VIII. GASEOUS ELECTRONICS*

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A. RADIATION TEMPERATURES IN ARGON ION LASER

Using microwave reflection and transmission techniques, we measured the radiation temperature of a narrowly confined argon discharge with a radiometer[1] at a frequency of 34.53 GHz. Using a tube of 2-mm bore diameter, with discharge currents in the 4-10 A range, we studied 1-5 Torr pressures. The discharge tube was a 2-mm ID quartz capillary, 40 cm long, enclosed in a 12-mm OD cooling jacket. The coolant was Dow Corning silicon fluid.

When no magnetic field is present, the radiation temperature, T, is defined[2] by

$$kT = \frac{-m \int_0^\infty Q(v)\, f v^5\, dv}{\int_0^\infty Q(v) \frac{\partial f}{\partial v} v^4\, dv},$$

where Q(v) is the total collision cross section for momentum transfer for an electron with any other species in the plasma, k is Boltzmann's constant, m is the electron mass, and f is the distribution function for electron velocities normalized so that $4\pi \int_0^\infty f v^2\, dv = 1$. The electron temperature is defined as $3/2kT_e = \bar{u}$ where $\bar{u}$ is the average electron energy.

We see that when f is a Maxwellian or $Q(v) \propto v^{-1}$, $3/2\ kT = \bar{u} = 3/2\ kT_e$ and the radiation temperature equals the electron temperature. Bekefi and Brown[3] have calculated the ratio $\frac{3/2kT}{3/2kT_e}$ for distribution functions of the form $f \propto \exp(-av^\ell)$ for values of ℓ from 1 to 8 and $Q(v) \propto v^{h-1}$. They have found that the ratio deviates from unity only for large negative values of h corresponding to fully ionized gases.

Radiation from a noise standard calibrated to have an effective noise temperature of 10,100°K was alternately channeled by a ferrite switch between the plasma and the

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radiometer, which periodically compared the intensity of radiation from the plasma with the noise standard alone. The radiation temperatures were then measured by observing the power emitted, reflected, and absorbed by the plasma.[4]

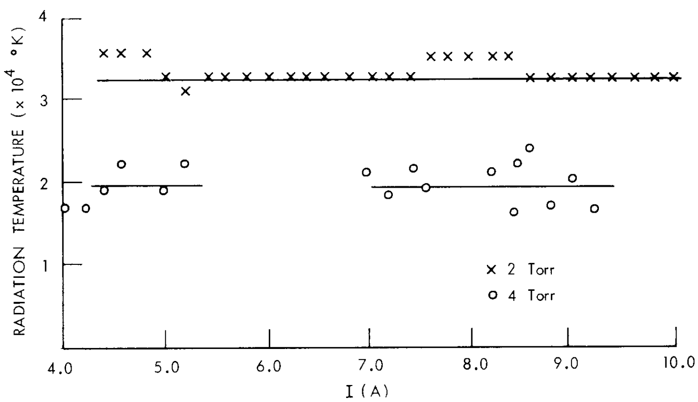

Fig. VIII-1. Radiation temperatures at 2 Torr and 4 Torr.

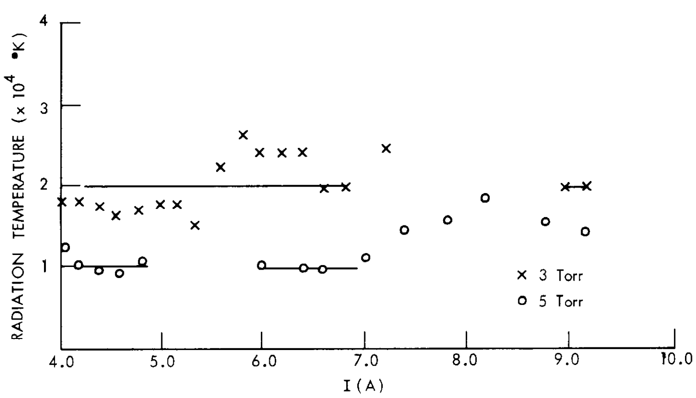

Fig. VIII-2. Radiation temperatures at 3 Torr and 5 Torr.

Figures VIII-1 and VIII-2 show the radiation temperature as a function of discharge current. The large gaps in the data correspond to regions where Tonks-Dattner resonances occur. Low emissivities and difficulties in determining the exact shape of the resonance kept us from obtaining useful information in these regions. Our results are in good qualitative agreement with both Schottky theory and the results calculated by using the spacing of Tonks-Dattner resonances.[5] The resolution of our apparatus was such, however, that we could not determine the dependence of the radiation temperature on discharge current.

D. Wildman

References

1. J. C. Ingraham, Ph.D. Thesis, Department of Physics, M.I.T., June 1963, p. 22 (unpublished).

2. G. Bekefi and S. C. Brown, J. Appl. Phys. 32, 25 (1961).

3. Ibid., p. 25.

4. D. Wildman, S.B. Thesis, Department of Physics, M.I.T., May 1972 (unpublished).

5. D. Prosnitz and E. V. George, Quarterly Progress Report No. 103, Research Laboratory of Electronics, M.I.T., October 15, 1971, pp. 99-101.