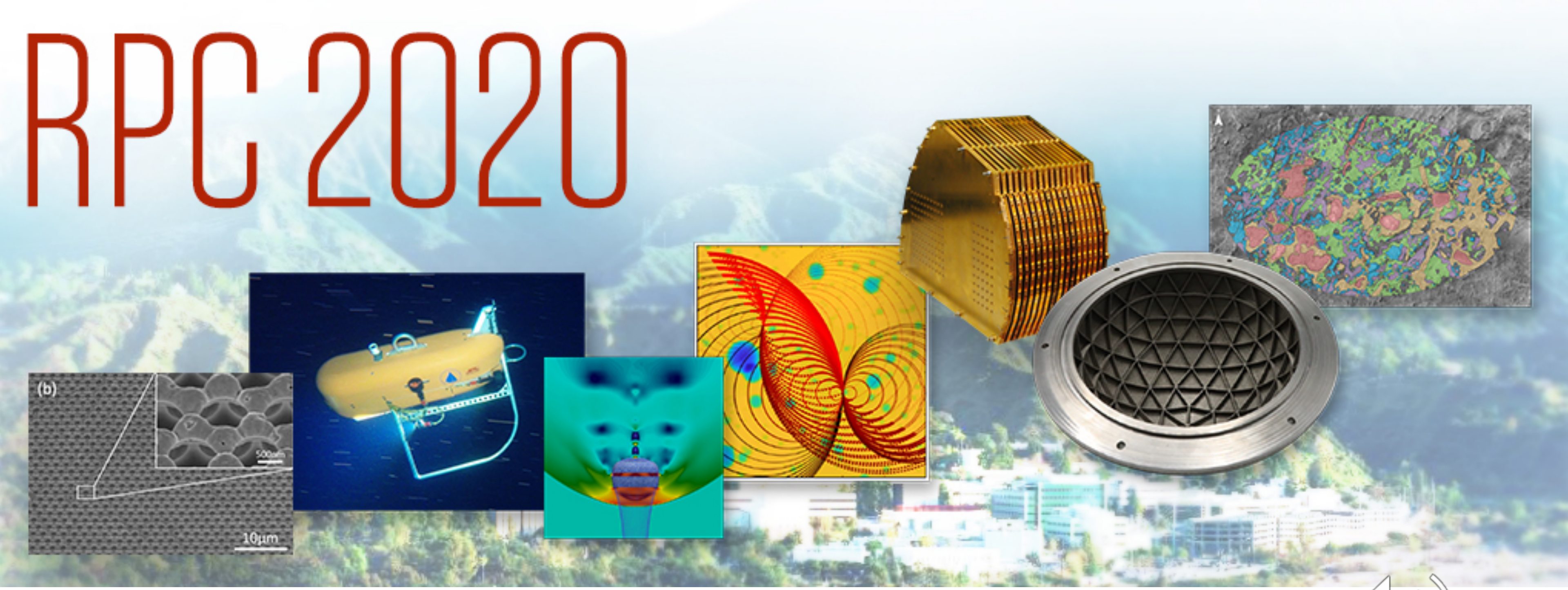


Virtual Research Presentation Conference

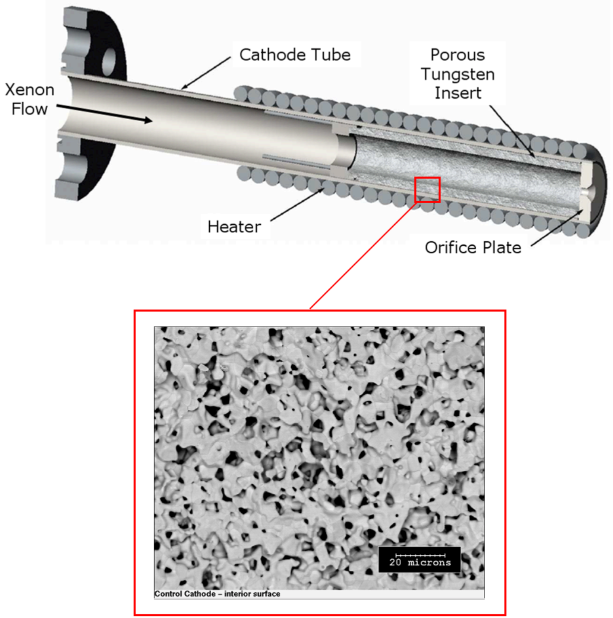
Validation of Barium Recycling in Hollow Cathodes for Electric Propulsion

Principal Investigator: Dr. Jay Polk (353)
Co-Is: Prof. Azer Yalin (Colorado State University)
Program: Spontaneous Concept

RPC-244

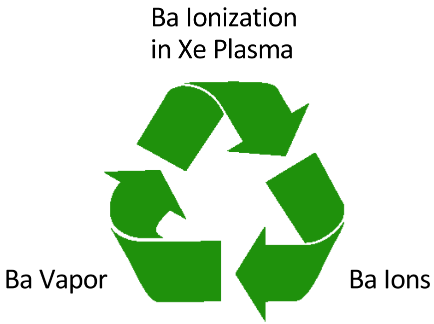
Jet Propulsion Laboratory
California Institute of Technology

Tutorial Introduction



Abstract

Hollow cathodes used as electron sources in electric thrusters use barium to reduce the work function of the tungsten electron emitter surface, allowing it to operate at lower temperatures (around 1100°C instead of 3000°C). The barium evaporates from the emitter and must be replenished from reduction of a barium-containing compound which is loaded into the porous tungsten emitter. Models of barium transport through the interior xenon plasma show that barium is very effectively recycled; neutral barium evaporated from the surface is ionized in the intense xenon plasma and pushed back to the surface by the electric field. This work focused on demonstration of a Cavity Ring-Down laser absorption Spectroscopy (CRDS) method to measure neutral and ionized barium densities to validate key model features.

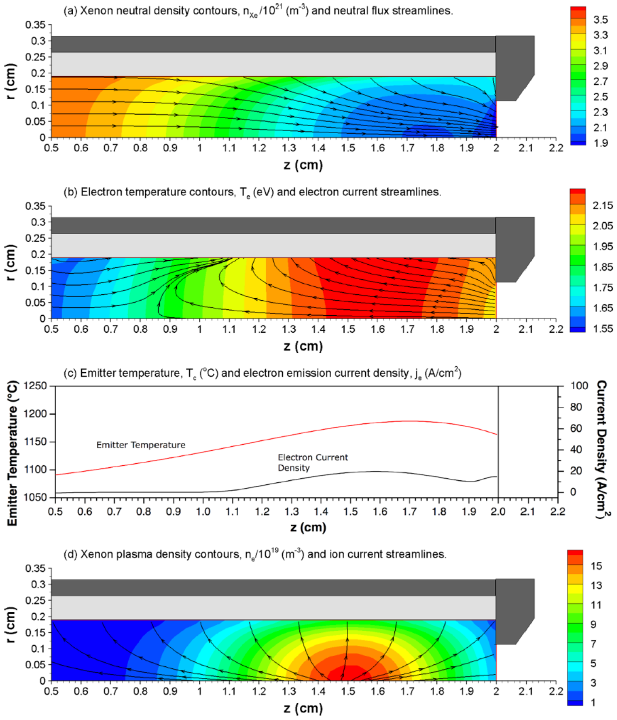


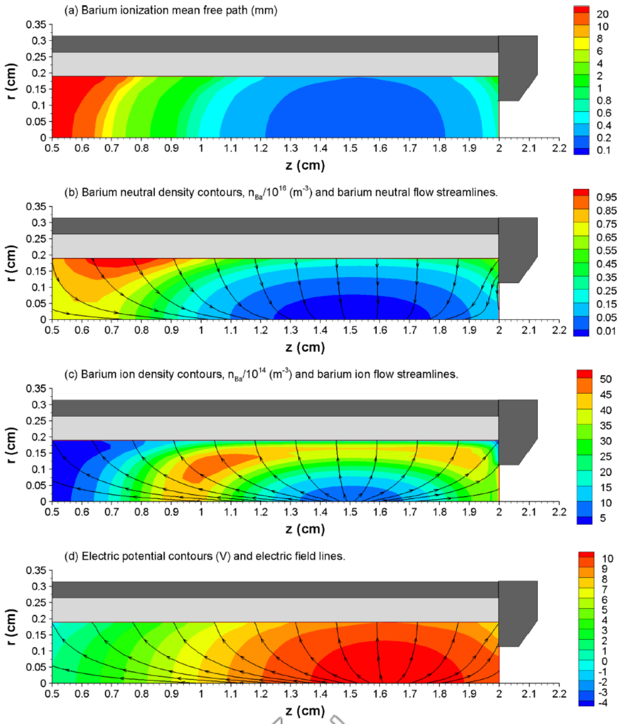
Problem Description

- **Understanding potential cathode failure modes is critical to managing risk in missions using electric thrusters**
  - The ion engines on the Dawn spacecraft used a hollow cathode to create the plasma and a second one to neutralize the ion beam
  - The Hall thrusters on the Psyche mission will use a single hollow cathode for both functions
  - Electron emitter lifetime is primarily determined by its operating temperature
  - Understanding material transport processes is the key to determining how temperature will change over time
- **This effort advances the state-of-the-art in modeling barium transport**
  - Models of the interior xenon plasma are relatively mature and well—validated
  - Models of barium transport through the xenon plasma agree well with life test data on barium consumption, but key model features have not been experimentally validated
  - The CRDS method under development will allow intermediate model parameters to be validated
- **CRDS combined with the modeling gives JPL a technical edge in developing electric thruster component technologies and managing risk on missions**

Modeling Barium Transport

- A state-of-the-art hollow cathode plasma simulation code predicts a high density, high temperature region in the cathode interior
- A model of barium transport in this xenon background plasma reveals a very high probability that barium gets ionized in the dense xenon plasma
- The internal electric field pushes those ions back to the surface where they are needed
- When the cathode is heated prior to ignition, the interior will have only barium neutrals
- When the plasma is ignited, the neutral density drops dramatically

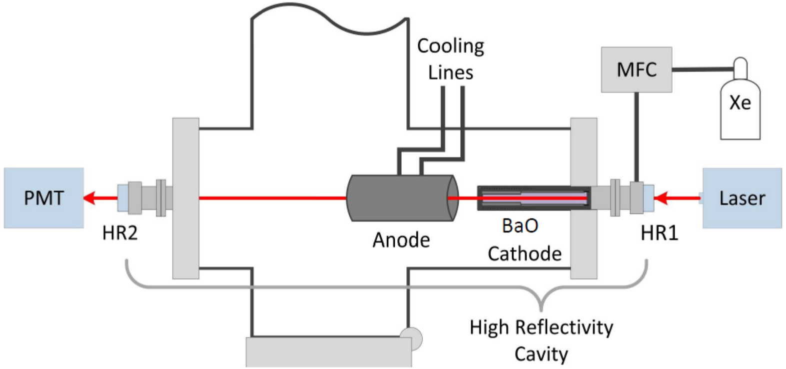




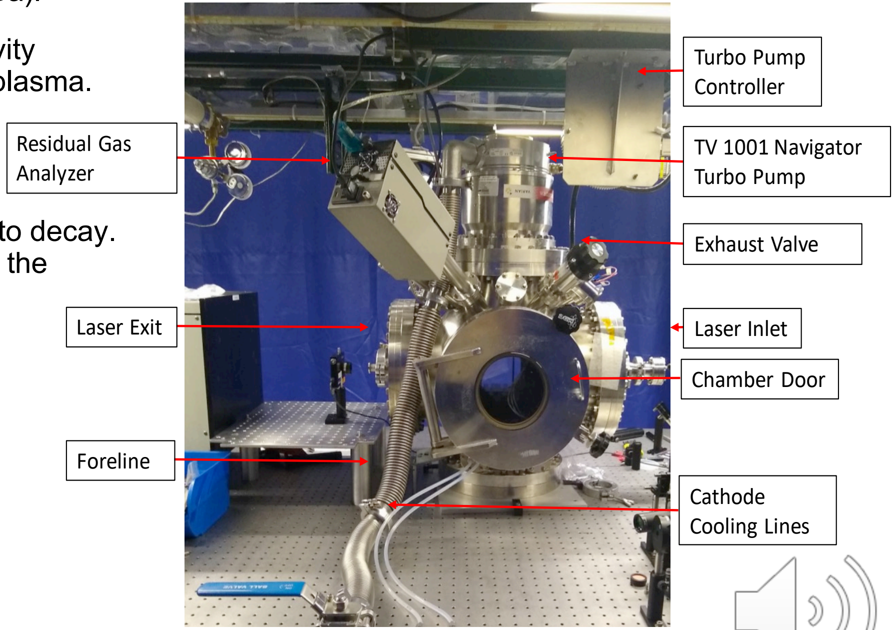
Key model predictions that CRDS can validate

Cavity Ring-Down Spectroscopy to Measure Barium

- A tunable, pulsed optical parametric oscillator (OPO) laser provides light at either 553.5 nm (for neutral barium) or 455.4 nm (for ionized Ba).
- A laser pulse is injected into a cavity formed by two high reflectivity mirrors, so the beam makes many passes through the cathode plasma.
- A small fraction of the light leaks out of the rear mirror and is measured by a photodetector.
- Absorption of photons by Ba neutrals or ions causes that signal to decay. The decay time constant can be related to known constants and the path-integrated species density.



Schematic of the cavity ring-down spectroscopy setup



Vacuum facility that contains the cathode and the optical cavity

Results

- **Accomplishments versus goals**
  - ✓ Design of the particular absorption scheme and performance modeling
  - ✓ Acquisition of parts, setup of the facility and optics, development of data processing method
  - ☐ Cavity tuning and demonstration of technique on a hollow cathode (COVID-19)
- **Significance**
  - Prepared to demonstrate a new and unique measurement capability
  - Measurements will demonstrate feasibility of the technique
- **Next steps**
  - Install a barium cathode in the chamber
  - Align the optical cavity
  - Perform CRDS with heating only and with a plasma discharge
  - Compare with model results

References (CRDS and Applications to Electric Propulsion)

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