RESEARCH PAPER | Physics | Volume : 5 | Issue : 1 | Jan 2015 | ISSN - 2249-555X

Dirac's Statement & Photon in terms of Lasing withoutm Inversion

KEYWORDS: Quantum optics, Photon, Lasing without Inversion, Quantum Interference.

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ABSTRACT *According to Dirac "a single photon does interfere with itself, two photons never interfere". This statement was made many decades ago in his famous book named "Quantum Mechanics" and this created a lot of confusion. In the present work we analyze Dirac's Statement in terms of lasing without inversion. It is believe that this work will help in making a proper definition of photon in quantum optics.*

1. Introduction

Quantum optics is the union of quantum field theory and physical optics. One can also say that it is the union between laser physics and quantum mechanics. It is worthwhile to note here that Hanbury-Brown and Twiss experiments [1-6] signals the origin of a new subject which is known as the quantum optics. We emphasize here that the intensity correlation stellar interferometer was a driving force in ushering in the modern era of quantum optics. It is a wonderful tribute to Michelson that the same interferometer concept is central to the gravity wave detectors which promise to provide new insights into general relativity and astrophysics in the twenty first century. The subject of Quantum optics has evolved from early studies on the coherence properties of radiation like, for example, quantum statistical theories of the laser in the sixties to modern areas of study involving, for example, the role of squeezed states of the radiation field and atomic coherence in quenching quantum noise in interferometry and optical amplifiers. On the one hand the counter intuitive concepts such as lasing without inversion and single atom (micro) masers and lasers are now laboratory realities. Many of these devices hold promise for new devices whose sensitivity goes well beyond the standard quantum limits. On the other hand, quantum optics provides a powerful new probe for addressing fundamental issues of quantum mechanics such as complementarity, hidden variables and other aspects central to the foundations of quantum physics and philosophy. In the present work we attempt to correlate the famous statement of Dirac that 'a single photon interferes with itself, two photons never interfere' with the counter intuitive concepts of quantum optics, that is, the lasing without inversion (LWI) which is also known as quantum interference laser.

2. Lasing without inversion and Quantum interference laser

What is lasing without inversion? We indicate here that a coherent superposition of a ground state doublet can cancel absorption. It is generally the case that a laser requires population inversion in order to overcome absorption, from the lower level. But what if we can arrange things (i.e. Phase atoms) such that the absorption is cancelled? Can we than have lasing without inversion? The answer is 'Yes'. One can present analysis of such problems in which lasing without inversion can be achieved using a coherently prepared three level atoms. Before analyzing the concepts of LWI let us first revisit the double slit experiment of Young. According to Feynman [7] the essentials of quantum mechanics could be grasped from an exploration of the double slit experiment. Let us consider the double slit experiment of Young. In this experiment a beam of light is aimed at a barrier with two vertical slits. The light passes through the slits and the resulting pattern is recorded on a photographic film. If one slit is covered the pattern is what is expected; a single line aligned with whichever slit is open. One would expect that if both slits are open, the pattern of light will reflect the fact that; there are two lines of light aligned with the slits. In fact, however, what happens is that the photographic plate is entirely separated into multiple lines of alternate light and bright intensities. This is of course well known as interference taking place between the waves or particles going through the slits, in what, seemingly should be two non-crossing trajectories. We should expect that if the beam of photons is slowed down enough to ensure that, individual photons are hitting the photographic plate, there could be no interference and the pattern of light would be two lines of light aligned with the slits. In fact, however, the resulting pattern still indicates interference, which means that, somehow, the single particles are interferes with themselves. This seems impossible, we expect that a single photon will go through one slit or the other and will end up in one of the two possible light line areas. But this is not what is happening. According to Feynman [7] each photon not only goes through both slits simultaneously, but traverses every possible trajectory on the way to the target, not just in theory, but in fact. In order to see how this might possibly occur, experiments have focused on tracking the paths of individual photons. What happens in this case is that the measurement in some way disrupts the photon trajectories (in accordance with uncertainty principle) and somehow the results of the experiment become what would be predicted by classical physics; two bright lines on photographic plate, aligned with the slits in the barrier. If we cease the attempt to measure, however, the pattern will become multiple lines in varying degrees of lightness and brightness. From what has been described above it is apparent that uncertainty principle is involved in explaining the phenomenon of interference.

It is now worthwhile to analyze the concept of lasing without inversion in the light of the double slit experiment. To present the basic physics of LWI it is best to consider the

Volume : 5 | Issue : 1 | Jan 2015 | ISSN - 2249-555X

theory of this effect in a three level Λ configuration and to demonstrate how this concept of LWI can be realized. The configuration of Λ type three levels atoms is presented in Fig 1.

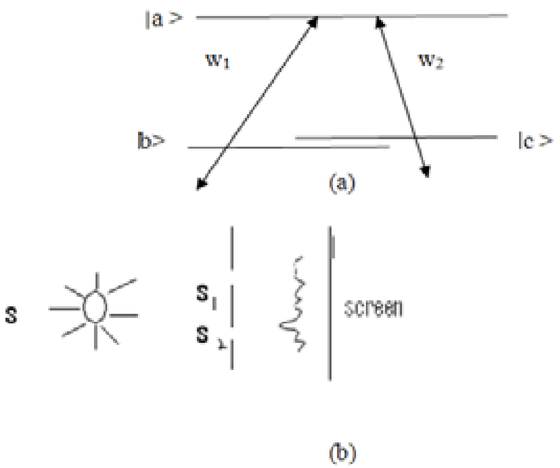

Figure 1: (a) Three level atom in a Λ configuration interacting with frequencies W_1 and W_2.
(b)Young's double slit experiment.

The three level Λ scheme is formed by upper levels la> and lc> through interaction with electromagnetic fields E1 and E2 respectively in such a way that only the atomic transitions la> → lc> and la> to lb> are allowed. The physical reason for cancellation of absorption in this system is the uncertainty in atomic transitions l c> → l a> and lb> →la> which results in destructive interference. The levels lc> and lb> are extremely close. The situation is similar to Young's double slit experiment, where the interference is a consequence of uncertainty in determining through which of two slits the photon passed. Fig 1 (b) shows Young's double slit experiment for comparison with three level Λ schemes.

3. Results and Discussion

As may be inferred from Fig-1, the energy levels lb> and lc> corresponds with the slits S1 and S2 of Young's double slit experiment. The phenomenon of lasing without inversion is the manifestation of the double slit interference or quantum interference. Dirac's statement definitely indicates the phenomenon occurring in the double slit experiment or three level scheme of LWI. This is one way to test the validity of the principle of superposition of quantum mechanics.

REFERENCE
1. H. Hanbury – Brown and R.Q. Twiss phil. Mag 45, 663 (1954); Nature 178, 1046 (1956) Proc. Roy. Soc. A242, 300 (1957) | 2. A. Forrester, R. Gudmundsen and P. Johnson Phys. Re. 99, 1691 (1955). | 3. E. M. Purcell, Nature 178, 1449 (1956). | 4. U. Fano, Am. J. Phys. 29, 539 (1961) | 5. G.Baym, Lectures on Quantum Mechanics (Benjamin Pub, New York 1969). | 6. R. Hanbury – Brown, The intensity. Interferometers (Taylor and Frances, London 1974. | 7. R.P. Feynman, R.B. Leighton and M. Sands, The Feynman Lectures on Physics, Addison – Wesley Publishing company, Reading Mass Vol. 1, (1965). |