

## ON THE USE OF FLUORESCENCE SPECTROSCOPY FOR THE DIAGNOSTICS OF LOW DENSITY PLASMAS

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In a typical fluorescence experiment /1/, a strong radiation source is focussed into a gas volume, where a selected particle species gets excited and emits fluorescence radiation, the intensity of which is proportional to the particle density. In principle the density of molecules, atoms and ions in the ground state as well as in a metastable or unstable excited state can be determined. Usually, the main interest is in the ground state. For high sensitivity, light sources of high spectral power at the line to be excited are necessary. Furthermore, transitions with large absorption cross-sections and transition probabilities have to be selected. The conditions can best be fulfilled, if electronic resonance transitions are used. Metals have their resonance lines mainly in the visible or near UV region above 2000 Å, whereas many permanent gases have their resonance lines in the vacuum UV.

In the visible spectral range tunable lasers /2/ can be used for excitation. For work in the UV the frequency of these lasers has to be doubled. Their bandwidth is chosen to be somewhat broader than the width of the line to be excited, if maximum sensitivity for density determination is desired. If the laser line width is much smaller than that of the absorption line, Doppler effects can also be measured and from these measurements velocity distribution functions and particle fluxes can be derived.

In the vacuum UV lasers are normally not available and pulsed gas discharges have to be used as light sources. Since their spectral power is comparatively low and wavelength selection is difficult they are in general not used for the measurement of velocity distributions. In this case a two step excitation is possible using a pulsed gas discharge in combination with a narrow band tuneable dye laser; e.g. hydrogen atoms are first excited by a broad band gas discharge lamp from the  $n = 1$  groundstate to the  $n = 2$  state. The velocity distribution of the excited atoms being representative for all atoms can then be measured with a narrow band dye laser using the  $n = 2 \rightarrow n = 3$  transition ( $H_{\alpha}$ ).

The applications of fluorescence spectroscopy to be discussed here are mainly in the field of plasma wall interaction. Preliminary estimates /3/ had shown that this method might offer the possibility to determine "in situ" the density, the velocity distribution and, in particular, the flux density of metal and of hydrogen atoms (molecules) in front of the wall of magnetic confinement experiments. Under these conditions the

advantages of this method - high sensitivity - independence on plasma parameter as  $n_e$  and  $T_e$  - local and time resolved measurements - little stray light problems by observing wavelengths shifted lines - are specially useful.

Our investigations show that all metals of interest can be detected with high sensitivity, e.g. the detection limit /4/ in case of Fe is about  $10^5 \text{ cm}^{-3}$ . Simulation experiments by means of a large area ion source demonstrate that the velocity distributions can be determined and that flux densities are relatively simply obtained /5/. A procedure for an absolute calibration of the fluorescence signal taking also into account metastable atoms has been developed.

Considering the detection of hydrogen and deuterium it has been shown that with existing light sources the detection limit for atoms is about  $10^8 \text{ cm}^{-3}$ , for molecules  $10^{10} \text{ cm}^{-3}$ . The measurement of the velocity distribution of the hydrogen atoms is under preparation and seems straight forward. Absolute calibration of signals is obtained by using Krypton /6/.

Measurements on the relaxation and diffusion of sputtered Fe-atoms in an argon glow discharge demonstrate the possibilities of fluorescence spectroscopy in other fields of plasma physics /7/.

#### REFERENCES

- /1/ A.C.G. Mitchell and M.W. Zemansky, Resonance Radiation and Excited Atoms (Cambridge University Press 1961)
- /2/ W. Demtröder, Grundlagen und Techniken der Laserspektroskopie, Springer Verlag, Berlin 1977
- /3/ P. Bogen and E. Hintz, Comments on Plasma Physics, Contr. Fusion 4, 115 (1978)
- /4/ A. Elbern, D. Rusbüldt, and E. Hintz, Proceedings of the International Symposium on Plasma-Wall Interaction (Pergamon, Oxford, 1977). p. 475
- /5/ A. Elbern, E. Hintz and B. Schweer, J. Nucl. Mat. (1978)
- /6/ P. Bogen and Y.T. Lie, Appl. Phys. 16, 139 (1978)
- /7/ A. Elbern, Ph. D. Thesis (Bochum 1976) Appl. Phys. 15. 111 (1978)