Two-photon absorption laser induced fluorescence measurements of neutral density in a hydrogen helicon plasma

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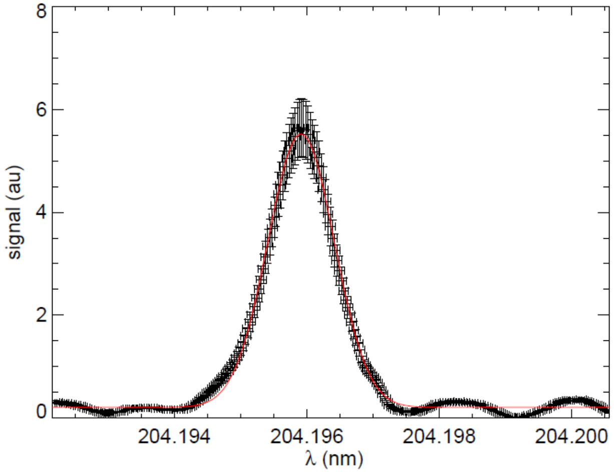
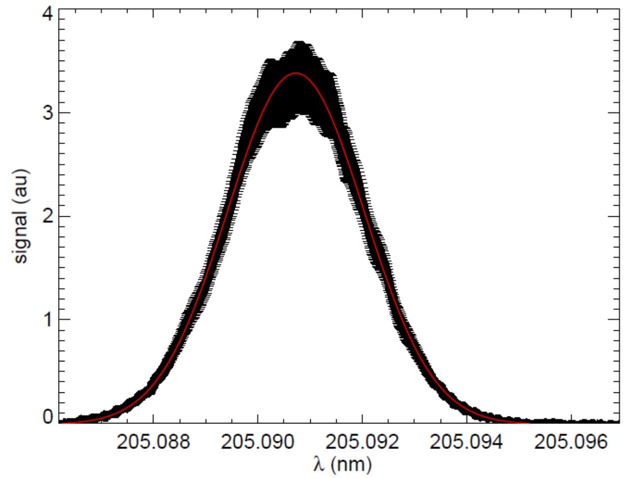
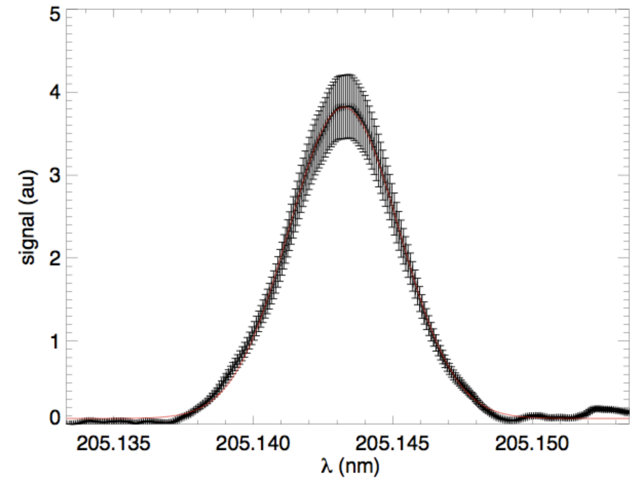
The How's and Why's of Neutral Profile Measurements

- Is the neutral density profile in helicon plasmas flat, peaked, or hollow, i.e., what is the ionization fraction?
- How does the profile vary with RF power and magnetic field?
- Are previous measurements reliable given that they were obtained with perturbative techniques or relied on indirect methods
  - Capacitive manometers
  - Excited state laser induced fluorescence (LIF)
- Is plasma production optimal when the driving frequency matches the lower hybrid frequency?
  - In atomic gases?
  - In molecular gases?

Using two-photon laser induced fluorescence (TALIF) we have directly measured ground state density of neutral Kr, H, and D



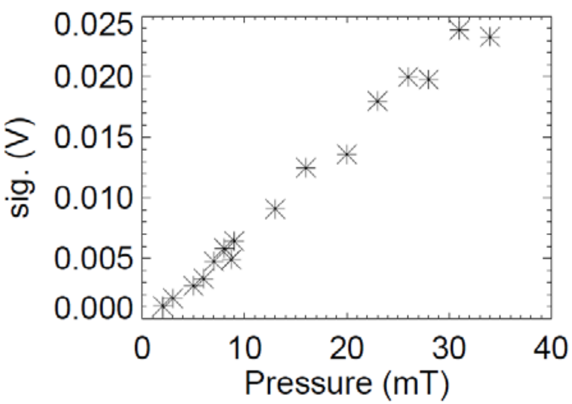


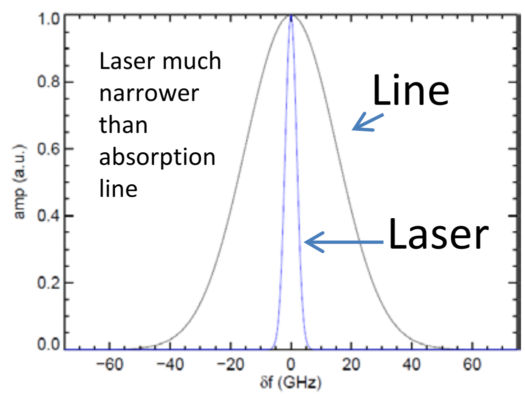


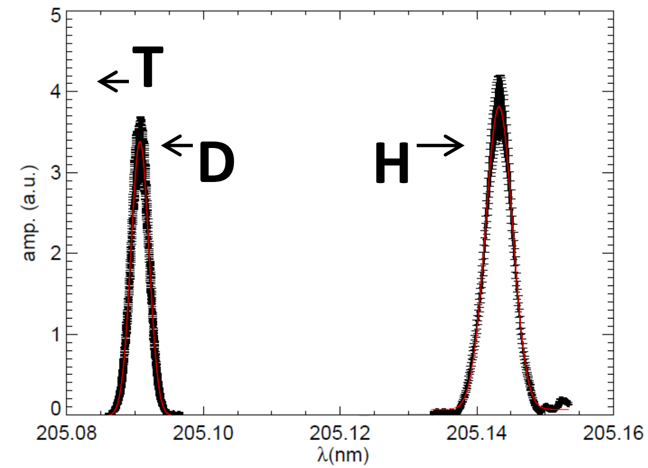
Krypton

Deuterium

Hydrogen



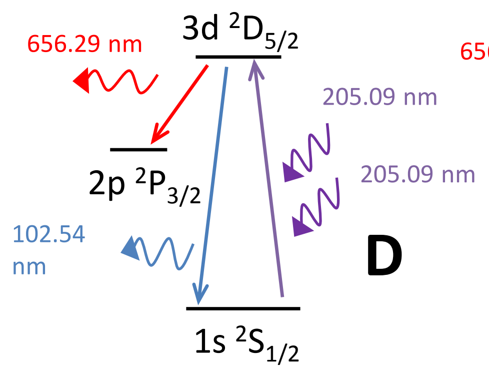


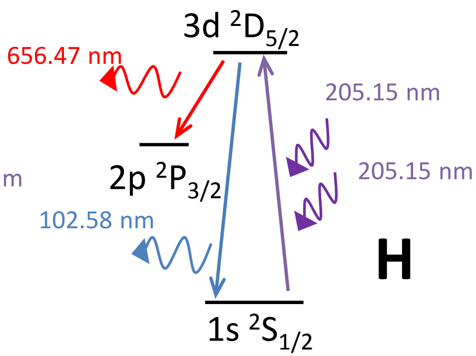


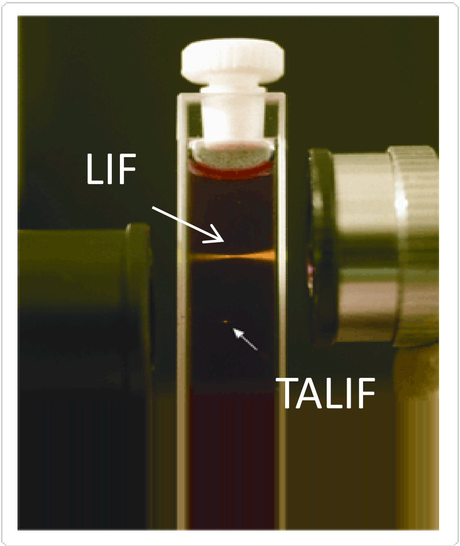
- System absolutely calibrated in Kr

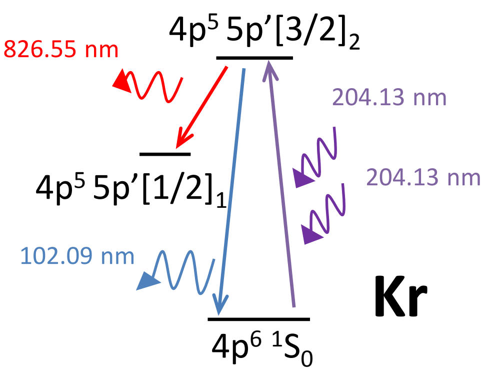
TALIF is a variation on traditional single-photon LIF with a number of advantages.

- Simultaneous absorption of two photons excites the transition.
  - Easier to create 205 nm than 102.5 nm photons.
  - Direct access to ground state.
- Excited state decays through single photon emission.
  - Non-resonant
- Emitted light proportional to absorption rate (lower state density).
- Signal proportional to square of laser intensity.
  - Highly localized

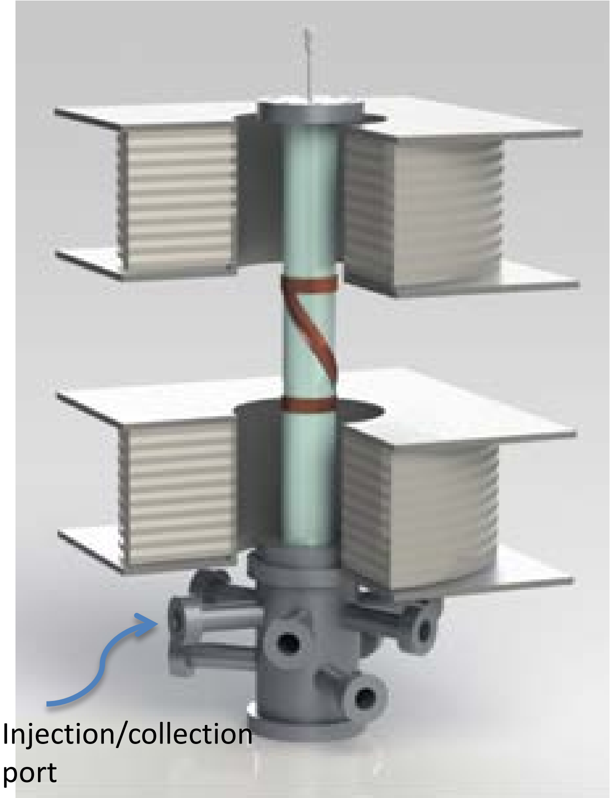




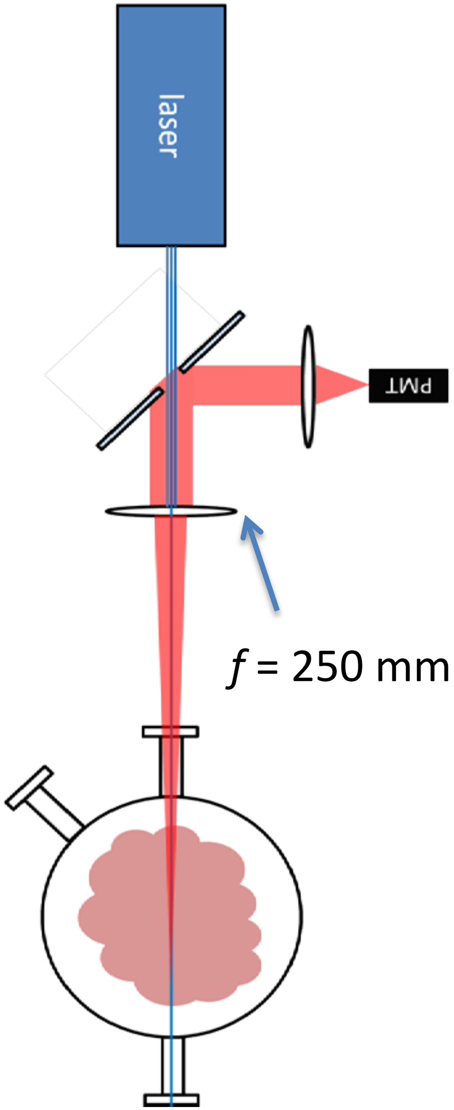




TALIF system

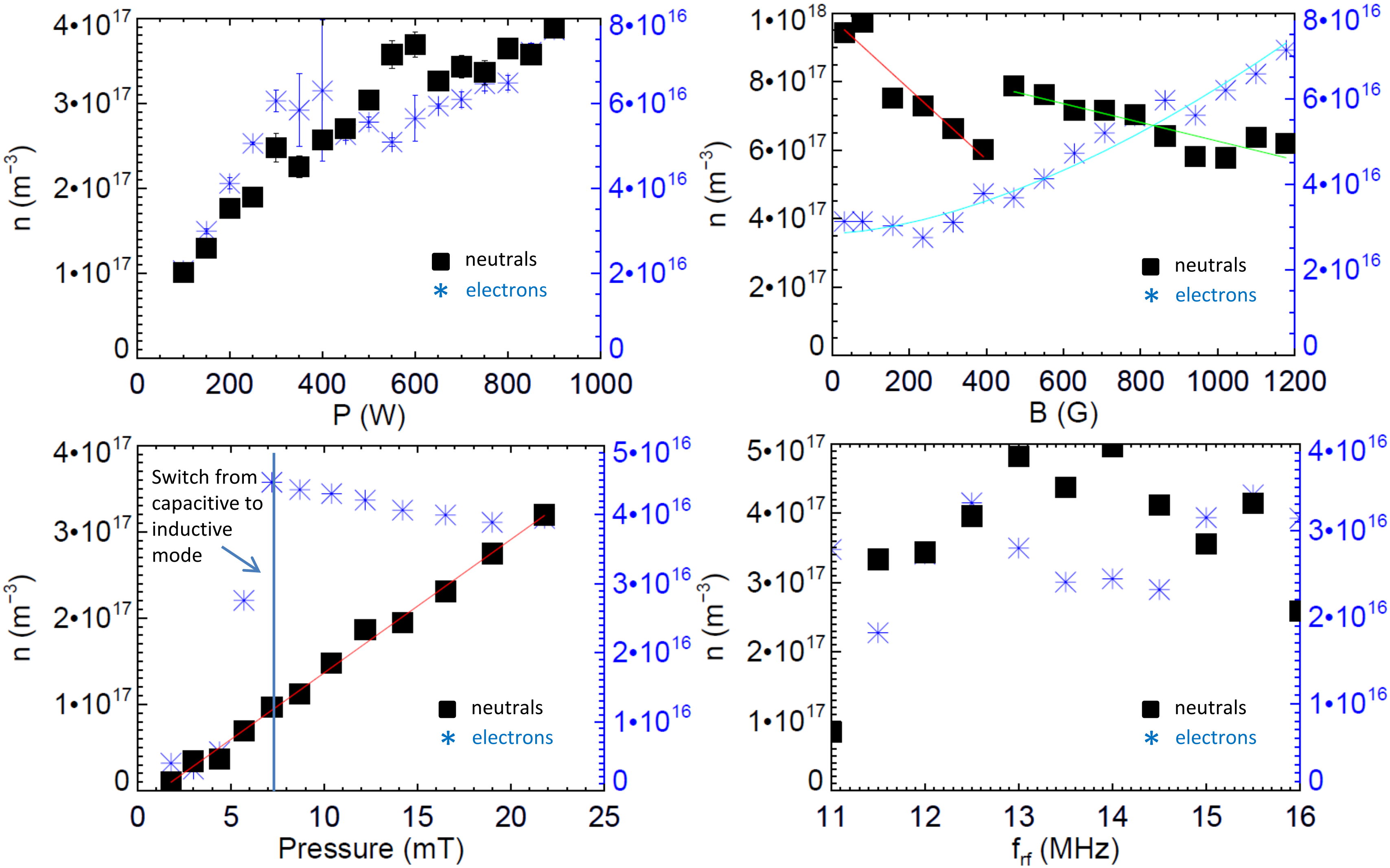


RF power = 0.1-1 kW
B = 0.01-1.2 kG
Fill pressure = 1-30 mTorr,
$n_e \sim 5\times10^{16}$ m^{-3}
$T_e \sim 10$ eV

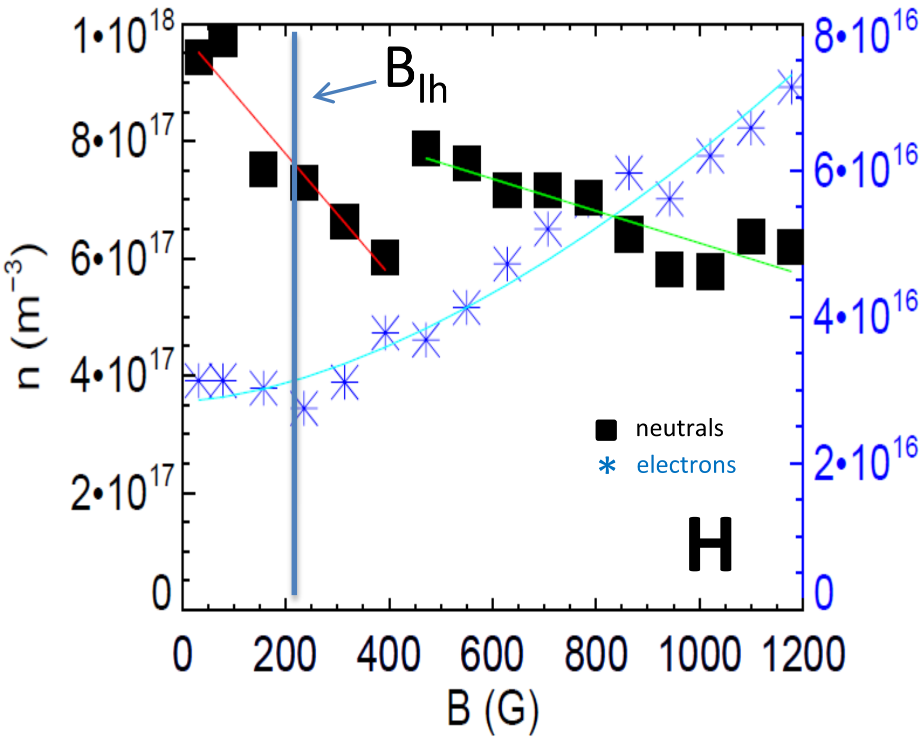


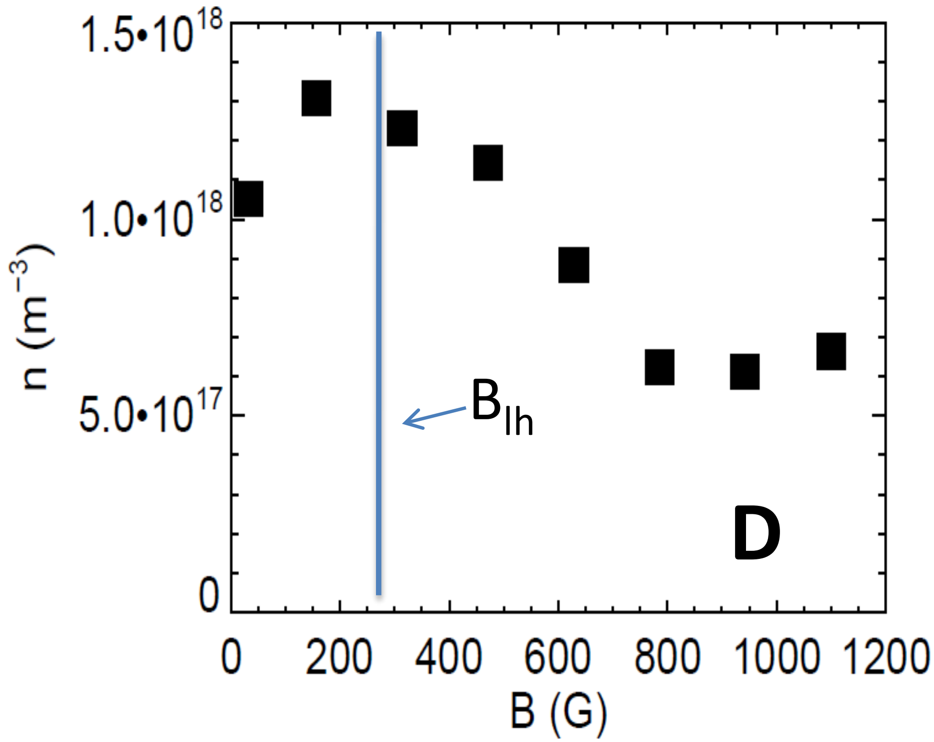
- Nd:YAG
  - 20 Hz, 1 J 532 nm
- Scannable Pulsed Dye Laser
  - 500 mJ, 615 nm
- 2-stage Frequency Tripler
  - 30 mJ, 308 nm
  - 4 mJ, 205 nm
- Spot focused to < 60 μm

Neutral density increases with increasing power and pressure, decreases with increasing field, and is roughly constant with frequency.



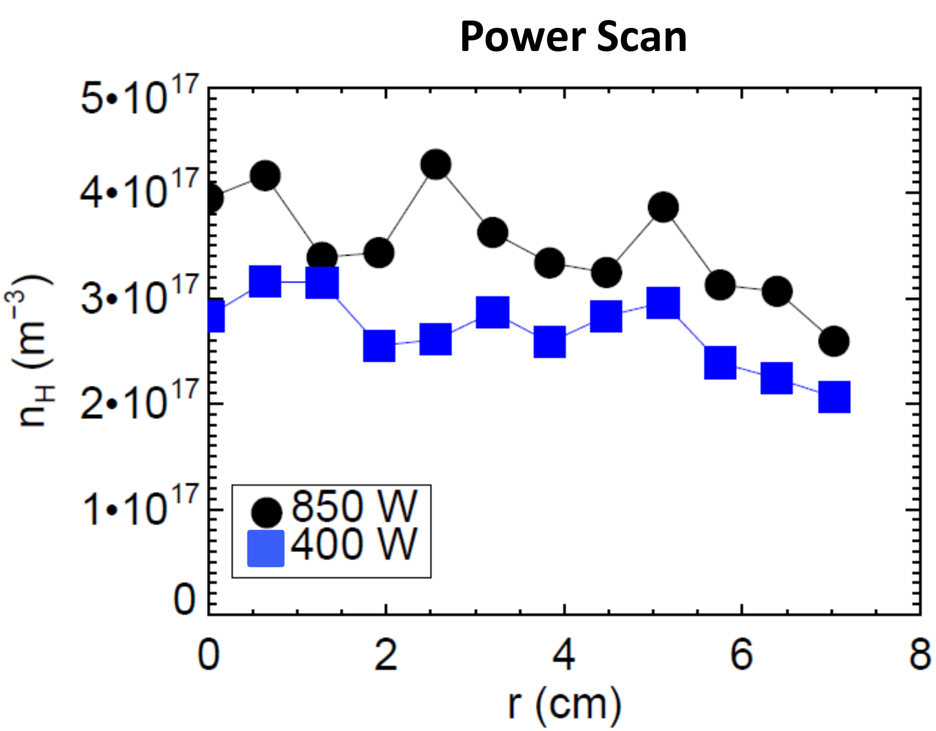
No enhancement in plasma production or decrease in neutral density near lower hybrid resonance in H.

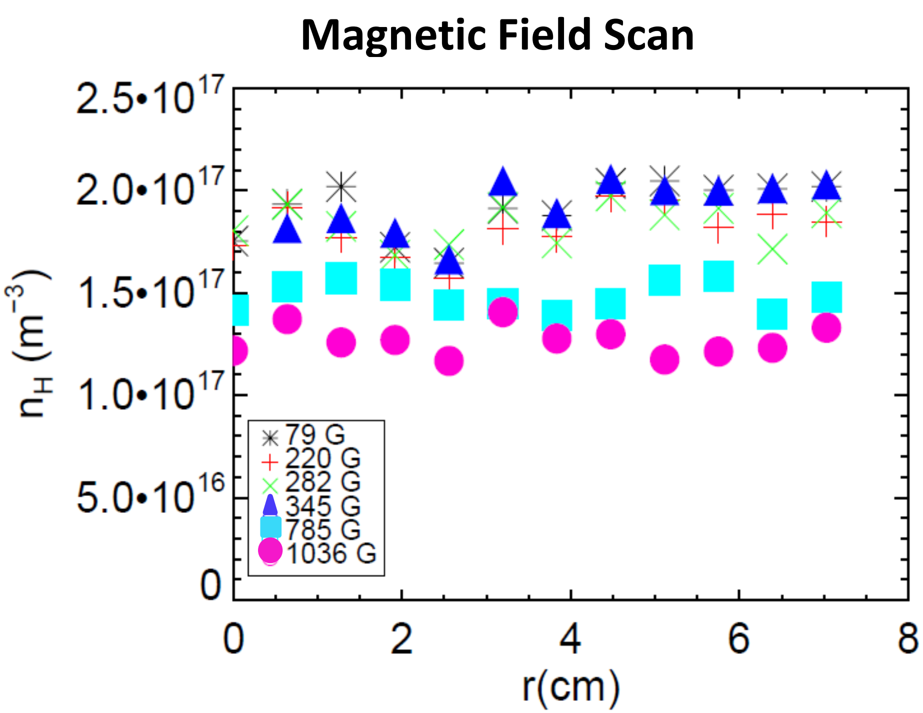




- Possible effect in deuterium, electron data needed to see if plasma production increases.

Hydrogen neutral profiles are center peaked or flat for all source parameters.

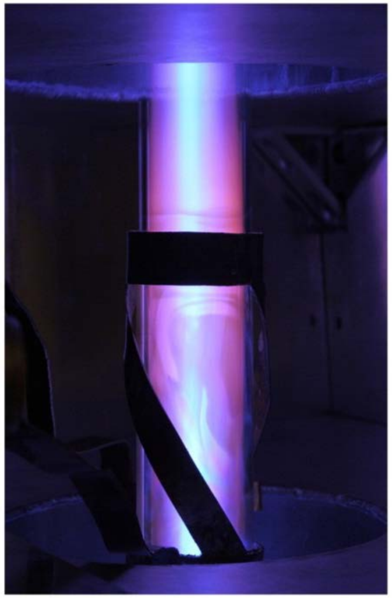




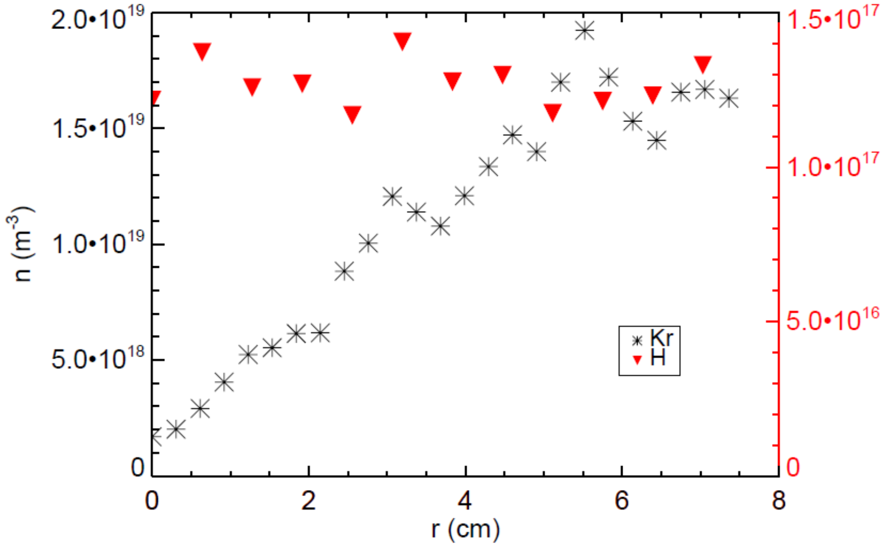
- Neutral depletion never observed.
- No change in neutral temperature.

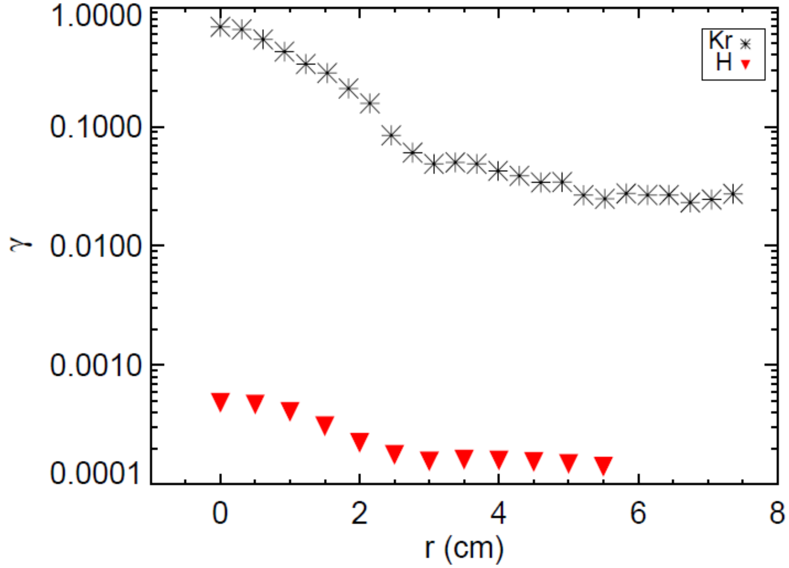
Krypton plasmas are >90% ionized for same source parameters as <0.1 % ionized hydrogen.

H



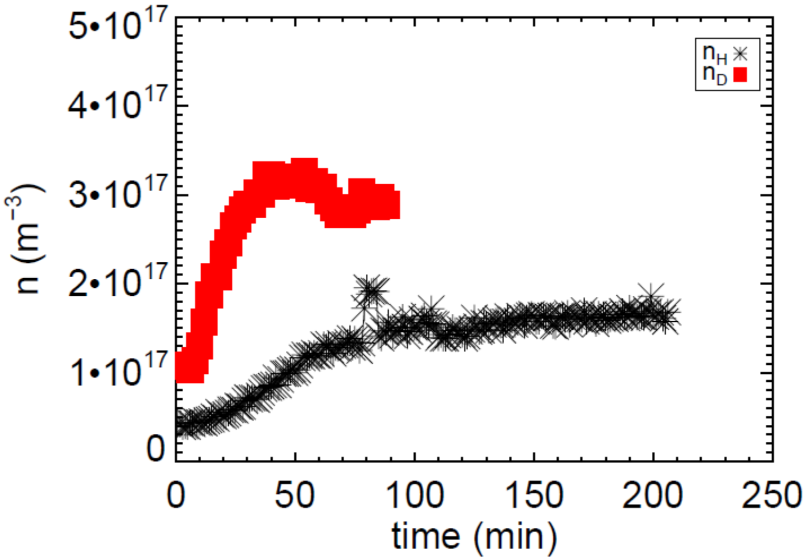
Kr

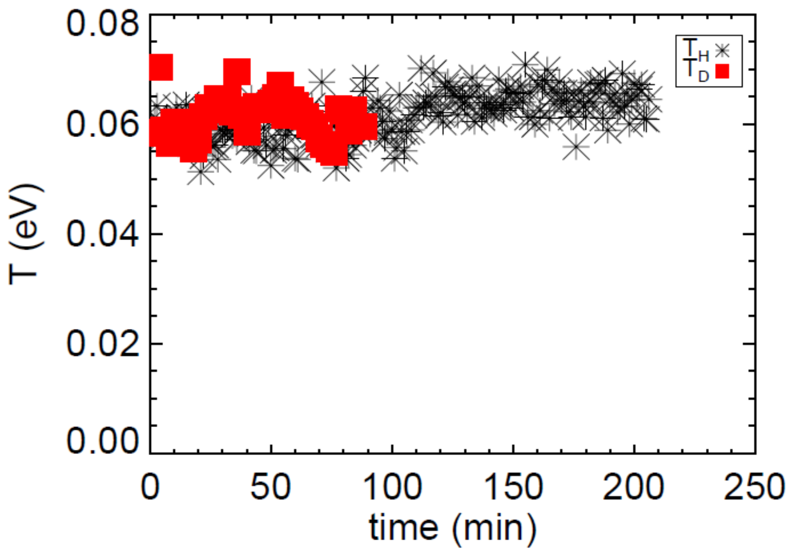




- Significant neutral depletion
  - Kr: Factor of 10 edge to center
  - H: No depletion
- Much higher ionization fraction (helicon mode).

Measurements show saturation of walls after inert gas plasma cleaning is faster for deuterium than hydrogen.





- Krypton cleaning discharges.
  - 10^{18} m^{-3}, 2-3 hours
- Hydrogen and deuterium densities increased by factor of 3.
- Difference in saturation time consistent with difference in neutral density.
  - Greater fluence of particles to wall
  - Walls load faster.
- Hydrogenic retention and recycling in fusion plasmas affects fuel cycles and energy confinement time.
  - Pedestal formation.

Conclusions

- Neutral hydrogen densities increased with increasing power and pressure.
- Neutral hydrogen density decreased with increasing magnetic field.
- Neutral hydrogen density was roughly constant with driving frequency.
- No changes in neutral temperature.
- No neutral depletion or lower hybrid resonance effects seen in H.
- Significant differences between hydrogen and krypton.
  - Magee poster Thursday 9:30
- Evidence of wall loading following cleaning discharges with inert species.