Laser Beam Measurement: Section Introduction

Julian Jones

To characterize a laser beam requires complete knowledge of its mutual coherence function—the power (or energy) distribution and the relative phase distribution over a single transverse plane—achieved by complex measurement and subsequent analysis. In Chapter 32, Brooke Ward describes a useful approximation to the ideal, based on measuring the beam diameter and divergence at a set of transverse planes along the axis of the laser beam, considering how the diameter is to be defined (using a second-moment technique) for different types of beams; how the measurements are to be made, using sensor arrays or scanning slits.

Intrinsic to the characterization of a beam is the ability to be able to measure optical power or energy. In Chapter 33, the authors consider various practical detector devices that are required to cover the range of wavelengths of the lasers described elsewhere in this Handbook, extending from ultraviolet to infrared. In the ultraviolet, there remains a place for the vacuum-tube photomultiplier, although photodiodes (notably of the Schottky type), using semiconductor materials such as Si, SiC, GaP and GaN, are useful. More recently, semiconductor artificial diamond has come forward as a promising material on account of its very wide bandgap. For many purposes, the silicon photodiode is ubiquitous for measurements in the visible wavelength range. Infrared detection poses more of a challenge. In the nearest wavelength range, say up to the 1.55 μm typical of optical communications, InGaAsP approaches the ideal. At longer wavelengths, where the thermal quantum approaches the optical quantum energy, more complex structures (such as quantum wells) and different materials are needed, such as the lead salts in the mid-infrared; perhaps HgCdTe is the most flexible material at these wavelengths. Thermal detectors, or bolometers, have their place for the detection of the longest wavelengths and development continues, e.g. with the silicon micro-bolometer.

International standards exist for the measurement of the radiant power and energy of lasers. Techniques for the transfer of these standards are discussed by Robert Tyson in Chapter 34, spanning the wide wavelengths (IR to UV) and pulse lengths (fs to cw) required for practical lasers, noting the standard calibration categories, and describing some standard test configurations. Returning to the complete characterization of a laser beam in terms of the irradiance and phase distributions in a single transverse plane and which are often written as $I(x, y)$ and $\phi(x, y)$, Bernd Schäfer in Chapter 35 reviews the relevant international standards ISO13694 and ISO15367. The irradiance (power density) is measured with array or scanning detectors. The phase distribution is measured with wavefront sensors, such as those used in adaptive optics (Chapter 14), e.g. the Shack–Hartmann sensor, or by using an interferometer (Chapter 3). Alternatively, the complete mutual coherence function can be measured using an optical arrangement similar to that used for producing Young’s fringes. Finally, temporal characterization of ultrashort laser pulses is reviewed in Chapter 36.