CHAPTER 6

CONCLUSIONS

6.1 CONCLUSIONS

Dye-doped PMMA slabs were fabricated by using the low-pressure-compression molding method. These dye-doped PMMA slabs underwent a 7 hours annealing process to improve the optical homogeneity of the dye-doped PMMA and hence increasing the laser efficiency. Dye-doped PVA films were fabricated by using dip-coat method. These dye-doped PVA films were also fabricated in various configurations, in order to study the effects of dye-doped PVA film thickness and the properties of substrate on the laser performance of dye-doped PVA films.

Laser emissions of C460-doped PMMA slabs, $R6G(ClO_4)$-doped PMMA slabs, C460-doped PVA films and $R6G(ClO_4)$-doped PVA films were obtained from the excitation of a two-stage Blumlein Transversely Excited (TE) nitrogen laser. The output energies of these solid-state dye lasers was measured by using a laser power meter; whereas the laser spectra was detected by using an optical multichannel analyzer (OMA). The operating lifetime of these dye-doped polymers were also determined.

For the dye-doped PMMA, $R6G(ClO_4)$ showed better compatibility than C460. $R6G(ClO_4)$-doped PMMA gave an optimum laser efficiency of 8.7% at a peak laser wavelength of 583 nm at the optimum dye concentration of 1×10^{-3} M; whereas C460-doped PMMA gave an optimum laser efficiency of 3% at a peak laser wavelength of 452.7 nm at dye concentration of 2.25×10^{-2} M. $R6G(ClO_4)$-doped PMMA was found to have better photostability under nitrogen laser pumping pulses compared to C460-doped PMMA. The laser efficiency of R6G(ClO_4)-doped PMMA suffered only a 7 – 8% reduction after 1000 laser pump pulses, whereas C460 suffered a reduction in laser efficiency of 50% after just 10 – 20 pumping pulses.

For dye-doped PVA, C460-doped PVA showed better laser performance compared to that of the R6G(ClO_4)-doped PVA. The peak lasing efficiency of C460-doped PVA was approximately 8.27% at a dye concentration of 8×10^{-3} M and approximately 6.3% for R6G(ClO_4)-doped PVA at a dye concentration of 2.5×10^{-3} M. C460 was more stably embedded in PVA matrix than the PMMA matrix. C460-doped PVA shows better laser performance and was photostabilized under nitrogen laser excitation. However, R6G(ClO_4)-doped PVA showed poor photostability compared to R6G(ClO_4)-doped PMMA.

In this project, the determinations of refractive index (Section 4.4.1) and film thickness (Section 4.4.2) had been carried out in order to monitor the optical quality of the dye-doped polymer cells. The refractive indices of dye-doped polymer cells were found to vary with the dye doping concentrations in a linear manner. These indices are important parameters used in the determination of dye-doped film thickness. For C460-doped PMMA, the range of refractive index determined is from 1.488 to 1.492 (for dye concentration ranging from 7.5×10^{-3} M to 3.0×10^{-2} M); whereas for R6G(ClO_4)-doped PMMA, the range of refractive index determined is from 1.489 to 1.500 (for dye concentration ranging from 7.5×10^{-4} M to 1.0×10^{-2} M). For C460-doped PVA, the range of refractive index determined is from 1.433 to 1.503 (for dye concentration ranging from 7.0×10^{-4} M to 1.5×10^{-2} M); whereas for R6G(ClO_4)-doped PVA, the range of refractive index determined is from 1.434 to 1.506 (for dye concentration ranging from 7.0×10^{-4} M to 7.5×10^{-3} M).

The thickness of the dye-doped PVA film is proportional to the number of immersion of glass substrate into the dye-doped PVA mixture. From the observation of the fringe patterns of C460-doped PVA films using Michelson interferometry, it was found that the unevenness of the surface of the film increased with the increment of immersion number. At film thicknesses of about 30 μm, the maximum laser efficiency of 17% had been achieved. Laser efficiency decreased at the further increment of film thickness, due to the poor quality of the surface of the dye-doped PVA films and the unevenness of the surface degrades the guiding of the photons in this active dielectric film and caused the decreases in laser efficiency.

Besides, the series of experiments (Section 5.2.4.2 and 5.2.4.3) had shown that the laser performance of dye-doped PVA film could be improved by using aluminium-coated glass substrate, and by a suitable choice of glass substrate thickness. For aluminium-coated glass substrate, laser efficiencies of 10.91%, 11.95% and 13.36% had been obtained at film thicknesses of 11.5 μm, 14.9 μm and 18.8 μm respectively. The optimum laser efficiency of 18.67% was achieved at the glass substrate thickness of 3 mm. This series of experiments also showed the role-play of the glass substrate during the excitation of dye-doped PVA film, such as (a) the glass used (n_g = 1.52) is a suitable material as a substrate for C460-doped PVA film at the optimum dye concentration, due to its refractive index being slightly higher than that of the dye-doped film; (b) the glass substrate acting as a multiple waveguide, allowing the photons to return to the film to contribute to the stimulation process; and (c) the vertical edges of the glass substrate act as output couplers for dye laser.

6.2 FUTURE WORK

In the fabrication process of the dye-doped PMMA cell, the molding process can be improved by increasing the compression pressure. This can be done by exerting compression pressure at various directions on the mold cavity instead of one direction as shown in this project. This may be able to reduce the molding duration to prevent the decomposition of the dye due to the long heating period. Furthermore, the optical homogeneity of the dye-doped PMMA may be improved by this method.

Dip-coat method was used in fabricating dye-doped PVA film used in this project, due to its simplicity. The main disadvantage of this method is that the control of the film thickness and especially the evenness of the surface are rather difficult. To achieve better surface quality of the films, spin-coating method may be a suitable choice.

In this project, the study of the role played by the glass substrate in the laser action of dye-doped PVA film was carried out and a qualitative reasoning for the behavior was proposed. This needs to be investigated in more details in the future.