INTRODUCTION

It has long been realised that propagation of an optical beam through a turbulent medium will result in redistribution of energy of the beam leading to fluctuations in the beam intensity which can only be interpreted in statistical terms. The study of the form of probability distribution functions of these irradiance fluctuations is still a subject of controversy\textsuperscript{1–3} and needs additional developments.

For the case of weak turbulence and relatively short propagation paths where the normalised variance of the irradiance $\sigma_i^2 << 1$, the method of smooth perturbations or Rytov theory\textsuperscript{4} has been highly successful, but it cannot be applied for the longer paths where experimental results show $\sigma_i^2$ saturating to a value of the order of unity rather than increasing monotonically\textsuperscript{2,5}. According to the Rytov approximation, the effect of turbulence is to perturb the propagating wave by a large number of independent, multiplicative events and a central limit theorem argument leads to a log-normal distribution. For the case of strong turbulence and large propagation paths the probability density function is expected to approach a negative exponential in the limit of infinite turbulence\textsuperscript{6,7}.

THEORETICAL BACKGROUND

We calculate higher order skewness and excess coefficients using central moments which are then compared with those of some known distributions like log-normal, Rice-Nakagami, and gamma\textsuperscript{8,9}. Higher order moments can give information concerning the contribution from the tails of the probability density functions. For practical purposes, moments up to eighth order are usually sufficient for the statistical characterization of the random process. Moments higher than eighth usually are difficult to extract and do not carry much statistical weight needed for characterization of the turbulence.

The $n^{th}$ order central moment $n(n = 2, 3, 4,...)$ of intensity ‘I’ can be written as:
\[ \mu_n = [I - <I>]^n \]

where \( < > \) is the ensemble average. The higher order non-dimensional coefficients are defined in terms of central moments as follows:

- \( \Gamma_3 \) (Skewness) = \( \frac{\mu_3}{\mu_2^{3/2}} \)
- \( \Gamma_4 \) (Excess) = \( \frac{\mu_4}{\mu_2^2} - 3 \)
- \( \Gamma_5 \) (Superskewness) = \( \frac{\mu_5}{\mu_3 \mu_2} - 10 \)
- \( \Gamma_6 \) (Supereexcess) = \( \frac{\mu_6}{\mu_3^3} - 15 \)
- \( \Gamma_7 \) (Hyperskewness) = \( \frac{\mu_7}{\mu_3 \mu_2^2} - 105 \)
- \( \Gamma_8 \) (Hyperexcess) = \( \frac{\mu_8}{\mu_3^2} - 105 \)

From the experimental measurements the coefficients \( \Gamma_3 \) to \( \Gamma_8 \) are calculated. Measured higher order coefficients are then compared with those of model distributions like log-normal, Rice-Nakagami, and gamma to identify the best fit distribution.

EXPERIMENTAL ARRANGEMENT

A block diagram of the experimental set-up is shown in Fig. 1. Experiments have been carried out in the laboratory generated turbulence as well as in the open atmosphere. Turbulence was simulated in the laboratory by using two electric heater bars rated at 0.5 KW capacity each to heat the air between two aluminum plates along the path of the laser beam. A cool stream of air was supplied from above. The warm layer of the air rising up mixes with the cool descending layer creating a temperature fluctuation and thereby a refractive index fluctuation in the medium. By using mirrors the laser beam traverses a multipass pathlength of 6 meters before being allowed to fall on the detection system. For the case of open atmosphere the range consisted of a folded path length of 400 meters at a height of 15 meters above the ground.

A 7mW Melles Griot He-Ne laser was used as a source of radiation. After suitable attenuation and expansion the collimated beam of 1.5 cm cross-section was allowed to pass through a turbulent region. The resultant beam was detected by a photomultiplier tube (PMT model RCA 31034A) with a narrow band interference filter with transmission peak at 632.8 nm to eliminate background radiation. The PMT was illuminated through a pinhole of 50 \( \mu \)m diameter. The output of the PMT after suitable amplification and pulse shaping was fed to a multichannel analyzer (MCA model 256D). Before using the MCA the output of the detection system is fed to a photon correlator\( ^{10} \) (a home made R6501 microprocessor system) which works on the principle of directly registering the arrival time of the photoelectron pulses to determine the sample time and the range of intensity correlation such that only independent events are used for our \( P(n,T) \) determinations. The data stored in various channels of the MCA is then used for constructing a frequency histogram from which higher order moments, cumulants and central moments up to eighth order are computed and analysed on a computer.

RESULTS AND DISCUSSION

The turbulence encountered here falls in the very weak turbulence region (as \( \sigma^2_n << 1 \) in our case). From the measured data we calculate higher order moments \( \Gamma_3 \) to \( \Gamma_8 \) and compare them with those for certain well known model distributions.