Correct exposition of complementarity in Unruh's and Afshar's experiments

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Abstract

We discuss the multiple pass interferometer setup proposed by Unruh, and clarify some of the fundamental issues linked with complementarity. We explicitly state all mathematical instructions for manipulating the quantum amplitudes and assessing the probability distribution functions. In this respect we show that certain purely math logical limitations (requirement for consistency) prevent one to argue that there is one-to-one corespondence between paths 1 and 2 and the exit gates 10 and 9 ("which way" interpretation), and at the same time insist on pure state density matrix, i. e. existent nonmeasured interference in the second building block of Unruh's interferometer. Furthermore one cannot even argue that Unruh's setup is described by mixed density matrix that keeps the one-to-one correspondence between the paths 1 and 2 and the exit gates. This last claim is mathematically consistent, however is experimentally disprovable - because one may potentially distinguish mixed quantum state from pure quantum state. One just lets the two beams captured at the exit gates cross each other. If interference can be observed the two exit gates were coherent and provide beams in pure state (superposition), while if interference cannot be observed, the state of the exit gates was mixed one. Since the captured beams at the exit gates in Unruh's experiment could interfere this implies that the whole setup is characterized with pure state density matrix and does not preserve the one-to-one correspondence between the entry points and exit gates, even in case where the destructive interference in arm 5 of the interferometer is not measured. Therefore the correct (experimentally plausible and mathematically consistent) exposition of complementarity introduced by Georgiev in 2004 is that Unruh's setup is characterized by pure state density matrix and does not keep the suggested by Unruh one-to-one correspondence. As an appendix is shown the equivalence between Unruh's setup and Afshar's setup and correct analysis of Afshar's experiment is also provided.

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