THERMALLY INDUCED OPTICAL PHASE CONJUGATION BY DEGENERATE FOUR-WAVE MIXING

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ABSTRACT

Thermally induced optical phase conjugation by degenerate four-wave mixing (OPC-DFWM) offers considerable scope for high power adaptive optics applications. A detailed study of the optical phase conjugation in solutions of Rhodamine 6G and Rhodamine B in acetone, ethanol, methanol and water has been made with second harmonic 532 nm radiation of Nd : YAG under near zero time delay conditions. Reflectivity up to 50% has been obtained and as expected from theory, Rh6G and RhB both show a much larger reflectivity in acetone than in the other solvents due to the Q factor and higher thermalization yield in acetone. The dependence of reflectivity on the angle of interaction and the pump and probe beam intensities are also reported. The autotracing and "healing" property of OPC are demonstrated with photographs of the original, distorted and corrected beams.

INTRODUCTION

Optical phase conjugation (OPC) has been obtained by the use of several nonlinear optical effects, to exactly reverse both the direction of propagation and the overall phase factor of a coherent beam of light. This wavefront or phase reversal of an electromagnetic wave is equivalent to performing an operation of complex conjugation of the complex spatial amplitude. This phenomenon has been observed with all states of matter utilizing various nonlinear optical effects viz. stimulated Brillouin scattering[1], three-wave mixing[2–4], four-wave mixing[5–8], photon echoes[9,10], surface effects[11,12], non-local field effects[13], etc. An extensive overview of various techniques mentioned above and their applications can be found in Fisher[14], Zeldovich *et al*[15] and Pepper[16].

Initially Caro and Gower[17] and later Gower[18] attempted to give a theoretical model for thermally-induced degenerate four-wave mixing (DFWM) in absorbing media. Even though they could satisfactorily take account of many parameters governing the phase conjugate reflectivity (PCR), the influence of important parameters relating to different time-scales involved in grating formation and decay was not clearly elucidated. Hoffman[19], on the other hand, gave a more detailed theoretical model based on coupled hydrodynamic equations which include the time-scale parameters unexplained hitherto.

The generation of phase conjugate signals, by the technique of formation of thermal gratings in absorbing media especially of dye solutions, has been shown to have several advantages. Thermal gratings are generated in a variety of media where absorption of light causes transitions in the molecules of the media. Subsequent local heating or thermalization by radiationless relaxation of the optically excited molecules gives rise to periodic temperature (or entropy) fluctuations in some cases and density fluctuations in others. These result in a spatial modulation of the refractive index of the solvent which then acts as a phase grating in the scattering of incident light. Generally the scattering by temperature or entropy fluctuations is termed as stimulated thermal Rayleigh scattering and scattering of light by density fluctuations is termed as stimulated thermal Brillouin scattering[20,21].

The use of dye solutions as nonlinear media for quantum electronics was originally based on the effect of saturation of their absorptivity in powerful radiation fields. Most of the experiments on OPC-DFWM in dyes show that pure thermal effects play a major role in the recording of the interference pattern, particularly if the absorbed energy relaxes into heat immediately. The spatially inhomogeneous heat release leads to inhomogeneous changes in permittivity. The nature of such disturbances largely depends on the relationship between pulse duration and the characteristic time scales of different physical processes in the medium.

Theory

The first theoretical model for stimulated scattering of light was given by Batra *et al*[21]. Hoffman[19] based her investigations on this approach and