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Atomic Beam Light Sources Applied to the Structure of the Magnesium I Resonance Line

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THIS paper is concerned with a comparison of two methods for the excitation of atomic beams but will make particular reference to the isotope structure of certain ultraviolet lines of magnesium which have been observed by means of these sources.

Several years ago Esclangon[1] described the production of a luminous atomic beam by means of the establishment of a high frequency electrodeless ring discharge in residual argon gas in the chamber with the atomic beam. A spectroscopic source employing this principle was subsequently constructed by B. Carpenter and myself. This source was used to excite lines of several of the more easily volatilized metals including sodium[2] and magnesium.[3] Figure 1 represents this source in the form used for the study of the ultraviolet lines of magnesium. The source tube is constructed of glass. The lower part of the tube, which contains the oven, is separated from the upper chamber, where the atomic beam is excited, by a spun aluminum diaphragm at whose center is the collimating aperture. The collimating aperture is 1×2 mm^2 in this arrangement and is 4 cm above the oven. The part of the tube above the diaphragm contains argon at such a pressure that the atomic mean free path is several centimeters, thus permitting the atomic beam to reach the cooled target without appreciable scattering. An electrodeless ring discharge is maintained in argon at this pressure by means of electrical oscillations of 30 megacycles per second in the coil surrounding the tube, the driver being a 200-watt vacuum-tube oscillator. The argon is maintained at the critical pressure required in the upper part of the tube by being "bled" in through a capillary at a controlled rate. The lower chamber of the tube is exhausted continuously by a fast diffusion pump, the gas from the upper chamber passing to the lower only by way of the collimating aperture.

This source was of such intensity that it gave the resonance lines of sodium and magnesium in exposures of one minute through an f: 25 optical system including a Fabry-Perot interferometer. The resonance lines of Mg II were obtainable in 10 minutes under similar conditions. Microphotometer traces of lines from this source indicate a half-intensity width of approximately 0.015 cm^{-1} in the favorable case of the sharp components of the sodium D lines as resolved by the Fabry-Perot interferometer. Excitation of the atoms of the beam is undoubtedly due primarily to semi-random impacts by electrons produced in the discharge.

The structure of the Mg I resonance line at 2852A as revealed by this source indicated a principle component accompanied by a faint satellite which was measured to be 0.066 cm^{-1} on the higher frequency side of the principal component. The Mg II resonance lines at 2795 and 2802A showed identical structure, a satellite at 0.098 cm^{-1} on the higher frequency side of the

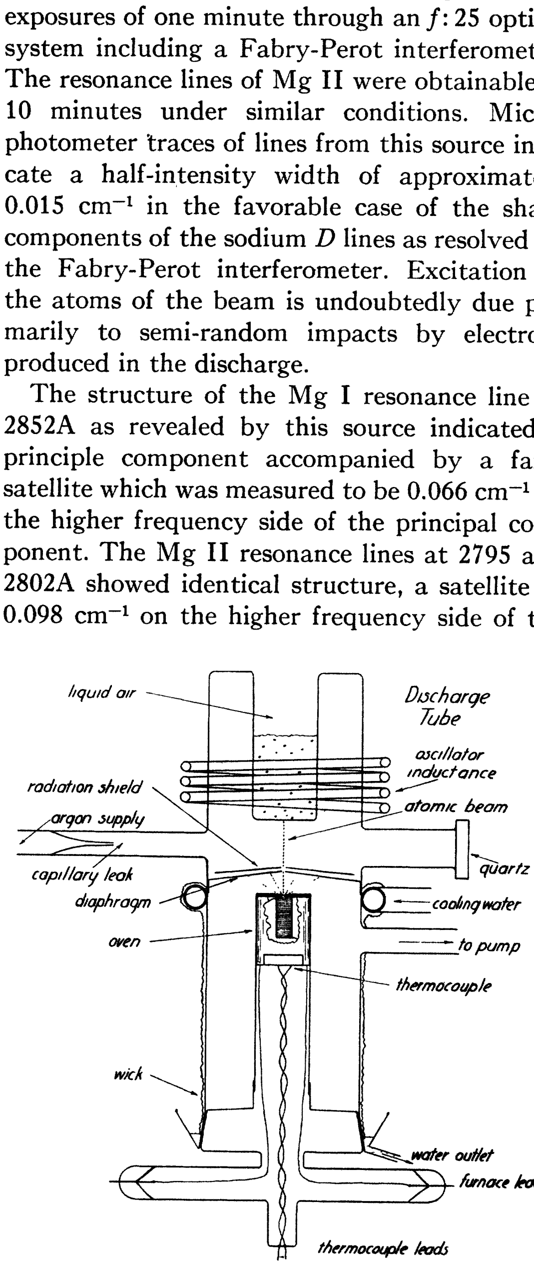

FIG. 1. Atomic beam source with electrodeless discharge excitation.

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[1] Esclangon, Ann. de physique **1**, 268 (1934).

[2] R. A. Fisher and B. Carpenter, Phys. Rev. **49A**, 417 (1936).

[3] R. A. Fisher, Phys. Rev. **51A**, 381 (1937).

principal component and possibly some unresolved structure nearer to the principal component.

Observations by Jackson and Kuhn,[4] who used an atomic beam in absorption, had shown the line λ2852 of Mg I with a single satellite at 0.033 cm^{-1} on the higher frequency side of the principle component. In view of this discrepancy between the emission and the absorption observations it seemed desirable to construct a new source employing directed and controlled electrons from an oxide coated emitter as had been done with remarkable success by Meissner and Luft.[5] Figure 2 illustrates the design of this source chamber which is constructed entirely of brass. It is built upon a somewhat smaller scale than those described previously and thus requires less of the material excited and less cooling. Figure 3 gives the detail of the electron gun assembly. Electrons from an indirectly heated cathode with a concave emitting surface are accelerated toward a grid about 2 mm away having approximately the same curvature as the emitting surface. The entire source chamber is at the potential of the grid so that no fields other than those due to space charge exist beyond the grid. When the curvatures of the emitter and grid are properly chosen the diverging effect of electron repulsion upon the initially strongly converging electron beam renders it approximately parallel at a point where its cross section diameter is about 2 mm. The electron beam intersects the atomic beam at this point of minimum cross section. In normal operation electron currents of 100 to 150 milliamperes are used. Accelerating potentials of 125 to 250 volts are applied to the electron gun.

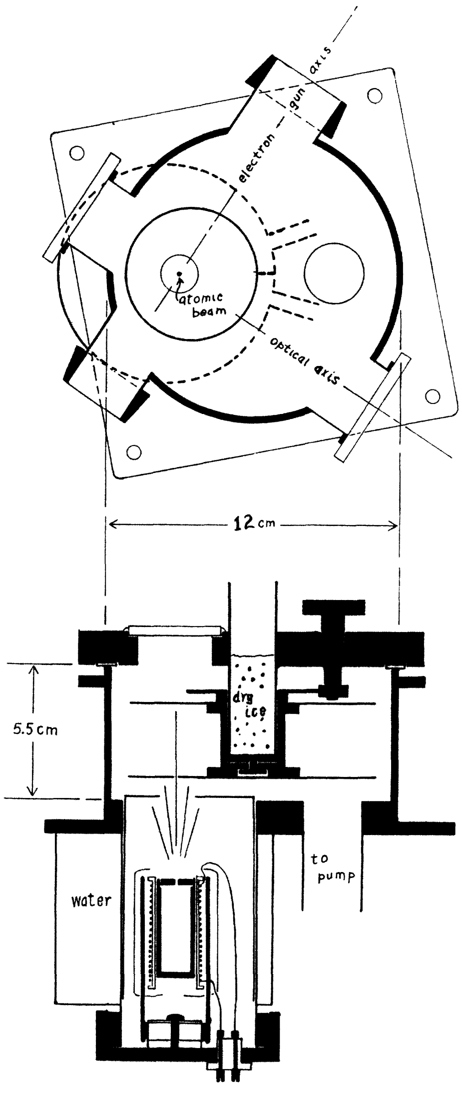

FIG. 2. Atomic beam source chamber for electron beam excitation.

Different collimating apertures, of which there are seven of 1-mm diameter spaced about a cooled disk, may be substituted for one another by rotation of the disk by means of gear wheels and a knob outside the chamber. Dry ice slush provides adequate cooling for both this disk and the upper disk which serves as collector for the material of the beam.

New observations of the structure of the Mg I resonance line λ2852 obtained with this source show three resolved components corresponding to the three magnesium isotopes of atomic masses 24, 25, and 26 and abundance ratios of 7 : 1 : 1, respectively. Figure 4 is a reproduction of such a pattern obtained with a Fabry-Perot interferometer having aluminum films and a spacer of 48.76 mm. This triplet isotope structure had previously been resolved by Meissner[6] in several of the visible lines of Mg I. In λ2852 the separation from the principal component (Mg^{24}) of the two weaker components is measured to be 0.030

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[4] D. A. Jackson and H. Kuhn, Proc. Roy. Soc. **A154**, 679 (1936).

[5] K. W. Meissner and K. F. Luft, Ann. d. Physik **28**, 667 (1937); **29**, 698 (1937); Zeits. f. Physik **106**, 362 (1937).

[6] K. W. Meissner, Ann. d. Physik **31**, 505 (1938).

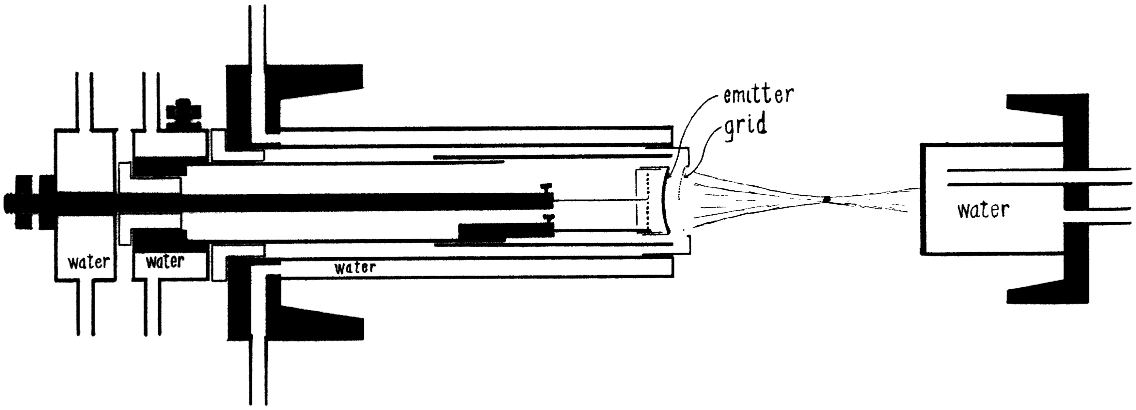

FIG. 3. Electron gun for atomic beam source.

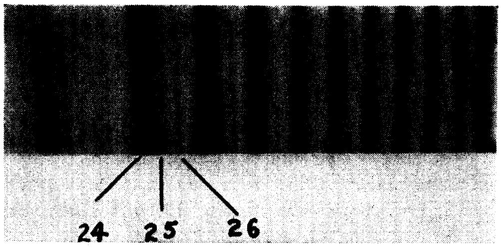

FIG. 4. Isotope fine structure of Mg I λ2852 obtained with Fabry-Perot interferometer with 48.76-mm spacer.

and 0.053 cm^{-1}, respectively, on the side of higher frequency. This is in agreement with neither the structure obtained with the discharge-excited atomic beam nor that obtained in absorption by Jackson and Kuhn. There is good reason to believe that the new source shows the true structure of the line and that the earlier results were distorted by absorption effects.

A comparison of the two methods for excitation of atomic beams based upon the performance of the two sources described here indicates that the electron beam method gives lines which are approximately five times sharper than those produced by the ring discharge. The discharge excited source is, however, twenty to thirty times more intense, for an atomic beam of comparable density. It would seem that because of its intensity this type of source may have use in cases where a line width of 0.02 cm^{-1} may be tolerated.

The significance of the newly observed isotope separations of the Mg resonance lines from the point of view of the theory of isotope fine structure will not be discussed in detail here.[7] It may be remarked, however, that calculations by Vinti[8] on the expected isotope structure of Mg I lines are in much closer agreement with the new measurements than with the data then available. Certain conclusions reached by Vinti based upon the then existing data are now subject to considerable revision.

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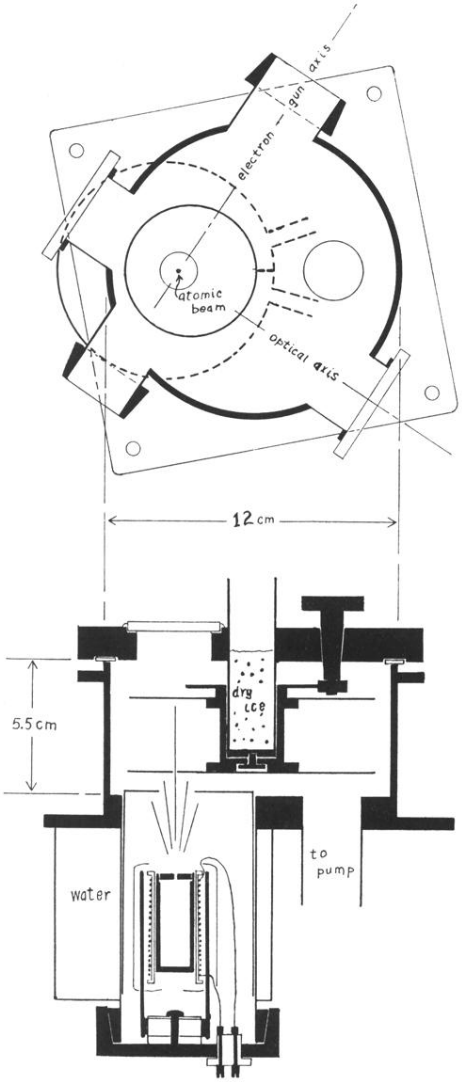
[7] To be discussed in more detail in a forthcoming note in *The Physical Review.*

[8] J. P. Vinti, Phys. Rev. **56**, 1120 (1939).



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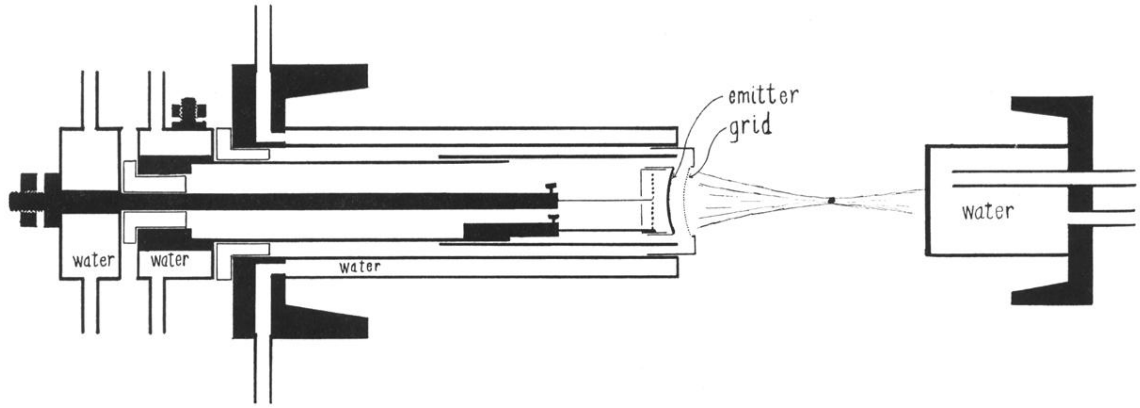

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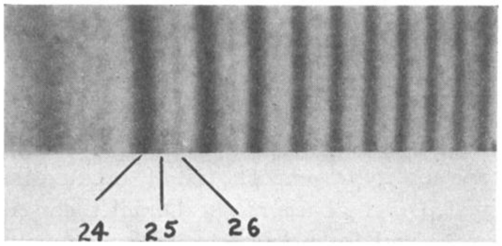

Fig. 4. Isotope fine structure of Mg I λ2852 obtained with Fabry-Perot interferometer with 48.76-mm spacer.