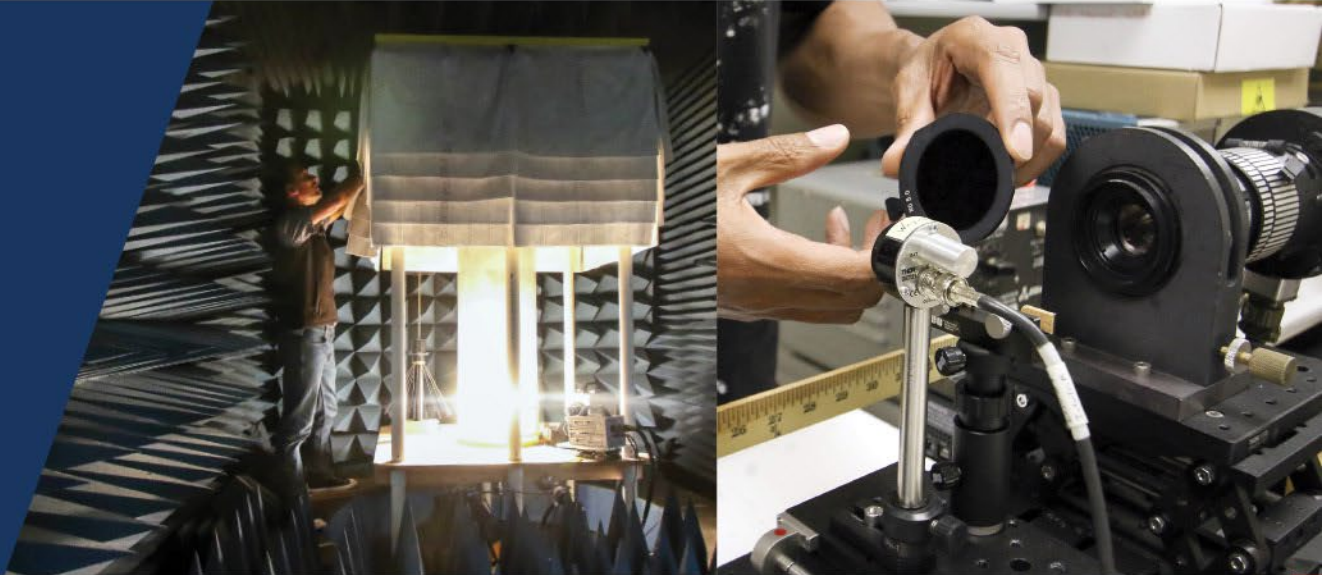


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Sintered tungsten carbide and martensitic stainless steel as new materials for Asay foils

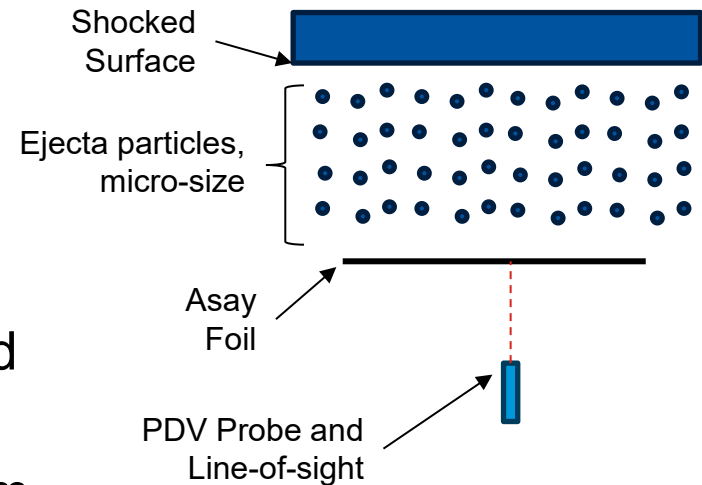
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- Louie Chacon (LANL)

What are Asay Foils?

- ▶ A diagnostic to measure the mass of material ejected from shocked metal surfaces.
- ▶ First used by Jim Asay in 1976*.
- ▶ A thin metal foil is mounted in front of the surface.
- ▶ Ejected particles (ejecta) hit the foil and accelerate it.
- ▶ By measuring the motion of the foil from the back side with PDV, the mass of the ejecta can be inferred.



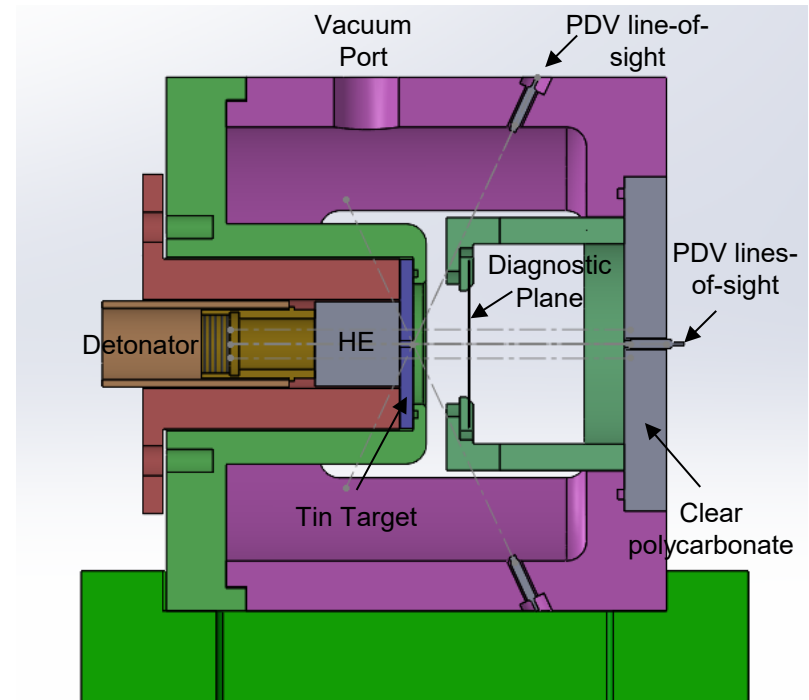
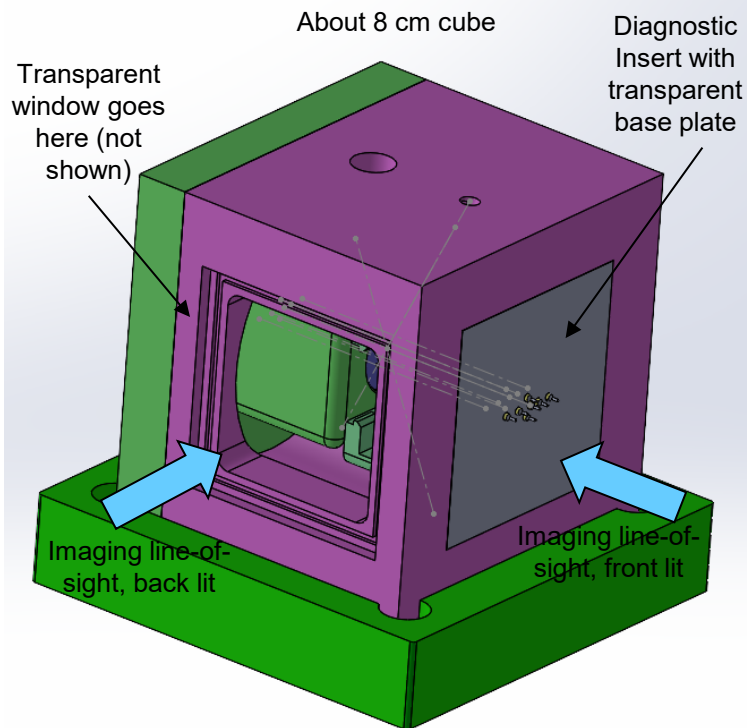
* Asay et al., Ejection of material from shocked surfaces, *Appl. Phys. Lett.* 29, 284–287 (1976)

We performed several experiments to validate different foil materials.

- ▶ We tested two never-before-tested, high-strength foil materials: Martensitic SS, Sintered Tungsten Carbide
- ▶ And three legacy materials: Titanium Alloy, Tantalum, and Austenitic SS.
- ▶ To test the diagnostics, we used a tin target driven by high explosive. Our general experimental setup is explained on the next two slides.
- ▶ We imaged the back of the foil material to observe evidence of punch-through.
- ▶ **Bottom line up front:** Martensitic stainless steel and sintered micro-grain tungsten carbide work well as Asay foils.

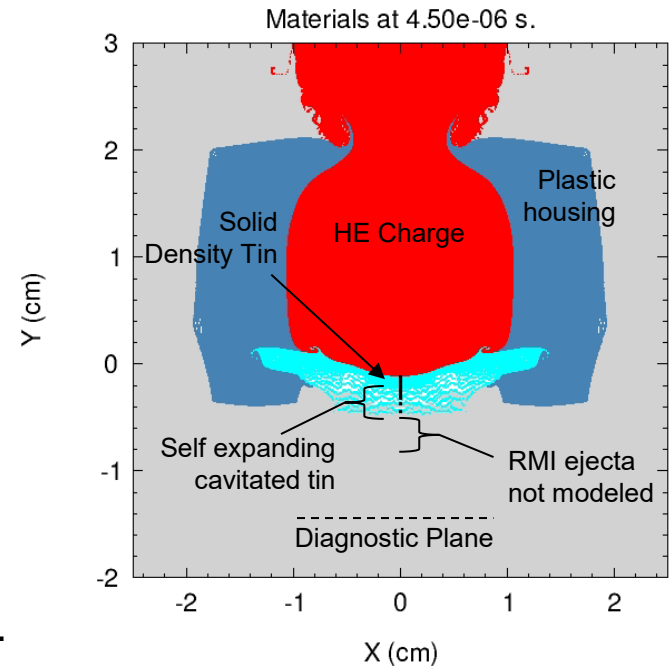
We designed a miniature chamber for these validation tests

- High explosive charge drives a shock wave through a tin target.
- The tin target is 2 mm thick and grooved on front side.
- The foil is placed 7 mm from the tin target.
- Chamber evacuated, roughly 0.1 mBar.

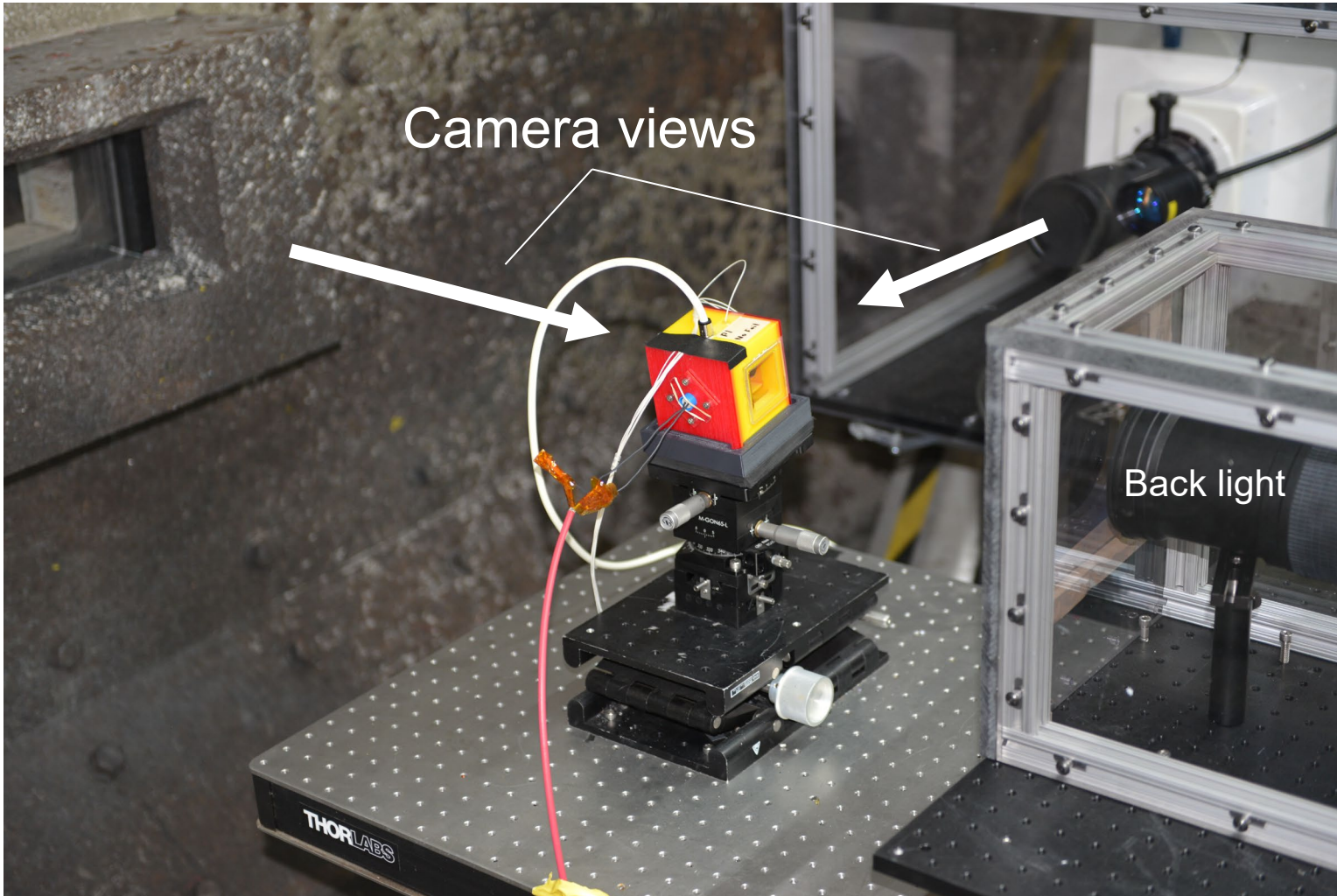


We throw RMI ejecta & cavitated tin at the diagnostic under test

- With a small charge of HE, we send a high-pressure wave through a tin target.
 - Relatively fast and light RMI ejecta is produced.
 - The front several hundred microns of tin cavitates (micro-spalls) and expands.
- The fastest RMI ejecta is >3000 m/s. The total mass of RMI ejecta is roughly 5 mg/cm².
- The fastest cavitated tin is ~ 2000 m/s. The total mass of the cavitated tin is hundreds of mg/cm².
- The ejecta and cavitated metal arrive at the diagnostic plane over roughly 4 microseconds. The pressure on the diagnostics is MPa during the arrival of the RMI ejecta, and GPa during the arrival of the cavitated tin.



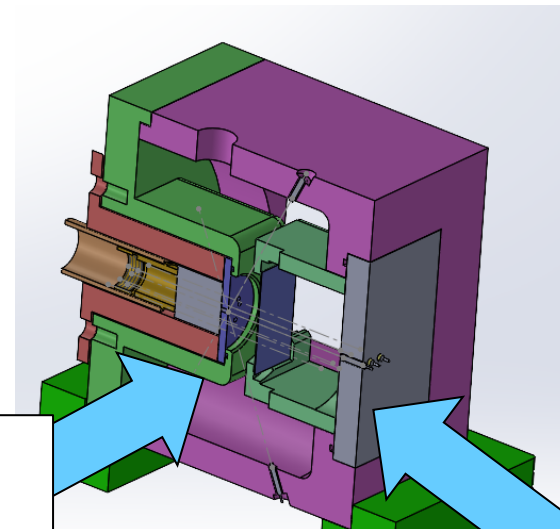
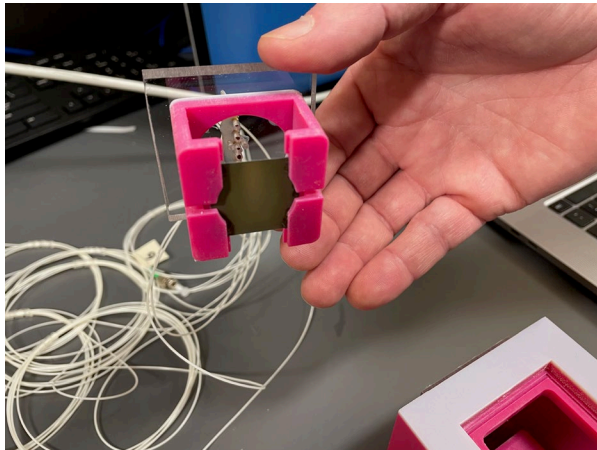
Device on test stand



We tested the performance of five foil materials and a buffered LiF window

- **440C martensitic stainless steel**, quenched & tempered, electrical-discharge machined*, 0.2 mm thick.
- **Ultra-fine grain sintered tungsten carbide**, electrical-discharge machined*, 0.2 mm thick.
- **Titanium 6Al 4V**, annealed, 0.2 mm thick.
- **Tantalum**, annealed, 0.2 mm thick.
- **302 austenitic stainless steel**, not annealed, 0.2 mm thick.
- **Lithium Fluoride Window**, with 0.5 mm Aluminum Buffer.

*The EDM will locally affect the material.

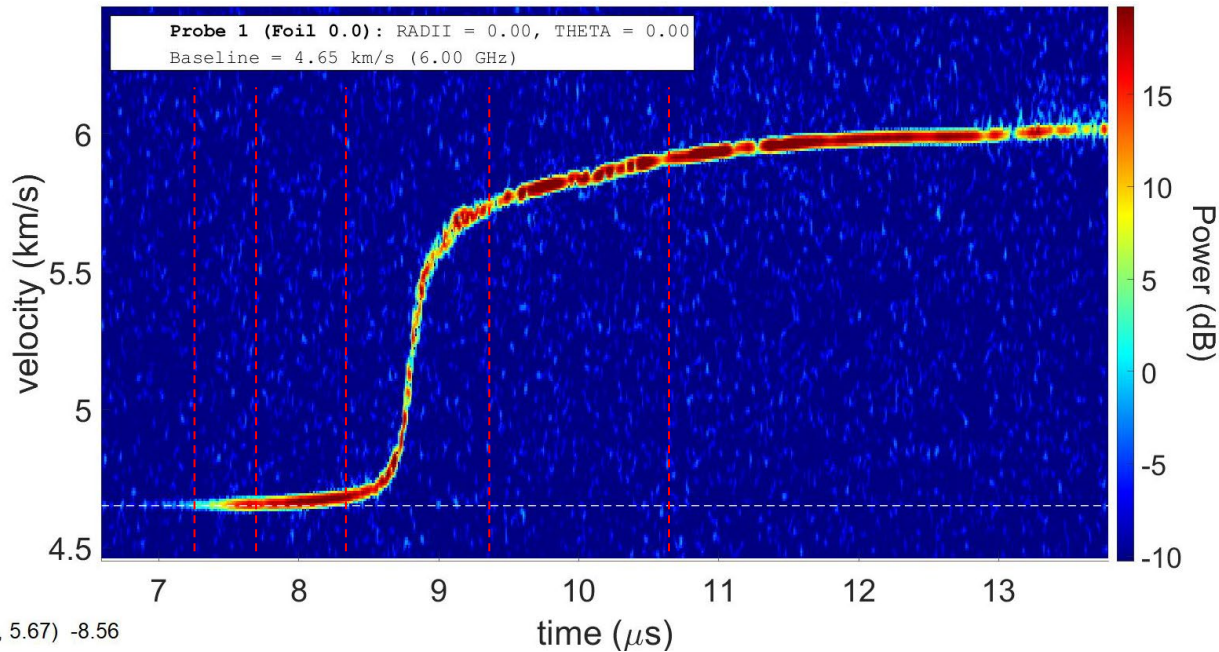
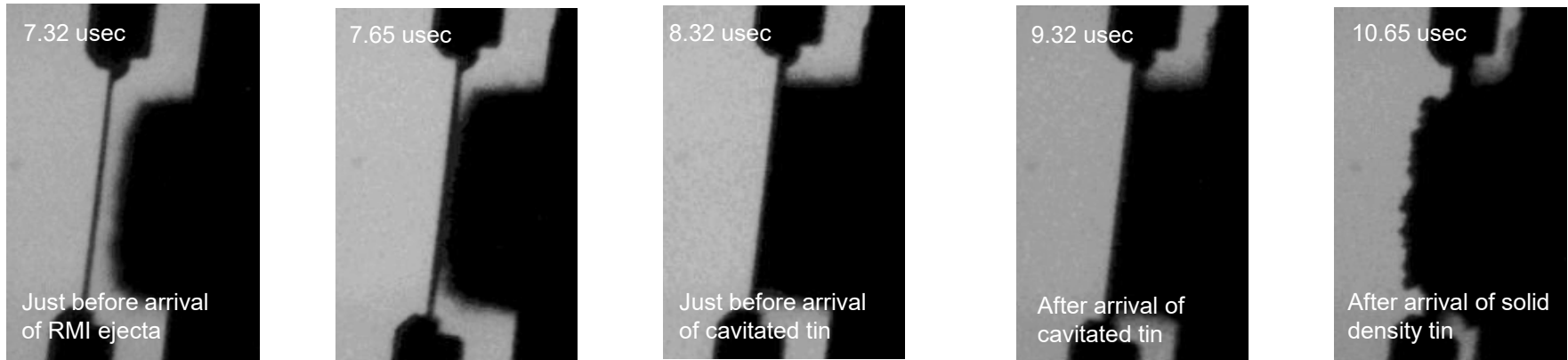


Camera looking perpendicular to flow of ejecta

Camera looking at back of foil

Results from 440C test

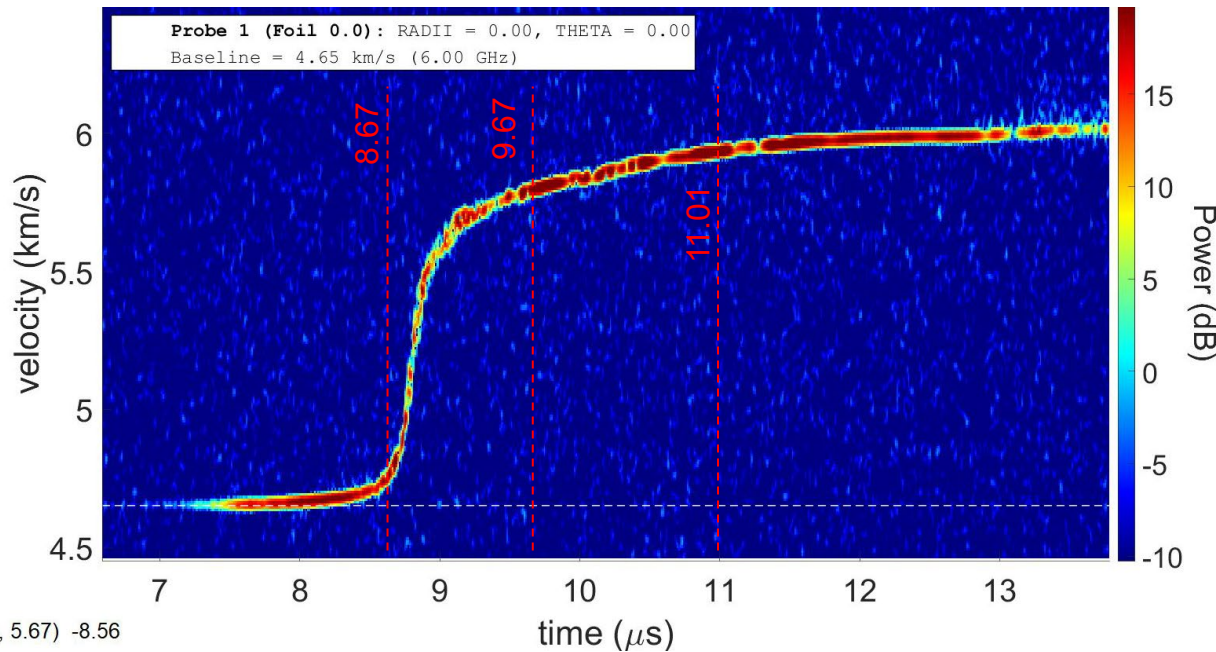
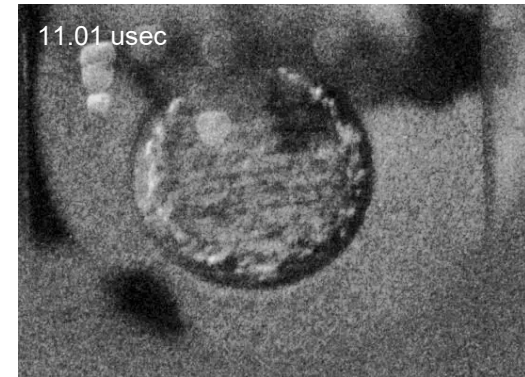
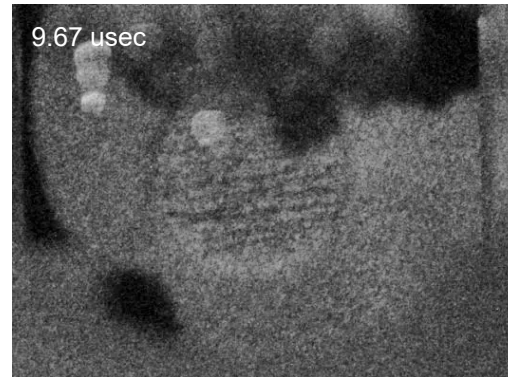
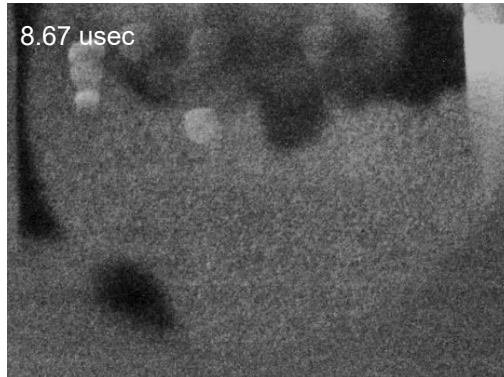
Side view of foil



The rapid acceleration at about 8.7 μ sec is very close to our expectation of the arrival of the cavitating tin. Corresponds to several GPa of pressure.

Results from 440C test, cont.

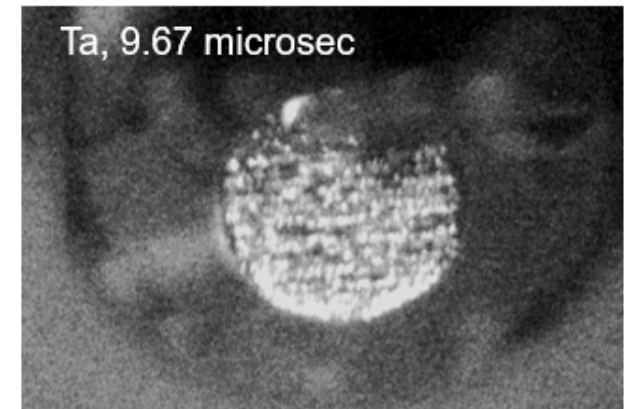
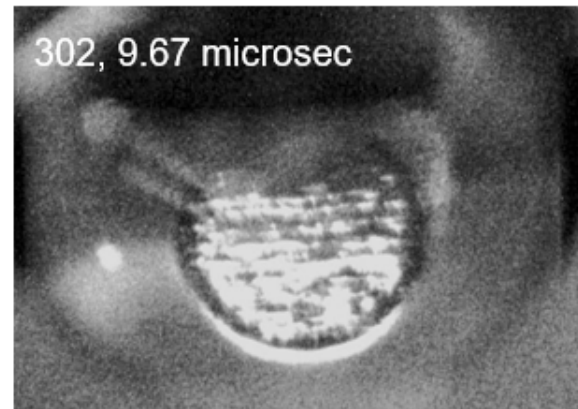
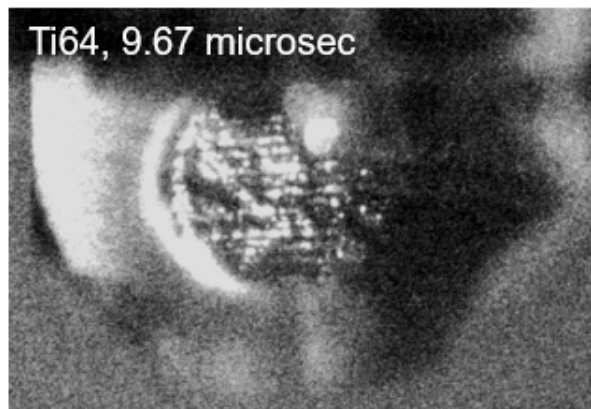
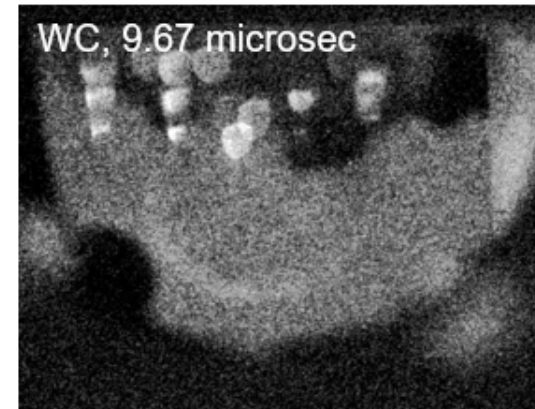
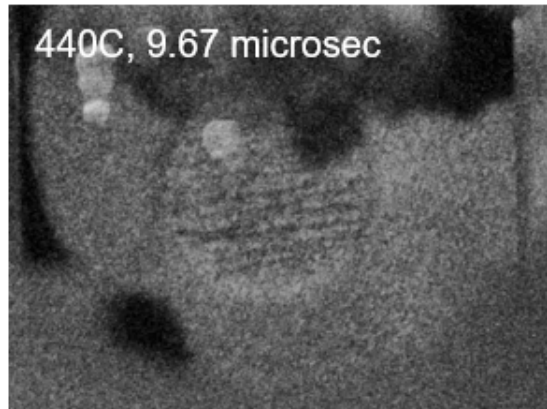
View of back of the foil



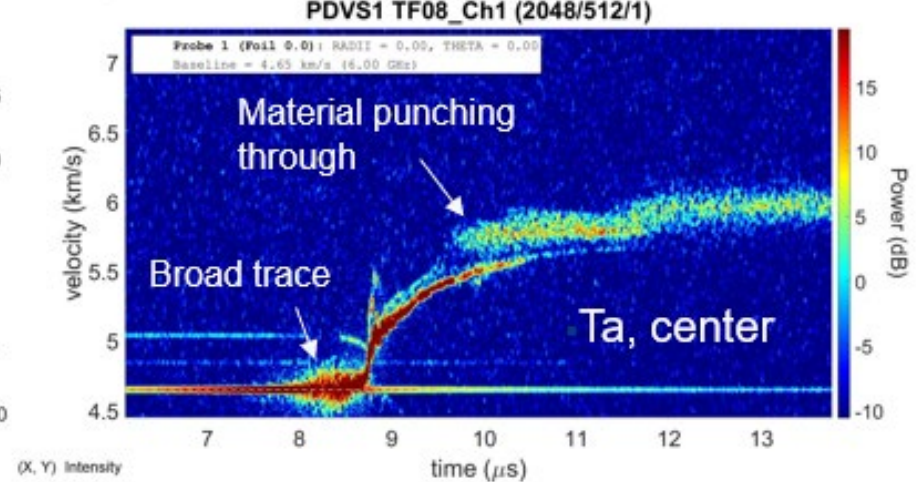
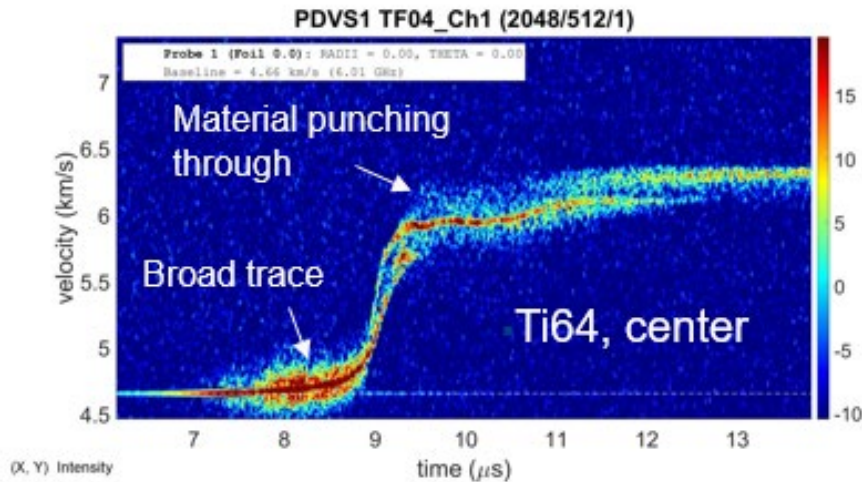
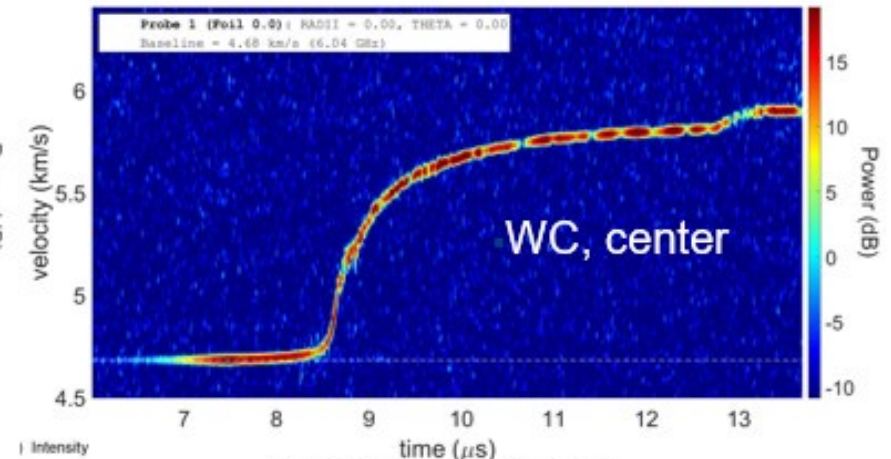
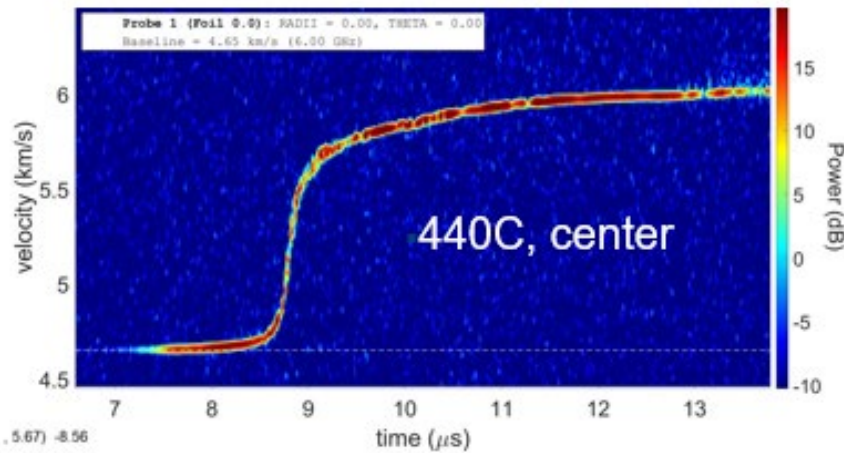
At 9.67 μsec , about 1 μsec after the arrival of the cavitating tin, we see the first signs of dimpling on the back of the foil. The view of the back of the foil at 9.67 μsec is telling of the performance of all the foils. Even through there is significant shearing force at the periphery of the loading area, the foil has not yet sheared-through at 11 μsec .

Performance of the foils after the arrival of the cavitating tin at 9.67 μs

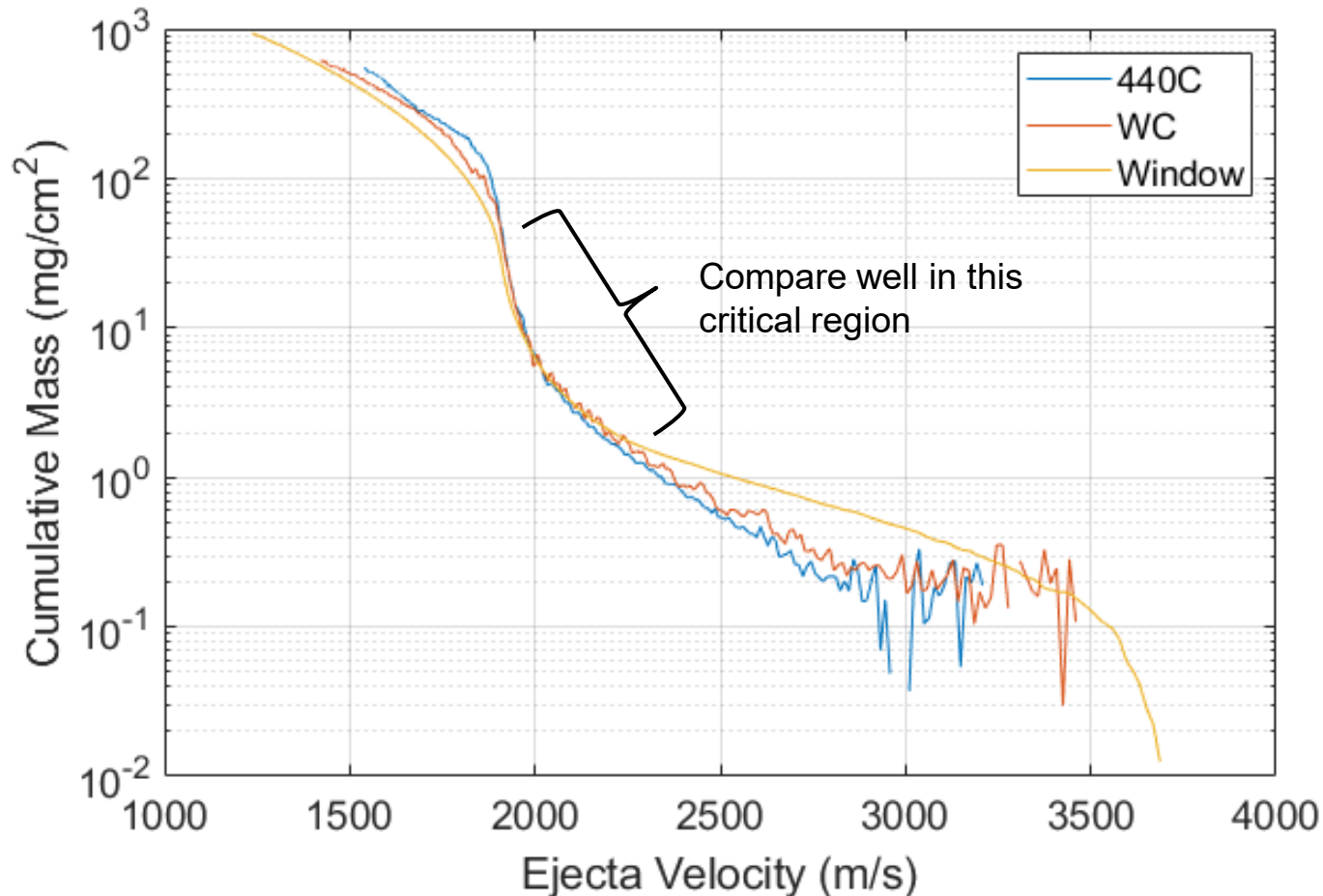
- The 440C and WC foils resisted punch through better than legacy foil materials.



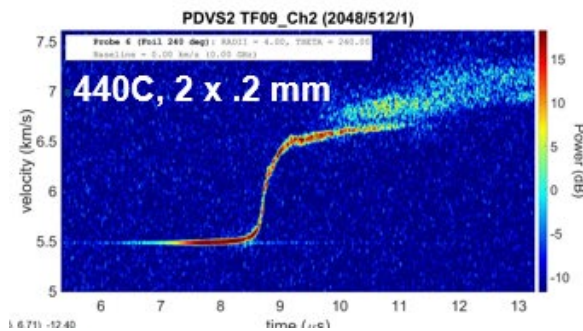
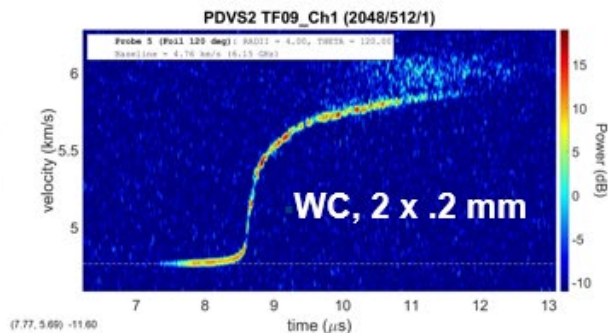
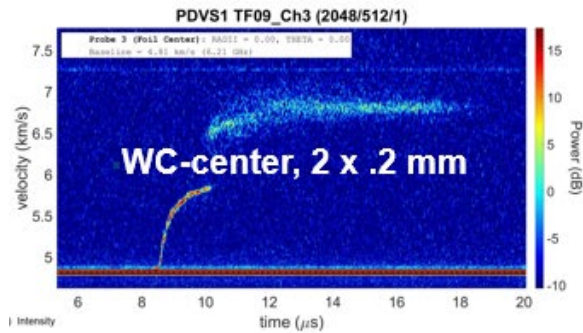
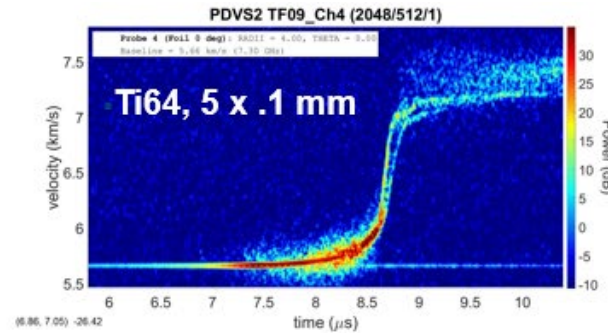
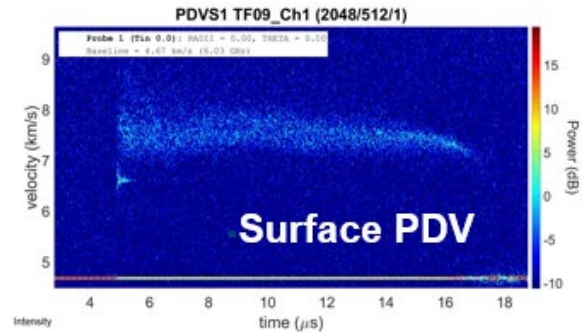
The 440C and WC foils had qualitatively better spectrograms



The measurement of cumulative mass with the 440C and WC foils compared well with the results from a large LiF window.



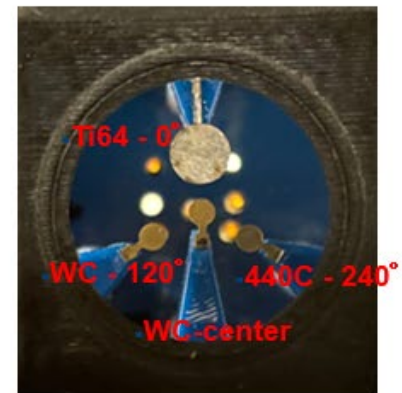
The 440C and WC materials work well as micro-foils.



- The traces do not last as long as with the large foils.

- If the foils are not breaking up, is ejecta wrapping around the foil to limit their length? From previous tests with high-speed imaging, after impact with the foil, the ejecta will tend to move laterally.

- The Ti foil has multiple traces when cavitation arrives and is likely breaking up as expected from the large foil tests.



- ▶ Under the loading conditions of our tests, 440C and WC worked better than legacy materials.
- ▶ Foils can be used to measure the mass in regions of micro-spall or cavitation, where the load on the foil is several GPa. We have not tested under Shallow Bubble Collapse* conditions.
- ▶ WC is denser, stronger, and retains much of its strength at high temperatures (the ejecta impacts create significant heat).
- ▶ But WC is more brittle and could fail catastrophically under high shear loading.

* Maskaly, Stevens, et al., **Non-Richtmyer–Meshkov instability ejecta production based on shallow bubble collapse**, *J. Appl. Phys.* 133, 025901 (2023).