S.P.39. – RAVISANKAR, M. Fabrication and Parametric Studies of a Triggered Nitrogen Laser and Investigations on the Influence of Dissolved Constituents of Sea water on the Optical Attenuation Using the Nitrogen Laser Pumped Dye Laser – 1989 – Dr. K. Sathianandan.

Optical attenuation study in sea water has assumed renewed interest because of its importance in the emerging areas of underwater applications such as optical communication, imaging, target finding and ranging. In recent years, many workers have carried out optical attenuation studies in clear water, "artificial" sea water and natural sea water by laboratory and in situ methods. A careful examination of the available information on sea water reveal that reliable data are not available. In addition, there are major disagreements among the results that are reported. The reasons for such discrepancies can be attributed to the differences in the composition of the sea water and to the experimental methods and procedures adopted by the various investigators. Therefore, to get reliable data, a systematic analysis of the effect of the dissolved constituents of sea water on optical attenuation has to be carried out using an experimental technique which takes care of all the possible errors. The present thesis contains the details of the work done by the author in this direction.

The material presented in the thesis can be broadly divided into two sections. The first section covers the fabrication details of a nitrogen laser which is used to pump a dye laser. The second section gives the optical attenuation studies of different solutions containing the constituents of sea water.

Chapter one is a general introduction to the nitrogen laser, nitrogen laser pumped dye laser and optical attenuation studies in sea water. A comprehensive review of the work on optical attenuation studies is presented here as a necessary introduction to the detailed investigations undertaken.

A continuously tunable dye laser has to be used for the determination of optical attenuation in the entire visible region. In order to get nanosecond pulses, which is required in the present experimental technique, the dye laser has to be pumped by a nitrogen laser. A pulsed nitrogen laser of about 500 kW and a repetition rate of 50 pps (maximum) is fabricated to suit the requirements. Design and fabrication details of this nitrogen laser are included in the second chapter of the thesis. Efficiency of the nitrogen laser has been improved by using a modified design of the spark gap and the trigger circuit. Trigger repetition rate can be selected as 10, 25 and 50 pps.

Parametric studies of the nitrogen laser were carried out and presented in the third chapter of the thesis. Pulse width, pulse energy and power were measured as a function of input voltage and nitrogen pressure. The optimum condition for

The second part of this chapter contains details of laser design and fabrication. The laser constitutes mainly of plasma tube, spark gap, high voltage capacitors, high voltage power supply, trigger circuit and gas flow system. To have high electrical-to-optical conversion efficiency and high pulse-to-pulse stability, it is necessary that the discharge be uniform in the plasma tube. For this, a cylindrical cathode and plane anode configuration is selected as suggested by some of the earlier workers. A free-running type spark gap and a triggered spark gap with trigger circuits are developed for the laser. These have low inductance and high current capability. A 20 KV switched mode power supply is used. Double side copper-clad fibre-glass epoxy laminates are used as high voltage capacitors. The gas supply into the plasma tube is designed so as to obtain uniform gas flow throughout the discharge region.

The second chapter gives the results of a thorough investigation carried out to optimise the laser characteristics. It includes a study on the variation of laser power with applied voltage and pressure in the plasma tube. This has been done for the laser with both free-running type spark gap and triggered spark gap. It is found that the laser with free-running type spark gap has higher efficiency. But stability in the repetition rate as well as in the pulse intensity is better for the triggered spark gap. The above studies could establish that the latter is more suitable for pumping a dye laser.

In the third chapter the design and fabrication details of a tunable dye oscillator pumped by the above nitrogen laser is given. The chapter begins with a discussion on different oscillator configurations with grating and prism as dispersing elements. The relative simplicity of grazing incidence grating configuration is established. The bandwidth of the tuned output for various angles of the grating are tabulated. Other performance details like pulsewidth, peak power, divergence, tuning range and efficiency are also given in detail.

A dye laser oscillator in narrow band operation is generally inefficient and has high amplified spontaneous emission (ASE) as background noise. If the oscillator is followed by an amplifier, high output power in narrow bandwidth can be generated with high conversion efficiency. Chapter four. describes how the overall performance of a dye laser is improved by adding a travelling wave amplifier to the oscillator described in the previous chapter. An analysis on travelling wave amplification is given at the beginning. Methods of decreasing ASE are described subsequently. Results on the measurements of optimum pump power distribution and optical delay between the oscillator and amplifier stages are given. The concentration range over which efficient extraction of laser energy takes place, is different for oscillator and amplifier. A study has been carried out to find out the same. Finally results are given to establish that, by using the amplifier, the power in the tuned wavelength is appreciably increased while divergence and ASE are decreased.

Dye laser efficiency and tuning range depend also upon the solvent and the concentration of the dye solution taken. The tuning range is directly related to the ASE bandwidth. It is, therefore, important to know the ASE bandwidth at different concentrations in different solvents. Chapter five contains such a study for the case of Rhodamine 6G in some frequently used solvents. It is observed that even within a small concentration range the bandwidth varied appreciably.

Chapter six presents the results of some studies on lasing characteristics of mixed dye systems. The peak laser wavelength as a function of the concentration of the donor and acceptor is measured. It is established that by using dye the maximum power was determined from these measurements. Also, the efficiency of the nitrogen laser was calculated. This nitrogen laser in the optimum condition was then used to pump the dye laser.

An electronic scan system was fabricated and was coupled to a grazing incidence dye laser. This was used to scan the wavelength of the dye laser output continuously and also in steps of 1, 2.5 and 5nm. It was possible to scan the wavelength of the dye laser from 430 nm to 630 nm with this set up. The circuit details and the working principle of the scan drive system are given in the fourth chapter of the thesis.

Querry et al. reported a split-pulse laser method to measure absolute attenuation coefficient of water. This method overcomes all the drawbacks of earlier methods. t was found to be very sensitive even to measure the low attenuation coefficients of distilled water. Hence, this method was adopted in the present investigations and attenuation coefficients as low as 10^{-4} cm^{-1} were measured with this set up. A detailed description of the experimental technique and the calculation of the attenuation coefficient are included in the fifth chapter of the thesis.

In order to determine the effect of dissolved constituents of sea water on the optical attenuation, a systematic study of optical attenuation was undertaken starting with distilled water. The study of optical attenuation in distilled water is required as a basic reference before attempting the solutions. It may also be pointed out that the existing results on distilled water reported by various authors show major discrepancies. Therefore, a detailed study was conducted in doubly distilled water. Seven distinct peaks were observed. The peaks are explained in terms of overtones and combinations of the O-H vibrational modes. The anharmonicity parameter for the O-H vibration is calculated. The absolute values of the attenuation coefficient and its relation with wavelength are determined accurately and are presented in the sixth chapter. Also, a comparison is given between the results of the present work with those of the earlier workers.

The salts of sea water can be broadly classified into major constituents, minor constituents and trace elements. The major constituents mainly determine the salinity of the sea water because the concentrations of the salts of the major constituents are about three orders above that of the minor constituents and about six orders above that of the trace elements. Therefore, a detailed study of the effect of the individual salts of the major constituents (NaCl, $MgCl_2$ and Na_2SO_4) was undertaken.

Attenuation coefficients were measured in solutions of NaCl, $MgCl_2 6H_2O$ and Na_2SO_4 for various concentrations. The concentrations were selected on the basis of the amount of individual salts found in natural sea water. Attenuation coefficients were measured in four concentrations of NaCl, three concentrations of $MgCl_2 6H_2O$ and two concentrations of Na_2SO_4. Absolute values and the relation of attenuation coefficient with wavelength are given. A comparison of the results of the above salts are also given.

"Artificial" sea water was prepared with a salinity of 35% with major constituents of sea water alone and the attenuation coefficients were measured. The result shows the influence of individual salts. In order to study the influence of the salts of the minor constituents of sea water, another artificial sea water was prepared with major and minor constituents with a salinity 35%. Attenuation coefficients were measured for this sample and the result indicates the influence of the minor salts. Absolute values of the attenuation coefficients and their relations with wavelength for all the solutions are given in chapter six. The results obtained from these experiments are also discussed. All the measurements were carried out in the wavelength range 430 nm to 630 nm in steps of 2.5 nm. Because of the narrow interval between the measurements as compared to the total wavelength range it was possible to obtain smooth curves for all the solutions studied here.

General conclusions are drawn based on the study and are presented in the last chapter. For all the solutions, there is a sharp increase in the value of attenuation coefficient above 580 nm. Attenuation coefficient is found to be influenced much by Na_2SO_4 and $MgCl_2$. But NaCl does not have much influence on the attenuation coefficient. Influence of the minor constituent of sea water is very small compared to that of Na_2SO_4 and $MgCl_2$. For all the solutions, the band at which the attenuation coefficient is minimum falls in the region 450-500 nm. General conclusions and suggestions for further studies on the optical attenuation in sea water are also given as a result of the present studies.