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A Comparison between Christiansen Effect and Electromagnetically Induced Transparency

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Abstract: In the present work we make a comparison between Christiansen effect and Electromagnetically induced transparency (EIT). These two phenomena are analogous.

I. INTRODUCTION

When an optically isotropic solid like glass is powdered and put inside a flat sided cell which is then filled with a liquid and the refractive index is adjusted suitably by varying its composition or altering its temperature chromatic effects are observed when the refractive index of the liquid is brought into coincidence with that of the powder for some chosen wavelength of the spectrum. The becomes transparent for the particular wavelength while rest of the incident light passing through the cell is diffracted out in various directions and appears as a halo corresponding to the light source. This is known as the Christiansen effect first observed by Christiansen in 1884 [1]. Christiansen effect can also be observed under different experimental conditions. As for example when two liquids of nearly equal refractive index and in general immiscible are kept in a glass tube containing glass spherules of suitable size, transparent diffusion patterns are observed at the boundary separating the two liquids and the glass spherules at the diffusion region become invisible. As time evolves the length of the diffusion band increases and the region of the diffusion band increases and the region of transparency also increases and eventually the entire tube becomes transparent. The glass spherules are not visible from outside. In this case we may appropriately term the phenomenon as Diffusion Induced Transparency (DIT). Chromatic effects are also observed in this case like Christiansen effect. Diffusion Induced Transparency has been observed by Mahanta *et al.* [2,3]. It was Raman and coworkers [4,] who gave a comprehensive explanation to Christiansen effect through a series of papers published in early fifties. In the present work we shall concern ourselves with the following questions. How much analogous are the phenomena observed in Christiansen effect and the phenomena of Electromagnetically induced Transparency (EIT) and Self Induced Transparency [5, 6]. In electromagnetically induced transparency one can make opaque resonant transitions transparent to laser radiation, often with most fo the atoms remaining in the ground state. This is not exactly what is observed in Christiansen effect but the phenomena are analogous. The root of the analogy is the fact that both Christiansen effect and Electromagnetically induced transparency are to a conceptual idealization, are phenomena in which under appropriate conditions, the medium becomes effectively transparent (zero absorption) for a probe field.

II. ELECTROMAGNETICALLY INDUCED TRANSPARENCY (EIT):

The EIT was originally observed by Harris and Coworkers [5]. In this case quantum interference is introduced by driving the upper two levels of a three level atomic configuration with a strong coherent field. Under appropriate conditions, the medium becomes effectively transparent for a probe field. Electromagnetically induced transparency is a technique for eliminating the effect of a medium on a propagating beam of electromagnetic radiation.

EIT may be used to eliminate optical self focusing and defocusing and to improve the transmission of laser beams through inhomogeneous gases and metal vapours. The technique may also be used to create large populations of coherently driven uniformly phased atoms, thereby making possible new types of optoelectronic devices.

To attain transparency or, at least to improve transmission one applies two laser wavelengths whose frequencies differ by a Raman transition of a medium. Fig. 1 shows few example to which the concepts of EIT apply. Fig. 1 a depicts a three-level system. Most of the experiments are done using three state lead-vapour of this type. Fig. 1b shows a system in which transmission or transparency is to be created at an energy that is above the ionization potential of an atom. Fig. 1c illustrates a case in which instead of overcoming absorption the objective is to reduce the refractive index to as close to unity as possible. In these ways the effect of the medium on the propagating beams is eliminated and in that case the medium becomes transparent to the outside world.

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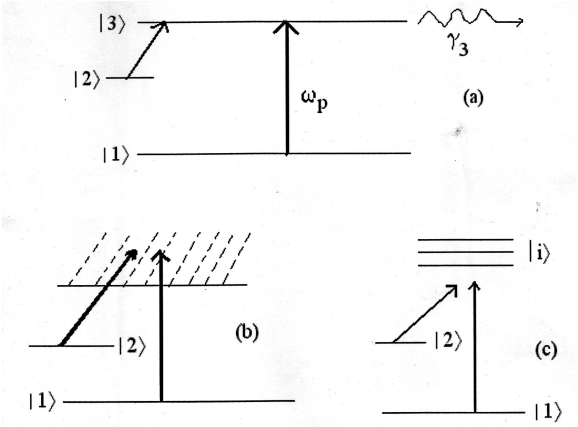

Fig. 1. Few schemes for Electromagnetically Induced Transparency. (a) A three level system in which the upper state decays with a rate γ_3 to states outside the system (b) Transparency in the medium (c) Transparency is created by modifying the refractive index.

If one asks for a classical explanation of how one may eliminate the effect of medium on a propagating beam, the answer is that the electrons must be stopped from moving at the frequencies of the applied field. If the electrons do not move, they will not contribute to the di-electric constants. Non movement will occur if, at each applied frequency, the electron is driven by two sinusoidal forces of opposite phases.

The impetus for the work on EIT was the realization that the emission and absorption line shapes of an atom need not be the same. In late 1988 Kocharovskaya and Khanin [7] and also Harris [4] suggested techniques for making three level laser without the need for a population inversion. Suggestion by Scully [6]followed rapidly and used a considerable effort aimed at developing a new laser what is known as laser without inversion.

III. THE COMPARISON

From what has been discussed in the earlier sections it appears appropriate that we make a comparison between EIT and DIT taking few salient features.

For convenience Table 1 shows the comparison between the salient features.

Table 1. Comparison between Christiansen effect and Electromagnetically Induced Transparency

EIT	Christiansen effect
Originally observed by Harris *et al.* in 1990	Observed by Christiansen in 1884
It cannot be explained classically	It is explained classically
The phenomenon can be observed at any range of wavelengths	The phenomenon can be observed at any range of wavelength
Transparency is created by manipulating the refractive index of the medium close to unity (only in one scheme)	In general, transparency is created by manipulating index of refraction
Quantum interference is involved	Quantum interference is not involved
Coherent superposition of a ground state doublet can cancel absorption for an incident beam	Superposition of molecules (diffusion) of two species causes destruction of absorption for an incident beam
There are application in the field like laser without inversion and other domains of quantum oplies	Application can be found in the field of precise optical filters

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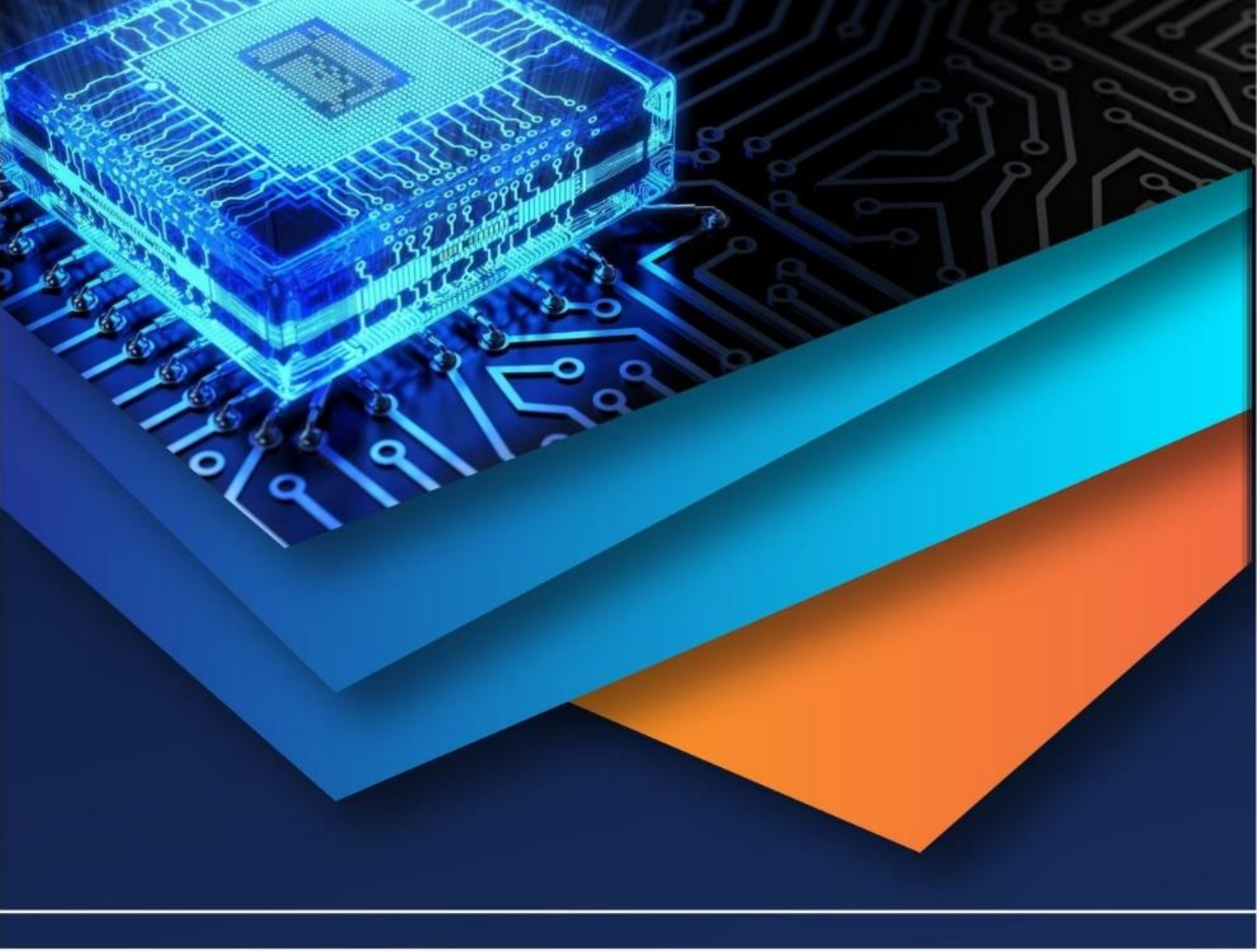

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