AN INTERFERENCE EXPERIMENT TO VERIFY THE CORRECTNESS OF THE NON-DUALISTIC INTERPRETATION OF QUANTUM MECHANICS

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Abstract: According to `the wave-particle non-dualistic interpretation of quantum mechanics at a single-quantum level' (NI), the Schrödinger wave function is proposed/shown to be an *instantaneous resonant spatial mode* in which a quantum moves. To verify this key proposal, a modified Mach-Zehnder interferometer experiment with a single-particle source is proposed. A negative result of this experiment simply implies that the NI is wrong.

INTRODUCTION

There are various interpretations of quantum formalism, like, the mainstream Copenhagen interpretation [1,2], de Broglie-Bohm theory [3], `many-worlds' interpretation [4], spontaneous collapse theories [5], modal interpretation [6], relational interpretations [7], consistent histories [8], transactional interpretation [9], QBism [10], etc. Though, each one of them is interesting by itself, but, all of them, in one way or the other, accept the Born's rule as it is, but, do not provide any derivation as a limiting case of the `relative frequency of detection' using the single-quantum events, as it was done by the "wave-particle non-dualistic interpretation of quantum mechanics at a single-quantum level" (NI) [11-17]. The NI naturally unites both the classical entities, i.e., the wave and particle, into a single entity which is named as non-duality. Moreover, the NI unambiguously explains not only the Young's double-slit experiment [11-13], but also Wheeler's delayed-choice experiment [11-13], delayed-choice quantum erasure experiment [11], Einstein's spooky action-at-a-distance [11,14], delayed-choice entanglement swapping experiments both in space and time [11,14] etc., and also resolves the well-known quantum paradoxes, like, Schrödinger's Cat, Wigner's Friend and Frauchiger-Renner's paradoxes [15] without assuming any deviations or modifications for the existing quantum formalism. Therefore, the NI can also be called as the "quantum formalism as it is – interpretation". All these were done by providing, for the first time, the physical meaning for Schrödinger's wave function as an *instantaneous resonant spatial mode* (IRSM). In the present article, an experiment using a modified Mach-Zehnder interferometer (mMZI) with a single-photon source is suggested to verify the correctness of the IRSM and hence, the NI.

THE EXPERIMENTAL ARRANGEMENT

According to the NI, the actual space around us is a complex vector space (CVS) as demanded by the quantum formalism and the eigen values associated with the position state vectors `effectively' form the 3D Euclidean space. The moment a quantum appears (ex:- emission of an electron from a metal surface), the state vector or equivalently, the Schrödinger wave function, i.e., IRSM, also appears instantaneously everywhere in the entire space. The quantum moves in its IRSM akin to the case of a test particle moving in the curved space-time of the general theory of relativity. Though the IRSM can appear instantaneously everywhere, the moving quantum is subjected to the Cosmic speed limit (in the relativistic case). The following mMZI experimental set up as shown in Fig. 1 can be used to verify this instantaneous nature of the Schrödinger wave function.

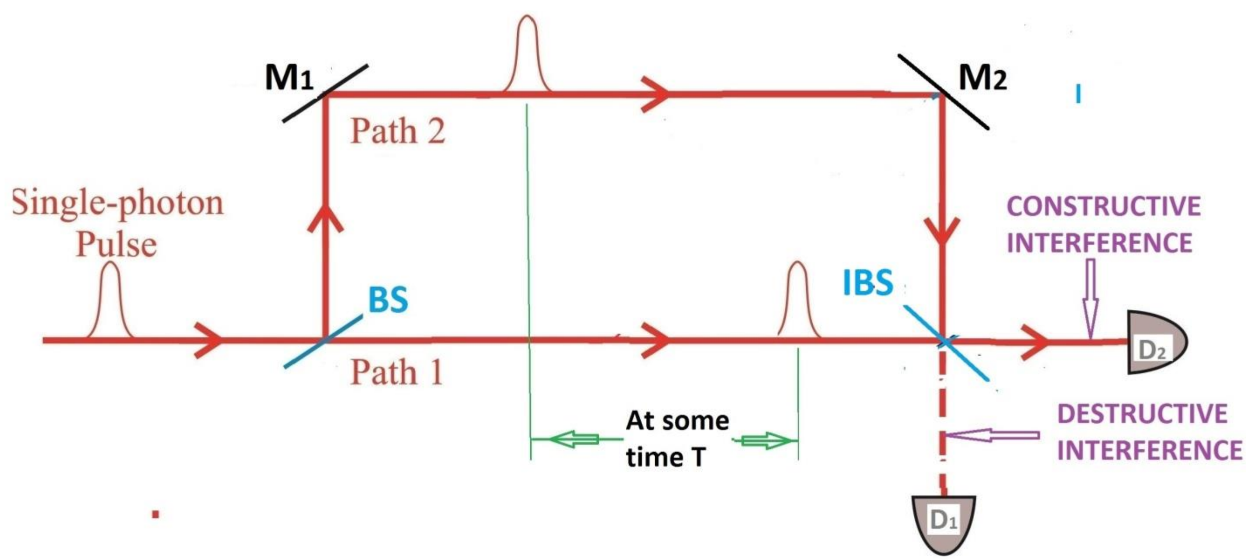

Fig 1. BS and IBS are 50:50 beam splitter and inverse beam splitter, respectively. M_1 and M_2 are 100% reflecting mirrors and D_1 and D_2 are single-photon detectors. A single-photon pulse, entering BS gets partially refracted and partially reflected along Path 1 and Path 2, respectively. At the moment when the refracted pulse reaches IBS, the reflected one, along the Path 2, lags behind by a path difference = Path 2 – Path 1, which is chosen to yield the destructive and constructive interferences towards the detectors D_1 and D_2, respectively. Also, the pulse width should be much smaller than the path difference. (If a ripple-packet produced for a brief time by dropping a single small stone on the surface of water is considered in the places of the refracted and reflected pulses, then their wave-fronts will never be recombined at IBS.)

BS is a 50:50 beam splitter which refracts and reflects the amplitude of a single-photon's state vector entering the mMZI along the Path 1 and Path 2, respectively, and they are recombined by the inverse beam splitter IBS. The path difference = Path 2 - Path1 = δ is to be chosen such that the recombined amplitudes interfere destructively and constructively towards the photon detectors D_1 and D_2, respectively.

Considering a situation where a large number of single-photons are fired into mMZI such that the time interval between any two consecutively fired photons is chosen to be sufficiently greater than the time of flight of a photon along the Path 2 to either D_1 or D_2. This guarantees that there will be no chance for any two photons to be simultaneously present anywhere inside the experimental set up.

If a continuous stream of photons is entering the mMZI, then no photon will be detected by D_1 while all are found at D_2, due to the already chosen δ. However, the next photon is not allowed to enter the mMZI before the detection of the current one. Hence, if the Schrödinger wave function associated with the photon is really propagating like a classical wave, then the refracted and reflected partial pulses will never be recombined by the IBS, because, they approach it at different times and the interference condition becomes invalid i.e., the reflected pulse along Path 2 lags behind the refracted one along Path 1 (see Fig. 1) and hence the IBS can't recombine them. Therefore, each one of D_1 and D_2 will detect 50% of the total number of photons, respectively.

Prediction by the NI: Suppose that the physical meaning of Schrödinger's wave function is an IRSM in accordance with the NI, then the interference condition is satisfied and D_2 will register 100% of all the photons entered into mMZI. This is because, the moment a photon appears, its IRSM gets refracted and reflected by the BS and recombined at the IBS, forming destructive and constructive interferences towards D_1 and D_2, respectively - all at once. Depending on the absolute phase associated with the IRSM, the photon moving in it will enter into either the Path 1 or Path 2 [11-17] and always emerges out of IBS towards D_2. Instead of photons, if the same experiment is done using slow-moving single-electrons, particularly single-atoms or single-molecules, then not only the results will be better obtained but also the instantaneous nature of the Schrödinger wave function, i.e., the IRSM, becomes very clear.

Also, according to the NI, when a quantum is flying in its IRSM, the position eigen values associated with the state vector, where the quantum is present, will always fall on a classical trajectory and hence, the time parameter entering the quantum formalism is same as the classical one [12,13]. This guarantees that the quantum mechanics is essentially a classical mechanics, but in the CVS. Therefore, if the difference between the time of flight of the photon along Path 2 (T_2) and Path 1 (T_1) is sufficiently larger and also very greater than all possible experimental errors involved in determining the initial time of production and final time of detection of the photon, then half of the total number of photons detected by D_2 will have arrival time T_2 and the remaining half will have T_1. Therefore, in this particular experiment, `which path information' can be easily obtained by merely measuring T_1 and T_2; this kind of path information is also available in the case of Afshar's experiment, but with respect to which one of the two detectors detected the photon [18].

CONCLUSIONS

In the present article, I proposed an experiment using a modified Mach-Zehnder interferometer with a single-photon source to verify the most important aspect of the `wave-particle non-dualistic interpretation of quantum mechanics at a single-quantum level', i.e., the physical meaning of the Schrödinger wave function is that it's an *instantaneous resonant spatial mode*, in which, a quantum flies akin to the case of a test particle moving in the curved space-time of the general theory of relativity. A negative result of this experiment simply implies the fact that the non-dualistic interpretation is wrong.

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