Electron impact transfer rates between metastable and resonance states of argon investigated by laser pump-probe technique

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In low temperature non-equilibrium plasmas, the effective lifetime of argon atoms in metastable states, $1s_5$ and $1s_3$ (in Paschen's notation), is strongly governed by their collisional transfers towards the $1s_4$ and $1s_2$ resonant states, which have apparent radiative lifetimes of a few μs. In low pressure, high density plasmas, heavy particle collisions are usually negligible and only electron impact collisions play any significant role [1]. An accurate knowledge of the electron impact transfer rates between the metastable and resonant states is then crucial for a correct description of argon gas discharges.

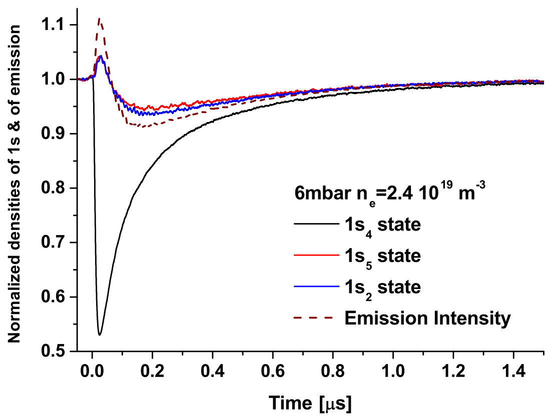

Fig. 1: *Temporal response of the $1s_2$, $1s_4$ and $1s_5$ states after the depletion of $1s_4$ by 426.63 nm line laser pulse. The fast recovery frequency of the $1s_4$ state corresponds to its transfer frequency towards the $1s_2$ and $1s_5$ states.*

In this work, the population transfer between 1s states of argon is studied by time resolved laser pump-probe technique: a nanosecond laser pulse tuned to a 1s-2p or 1s-3p transition depopulates one of the 1s states. The plasma remains in its steady state and the optical pumping leads to a highly selective and controlled perturbation in the excited atoms densities. The time variation of the densities in the depleted state and the other 1s states is then monitored by laser absorption spectroscopy with different continuous diode lasers. The gas temperature is deduced from the absorption line profiles [2] and the electron density and temperature are known from Thomson scattering measurements [3]. The plasma used in this study to generate atoms in the 1s states is a 6 mm diameter surfatron plasma belonging to the category of surface wave discharges. In the example given in Fig. 1, the $1s_4$ state is selectively depleted with a pulsed dye laser tuned on 426.63 nm ($1s_4$-$3p_6$) transition. The later is pumped by a frequency tripled Nd:YAG laser. The pulse-duration is about 8 ns and the repetition rate can vary up to 5 kHz, with a maximum energy per pulse of 0.4 mJ. Other pumping schemes on 1s-2p transitions have also been used with the dye laser pumped with a frequency doubled Nd:YAG laser. Three external cavity diode lasers tuned on 772.38, 810.37, 772.42 and 826.45 nm lines monitor the time variation of atoms density in $1s_5$, $1s_4$, $1s_3$ and $1s_2$ states, respectively.

In a recent paper [1], we have reported a rate coefficient of about $9.0{\cdot}10^{-13}\,\mathrm{m^3/s}$ for the electron impact transfer rate coefficient from the metastable state $1s_3$ to the resonance state $1s_2$. Very recently, we have studied the electron impact transfer from metastable $1s_5$ to the resonance $1s_4$ state and determined a rate coefficient of $1.6 \cdot 10^{-13}\,\mathrm{m^3/s}$ for it at an electron temperatures in the range of 1-2 eV. Different pumping schemes between the 1s and 2p states but also 3p states were used to verify the obtained value but also to probe the transfers between states belonging to different ion-cores. Our results show the presence of an important transfer channel between $1s_2$, who has $^2P_{1/2}$ ion-core, and $1s_4$ state, who has $^2P_{3/2}$ ion-core, with a rate coefficient of $2.0 \cdot 10^{-13}\,\mathrm{m^3/s}$.

References

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