National Aeronautics and Space Administration

Measurement Of Erosion Product Densities In Lanthanum Hexaboride (LaB_6) Cathodes to Validate Life Models

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Program: Innovative Spontaneous Concepts

- **Project Objective:** To develop in situ Cavity Ring-Down Spectroscopy (CRDS) to measure lanthanum density in lanthanum hexaboride (LaB_6) hollow cathodes, including both lanthanum neutrals and ions, to help validate existing plasma models of the LaB_6 cathode. Quantitative chemical analysis of the species of interest in the plasma presents two major challenges: the extreme dilution of lanthanum in the plasma which requires extreme measurement sensitivity, and the lack of access to the interior plasma region given the compact geometry of the cathode assembly. CRDS was identified as the most promising technique to address these two constraints and enable the critical measurements of lanthanum species in the cathode interior.

FY18/19 Results: A laboratory-model cathode is mounted in the vacuum chamber within a high-finesse optical cavity formed from two high-reflectivity mirrors (R>0.9999), Figs. 1 and 2. The broadly tunable OPO laser is coupled into the cavity and passes back-and-forth many times within it. Upon each reflection at the rear mirror, a small fraction of the cavity light leaks out to a photodetector which measures the decay of intensity within the cavity. By fitting these “ring-down” decay signals we determine the absorption coefficient, from which the path integrated number density is determined. For the cathode configuration, we assume that the species are present over a length of ~1 cm to infer actual density from the path-integrated value. Simulations based on spectroscopic constants yield a detection limit of ~10^7 cm^{-3} for lanthanum neutrals and ions.

Scans with the cathode heater only and with a xenon discharge did not yield absorption peaks due to lanthanum (Fig. 3, for example). From the noise level in the measurements we can determine the maximum (upper-bound) concentration of lanthanum as ~10^7 cm^{-3}. Excited states of xenon could be detected (Fig. 4), which is useful for quantifying singly-ionized xenon densities in the plasma.

The results show that CRDS can be performed on the hollow cathode geometry, with the xenon measurements demonstrating clearly that the challenge of optical access can be met. The results show that we need even lower detection limits, which points to the need for continuous wave CRDS, which should allow detection of lanthanum densities below 10^6 cm^{-3}.

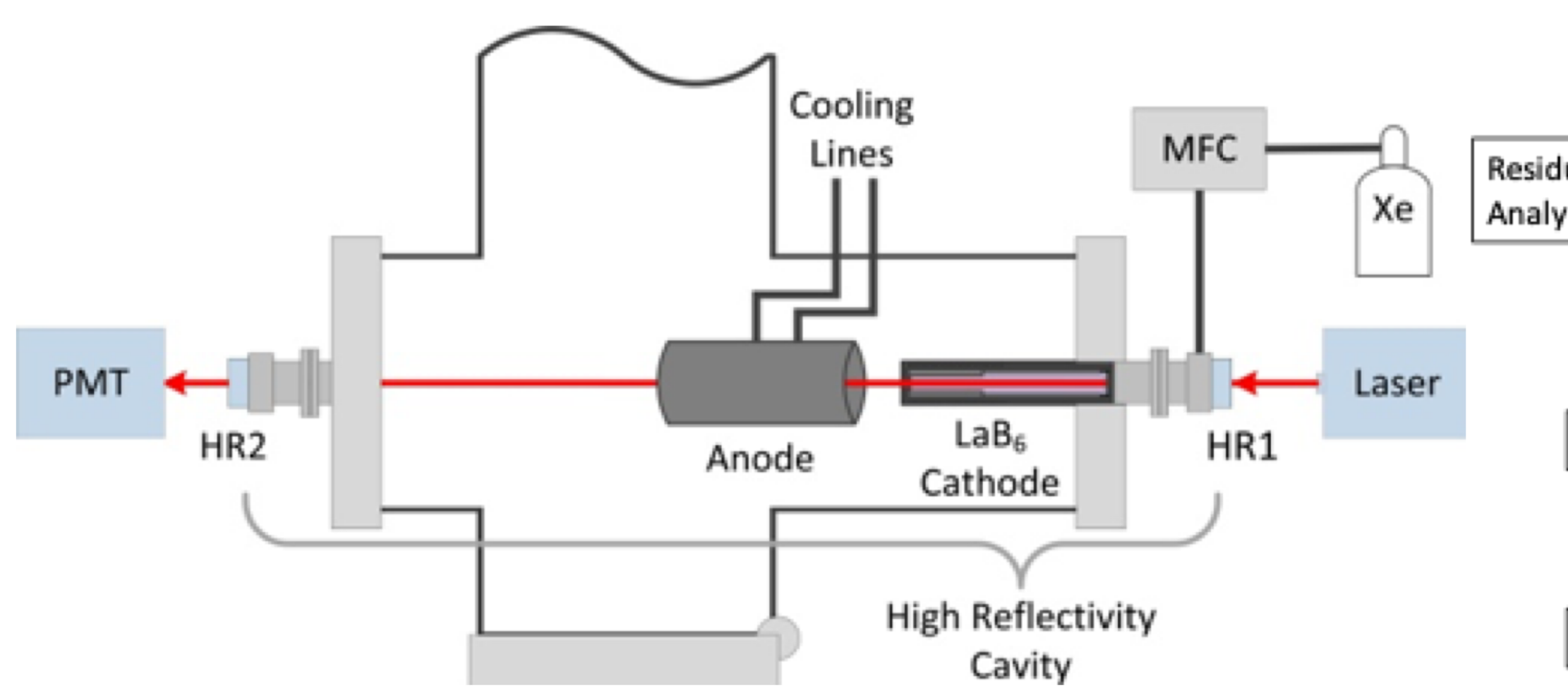

Fig. 1: Schematic of the pulsed CRDS lanthanum experiment. The CRDS optical axis (beam diameter ~1 mm) is aligned along the centerline of the LaB6 hollow cathode with cavity high reflectivity (HR) mirrors surrounding the cathode. The cavity decay is monitored via a photomultiplier tube (PMT) after HR2.

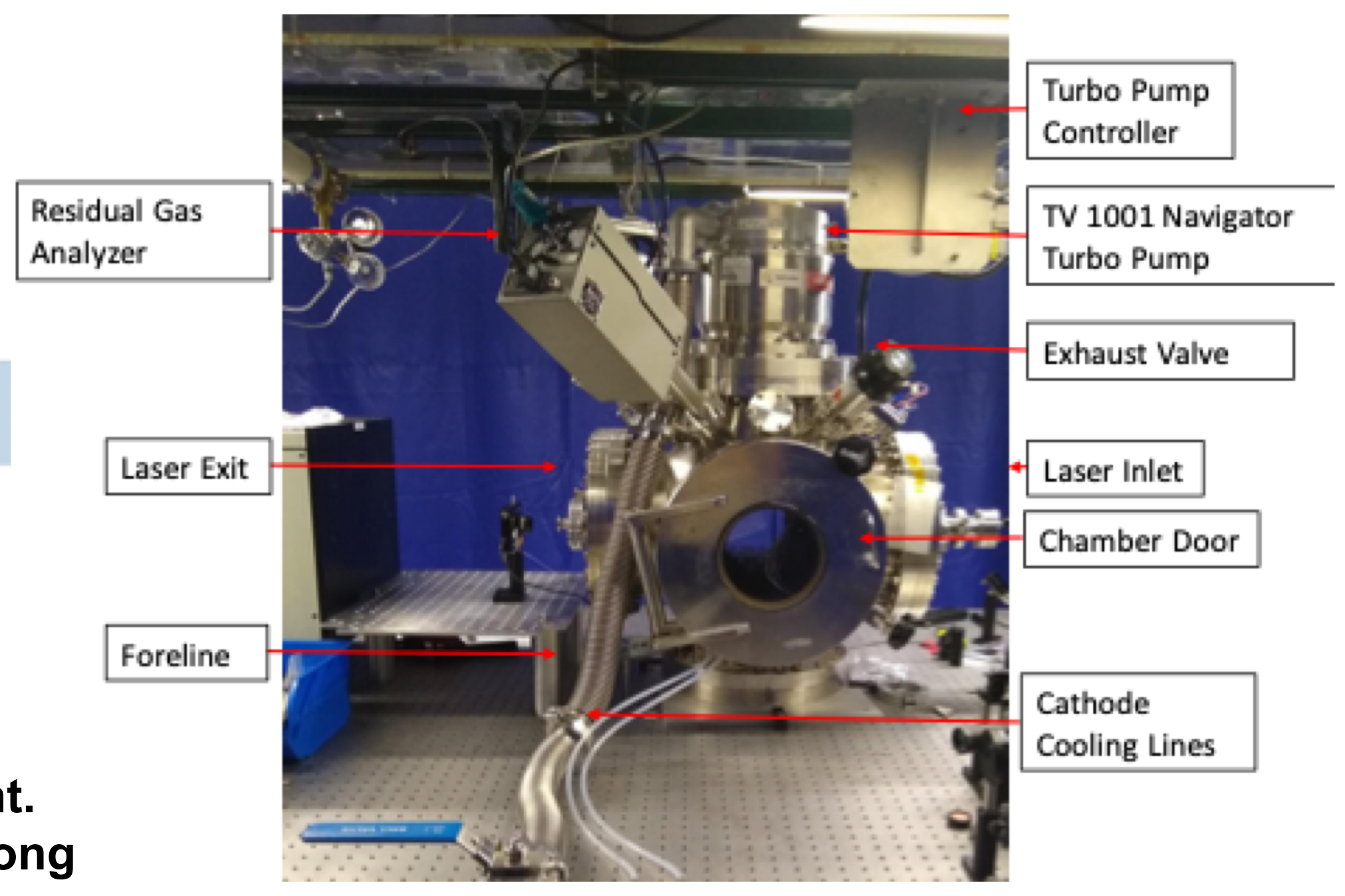

Fig. 2: Photograph of the pulsed CRDS lanthanum experiment.

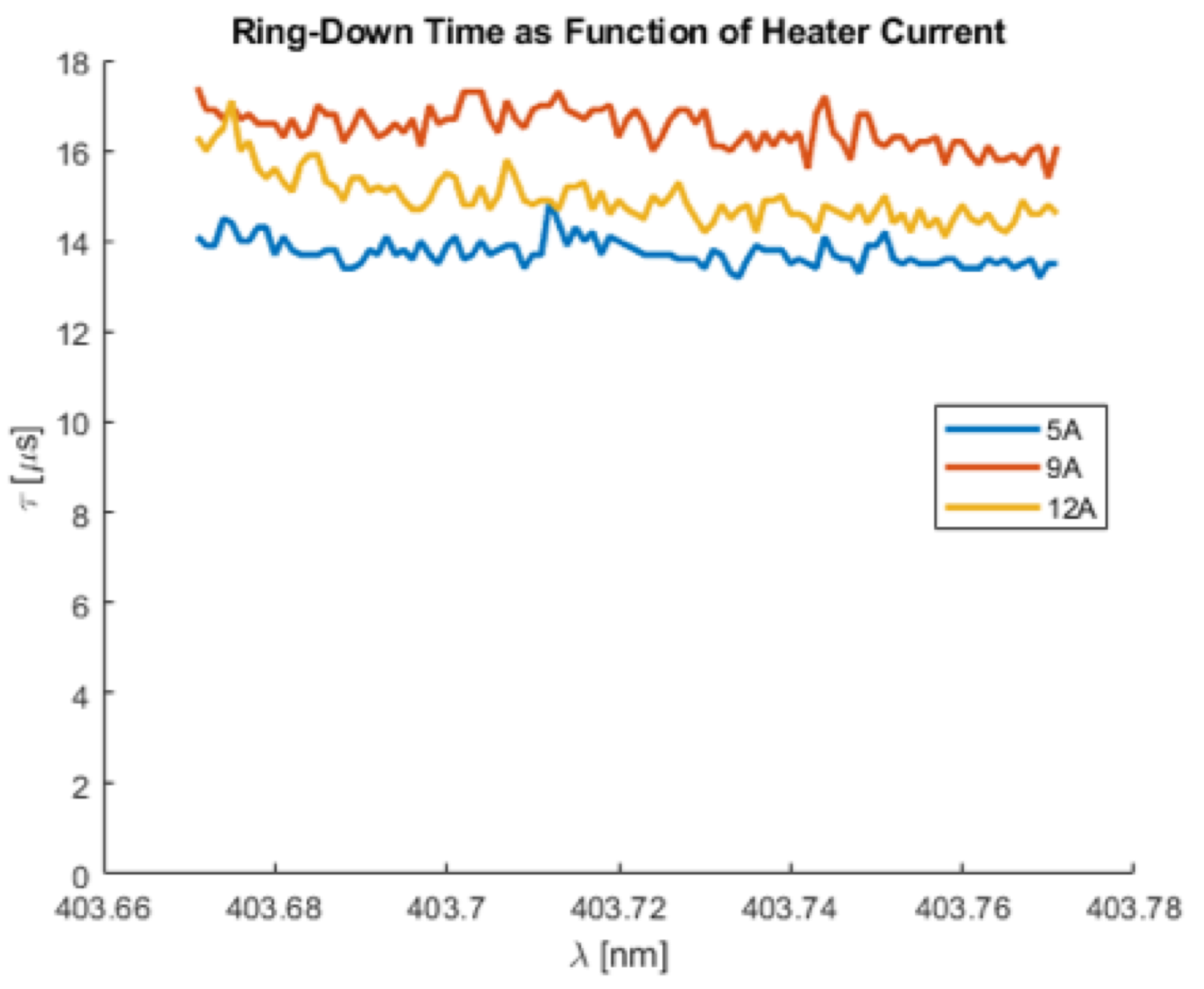

Fig. 3: CRDS scans (signal decay constant) in the spectral region of neutral and ionized lanthanum. The scans do not reveal the presence of absorption lines and imply a maximum neutral lanthanum density of ~10^7 cm^{-3}.

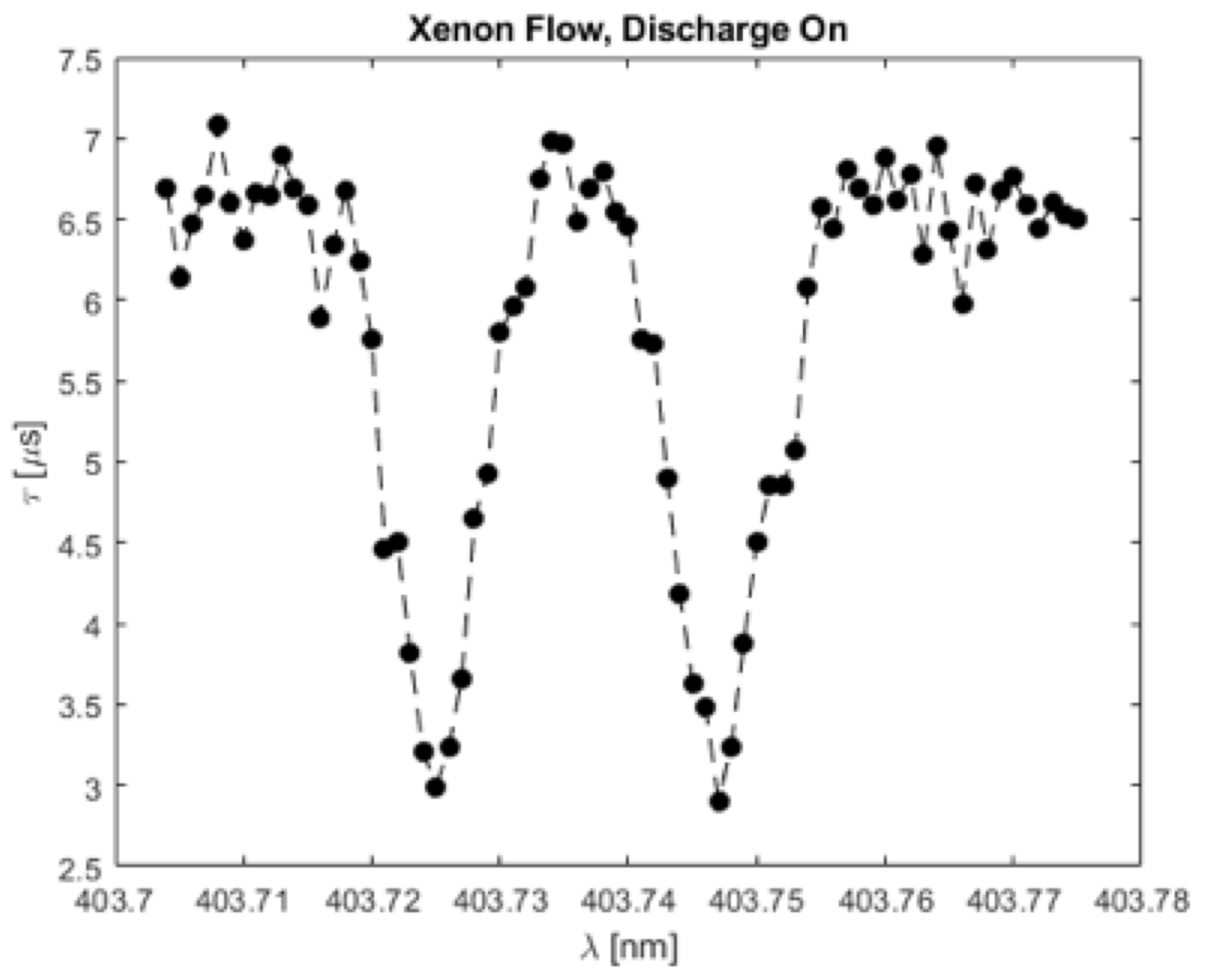

Fig. 4: CRDS scans in the spectral region of ionized xenon.

Benefits to NASA and JPL: Lanthanum hexaboride hollow cathodes show great potential for electric propulsion given their resilience against erosion and contamination compared to conventional barium oxide cathodes. However, the chemical processes that govern the electron emitter surface chemistry evolution and operating temperature are still unknown. The quantification of the neutral and ion erosion products such as lanthanum in the plasma is a key measurement. This knowledge, combined with results from JPL simulation codes, will enable prediction of emitter erosion and cathode lifetime. The results of the proposed effort will provide key ammunition for proposals on next generation electric thrusters using the more robust LaB_6 cathodes. Quantification of the lanthanum density will provide a more fundamental understanding of the erosion product transport and will inform future design and operation of LaB_6 cathodes to meet the demanding requirements for future deep space missions. The results of this effort set an upper bound on the lanthanum density of about ~10^7 cm^{-3}, which is about a factor of three lower than we would expect based on the evaporation rate at 1400° C. This suggests either a lower operating temperature or a lower evaporation rate at a given temperature, both of which indicate longer cathode life than anticipated. Future modeling results will have to be consistent with this upper density limit.

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