of this comparison is that the radar and space-probe results can be made to agree, with reasonable assumptions concerning the coronal structure.

JOHN C. BRANDT

Kitt Peak National Observatory, Tucson, Arizona*

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Accurate Length Measurement of Meter Bar with Helium-Neon Laser

Abstract. *A helium-neon gas laser has been successfully used in conjunction with an automatic fringe-counting interferometer to measure the length of a meter bar. The agreement obtained was 7 parts in 100 million with respect to the assigned length of the bar.*

In a recent article in this journal, McNish (*1*) reported that experiments were being undertaken at the National Bureau of Standards to measure length with a laser-illuminated, automatic fringe-counting interferometer. These experiments have now been successfully completed; the equipment used is schematically shown in Fig. 1.

A helium-neon laser with external confocal mirrors of 60-cm focal length, operating at 633 nm, was used. It was kept in single mode by adjustment of the radio-frequency power supply; the single-mode operation was monitored throughout the experiment by means of a spectrum analyzer. The laser was "unstabilized" in the sense that no electronic feedback mechanism was used to lock its wavelength to the center of the neon line. Variations of its wavelength had been minimized by rigid connection of the cavity mirror to a sturdy fused-quartz spacer tube. Its absolute wavelength stability, relative to a standard line of mercury-198, had previously been measured to be a few parts in 10^7, for averaging times of several minutes (*2*). The laser was made to oscillate still closer to the center of the neon line by piezoelectric tuning of the cavity length, so that the fringe visibility in the interferometer was at a maximum at each reading.

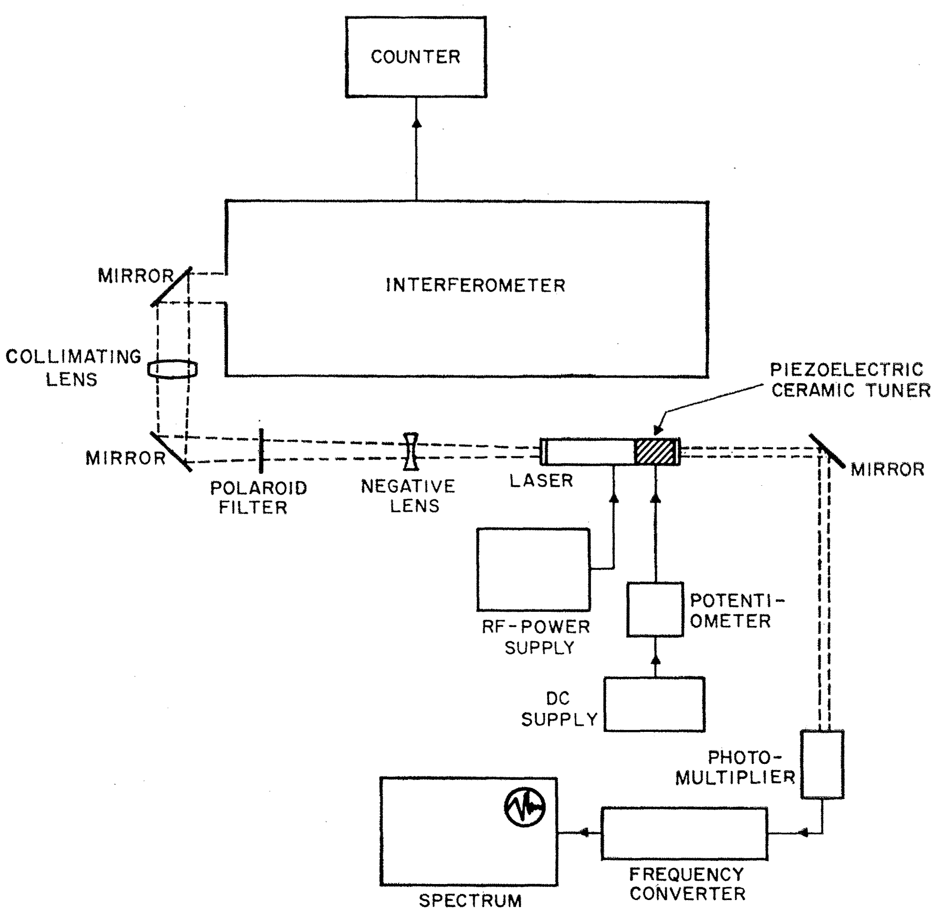

Fig. 1. Equipment used to measure length with a helium-neon laser. As a meter bar inside the interferometer is moved over its entire length, interference fringes produced by a laser are automatically counted. The total number of fringes thus obtained is multiplied by one-half the value previously determined for the laser wavelength. Thus, the accurate length of the meter bar is obtained.

The automatic fringe-counting interferometer (line-scale comparator), as described in (*1*) and (*3*), permits the measurement of lengths up to 1 meter, the limit of travel for the carriage holding the line scales to be calibrated. However, its practical range was previously limited to a few decimeters by the limited coherence of the mercury-198 standard lamp used.

Since the wavelength produced by the laser was not known with sufficient accuracy, it had to be determined before accurate length measurements could be carried out with the laser. Thus, interference fringe counts were obtained over various portions of a decimeter line standard, first by use of the standard mercury-198 lamp and then by use of the laser. From the fringe counts and the internationally accepted value (*4*) for the mercury-198 wavelength at 436 nm, the wavelength of the laser used was obtained as 632.81983 nm under standard metrological conditions (air at 20°C, standard atmospheric pressure, 59 percent relative humidity, and 0.03 percent CO_2 content).

The fringe-counting interferometer, with the laser as the light source, was then used to measure the length of a meter bar in terms of this wavelength. From a total count of 3 160 460.33 fringes, or half-wavelengths, the length of the meter bar was determined to be 1.000 000 98 m. This length agreed to within 7 parts in 100 million with an assigned value of 1.000 001 05 m for this bar. In addition, measurements of each decimeter graduation on the bar agreed with the assigned values to better than 0.000 000 5 m.

Throughout the experiment, the performance of the interferometer was found to be improved when the laser was substituted for the mercury-198 lamp. With the laser, the contrast of the fringe pattern remained constant over the full length of the meter, thus providing a high signal-to-noise ratio over the entire path. With mercury-198 light, a fading of the fringes and, hence, an increase of the noise level was noticeable even over the length of a decimeter bar.

The experiment has provided information about the performance of both laser and interferometer, which is now being used for further development work so that accurate length measurements by means of lasers may ultimately be performed routinely.

K. D. MIELENZ, H. D. COOK
K. E. GILLILAND, R. B. STEPHENS
National Bureau of Standards, Washington 25, D.C.

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18 November 1964

Diamond Synthesis with Bridgman Opposed-Anvil Apparatus

Abstract. *Bridgman opposed-anvil, high-pressure apparatus, which was available in the early 1940's, has been used successfully to synthesize diamonds from graphite in the laboratory.*

Thermodynamically, graphite is the most stable form of elemental carbon at ordinary pressures, whereas diamond is thermodynamically stable only at very high pressures (*1*). Thermodynamic calculations also indicate that at higher temperatures still higher pressures are required for stability of diamond.

In the early 1940's Bridgman described (*2*) a simple opposed-anvil apparatus for generating pressures of over 100 kb—pressures well within the diamond-stable region suggested by thermodynamics. Before 1920 Parsons (*3*) had introduced electric-resistance heating within the pressurized cells of high-pressure apparatus. Thus in the early 1940's pressure apparatus and heating techniques were available for attaining the conditions suggested by thermodynamics for synthesis of diamond; a number of serious, but unsuccessful, efforts were made during this period.

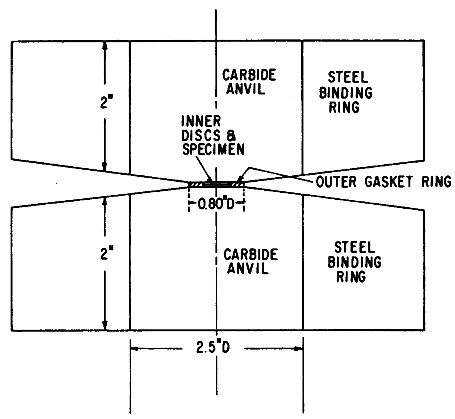

Fig. 1. Sectional drawing of the Bridgman opposed-anvil apparatus used to synthesize diamond from graphite.

This paper recounts the successful synthesis of diamonds in Bridgman opposed-anvil apparatus by a process discovered at General Electric Research Laboratory [announced, 1955 (*4*); published, 1959 (*5*)].

The anvils of the apparatus (Fig. 1) were of grade 883 Carboloy, 6.35 cm in diameter and 5.08 cm high. The working end of each piston was a truncated cone tapering at a 7-deg rise angle to a 2.03-cm diameter flat head. The pistons were pressed into strong steel binding-rings to hold the carbide in a prestressed state, as suggested by Bridgman.

The pressure cell consisted of (i) a pyrophyllite outer gasket ring, 2.03-cm outer diameter, 1.01-cm inner diameter, and 0.101 cm thick, and (ii) an inner part made of two pyrophyllite discs 1.01 cm in diameter and 0.056 cm thick. The diamond-making specimen was a graphite-nickel-graphite sandwich 0.0381 cm thick, 0.0635 cm wide, and 0.508 cm long which was inserted in a space between the two inner pyrophyllite discs. This space was formed by carving appropriate shallow grooves 0.017 cm deep in the adjacent faces of the two inner discs. One end of the sandwich-strip was connected to the top piston face by a nickel pin (0.051 cm in diameter) embedded in the top pyrophyllite disc; the other end was connected to the bottom piston face by a similar pin in the bottom disc.

The apparatus was pressure-calibrated in the usual way by inserting a thin strip of bismuth in place of the nickel-graphite specimen and by observing the force on the pistons required to produce the well-known 25- and 88-kb electric resistivity transitions of bismuth.

In the diamond-making experiments the cell, compressed at room temperature to a pressure of approximately 90 kb, was heated until the nickel strip just melted, as indicated by abrupt rise in resistance. The nickel and graphite were allowed to react for about 30 to 60 seconds at temperature. Then the temperature was lowered quickly; and this reduction was followed by a more deliberate reduction of pressure. After several successful experiments with nickel as the catalyst metal, iron was successfully substituted for the nickel.

In each successful case approximately the central third of the catalyst metal strip melted and reacted with the graphite adjacent to it to form a crust of small diamond crystals (Fig. 2). The unmelted stubs of nickel did not react with the graphite and remained uncarburized and ductile. The central metal which had melted was carburized and brittle, but contained no diamond crystals. The diamond crystals were all at the interface between metal and graphite and were all covered with skins of the catalyst metal, as is usually the case with this process; they were identified by scratch tests on sapphire and by x-ray diffraction patterns.

Opposed-anvil Bridgman high-pressure apparatus, which is conventionally used for studies in the temperature

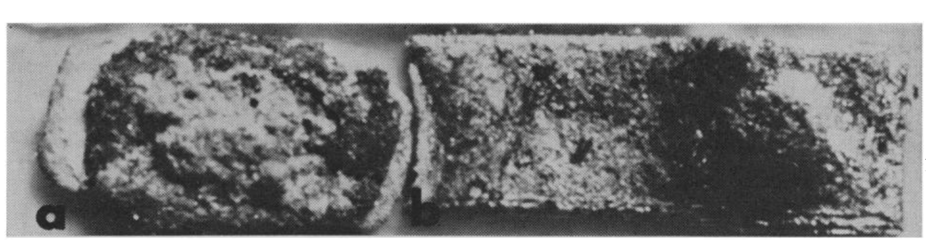

Fig. 2. Specimens from an experiment with nickel as catalyst. *a*, Crust of diamond crystals on metal that was melted and carburized; *b*, unmelted, unreacted stub. These are the central and right sections of nickel, respectively; the left section, mate to the right, is not shown; *a* measures roughly 0.126 by 0.063 cm.