On the line intensity ratio for electric field measurement in dielectric barrier discharge in argon at atmospheric pressure

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Argon discharges belong to the most important plasma sources for non-thermal plasma applications at atmospheric pressure. Various cold plasma jets, relying on argon gas and AC, RF, MW or pulsed DC power have been developed [1]. However, no reliable optical emission spectroscopy method of local electric field measurement in the argon atmospheric pressure discharge has been yet developed. The intensity ratio of intensive lines from 4p ($2p_i$ levels in Paschen notation) levels can be better used for electron density measurement [2] than for the electron energy and the electric field diagnostics. Another complication for optical diagnostics is the filamentary nature of the argon plasma [3].

This contribution aims to measure the line intensity ratios of several argon lines originating from $3p^5$ 4p and $3p^5$ 5p levels using time-correlated single photon counting (TCSPC). The TCSPC method provides both the sensitivity required for the measurement of weak 5p lines as well as the capability to capture the evolution of streamer breakdown in random-in-time microdischarges with an exceptional time resolution (<0.2 ns).

A filamentary volume dielectric barrier discharge was generated by harmonic AC voltage (4.3 kV_{pp}) in 1 mm gap between hemispherical electrodes (4 mm in diameter, covered with a 0.5 mm thick 96% Al_2O_3 dielectric layer). The spatially resolved emission was monochromatized and measured by a time-correlated single photon counter (Becker & Hickl SPC-150). Four Ar I lines originating from $3p^5$ 4p levels (750.4, 751.5 nm) and $3p^5$ 5p levels (419.8, 420.1 nm) were measured.

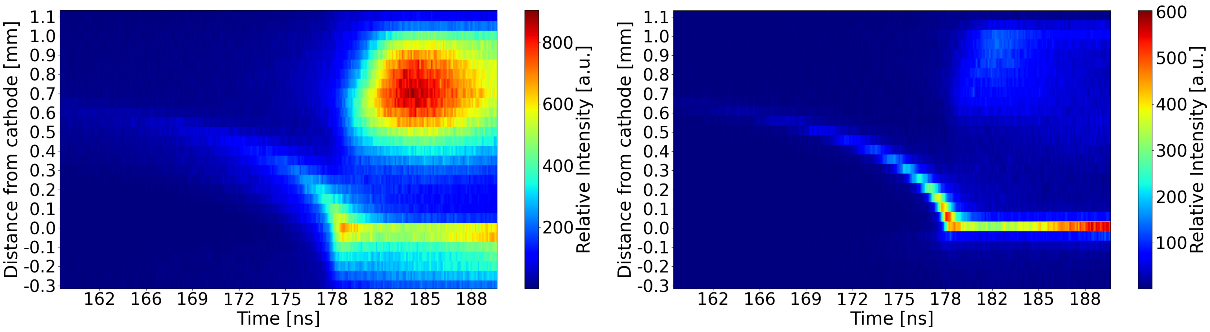

Fig. 1: Spatio-temporal distribution of the light emitted from the argon microdischarge on 751.5 nm transition (4p level $2p_5$, left) and 419.8 nm transition (5p level $3p_5$, right). The instantaneous cathode is located at zero position, the anode is at the position of 1 mm.

The spatio-temporal development of light emission from the argon microdischarge is for two wavelengths displayed in figure 1. Whilst the light emission from $2p_5$ level is broader and the light at the anode is more intensive than the light emitted by the cathode directed streamer, the emission from higher $3p_5$ level clearly maps the streamer development.

The example of the obtained temporal developments of the line intensity ratios is displayed in figure 2. The streamer passage at a position close to the cathode, starting the light emission of the discharge, is not captured at all when combining the lines both originating from 4p levels (750.4, 751.5 nm, top right). The intensity ratio constructed of 5p 419.8 and 420.1 nm lines (top left), developed to measure electron temperature at low pressures [4], seems to lose the sensitivity at high electric fields. This may be explained by the low importance of step-wise excitation through metastable states at atmospheric pressure. The intensity ratios combining the lines out of 4p and 5p levels seem to have the ability to track the streamer field depending on the line sensitivity to the electric field calculated from a simple collisional radiative model and the Boltzmann equation.

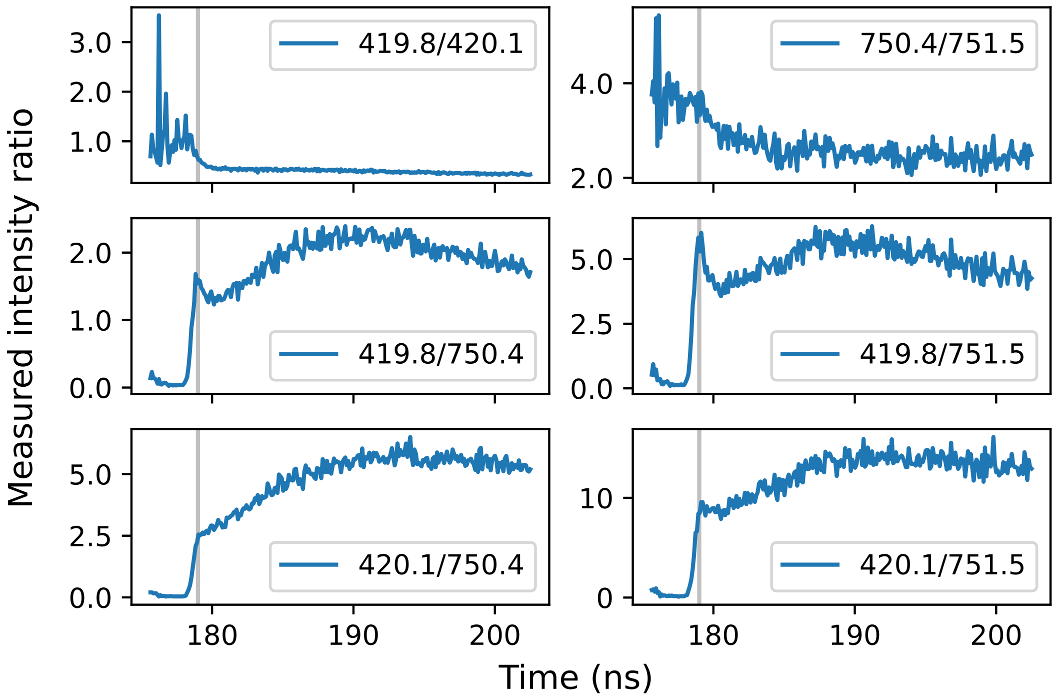

Fig. 2: Line intensity ratios during microdischarge ignition constructed from argon lines originating from $3p^5$ 4p and $3p^5$ 5p levels. The streamer passage is observed at the times around 179 ns (marked by a vertical line in the plots).

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