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Detailed Beam and Plasma Measurements on the VESPA Penning H^- Ion Source

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The Vessel for Extraction and Source Plasma Analyses (VESPA) [1] has been operational at the Rutherford Appleton Laboratory (RAL) for one year. This project supports and guides the overall ion source R&D effort for the ISIS pulsed spallation neutron and muon facility at RAL. The overall aims for the project are: to investigate exactly what properties and H^- production mechanisms the ion source plasma has, through optical emission spectroscopy techniques; to completely redesign the extraction system for loss-less injection into a magnetic low energy beam transport (LEBT); to quantify the effect of removing caesium trapping; to investigate whether the source lifetime can be increased through overall efficiency improvements, and to support R&D occurring in parallel, such as a scaled ion source [2].

Having commissioned the VESPA and successfully extracted beam [3], the initial problems, such as high operating temperatures, poor vacuum pressure and lower than expected beam current, have been solved. The VESPA produces 100 mA of pulsed H^- beam, proving that collimation on the analyzing dipole magnet is the reason only 50 mA is measured on the ISIS operational source for the same set-points. Perveance scans indicate that the source is production-limited (i.e. saturates away from the Child-Langmuir curve) at extraction voltages above 14 kV unless the discharge current in increased from the standard 55 A to 70 A.

A high resolution optical monochromator is used to measure plasma properties using argon as a diagnostic gas. The hydrogen gas temperature increases by the square root of arc current, up to 2.8 eV for 50 A; whereas the electron temperature has a slight linear decrease toward 2.1 eV. Gas and electron densities are in the same order of magnitude at around 1×10^{19} m^{-3}, with electron density increasing and gas density decreasing with arc current. SRIM calculations prove that operating the ion source under argon in high current pulsed mode is extremely difficult because the cathode-coated caesium is heavily sputtered by argon.

References

[1] S. R. Lawrie *et al*, "Development of the Front End Test Stand (FETS) and Vessel for Extraction and Source Plasma Analyses (VESPA) Negative Hydrogen Ion Sources at the Rutherford Appleton Laboratory (RAL), Rev. Sci. Instrum 85, 02B127 (2014).

[2] D. C. Faircloth et al, "Operational and Theoretical Temperature Considerations in a Penning Surface Plasma Source", AIP Conf. Proc. 1655, 030013 (2015).

[3] S. R. Lawrie *et al*, "First Beam Measurements on the Vessel for Extraction and Source Plasma Analyses (VESPA) at the Rutherford Appleton Laboratory (RAL), AIP Conf. Proc. 1655, 030011 (2015).