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Title:	Quantum measurements: Studies of weak measurements describing the past of quantum particles, no-go theorem, and quantum key distributions
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Keywords:	quantum particles quantum key distributions Wave-particle
Issue Date:	Dec-2023
Publisher:	IISER Mohali
Abstract:	This thesis focuses on both fundamental and applied aspects of quantum measure- ments, specifically their role in describing the past of quantum particles, the two-state vector formalism, wave-particle complementarity and quantum key distributions. We investigate the predictions of the two-state vector formalism and weak values, which are recognized as elements of reality in weak measurements. The combination of weak values and the two-state vector formalism is utilized to operationally define the past of quantum particles. The latter results in inception of various quantum paradoxes known as weak value paradoxes. Through a thought experiment, we demonstrate that weak values cannot consistently describe the past of quantum particles. To address this, we develop novel techniques for describing the past of photons in an interferometer. Our findings reveal that photons provide information about the past that is absent in weak measurement scenarios. These predictions can be experimentally validated. Furthermore, we explore the role of generalized weak values in quantum informa- tion processing tasks. Our research demonstrates that the use of weak values can lead to erroneous conclusions, particularly in quantum state discrimination and quantum key distribution. Moreover, our results shed light on various shortcomings associated with weak values and the weak measurement approach. Subsequently, we develop a quantum key distribution protocol that employs block- wise processing and post-selections. This protocol exhibits high noise tolerance against collective attacks in asymptotic limits. Building upon the existing six-state protocol, we divide the raw keys obtained into blocks of finite length. By performing specific post-selections on these blocks, we generate new raw keys. The unconditional security of this protocol is proven using information-theoretic proofs. In addition, we establish a no-go theorem that states the impossibility of manip- ulating or measuring the internal degrees of freedom of a quantum particle without disturbing its spatial wavefunction. This theorem is derived based on the principle of no-faster-than-light communication. We then apply this no-go result to a quan- tum Darwinian scenario to explain the emergence of objectivity in the position basis. Furthermore, we consider a decoherence model involving randomized spin-spin inter- actions between a system in spatial superposition and a spin environment with spins in arbitrary random states. By formulating the interaction Hamiltonian in accordance with our no-go theorem, we demonstrate that it leads to the emergence of classical objectivity in the position basis. Finally, we propose an experiment to demonstrate wave-particle complementar- ity using von Neumann interaction between a Gaussian pointer and a pre- and post-selected qubit. Our research reveals that the complementarity between two observables of a qubit can be operationally translated into a wave-particle complementarity rela- tion. Additionally, we establish that for every pre- and post-selected qubit, there exists an operationally equivalent Mach-Zehnder interferometer. These results can be easily extended to higher-dimensional discrete-level systems.
URI:	http://hdl.handle.net/123456789/5884
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