VIII. MOLECULAR BEAMS[*]

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A. CHARGED ATOMS

Renewed interest in the possibility that matter may not be electrically neutral, as considered by Bondi and Lyttleton, has led us to the design of an atomic-beam electric deflection apparatus that is intended especially for setting an upper limit on the charge carried by neutral atoms. The apparatus is of conventional design, except for the obvious refinements required for measuring deflections of the beam that are of the order of 10^{-8} cm. Construction is now nearly completed.

We have also repeated the experiment of Piccard and Kessler (1), in which gas is allowed to escape through a de-ionizer from a container connected to an electrometer. The present results are by no means conclusive, but it appears that the release of 4 moles of the gas at a uniform rate over a period of 100 seconds causes less than 6×10^{-15} coulomb to flow in the electrometer. We conclude from a preliminary interpretation of the data that the charge carried by each helium atom is less than 2×10^{-20} of the charge on the electron. The situation with other gases is not clear, and a series of experiments must be performed to distinguish an effect caused by charge from many possible artifacts. First, however, it is desirable to increase the sensitivity of the experiment, and, fortunately, we have a factor of 10, at least, readily available.

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References

1. A. Piccard and E. Kessler, Arch. Sci. Phys. et Nat. 7, 340 (1925).

B. CESIUM MASER

The object of this experiment is still to observe the emission of coherent power from the hyperfine transition in cesium $F = 4$, $m_f = 0 \rightarrow F = 3$, $m_f = 0$. A state-selected beam of atoms is focused into a cavity by means of a four-pole magnetic field. The cavity has within it a buffer gas and is kept at liquid-helium temperature. Atoms that enter the cavity will lose energy, because of the exchange of kinetic energy with the buffer gas, and take a relatively long time to reach the cavity walls; thus the number

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of atoms within the cavity can be made large and their lifetime long. Furthermore, the Q of the cavity, resulting from its superconducting inner coating of lead, will be approximately 10^6. The combination of high Q and large numbers of atoms within the cavity will result in sustained coherent oscillation on account of the cooperative, or ringing, effect of the atoms in the cavity as they decay to the lower energy state. In order to sustain this oscillation, the atoms are put into the so-called superradiant state by the application of a $\pi/2$ pulse as they pass through a prestimulating cavity. This gives the atoms phase coherence, and if they continue to be exposed to an inphase coherent field, the atoms will continue to decay to the ground state. Their energy, emitted into a high-Q cavity, provides the above-mentioned field, and a self-consistent calculation, such as that made by Bloom (1), demands the following requirements:

(a) a lifetime of the atoms in the cavity of 1/10 sec;
(b) number of atoms entering in the proper state, $\sim 10^{10}$ per sec; and
(c) a Q of 10^6 of the main cavity.

The output power is approximately 10^{-15} watt, and, since the output spectrum should be very narrow, that is, of the order of tens of cycles per second, this power will be detectable with a narrow-band microwave receiver that has an ordinary noise figure.

There are quite a few parameters in the experiment, and it is not surprising that the first try did not work. The apparatus that was described in the Quarterly Progress Report of April 15, 1958 (pages 32-35) has been modified and, as the following description will show, has a great deal more flexibility in operation.

First, in order to determine the lifetime of the atom in the cavity, a straightforward molecular-beam technique was adopted. We employed an A magnet (the focuser) and a B magnet (another four-pole magnet state selector), between which the C region containing the cavity was located. The cavity now has two apertures so that the beam may pass through. Atoms that go through the apparatus are detected by means of a hot platinum ribbon ionizer, a mass spectrometer, and an electron multiplier. The lifetime of the atom is inferred from the linewidth of the resonance curve. Both the lifetime and the frequency shift are of interest, and several gases will be tried at various temperatures and pressures in order to obtain pressure-shift data at low temperatures. Once the lifetime of the state and the frequency of the radiation have been determined, the beam is used to determine the level of prestimulation by applying power to the stimulator cavity, after detuning the main cavity. The proper level, giving the greatest rate of decay, is determined by adjusting the power so that one-half of the atoms make the transition to the lower state. The main cavity is then retuned, and there should be a further reduction in the number of atoms to the detector, since the atoms give power to the cavity and go to the ground state.

Figure VIII-1 shows the apparatus as it now exists. The can consists of three chambers; the upper and lower operate at high vacuum (10^{-7} mm Hg, or better), and the

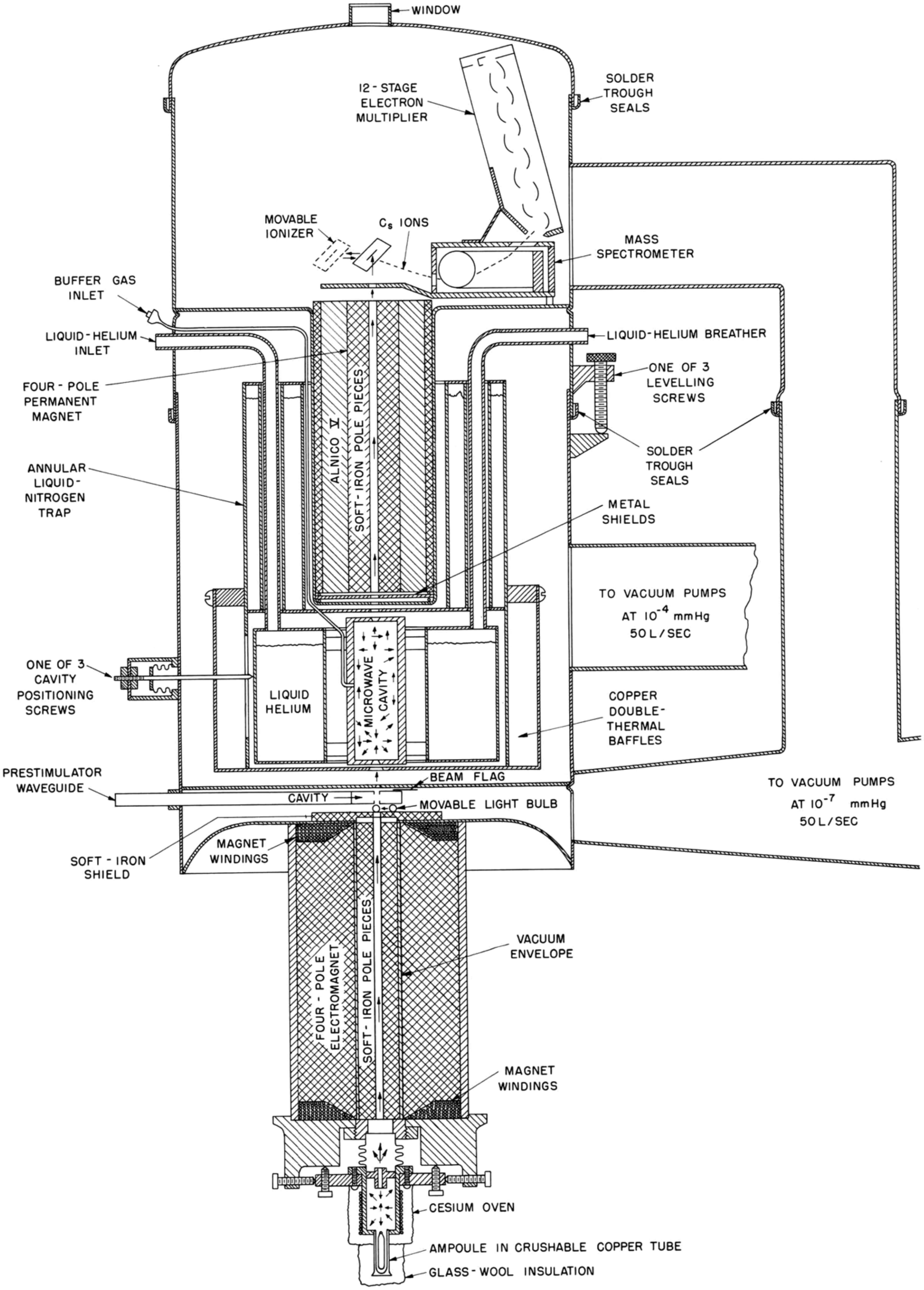

Fig. VIII-1. Cesium maser.

middle one at 10^{-4} mm Hg, or better. The pumping speeds are such that these pressures are possible with the cavity pressure at 10^{-2} mm Hg at 4.2°K.

At the present time, a cesium beam is being run with no buffer gas, and work is in progress to optimize the "flop-to-background-ratio." The linewidth is around 2 kc, which implies a beam velocity of approximately 2.5×10^{4} cm/sec for the focused atoms.

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References

1. S. Bloom, J. Appl. Phys. 27, 785 (1956).

C. PRECISION MEASUREMENT OF THE HYPERFINE-STRUCTURE CONSTANTS OF THE STABLE BROMINE ISOTOPES

Before the vacuum envelope of the atomic beam apparatus was last closed, two hot-wire detectors were installed: one was tungsten; and the other, thoriated tungsten. Since the thoriated wire would not follow 10-cps modulation of the beam, the plain tungsten wire was used with a 10-cps lock-in amplifier. With this arrangement, low-frequency ($\Delta M=\pm 1, \Delta F=0$) transitions were observed, and also one high-frequency ($\Delta M=0, \Delta F=\pm 1$) transition. The Ramsey pattern of the high-frequency transition was not clean, and could have been caused by atoms of approximately the same velocity. At this point, the bromine background became so bad that the signal-to-noise ratio was almost two to one.

To discriminate against the bromine background, the hot-wire detector was put in a box. The mass-spectrometer magnet, an ionization gauge, heaters, and a liquid-nitrogen trap are also in the box. It has a crinkly foil entrance to admit the beam. The crinkly foil will not let atoms that are more than approximately 5° off the beam axis into the box. The box also has a hole that can be covered or uncovered by a door. The hole looks out to another liquid-nitrogen trap. When a beam is being detected, the door will be shut. To get rid of the bromine that accumulates in the box, the door will be opened, and the heaters turned up.

A thoriated tungsten wire that should give a better signal-to-noise ratio than the plain tungsten wire has been installed. We may, or may not, modulate the beam. If the beam is modulated, the modulation frequency will be 1 cps, or less.

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