VII. GASEOUS ELECTRONICS*

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A. TONKS-DATTNER RESONANCES IN ION LASER

Tonks-Dattner resonances have been observed in an argon ion laser discharge. These resonances enable one to calculate the electron temperature of the plasma.

The discharge was contained in a 40-cm quartz tube (2 mm i. d.) surrounded by a 12 mm o. d. cooling jacket. The resonances were observed by shining a 35.1 GHz source on the discharge and observing the power reflected as a function of discharge current. The electron density was determined at each resonance by measuring the frequency shift of the TE_{011} mode of a microwave cavity. (This method is fully described elsewhere.[1])

Tonks-Dattner resonances are the result of standing waves which may form between the plasma sheath and the point where the driving frequency (ω) is equal to the local plasma frequency ($\omega_p(r)$). [$\omega_p^2(r) = n(r)\, e^2/M\epsilon_o$, where n(r) is the electron density and M the electron mass.] Schmitt et al.[2] have used a WKB approximation to obtain the following condition for the existence of a standing wave.

$$\left(m+\frac{3}{4}\right)\pi = \int_{r_o}^{a} K\, dr = \int_{r_o}^{a} \left[\frac{\omega^2 - \omega_p^2(r)}{3kT/M}\right]^{1/2} dr,$$

where m is the resonance index (m = 0, 1, 2...), T the electron temperature, a the tube radius, and r_o the point where $\omega = \omega_p(r_o)$. They then assume a Bessel function density profile $\omega_p^2(r) = \omega_{p_o}^2 J_o\left(\frac{2.405\, r}{a}\right)$ to obtain

$$\left(m+\frac{3}{4}\right)\pi \approx \frac{2a\omega}{3\left(\frac{3kT}{M}\right)^{1/2} 2.405\, J_1(2.405)} \frac{\omega^2}{\omega_{p_o}^2} \left\{1 - \frac{J_2(2.405)}{5J_1^2(2.405)} \frac{\omega^2}{\omega_{p_o}^2}\right\}.$$

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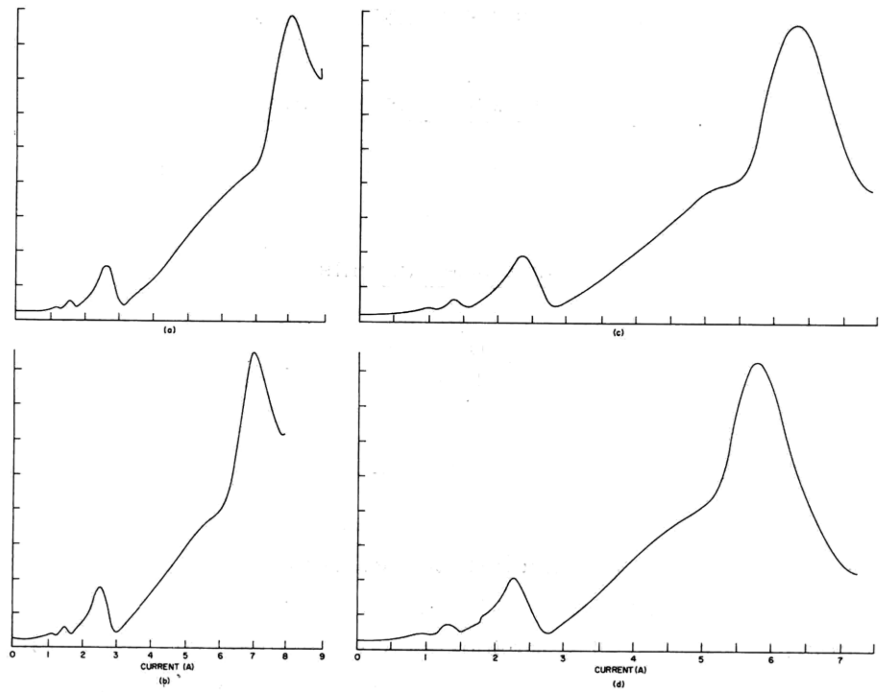

Fig. VII-1. Tonks-Dattner resonances in the reflection of an argon ion laser discharge.
(a) 3.0 Torr. (c) 4.1 Torr.
(b) 3.5 Torr. (d) 4.7 Torr.

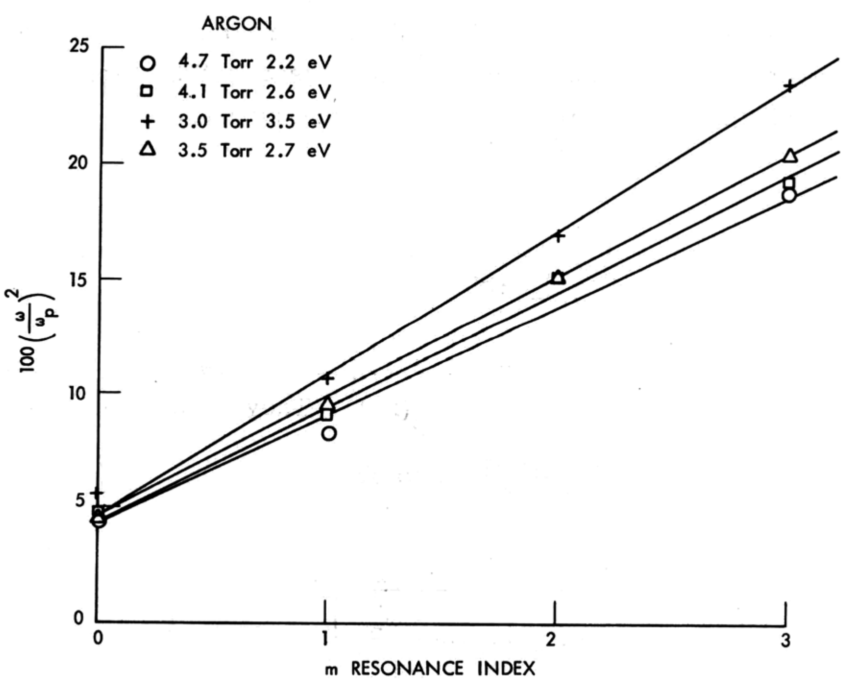

Fig. VII-2. $\left(\frac{\omega}{\omega_p}\right)^2$ plotted against the Tonks-Dattner resonance index. The resonance spacing enables calculation of electron temperature.

The expression above may then be used to determine the electron temperature.

Figure VII-1 shows the resonances as a function of discharge current. Figure VII-2 shows $(\omega/\langle\omega_p\rangle)^2$ plotted against the resonance index m, where $\langle\omega_p\rangle^2$ is the average plasma frequency,

$$\left[\langle\omega_p\rangle^2 = \frac{\langle n\rangle e^2}{M\epsilon_o}\right].$$

The slope of these lines determined the designated electron temperature. Here we have assumed that

$$\frac{J_2(2.405)}{5J_1^2(2.405)} \frac{\omega^2}{\omega_p^2} \ll 1.$$

An instability[1] in the discharge prevents us from obtaining a full range of resonances at lower pressures. Figure VII-3 shows the electron temperatures calculated

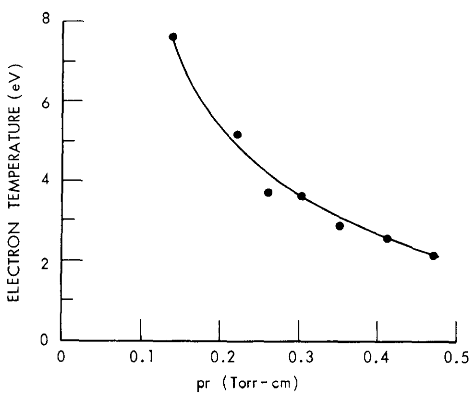

Fig. VII-3. Electron temperature of argon ion laser as calculated from m = 1 Tonks-Dattner resonance.

using the single resonance for which the most data were available (m = 1). It is seen that this gives good qualitative agreement with Schottky theory.

We realize that this method can only yield approximate figures for the electron temperature as all computations depend on the assumed density profile. A radiometer is being constructed so that more accurate temperature measurements may be made.

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References

1. L. D. Pleasance and E. V. George, Appl. Phys. Letters 18, 557-561 (1971).
2. H. J. Schmitt, G. Meltz, and P. G. Freyheit, Phys. Rev. 139A 1432 (1965).