S.p.35. REGHUNATH, A.T–Studies on Optical Attenuation in Sea Water Using Dye Laser and Laser Propagation in a Turbulent Medium–1988–Dr. V.P.N. Nampoori.

With the advent of lasers, there has been a revived interest in the field of under water optical systems. Lasers, because of their low divergence, narrow bandwidth and high power are identical sources for under water optical communication, ranging and photography. In order to develop any under water optical system, the region of minimum attenuation of light in water must be identified. The search for an optical window demands an extensive study of the transmission characteristics of sea water for different wavelengths in the visible region. The sea water constituents are of two types; the dissolved salts which are mostly in ionic state and the suspended particules such as organic matter and dust. The dependence of optical attenuation on the concentration of these constituents is an essential scientific information to be gathered. the sea water being in random turbulent motion, the laser propagation in a turbulent medium is also a related area of importance. The variations in the temperature and salinity of sea water will give rise to variations in the refractive index of the medium. Even though the refractive index variation from the mean value is small, in a situation of practical interest, a propagating laser beam encounters a large number of inhomogeneties resulting in a significant cumulative effect. The central theme of the work presented in the thesis is a careful investigation of the factors influencing the attenuation of laser beams through sea water.

The thesis presents a detailed report of the work done by the author on the attenuation studies in sea water and some effects of turbulent medium on laser propagation. The thesis contains six chapters. The first chapter gives an introduction to the subject of laser propagation through sea water. A review of the earlier work on attenuation studies in water is included in this chapter. The theoretical background of the problem of laser propagation through a turbulent medium is summarized in the last part of this chapter.

Chapter II gives the fabrication details of a nitrogen laser pumped dye laser used for the attenuation studies in sea water. For the dye laser, a holographic grating is used in grazing incidence. The laser gives 3 ns pulses of 0.04 nm line-width. Using different dyes, the laser is tuned from 425 nm to 630 nm. The parametric studies of the dye laser which form an important part of the required instrumentation are also reported in this chapter.

The experimental set up for the attenuation measurements is described in chapter III. The split-pulse laser method is adopted using a nitrogen laser pumped dye laser as the source. The laser pulse is split into two by a beam splitter; one part of which goes through a 20 cm long reference cell and the other part goes through a 500 cm long sample cell. The pulses are reflected back by the mirrors kept at the end of these cells and are detected by a photodiode. The advantages of this technique over other high sensitive absorption measurement methods are described in this chapter.

In chapter IV, the results of attenuation studies in distilled water, 'synthetic' sea water and natural sea water are described. Several authors had reported the attenuation coefficients of distilled water. But these values are found to differ by a factor of 2 owing to the low value of attenuation coefficient coupled with several experimental corrections required to arrive at the final experimental result. Hence the optical attenuation in distilled water is re-investigated using the present set up.

Attenuation studies of sea water form a major part of this chapter. In order to determine the effect of dissolved constituents of sea water on attenuation, the measurements are conducted in 'synthetic' sea water prepard by dissolving the respective chemicals in the right proportion in doubly distilled water. Two samples of synthetic sea water are studied. The first sample contains only the major constituents and the second sample contains the major and minor constituents. The nature of attenuation curves are found to be similar to that of distilled water. It is concluded that the presence of minor constituents in the present concentration levels has negligible effect on optical attenuation. The details of sample preparation, experimental procedure and results are reported.

The results of the studies on two samples of natural sea water are reported in the last part of chapter IV. The two samples collected from the Arabian sea are – one from 3 Km. off the coast and the other from 30 Km. off the coast. These samples are filtered using whatman grade 1 filter paper to remove large scale suspended particles. The attenuation in natural sea water was found to be much higher than that for synthetic sea water. The chemical composition of both being almost same, the high value of attenuation coefficient of natural sea water is concluded to be due to the presence of suspended particles. The sample collected from 3 Km. off the coast showed very high attenuation indicating the increased effect of suspended particles.

Chapter V describes the details of the experiment on the laser propagation through a turbulent medium. Experiments are conducted in a laboratory simulated turbulent medium. The laser propagation characteristics through the simulated turbulent medium, are studied using a He-Ne laser. The fluctuations in the intensity of the propagated laser beam are detected and recorded in a data logger. The change in the variance of log-intensity with the propagation length shows a saturation behaviour, as reported for the case of atmospheric turbulence. The power spectrum of the irradiance fluctuations shows a-5/3 power law behaviour, in agreement with the Kolmogorov-Obukov model turbulence for the atmosphere. From the observations, it is concluded that the laboratory simulated turbulence, behaves similar to the atmospheric turbulence. The probability distribution function for the weak turbulence and the strong turbulence are suggested.

A new method of qualitative characterising the hydro-dynamic turbulence is proposed in this chapter. The time series obtained from the fluctuating intensity measurements is Fourier analysed to obtain the a_n and b_n coefficients. The points R_n obtained from these values are plotted in (a_n, b_n) space. Trajectories in the Fourier space show certain characteristics, depending on the strength of the turbulence. It is also found that the phase space trajectories will characterise the turbulence qualitatively.

Quantitative characterisation is also done by K entropy method. The values of K entropy gives a quantitative picture of the strength of turbulence averaged over the path.

Chapter VI gives the general conclusions drawn from the results reported in the earlier chapters. There is no well defined optical window for sea water. However, because of the high scattering loss in the blue region and high absorption in the red region, there is a broad minimum for the attenuation at around 500 nm. It is further concluded that the attenuation of sea water essentially depends on the amount of suspended particles present. The dissolved constituents have lesser effect on the attenuation. The behaviour of the fluctuations in the intensity of the propagated laser beam, due to the variation in the temperature of the water medium is similar to that in the case of the atmosphere. The major difference between the two cases is in the time scales in which the fluctuations occur.