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MEASUREMENT OF THE LOCAL ELECTRIC FIELD IN DISCHARGES USING LASER STARK SPECTROSCOPY OF THE NaK MOLECULE

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A heteronuclear diatomic molecule has a permanent electric dipole and consequently can interact strongly with an electric field. In some favorable cases this results in spectacular modifications in the laser induced fluorescence spectrum.

Fig. 1. Effect of electric field on the laser induced fluorescence signal for NaK excited in the (B1 Π;v=5,j=4e) level.

Fig. 1 shows the fluorescence spectrum of the NaK molecule, excited in the e λ-doublet component of the B1 Π,v′=5,j′=4 level by mean of a C.W. single mode laser tuned to the (B1 Π;v′=5,j′=4-X1 Σ+,v″=0,j″=5) transition at 17286.58 cm⁻¹. In the absence of an electric field, the fluorescence spectrum to the ground X1 Σ+ state is composed of a series of "P-R" doublets, one of which is shown on Fig.1. However an external electric field couples the e to the f λ-doublet component [1], and consequently the fluorescence spectrum becomes a series of "P-Q-R" triplets. The ratio of Q to R (or P) line intensities can be directly related [1,2] to the amplitude and direction of the electric field, relative to the polarization of the exciting laser beam and of the observed fluorescence spectrum (Fig.2). It can thus be used to measure the electric field in low pressure discharges containing a small amount of NaK [3].

Previously, Gottscho and coworkers [4] have studied discharges in electronegative gases using the same molecular laser Stark spectroscopy technique with BC1 instead of NaK as the spectroscopic probe.

Fig. 2. Ratio of Q/R line intensities for NaK(B1 Π;v=5,j) In each case the laser is tuned to a P or R transition, exciting only the e λ-doublet component.

°:experiment. ---:theory.
As shown on Fig. 2, the sensitivity can be adjusted by choosing the rotational level $j'$ excited by the laser. It goes from a few V/cm for $j'=4$ up to 1000 V/cm for $j'=24$. Higher fields could be measured as well using larger $j'$.

On Fig. 3 is shown a series of laser induced fluorescence spectra of NaK(B-X) recorded at different positions in a discharge established in a mixing of Ar+K+Na. The fall of the electric field is clearly apparent. The spatial resolution of about 0.2 to 0.3 mm is mostly determined by the slit width of the monochromator and could be improved by focusing the laser beam.

![Fig. 3. Laser induced fluorescence spectra of NaK(B111;v=5, j=10e) present as traces in a mixing of Ar+K+Na. a) without discharge. b) with a D.C. discharge, as a function of the distance to the cathode (mm)](image)

On Fig. 4 we show some results obtained with the present technique concerning the distribution of the electric field in discharges in a Ar(98%)+K(2%)+Na(0.04%) mixing (0.4 Torr 483°K) for different values of the current density. This kind of measurements is presently used to test the validity of different discharge models.

![Fig. 4. Distribution of the electric field, measured using the Laser Stark Spectroscopy in NaK, in discharges in a mixing of Ar+K+Na.](image)
Finally Fig. 5 demonstrates the ability of the method to be used to do time resolved measurements of electric fields in non stationary (RF or pulsed) discharges. Represented is the predicted response of the NaK molecule to steps of electric field of various amplitudes applied at t=0. The response is defined as the ratio of integrated fluorescence intensities. One sees that the stationary value is reached within about 5 ns.

![Graph showing the response of the NaK molecule to steps of electric field.](image)

In conclusion the present laser Stark spectroscopy technique has many advantages to probe the electric field in low pressure discharges. It is nonintrusive, local, fast and sensitive. However the use of NaK as the spectroscopic probe requires the presence of Na and K as impurities in the gas studied. It is thus restricted to the study of electropositive gases heated at 200 to 250 °C. This is still interesting for improving our knowledge on discharges physics and may be of relevance for optimizing alkali vapor lighting devices.

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