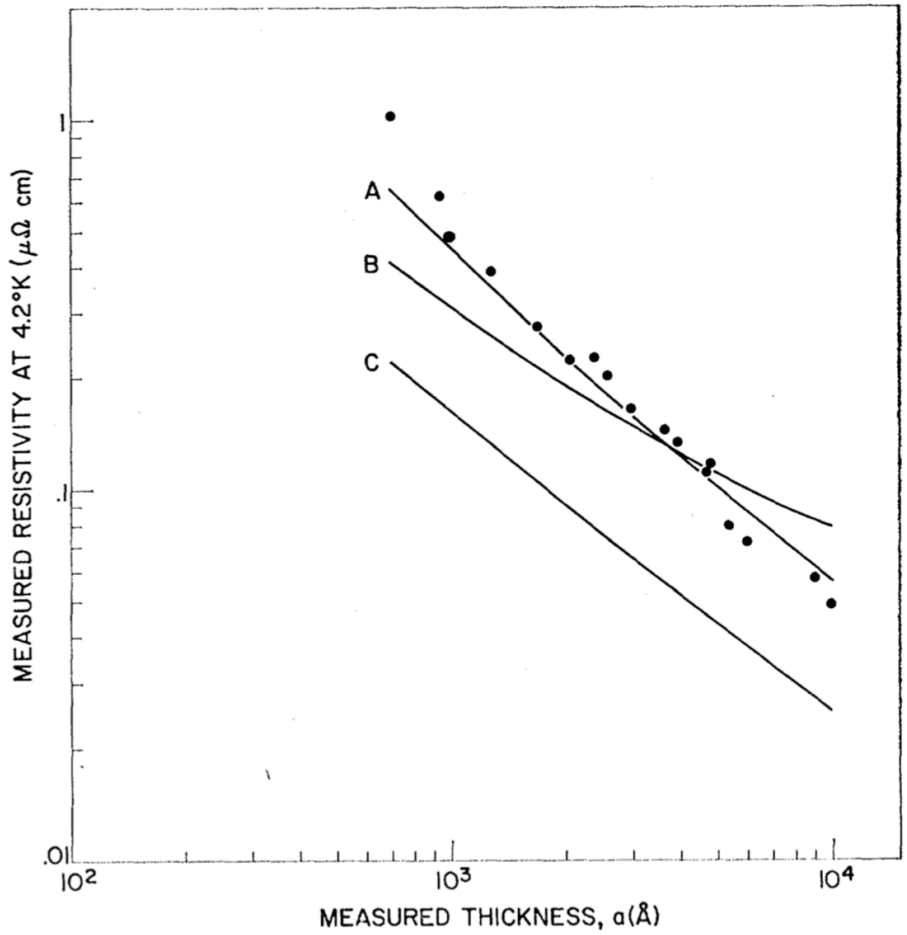
Force-Field Simulation of GB melting

J. Berry, K. Elder and M. Grant, PRB 77 224114 (2008)

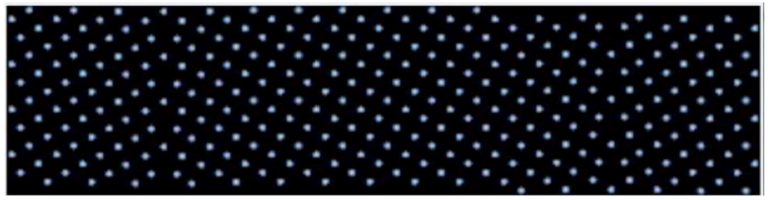


Resistivity of Al Thin Films

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



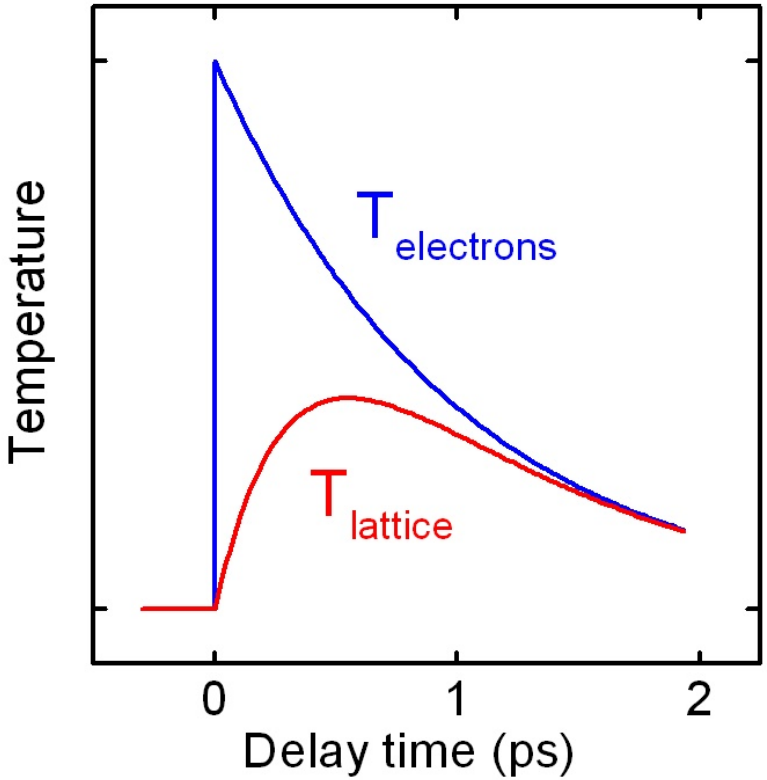
- "Universal curve" of MFP vs electron energy
- Thermal MFP removed at low temperature
- Grain size proportional to thickness (model)



"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)



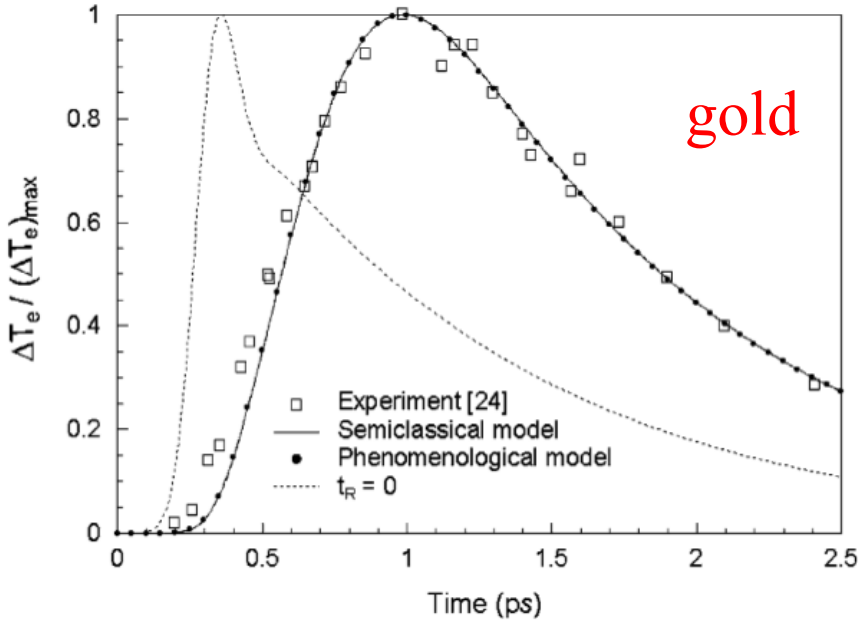
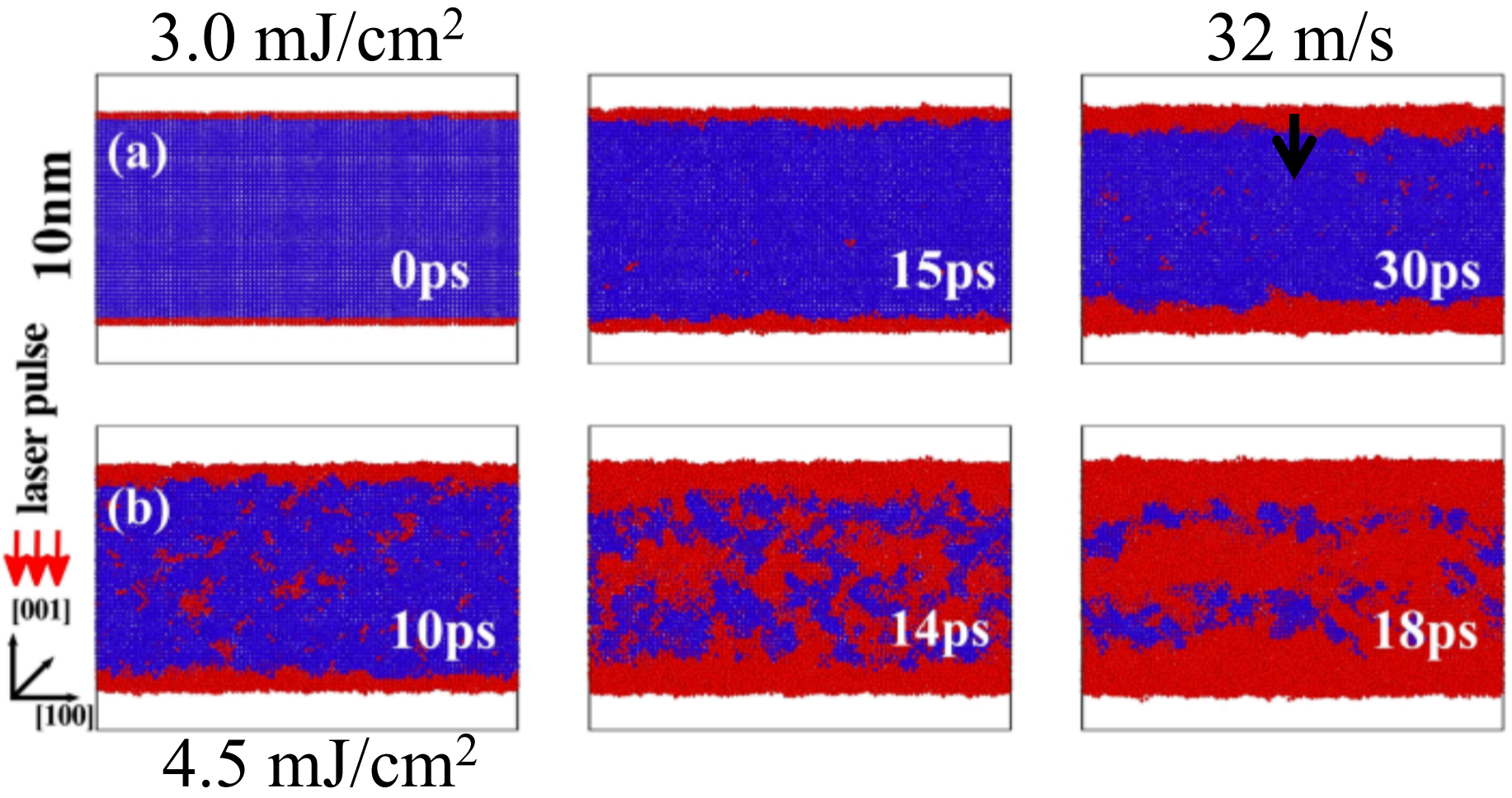


Fig. 2. Comparison of the change in electron temperature at the front surface of an 80-nm gold film irradiated by a 2.8 mJ/cm^2, 800 nm, 150-fs laser pulse.

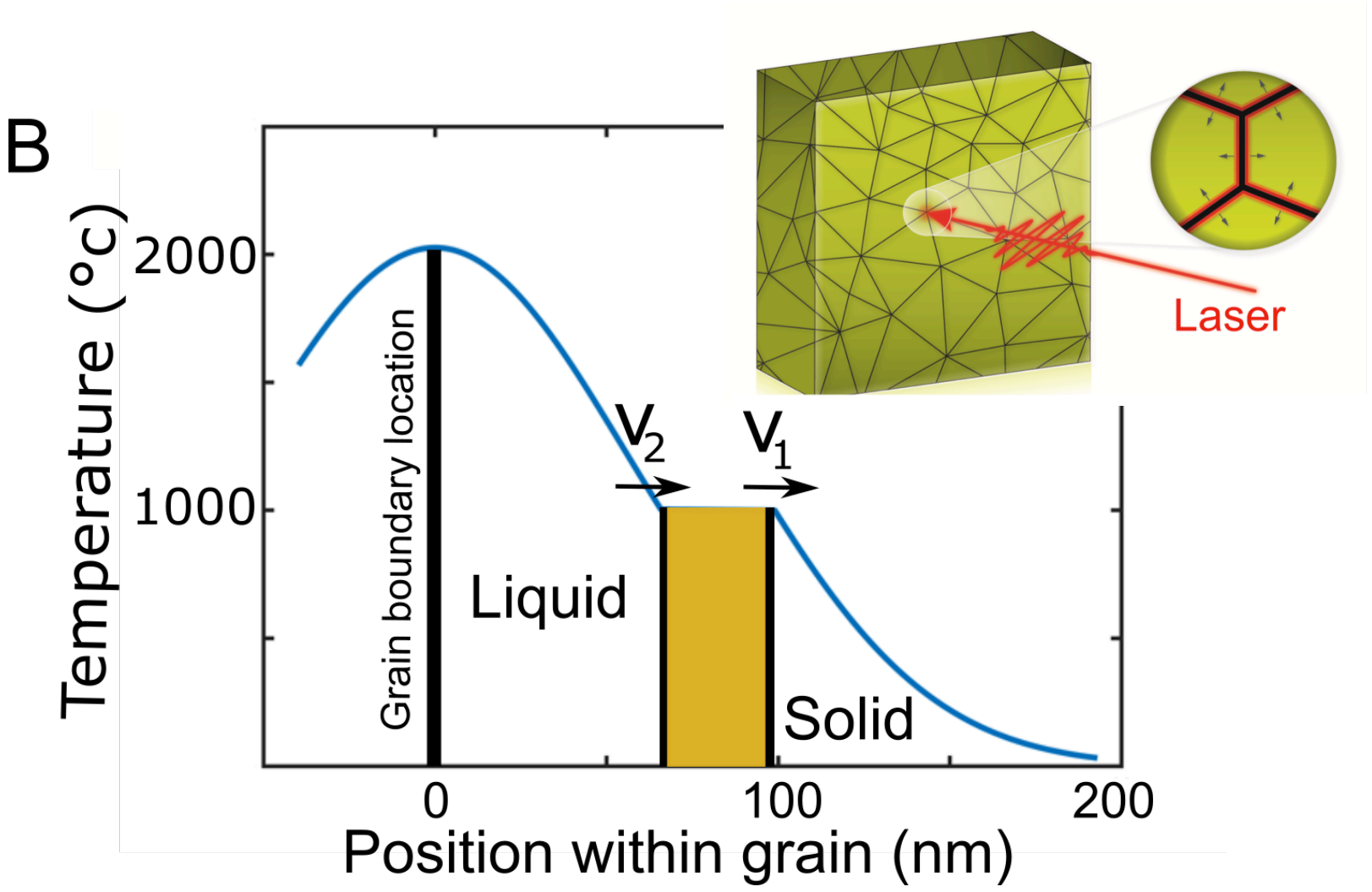
2TM-MD (EAM) simulation Au slab

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

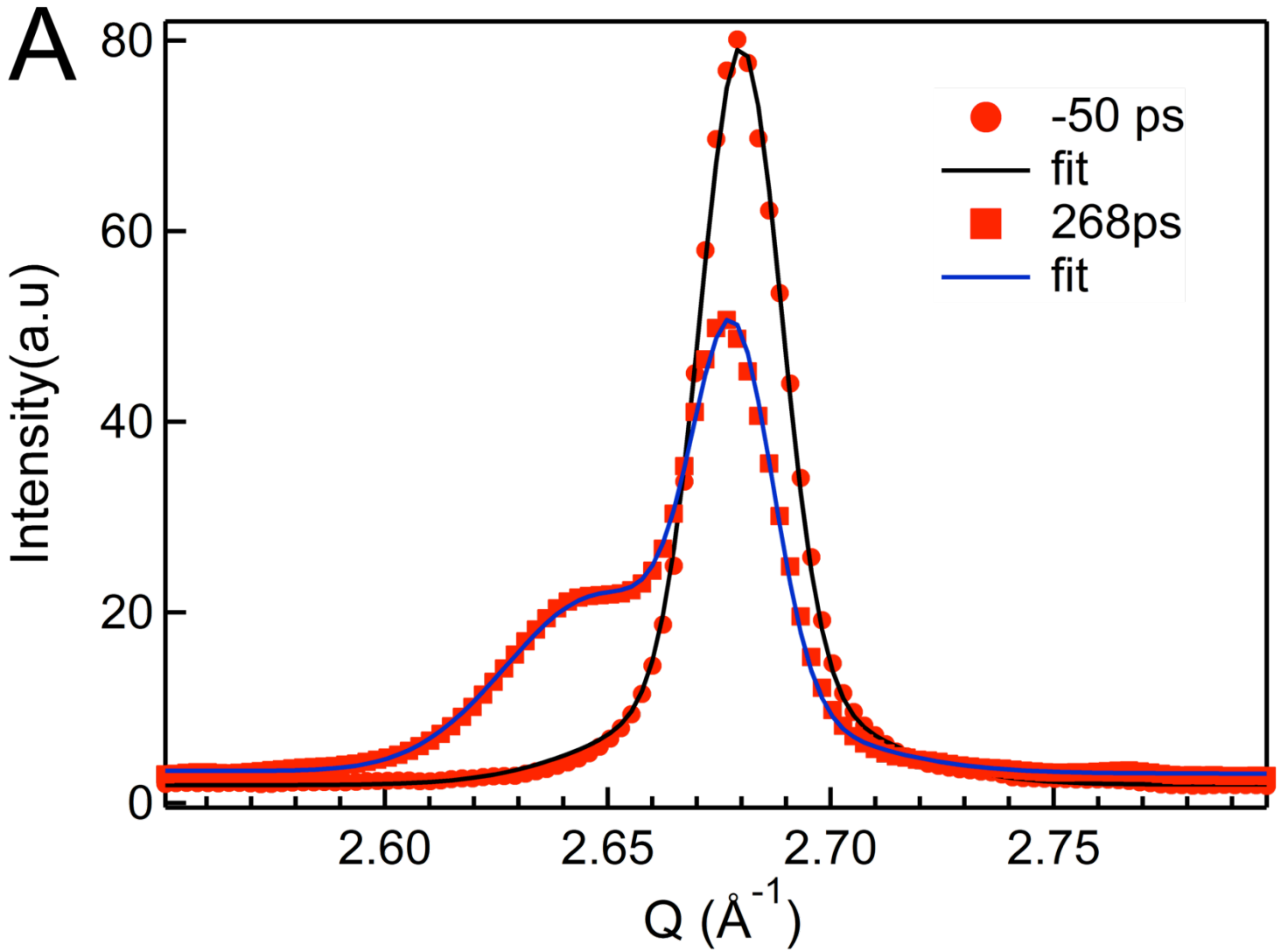


Double Melt-Front Picture

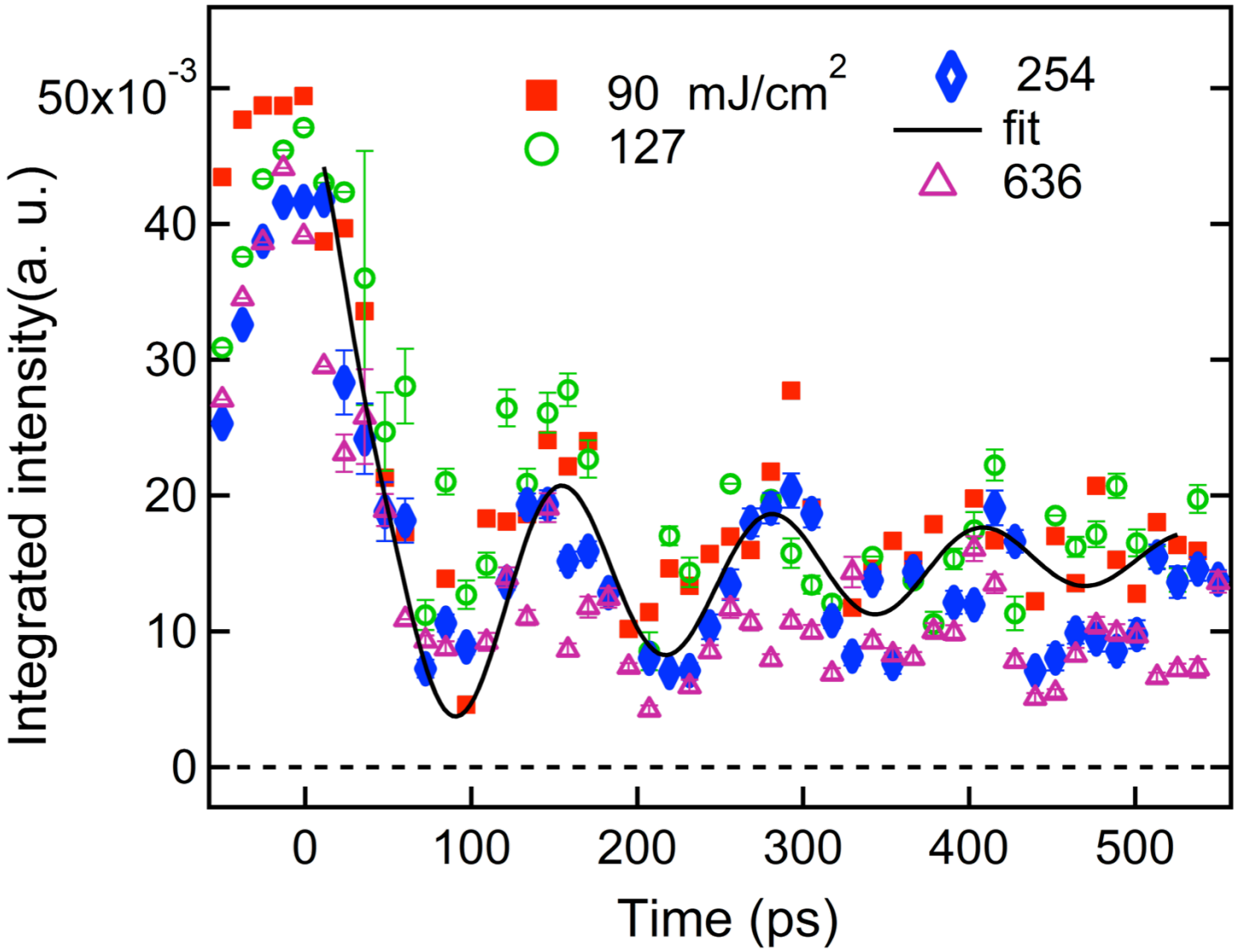
T. Assefa et al, Science Advances (2019)



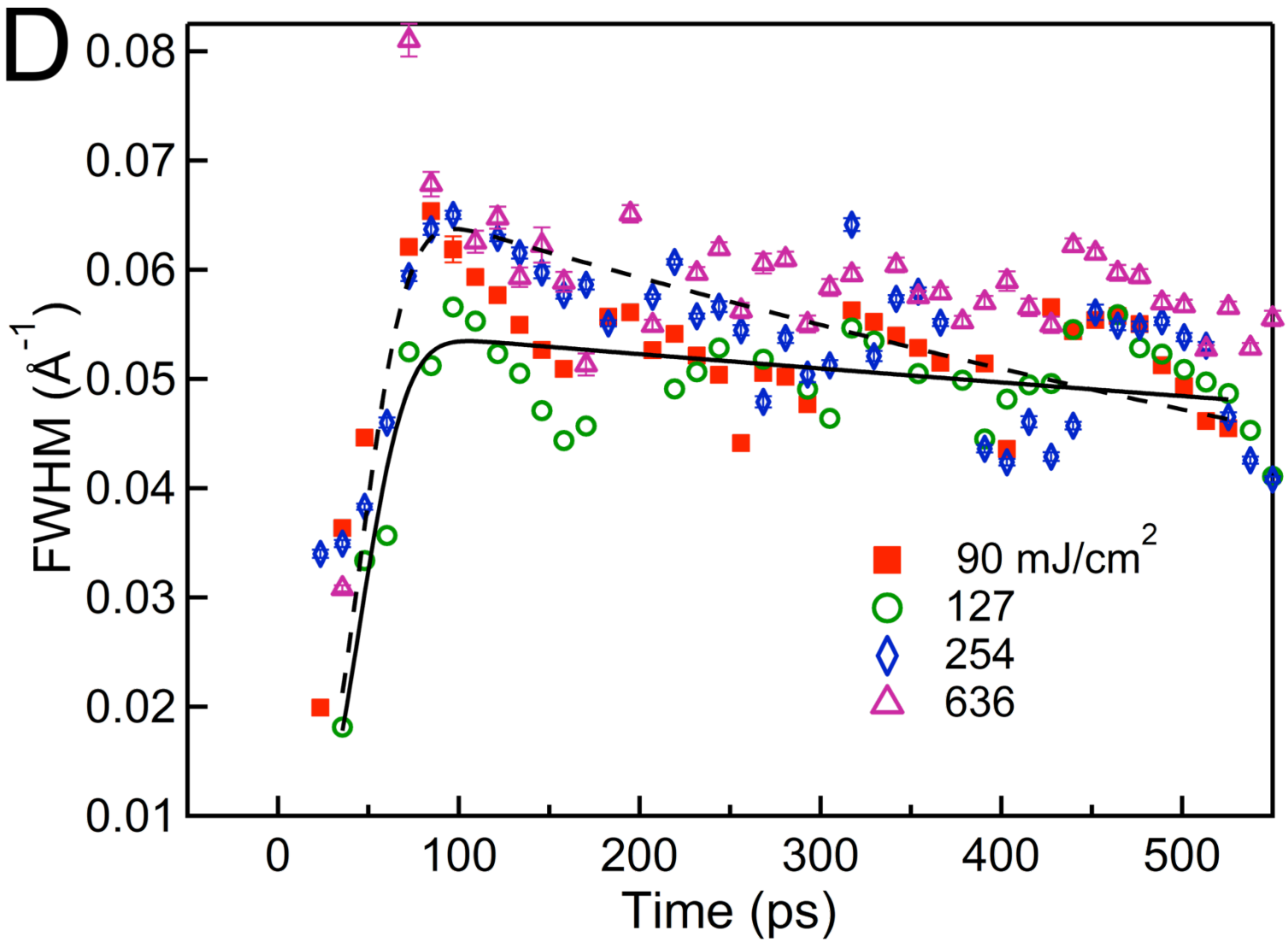
Deconvolution of Peaks

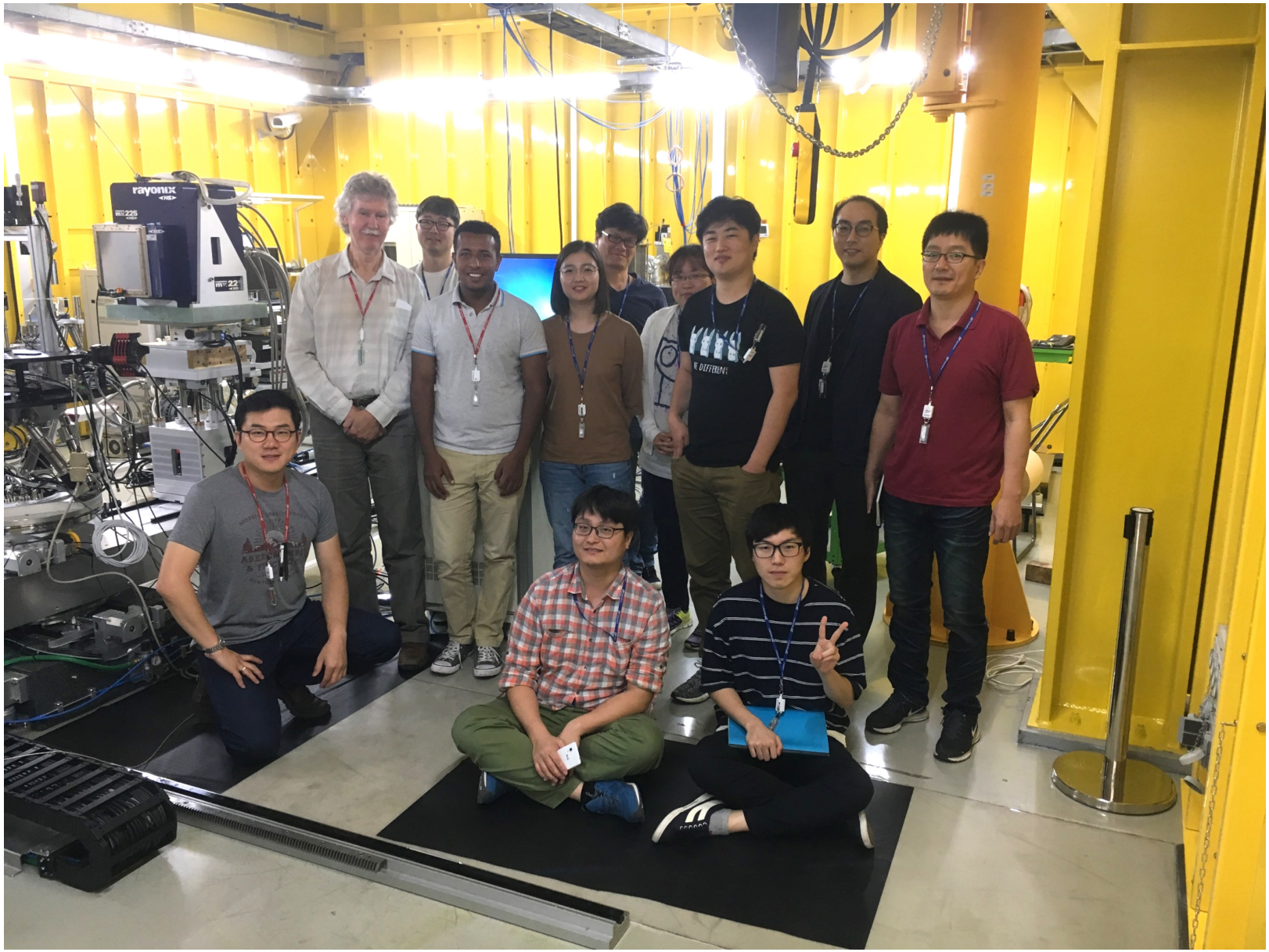


PP kinetics of Crystal Peak



Width of Melt-Front Peak




rayonix

Laser machining: what happens with ultrafast lasers?

- Ultrafast lasers better for machining
- Pump-probe approach to excitations
- Sample scanner for destructive pump
- Melt-front picture of Ultrafast melting

T. Assefa et al, Science Advances (2019)

Acknowledgements

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