VI. GASEOUS ELECTRONICS*

Academic and Research Staff

Prof. E. V. George
Prof. W. P. Allis
Prof. G. Bekefi
Prof. S. C. Brown
J. J. McCarthy
W. J. Mulligan

Graduate Students

C. Johnson
C. W. Werner
D. Wildman

A. ELECTRON DENSITIES IN AN ARGON-ION LASER

The electron densities in argon-ion lasers have previously been measured by use of microwave diagnostics and Stark-broadening calculations of neutral argon and argon-ion lines.[1,2] Under the assumption of a Bessel function density profile, microwave measurements have consistently given density values an order of magnitude below those calculated from line broadening. In this investigation the halfwidth of the H_α line was measured in an argon discharge that contained 1% hydrogen. We used the well-established theory of linear Stark broadening to obtain electron densities over a range of discharge currents at a filling pressure of 2.5 Torr.

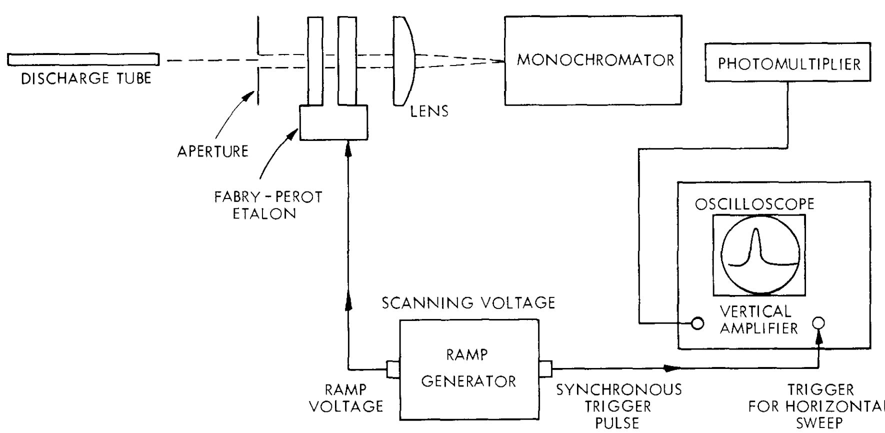

Fig. VI-1. Experimental arrangement.

The experimental apparatus is shown in Fig. VI-1. The laser discharge tube was a 2-mm ID quartz capillary surrounded by a 12-mm OD cooling jacket. Light emitted in the axial direction first passed through an aperture 3 mm in diameter 75 cm from

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the discharge tube before illuminating the Fabry-Perot plates. The Fabry-Perot interferometer was the Spectra Physics Model 380 equipped with both mechanical and piezoelectric micrometers to align the $\lambda/100$ flat plates of 2 in. diameter. Both mirrors had a reflectivity greater than 99% at 6500 Å. The mirror spacing d was varied by the z-axis translator coupled with a linear ramp generator that swept 0.75 μm per 100 volts with sweep duration of 0.2-200 ms. The translator could also be swept manually and the photomultiplier output displayed on an x-y recorder. In general, plates flat to λ/m limit the resulting finesse of the interferometer to values $\leq m/2$. With a He-Ne laser as a monochromatic source, the finesse was found to exceed 35 with manual sweeping. The Fabry-Perot fringe pattern, which is localized at infinity, was then focused on the 150-μm entrance slit of a 0.25 m monochromator with a bandwidth of 5 Å. An RCA 6199 photomultiplier tube placed at the monochromator exit slit served as detector.

While measuring the halfwidth of the H_α line, mirror separations of 1-2 mm were used. The z-axis translator was swept through 4 free spectral ranges during a period of 5 ms. The oscilloscope output not only displayed the observed line profile but also provided a convenient method of monitoring the instrument finesse. Any decrease in the observed finesse from mirror misalignment caused by vibrations produced a decrease in the line intensity. This could immediately be corrected by adjusting the voltages on the piezoelectric crystals until the mirrors were again parallel. In this manner all halfwidths were measured with the maximum finesse of the instrument.

The unfolding of the observed profile into its Gaussian and Lorentzian components was accomplished by the well-known Voigt profiles. If we let I_D be the intensity profile attributable to Doppler effects and I_L be the intensity profile resulting from Stark broadening, the observed intensity profile may be expressed in the form[3]

$$I(\Delta\lambda') = \int_{-\infty}^{\infty} I_D(\Delta\lambda)\, I_L(\Delta\lambda'-\Delta\lambda)\, d(\Delta\lambda),$$

where $\Delta\lambda$ is the distance from the center of the line, and I_D, I_L, and I are normalized

$$\int_{-\infty}^{\infty} I_D(\Delta\lambda)\, d(\Delta\lambda) = \int_{-\infty}^{\infty} I_L(\Delta\lambda)\, d(\Delta\lambda) = \int_{-\infty}^{\infty} I(\Delta\lambda)\, d(\Delta\lambda) = 1.$$

Values of $\Delta\lambda_{L\ 1/2}/\Delta\lambda_{1/2}$ have been tabulated as a function of $\Delta\lambda_{D\ 1/2}/\Delta\lambda_{1/2}$, where $\Delta\lambda_{L\ 1/2}$ and $\Delta\lambda_{D\ 1/2}$ are the halfwidths from pure Lorentzian and Doppler broadening, and $\Delta\lambda_{1/2}$ is the observed halfwidth.[4]

The determination of electron densities from full Stark halfwidths made use of Griem's formula[5] which relates the electron density N_e to $(\Delta\lambda_{L\ 1/2})^{3/2}$

$$N_e = C(N_e, T)(\Delta\lambda_{L\ 1/2})^{3/2}.$$

The coefficient $C(N_e, T)$ is a weak function of electron density and has a slowly varying temperature dependence because of corrections for ion-ion correlation, Debye shielding, and the velocity dependence of impact broadening. Griem has calculated values of $C(N_e, T)$ from complete line profiles and has tabulated the halfwidths associated with various temperatures and densities.[6] Interpolation between known halfwidths is justified, since $C(N_e, T)$ is a slowly varying function.

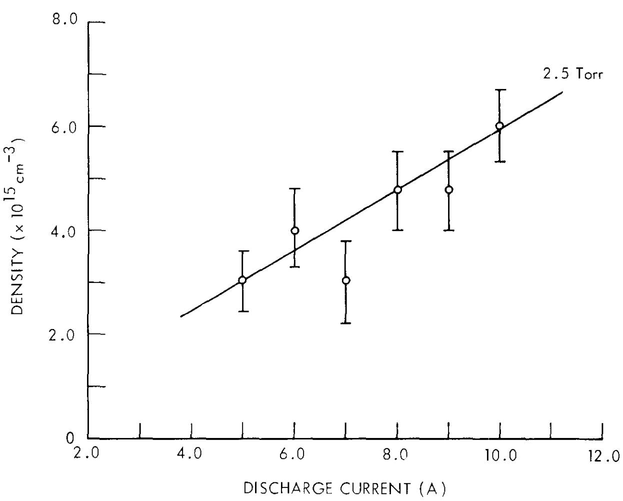

Fig. VI-2. Electron density as a function of discharge current for a filling pressure of 2.5 Torr.

The electron density as a function of discharge current is shown in Fig. VI-2. In calculating these results we used electron temperatures of 40,000°K and ion temperatures of 1500°K. The exact choice of temperatures is not critical because $\Delta\lambda_{L\ 1/2}$ is a slowly varying function of electron temperature for any given electron density, $\Delta\lambda_{D\ 1/2}$ is proportional to $T^{1/2}$, and the Voigt profiles are not extremely sensitive to the Doppler width for small values of $\Delta\lambda_{D\ 1/2}/\Delta\lambda_{1/2}$. There is good agreement between our data and previous results obtained from the Stark broadening of argon lines.[2] The discrepancy between these data and the microwave diagnostic results may come from the assumption of a Bessel function density profile. If the density decreases faster than a Bessel function, substantial errors could be encountered in the microwave diagnostic theory.

D. Wildman

References

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