Experimental testing of three-qubit nonlocality

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We are used to the fact that all bipartite pure entangled quantum states violate a Bell inequality. This means that measurement results on this quantum system manifest nonlocal correlations. So far the relationship between entanglement and nonlocality is still a subject of an intense study. Recently a new measure of nonlocality was proposed [1]. It is defined as the probability, that the pure state will display nonlocal correlation when subjected to random measurements. When scanning over all possible projection measurements, we can define a nonlocal volume, which corresponds to the subspace in which the projection measurements prove nonlocality of the imput state.

We decided to test these relations for three-qubit states, generalized Greenberger–Horne–Zeilinger states [2]:

$$|gGHZ\rangle = \cos(\theta)|000\rangle + \sin(\theta)|111\rangle, \qquad \theta \in \langle 0, \pi/4\rangle.$$

It was recently shown that the nonlocal volume has very convenient properties. For example, for pure states this measure is monotonic with entanglement described by the angle θ. The more the state is entangled, the larger is the probability to violate Bell inequalities selecting random measurements. For this purpose we first had to build an efficient experimental setup, that is capable to generate $|gGHZ\rangle$ states and to carry out the optimal measurements very fast. Secondly, we have experimentally verified numerical simulations of optimal measurements proposed to detect the greatest violation of several Bell-type inequalities for three-partite states [3, 4]. Finally, we have started detailed experimental mapping of the projection measurement space to get the nonlocal volume of the tested states.

We hope that this both theoretical end experimental research can help to get better insight into the abstract quantities characterizing quantum states and also to the mutual relationship between them [5, 6].

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