CONFIRMATION OF THE CURRENTLY ACCEPTED VALUE 299 792 458 METRES PER SECOND FOR THE SPEED OF LIGHT

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The speed of light has been determined from a completely independent measurement of the wavelength and frequency of the CH_4-stabilized He–Ne laser. The wavelength is 3 392 231.40 ± 0.02 pm, the frequency 88 376 181.57 ± 0.20 MHz, and the speed of light 299 792 458.1 ± 1.9 m/s.

The value of the speed of light is currently of special interest in discussions concerning the redefinition of the international metre. The Comité Consultatif pour la Définition du Mètre (CCDM), in June of 1973, adopted the value 299 792 458 m/s in its Recommendation M2 on the basis of measurements made up to that time. Use of this value was then recommended in Resolution 2 of the 15th Conférence Général des Poids et Mesures (CGPM) in 1975. In June of 1979 the CCDM, in Recommendation M2, used this value in proposing a new definition of the metre, based on the second:

"The metre is the length equal to the distance travelled in a time interval of 1/299 792 458 of a second by plane electromagnetic waves in vacuum".

The results of recent speed of light measurements have been conveniently summarized in accounts by Evenson and Petersen [1], and by Evenson et al. [2]. Among those determinations having the accuracy implicit in the currently accepted value of c, only two have been completely independent. Before the proposed definition of the metre is made final, a third confirmation is highly desirable. The result of a series of measurements recently completed in this laboratory provide such confirmation.

Both of the two most accurate and independent determinations have been made by measurements of the frequency f and wavelength λ of stabilized laser radiation; the speed of light was then computed by use of the relation $c = f\lambda$. Evenson et al. [3] used the He–Ne laser at 3.39 μm, stabilized on the P(7) line of the ν_3 band of CH_4. Blaney et al. [4] used the CO_2 laser, stabilized on the 9.32 μm R(12) transition of CO_2.

Our measurement also makes use of the $c = f\lambda$ relation, but differs considerably in the manner in which the frequency and wavelength were determined. The value reported here is based on measurements of f and λ of the 3.39 μm radiation from a CH_4-stabilized He–Ne laser.

The description and result of the measurement of the wavelength of the CH_4-stabilized He–Ne laser have been given by Baird et al. [5]. The result is

$$\lambda_{CH_4} \cong 3\,392\,231.40 \pm 0.02 \text{ pm}.$$

The uncertainty here of 0.02 pm and the other uncertainties given in this paper are close to one-standard-deviation values; where applicable, the values include the uncertainty, due to possible line asymmetry, in the ^{86}Kr length standard.

The frequency measurement was made in two separate experiments. In the earlier experiment by Whitford and Smith [6], the frequency of the CH_4-stabilized laser was measured against the frequency of the 10.17 μm R(32) transition of a 4.3 μm-fluorescence-stabilized CO_2 laser. The value obtained for the difference between the third harmonic of the CO_2 frequency and the CH_4 frequency is

Table 1
Completely independent measurements of the speed of light at three national laboratories

Laboratory	References	Speed of light m/s
NBS, U.S.A.	[3], [8], [9]	299 792 457.4 ± 1.1
NPL, U.K.	[4], [10], [11], [12]	299 792 458.8 ± 1.2
NRC, Can.	this paper	299 792 458.1 ± 1.9
	weighted mean ———	299 792 458.05 ± 0.75

$3f_{R(32)} - f_{CH_4} = 55\,300\,952 \pm 10$ kHz.

In the second experiment, by Whitford [7], the frequency of the 10.17 μm R(32) transition of a 4.3 μm-fluorescence-stabilized CO_2 laser was measured against the NRC Cs standard. The value found for the frequency is

$f_{R(32)} = 29\,477\,160\,840 \pm 66$ kHz.

Combining this with the result of the earlier experiment for the frequency of the methane line

$f_{CH_4} = 88\,376\,181.57 \pm 0.20$ MHz.

The 0.20 MHz uncertainty results entirely from the uncertainty in the frequency of R(32) line.

The speed of light then is

$c = \lambda_{CH_4} \cdot f_{CH_4} = 299\,792\,458.1 \pm 1.9$ m/s.

This value and the other two independent measurements are listed in table 1. The three values are in excellent agreement. If they are averaged, with each value weighted inversely as the square of the uncertainty, the result is 299 792 458.05 ± 0.75 m/s. This provides further evidence that the CGPM recommended value 299 792 458 m/s should remain unchanged.

In providing the third of three completely independent measurements of c in agreement with one another and of accuracy largely limited by the ^{86}Kr metre definition, the present measurement provides considerable assurance that the proposed redefinition of the metre will lead to no significant discontinuity in its value.

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