

## IX. ATOMIC BEAMS\*

Prof. J. R. Zacharias  
Prof. J. G. King  
Prof. C. L. Searle

Dr. R. F. C. Vessot  
H. H. Brown, Jr.

E. P. Hilar  
G. W. Stroke  
R. Weiss

### A. MEASUREMENT OF THE VELOCITY OF LIGHT

#### 1. Introduction

Three significant steps in the building of the apparatus for measuring the velocity of light can now be reported: the completion of the main mechanical elements of the apparatus, the successful testing of the guiding of the cavity-tuning piston by dry-boundary glass-on-brass bearings, and the successful use of a hypodermic syringe to control the rate of advance of the guided piston that rests upon this syringe as it advances parallel to itself to tune the cavity in its successive resonance positions.

We have completed the 70-mc oscillator that excites the  $\text{Hg}^{198}$  light source, one of the three interferometric photoelectric recording systems, and the microwave resonance detecting system described by E. P. Hilar in the Quarterly Progress Report of January 15, 1958, page 61 [further details will be found in E. P. Hilar's Master's thesis (1)]. We are in the final building stages of the apparatus for measuring the velocity of light, the problems of which were outlined in the Quarterly Progress Report of October 15, 1956, page 46. A schematic view of the apparatus is shown in Fig. IX-1, and a photograph of the partially assembled system is shown in Fig. IX-2.

#### 2. Description of Apparatus

A description of the completed parts of the apparatus follows. The schematic view of Fig. IX-1 shows the principle of the design that is carried out in the assembly shown in Fig. IX-2. The completed fused-quartz cavity (2) is being fed from the atomic-clock oscillator, and the resonances are detected through conical irises in the upper plate. The microwave radiation reaches and leaves the cavity through rectangular  $\text{TE}_{01}$  waveguides, the transverse "straight" H fields of which are made to couple into the "radial" H field of the  $\text{TE}_{01n}$  mode in the cavity. This arrangement, with an iris diameter of 3 mm inside the cavity, leads to very good energy transfer, and, at the same time, to good cavity isolation. The two irises are centered at 0.4804 of the radius from the center and placed  $90^\circ$  apart.

The apparatus, which is arranged to operate in vacuo, is designed in such a way that all critical elements (cavity, moving piston, waveguides, and interferometers) are fastened as directly as possible to a single brass plate, 1 inch thick. This plate is

---

\* This research was supported in part by Purchase Order DDL-B222 with Lincoln Laboratory, which is supported by the Department of the Army, the Department of the Navy, and the Department of the Air Force under Contract AF19(122)-458 with M. I. T.

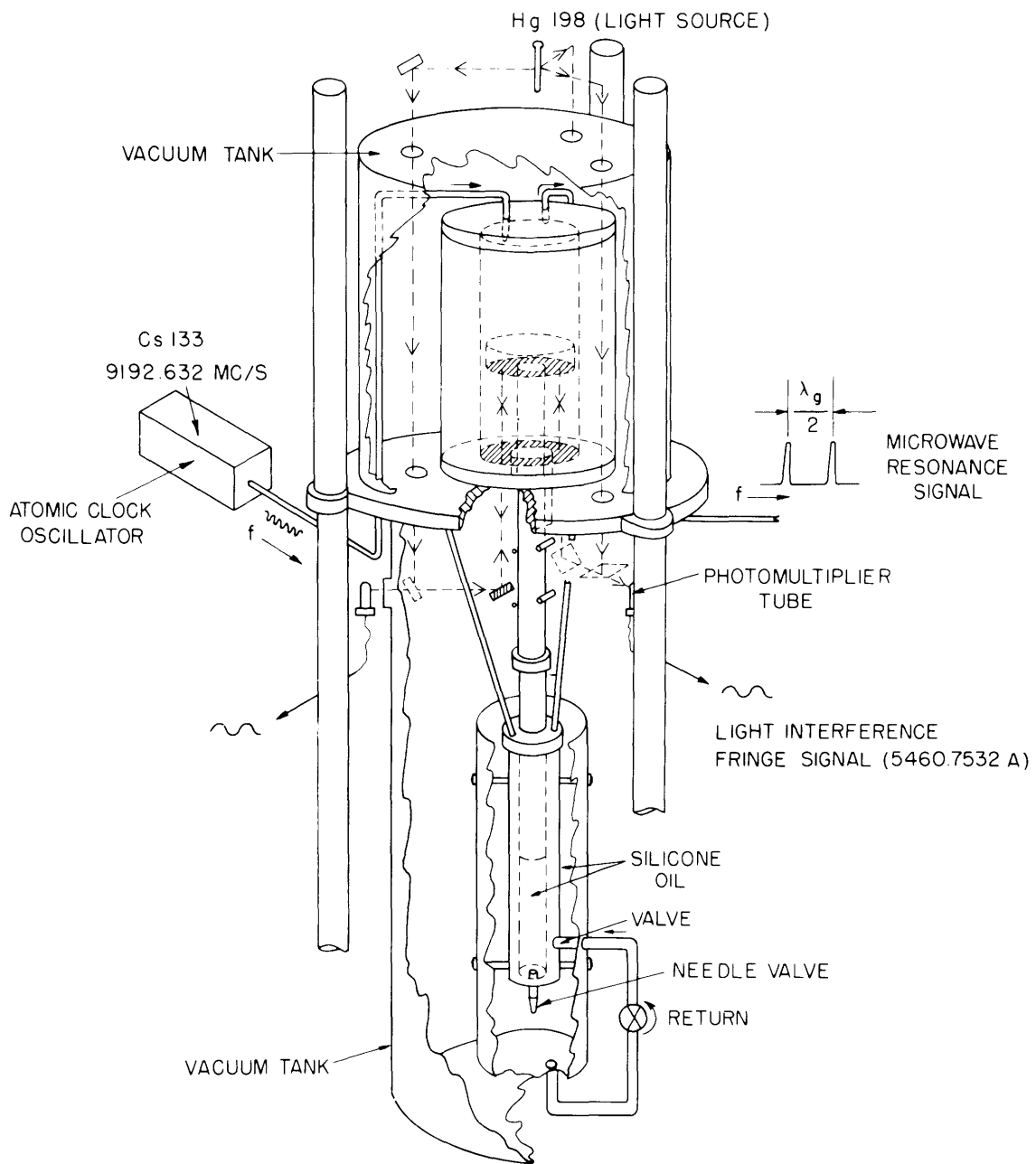


Fig. IX-1. Schematic view of velocity-of-light measurement apparatus.

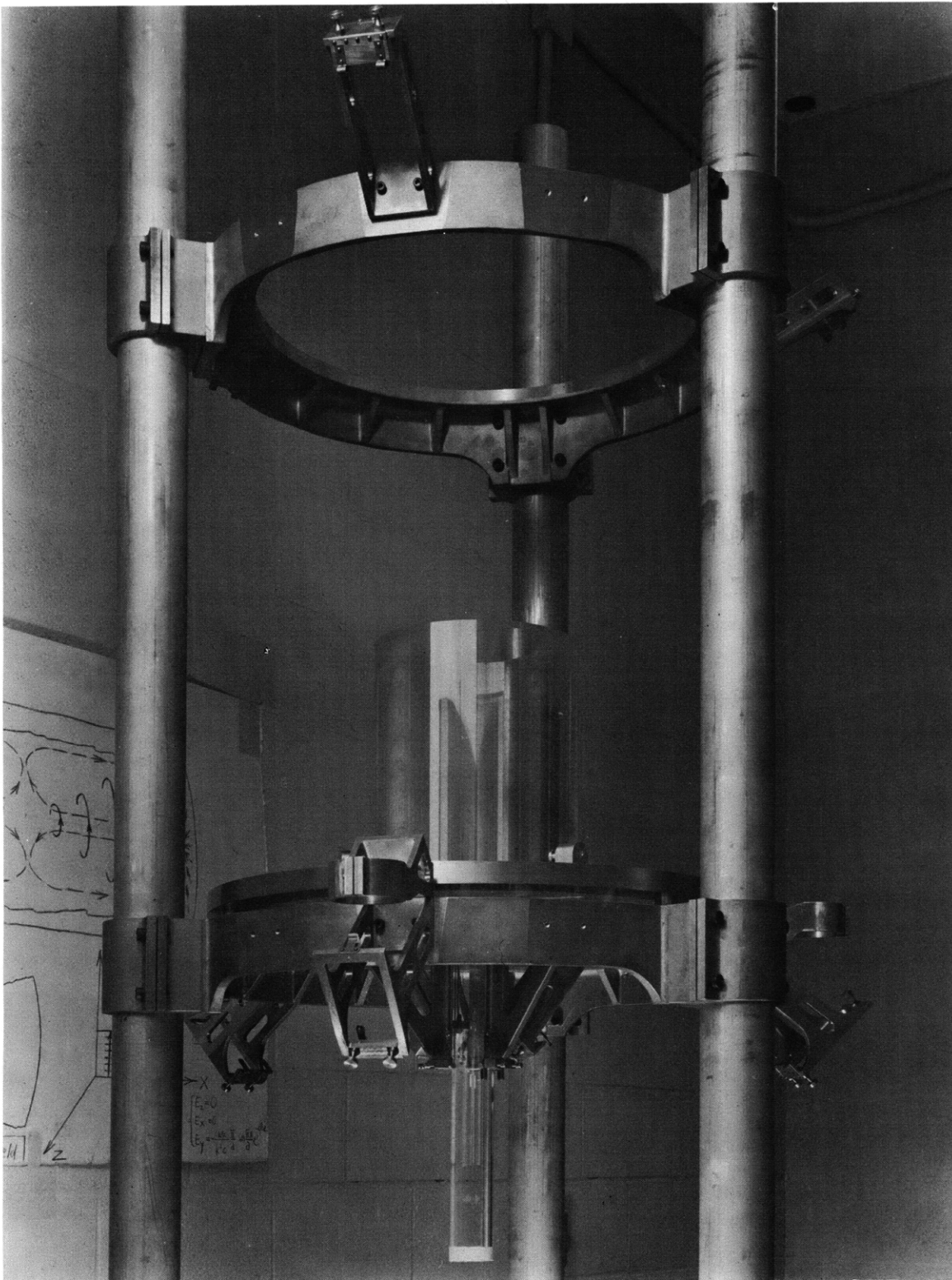


Fig. IX-2. Velocity-of-light measurement apparatus partially assembled with finished fused-quartz cavity and long sliding piston rod.

## (IX. ATOMIC BEAMS)

supported on a sturdy brass ring attached to three brass columns, as shown in Fig. IX-2. In this manner, reliable interferometric distance measurements in the fractional micro-inch domain should be least affected by mechanical distortion, temperature, and possible vibrations. The parts of the feeding and receiving waveguides inside the vacuum system are fastened to the inside of a brass ring that rests on the large brass plate, with the microwave radiation traveling through mica windows from and to the outside connections. The upper stainless-steel vacuum tank rests on this ring. All these mechanical and microwave parts have been completed with the exception of a choke arrangement inside the vacuum system, between the waveguide sections from the ring to the irises. This choke will ensure complete mechanical isolation of the upper cavity plate from the ring and thereby eliminate distortion or temperature effects caused by the waveguides.

The successful principle of the glass-on-brass guiding of the piston without "stick-slip" effects, which was described in the Quarterly Progress Report of October 15, 1956, page 46, has been adopted. It now takes the form of a cylindrical glass piston (2-inch diameter) sliding between two groups of three tangential brass rods (0.25-inch diameter). Two rods form a 120° Vee, and the third is spring-loaded to push the cylindrical glass piston gently against the Vee. The full weight of the piston (except for the frictional components of the springs which have been proved to be negligible) rests on a hypodermic syringe filled with silicone oil and fastened to the large brass plate. The good stick-slip-free motion, as detected by a photoelectric interferometer that uses the green line (5460.74 Å) of  $\text{Hg}^{198}$ , is shown in Fig. IX-3. This should be compared with similar

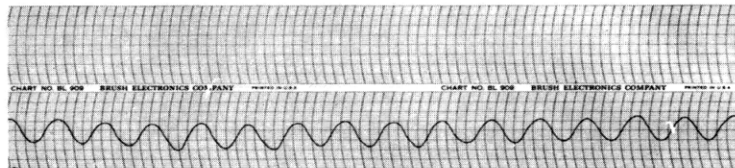


Fig. IX-3. Photoelectric-fringe signal as a function of piston advance, obtained in green  $\text{Hg}^{198}$  light with dry-boundary glass-on-brass bearings. The piston rod rests on silicone oil-filled hypodermic syringe (1 cycle  $\approx 10^{-5}$  inch, approximately 4 cps).

records from the experimental apparatus that was used to lay the groundwork for the present apparatus (3). This result was achieved by optically polishing the outside of the 2-inch glass cylinder to a very good scratch-free finish after it had been ground within a few hundred thousandths of an inch on a cylindrical grinder. Measurements of the straightness of the cylindrical piston still need to be carried out to determine whether

or not, and if so what, improvements are needed. It should be noted that the bearing design places greater emphasis on straightness than on circularity in this rod, and one good way of measuring the straightness is to observe interferometrically the degree to which parallelism is maintained during the motion of the piston which traverses many inches. We recall that the motion of the tuning plate is observed by means of three interferometers placed  $120^\circ$  apart, and that they will permit servocorrections of rotation effects about horizontal axes which are partly caused by the piston shape, if such compensations are necessary.

G. W. Stroke, J. R. Zacharias

#### References

1. E. P. Hilar, Resonance detector for a resonant-cavity measurement of the velocity of light, S.M. Thesis, Department of Electrical Engineering, M.I.T., May 26, 1958.
2. J. R. Zacharias and G. W. Stroke, Precision cylindrical cavity, Quarterly Progress Report, Research Laboratory of Electronics, M.I.T., Jan. 15, 1958, p. 57.
3. Quarterly Progress Report, Research Laboratory of Electronics, M.I.T., Oct. 15, 1956, Figs. VI-3 and VI-4, p. 50.