65th APS DPP Meeting, CP11.00012, 2:00-5:00, October 30th, 2023

Spectral Characterization of an Educational Hall Effect Thruster

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Abstract

An SPT-type Hall Effect Thruster was built by a team of students form several MA colleges [1]. Test operation on Ar and Kr propellants was recently attempted at the Northeastern University Plasma Laboratory. HET was mounted inside the 10 m^3 vacuum chamber with ~10,000 L/s pumping capacity using the infrastructure developed for the BHT-200 [2,3]. Broad NUV-NIR spectra were collected for both propellants. They reveal the presence of neutral atoms, ions, and diatomic molecules. Doppler spectroscopy of a strong Kr ion emission line was attempted using the high-resolution system for non-invasive plasma diagnostics [4]. The collected Ar/Kr data and their analysis will be presented and discussed.

[1] Braden Oh, et al, Design, fabrication, and testing of an undergraduate hall effect thruster, Journal of Electric Propulsion volume 2, Article number: 6 (2023)

[2] O.Batishchev, A.Hyde , J.Szabo, Spectral Characterization of Hall Effect Thruster Exhaust, 62nd Annual APS DPP Meeting, NP14.13, Nov. 11th, 2020

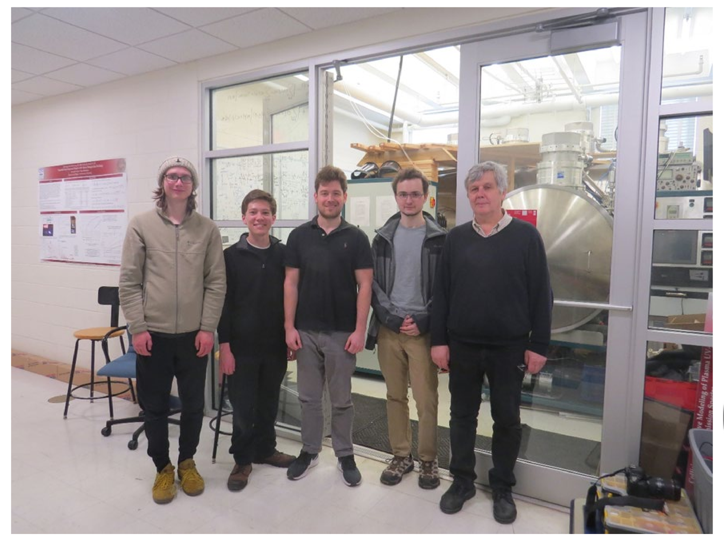
[3] O.Batishchev, A.Hyde , J.Szabo, Spectral characterization of the HET opera-ting on Kr propellant, 63rd Annual APS DPP Meeting, PP11.28, Nov. 10th, 2021

[4] A. Hyde, O. Batishchev, A high-resolution spectroscopic system for remote measurement of plasma parameters, Review of Sci. Instr. 91(063502), June 2020.

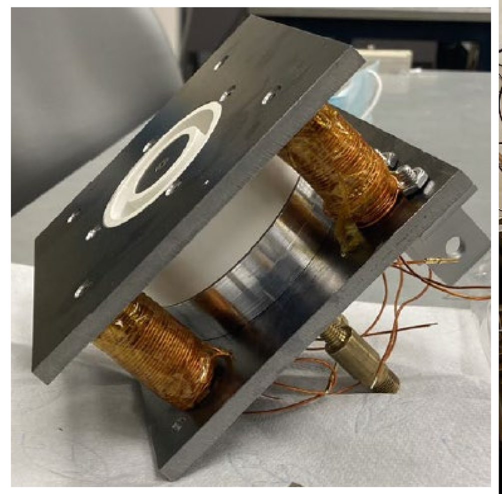
Motivation

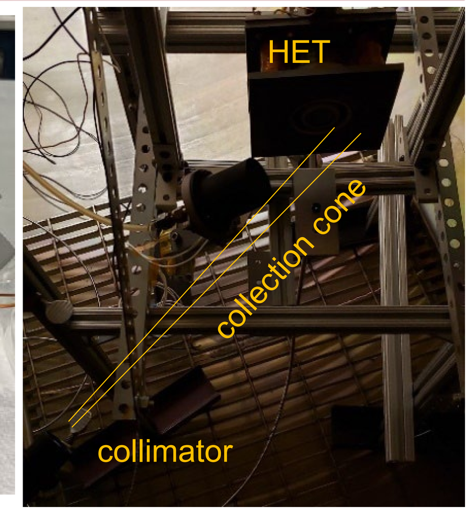
Hall Effect Thrusters are current EP technology employed by both government and industry (Starlink, Kuiper, OneWeb) projects. When a potential difference is applied between the external cathode and anode, electrons travel from the cathode through the discharge channel, inducing an electric field. Electric coils inside the discharge channel create a strong radial magnetic field, effectively slowing down the electrons before they arrive at the anode. Electrons through the ExB drift create a Hall current and ionize neutral atoms such as Ar or Kr that are injected into the channel. The ions are then accelerated by the applied electric field, creating the thrust force. The collected plasma emission spectra from a 200W educational HET with 3D printed epoxy diffuser are analyzed for chemical composition and ion exhaust velocity.

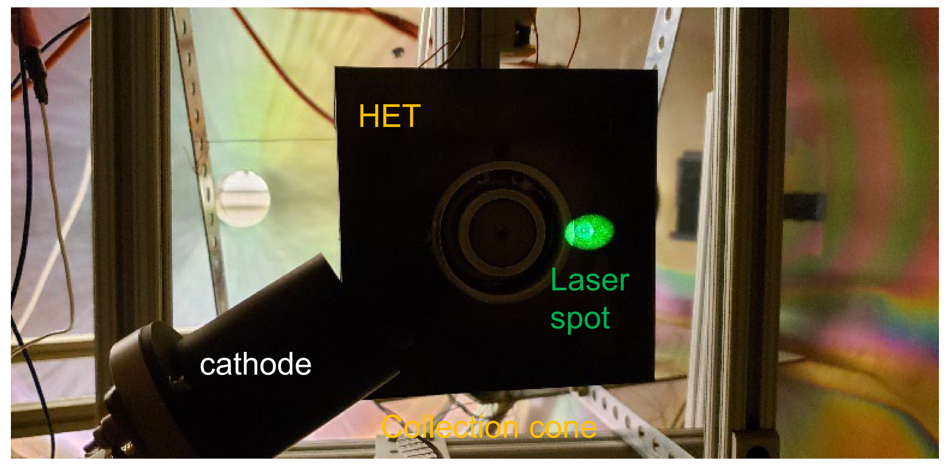
Team at NU Plasma Lab

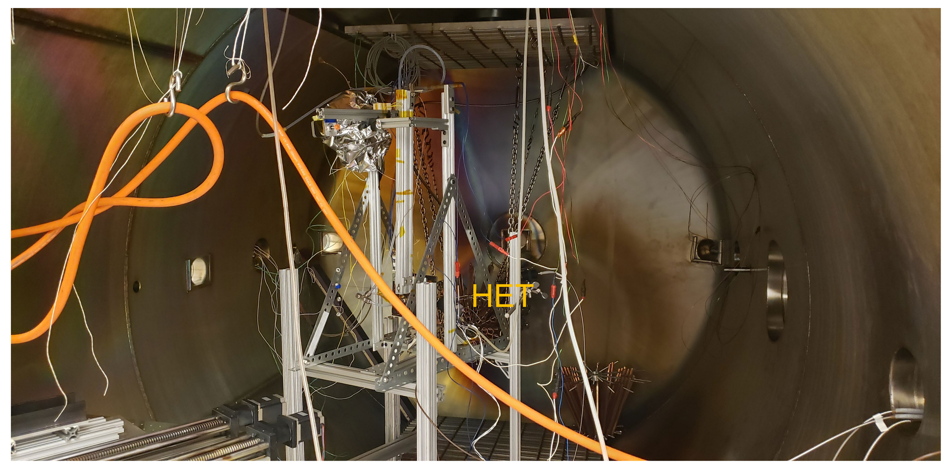


Experimental Apparatus

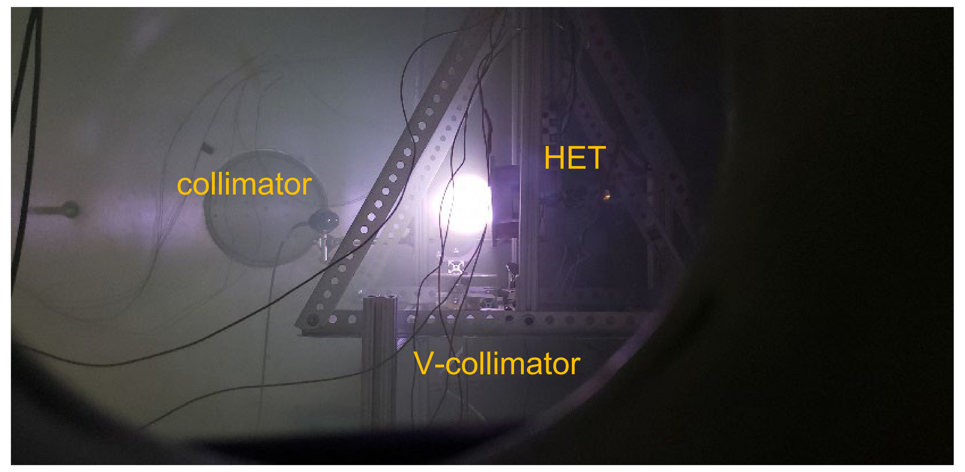


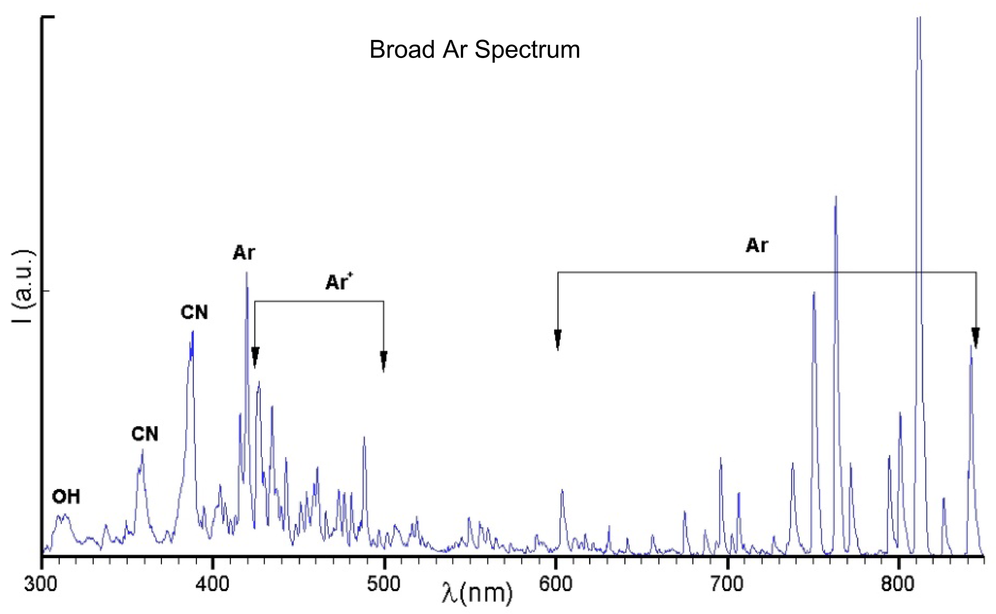




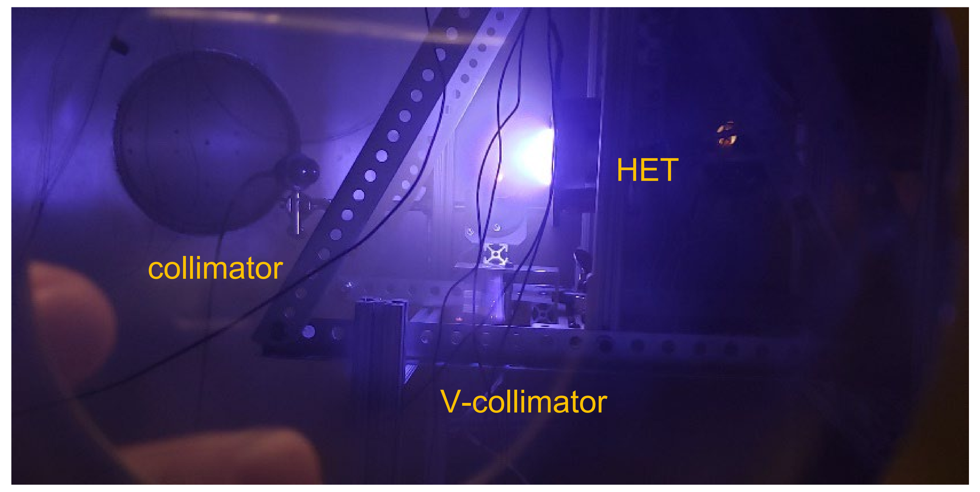


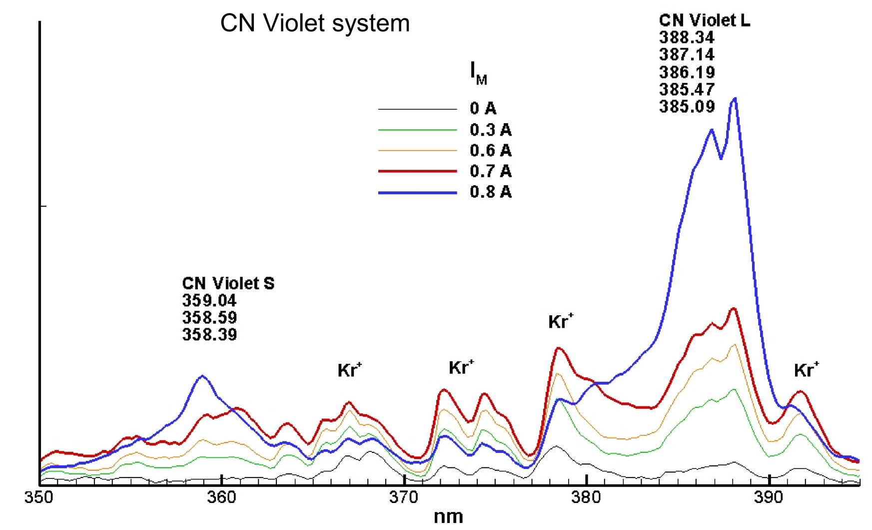
Ar operation – light source

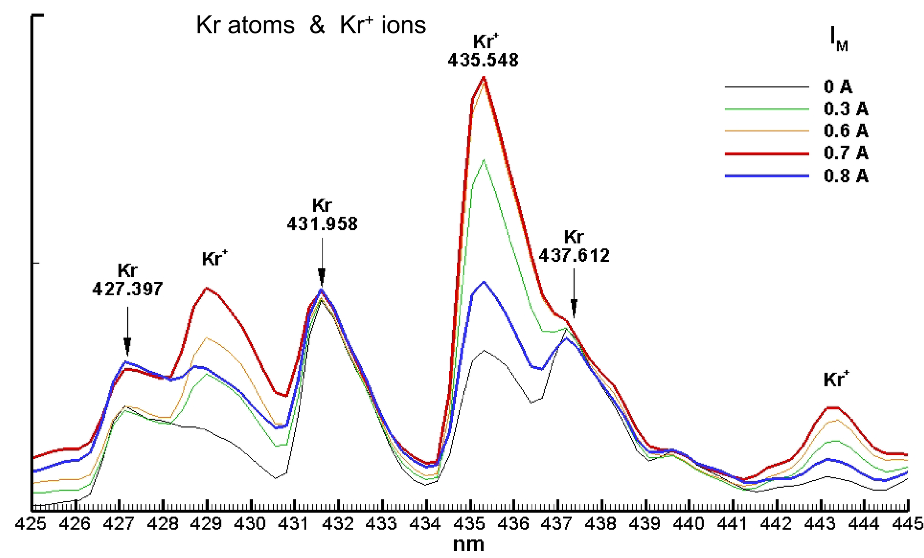


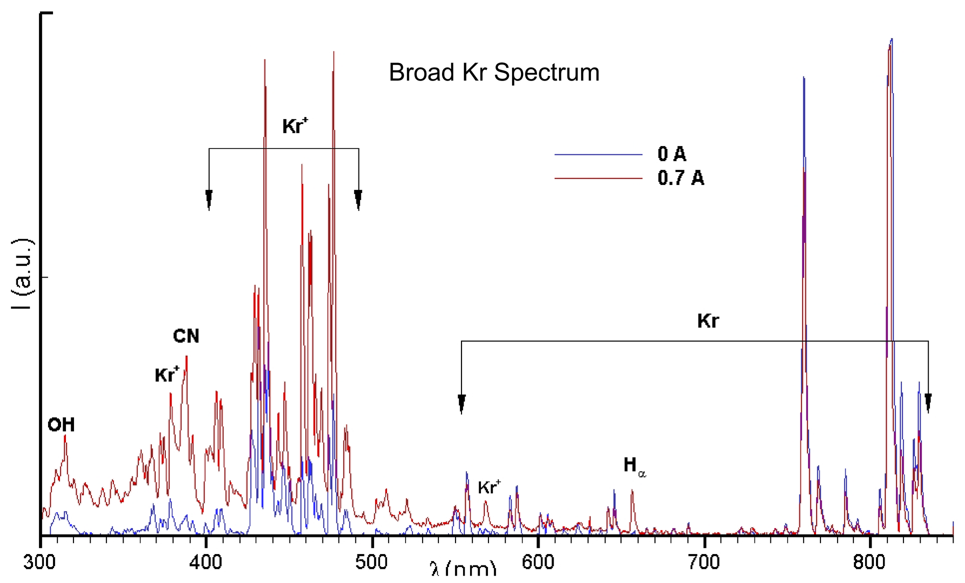


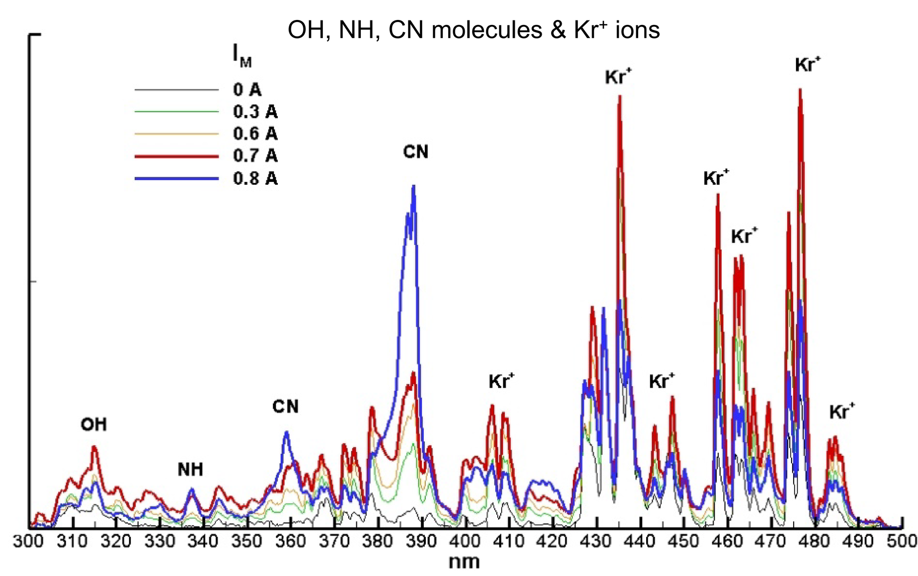
Kr propellant – plasma source

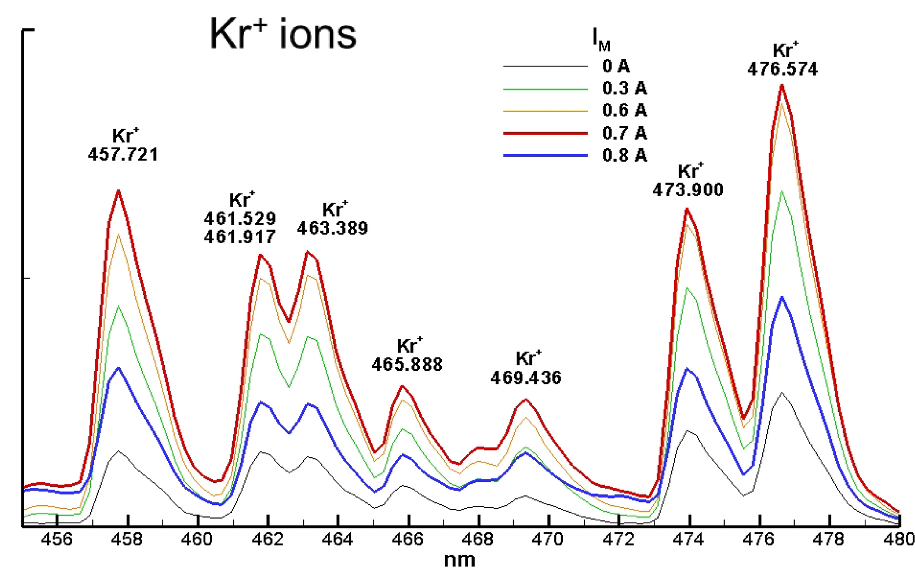




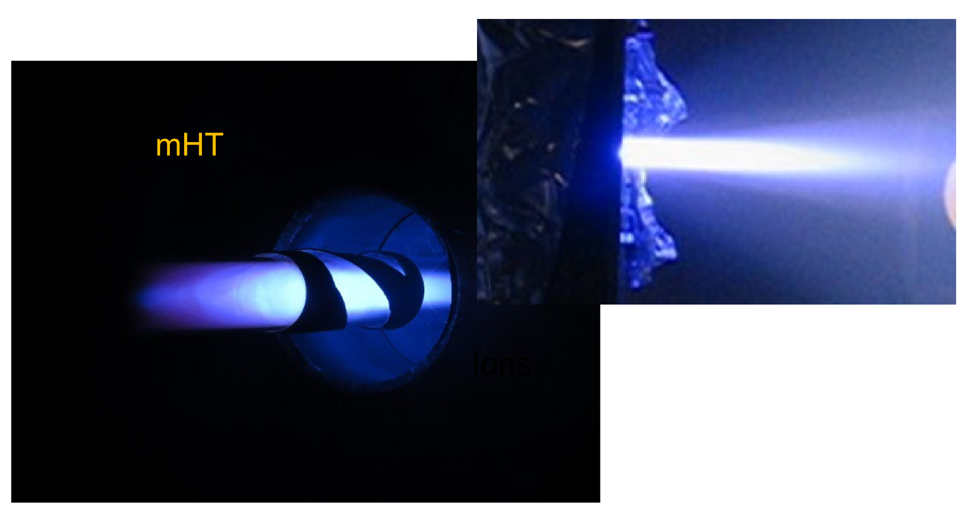


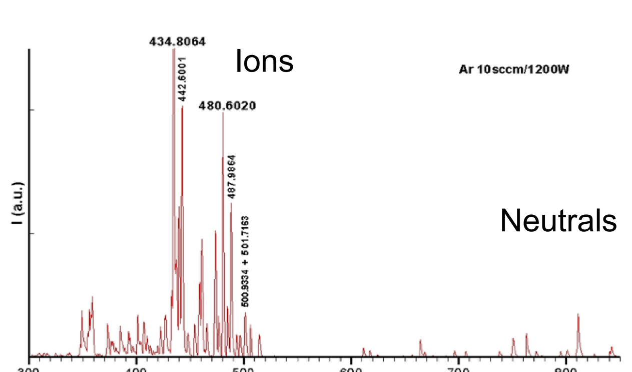


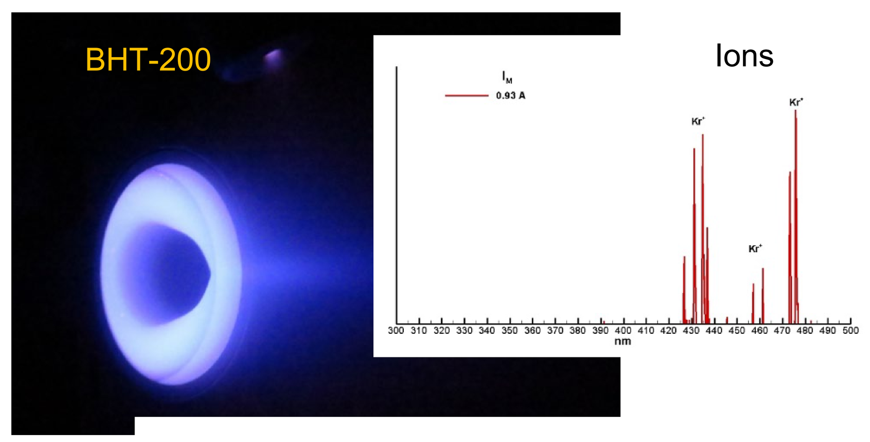


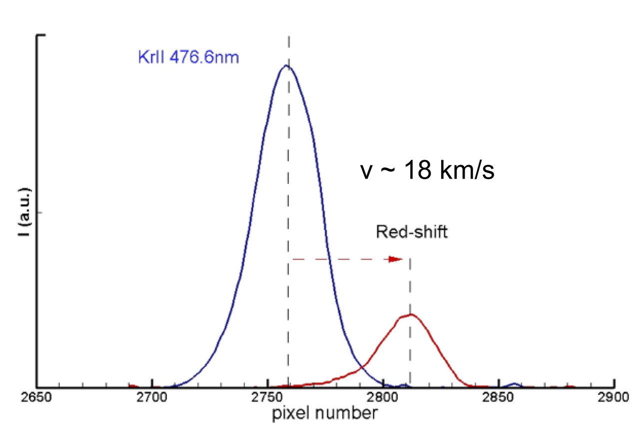


Comparison to mHT (Ar) & BHT-200 (Kr)



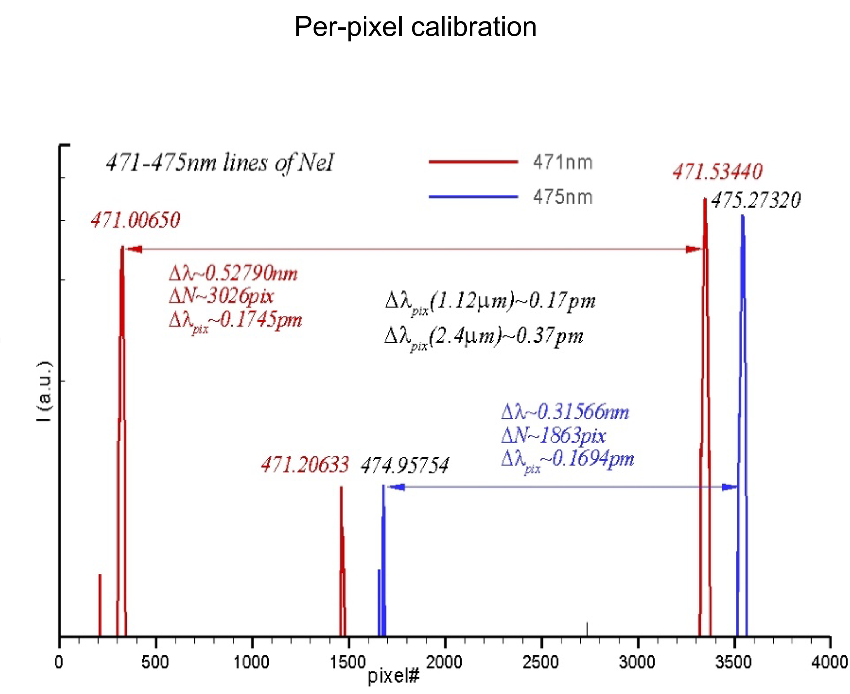


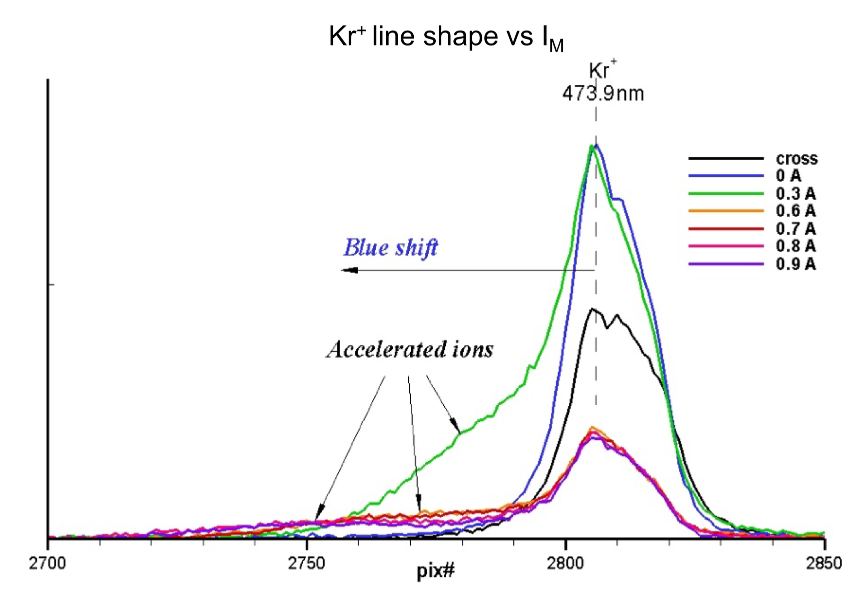


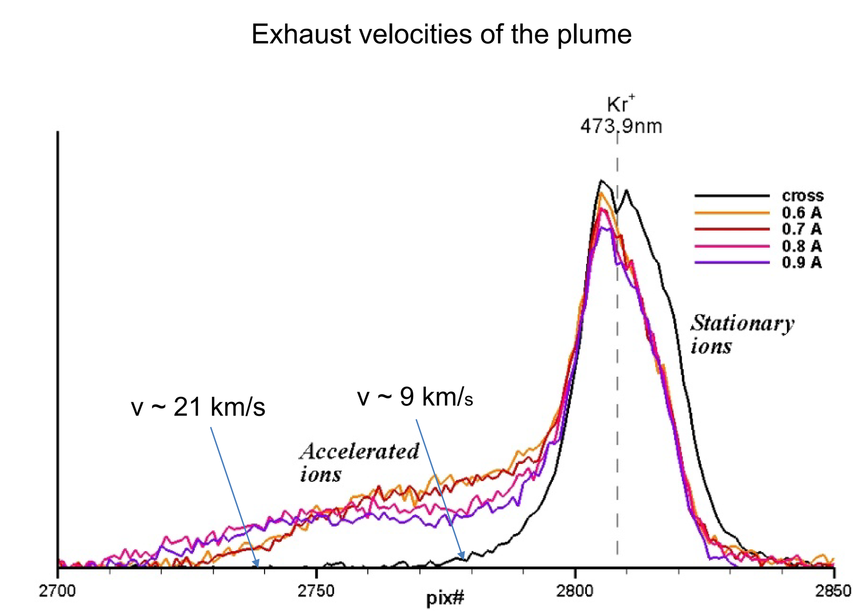


Doppler Shift

Doppler spectroscopy was attempted on the ion line at 473.9 nm, using the NU PL high-res NUV-NIR system [4]. Calibration was done by measuring NeI lines on both sides of the Kr+ line, such that we could find an interpolated per pixel value. Per pixel calibrations were taken with a color camera such that the resolution was about 0.17 pm/pix. The Doppler measurements taken with a cooled mono CMOS camera that gave a 0.37 pm/pix resolution, which corresponds to velocity increases of about 3 km/s per 10pix. We see extended blue shifted ion population.





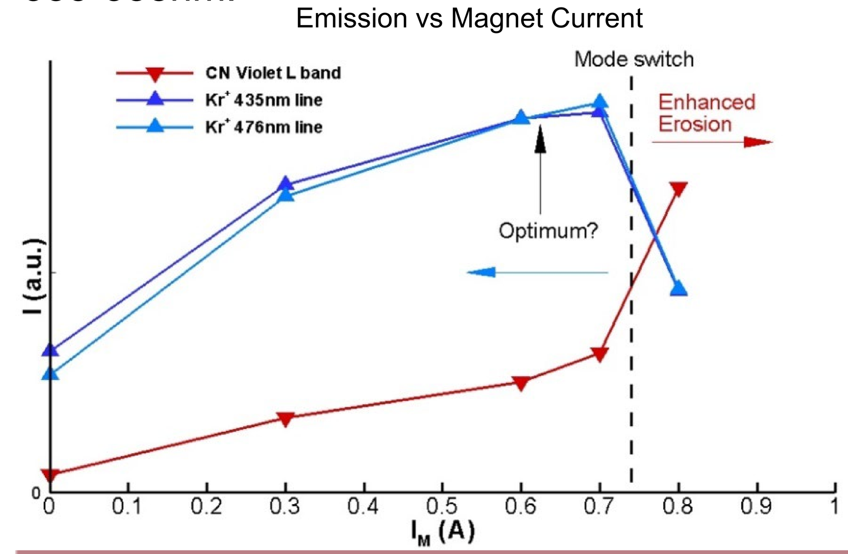


Discussion

Broad Spectrum measurements of Ar and Kr discharge show neutral atoms, ions, and diatomic molecules. The presence of the latter implies outgassing from the bearing materials. We note that we were unable to ignite the thruster with Ar propellant. The spectrum shows that the discharge is composed of mostly neutrals and therefore does not make an efficient plasma source. As ignition occurred for Kr, we can see the difference in exhaust spectra with and without a B field. After the field is applied, the ion lines become stronger and the neutrals weaker, suggesting a transition to a plasma source regime. Both here and for the narrower spectra, decomposition of the thruster material is shown.

The remainder of the graphs demonstrate how the presence of Kr ions in the exhaust plume increases as the current does, while the intensities of neutrals are relatively stable in comparison.

This behavior holds for a current range from about 0-0.7A, with ion lines becoming strongest between 0.6 and 0.7A. A mode change occurs for currents above this point, as ion intensities fall, and molecular intensities become comparable if not stronger. This change is exhibited by the CN molecular bands between 385-388nm.



Conclusions

The educational HET has demonstrated good performance with new BO hollow cathode run on Kr propellant.

Spectroscopic measurements show a high degree of ionization with strong KrII emission lines. At the same time, strong molecular bands are detected indicating epoxy resin decomposition. Maximum ion production corresponds to 0.7A magnet current. Ions in the exhaust have high velocities of 10-20km/s, comparable to BHT-200 running on Kr.

Operation on Ar requires high applied power and a different design of the gas diffuser.

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