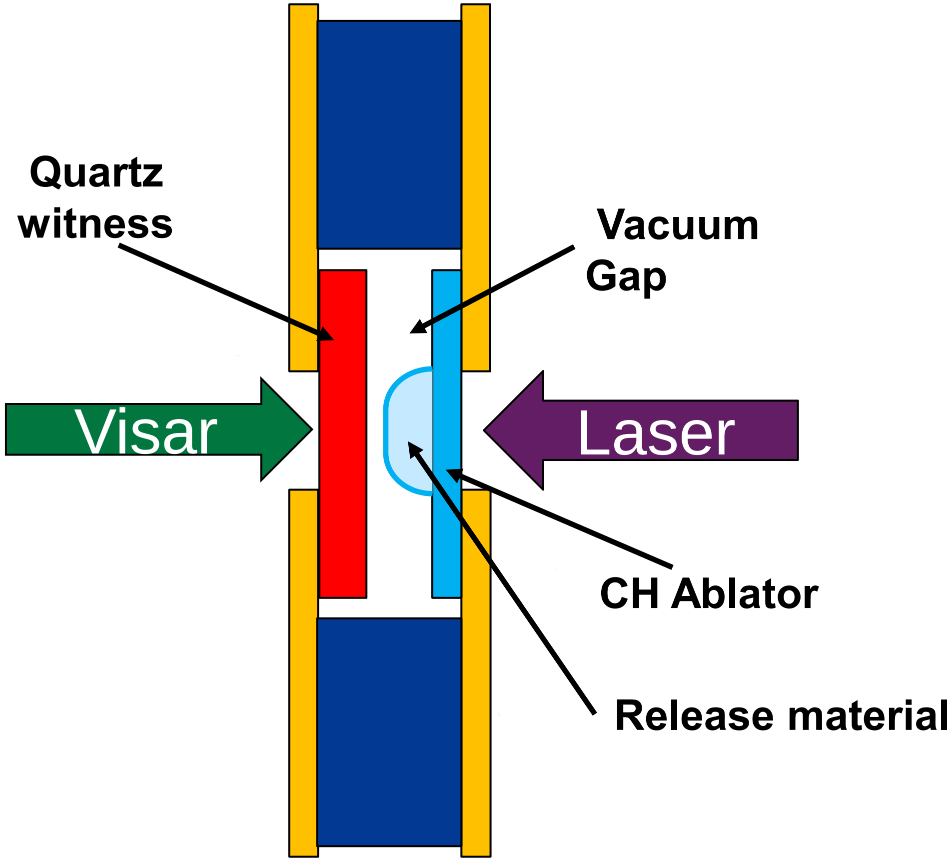
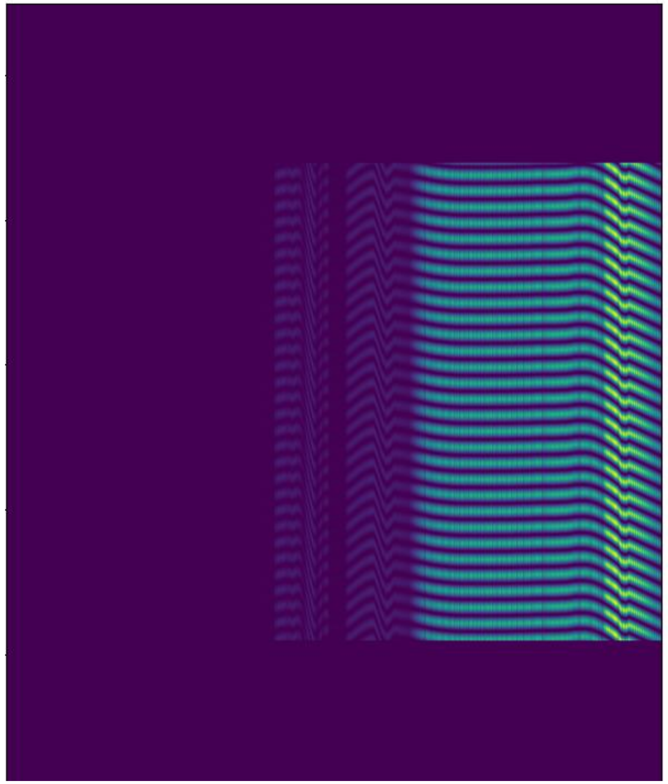
Understanding shock release experiments using a numerical simulation of VISAR



Synthetic VISAR



University of Rochester
Laboratory for Laser Energetics

63rd Annual Meeting
American Physical Society
Division of Plasma Physics
Pittsburgh, PA
11/11/21

Synthetic VISAR can provide insight into experimental outcomes beyond the standard VISAR data analysis methods

- Forward simulations of the VISAR diagnostic provides synthetic data from simulations that can be directly compared to experimental images eliminating possible fringe shift ambiguities
- VISAR simulations can accurately reproduce phenomena such as sudden fringe jumps and blanking
- Understanding and predicting VISAR measurements is valuable to future experimental design

Simulating VISAR can help improve VISAR systems and HEDP experiments in the future

Collaborators

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Full wave transport* with correct dielectric properties** must be considered to model phase and intensity of the VISAR probe in the quartz witness***

- **Solving the Helmholtz equation for the electric field:**
  - $\Delta E_z - \nabla \cdot \nabla E_z + \frac{n^2\omega^2}{c^2} \mathrm{E_z} = 0$

- **For T<5000K $n = 1.5 + i\alpha_0 e^{-T_0/T}$ which is a curve fit of a result from ab initio DFT using GGA †**
  - **Temperature region responsible for preheat and blanking**

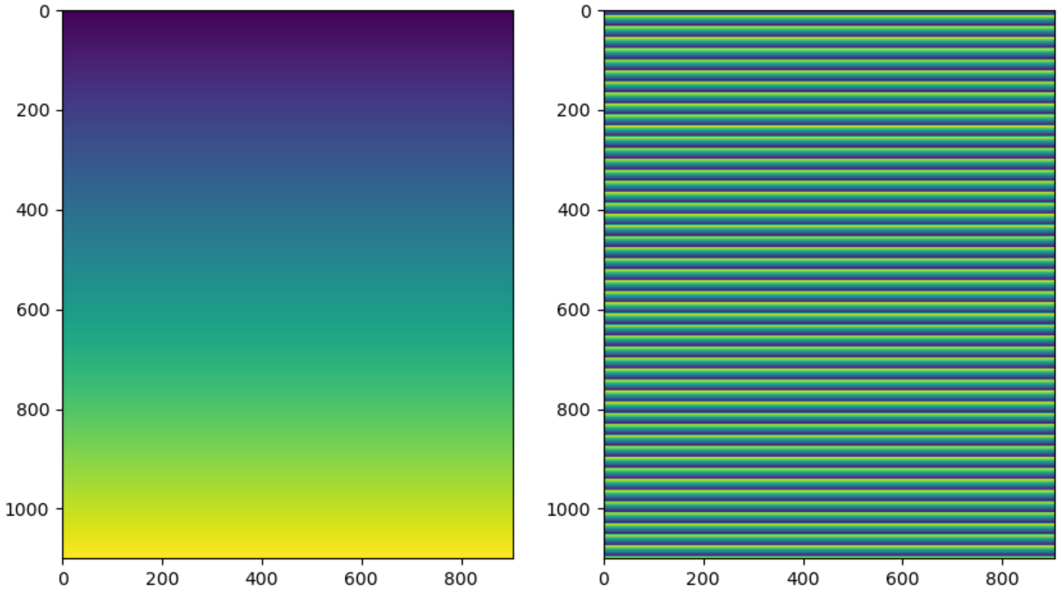
- **For T>5000K the index is modeled successfully with a Drude model as verified through experiment****

* Tingting Q. et al, Phys. Plasmas 22, 062706 (2015)
** D. G. Hicks et al, PRL 97, 025502 (2006)
***J. P. Perdew et al., Phys Rev B 54, 16533 (1996)
† S. Laffitte et al., Phys. Plasmas 21, 082705 (2014)

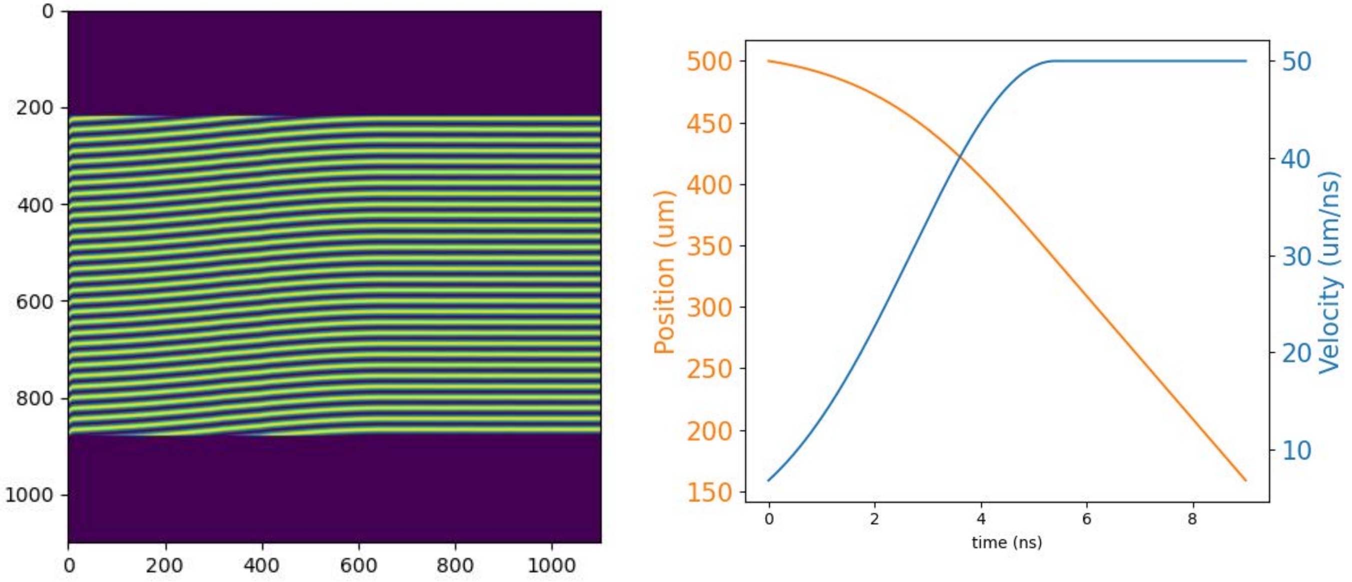
Total phase from the wave transport is sent through the synthetic VISAR optical path using the VISAR equation and added to the initial phase pattern

- **VISAR equation: $\frac{\lambda}{2} g(t) = z(t) - z(t - \tau) + \delta \frac{dz(t-\tau)}{dt} \tau$ where $g(t)$ is the is the fringe shift, τ is the etalon delay time, and δ is the etalon dispersion. Remember phase is related to z!**
- **The fringe shifts are then added to the reference phase and wrapped to 2π**
- **The amplitude from the wave transport is then applied to retrieve the signal strength**

Unwrapped and 2π wrapped reference phases



Synthetic VISAR for a perfect reflector

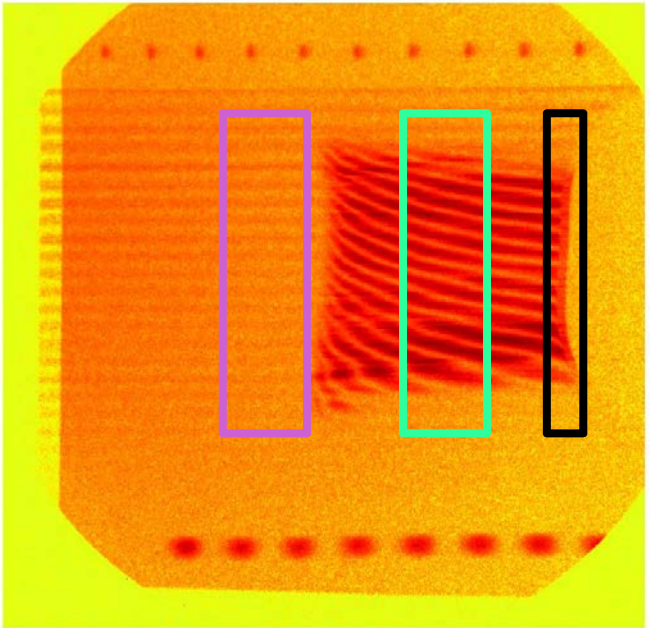


Synthetic VISAR shows a region of relative blanking similar to experiment

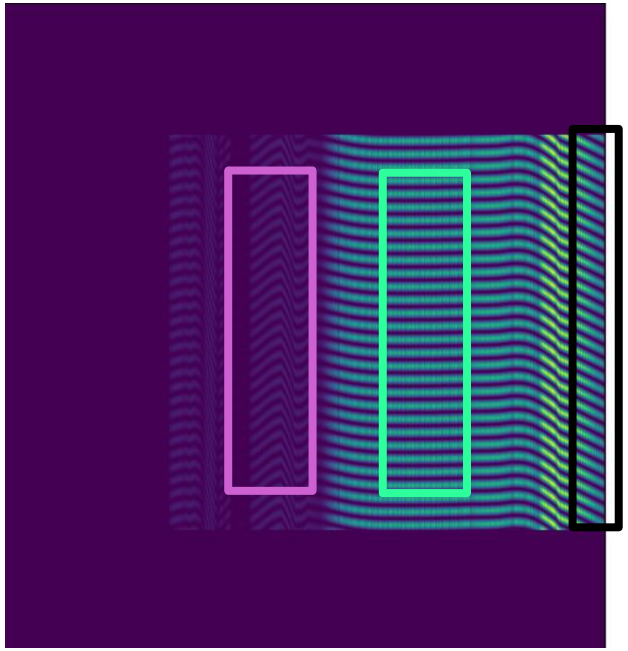
Shock acceleration through the quartz, which gives a low intensity reflection

Shock exits the quartz

125 μm ablator 100 μm gap



Simulation



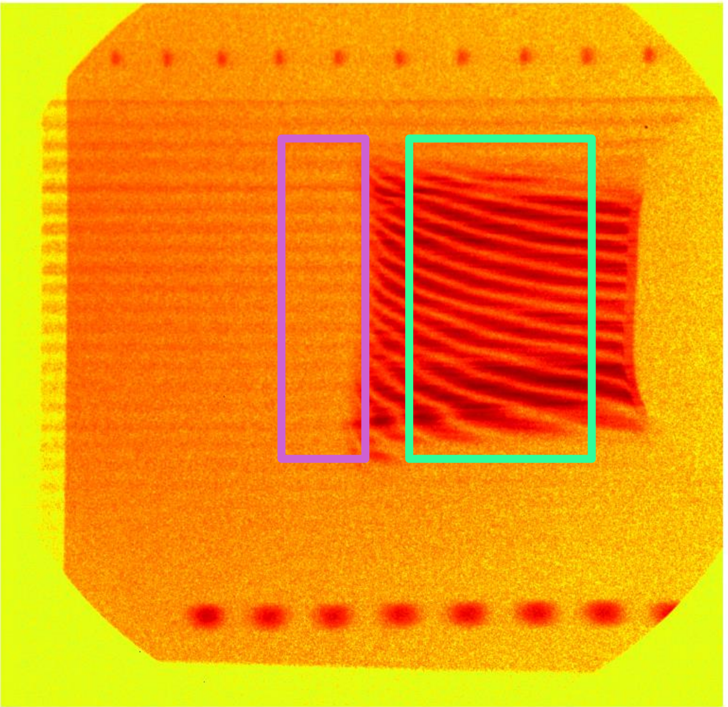
Shock decays as it travels through the quartz

The shock decay happens at a constant deceleration in experiment versus in stages in simulation

Understanding and predicting the blanking process enabled measurements of shock acceleration through experimental redesign

- **Synthetic VISAR correctly predicted a 30% decrease in laser intensity would allow measurement of initial shock acceleration**

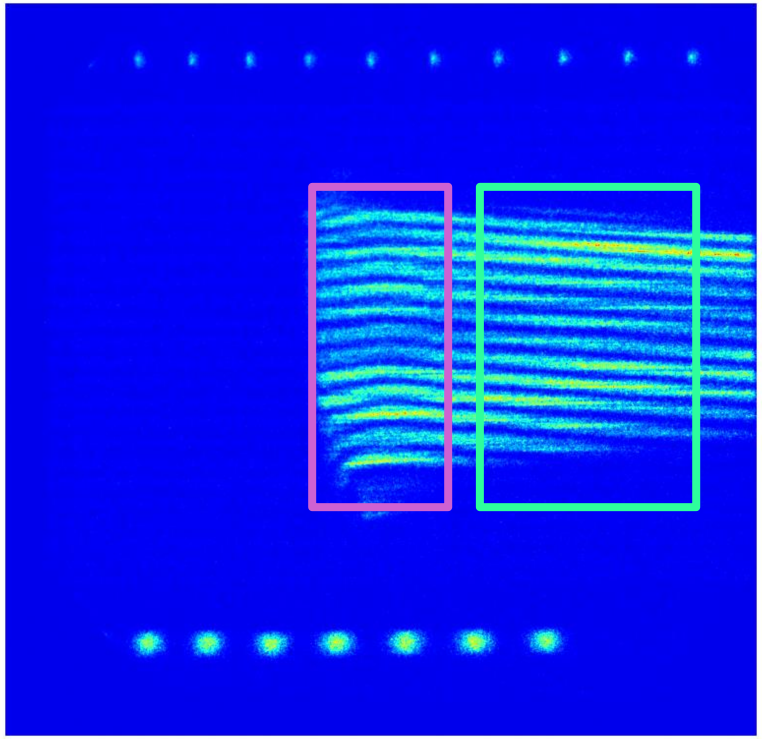
125 μm ablator 100 μm gap
First design



Shock acceleration region

Shock decay region

125 μm ablator 100 μm gap
Redesigned with synthetic VISAR



Future Work

- Implement more materials than quartz witnesses such as LiF* ** utilizing DFT calculations for material properties

- Have better discretization of the index of refraction within material layer
  - ODE solver for Helmholtz equation rather than a matrix inverse method

- Benchmark against known shock conditions and build a predictive capability between hydrocodes, synthetic VISAR, and experiments

*J. Clérouin et al. Phys Rev B 72, 155122 (2005)
** D. G. Hicks Phys Rev 91, 3 (2003)

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