Line Integrated Barium Absorption Spectroscopy Along Cathode Axis

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Introduction

Hollow Cathode Assemblies (HCA) are used for plasma production and beam neutralization in gridded ion engines and Hall thrusters. The lifetime of HCA in many cases determines the overall lifetime of the thruster. Both lanthanum hexaboride and oxide impregnated tungsten are used as emitter material for most common HCAs. The lifetimes of both cathodes are is effected by the state of the emitting surface, which is characterized by a mean work function. Due to erosion, evaporation, and thermochemical processes, the work function tends to increase over time, leading to loss of cathode function. Future thrusters will require higher emission currents and longer lifetimes. Qualifying new electric propulsion devices currently requires expensive life-time testing. A more desirable qualification process relies on simulation, but such models must be rigorously verified and tested against experiment. This work focuses on gaining insight into the barium supply within the insert region of a barium oxide impregnated tungsten emitter HCA. Through the use of absorption spectroscopy, we aim to monitor the population of ground state barium in the gas phase within the HCA.

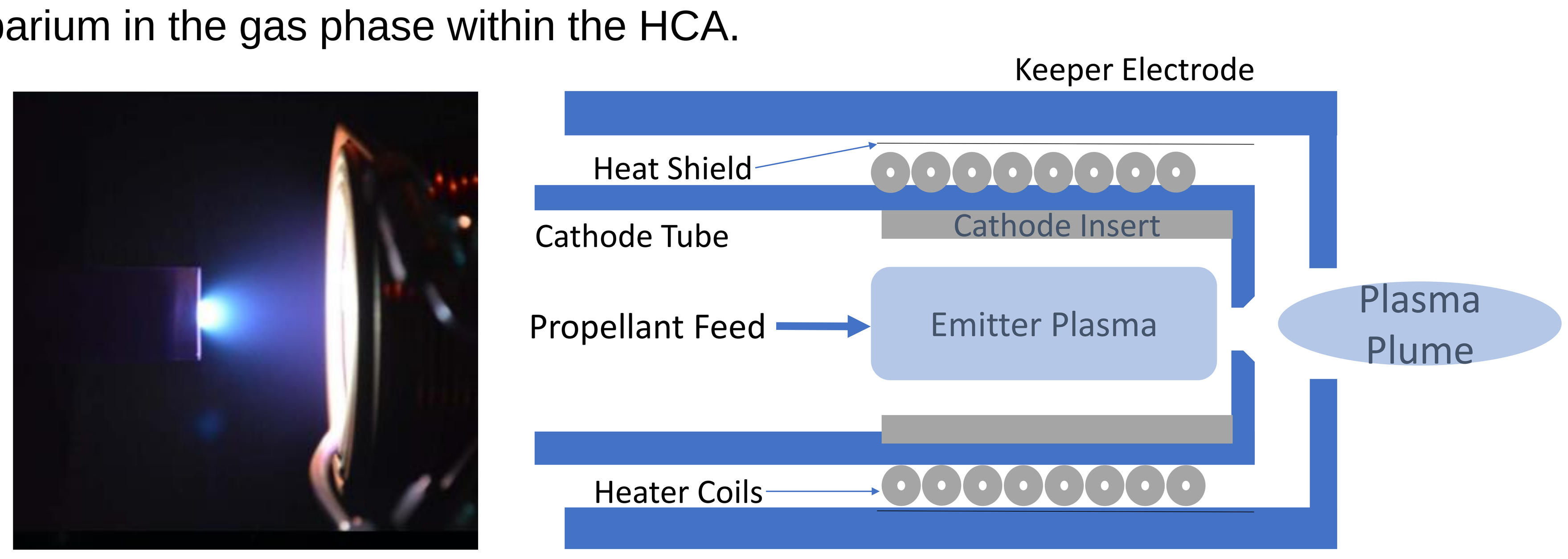

Figure 1: Hollow Cathode in operation with an annular (left). HCA schematic showing the cathode tube, inset, and heater enclosed in a keeper (right).

Diagnostic Concept

1. Gas phase barium density can be measured using absorption spectroscopy.
2. Classic setup featuring a Xenon arc lamp used as a broadband light source.
3. Spectral window for absorption measurements selected using a small monochromator.
4. Resulting spectrum analyzed using the equivalent width method.
5. Benchtop demonstration will be used to validate the method before direct application to measurement with an HCA.

Absorption Theory: Equivalent Width

1. Equivalent width represents the width of a rectangle of equal area to that of the absorption profile and the same height as the continuum in the vicinity of the spectral feature.

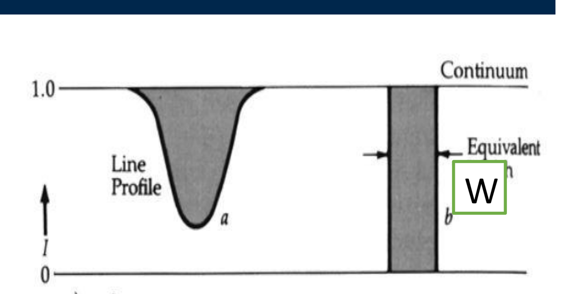

Figure 2: Equivalent width example spectrum.

2. Density of the absorbing species is related to equivalent width:

$$W = \int d\nu \left[1 - \frac{I(\nu)}{I_0}\right] = \int d\nu [1 - e^{-P(\nu - \nu_0)X}]$$

3. In the optically thin regime, the absorbing species number density is:

$$N = W * \frac{8\pi\nu^2}{Xc^2A}\left(\frac{g_l}{g_u}\right)p$$

Experimental Setup

Below is the experimental setup of the benchtop demonstration. In this setup, the we use an optogalvanic cell with Xenon fill gas and Barium electrodes as an absorption medium. This will allow us to validate the concept before implementation with an HCA.

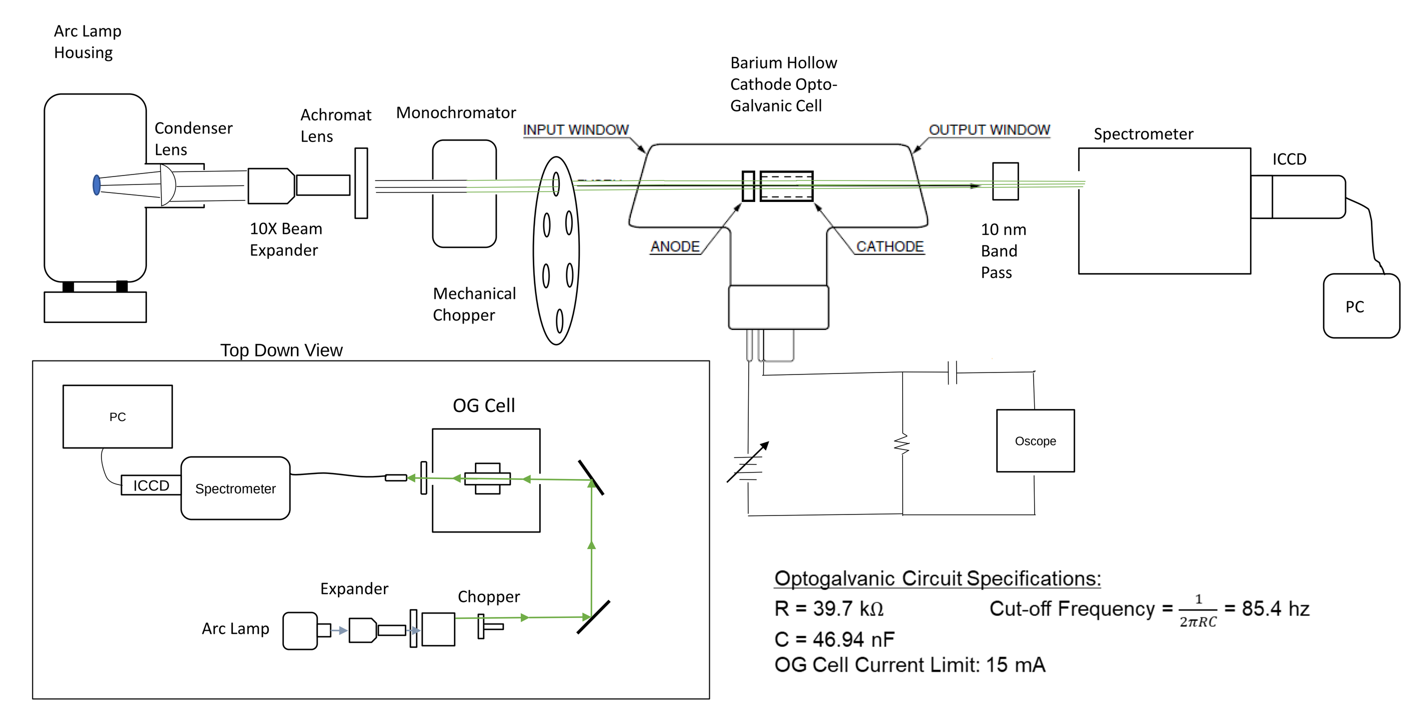

Figure 3: Experimental setup for bench top demonstration using an optogalvanic cell as the absorbing medium.

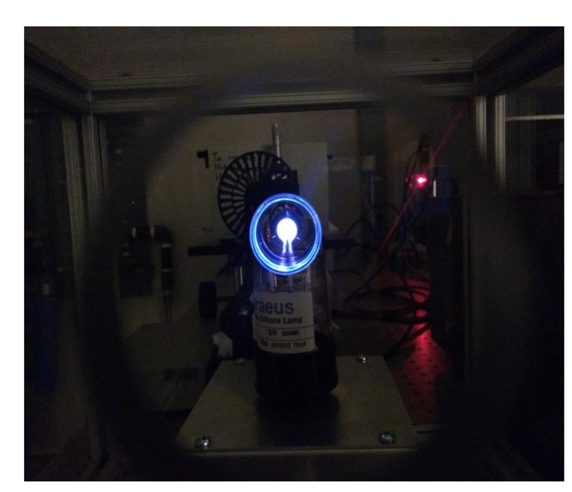

Figure 4: Optogalvanic cell in operation.

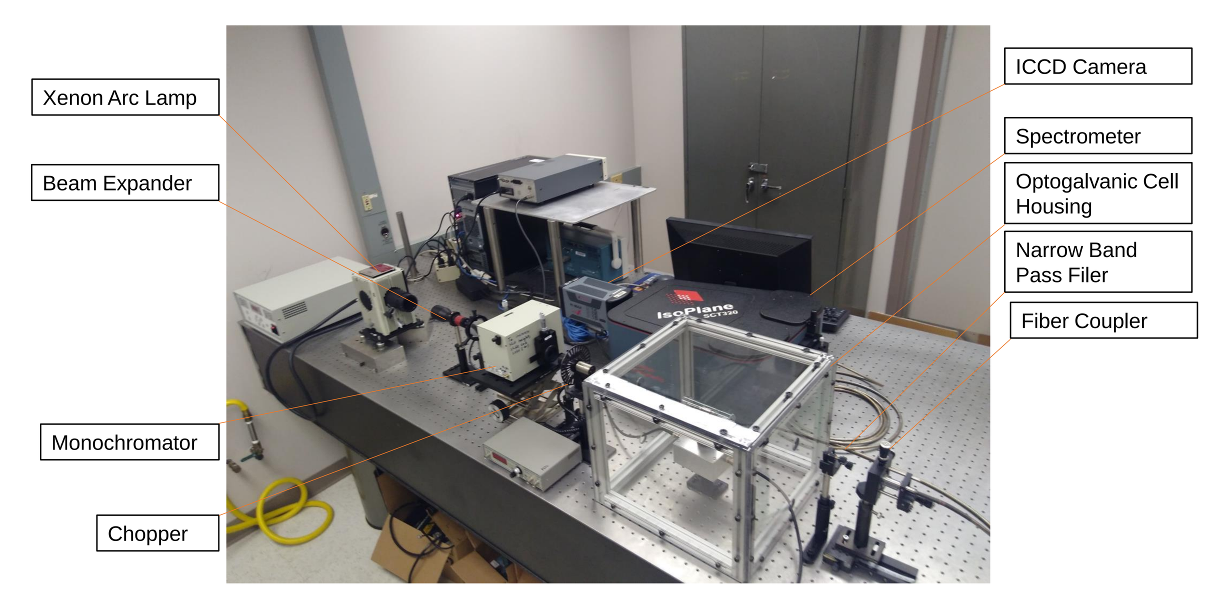

Figure 5: Photograph of benchtop setup.

Light produced in the Xenon arc lamp is passed through a monochromator to obtain a narrow spectral window. It is then focused through a mechanical chopper and through the absorbing medium. It is then filtered using a narrow band pass filter. Lastly, the light is collected in a spectrometer and the signal recorded by and ICCD. The spectrum is then analyzed using the equivalent width method.

Conclusions

This project seeks to obtain HCA experimental data in order to inform models used for lifetime qualification of new high power, long duration HCA designs. The development of a Barium absorption diagnostic will provide volume averaged Barium density data. This project is to take place in two phases, a benchtop demonstration phase followed by implementation with an operational HCA. Currently, we are in the benchtop demonstration phase of the project.

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