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On classical interpretation of quantum interference
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Introduction

The Feynman's quantum mechanics formulation prescripts to calculate the *probability* of a transition *from* an initial state to another (final) state by summing the *probability amplitudes* over all the possible "paths" through different intermediate states. In contrast to (real-valued) probability per se an *amplitude of probability* is complex-valued, i.e. is specified by modulus and phase. A phase presence leads to the appearance of some interference that is normal in classical wave processes but cannot be clearly interpreted for quantum particles.

In the work **[Rave, 2008]** the new point of view is proposed. Firstly, it provides to consider a full set of possible transitions – not only direct ones (from initial state to final state), but reversal ones (from final state to initial state) too. More precisely, we should consider the full set of all the ring routes – *closed* loops including initial and final states. Secondly, for each such loop the product Γ of complex amplitudes of transition between a pair of states is defined. This quantity Γ for any closed loop does not depend on choice of an initial state phase, so it presents the phase invariant loop feature like Berry's phase. As result one can sum these Γ's over all such possible closed loops and get the same total transition probability as in Feynman's approach.

The cited work's author uses that the quantity $\boldsymbol{\Gamma}$ presents the complex-valued analogy of the probability (not probability amplitude) and concludes that his point of view lets interpret the quantum interference "classically", i. e. sum namely the "probabilities" themselves. However, one should now sum over closed transition loops. As the author says, *if we accept such loops, then quantum interference can be classically interpreted, and the "mystery" of quantum probabilities is replaced with the "mystery" of how time can loop back on itself.*

I'm agree to the author approach. However, in my opinion, two points have to be discussed. Firstly, in the cited paper the *real-valued* probability is replaced by *complex-valued* quantity Γ. This leads the explicit difference between the *forward* and *backward* in time transitions. Secondly, we should discuss the actual meaning of the time closed loops.

Meaning and reasons to use complex quantities in quantum mechanics

Let us remember that W. Heisenberg at 1925 had firstly represented a quantum particle position and velocity as an infinite serie of complex-valued harmonics. At the same time, he limited its modulus and multiplication rules (which become similar to the matrix multiplication rules), so all the following was deduced from these conditions. Because of that the complex-valued functions appeared in QM, however, as it turned out, its physical meaning was not clear. M. Born at 1926 proposed the statistical interpretation of wave function, that allowed calculate the quantum processes probability distributions.

The actual meaning and reasons of complex-valued quantities usage in quantum mechanics I considered in **[Shulman, 2004]** and **[Shulman, 2008]**. I assume that all the quantum objects really participate in two motions types. The first one (a "slow" motion) is described by the standard equations of classical dynamics. The second motion type corresponds to a very “fast” forced oscillation that phase has not be monitored by a modern observer. This general fact produces such “quantum” phenomena as non-commutativity of observables and necessity of usage complex-valued quantities.

The complex quantities are successfully applied in the alternative currents linear circuit theory. In this theory a current and tension vector is considered as “rotating” in the *positive* or *negative* direction. No time paradoxes appear here because we have the purely *phase* effects for *stationary* processes. At the same time the essential real-valued parameters calculation (for example – active power consuming at the branch) is explored by multiplication of current by the quantity that is *complex conjugated* with the tension (or vice versa). It is due to the fact that when one integrates the instantaneous power over the period, then the time disappears from a result. Just the same reason in quantum mechanics leads that an averaged over time value is calculated as $\psi^*\psi$ (where ψ is the wave function).

As it shown in **[Beniaminov, 2007]**, a motion in the compete *classical mechanics* configuration space (coordinates plus momentum), presented by a sum of the “slow” motion and the “fast” oscillation one, comes to the reduced motion due a specific diffusion process. The fast motion reduces an arbitrary wave function to a function from a subspace whose elements are parameterized by complex-valued functions of coordinates *only*. The slow motion occurs in this subspace and is described by the Schrödinger equation. By the way, this leads a new possible interpretation of the Heisenberg uncertainty principle.

Closed in time loops as statistical effect

So, the usage of “negative” time should have formal (purely phase-like) interpretation only as well in the quantum mechanics as in the circuit theory. What a meaning do the closed loops have about which the paper **[Rave, 2008]** says?

I thing, such loops can be considered as *ideal* objects only. In fact, there is no any looping in time. However, there are always many *realizations* of similar states that are included in such loops, and corresponding number of transitions (to the both sides) between these states. By this way, we have a situation that seems to be similar to the ideal group of loops *statistically* only.

On Feynman’s advanced potentials

I would like to add that the closed in time interaction loops were considered firstly by Weeller and Feynman in 1945 **[Weeler, Feynman, 1945]**. In this work the *advanced* potentials were used to calculate a radiation friction value. Further, in 1949 the authors investigated the possible paradoxes in time **[Weeler, Feynman, 1949]**.

In the paper **[Shulman, 2007]** I tried to show that these authors practically examinated the stationary wave processes only, because of that it is enough to consider the only formal – purely phase-like – effect, where a current part of the *retarded* wave is supposed on a in-phase part of the *before reflected* (from an absorber) wave.

It seems that in the both cases we get the same “paradox”: the purely phase-like effect is considered as really existing evolution “backward in time”.

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