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Measurement of collisional-radiative matrix elements from the time evolution of laser-induced fluorescence

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Laser-induced fluorescence (LIF) is a widely used diagnostic tool in the study of low-temperature plasmas. LIF experiments usually focus on analysing the signal in the spectral domain, which allows the determination of the velocity distribution function (VDF) of the probed species. From the VDF several key parameters can be extracted, such as the temperature and flow velocity, as well as the density if an absolute calibration is performed. The temporal behaviour of the LIF signal is more difficult to study owing to the fact that its accurate determination requires ultrashort laser pulses (<<1ns) and a high temporal resolution (≤1ns) of the detection system. LIF with ultrashort laser pulses effectively allows an instantaneous perturbation of the densities of the absorbing and laser-pumped states. The time evolution of the density of an excited state after absorption of the pulse is determined by reaction rates that populate or depopulate the state and is described by the rate equation $\frac{d\vec{n}}{dt} = M\vec{n}$. By pumping a state i and measuring the temporal evolution of the fluorescence emitted by a state j, it may be possible to determine the total reaction rate from i to j and therefore the matrix element M_{ij} [1].

As an example of this approach, we present time-resolved measurements of the fluorescence signal performed using the recently installed two-photon absorption laser-induced fluorescence (TALIF) diagnostic on the RAID linear device [2,3]. A ps laser system tuned to 205.1nm is used to excite ground state H atoms into the n=3 states. The subsequent decay of the n=3 states is monitored at high temporal resolution (< 3ns) by recording the intensity of the Balmer alpha line (656nm) using a fast-gated ICCD camera. The time evolution of the fluorescence signal is close to exponential, with an e-fold time ≤ 10ns, corresponding to the inverse of the total depopulation rate of the n=3 state [4] and the matrix element M_{33}.

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