# The photometric base unit – the candela

The SI base unit for luminous intensity, the candela, is expressed in strictly physical terms. The objective of photometry, however, is to measure light in such a way that the result of the measurement correlates closely with the visual sensation experienced by a human observer of the same radiation. For this purpose, the International Commission on Illumination (CIE) introduced two special functions $V(\lambda)$ and $V'(\lambda)$, referred to as spectral luminous efficiency functions, which describe, respectively, the relative spectral responsivity of the average human eye for photopic (light adapted) and scotopic (dark adapted) vision. The more important of these two, the light-adapted function $V(\lambda)$, is expressed relative to its value for the monochromatic radiation to which the eye is most sensitive when adapted to high levels of luminance, i.e. at a wavelength of 555 nm in standard air [1].

The CIPM has approved the use of these functions (PV, **61**, 1972 et PV, **65**, 1976), with the effect that the corresponding photometric quantities are defined in purely physical terms as quantities proportional to the integral of a spectral power distribution, weighted according to a specified function of wavelength (for details, see *Principles governing photometry, Monographie BIPM, 1983*).

Since the inception of the SI, the candela has been one of its base units. The original photometric standards were light sources, the earliest ones being candles, hence the name candela as the name of the photometric base unit. From 1948 to 1979 the radiation from a black body, Planck radiation, at the temperature of freezing platinum was used to define the candela. Since 1979 the definition is given in terms of monochromatic radiation rather than the broadband radiation implied by the former blackbody definition. The value 1/683 watt per steradian which appears in the present definition was chosen in 1979 so as to minimize any change in the representations of the photometric units maintained by the national standards laboratories. This value is specified for monochromatic radiation at $540 \times 10^{12}$ Hz, which corresponds to a wavelength of 555.016 nm in standard air. Therefore, the value of the luminous efficacy expressed in lumens per watt (lm/W) for monochromatic radiation at the peak of $V(\lambda)$, known as the maximum spectral luminous efficacy $K_m$, is $683/V(555.016 \text{ nm})$ lm/W = 683.002 lm/W, based on linear interpolation of $V(\lambda)$ at 1 nm intervals. The rounded value $K_m = 683$ lm/W is generally used with negligible errors in calculations for all practical photometric measurements. The constant $K_m$, together with $V(\lambda)$, relates photometric quantities and radiometric quantities.

The 1979 definition gives no prescription as to how the candela should be realized, which has the great advantage that new techniques to realize the candela can be adopted without changing the definition. Today, many national standards laboratories realize the candela by radiometric methods utilizing absolutely calibrated detectors. Standard lamps are still commonly used, however, to maintain and transfer the photometric units.

In 2007 the CIPM concluded an agreement with the CIE, in which the two organizations recognize that:

- the CIPM's responsibility for the definition of the photometric units in the SI and
- the CIE's responsibility for the standardization of the action spectra of the human eye

are the interlinked cornerstones of practical physical photometry worldwide. Therefore the Parties undertook to inform and consult each other whenever either Party is considering a change in any of these foundations of physical photometry.

[1] Edlén B., The refractive index of air, *Metrologia*, 1966, **2**, 71-80.

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