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Reaction dynamics in a magnetized hydrogen plasma unraveled by optical spectroscopic techniques

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The development of efficient sources of reactive hydrogen radicals is important in many research fields and applications. For instance, atomic hydrogen radicals serve as primary reactive particles for surface modification or thin film deposition. For fusion plasma heating, one of the main research challenges is to develop efficient negative ion sources. A promising route is via dissociative attachment of ro-vibrationally excited hydrogen molecules $H_2^{r,v}$. The ro-vibrationally excited molecules are important precursors in volume reactions leading to excited hydrogen atoms. During my presentation I will discuss the importance of several molecular activated recombination (MAR) processes in an expanding thermal hydrogen plasma, and especially, the formation of excited atoms via the mutual neutralization process of H^- and H_2^+.

When an expanding hydrogen plasma jet, produced from a cascaded arc source, is weakly magnetized, the emission of the expanding plasma jet is dominated by the red H_α emission in the first centimeters from the exit of the source, but changes to blue at larger distances from the exit due to higher Balmer lines ($n > 4$) (see attached Figure 1). Since electron energies in the jet are too low (1 eV and less) to excite atomic hydrogen to the state $n = 3$, a possible formation route is via mutual recombination of atomic ions: $H^+ + H^- \rightarrow H + H(n = 2, 3)$. After 22 cm H_β to H_δ light becomes dominant (i.e. the reason for the blue appearance of the jet at larger z) and the corresponding weighted densities n/g become higher than the one for $n = 3$. The proposed formation mechanism for these highly excited hydrogen atoms is the mutual recombination reaction of positive molecular (H_2^+) and negative atomic ions (H^-). The molecular ions are produced in charge exchange reactions of $H_2^{r,v}$ with H^+, while the latter are formed by dissociative attachment of electrons with $H_2^{r,v}$. Both processes depend strongly on the internal excitation (r, v) of the neutral molecule. In earlier studies we have shown the presence of large densities of these highly ro-vibrationally excited hydrogen molecules. During my presentation I will focus on the reaction dynamics and kinetics leading to excited molecular and atomic hydrogen.

Figure1: picture of expanding (left to right) magnetized hydrogen plasma

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