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OBSERVATION OF $3\omega_o/2$ RADIATION FROM MICROWAVE DECAY INTO TWO PLASMONS

R. W. Means

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Abstract

Parametric decay of microwave radiation (frequency ω_o) into two plasma waves at the $\omega_p = \omega_o/2$ point has been observed. The scattered radiation at $3\omega_o/2$ has both upper and lower frequency sidebands, as predicted theoretically.

We have observed the generation of two Langmuir waves in an inhomogeneous large volume, quiescent plasma at the point where the local plasma frequency, ω_p, is half the frequency, ω_o, of the incident electromagnetic pump wave. This parametric decay has been studied theoretically[1-4], but previous experimental observations[4-7] have involved only the detection of the scattered radiation at $3\omega_o/2$ in laser produced plasmas where incident radiation also created the plasma. The parameters of these plasmas are all difficult to measure accurately so only qualitative comparisons with theory have been possible.

We report here the observation of radiation at $3\omega_o/2$ in a multipole d c discharge plasma. The plasma is steady state with parameters independent of the incident microwave radiation. Typical experimental plasma parameters for Argon are : $\omega_o/2\pi = 8.545 \cdot 10^9$Hz; electron temperature $T_e = 1.5$eV; gradient scale length $L \equiv \left(\frac{1}{n}\frac{dn}{dX}\right)^{-1} = 250$ cm; collision frequency ν_{ei} = $= 4.1 \cdot 10^6$Hz:, maximum pump intensity = 250 W/cm^2; maximum pump pulse length = 2.25μs. A sketch of the apparatus and typical density profile is given in figure 1.

A spectrum of the backscattered signal just above threshold is shown in figure 2. Both upper and lower frequency sidebands are observed. The frequency shift is symmetric about $3\omega_o/2$ and equal to 160 MHz. This is in strong disagreement with Avrov et al.[4] who predict a frequency shift of 40 KHz but in rough agreement with Liu and Rosenbluth[1] who predict a frequency shift of 33 MHz using a maximum $k_y = 77$ cm^{-1}. The down shifted wave is a result of the interaction between the incident transverse wave and one of the parametrically excited Langmuir waves propagating down the density gradient. The upshifted wave could be a result of the interaction of the incident transverse wave and the other excited Langmuir wave traveling up the density gradient. This would then reflect from the metal wall at the far end of the chamber into the receiving antenna. However, the upgoing Langmuir wave could also be reflected at its critical surface and be traveling down the gradient where it could then interact with the incident transverse wave to scatter radiation into the receiving antenna.

The backscattered wave at $3\omega_o/2$ gave a received power of approximately 0.1μW. This is in good agreement with Liu and Rosenbluth[1], but in considerable disagreement with Avrov et al.[4] who predict a received power of 10^{-20} watts. This extremely low power level was found because Avrov et al.[4] considered the reaction at the quarter-critical surface to be non-resonant. It is correct that the reaction $\ell + t \rightarrow t$ is non-resonant because momentum is not conserved. However, one can invoke an ion acoustic wave so that the reaction becomes a four wave resonant process[8] $\ell + t \rightarrow t + s$. This should have approximately the same threshold if the ion acoustic wave is undamped.

The observed threshold was approximately 150 W/cm^2. A graph of received power at $3\omega_o/2$ vs. pump intensity is shown in figure 3. The inhomogeneous threshold predicted by Liu and Rosenbluth is given by the expression

$$I = 8\, mnc \frac{\nu_{ei}}{k_o^2} \left[1 + \left(1 + \frac{3V_e^2\, k_o}{\nu_{ei}^2 L} \right)^{\frac{1}{2}} \right]^2$$

where I is the pump intensity, m is electron mass, n is the plasma density, c is the speed of light, V_e is the electron thermal velocity, and k_o is the pump wave number. For the parameters of our experiment this gives a threshold of 160 W/cm^2, in good agreement with the experiment. When the density was lowered so that it was below $n_c/4$ everywhere in the chamber the signal at $3\omega_o/2$ disappeared completely.

Helium and Xenon plasmas were also investigated. The frequency shift did not appear to be a function of ion mass. However, the width of the spectrum appeared to increase by a factor of 3 for the Helium plasma with respect to the Argon plasma suggesting that ion acoustic waves are involved, e.g. in the decay process. Additional details of the observations will be published elsewhere.

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Figure Captions

1. Sktech of the experimental apparatus. There are two microwave horns at one end of the plasma chamber. The transmitting horn has a narrow beamwidth (8^{o}) and the receiving horn a wide beamwidth (28^{o}). The density profile is shown schematically. The maximum density is $2.7 \cdot 10^{11}$ particle/cm.

2. Power spectra near $3\omega_o/4\pi$ = 12.818 GHz. The region between 12.700 and 12.950 showed no peaks and is not shown here. The incident microwave intensity was 150 W/cm , just above threshold. The vertical scale is logarithmic in arbitrary units.

3. Power received in the lower sideband at $3\omega_o/2$ vs. incident microwave intensity. The experimental uncertainties are less at lower power levels.

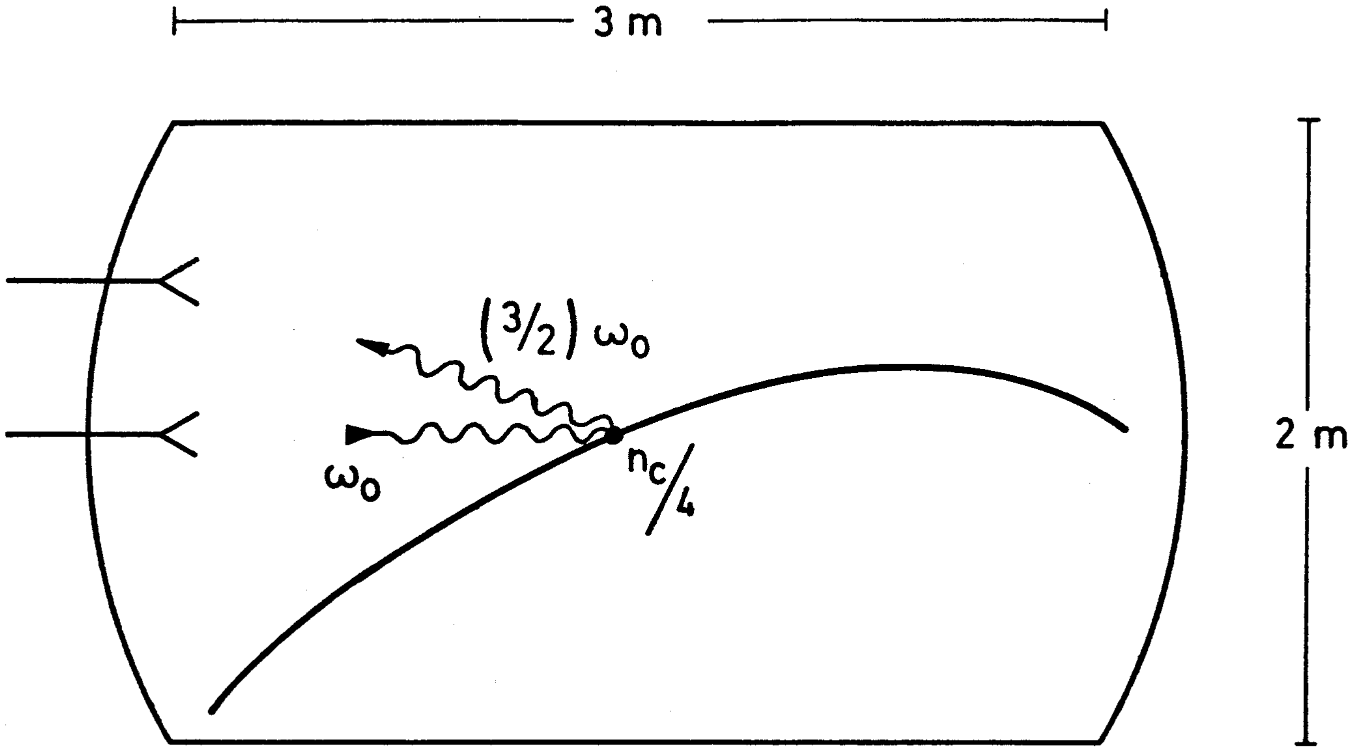

Figure 1.

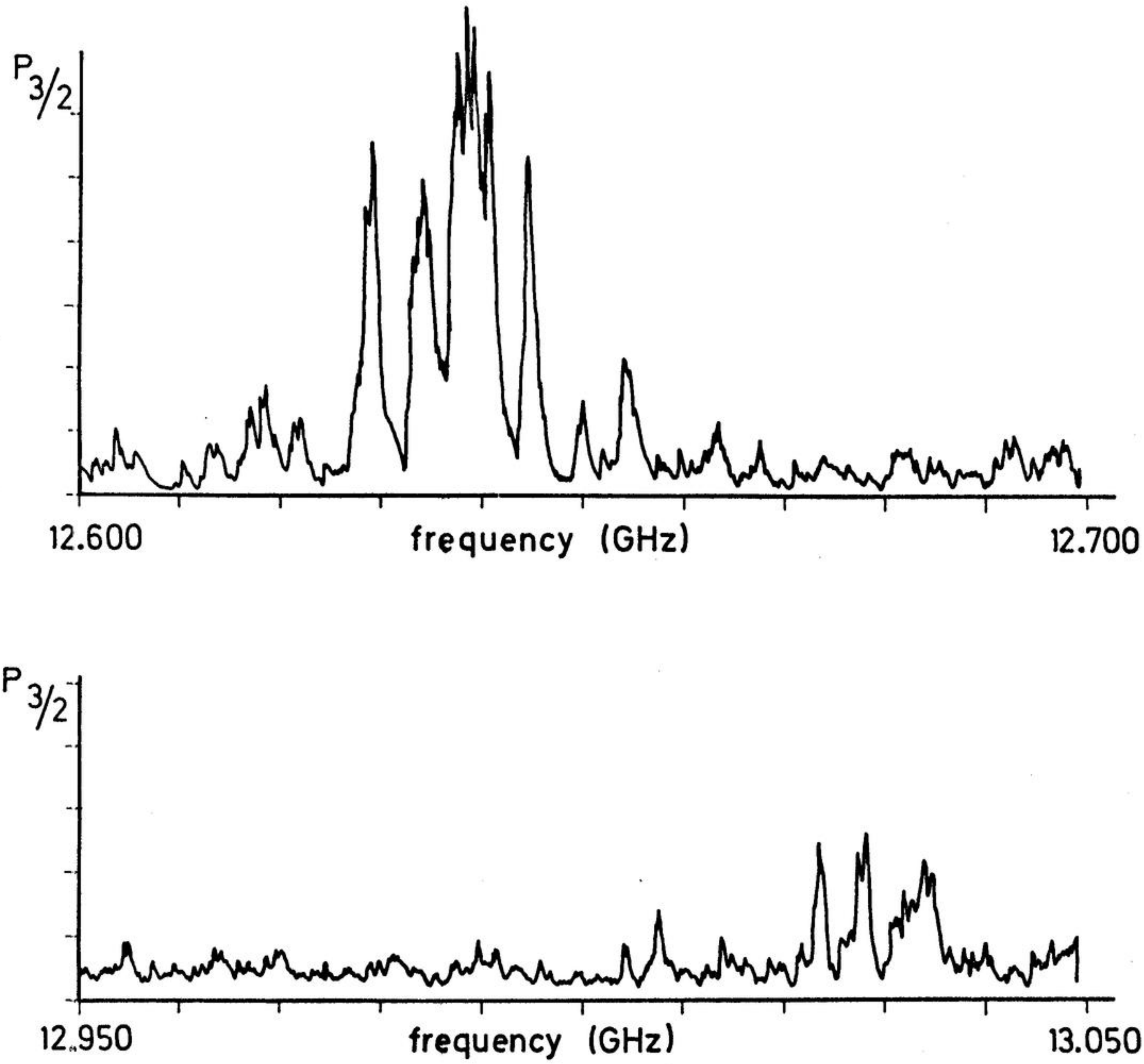
P3/2
12.600
frequency (GHz)
12.700
P3/2
12.950
frequency (GHz)
13.050

Figure 2.

Figure 3