surface. Also, an aperture through which photons can reach the detector is located on the inner surface. Orientation of the sample relative to the aperture is arranged to prevent photons originating in the sample reaching the photodetector directly, but photons at all angles of emergence can reach the detector after multiple reflection with comparable probabilities. Therefore, integrating spheres realise a very large acceptance angle and, hence, overcome the problem of photons missed by scattering in normal spectrophotometers.

In principle, transmittance of samples is calculated from the detector signal obtained with the interior illuminated through the sample, divided by the signal measured with direct illumination of the inner sphere. For reflection measurements, the sample is flipped over and illuminated from the inside of the sphere: by relating the signal obtained under these latter conditions with that recorded from a highly reflecting reference surface a value for reflectance is obtained. Absorptance of a sample is calculated according to:

$$\text{absorptance } (\%) = 100\ (\%) - \text{reflectance } (\%) - \text{transmittance } (\%) \qquad (6.1)$$

Equation 6.1 illustrates that reflectance, which determines the optical appearance of plant organs viewed from the illuminated side, is determined by absorption and transmission properties. We emphasise that absorptance is not to be confused with absorbance: in the absence of reflection, the logarithmic relationship between these two terms is given by:

$$\text{absorbance} = \log\{100/[100 - \text{absorptance } (\%)]\} \qquad (6.2)$$

Integrating spheres are frequently employed to study intact leaves. At wavelengths of high electronic absorption by the leaf, information on surface reflectance can be derived from intact material (see Section 6.4.1). With plant species allowing the preparation of sufficiently large epidermal patches, optical properties of plant surfaces can be studied over the entire wavelength range of interest (Figure 6.1; Grammatikopoulos *et al.*, 1999; and references in Section 6.4.1).

6.2.3 Microfibre optics

Information on plant surface optics is also available from measurement of gradients of radiation intensities inside leaves using fibre microprobes (Vogelmann and Björn, 1984; Vogelmann and Haupt, 1985). These gradients are obtained with a fibre optics probe having a thickness of a few micrometres by advancing it stepwise through the tissue and recording the radiation accepted by the probe using a spectroradiometer. The steepness of intensity curves below the illuminated surface and the depth of penetration of the radiation are both key parameters from which absorption properties of surfaces can be derived. This technique has been useful in obtaining information on UV screening of leaf surfaces (Bornman and Vogelmann, 1988; Bornman and Vogelmann, 1991; Day *et al.*, 1992; Cen and Bornmann, 1993; Ålenius *et al.*, 1995; Turunen *et al.*, 1999; Olsson *et al.*, 2000; Liakoura *et al.*, 2003).