Loophole-free Bell Inequality Violation with Superconducting Circuits

Anatoly Kulikov[1]
Simon Storz[1], Josua Schär[1], Paul Magnard[1], Philipp Kurpiers[1], Janis Lütolf[1], Theo Walter[1], Adrian Copetudo[1], Kevin Reuer[1], Abdulkadir Akin[1], Jean-Claude Besse[1], Mihai Gabureac[1], Graham J. Norris[1], Andres Rosario[1], Ferran Martin[2], José Martinez[2], Waldimar Amaya[2], Morgan W. Mitchell[3,4], Carlos Abellan[2], Jean-Daniel Bancal[5], Nicolas Sangouard[5], Baptiste Royer[6,7], Alexandre Blais[7,8], Andreas Wallraff[1,9]

[1]ETH Zurich, Switzerland; [2]Quside Tec., Spain; [3,4]ICFO, ICREA, Spain; [5]Université Paris-Saclay, CEA, CNRS, France; [6]Yale University, USA; [7]Université de Sherbrooke, Canada; [8]CIFAR, Canada; [9]QC-ETHZ, Switzerland

akulikov@phys.ethz.ch

Superposition, entanglement and non-locality constitute fundamental features of quantum physics. Remarkably, the fact that quantum physics does not follow the principle of local causality can be experimentally demonstrated in Bell tests performed on pairs of spatially-separated, entangled quantum systems. While Bell tests, which are widely regarded as a litmus test of quantum physics, were explored using a broad range of quantum systems over the past 50 years, only relatively recently experiments free of so-called loopholes succeeded. Such experiments were performed with spins in nitrogen-vacancy centers, with optical photons and neutral atoms. In this talk, I present a loophole-free violation of Bell's inequality with superconducting circuits[1], which are a prime contender for realizing quantum computing technology. To evaluate a CHSH-type Bell inequality, we deterministically entangle a pair of qubits[2] and perform fast and high-fidelity measurements along randomly chosen bases on the qubits connected through a cryogenic link[3] spanning a distance of 30 meters[4]. Evaluating more than one million experimental trials, we find an average *S*-value of 2.0747±0.0033, violating Bell's inequality with a p-value smaller than $p = 10^{-108}$.

Our work demonstrates that non-locality is a viable new resource in quantum information technology realized with superconducting circuits with potential applications in quantum communication, quantum computing and fundamental physics.

Figures

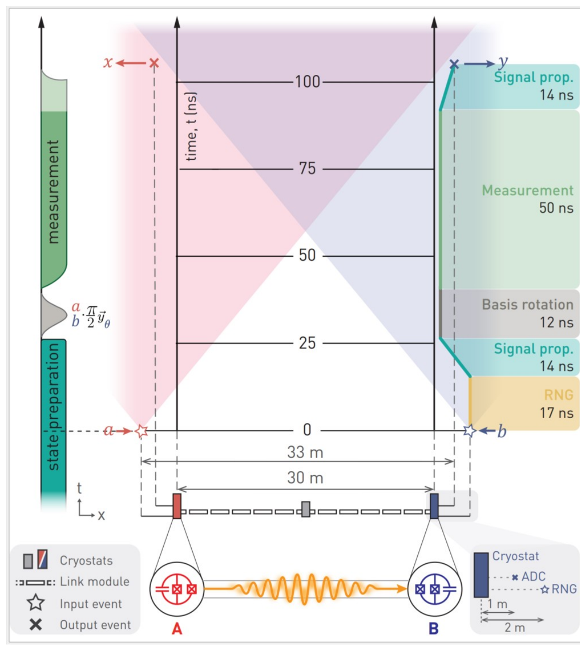

Figure 1: Space-time diagram of the setup. The vertical axis marks time and indicates the duration of the individual Bell test protocol segments (right) and applied MW pulses (left). The horizontal axis marks the spatial locations of the nodes (A and B) and relevant room-temperature devices (bottom right inset). The space-time locations of the start and stop events of a Bell test trial are marked with stars and crosses, respectively.

References

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