V. GEOPHYSICS*

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A. ABSORPTION OF $\lambda = 4880$ Å LASER BEAM BY ARGON IONS

The absorption of the output beam of a steady-state argon ion laser ($\lambda = 4880$ Å) by excited argon ions in a low-pressure arc discharge has been observed. The argon ions, excited to the $4s\,^2P_{3/2}$ state, strongly absorb the laser beam that is produced by the Ar II transition $4p\,^2D^o_{5/2} \rightarrow 4s\,^2P_{3/2}$.

The ultimate purpose of this work is to develop a technique to measure the temperature of ions in moderate temperature plasmas by determining the Doppler width of an ion absorption line. The steady-state ion laser provides a series of extremely sharp emission lines corresponding to the optical resonant cavity modes of the laser. The ratios of the intensities of the laser modes, determined with and without the absorbing ions, can be related to the Doppler width of the ion absorption line. For excited argon ions absorbing energy corresponding to the $4s\,^2P_{3/2} \rightarrow 4p\,^2D^o_{5/2}$ transition, the relation between the Doppler width of the absorption line and the ion temperature is shown in Fig. V-1. The density of the excited ions can also be determined if the total absorbed power from the beam and the oscillator strength of the absorption line are known. The

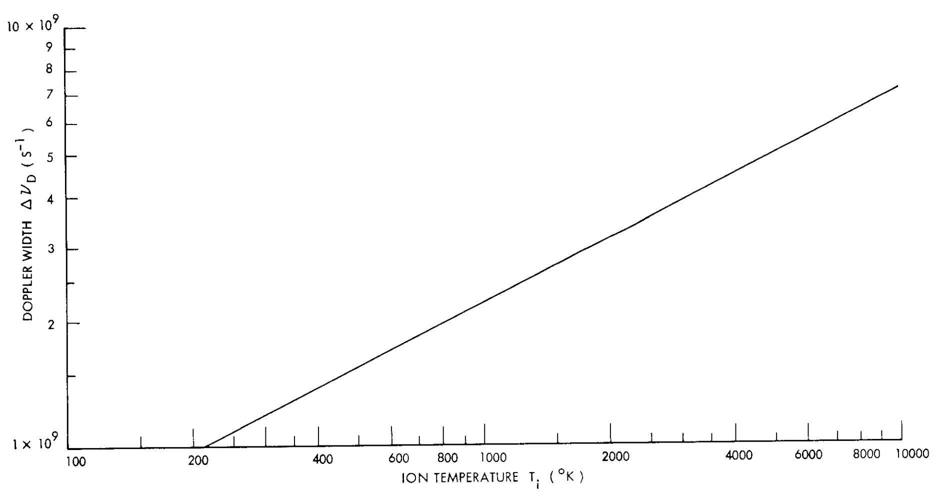

Fig. V-1. Absorption linewidth resulting from Doppler broadening of Ar II transition $4s\,^2P_{3/2} \rightarrow 4p\,^2D^o_{5/2}$ ($\lambda = 4880$ Å).

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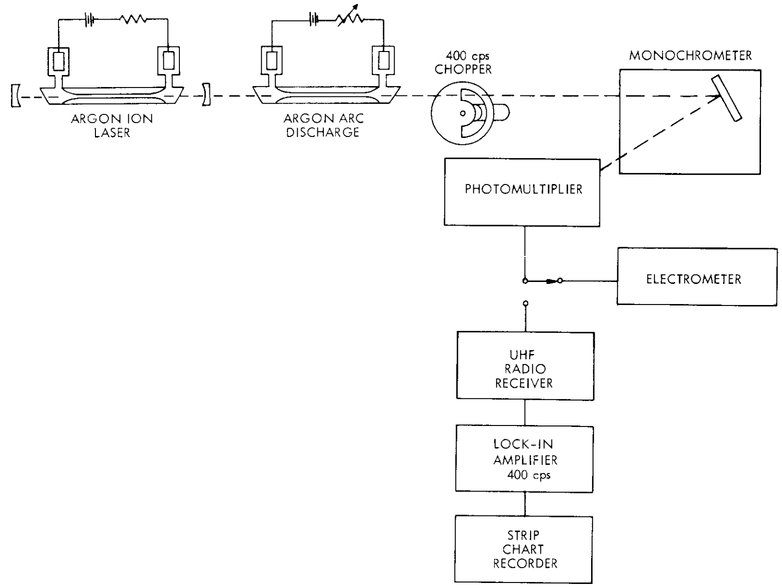

Fig. V-2. Experimental arrangement.

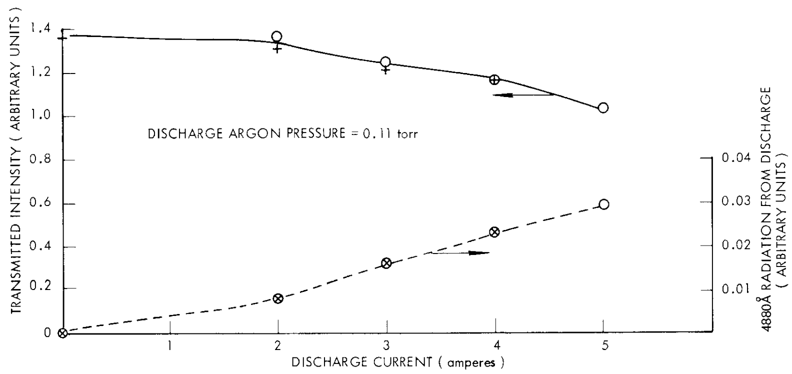

Fig. V-3. Laser beam intensity transmitted through argon discharge and background radiation at λ = 4880 Å vs discharge current.

oscillator strengths of important argon ion lines have been measured by Olsen.[1]

For preliminary evaluation of this technique, the experimental arrangement of Fig. V-2 was set up. A steady-state argon ion laser (λ = 4880 Å) sends a beam through a second argon discharge in a capillary, 2-mm in diameter and 49 cm long. The beam is then sent into a Jarrell-Ash monochromator and the λ = 4880 Å component is detected by a photomultiplier. The transmitted laser beam intensity and the argon discharge background radiation at 4880 Å, monitored directly at the photomultiplier output by a high-impedance electrometer, are shown in Fig. V-3 as a function of discharge current. The beam intensity decreases by 24 per cent as the absorbing discharge current is increased from 0 to 5 amps.

In order to have a preliminary idea of the absorption of the individual laser modes, the radiofrequency beats between the modes were detected by a UHF radio receiver. The signal-to-noise ratio of the receiver output is increased by chopping the transmitted laser beam at 400 sec^{-1} and amplifying the audio output with a Princeton Applied Research lock-in amplifier tuned to 400 sec^{-1}. The laser modes are separated in frequency by approximately 150 Mc/sec.

Preliminary measurements of the laser beat frequencies up to 1 Gc/sec have been made, but problems in obtaining reproducible data have been encountered because the laser output power had not been adequately stabilized. Modifications of the experimental arrangement are now under way which should correct this problem and extend the frequency spectrum.

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References

1. H. N. Olsen, J. Quant. Spectroscopy and Rad. Transfer 3, 59-76 (1963).

B. OPTICAL DOPPLER RADAR I

Preliminary experiments to demonstrate the feasibility of developing an optical radar capable of measuring the velocity of moving reflectors are being carried out. Our aim

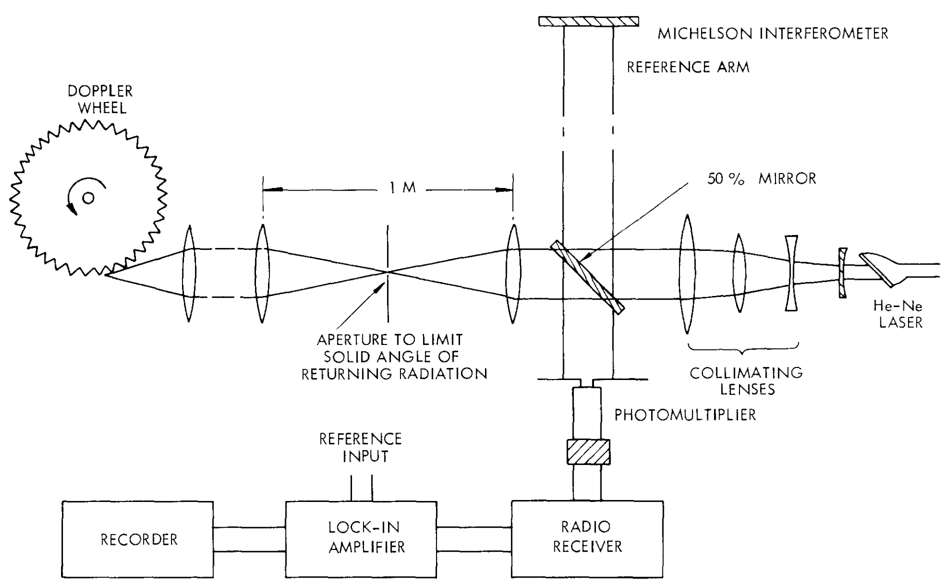

Fig. V-4. Detection system for an optical Doppler radar.

is to construct a device capable of measuring velocity distributions of atmospheric gases at a distance, by the detection of the broadening and shifting of a laser-emitted line.

For this purpose, we have assembled in the laboratory the device illustrated in Fig. V-4. This is basically a Michelson interferometer in which the signal in one of the arms is reflected from a moving surface. The moving surface simulates the motion of a real target; in the present case it consists of a wheel, 25 cm in diameter, with 180 teeth that can be rotated at various speeds. The wheel is contained in an enclosure that can be evacuated in order to achieve high speeds. At present, however, the wheel rotates at 1800 rpm which results in a peripheral speed of 24 m/sec^{-1}. Taking into account the geometry of the encounter, the frequency shift is calculated to be approximately 45 Mc.

The signal from the wheel is mixed with the signal from the reference arm of the interferometer and both are detected by a photomultiplier. Frequency analysis is carried out with a radio receiver with a bandwidth of 13 kc. To improve the signal-to-noise ratio, synchronous detection methods in which a lock-in amplifier is used in conjunction with a beam chopper placed in the wheel arm have been employed.

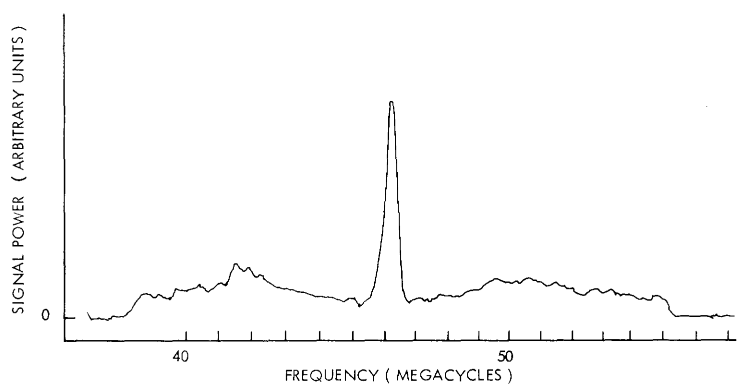

Fig. V-5. Power spectrum after detection.

Figure V-5 is a reproduction of the power spectrum after detection showing the beat signal at 46.6 Mc. The line has a width of approximately 1 Mc which is caused by the fact that the reflection occurs over the surface of a tooth which moves faster on the inside edge than on the outside edge. In obtaining this beat signal, a number of the conditions necessary for successful detection have been clarified.

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C. INVESTIGATION OF A REFLEX DISCHARGE

Electron gyro frequency or cyclotron harmonic radiation has been observed from a hot-cathode reflex or Penning discharge. Probe measurements have been made and the density determined from the ion saturation currents. No change in radiometer output maxima near the harmonics was observed for densities between 2 and 20×10^{18} m^{-3}.

The discharge cavity was a water-cooled, stainless-steel cylinder, 19.7 cm in diameter and 15.2 cm high. The anodes, also water-cooled, were hollow copper annuli, 10.2 cm apart. Spirals of 25-mil tungsten wire were used for cathodes (see Fig. V-6). These cathodes emitted tungsten copiously and soon developed hot spots that resulted in copious, but localized, emission of tungsten and electrons, and a bright pencil in the discharge.

Magnetic fields of up to 0.15 Wb/m^2 were used. The field was uniform 1 per cent within 3 cm of the axis of the cavity. The X-band radiometer had no filter before the mixer and so was sensitive to two 20 Mc/sec bands 120 Mc/sec apart. The IF amplifier detected output was fed through a P. A. R. lock-in amplifier to an X-Y recorder. A

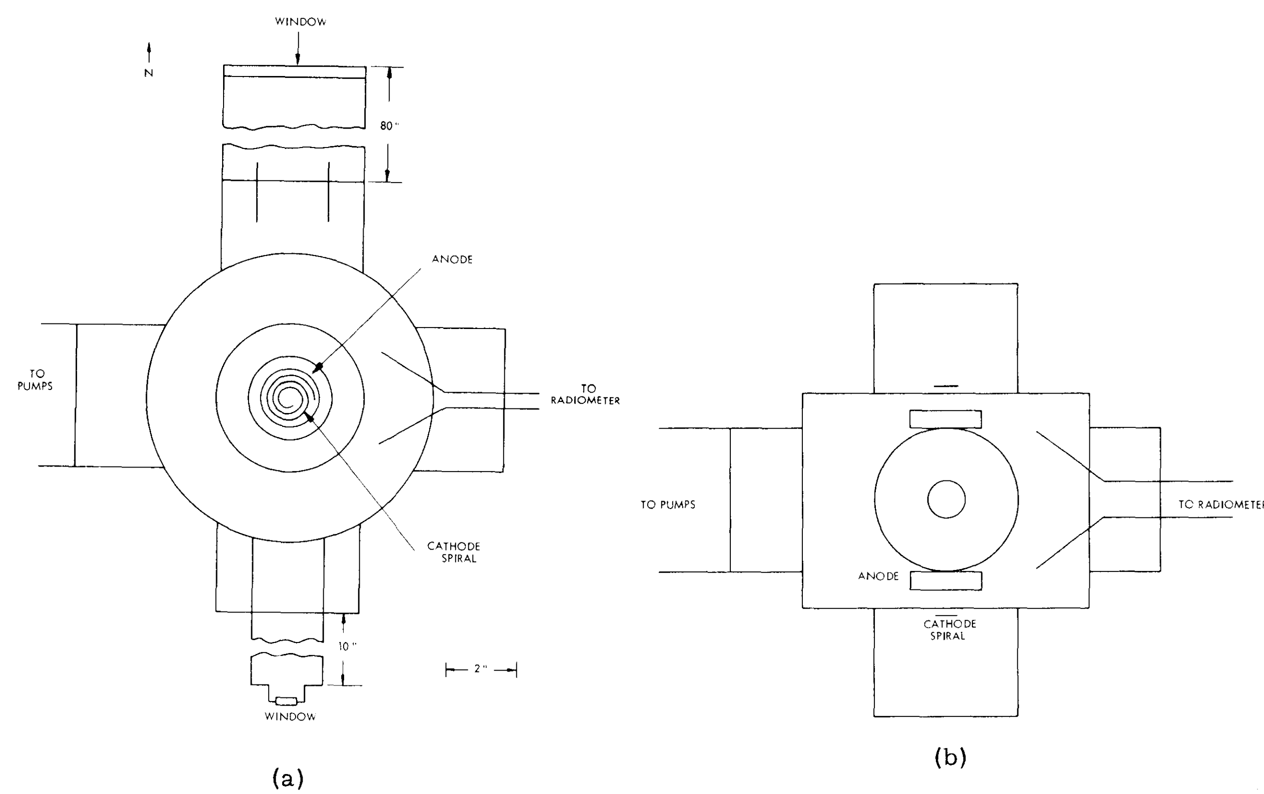

Fig. V-6. (a) Cavity seen from above.
(b) Cavity seen from the North.

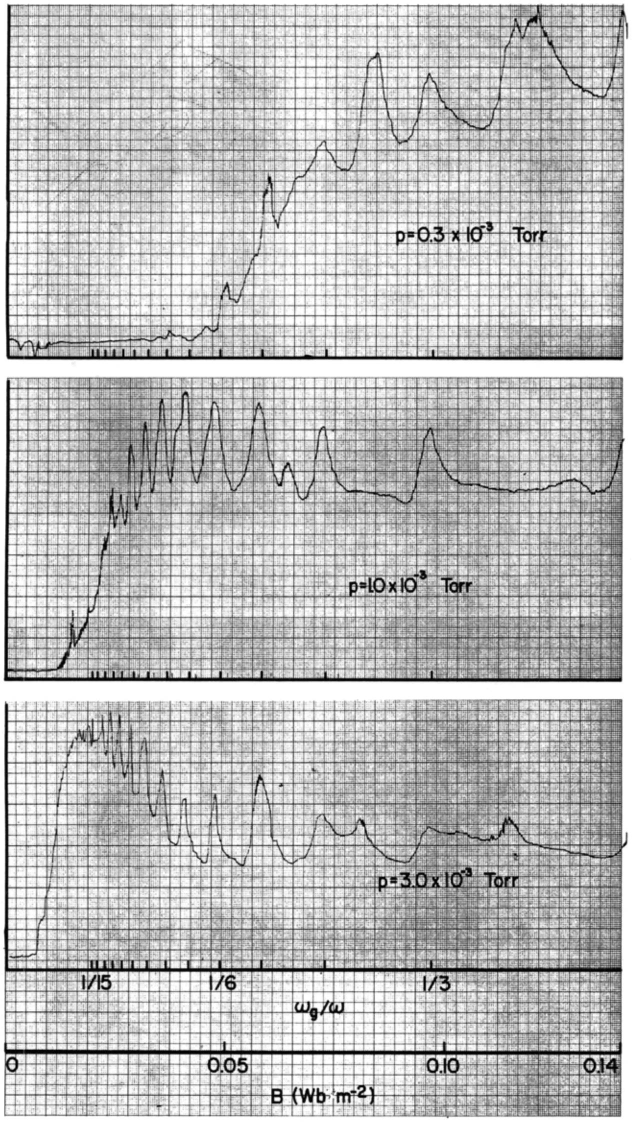

Fig. V-7.

Radiometer output as a function of magnetic field; I_{DC} = 0.8 amp. The vertical scale is arbitrary, except that the lowest curve has been amplified by a factor of 100 with respect to the others.

signal proportional to the current through the magnet coils was fed to the other axis of the recorder.

Densities were calculated from the ion saturation current by using the small-sheath approximation. Sheath radii calculated from the $V^{3/2}$ law were found to be between 1.2 and 1.4 times the probe radius which was 3 mil. The effect of the magnetic field on these results should be negligible because the probe radius was an order of magnitude smaller than the minimum ion gyro radius. The density could be changed by varying the neutral pressure in the cavity and/or the discharge current. Densities between 2 and 20×10^{18} m^{-3} were obtained. The electron thermal energy was found to be approximately 3 ev.

Figure V-7 shows some typical results for three different pressures. Peaks near the gyro-frequency harmonics were usually observed for harmonic numbers 3-10 and occasionally as high as 25. Within the accuracy of the system, the peaks were located right at the harmonics and no change with density could be found. Peaks not near the harmonics were also present, but their occurrence and intensity were directly related to the prominence of the pencil in the plasma. When the plasma was uniform these maxima were either greatly diminished or absent. The intensity of the peaks at the harmonics was also dependent on the strength of the pencil.

In our future plans we envision improvement of the discharge by the use of other cathodes that will provide a uniform plasma. A filter and an IF amplifier with a narrower bandwidth will give narrower peaks and improved accuracy. Improvements in probe design should extend the range and increase the accuracy of the density determinations.

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