3rd URSI AT-AP-RASC, Gran Canaria, 29 May – 3 June 2022

Emulation of quantum states with classical mixtures for quantum measurements certification

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Here we discuss a possibility to emulate results of quantum measurements by representing quantum states as mixtures of classical states with positive and negative weights. This allows us to successfully reproduce well-known quantum effects using resources that can be much more feasibly generated in the laboratory than the genuine non-classical states. Our work is especially relevant for longer wavelengths when both generating quantum states and measuring quantum effects are generally challenging tasks.

Our methodology offers a simple and economical way to represent with high fidelity few-photon few-mode non-classical states with a modest number of classical states. For example, we show how to emulate few-photon Fock states or NOON states with coherent state mixtures or mixtures of thermal states. We also show that our method allows to representation of certain classes of single and multi-mode quantum states with large number of photons, for example, coherently shifted Fock states. We also discuss limitations of the emulation technique connected with enhanced statistical errors stemming from presenting quantum states with classical mixtures.

We demonstrate that our method can be a practically useful tool for certification of measurement set-ups created for registering quantum effects. We show how the results of fundamental quantum measurements can be reproduced with our emulation technique. As examples, we consider the Hong-Ou-Mandel experiment, Bell testing and witnessing of non-classicality.

We also show how our methodology can be extended to longer wavelength ranges, for example, the microwave range with the state generators and measurement set-ups feasible for these wavelengths.