Stark polarization spectroscopy in the cathode sheath of a Grimm-type glow discharge in neon

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The quadratic Stark effect occurs in many-electron atoms as a result of an external field-induced electric dipole in an atom, and the lines and their split components in the spectrum are shifted asymmetrically relative to the unshifted zero-field line. As the atomic number rises above hydrogen and hydrogen-like atoms, the quantum mechanical calculations of energy levels become more demanding and involve appropriate approximations verified by experimental results in terms of the number of components detected and their shifts from the unperturbed transition. For a number of argon and neon spectral lines, Windholz 1980, and Jäger and Windholz 1984 identified the numbers and shifts of the Stark components in strong electric fields up to 1000 kV/cm.

We report on the polarization-dependent excitation of five asymmetrically shifted Stark components of neutral neon lines Ne I 503.775 nm [5*d* (7/2) 4 → 3*p* (5/2) 3] and Ne 508.038 nm [5*d* (7/2) 3 → 3*p* (5/2) 2] in the cathode sheath of a Grimm-type DC glow discharge source (GDS), operating in Ne+0.8%H_2 mixture. Optical emission spectroscopy (OES) is applied to study a narrow dark slice of the discharge next to the cathode surface where externally applied voltage produces a linearly decreasing electric field and where ions and electrons are accelerated in opposite directions, resulting in charge-exchange fast neutrals generation, secondary electron emission, and various other elastic and inelastic collisional processes. OES measurements are made at the position in the cathode sheath where a maximum electric field strength of around 15 kV/cm is attained to ensure the largest shifts of Stark components. A linear light polarizer is used to select the polarization-dependent components, i.e., the ones with electric vector linearly polarized in the direction of the external electric field (so-called π components), and ones with electric field vector circularly polarized in the plane perpendicular to the external electric field (σ components), see Fig. 1 and Ryde 1976.

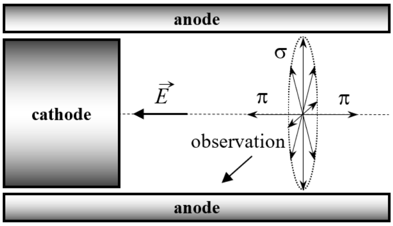

Fig. 1. Central part of Grimm GDS and the schematics of π and σ light polarization.

The OES results are shown in Fig. 2. While the unpolarized profiles (black line/circles) reproduce well Windholz's measurements (1980), which for the 5*d*–3*p* transitions identified 3 Stark components (in addition to the unshifted zero-field line at λ_0), the polarization spectroscopy reveals more complex structure, with 3 shifted σ (red line/triangles) and two π (blue line/squares) components. While Windholz's 1980 study of unpolarized emission is based on the assumption that for noble gasses with Z > 4, the upper transition levels only split and contribute to the excitation of Stark components, the detection of 5 Stark components in total can be explained following Ryde's 1976 considerations that the small splitting of the lower levels occurs too. The apparent energy overlapping of two higher red-shifted σ transitions with both π components, see Fig. 2, indicates the indeed small energy splitting of the lower *p* levels. In the unpolarized profile, the σ and π components show their joint footage, appearing as an integral 3-component structure, detected by Windholz 1980.

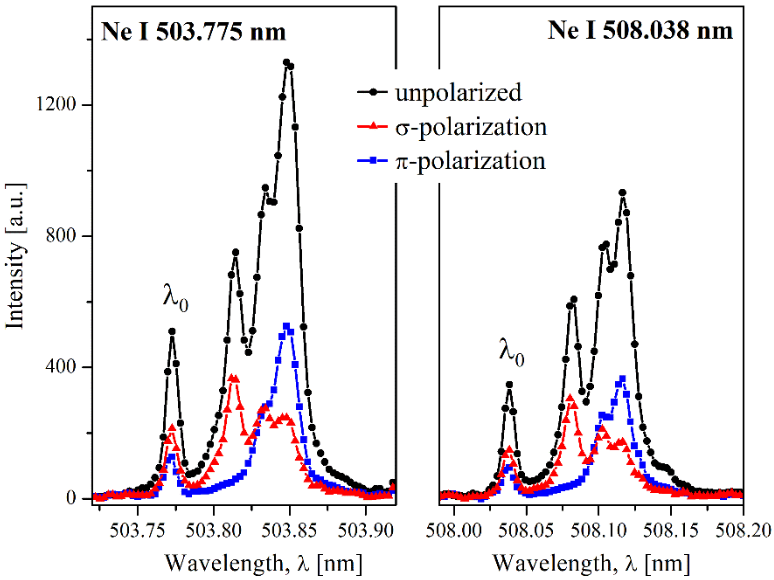

Fig. 2. Unpolarized and polarized profiles of neutral neon Ne I 503.775 nm and Ne I 508.038 nm spectral lines, recorded in the cathode sheath. λ_0 denotes the position of the unshifted line.

References

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Ryde, N., 1976, Atoms and molecules in electric fields, Almqvist & Wiksell
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