

## XII. GASEOUS ELECTRONICS\*

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#### A. MICROWAVE CAVITY DIAGNOSTIC TECHNIQUES

In the afterglow of a pulsed helium discharge, the number of helium atoms in the singlet ( $2^1S$ ) and triplet ( $2^3S$ ) metastable states decays with time, because of various destruction mechanisms. One important mechanism that determines the lifetime of the singlet state, is the conversion of the singlet to the triplet state by a collision with a thermal electron.<sup>1</sup> Thus to determine the cross section for this process from the measured  $2^1S$  lifetime, it is important that the electron densities be accurately known at all times in the afterglow.

The usual technique for determining electron densities is from the shift in the resonant frequency of a microwave cavity. But the usual first-order perturbation theories used to interpret the cavity data do not take into account the fact that the plasma is surrounded by a quartz tube and that the cavity has end holes for the quartz discharge tube. An experiment has been conducted to account for these errors, and a computer program has been written to predict electron densities from the measured resonant cavity frequency shift.

To experimentally determine the errors involved in measuring the electron densities attributable to the quartz tube and the cavity end holes, polystyrene foam was used to simulate low electron densities where the index of refraction is close to that of air.

The microwave cavity is a cylindrical brass, silver-plated cavity of 7.003 cm height, 5.403 cm radius, and 1.273 cm end-hole radius for the quartz discharge tube. The end holes are along the cylindrical axis of symmetry with collars extending out to limit end-hole effects. The cavity resonates at 4928 MHz for the  $TM_{020}$  mode, and at 4014.5 MHz for the  $TE_{011}$  mode, the two principal modes that are being used in this experiment. First, the index of refraction of the polystyrene foam was determined by comparing the resonant frequencies of the  $TM_{020}$  and  $TE_{011}$  modes when the cavity was filled with styrafoam and when the cavity was empty. The index of refraction was found to be  $n = 1.0157 \pm 0.0004$  in the region 4000-5000 MHz.

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Next, a column of styrafoam was shaped to simulate the plasma column and inserted in the cavity with and without the surrounding quartz tube. The shift in resonant frequency of the  $TM_{020}$  mode was  $19.4 \pm 0.2$  MHz without the quartz tube, and  $14.0 \pm 0.2$  with the quartz jacket. The  $TE_{011}$  mode frequency shift was approximately 1.0 MHz for both cases, but the experimental errors involved in measuring the frequency shift were too large, and the  $TE_{011}$  mode will not be discussed further.

A computer program was written to determine theoretically what the frequency shifts should be. The program matched electric and magnetic fields across the plasma, quartz, and air boundaries for a cavity with no end holes. The program predicts a resonant frequency shift of the  $TM_{020}$  mode of 19.76 MHz for styrafoam without a quartz tube, and a shift of 12.31 MHz with a quartz tube.

From these measurements it follows that for the  $TM_{020}$  mode the end holes introduce a 1% error in the absence of the quartz, whereas in the presence of the quartz they introduce a 15% error. It also follows that the quartz introduces a 50% error if not accounted for in the calculation.

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### References

1. A. V. Phelps, Phys. Rev. 99, 1307 (1955).