EUV Source Gas Target Subsystem

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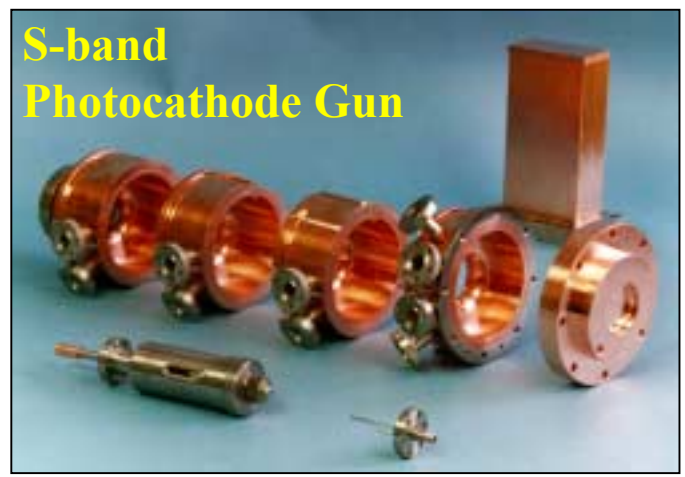
Outline

- Advanced Energy Systems overview
- Gas target subsystem requirements
- AES gas target subsystem
- AES in-house experimental program
- Future directions

Corporate Profile

- Privately held company incorporated in New York in September 1998 (formerly Northrop Grumman)
- Located in Medford, NY & Princeton, NJ
- Products:
  - Accelerator Components
  - Turnkey Ion & Electron Beamlines
  - Advanced Radiation Sources
  - Engineering & Physics Services
  - Systems Engineering & Radiation Analysis
- US & International Customers:
  - Commercial
  - National Laboratories
  - Government
  - Universities
- Markets:
  - Material Processing
  - Medicine
  - Semiconductor Manufacturing
  - Explosive Detection
  - Defense
  - Research & Development

TURNKEY SYSTEMS & COMPONENTS



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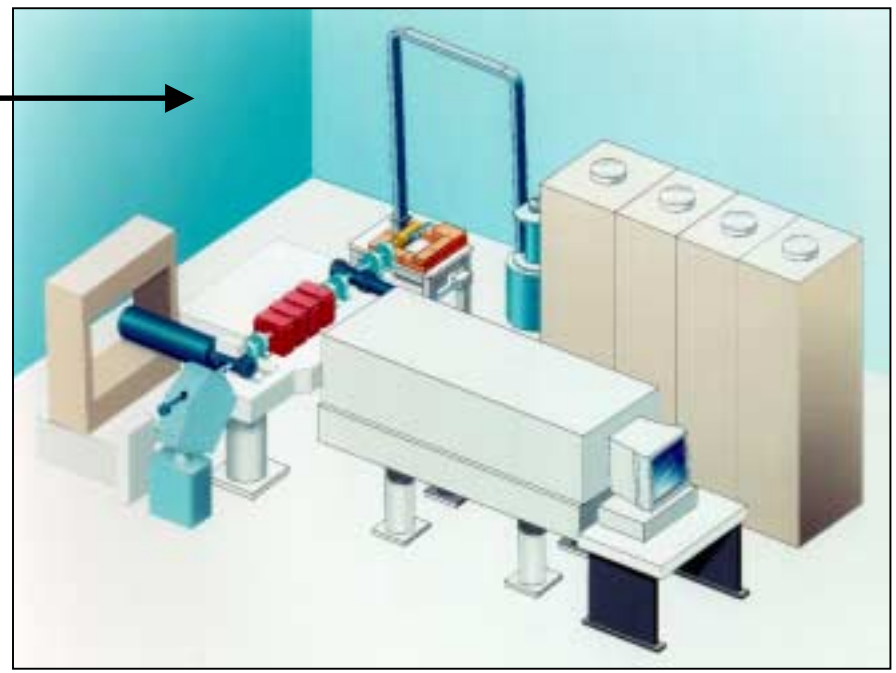
AES Lithography Activities

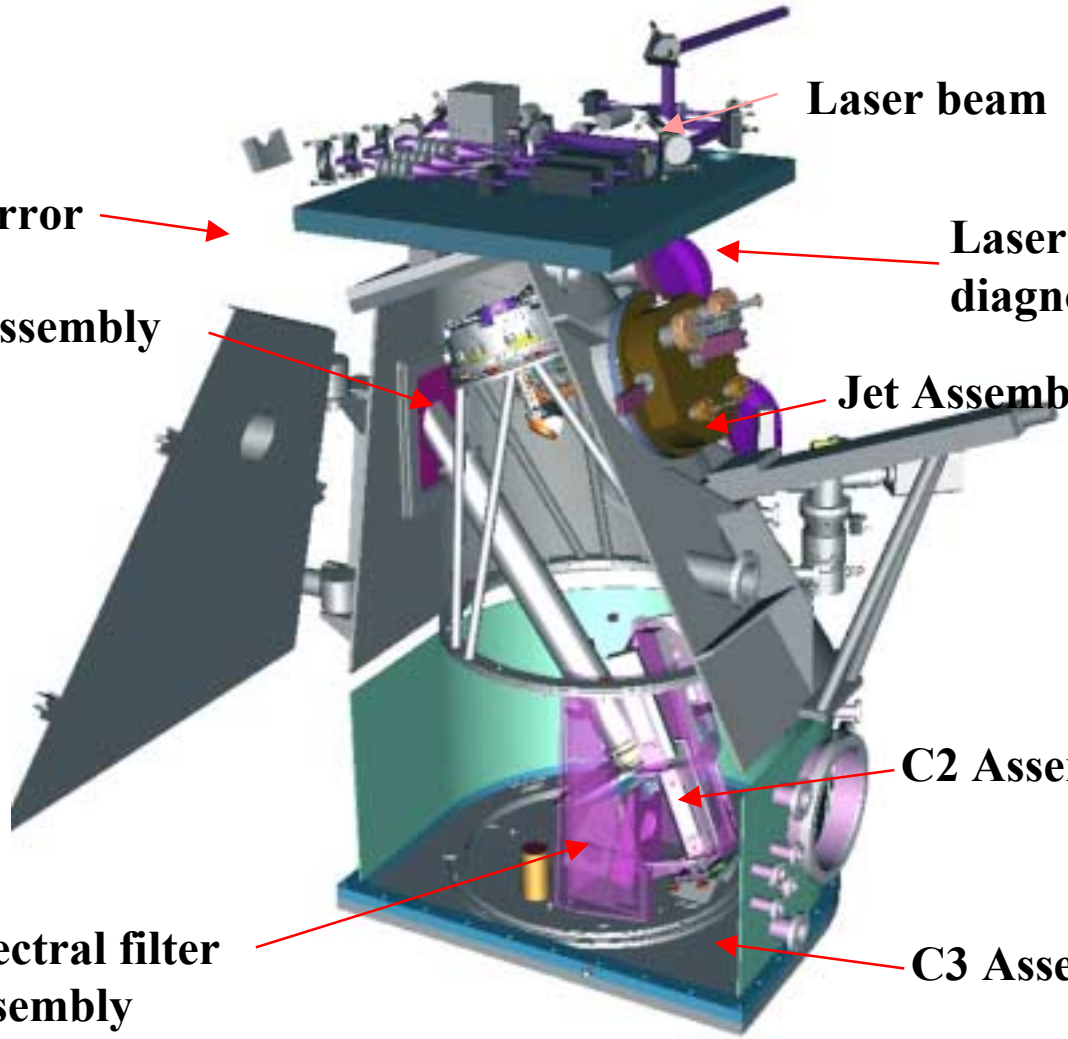
- **Activities within Grumman**
  - Produced electron guns for early IBM E-beam writers
  - Industrial Partner for Brookhaven Superconducting X-ray Lithography Source (SXLS) project
  - Tachonics GaAs foundry
  - Delivered IBL source hardware to ALG/IMS

- **Los Alamos/Grumman DOE/DP EUV CRADA**
  - High-charge, short-pulse electron beam-gas jet anomalous interaction with neon to produce EUV- and X-radiation



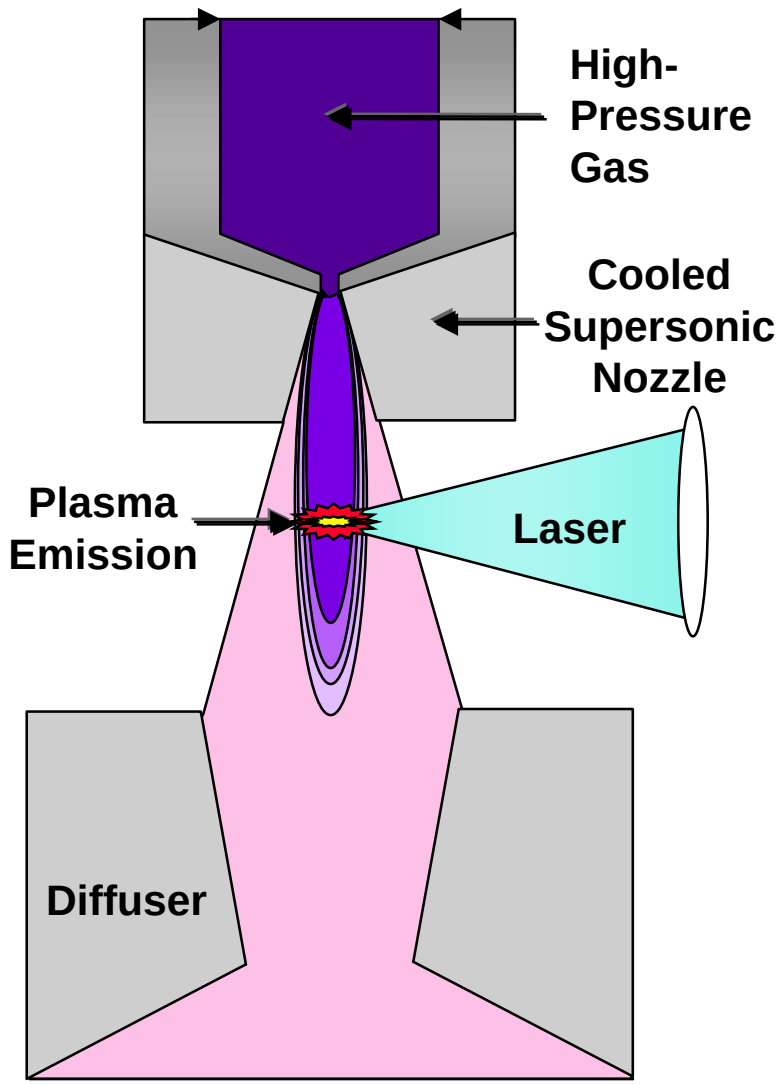
- **EUV LLC Supplier**
  - Radiation source gas jet target subsystem

ETS Illumination Subsystem



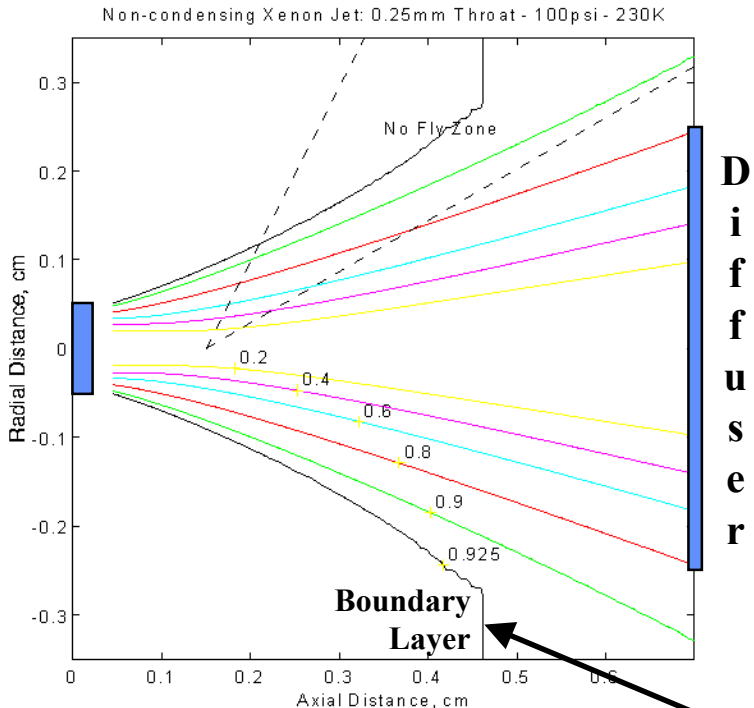
Gas Target Subsystem Requirements

- **CoO**
  - reduce continuous flow nozzle & diffuser dimensions to minimize flow rate, pumping & EUV re-absorption
  - deliver stable flow stagnation characteristics for condensation conditions that maximize EUV yield
- **Debris Reduction**
  - select materials & geometry that minimize debris production
  - deliver stable flow geometry & characteristics to permit laser & plasma standoff from proximate surfaces
- **Specifications**
  - nozzle throat diameter ≤ 250 µm
  - axial jet alignment ≤ 100 µm
  - transverse jet alignment ≤ 30 µm
  - stagnation temperature ≤ 200 ± 1 °K
  - Xenon pressure ≥ 200 psig with recycling
  - vacuum base pressure ≤ 1 mTorr for ≤ 15% EUV path loss
  - ≥ 10^{10} pulses with ≤ 10% C1 reflectivity reduction

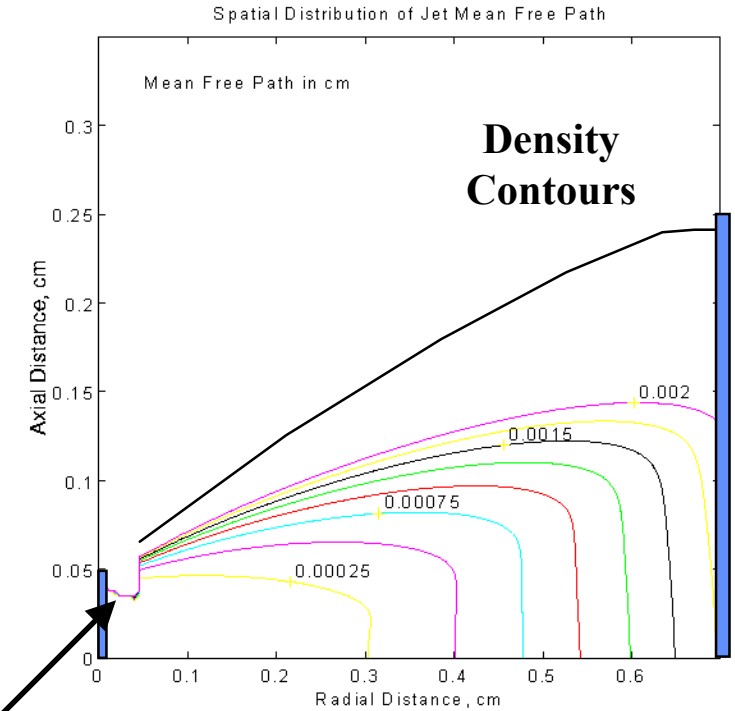


Calculated Gas Jet Streamlines & Density

> 80% capture

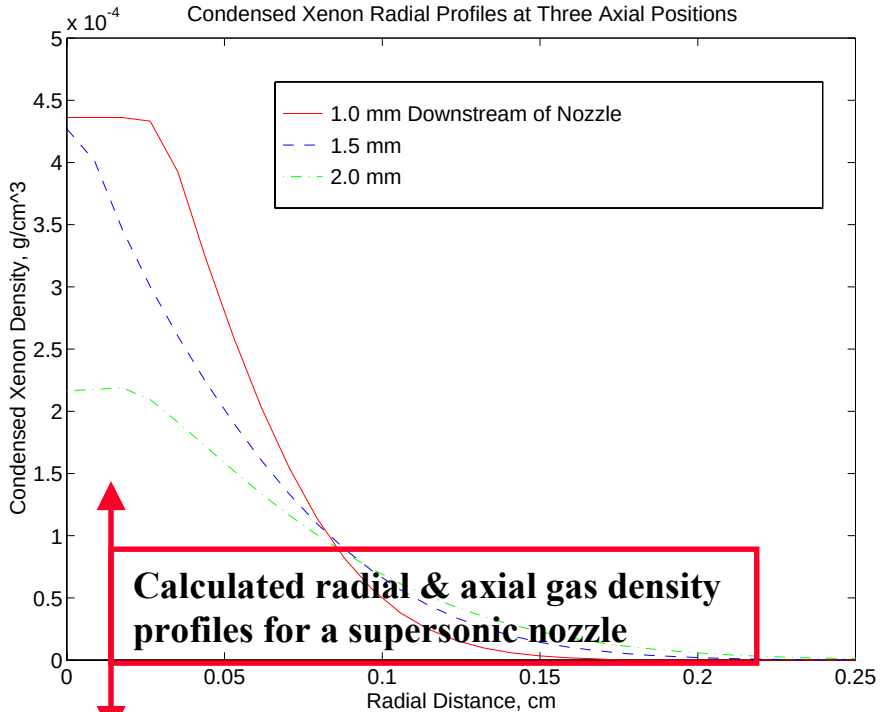


mean free path << diffuser diameter

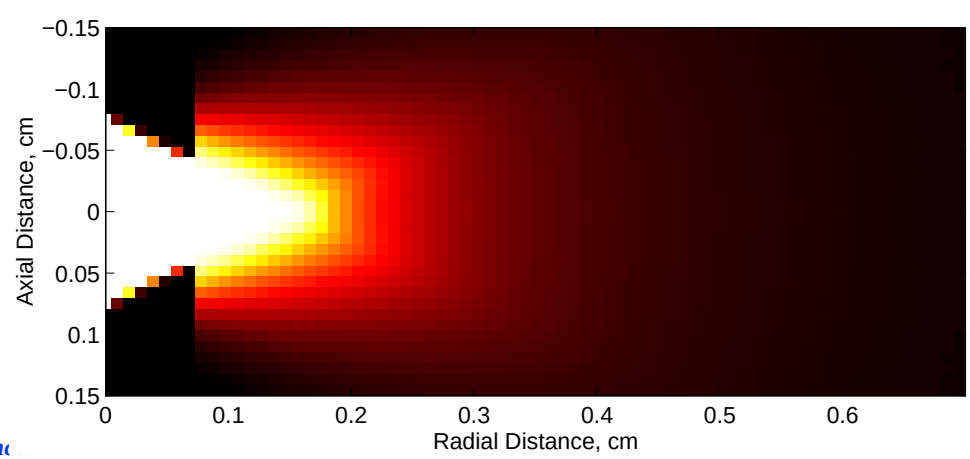


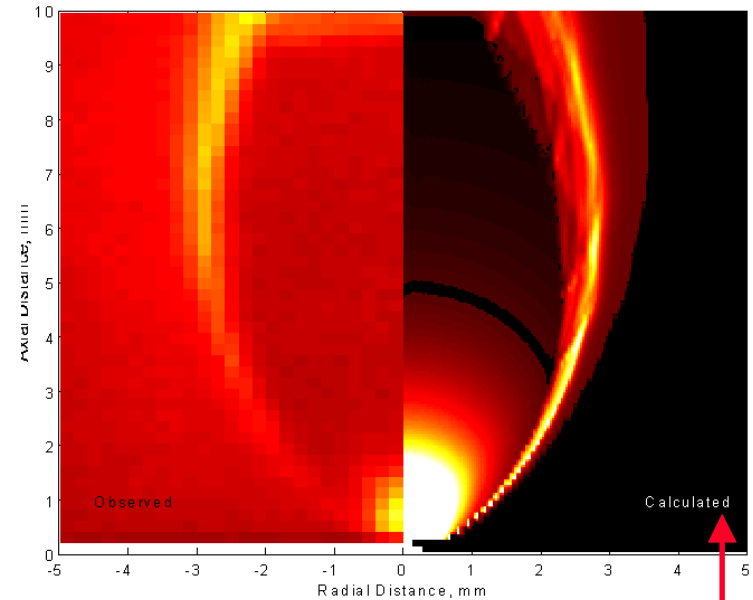
Artifact of Boundary Layer Model

Theoretical Gas Flow Analysis & Measurement



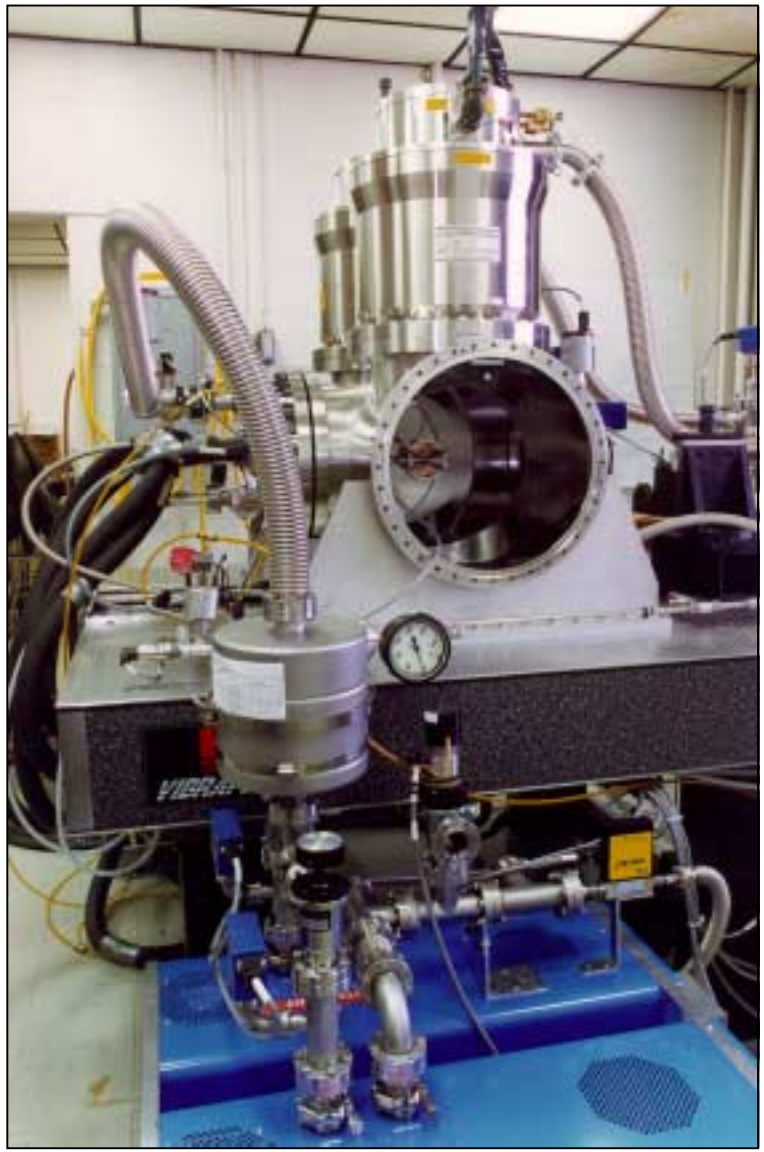
Calculated radial & axial gas density profiles for a supersonic nozzle

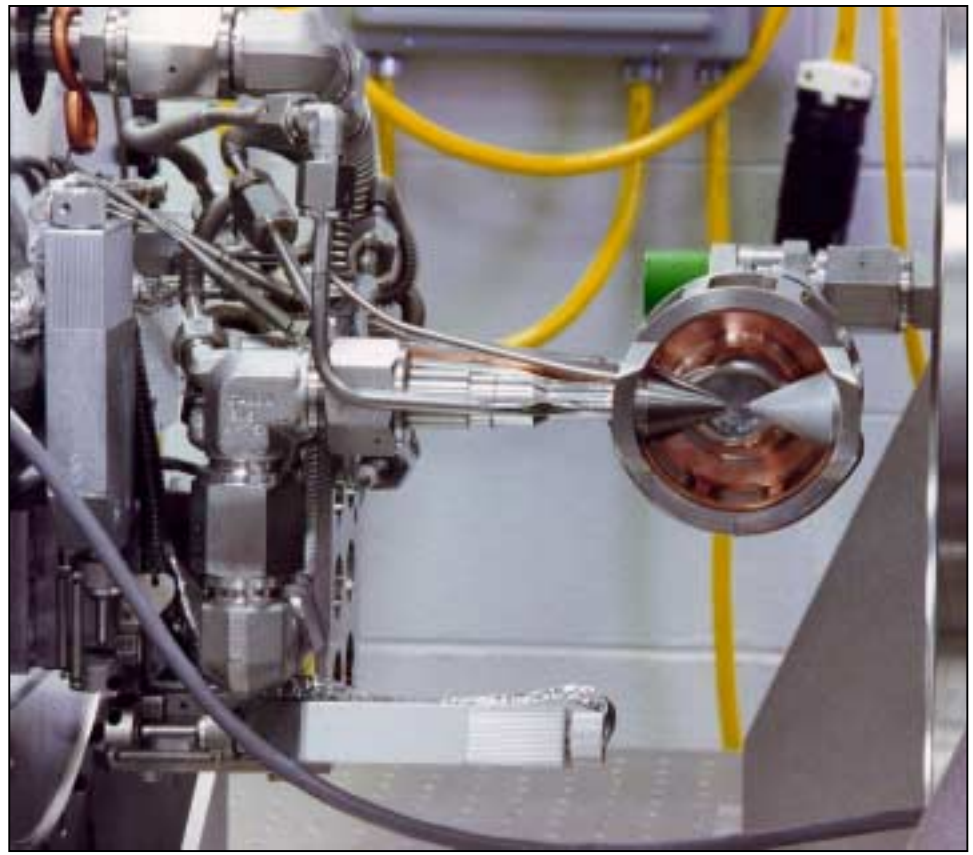




Comparison of Laser Induced Fluorescence (LIF) measurements & theoretical calculations for a sonic nozzle

Gas Jet Target Subsystem Hardware





AES gas system delivered to VNL showing vacuum tank, pumps and close-up of target zone arm

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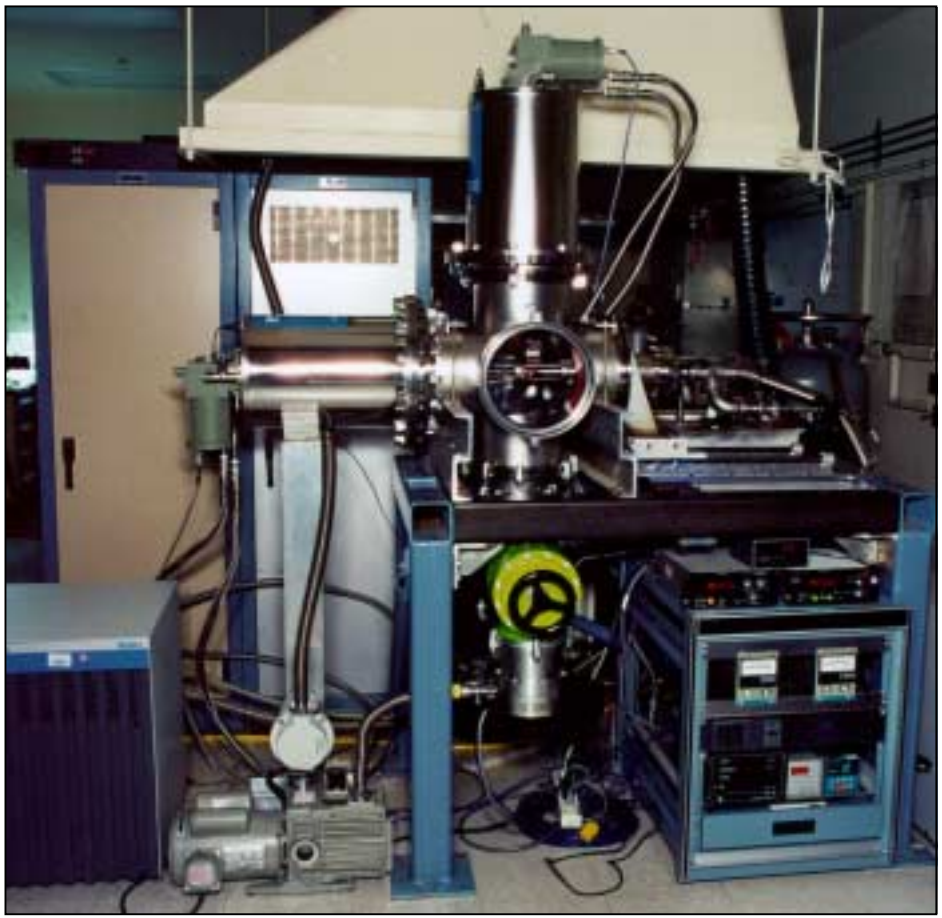
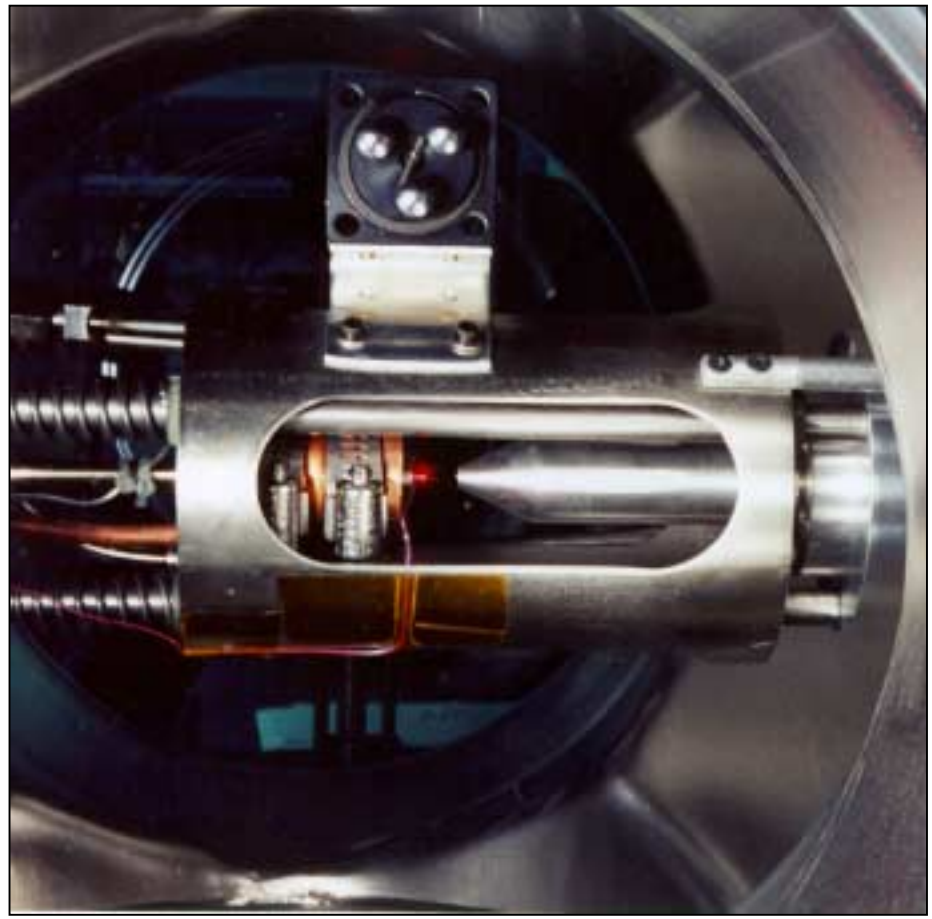
AES Gas Jet Test Stand





Nozzle & diffuser test chamber - Long Island, NY

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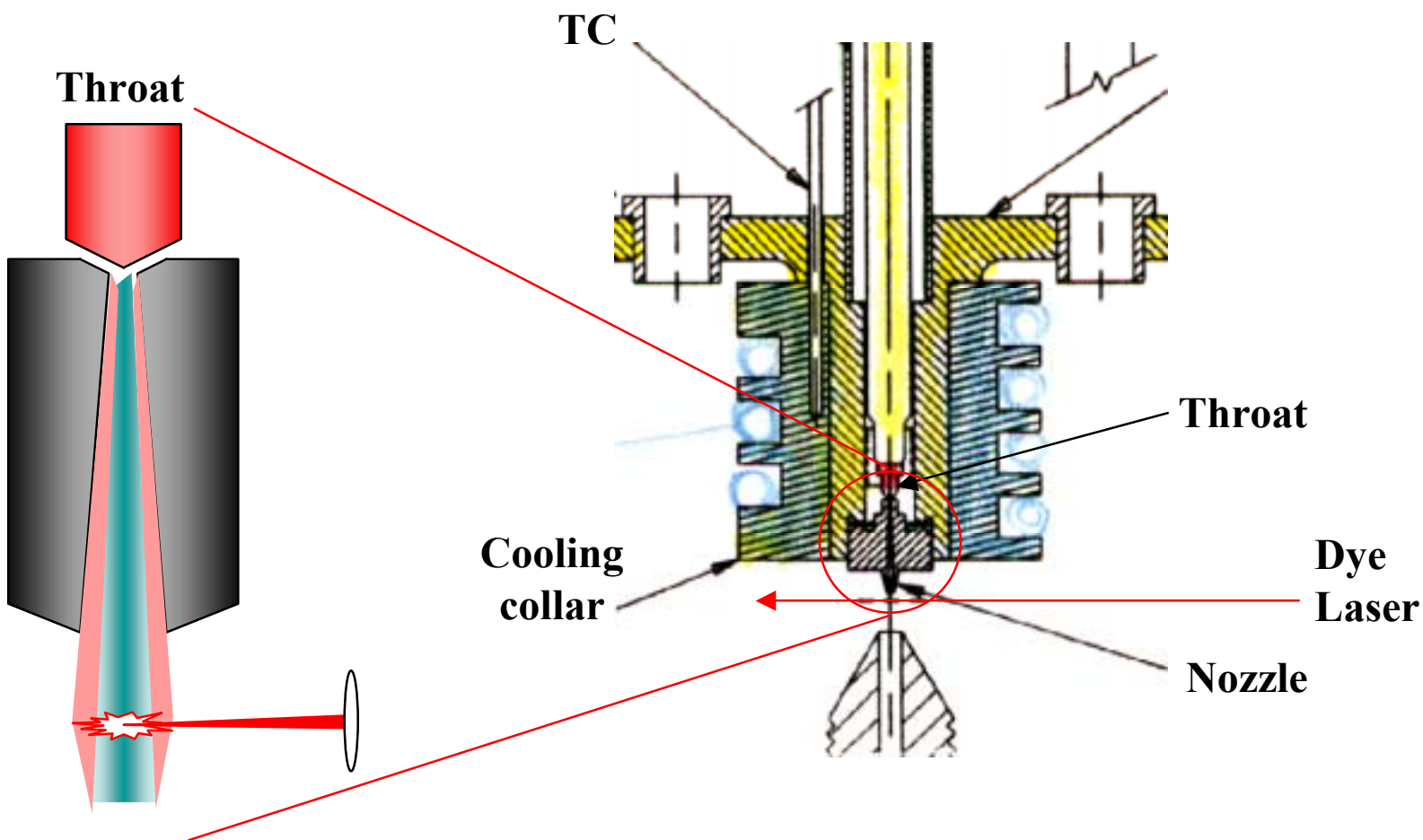
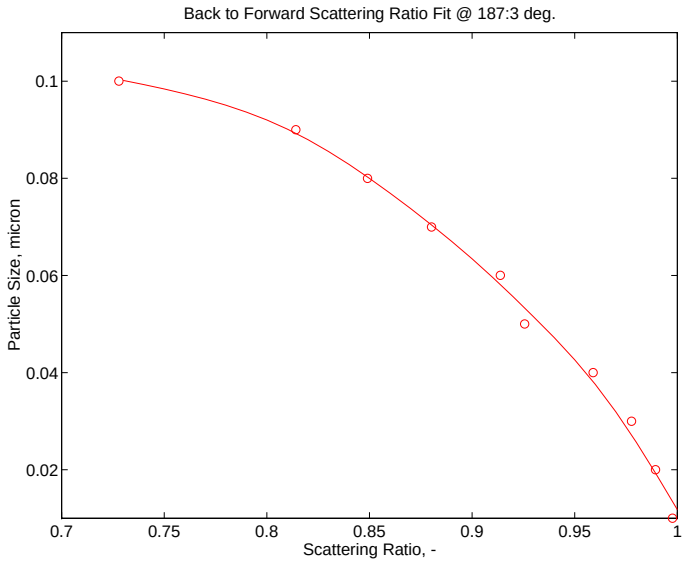
AES Cluster Formation Studies

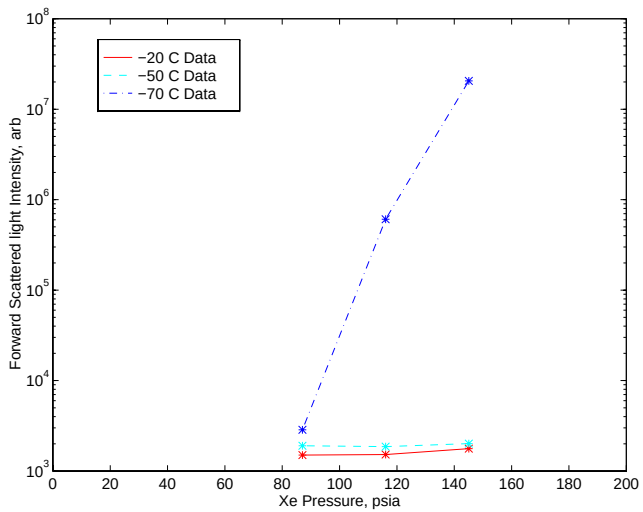
Light scattering is being used to infer cluster size

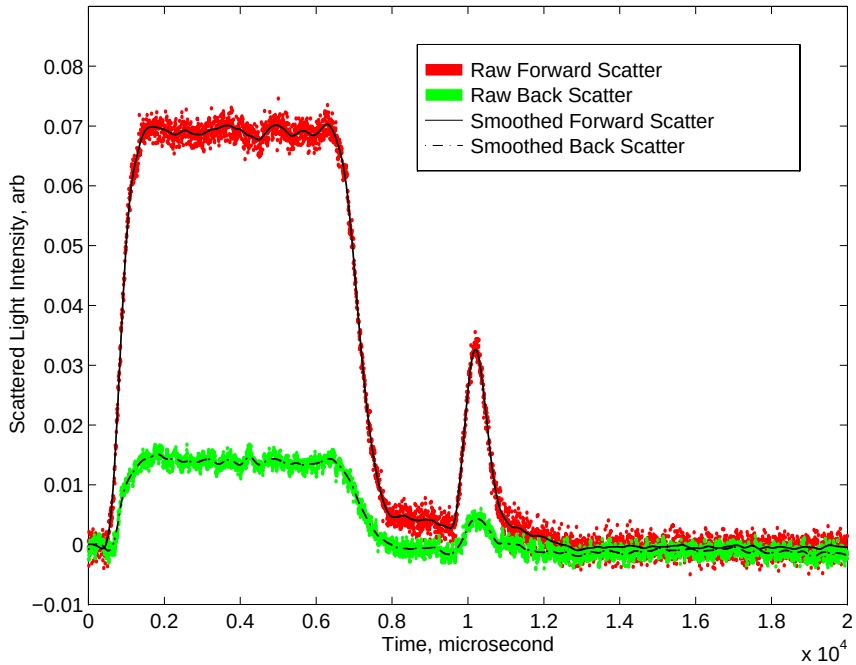


Light Scattering Experiments



- **Particle size related to forward/backward scattering ratio**
- **Time dependent Mie scattering data used to study cluster evolution**





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Future Directions

- **Perform fast pulser experiments to complete flow characterization and optimization**
- **Optimize nozzle and diffuser geometry with respect to the target location for optimum EUV conversion efficiency, gas recycling and minimum debris production**
- **Improve high heat flux nozzles and diffusers to achieve the required number of cycles within the debris tolerance specification of the optical components**