Ultra-fast multi-wavelength pyrometer for high temperature measurements

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The pyrometrical determination of surface temperatures by an analysis of thermally emitted light is often the only available method for temperature measurements. Typical examples for applications are temperature measurements in laser heated levitation experiments, during self-propagating synthesis experiments or in experiments with warm dense matter. Here, the design of a flexible and accurate pyrometer for these applications is presented.

The pyrometrical technique is based on measurements of wavelength-dependent thermal radiation or spectral radiance, and its "comparison" to that of blackbody (Planck) radiation or its Wien's approximation (eq. 1):

$$I(\lambda, T) = \varepsilon(\lambda, T)\frac{2\pi hc^2}{\lambda^5}exp(-\frac{hc}{\lambda kT}) \quad (1)$$

where $I(\lambda, T)$ is dependence of intensity of light on the wavelength (λ) and temperature (T), ε is emissivity. The main uncertainty in traditional pyrometry is the surface emissivity ε, which is generally unknown and hard to measure. A common approach to deal with this problem is to measure the thermal emission at multiple wavelengths – an approach called multi-wavelength pyrometry [1]. The emissivity in that case is approximated by some function of the wavelength.

In practice, the grey body approximation $\varepsilon(\lambda) = const$ is commonly used, but it is accurate only for certain materials in a narrow temperature and wavelength range. As a more advanced technique a polynomial dependence of $\varepsilon(\lambda)$ on λ is often assumed. The temperature is then determined from a fit, in which the polynomial coefficients and the temperature are variables. The most popular multi-wavelength pyrometry emissivity models are the linear model, the polynomial model, and the exponential raised to a polynomial emissivity model [2, 3].

Our new pyrometer uses 8 wavelengths from 600 to 1500 nm and different types of detectors, such as photodiodes and Multi Pixel Photon Counters (MPPC) for low levels of light, which is a new technical development in pyrometry. This allows one to measure the temperature in a broad temperature range up to a few thousand Kelvins with high temporal resolution up to nanoseconds.

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[1] Coates P.B. Multi-wavelength pyrometry. Metrology, 17, 103 (1981)
[2] Svet D. Ya. Determination of the emissivity of a substance from the spectrum of its thermal radiation and optimal methods of optical pyrometry. High Temp.–High Press., 8, 493–498 (1976)
[3] Khan M.A., Allemand Ch. and Eagar Th. Noncontact temperature measurement. II. Least squares based techniques. Rev. Sci. Instrum., 62, 403 (1991)