Experimental Studies of Kr+ with Laser-Induced Fluorescence NW1.00065

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This work is diagnostic development in service of cool experiments!

We have succeeded in obtaining a laser-induced fluorescence (LIF) signal from Kr^+ in a low temperature Kr plasma discharge, using a diode laser, for a wavelength near 729nm. An atomic energy level scheme that is accessible to diode lasers is $4p^4 4d^4 D_{7/2} \rightarrow 4d^4 5p^4 P^0_{5/2} \rightarrow 4d^4 4d^4 P_{5/2}$. The metastable state, $4p^4 4d^4 D_{7/2}$, one of several possible metastables states for excitation, proved to be sufficiently populated in the in a low temperature DC plasma discharge ($T_e \sim 1eV, T_i \sim 1/40eV, n_i \sim 10^9 cm^{-3}$) to produced a high quality signal. The excitation wavelength is nominally 729 nm, and the detected photon is nominally 473 nm. We used an extended cavity diode laser in the Littrow configuration (Sacher-Lasertechnik TEC-100-0730-20).

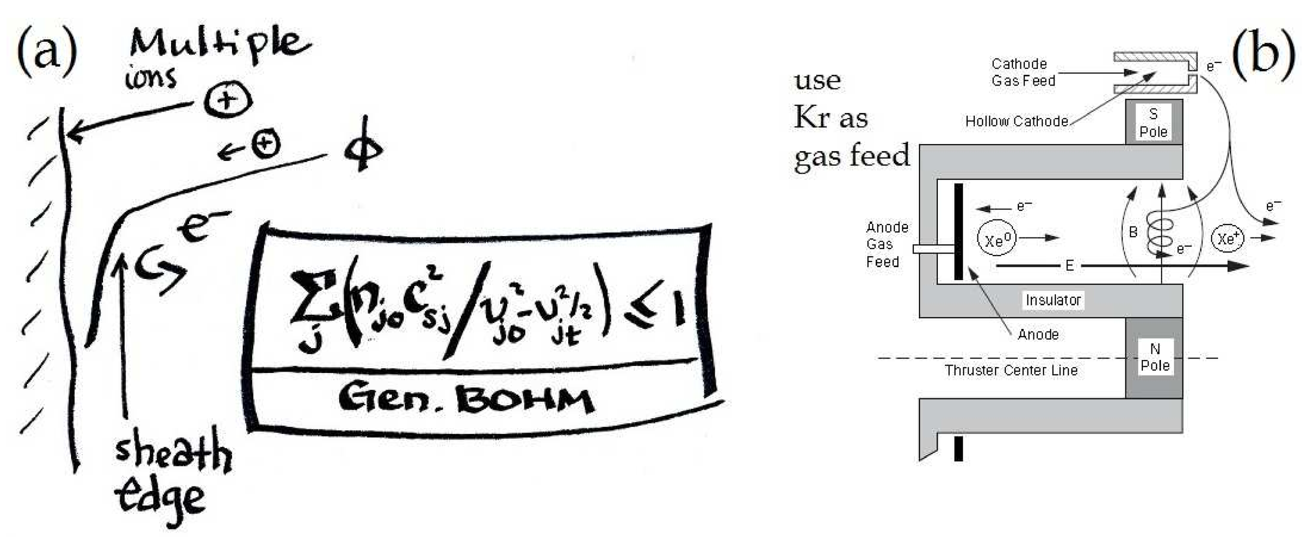

Figure 1:

Successful completion of these experiments will provide a new ion velocity diagnostic for Kr ions which will aid in at least 3 basic plasma science experiments:

[1] sheath formation and the generalized Bohm Criterion multiple ion species plasmas (with 3 ion species, and with new pairs of 2 ion species),

[2] studies of the comparison between ion velocities of metastable state rare gas ions and known ground state ion mobilities, as suggested in fig.1a, and

[3] Hall Thruster ion plume measurements, as shown in fig.1b

LIF Collection Optics now includes 3" optics and beam expander

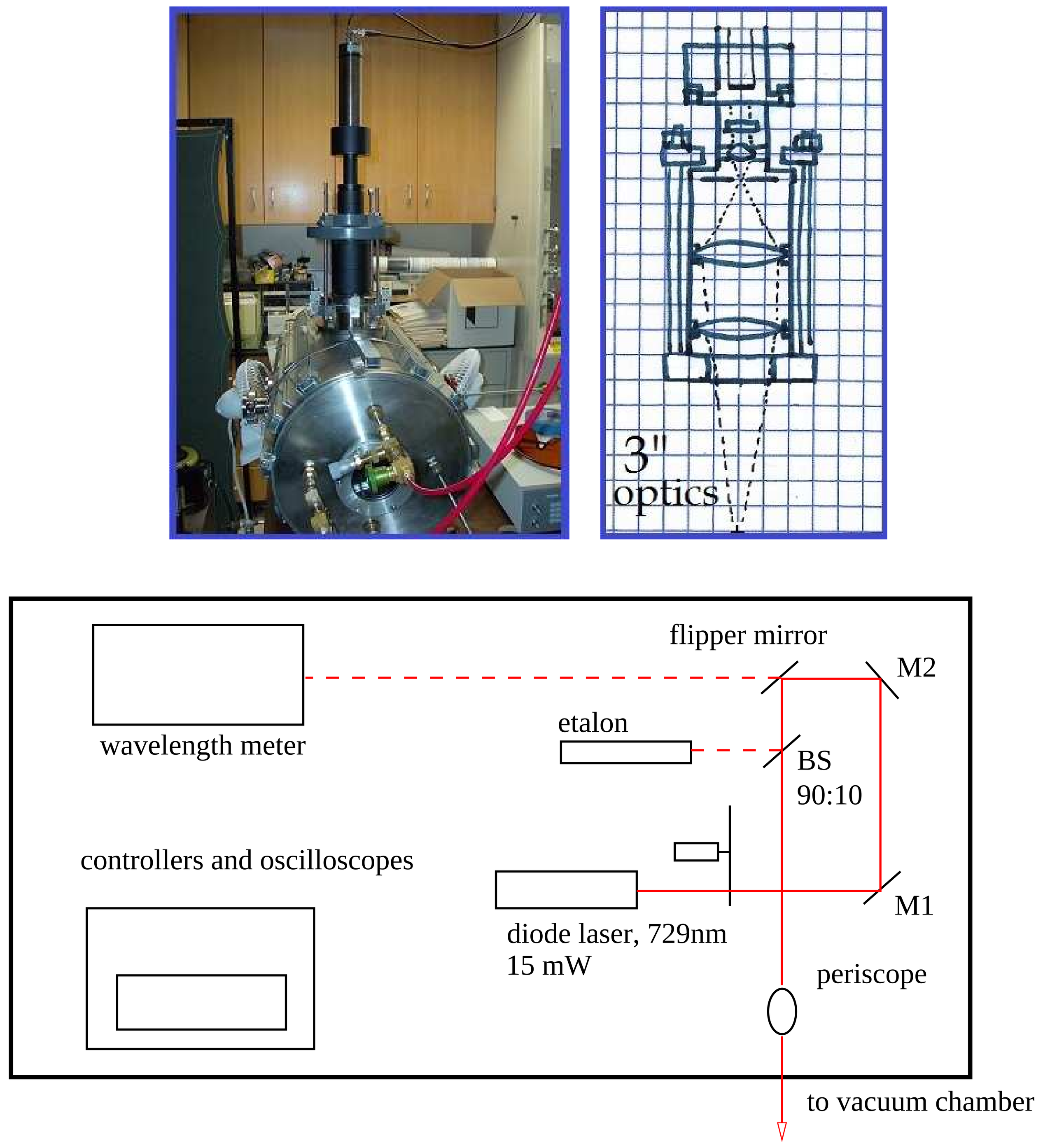

Figure 2:

The new collection optics system at USD (shown on top) was designed

[1] for 3" optics to maximize the solid angle of collected fluorescence, and for maximum compactness.

[2] The optics tubes permit flexibly changing optics location so that we can test whether fluorescence efficiency can be improved by focusing collected light directly on the photocathode as opposed to focussing the light on the iris, in conjunction with a beam expander to make parallel light impinge on the interference filter.

[3] The 4'X 8' optics table supports the laser, beam steering optics, and Burleigh wavemeter, along with controllers and oscilloscopes. We use an etalon to mark fine tuning sweeps in order to monitor sweep linearity, and to verify detuning from the line center. We now use a flipper mirror so that we minimize realignment of beam injection (whether into the wavemeter or the vacuum chamber).

[4] The laser beam is chopped at $\sim \pi kHz$ and the PMT output is terminated in $10k\Omega$ resistor and the voltage is sent to a lock-in amplifier (SRS 510).

Our Kr^+ metastable state has a kinda simple, kinda complex Hyperfine structure, and simple deconvolution schemes confirm that the ions are near room temperature in the bulk plasma

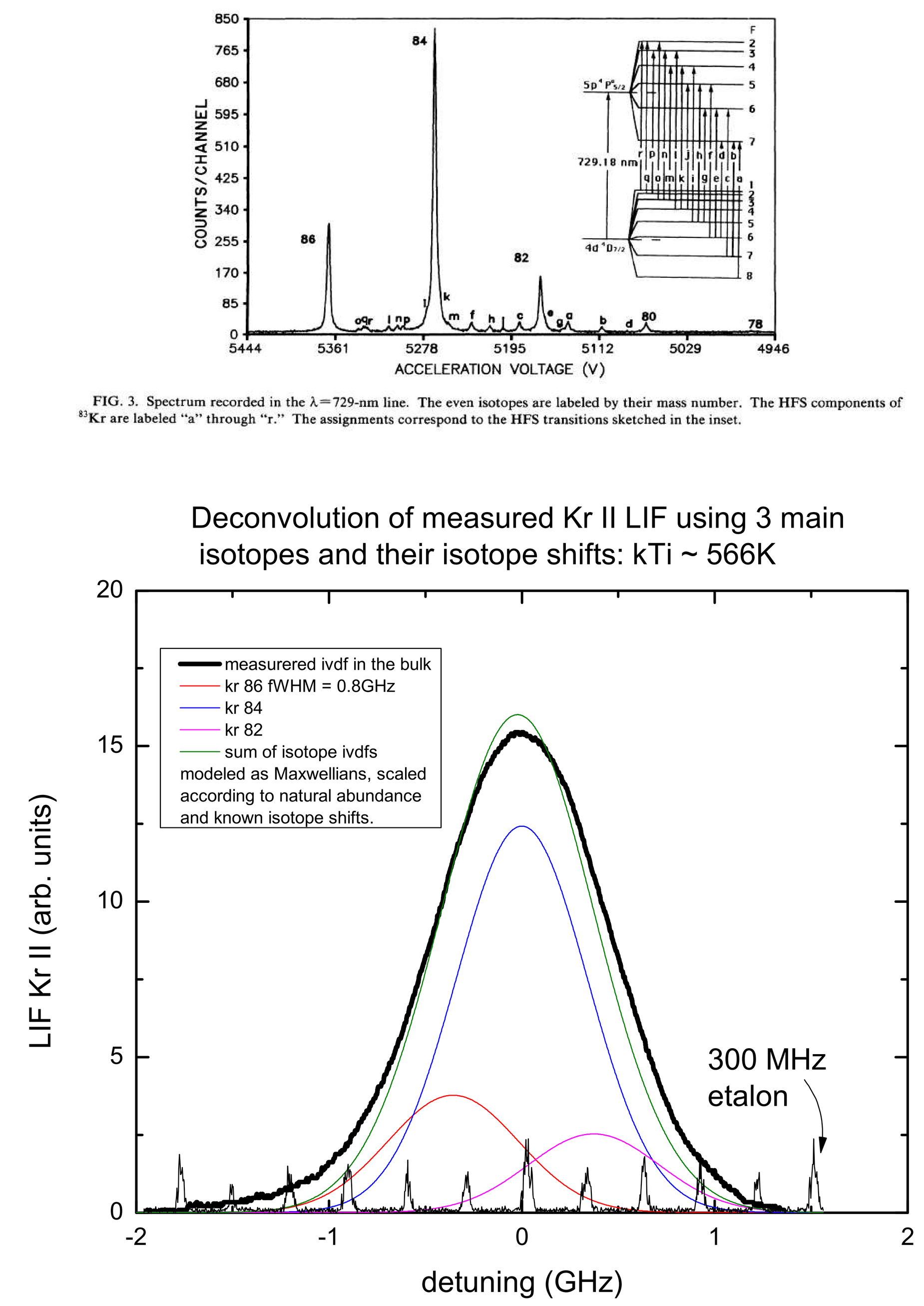

Figure 3: The top figure is fig. 3. in Schuessler, et al., PHYSICAL REVIEW A **45**, (1992),“ Isotope shifts and hyperfine-structure-splitting constants of the 4d-5p transition of Kr II at A.=729 nm”

Our principal results are:

- last year, we achieved the first light for the Kr^+ LIF scheme in a plasma, in our lab at USD.
- we have shown that KrII line at 728.982nm (air) can be exploited for measuring ivdfs (ion velocity distribution function), taking into consideration the Hyperfine structure of the transition.
- By focussing the diagnosed volume onto the iris (3mm in diam), the LIF signal increased by a factor of at least 2, compared with not using an iris at all, and focussing the diagnosed volume onto the interference filter.

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