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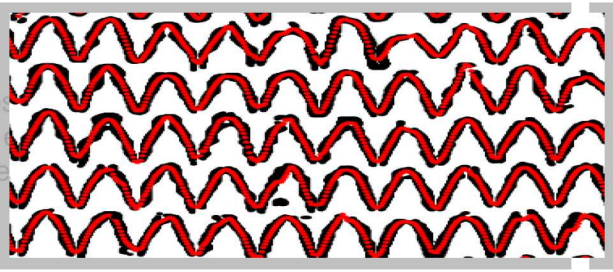

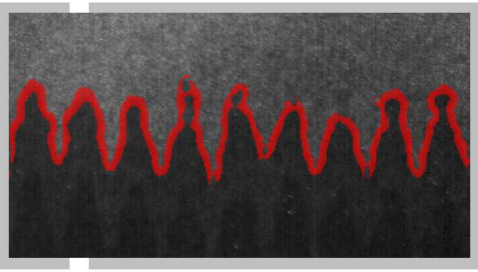

Perturbation Decay Experiments on Granular Materials

Tracy Vogler and Marcia Cooper

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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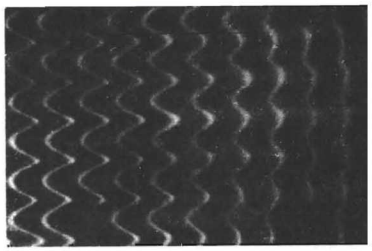
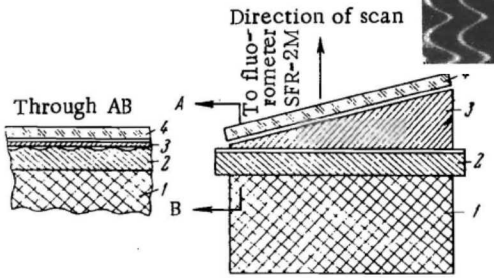
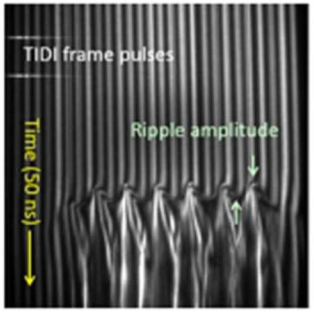
Measuring shock perturbation evolution

Soviets (1960's).
- solids, liquids

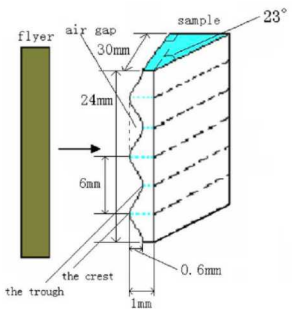




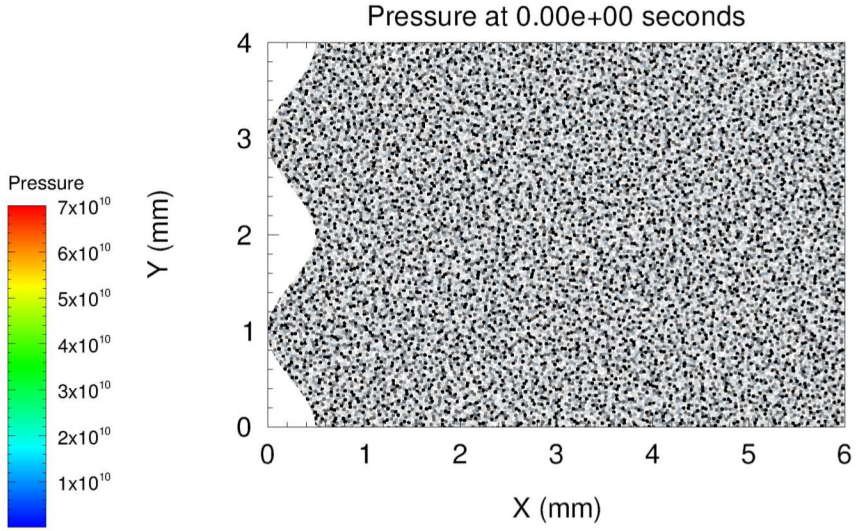
Opie et al. (2017)
- ASU/LANL
- laser-driven
- solids



Chinese - Ma, X., F. Liu and others (2009-2018)
- solids

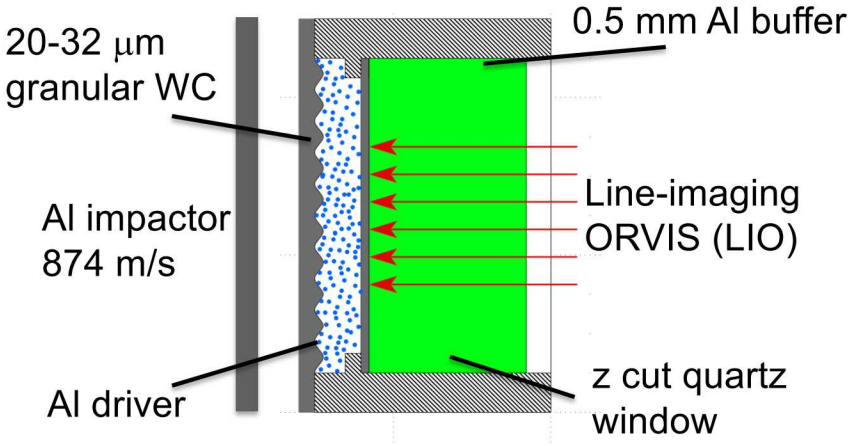


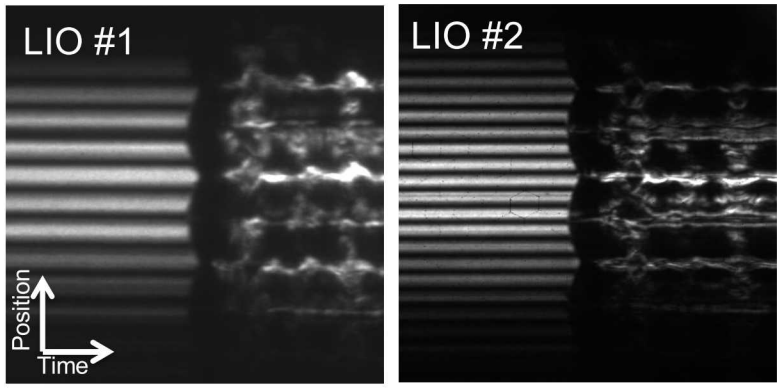
Vogler (2015) applied technique to powders



JDBM vol 1, n. 4, 370-387, (2015)

Initial experiments conducted in a planar geometry

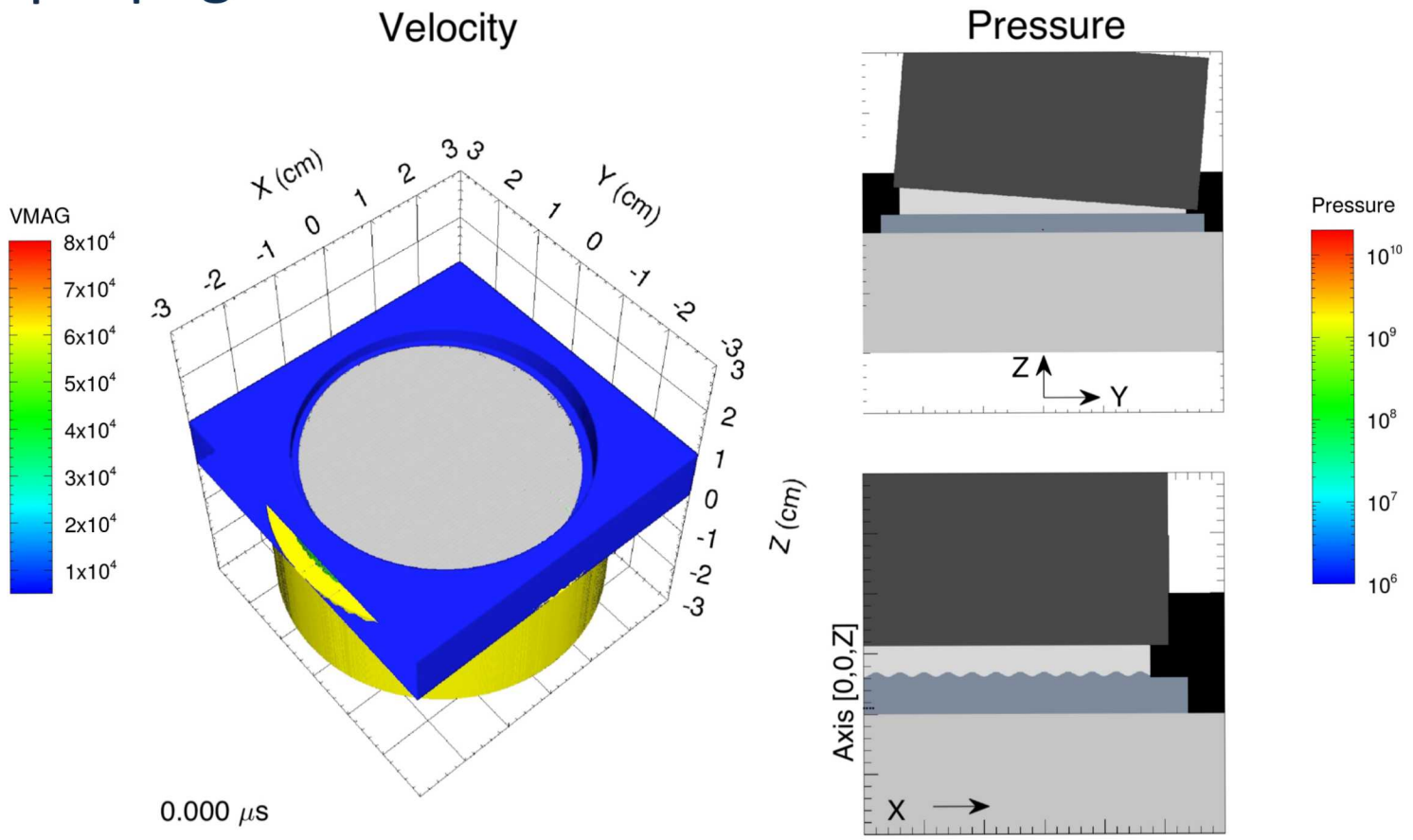




- Planar targets will require **large number of tests** to populate perturbation decay plot
- New tests employ wedge geometry and 2D imaging at high speed

M. Cooper, Appl. Opt. **53**, F21-F30 (2014)

Wedge sample to observe decay with propagation distance



WC, Ta, and their mixtures studied

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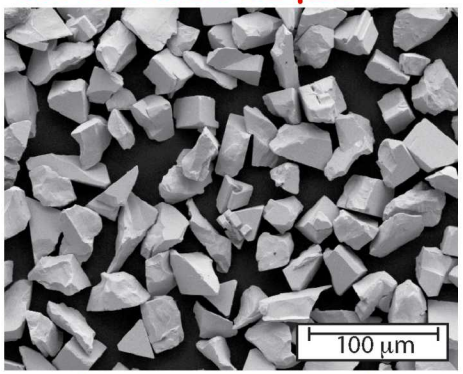
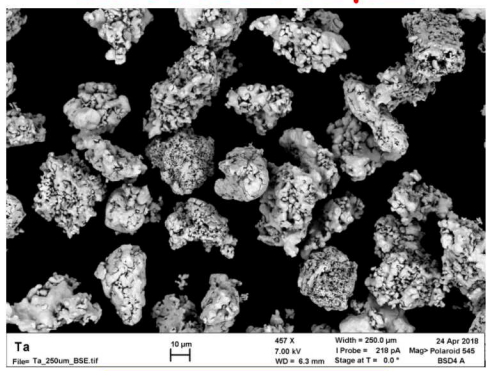
Tungsten Carbide, WC
sieved to 20-32 μm



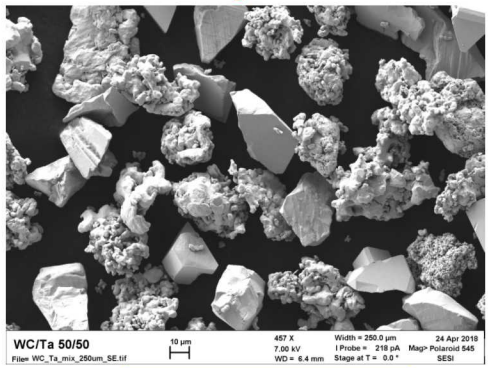
ρ_{oo} = 8.8 g/cm^3
v_f = 56%

Tantalum, Ta
sieved to 20-32 μm



ρ_{oo} = 7.1 g/cm^3
v_f = 44%

50/50 mix of WC and Ta by mass



ρ_{oo} = 5.4 g/cm^3
v_f = 33%

Shock propagation and perturbation decay observed in experiments

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Target Wavy B-13

Tungsten Carbide / Tantalum

Impact Velocity: 0.88 km/s

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Automated process to extract results from images

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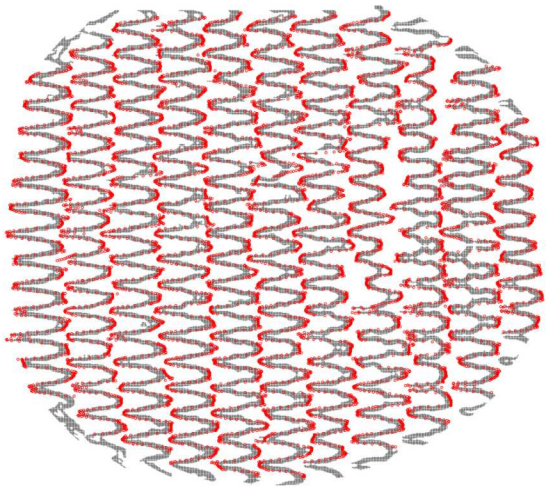
Image Processing to find Edges (gray)
- 2D low pass filter
- Threshold on gradient magnitude

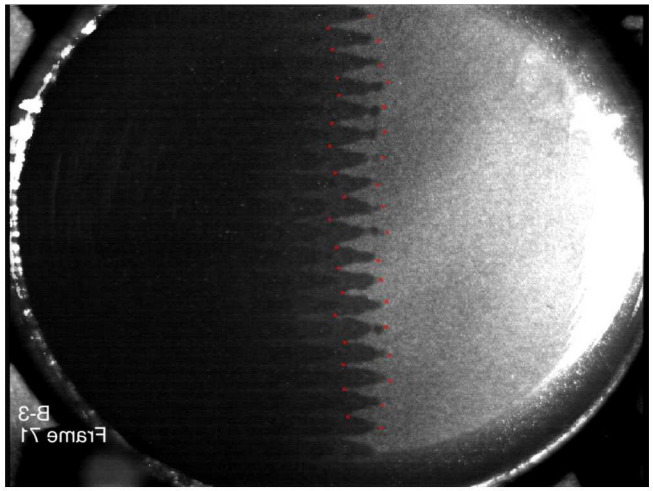
Calculate continuous edge (red)
- Rolling window sinusoid fit to ¼ period

Extract peak and trough pixel location

Convert to spatial dimensions with image scale
- Edge pixels relative to center pixel of target

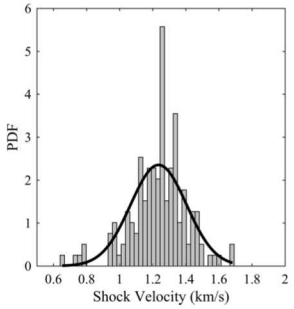
Calculate perturbation time scale from target geometry



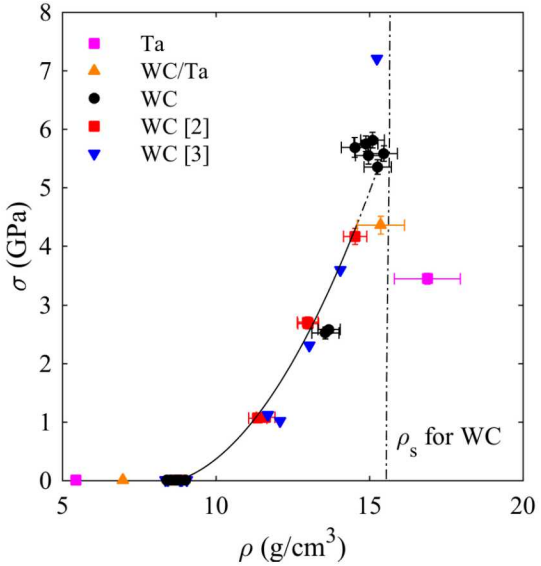


TOE → TIME → HEEL

New data for granular WC consistent with established Hugoniot



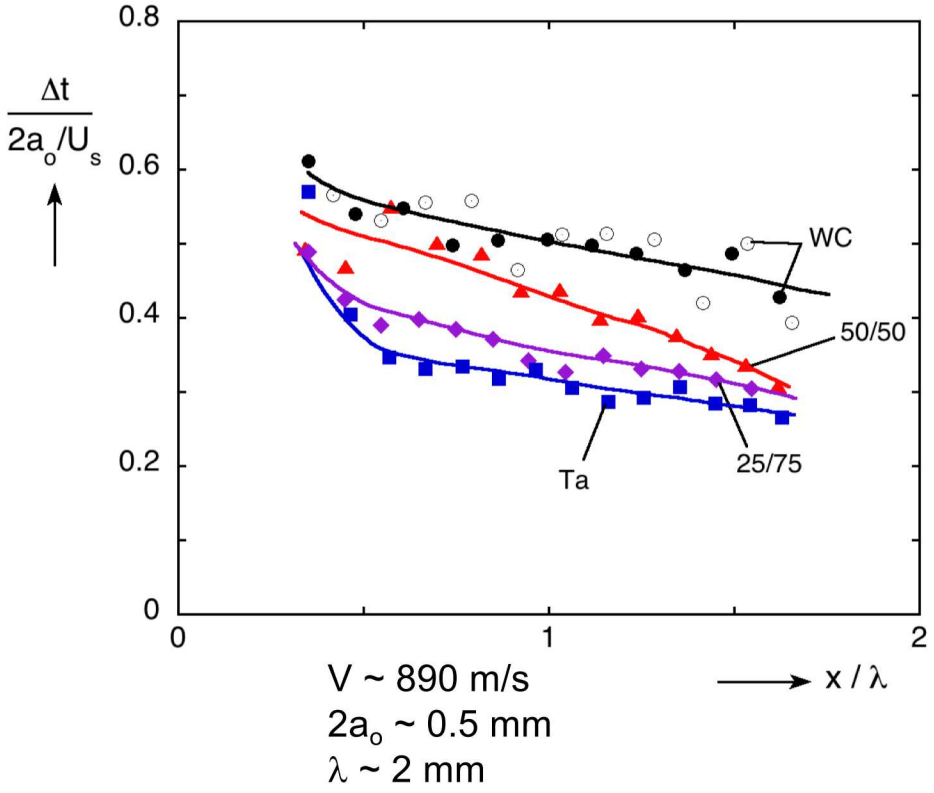
- Change in position of peaks and valleys between each frame provides large number of velocity measurements – use uncertainty on mean for U_s
- Results at 500 m/s and 900 m/s impacts consistent with previous data



- Scatter in data consistent with uncertainty estimates
- Ta response softer; 50/50 mix intermediate

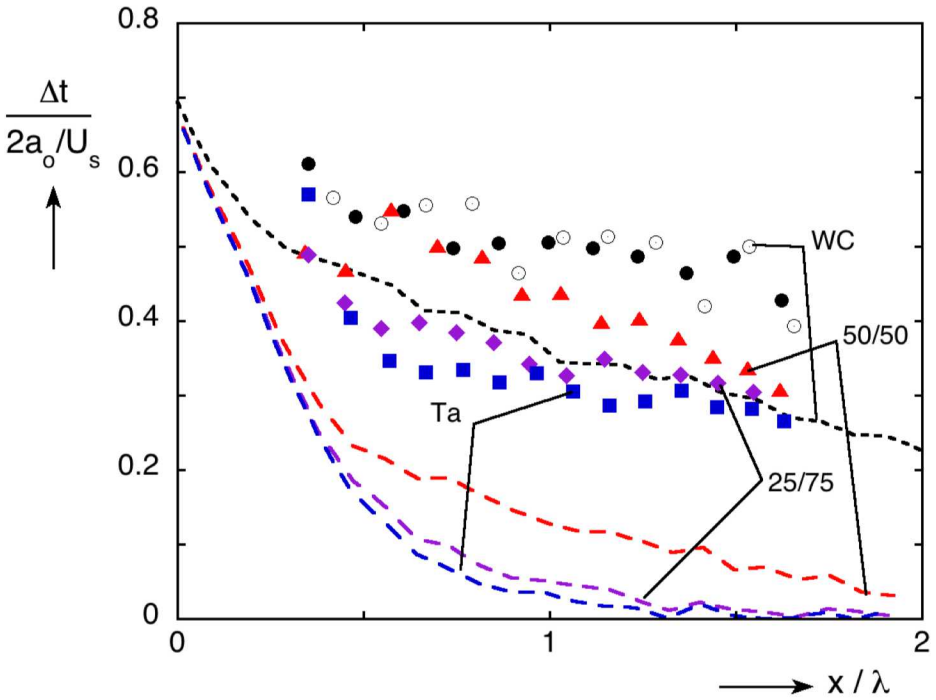
Results for the WC/Ta system

- Gradual decay over region measured; decay greater initially
- 25% WC / 75% Ta results close to pure Ta
- 50/50 mix starts closer to WC but trends toward Ta

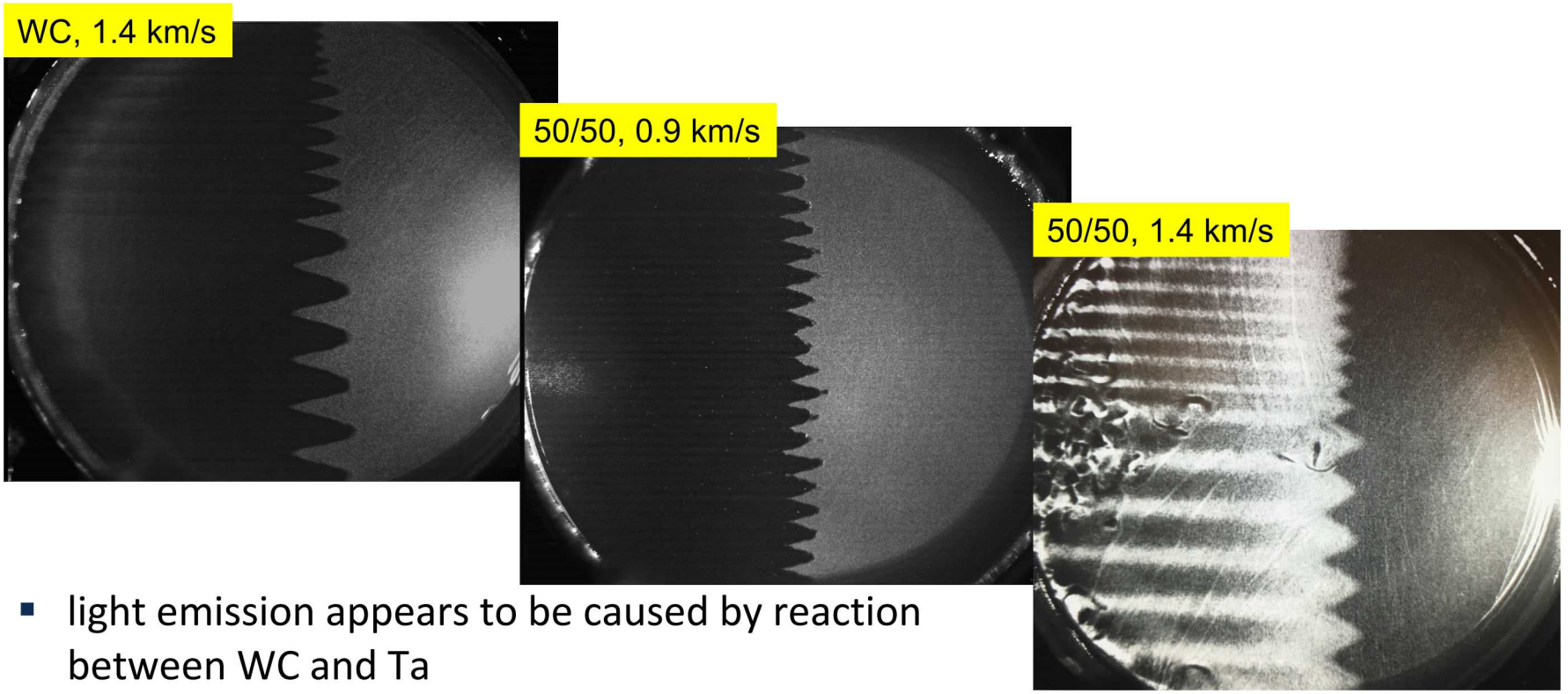


Comparison to mesoscale simulations

- Overall, poor agreement – reason unclear
- Consistent trend of increased attenuation as Ta content increases
- 25 WC/75 Ta close to Ta in both cases
- 50/50 attenuates more rapidly in mesoscale
- Strength used for Ta may be too low



Unexpected phenomena at higher velocity



- light emission appears to be caused by reaction between WC and Ta
- critical shock pressure needed to initiate reaction
- effect on response not known

Conclusions

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- Wedge geometry with high speed imaging to observe perturbation decay through loss of reflectivity
- Approach provides good shock data – may be viable approach
- Mixtures of WC and Ta show greater decay as Ta content increases
- Future / related work:
  - multi-λ driver
  - additional continuum and mesoscale modeling
  - imaging with x-rays and protons; RMI configuration
  - understand WC/Ta reaction

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Extra Slides

High speed imaging of reflectivity loss

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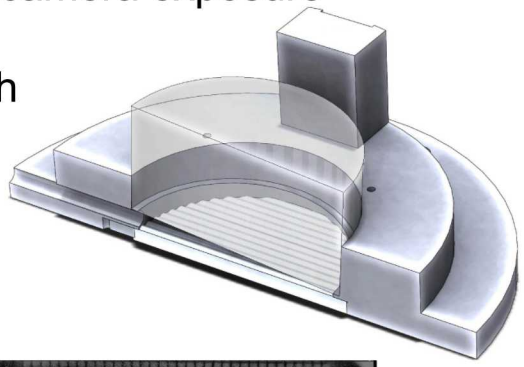
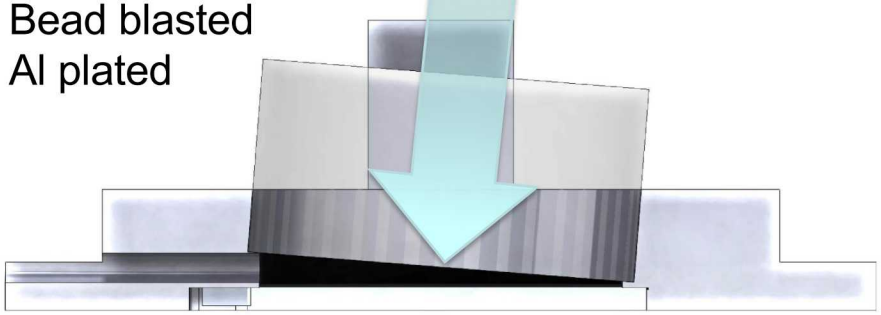
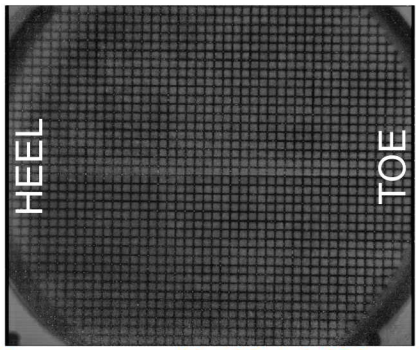
Kirana camera
5 MHz
200 ns exposure

SILUX 640 laser illumination
synchronized to camera exposure
10 ns delay
40 ns pulse width



Surface preparation
Bead blasted
Al plated





Grid frequency = 20.432 ± 0.026 px/mm