# Chapter 4

# Emission characteristics of dye-doped PVA films

## 4.1 Beam profile

Figure 4.1 shows the profiles of the laser beams that exited from the as-cut edge and the frosted edge (as defined in Section 2.2), which have been captured on Polaroid films. The beam exiting from the as-cut edge of each side of the glass consisted of two streaks of nearly equal intensity, and that from the frosted edge consisted of a single, nearly circular spot. The as-cut edge, which is smooth, acted as a medium boundary that diffracts the beam; the diffraction phenomenon is also noted in a study by Reisfeld & Shamrakov, 1993. The single spot is produced by diffuse transmission and scattering that take place at the glass-air interface. This effect was also observed by using an as-cut edge that had been polished (see comparison of photographs in section 2.2).

The profile of the output beam is better described in terms of vectors. The polar diagram in Figure 4.2 shows the vectorial representations of the intensity and direction of the incident beam at the smooth 'as-cut' edge and the frosted edges. The

intensity distribution is Gaussian for the homogeneous surface of the frosted rough edge.

The beam divergence of the frosted-edge slide is estimated to be ~12° compared with ~6° for the diffracted beam, and was almost identical for all dye/PVA systems. The dye/PVA systems yield an incident angle of 86°, which is too large to lead to high amplification as the number of internal reflections within the glass slide itself is limited. The dye/PVA results suggest that the use of either a longer or a thinner glass slide is necessary for high amplification and more intense emission. However, the beam divergence increased to ~9.5° for a 0.175 mm as-cut slide. (The relationship between the thickness of the films and the beam divergence is explained in section 4.2.) The dye/PMMA system gave a larger divergence angle of 14°.

The output energy that was measured for the as-cut edge sample that had been polished was reduced by 30-40% compared with the energy of the sample before the edge was polished. The magnitude of such a loss indicates energy loss involving a diffuse transmission mechanism.

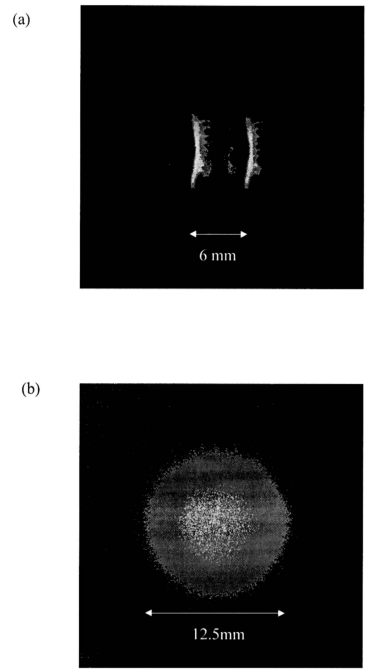



Figure 4.1 Beam profiles from (a) a smooth as-cut edge (b) a rough frosted edge, taken at 3 cm from edge.

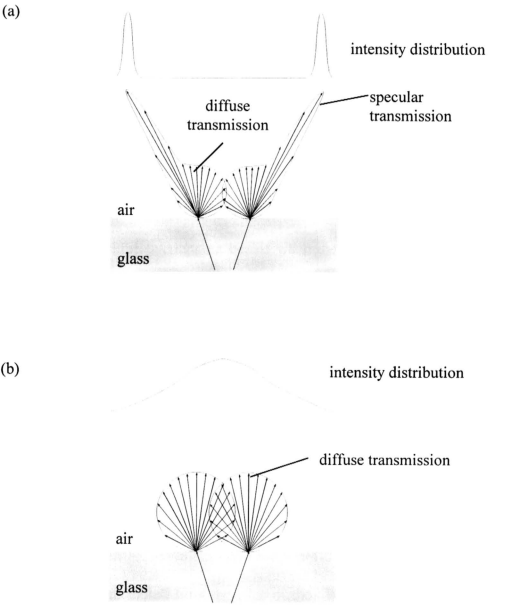



Figure 4.2 Polar diagrams of emission beams from glass to air at (a) a rough surface (the frosted edge), and (b) a smooth surface (the as-cut edge).

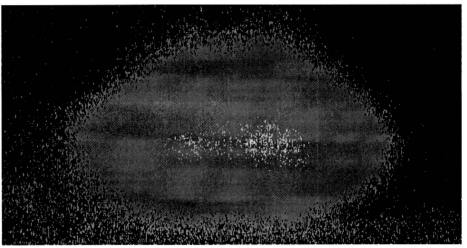
### *4.2 Film thickness*

The pure waveguide properties diminished when the thickness of the coated film exceeded 25 μm per layer. This effect was observed on the glass edge that was frosted. Two other emissions from the edge of the film interfered with the single output beam from the glass, gradually replacing the waveguided emission from the glass as the thickness of the film was increased.

A 30 μm film produced a single faint beam when the film edge was covered by an opaque foil, and three overlapping beams when the foil was removed, which supports the thickness limitation of the waveguide phenomenon described above. The beam profiles of these are shown in Figure 4.3. Emission also took place at both film and glass edges on a 0.175 mm thin as-cut edge glass slide; a ratio of glass thickness to film thickness of 14 may be too small for fully waveguided emission compared with that ratio of ≥35 for the fully waveguided emission.

The energy output of a coated glass slide that is coated by a second layer of film (~20μm) (Figure 4.4) showed a doubling of the energy output relative to that of the first layer but little difference in emission beam profiles was noted. Observation showed that the emissions exited from the edge of the glass although the combined thickness of the two films gave a small glass-thickness/film-thickness ratio. On the other hand, a single layer film at this ratio gave emissions from the edge of the film.

(a)



(b)

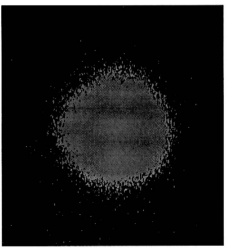


Fig. 4.3 Emission beam of a 30 μm film (a) without masking (single pulse) (b) with film edge masked (2 pump pulses).

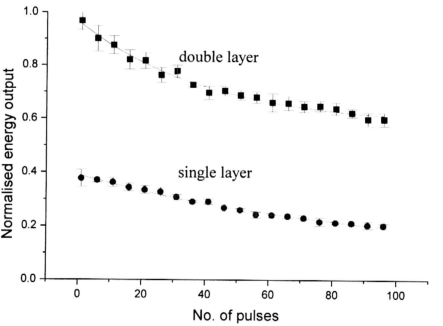



Figure 4.4 Intensity difference of a single layer coating and a double layer sample.

### 4.3 Red-green-blue (RGB) emission

Studies on two-colour and three-colour emissions from dye lasers are generally limited to studies on the liquid system, and a mixture of two (or three dyes) is used to attain this effect (Hilborn & Brayna, 1974; Saito *et al.* , 1990; Saito *et al.*, 1992). Such dye lasers are difficult to design because the energy transfer mechanism that governs these emissions itself is hard to control. They also suffer from undesirable time delay of the emissions as energy transfer occurs when the dye mixture is optically excited (Yap *et al.*, 1996; Tou *et al.*, 1997). A solid-state dye laser will suffer from these if the dyes are first mixed together before the dyes are incorporated into the host material; however, if each dye is doped into polymer individually and coated as non-overlapping films on a common support, the dye molecules of one dye will be physically separated from the dye molecules of the other. A solid-state dye laser constructed in this manner should also yield two-colour emissions.

A single white beam was produced from the system described in section 2.1, Figure 2.17; the laser emission wavelengths were 456.70 nm, 533.84 nm and 654.21 nm (Figure 4.5). The bandwidths of each wavelength increased by 6-8 nm compared to those of the single dye systems (4-6 nm). As diffusion occurred at the frosted edge, the total emission energy was only ~15 μJ. The dye laser is capable of producing ~1200 pulses if the film is moved to a fresh spot after every 40 pulses.

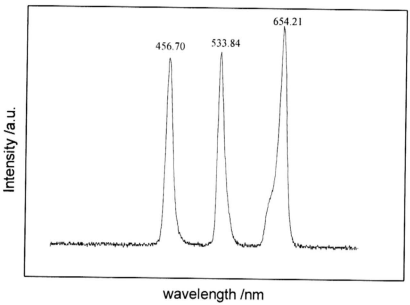



Figure 4.5 RGB simultaneous emission spectra of C460 (2.0 x $10^{-3}$M), DF (1.0 x $10^{-4}$M) and R640 (8.0 x $10^{-4}$M), with the total energy output of ~15 μJ.