

CHAPTER THREE

EXPERIMENTAL

3.1 Pumping of dye-doped PMMA slabs

The set-up (figure 3.1a) for the optical excitation of the doped slabs uses a cylindrical quartz lens (focal length = 5.5 cm) to focus the nitrogen laser beam. The slab was mounted on a vertical-horizontal (z -axis/ y -axis) translator. Horizontal translations focussed the nitrogen laser onto the slab and vertical translation moved the slab to other pumping positions. A visible-broadband 100% reflectivity mirror was also used to feed the laser beam back into the slab. The surface of the mirror and the two opposite sides were arranged to be perpendicular to the dye laser beam. A 4% surface reflectivity was estimated from the difference of the refractive indices between the PMMA ($n = 1.49$)³⁵ and air ($n_0 = 1$).

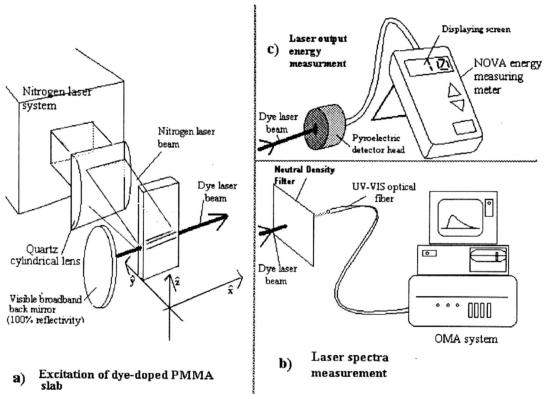


Figure 3.1 a) Set-up for pumping solid-state dye laser, b) OMA system for laser spectra measurement and c) NOVA system for laser energy measurements

3.2 Laser spectral measurements

In the experimental arrangement (figure 3.1b) for recording the laser spectra, a UV-VIS optical fibre guided the laser beam into the Optical Multichannel Analyser (OMA, model 1461). The OMA had a 1/8-metre monochromator consisting of a 800 line mm^{-1} grating plate to disperse the incoming laser according to wavelengths and an array of photodiodes to register the intensity at each wavelength. The OMA was placed in an electrically-grounded metal box in order to shield it from electromagnetic interference of the pumping source (i.e., the N_2 laser) nitrogen laser. Strong emissions were dampened by a neutral density filter.

The detector head of the OMA system, whose operation was controlled by a microcomputer, was cooled to -5°C for the spectral measurements. The window of the photodiode array was set to 3 seconds in order to ensure that the dye laser pulse could be detected by the photodiode array. The background dark noise associated with this acquisition time was eliminated by means of background subtraction.

3.3 Laser output energy measurement

The NOVA (model PE-10, USA) system (figure 3.1c) that was used to measure the laser output energy comprised a microprocessor-based laser power/energy meter and a 1-cm diameter pyroelectric-metallic detector head. The measurement depended on the fact that laser falling on the detector head produces a temperature gradient along the pyroelectric crystal, generating an electric charge that is proportional to the photon energy absorbed. The NOVA system has a sensitivity of the order of μJ . A self-correcting programme in the EEROM ensured accurate readings in the $1.93 \times 10^2 \text{ nm} - 1.2 \times 10^4 \text{ nm}$ wavelength range. Wavelengths of 248, 332, 532, 1064, 3516 and $1.06 \times 10^4 \text{ nm}$ were pre-set into the EEROM. Other wavelengths were selected by changing these pre-set values. The specifications of this NOVA system as supplied by the manufacturer are as below.

Table 3.1 Maximum error in energy as a function of wavelength

Wavelength	Errors
190 - 350 nm	$\pm 8\%$
400 - 800 nm	$\pm 4\%$
1064 nm	$\pm 0\%$
$2 - 3 \times 10^3 \text{ nm}$	$\pm 8\%$
$10.6 \times 10^3 \text{ nm}$	$\pm 15\%$

The system was operated in the energy measurement mode, with the laser pulse length was set to $< 50 \mu\text{s}$ and the energy range set to according to the output energy of the laser. The NOVA system was placed in another electrically grounded metal box to shield out electromagnetic interference from the nitrogen laser.

3.4 Nitrogen Lasers

Two nitrogen lasers, each of which produced 337 nm of UV laser, were used for pumping the dye-doped PMMA. The Transversely Excited Atmospheric (TEA) pressure nitrogen laser delivered 1-ns laser pulses whereas the low pressure (40 - 180 mbar) Transversely Excited (TE) nitrogen laser delivered approximately 6 ns laser pulses. The output energy of the TEA was controlled to within 200 - 400 μ J by varying the charging voltage and that of the TE laser, to within 300 - 1700 μ J by varying both the charging voltage and the gas pressure.

Construction of the TEA nitrogen laser

The TEA nitrogen laser was assembled based on a published laser⁵⁷, and the scheme is presented in figure 3.2. C_1 and C_2 are two capacitors, each consisting of three 2-mil Mylar sheets sandwiched between an aluminium foil and the ground plate. The Mylar sheets were coated with a film of transformer oil to reduce the localisation of high electric fields around dust particles, which would puncture the sheets. The capacitors, each having an area of 25 x 30 cm², provided about 7.5 nF capacitance. A trigatron spark gap, which was triggered by a stepped-up SCR pulse from an ignition coil, was used for switching the Blumlein circuit. Two 1.25 x 2.5 x 3.5 cm³ brass laser electrodes were placed in parallel on top of the two high-voltage capacitor plates at a distance of 3 mm. Four strips of aluminium foils were placed with their protruding sharp edges functioning as

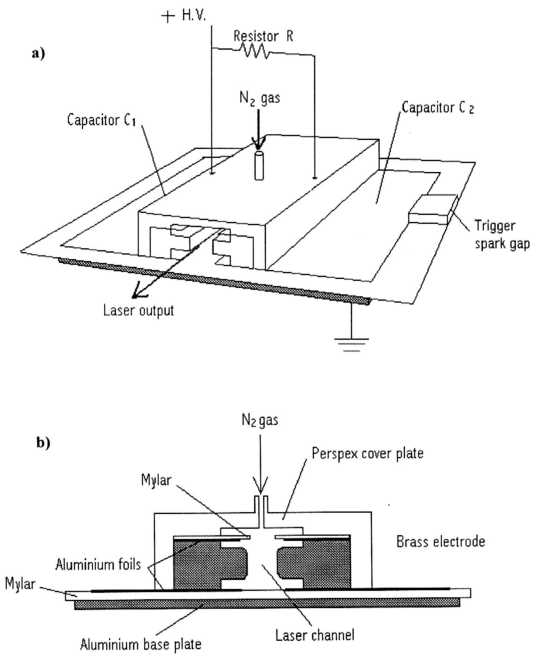


Figure 3.2 a) TEA nitrogen laser and b) cross-section of TEA N_2 laser

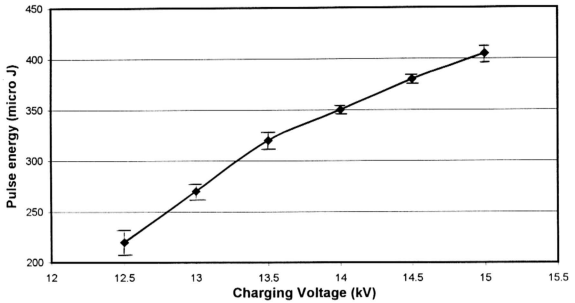


Figure 3.3 Laser output versus charging voltage for the TEA nitrogen laser

corona preionisers that would provide photoelectrons for ensuring a uniform glow in the laser discharge (figure 3.2b). The laser electrodes, aluminium foils and the Mylar sheets were encased in a Perspex box having a aperture in the top and openings in the front and the back. Nitrogen gas was admitted into the box through the top at the rate of $7.5 \text{ cm}^3 \text{ s}^{-1}$. A thin quartz plate was placed over the front opening and a 100% reflectivity mirror over the back. The output energy of this TEA nitrogen laser is shown as a function of charging voltage in figure 3.3.

Construction of the TE nitrogen laser

The TE nitrogen was also assembled following a system described in the literature⁵⁸. The three discharge loops of the two-stage Blumlein TE nitrogen laser are shown in figure 3.4. Capacitor C_1 uses a 10-piece door-knob 1.93 nF ceramic obtained commercially (Murata Ltd, Japan). The C_2 capacitor (10-piece door-knob 0.81 nF capacitors) was discharged into the C_3 capacitor (10-piece door-knob 1.12 nF capacitors) in order to ensure rapid voltage growth. The laser output is improved by a large over-voltage across the laser channel, enabled by the delayed breakdown in the PSSGs. The use of three PSSGs instead of merely only one in the TEA laser system also ensured a more uniformity current distribution in the laser channel, and, consequently a more homogeneous excitation of N_2 gas and laser emissions were observed.

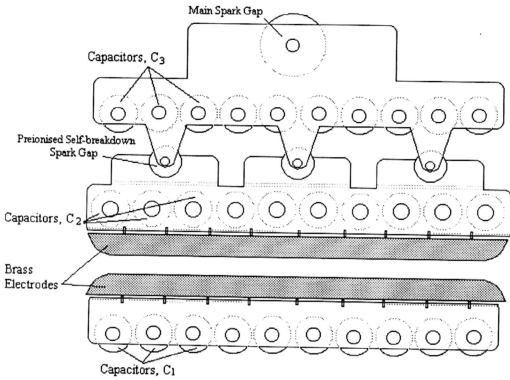


Figure 3.4a Top view of TE nitrogen laser

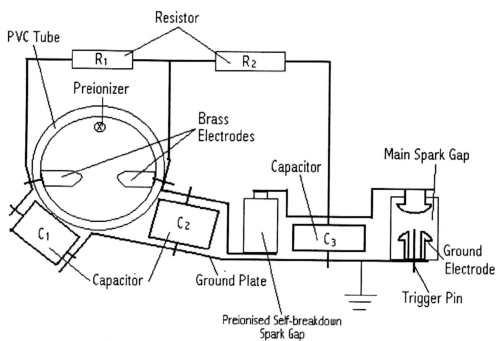


Figure 3.4b Cross section of the TE laser

The laser system consisted of two round -end 50-cm electrodes that were mounted below the mid-plane of a PVC tube; the laser discharge volume was estimated to be $5 \times 15 \times 480 \text{ mm}^3$. The UV-preionizer consisted of a linear array of stainless steel blades with tapered ends separated by less than 0.5 mm.

The TE nitrogen laser operated at 40 to 180 mbar to provide laser. The energy, ranging from 300 to $1700 \mu\text{J}$, was controlled by changing the charging voltage and the gas pressure (figure 3.5).

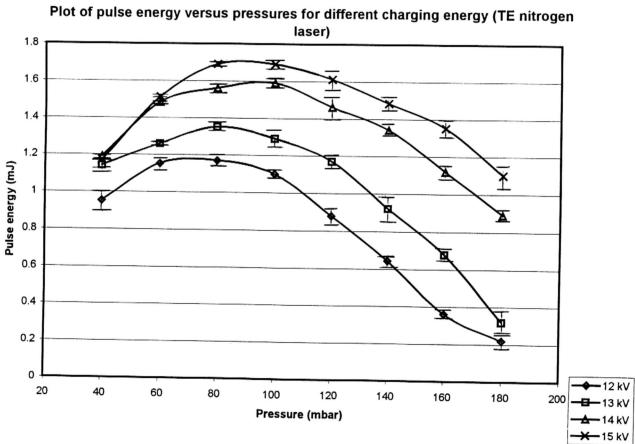


Figure 3.5 Laser output versus gas pressure for TE nitrogen laser at various charging voltages

3.5 Absorption and fluorescence measurements

A small fragment (approximately 0.5 g) of a selected slab was dissolved in chloroform (30 ml); this solution was further diluted to give a dye concentration of 10^{-6} M, a concentration for which the effect of dye aggregation is expected to be minimal. The spectra were measured against a control, which was prepared by dissolving calculated quantities of the dye and PMMA granules in chloroform.

An estimation of the errors resulting from instrumental fluctuations is given in table 3.2.

Table 3.2 Estimations of measurement errors

Dye	Estimated error
C460	$< \pm 3.5 \%$
R640 (ClO ₄)	$< \pm 3 \%$
R6G (Cl)	$< \pm 2 \%$
R6G (ClO ₄)	$< \pm 3 \%$
PM 546	$< \pm 6.5 \%$

Absorption spectra were recorded on a Shimadzu UV-VIS Spectrophotometer (model 3101 PC) in the fast scanning mode (1600 nm min^{-1}); a slit width of 3 nm was used for all measurements. The accuracy is ± 0.002 the range 0 - 0.5 absorbance, range and ± 0.004 in the 0.5 - 1.0 absorbance range.

Beer-Lambert's Law was assumed to hold for the concentration range used in the measurements. The wavelength ranges for the dyes are given in table 3.10.

Table 3.3 Wavelength ranges for laser dyes

C460	300 - 450 nm
R640 (ClO ₄)	300 - 700 and 320 - 670 nm
R6G (Cl)	320 - 620 nm
R6G (ClO ₄)	300 - 650 nm
PM 546	300 - 650 nm

Fluorescence spectra were recorded on a Luminescence Spectrometer (Model LS 50B). The excitation and emission slits were adjusted according to the dye that was used. The wavelength ranges are given in table 3.4.

Table 3.4 Scanning range used for laser dyes

C460	350 - 550 nm
R640 (ClO ₄)	520 - 660 and 520 - 640 nm
R6G (Cl)	480 - 640 nm
R6G (ClO ₄)	500 - 660 nm
PM 546	480 - 600 nm