Spectrochemical Analysis

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A pellicle beam splitter is made of a durable elastic membrane stretched over an optically flat metal frame and bonded to the edges as illustrated in Figure 3-31b. Typically, the membrane is made from optical-grade nitrocellulose and has a thickness of only 7 μm. An uncoated pellicle beam splitter reflects 8% and transmits 92% of the incident radiation throughout the visible and near-infrared regions. Coatings are used to vary the ratio of the reflected to transmitted beam intensities. Standard coatings provide ratios of (33/67%, 40/40%, and 50/50%). Pellicles are of high efficiency and they do not produce multiple beams.

The beam splitters described above all produce beams that are spatially separated, but temporally overlapping. In some applications it is desirable to split a single beam into two spatially separated beams at different times. The double-beam in-time spectrometer described in Section 4-6 is an example. For such applications, the chopper/beam splitter illustrated in Figure 3-31c is often used. The chopper wheel is usually made by cutting open slots in a circular mirror.

Many other types of beam splitters are used. Several of these separate an unpolarized beam into its two mutually perpendicular components. We have already encountered such a polarizing beam splitter in Section 3-2, where an optically anisotropic crystal, such as calcite, was shown to produce an ordinary and an extraordinary ray. Polarizing prisms, used as beam splitters, are described in Section 3-5. Another polarizing beam splitter is often referred to as the "pile-of-plates" polarizer. This type of beam splitter is based upon polarization by reflection, as described in the preceding section. The pile-of-plates polarizer is illustrated in Figure 3-31d. This type of beam splitter can be made with glass plates for use in the visible region, with quartz plates for the ultraviolet region or with alkali halide plates for use in the infrared region. A crude beam splitter of this type can be made from 10 to 12 microscope slides.

Another type of beam splitter is a wavelength-selective beam splitter or **dichroic mirror**. Such mirrors are made from multilayer, nonabsorbing films. (See Section 3-5 for a description of interference filters based on thin films.) A hot mirror reflects infrared radiation while transmitting visible radiation as illustrated in Figure 3-31e. A cold mirror reflects visible radiation and transmits infrared radiation. There are many uses of dichroic mirrors. Many sources used in the visible also produce intense infrared radiation which can cause heating problems. A dichroic mirror can be used to direct the unwanted infrared radiation away from the sample. In movie projectors, dichroic mirrors are often used to send the infrared radiation to the back of the projector away from the film. Like other beam splitters, dichroic mirrors can be used in reverse as beam combiners. For example, the fundamental infrared beam from a Nd:YAG laser (1.06 μm) is often combined with visible harmonics or with a visible dye laser beam by using a dichroic mirror.

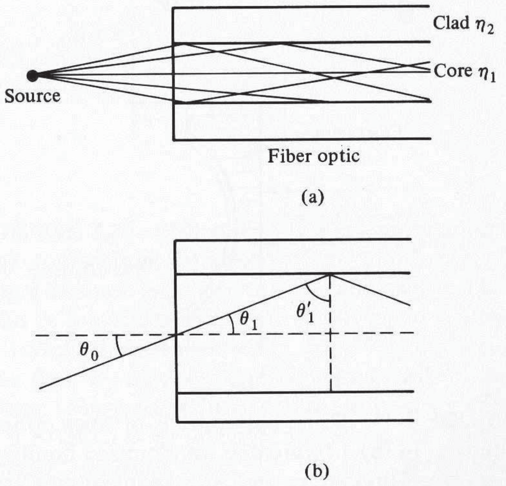
Another type of beam splitter is based on bifurcated fiber optics bundles as described below.

Fiber Optics

Fiber optics from the communications industry are being used in and with spectrometers to transfer light between various points. The construction of a fiber optic is shown in Figure 3-32. A light ray entering the core at angle θ_0 will be totally internally reflected if $\sin \theta_1' \geq \eta_2/\eta_1$. Since $\sin \theta_1' = \cos \theta_1$ and $\cos^2 \theta_1 = 1 - \sin^2 \theta_1$, the condition for total internal reflection is $1 - \sin^2 \theta_1 \geq (\eta_2/\eta_1)^2$ or $\eta_1 \sin \theta_1 \leq (\eta_1^2 - \eta_2^2)^{1/2}$. The entrance angle θ_0 is related to θ_1 by Snell's law ($\eta_0 \sin \theta_0 = \eta_1 \sin \theta_1$), so total internal reflection occurs when $\eta_0 \sin \theta_0 \leq (\eta_1^2 - \eta_2^2)^{1/2}$. There is thus a maximum value of θ_0 for which total internal reflection occurs given by $\eta_0 \sin \theta_0 = (\eta_1^2 - \eta_2^2)^{1/2}$. Rays that are incident at larger angles are only partially reflected at the core–clad interface and soon pass out of the fiber. The **numerical aperture** NA is defined as $\eta_0 \sin \theta_0$, or

$$\mathrm{NA} = \eta_0 \sin \theta_0 = (\eta_1^2 - \eta_2^2)^{1/2} \tag{3-46}$$

The NA represents the cone of light accepted by the fiber. The F/n of a fiber optic is related to the NA by $F/n = 1/(2 \tan \theta_0)$. Core diameters are typically 50 to 600 μm and the refractive index of the clad is typically



(a)

(b)

FIGURE 3-32 Fiber optic. The fiber optic in (a) consists of a core of refractive index η_1 and a clad of refractive index η_2, where $\eta_2 < \eta_1$. Normally, additional jackets surround the clad to provide physical strength. In (b) the various angles are defined.