Using Uncalibrated Lasers as Wavelength Standards

Plática Invitada

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ABSTRACT

The fundamental atomic physics of a gas laser transition is such that the transition frequency, or equivalently, the vacuum wavelength of the laser, cannot vary from its central value by more than a few parts in 10^6. The uncertainty of the gas laser wavelength is bounded by the Doppler width of the gain curve, with an additional important contribution from isotope shifts if the isotopic content of the laser is not known. For a stabilized red helium-neon laser (633 nm), this uncertainty of frequency/wavelength can be reduced via calibration— a heterodyne comparison to an iodine stabilized laser— but the heterodyne comparison is not needed or useful in applications where an uncertainty of a few parts in 10^6 is fully sufficient for measurement needs.

The basic argument of this paper is that, in some circumstances, normal calibration procedures for lasers do not provide useful information in terms of establishing traceability to the SI unit, and that consequently these calibration procedures should not be required. An uncalibrated laser—either stabilized or unstabilized—can often be employed with full confidence for measurement needs that do not require the highest possible accuracy. Nevertheless, we must recognize that there are certain pitfalls that must be avoided when adopting this viewpoint. The nature and severity of these pitfalls may differ depending on the type of laser employed for a measurement. In the metrology community, we have greatest experience with the red 633 nm helium-neon laser, and we know that there is some danger that a commercial laser, advertised as operating on the red $3s_2 \rightarrow 2p_4$ transition at 633 nm, may also emit some light from the nearby $3s_2 \rightarrow 2p_2$ transition at 640 nm. This problem must be addressed before using the laser wavelength as a standard.

These issues have been carefully considered by an ad hoc subcommittee of the CCL (Consultative Committee for Length) of the CIPM (International Committee on Weights and Measures). The subcommittee decided that the problem of 640 nm radiation, although important, does not present an intractable obstacle to the use of uncalibrated 633-nm lasers for length metrology. At the 2007 meeting of the CCL, the CCL recommended that unstabilized helium-neon lasers operating at 633 nm should be included in the list of recommended standard frequencies (formerly known as the *Mise en Pratique* of the Definition of the Meter).

This paper will discuss the technical basis for assigning a wavelength and uncertainty to the 633 nm radiation, how to deal with the problems of 640 nm radiation, and how the basic reasoning that has been applied at 633 nm might be extended to other lasers. The paper will also touch on the similarity of these laser standards to intrinsic standards and primary standards, as defined by the VIM ("International Vocabulary of Metrology - Basic and General Concepts and Associated Terms").