

# Embedded Fiber Optic Sensors for Measuring Transient Detonation/Shock Behavior

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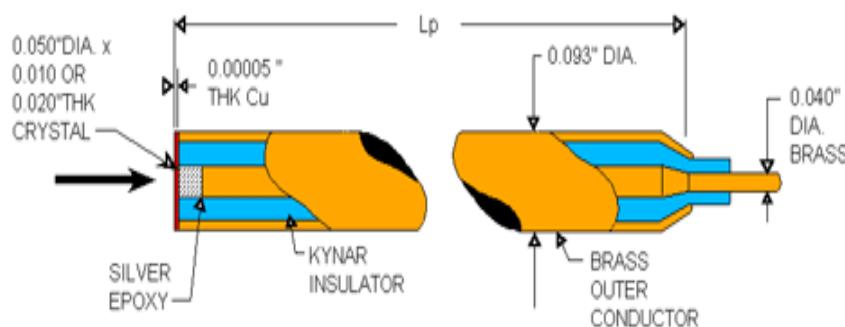
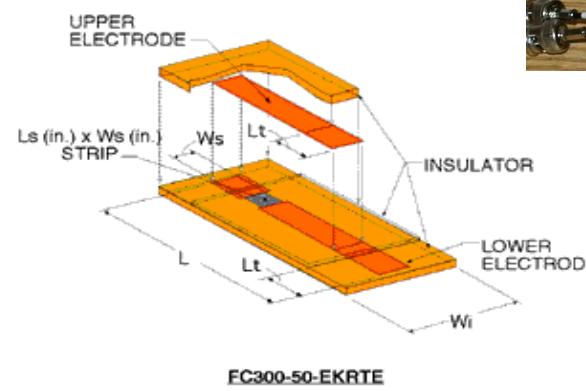
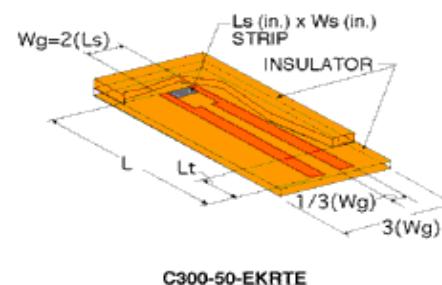
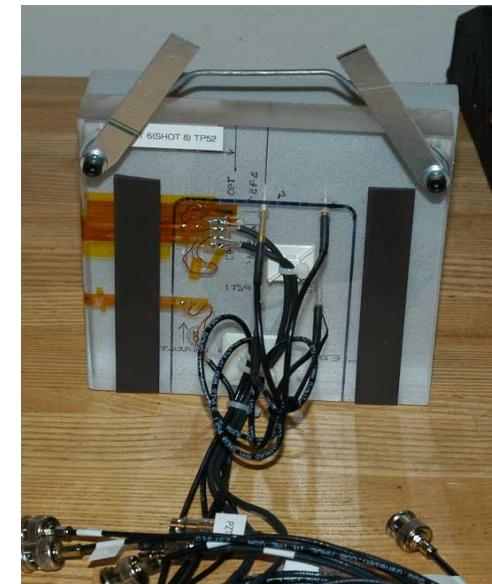
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# Outline

- Why does anyone care?
- Macroscale Interface Velocity Gauges
- Photonic Doppler Velocimetry
- Micro-energetic Experimental Considerations
- Miniaturized Interface Velocity Sensors: EFOS
- Hydrocode Simulation
- Measurements with EFOS
- Summary
- Acknowledgements
- Questions

# Traditional Diagnostic Limitations

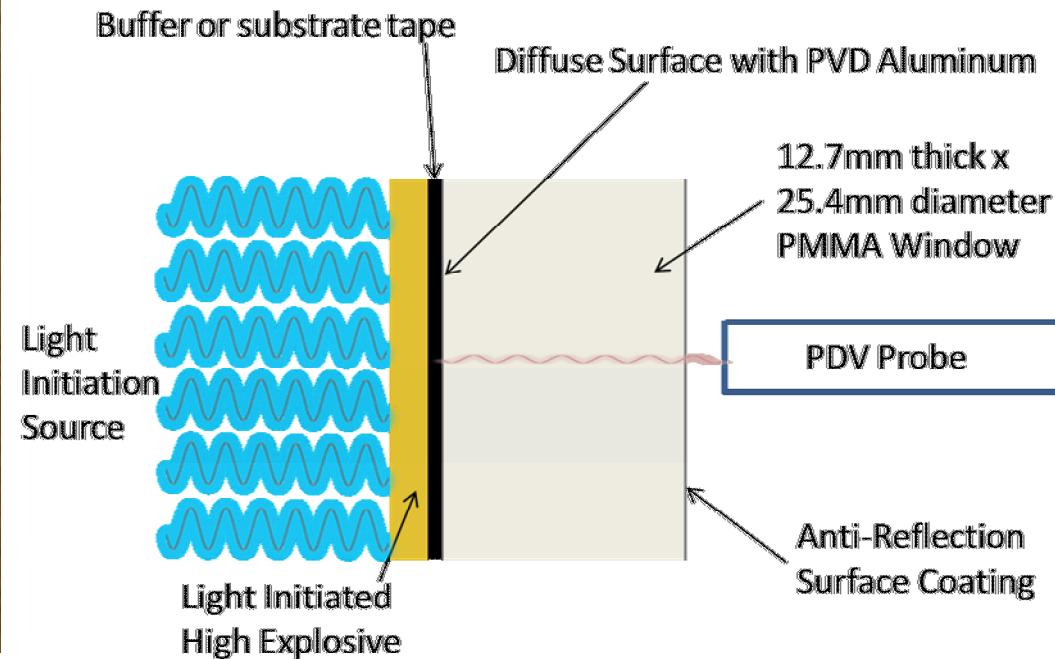
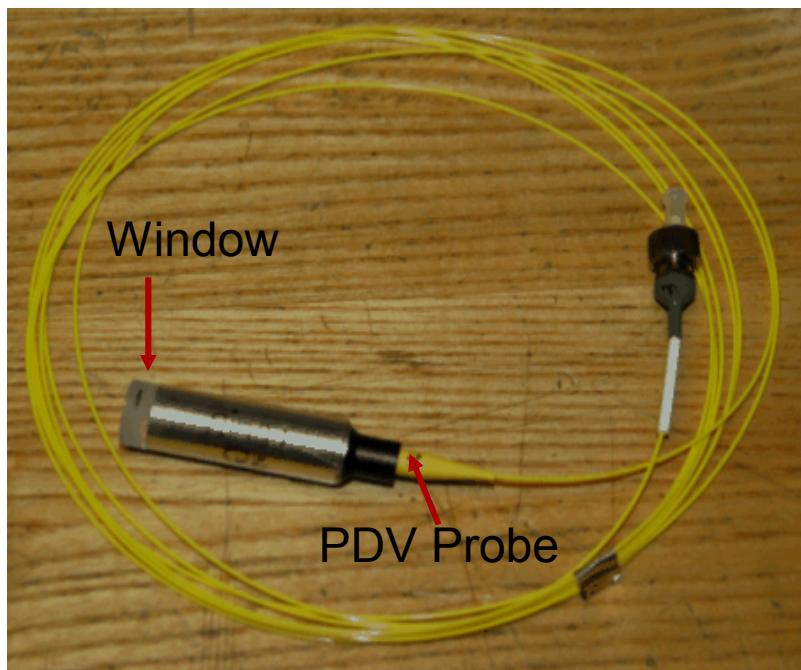
- Push for miniaturization due to smaller energetic packages
- Probes are obtrusive
  - Must account for this in experiments
- Electromagnetic noise
  - Carbon gauges
  - PVDF gauges
  - PZT pins



CA-1136

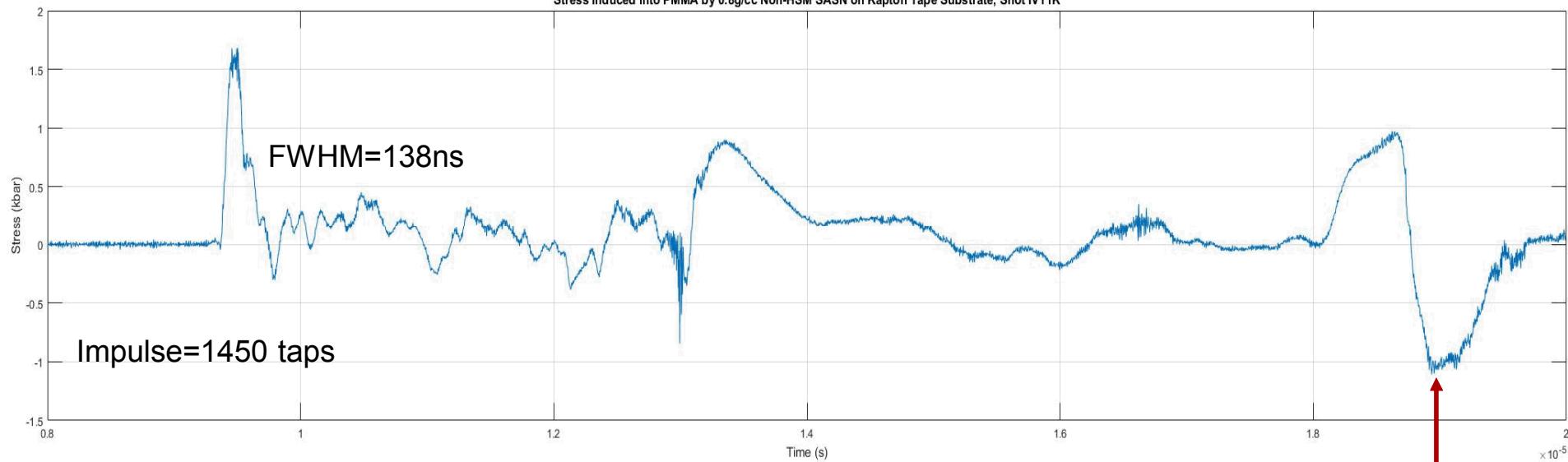
# Macroscale Interface Velocity

- Interface velocity measurements are ubiquitous
- Noise is reduced from an electromagnetic standpoint
- Relatively large devices (order of centimeters)
- Several optical systems provide this type of data



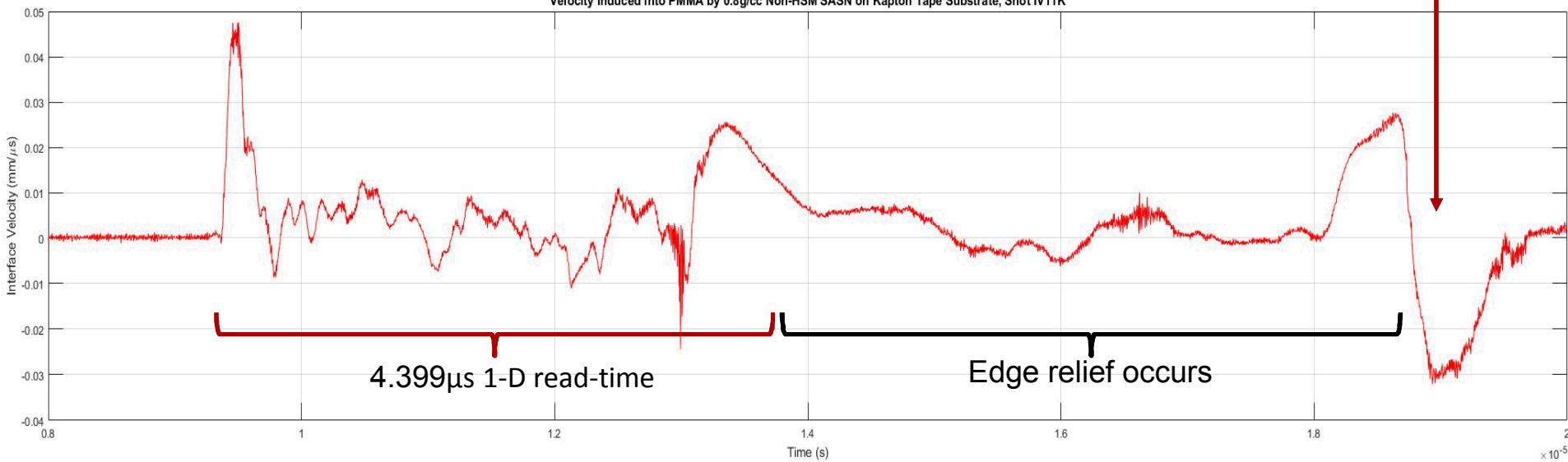
# Macroscale Interface Velocity

Stress Induced into PMMA by 0.8g/cc Non-HSM SASN on Kapton Tape Substrate, Shot IV11K



Shock reflection

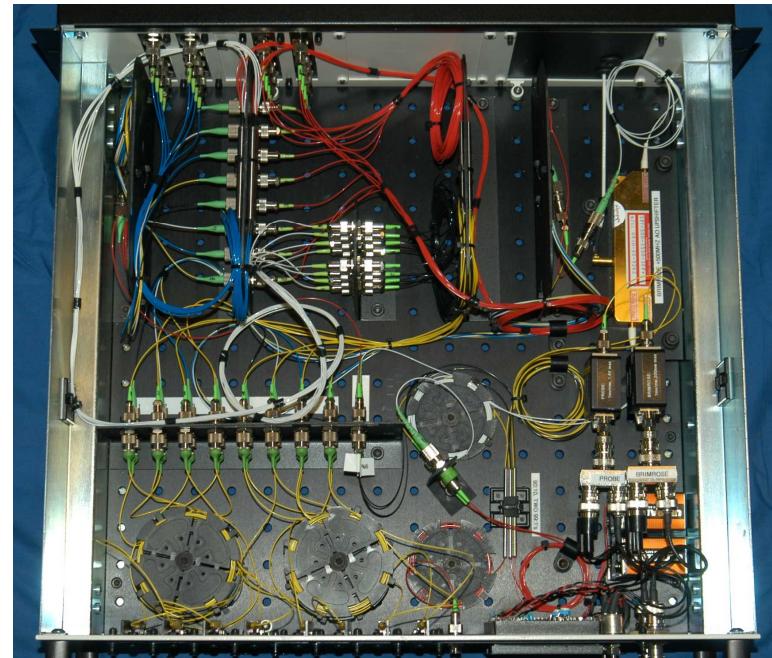
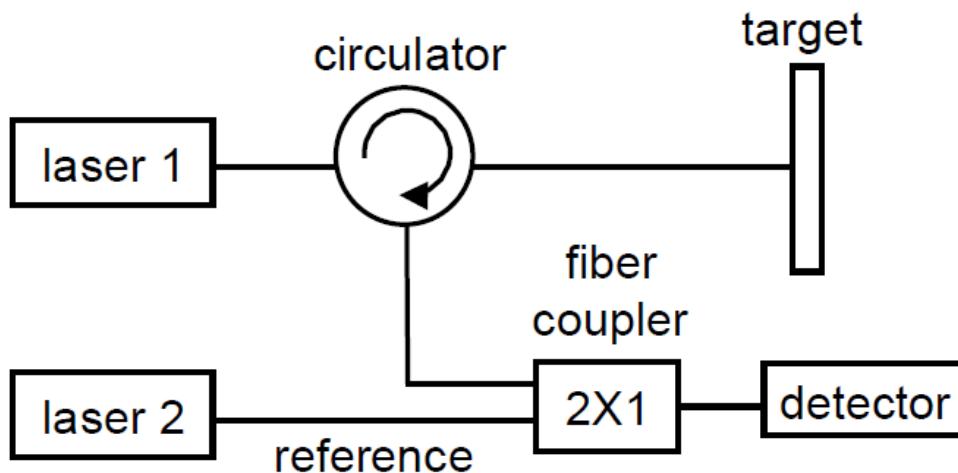
Velocity Induced into PMMA by 0.8g/cc Non-HSM SASN on Kapton Tape Substrate, Shot IV11K



# Photonic Doppler Velocimetry

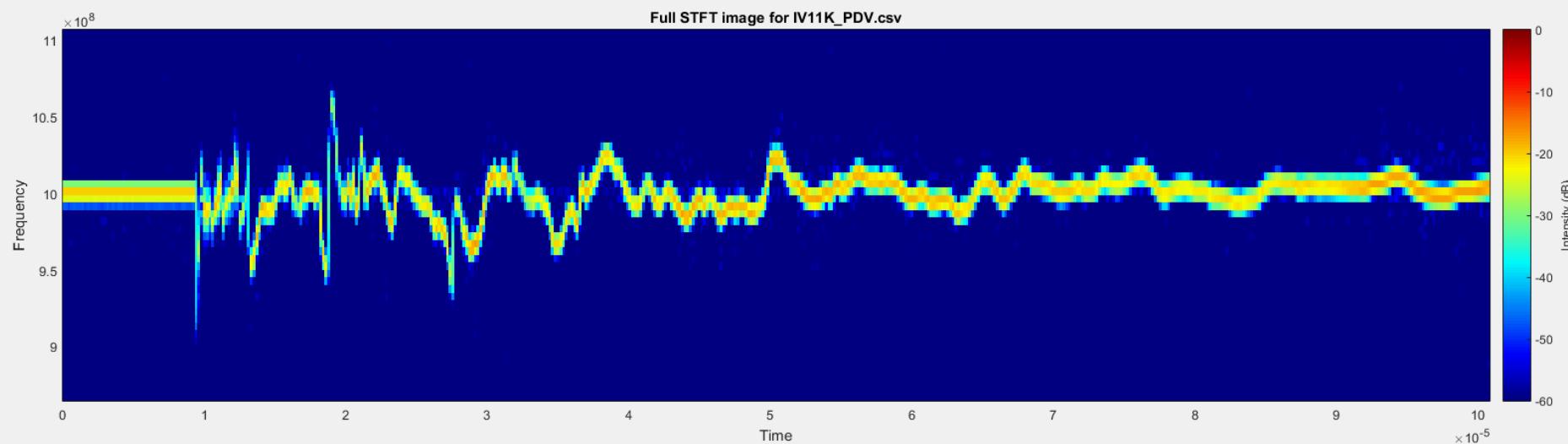
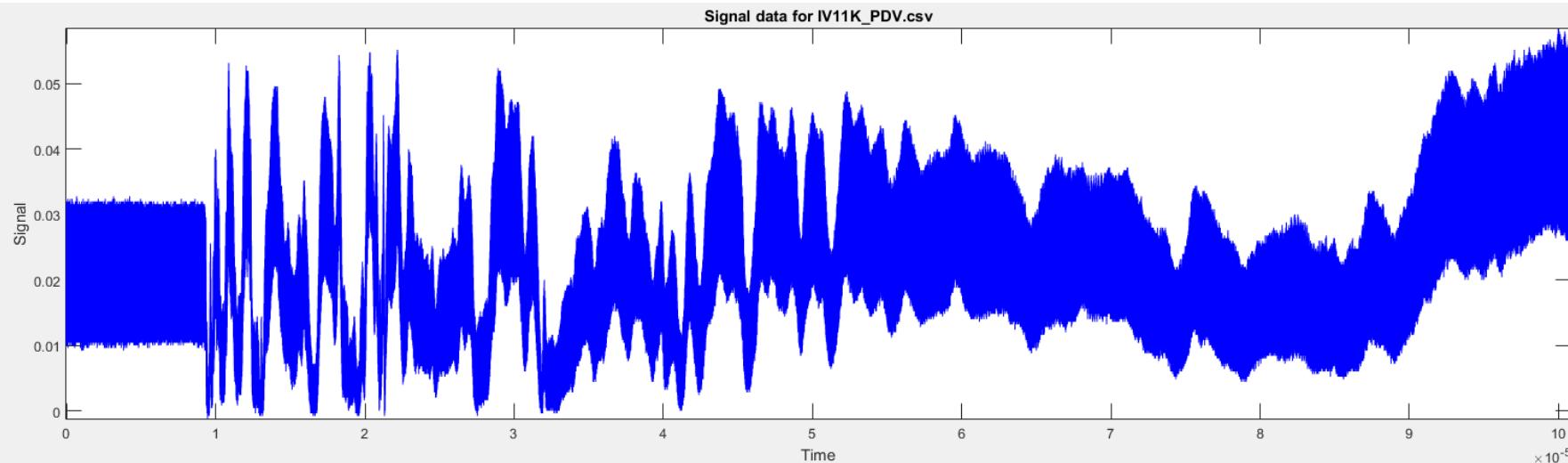
- Developed at Lawrence Livermore National Laboratories
- Short-time Fourier transform needed to transform beat frequency time history to apparent velocity

$$v_a = \frac{\lambda_0}{2} f$$



LIHE Facility PDV System

# Photonic Doppler Velocimetry



Reduction of interface velocity in SIRHEN, MatLab based script

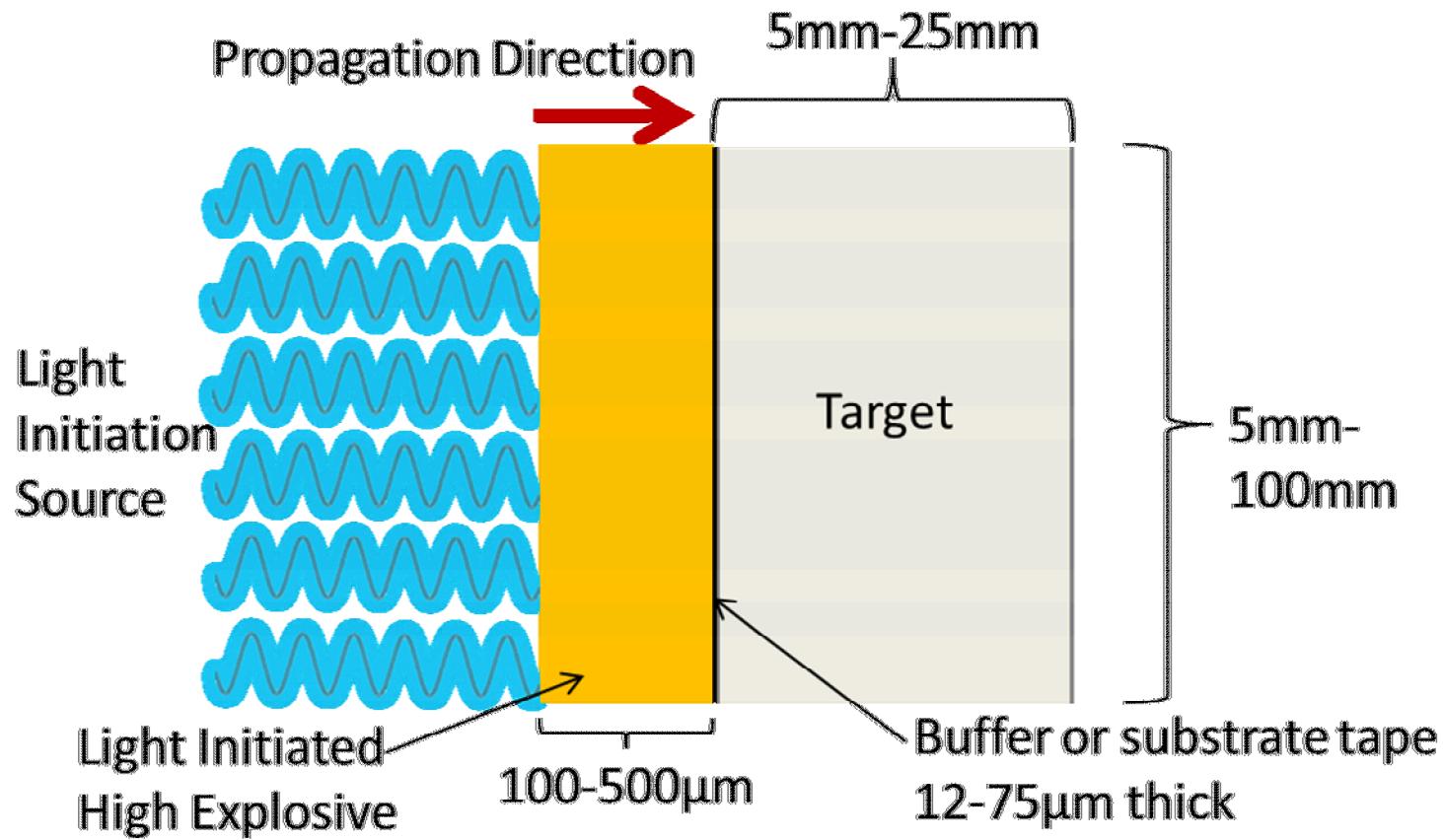
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# Experimental Considerations

- Micro-energetics pose many issues:
  - Diagnostic and the limited space available
  - Geometry influencing phenomena
  - Manufacture of micro-geometry difficult
- Measurements of interest:
  - Particle or interface velocity
  - Pressure
  - Temperature
  - Reaction wave propagation rate
- “Cut-back” one-dimensional experiments may get around some issues, but with caveats

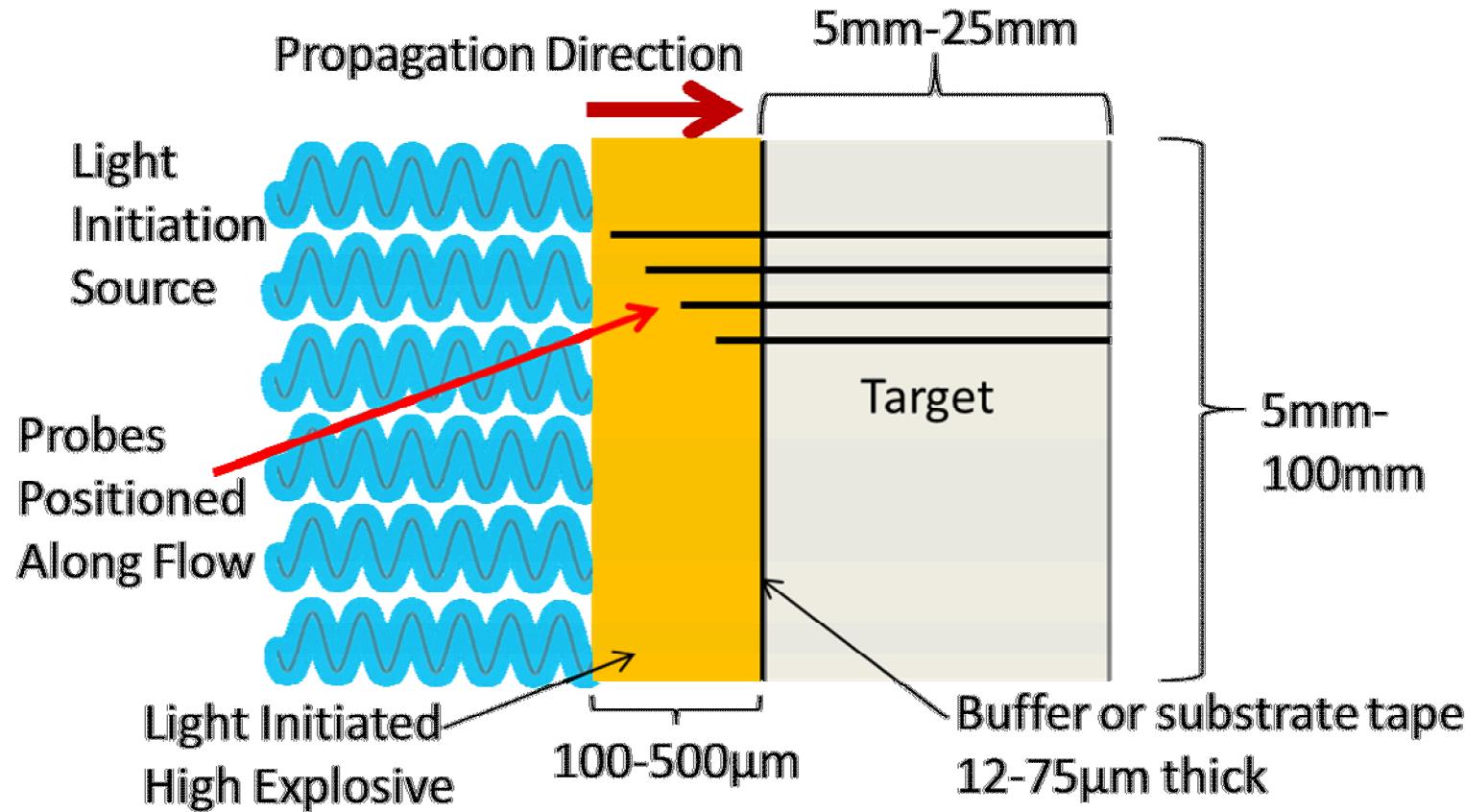
# Experimental Considerations

- Silver acetylide-silver nitrate (SASN) explosive is light initiated for impulse testing

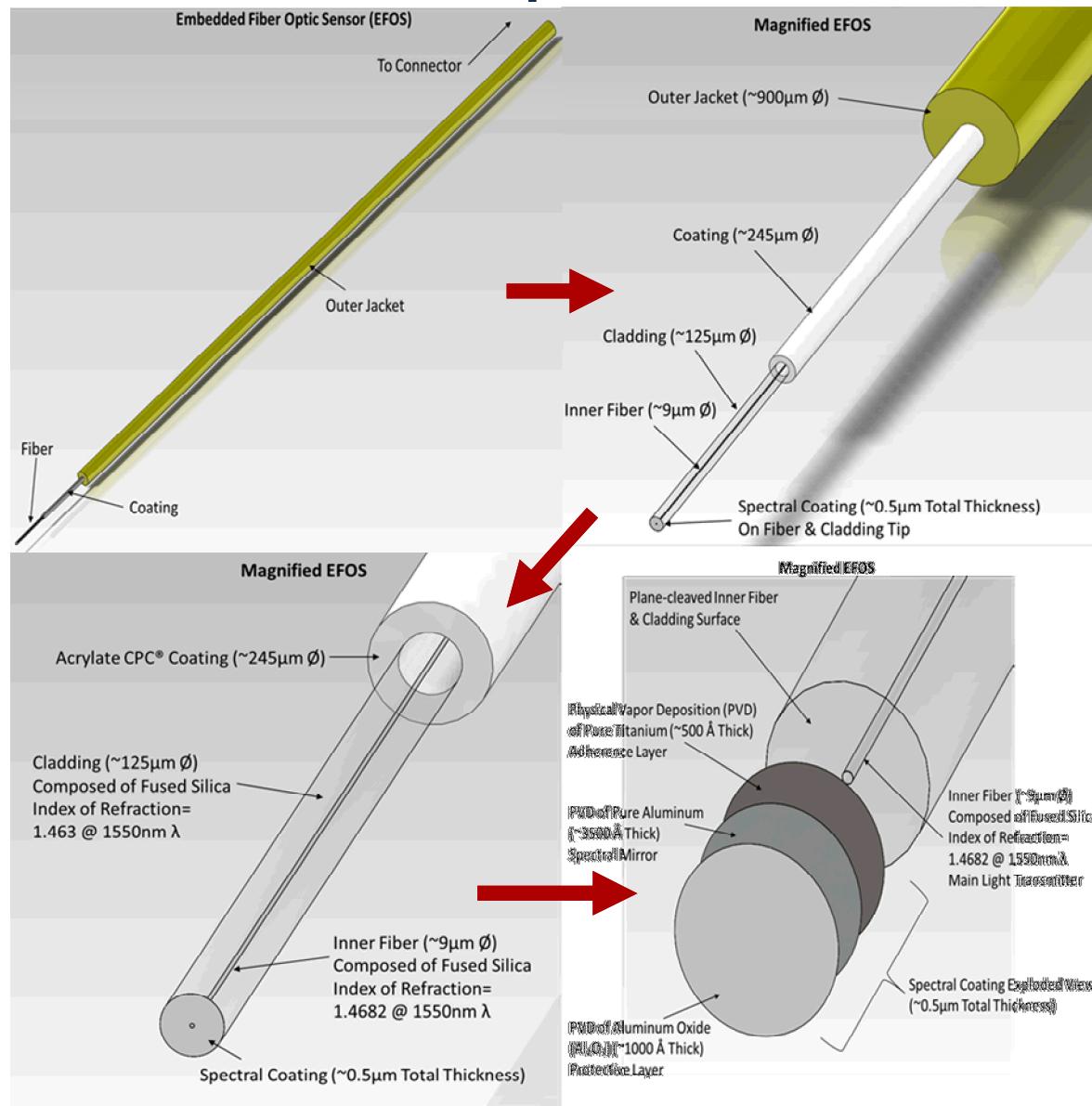


# Miniature Interface Velocity

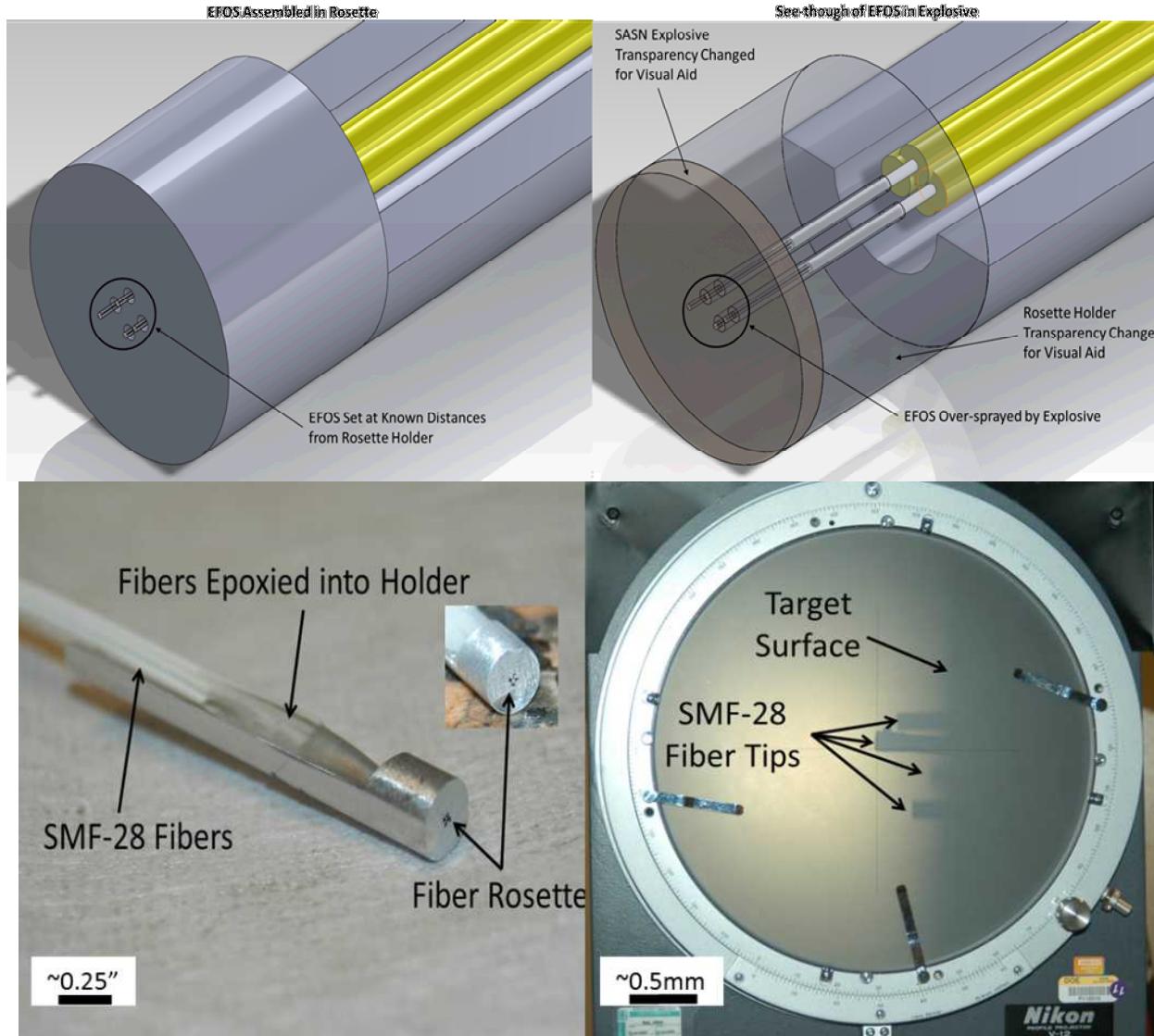
- Originally, time-of-arrival (TOA) pins were envisioned



# Embedded Fiber Optic Sensors

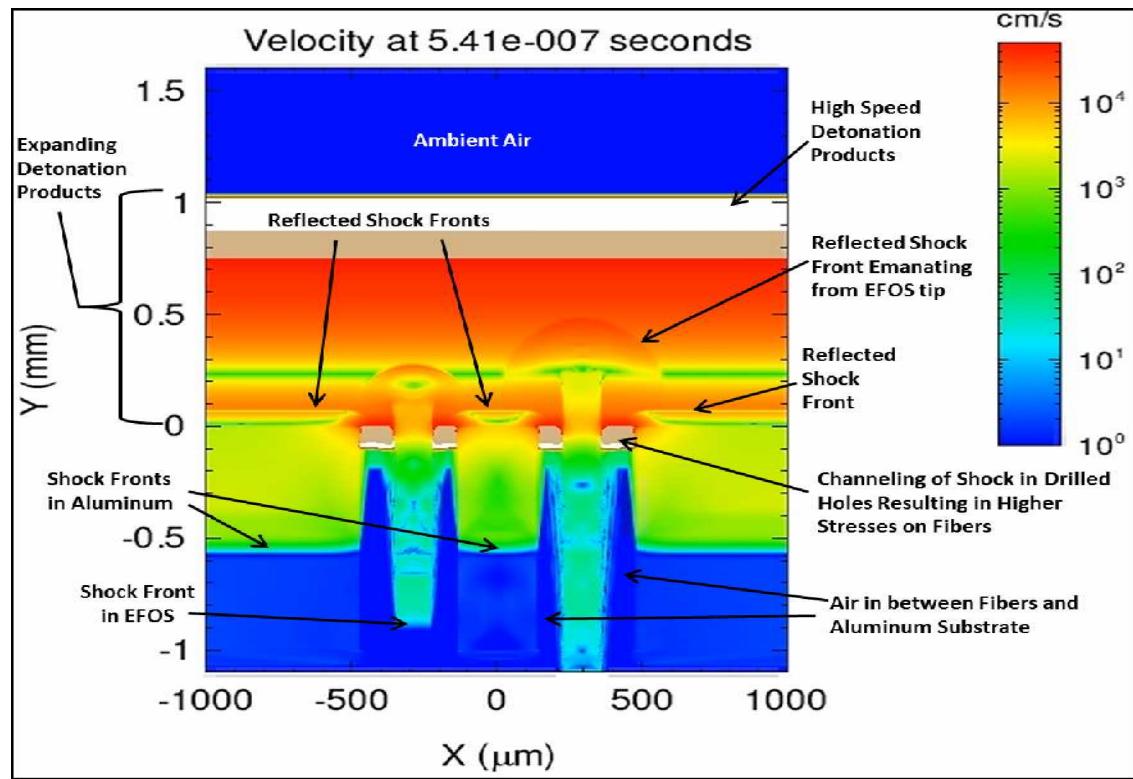
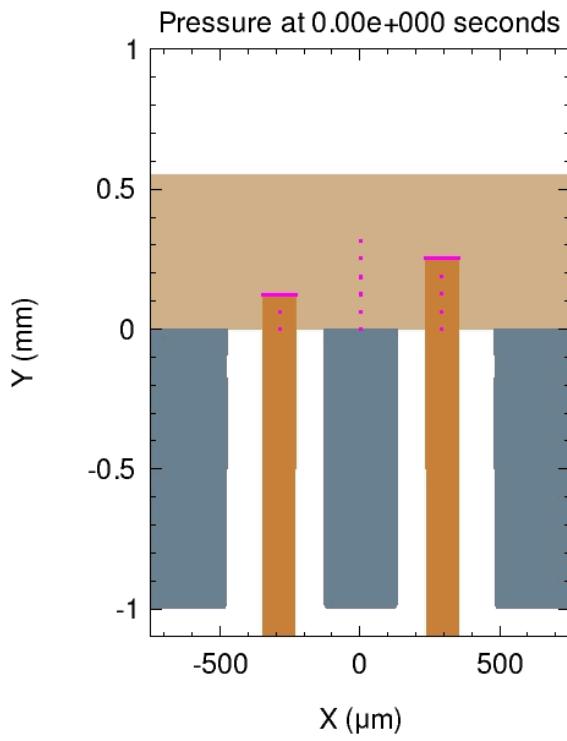


# Embedded Fiber Optic Sensors



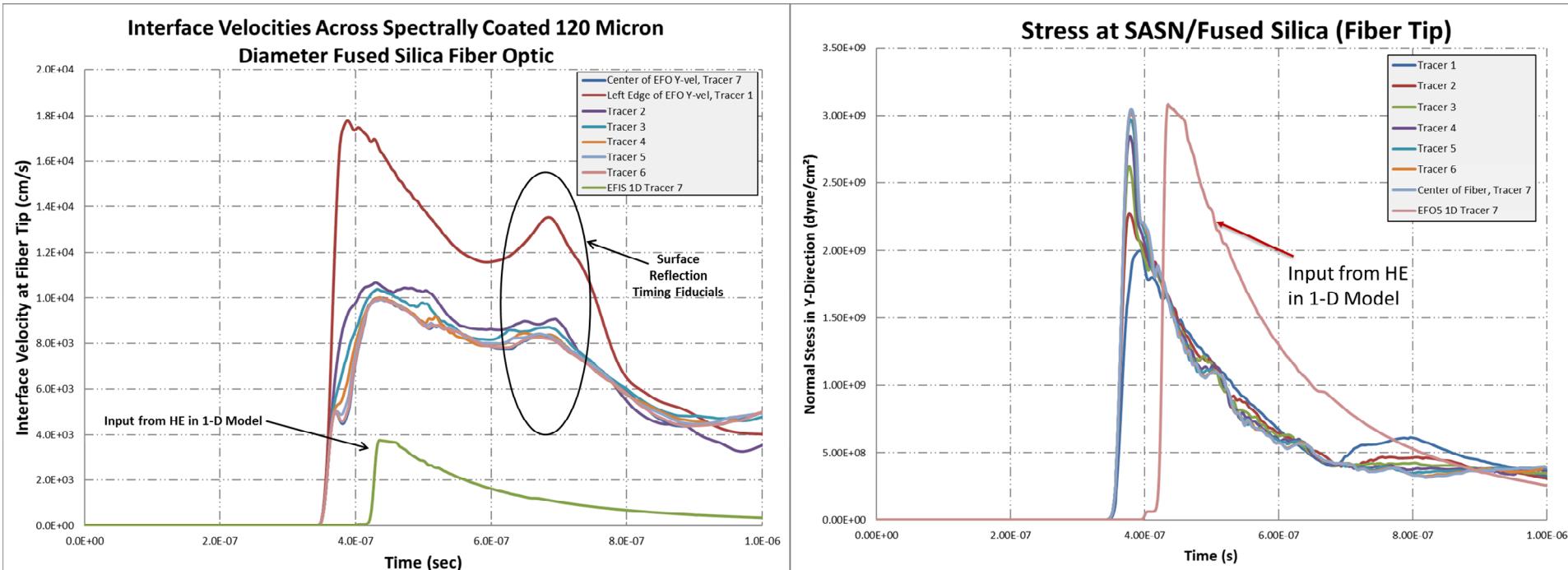
# Hydrocode Simulation

- Advanced mesh refinement used in 2D rectangular model
- Arbitrary SASN JWL EOS with programmed HE burn
- Elementary model needs further refinement

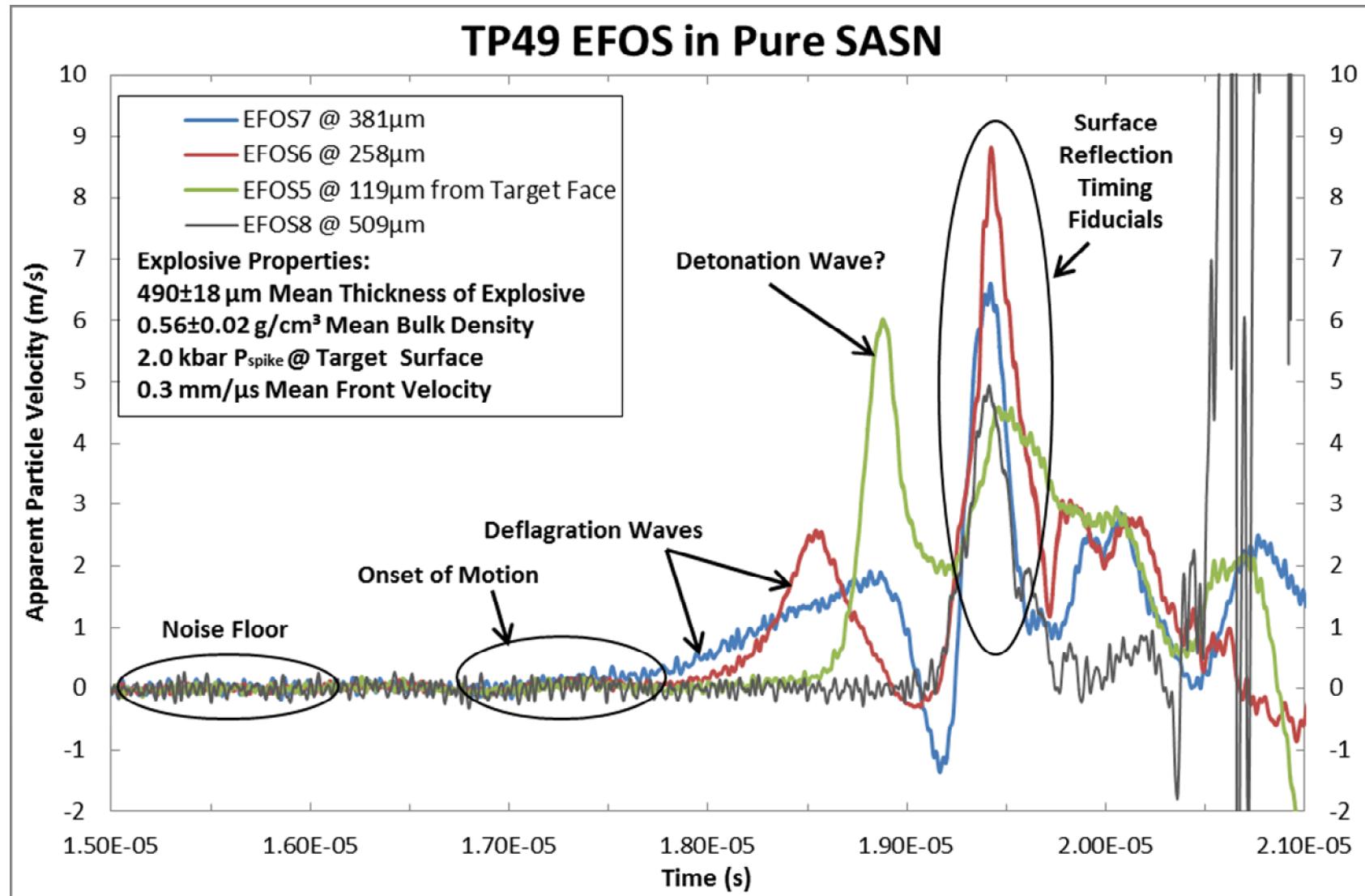


# Hydrocode Simulation

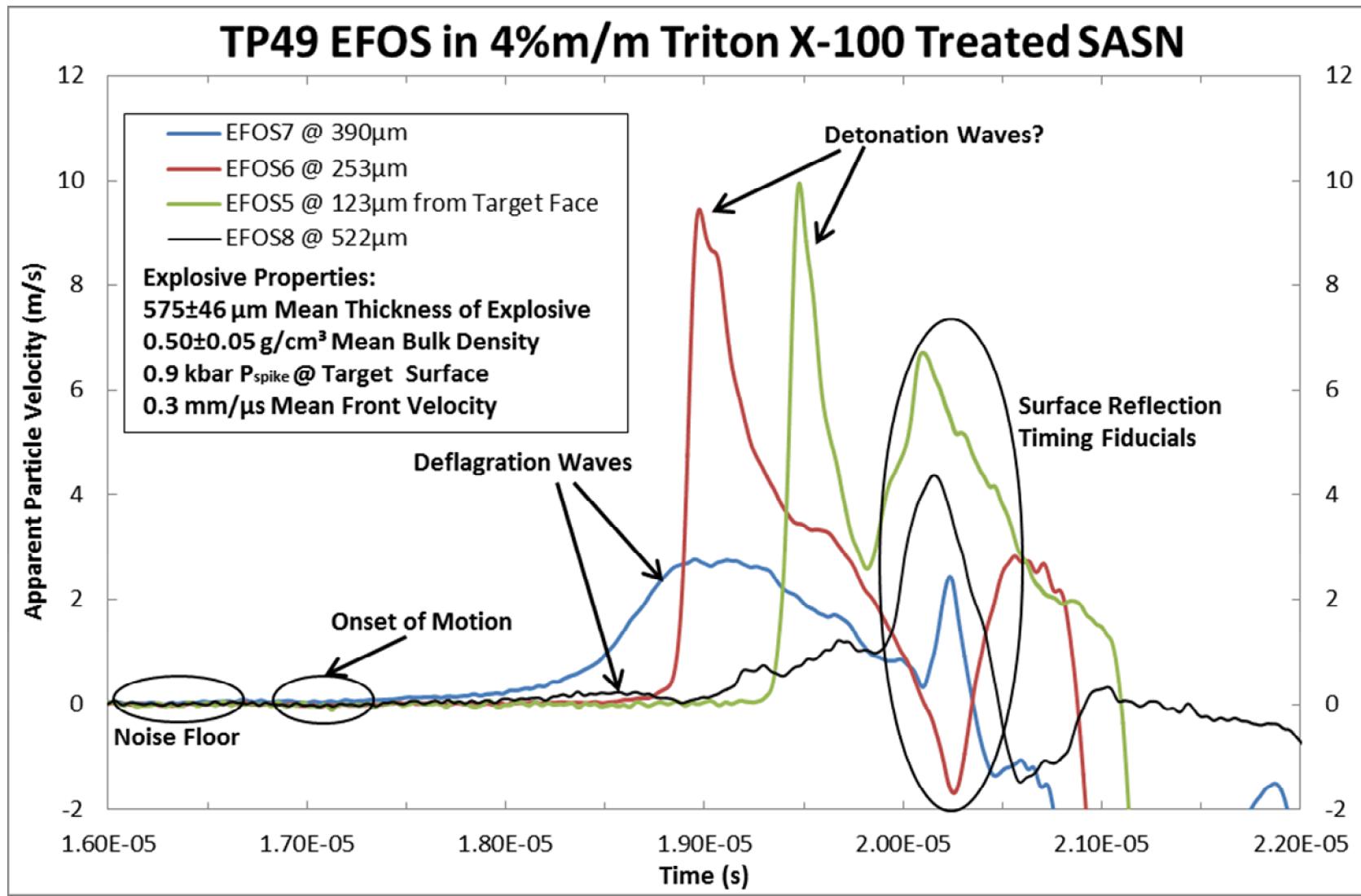
- Stress and velocity at center of fiber modified from original input pulse shape
- Aid in data analysis: surface reflection timing fiducials from experimental configuration



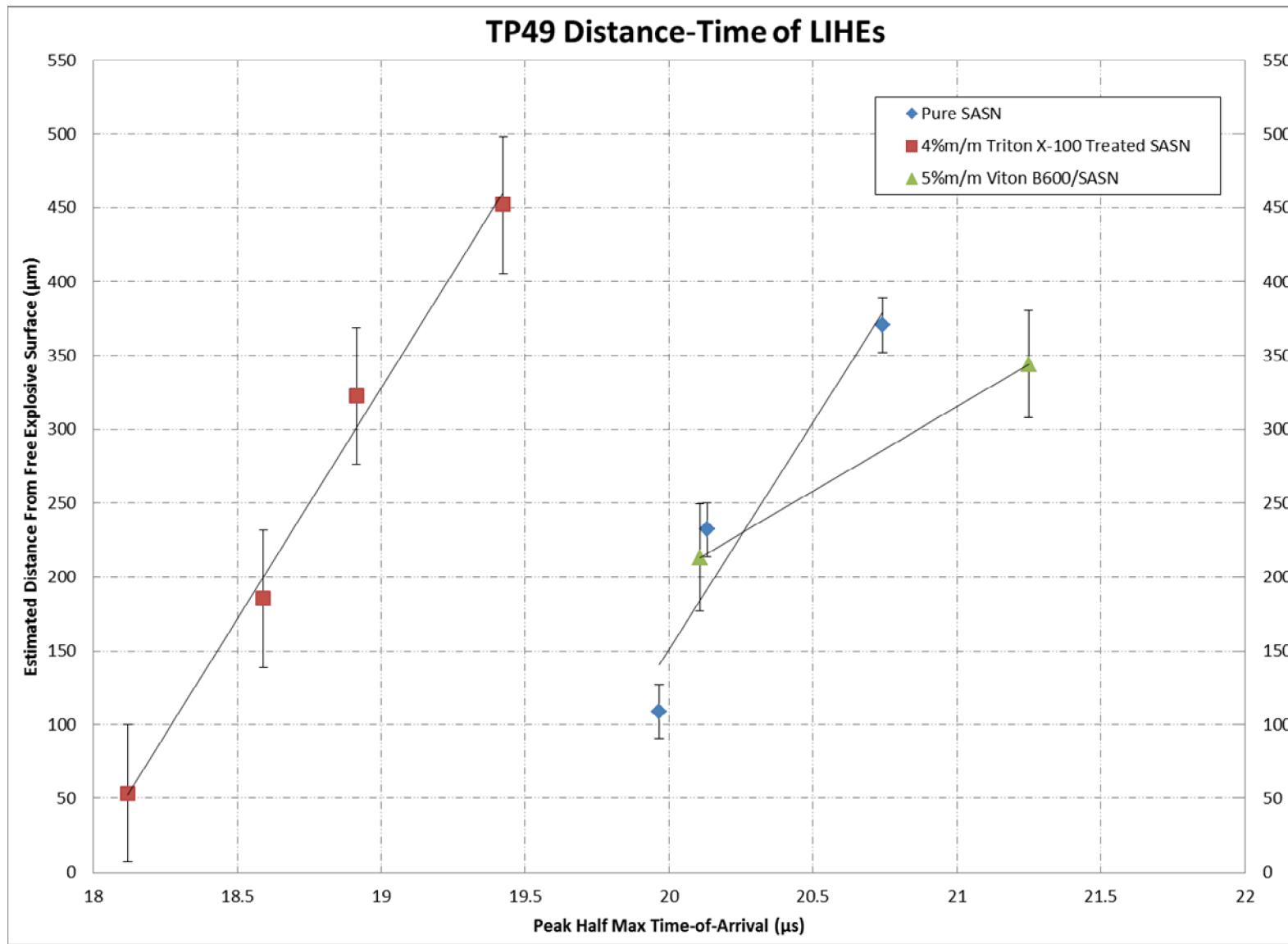
# EFOS Measurements



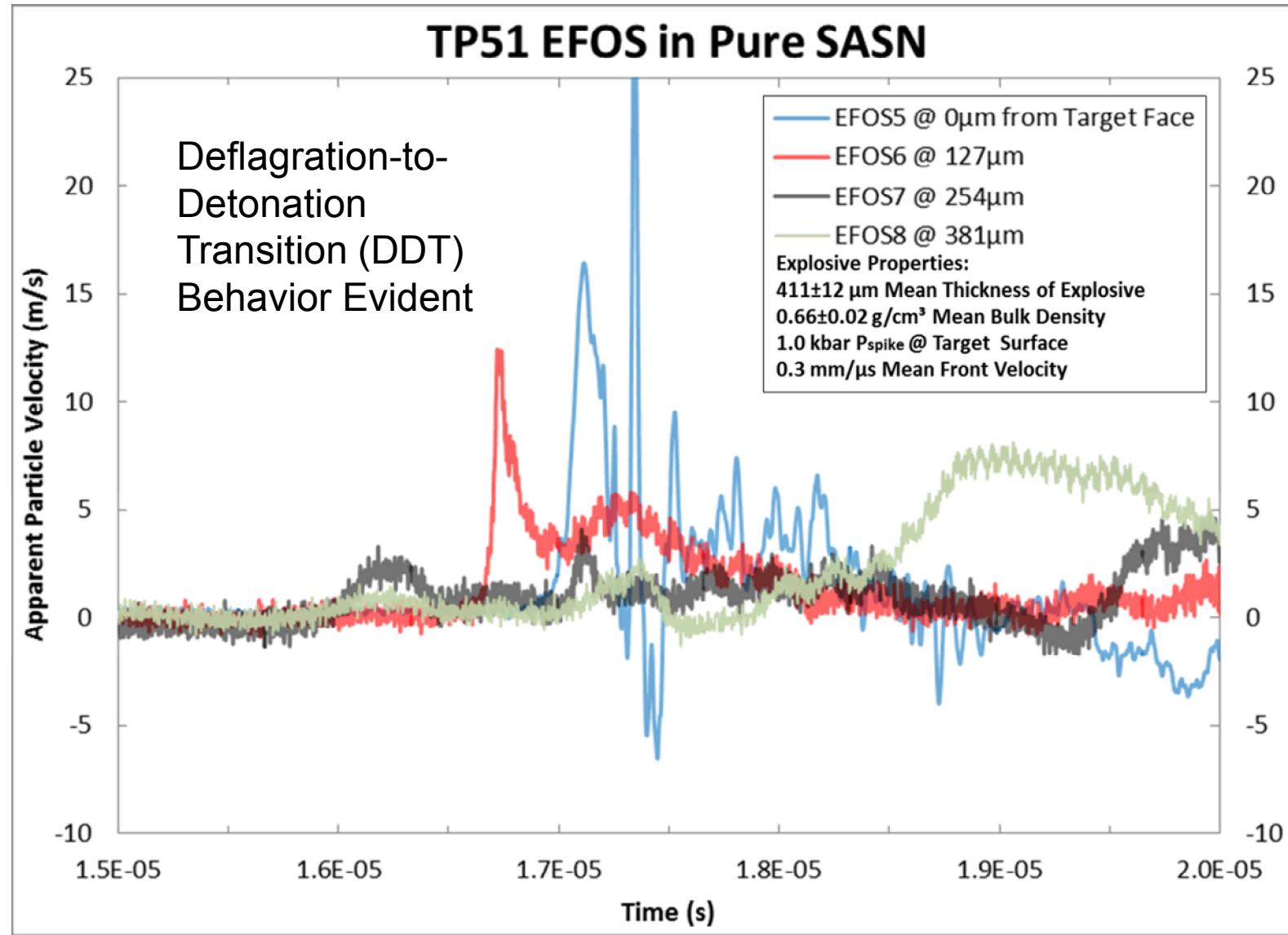
# EFOS Measurements



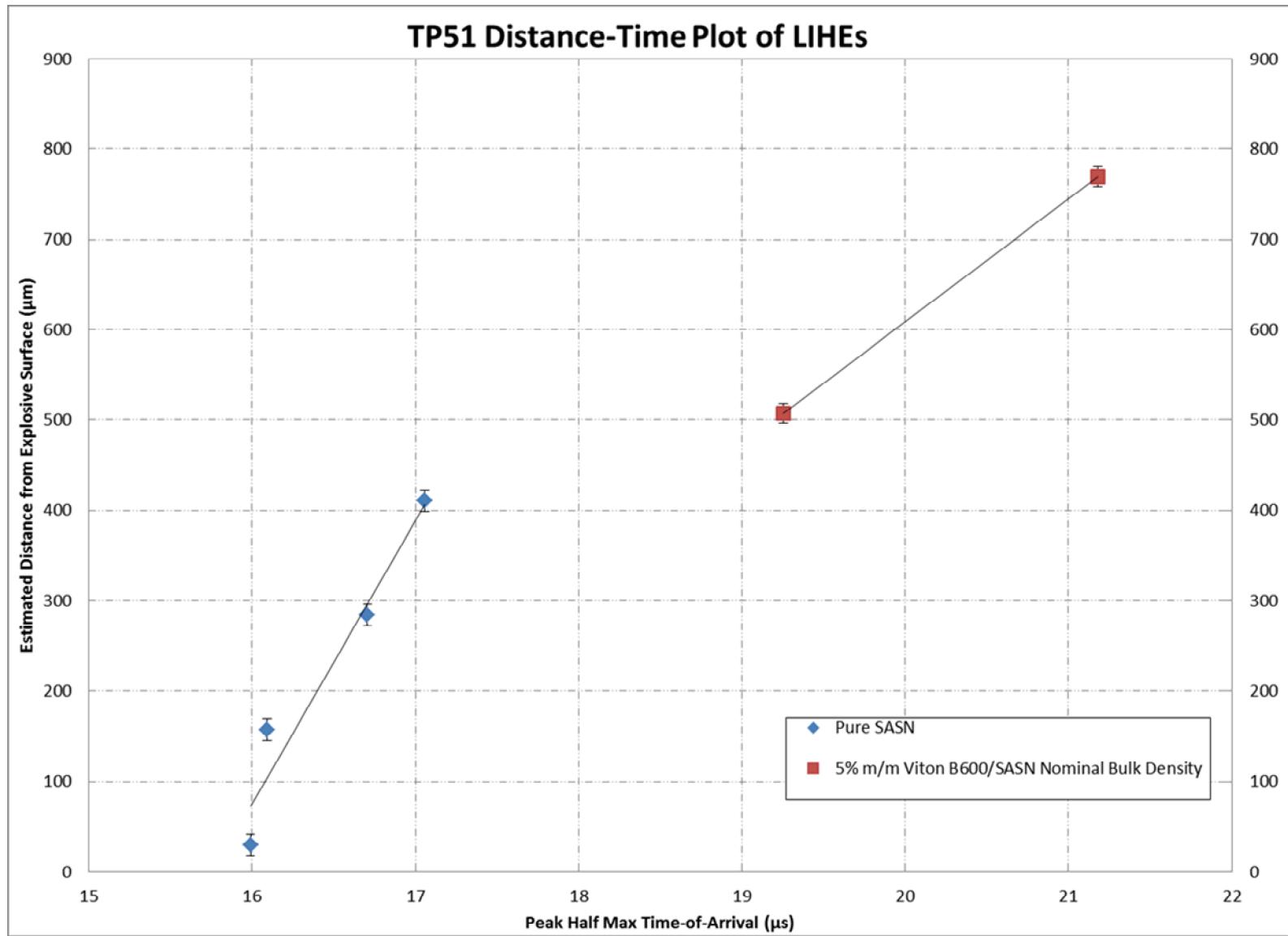
# EFOS Measurements



# EFOS Measurements



# EFOS Measurements



# Summary

- EFOS presented here are a miniature sensor for probing combustion phenomena in microscale settings
- EFOS employed in 100-500MPa pressure range and successfully acquired: TOA and apparent interface velocity data
- Deflagration-to-detonation behavior apparent in SASN HE
- Hydrocode simulations and experimental data show that a true velocity and stress transformation possible with more effort
- Uncertainty quantification necessary once true velocity and stress transformation achieved
- SNL Technical Advance (SD# 12638) with patent currently pursued

# Acknowledgements

- Daniel Dow
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- Sandia National Laboratories

- Questions?