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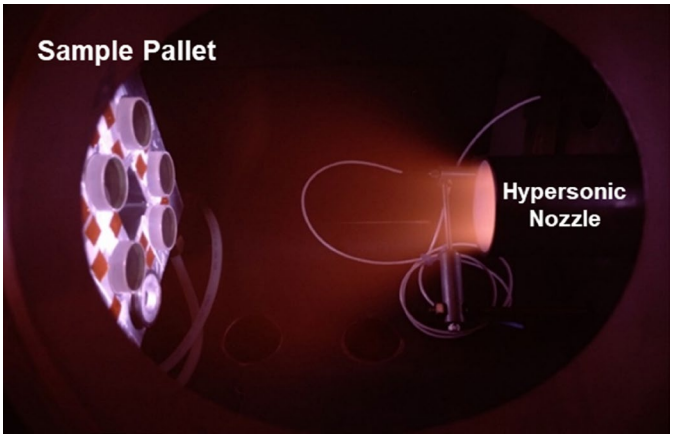
FAST™ Atomic Oxygen Source

Atomic Beam Source for Simulating Low Earth Orbit Conditions
PSI's Laser Detonation Source is the Gold Standard in AO Testing

FAST AO Source Chamber (Left) and Controller (Right).



Samples exposed to 5 eV atomic oxygen in FAST

Overview

Satellites in low earth orbit (LEO) at altitudes greater than 200 km sweep through a rarified atmosphere composed primarily of atomic oxygen (AO). Even though the atomic oxygen density is. very low (10^6 to 10^{10} cm^{-3}) at these altitudes, high incident fluxes (10^{12} to 10^{16} $/cm^2/s$) of energetic (5 eV translational energy) oxygen atoms are generated due to the orbital velocity (7.8 km/s). PSI developed and patented (US patent 4,894,511) its FAST™ technology in 1985 in response to NASA's call for ground-based test facilities capable of producing high flux atomic oxygen at ~ 8 km/s. To this day, the FAST technology remains the gold standard for simulating the interaction of spacecraft materials in the LEO environment.

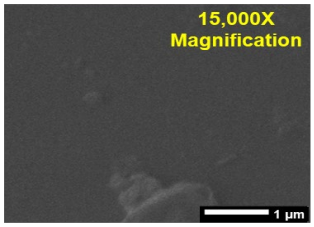
Comparison of FAST to LEO environment

FAST™ AO Source	LEO
5 eV O-atoms	5 eV O-atoms
10^{-4} UV/VUV photons/atom	Match at ~230 km
<30 mJ thermal load	140 mW thermal load
10^{-2} O^+/O	Match at ~ 600-800 km

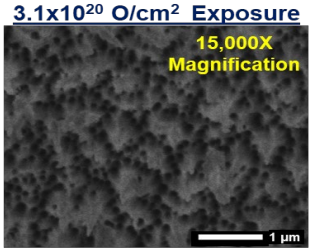
FAST Source Features

- **Tunable velocity**: 5 – 12 km/s
- **Velocity control:** Better than 2% of set point
- **Accelerated testing**: 1 day in FAST equals up to 300 days in LEO (space station at 400 km)
- **Large area testing**: Up to 1600 cm^2 (45 cm diameter) at reduced fluence
- **Dedicated control system**: Automated velocity control via in-situ diagnostics
- **Comprehensive LEO Simulation**: oxygen atom, oxygen ion and UV fluence

Untreated Kapton



$3.1x10^{20}$ O/cm^2 Exposure



Atomic Oxygen Testing Services

- **Turn-key AO Source:** PSI provides AO source + controller for installation on customer's chamber
- **Turn-key System**: PSI builds complete system to customer's specification
  - AO source, vacuum chamber, pumping system + integrated control system
- **Accelerated testing**: Samples exposed to customer specified 5 eV AO fluence
  - To date: AO Test fluences up to $6x10^{21}$ cm^{-2} (3 years at space station)
  - Measure erosion rate + surface effects

AO Source Technical Specifications	
Parameter	**Specification**
Tunable AO Peak Velocity[1] : km/s	5 – 12
Velocity Error[2]	≤ 1.9%
Centerline Fluence[1,3] : /cm²/pulse	$1.7x10^{15}$
AO Beam (±5% Variation)[3]: cm	12
Source Repetition Rate[4] : Hz	1-10

[1] CO_2 pulse energy: ≥ 10 J/pulse, [2] 100 pulse average, [3] Axial distance = 30 cm.
[4] Facility pumps to maintain mean free path to > test axial distance

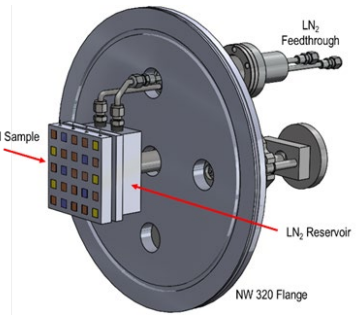
AO Source Applications:

- **Erosion Rate Measurements**:
  - Validate new materials for their Intended application in LEO
- **AO Impact on Optical Properties:**
  - Measure reflectivity and/or transmission after AO exposure
- **AO Impact on Thermal Properties**: Measure solar absorbance (α) / emissivity (ε) vs. AO fluence
  - Key properties in satellite thermal design
- **Energy Accommodation Measurements**:
  - Assess materials dependent drag in LEO
- **Signature Phenomenology:** UV – LWIR emissions induced by AO induced reactions
  - **Surface Glow:** AO induced emissions from surface reactions, e.g. shuttle glow
  - **Plume Signatures:** Rocket plume species reactions with the LEO atmosphere
    - $O/N_2 + H_2O \rightarrow H_2O(v)$: Collision excitation produces IR emission from vib excited H_2O
    - Measure velocity dependent cross sections in FAST

AO Source Accessories:

- **Temperature Controlled Sample Holder:** Assess temperature dependent AO effects
  - -100 C to +250 C
  - ±1 C precision
- **Solar Illumination:** 1-sun during AO exposure
  - Assess synergistic effects: e.g UV + AO
- **Quartz Crystal Microbalance**:
  - In-situ AO fluence monitor
- **Langmuir Probe**:
  - In-situ oxygen ion (O^+) monitor
- **Customer Specified:**
  - PSI designs to meet customer requirements

Temperature Controlled Sample Holder



AO Fluence and Beam Φ vs. Axial Distance