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Born's rule as signature of a superclassical current algebra

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HIGHLIGHTS

- Calculating the interference patterns and particle trajectories of a double-, three- and N-slit system.
- Deriving a new formulation of the guiding equation equivalent to the de Broglie–Bohm one.
- Proving the absence of third order interferences and thus explaining Born's rule.
- Explaining the violation of Sorkin's order sum rules.
- Classical simulation of Talbot patterns and exact reproduction of Talbot distance for N slits.

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ABSTRACT

We present a new tool for calculating the interference patterns and particle trajectories of a double-, three- and N-slit system on the basis of an emergent sub-quantum theory developed by our group throughout the last years. The quantum itself is considered as an emergent system representing an off-equilibrium steady state oscillation maintained by a constant throughput of energy provided by a classical zero-point energy field. We introduce the concept of a "relational causality" which allows for evaluating structural interdependences of different systems levels, i.e. in our case of the relations between partial and total probability density currents, respectively. Combined with the application of 21st century classical physics like, e.g., modern nonequilibrium thermodynamics, we thus arrive at a "superclassical" theory. Within this framework, the proposed current algebra directly leads to a new formulation of the guiding equation which is equivalent to the original one of the de Broglie–Bohm theory. By proving the absence of third order in-

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terferences in three-path systems it is shown that Born's rule is a natural consequence of our theory. Considering the series of one-, double-, or, generally, of N-slit systems, with the first appearance of an interference term in the double slit case, we can explain the violation of Sorkin's first order sum rule, just as the validity of all higher order sum rules. Moreover, the Talbot patterns and Talbot distance for an arbitrary N-slit device can be reproduced exactly by our model without any quantum physics tool.

1. Introduction

In 1926, Born [1] suggested that $|\psi(\mathbf{x}, t)|^2$ is the probability to find the particle in the time interval $[t, t + \mathrm{d}t]$, and in the length interval $[x, x + \mathrm{d}x]$. For different mutually excluding paths of particles between source and detector one has to sum up the ψ functions of these paths coherently and then take the absolute square of the linearly summed contributions. As a direct consequence of this construction, a term appears describing the interference pattern in the double slit diffraction experiment. Born's rule is one of the key laws in quantum mechanics and it proposes that interference occurs in pairs of possibilities, but never in triples etc. So-called multipath interference terms representing interferences of higher order are ruled out, be it in standard quantum mechanics or in the de Broglie–Bohm theory, for example. Consequently, an addition of slits or paths does *not* increase the complexity of the whole system, but has to be considered only quantitatively.

Although one can conclude that Born's rule is, at least indirectly, confirmed by practically all quantum mechanical experiments within the last hundred years, there had been no *explicit* experiment to support this proposition until a few years ago. The experimental results hitherto seem to confirm the exact validity of Born's rule up to the order of 10^{-4} [2–4]. However, these experiments were commented critically by De Raedt et al. [5]. The decomposition of a three-path wave function into its lower order interference terms might not correctly represent the experimental setup. So, it is still an open question whether or not the mathematically correct derived double slit contributions to the three-slit result can be identified with the sum of the experimentally derived double and single slit contributions.

From the theoretical point of view no generally accepted derivation of Born's rule has been given to date [6], but this does not imply that such a derivation is impossible in principle.

In the following we try to shed light on this puzzle by combining results of recently developed "Emergent Quantum Mechanics" [7] with concepts of systems theory which we denote as "relational causality" [8]. Since the physics of different scales is concerned, like, e.g., sub-quantum and classical macro physics, we denote our sub-quantum theory as "superclassical". We consider the quantum itself as an emergent system understood as off-equilibrium steady state oscillation maintained by a constant throughput of energy provided by the ("classical") zero-point energy field. Starting with this concept, our group was able to assess phenomena of standard quantum mechanics like Gaussian dispersion of wave packets, superposition, double slit interference, Planck's energy relation, or the Schrödinger equation, respectively, as the emergent property of an underlying sub-structure of the vacuum combined with diffusion processes reflecting the stochastic parts of the zero-point field.

In Section 2 we contrast the well-known physics behind the double slit with an emergent vector field representation of the observed interference field. In Section 3 the essential parts of our superclassical current algebra are presented and the velocity field (corresponding to the guiding equation of the de Broglie–Bohm theory) is derived. The crucial case testing the validity of Born's rule by means of a three-slit configuration is analyzed in Section 4, whereas the general N-slit setup is discussed in Section 5. In Section 6 we summarize our results and give an outlook on a possible breakdown of orthodox quantum mechanics representing the emergent mean field theory out of our sub-quantum dynamics, consequently associated with the violation of Born's rule.