The paradox of the primary standard of length

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Summary: The trend in primary length standards; possible definition of this standard in the near future. For practical metrology no consequences are to be expected as the accuracy of measurement will - as before - be limited by the accuracy of the temperature scale.

It is well known that the primary standard never is used for practical measurement. Since Pérard in 1972 (1) for the first time in history measured a gage block by optical interferometry, all precise calibrations have probably been done by interferometry, using secondary wavelength standards.

After the changeover to the Engelhard krypton lamp was made in 1960 (2), it was in principle possible to use the primary standard for such calibrations. However, the experimental effort needed to operate the krypton lamp makes it use impractical for everyday use.

One might speculate upon the nature of the physical process to be adopted in the near future for a primary standard of length. Popular believe has it that a laser can be used for accurate length measurements, but it is well known that the long-term instability of even the best commercially available laser is two orders of magnitude greater than that of the krypton standard. Nevertheless, recent developments (3) have opened two possible ways to define a metre standard:

(1) a laser stabilised on an I_2 absorbtion line (4) is now operative in a number of metrology laboratories and such a laser promises an inaccuracy which is at least an order of

magnitude smaller than that of the krypton standard.

(2) it is now possible to determine the frequency of an infrared laser by direct counting, thus it is possible to calibrate wavelength standards and to define the metre by specifying an exact value for the velocity of light and using the primary standard of the second.

Evidently there is a principal difference in these two procedures. Adoption of the first method results in different (if more accurate) values for the velocity of light every time the experimental techniques involved in the measurements are refined. If the second method is adopted, the length of the metre will in that case be changing.

The paradox referred to in the title of this paper is that although it is possible to define the metre to (at least) 10^{-10}, this is an empty accuracy as all length measurements in physical and technical systems will as before be limited to an inaccuracy of the order of 10^{-8} caused by an indeterminacy of temperature (4). As before, practical length measurement has no use for the primary standard.

There seems to be strong arguments in favour of a fixed value of the velocity of light for the purpose of precise astronomical length measurement which is in fact a time-of-flight method. Therefore, one might guess that the future definition of the metre will be by the method 2, a fixed value for the velocity of light in vacuum.

(1) Pérard Comptes Rendues 154 (1912) - 1798

(2) In reality the 1960 definition of the metre is more sophisticated than is suggested here. See Metrologia, 4-147-(1968)

(3) Metrologia, 10-75-(1974)

(4) Hanes, G.R. and K.M. Baird Metrologia 5-32-(1969)

(5) Koning Annals C.I.R.P. 29-259-(1971)