Quantum Position Verification in Spacetime

Gautam A. Kavuri,[1, 2] Yanbao Zhang,[3] Abigail R. Gookin,[4, 2] Soumyadip Patra,[5] Joshua C. Bienfang,[6] Honghao Fu,[7] Yusuf Alnawakhtha,[8] Dileep V. Reddy,[1, 2] Michael D. Mazurek,[1, 2] Carlos Abellán,[9] Waldimar Amaya,[9] Morgan W. Mitchell,[10, 11] Carl A. Miller,[12, 8] Richard P. Mirin,[13] Martin J. Stevens,[13] Scott Glancy,[14, 1] Emanuel Knill,[14, 1, 15] and Lynden K. Shalm[1, 13, 16]

[1]Department of Physics, University of Colorado, Boulder, CO, 80309, USA, [2]Associate of the National Institute of Standards and Technology, Boulder, CO, 80305, USA, [3]Quantum Information Science Section, Computational Sciences and Engineering Division, Oak Ridge National Laboratory, Oak Ridge, TN, 37831, USA, [4]Department of Electrical, Computer, and Energy Engineering, University of Colorado, Boulder, CO, 80309, USA, [5]Department of Mathematics, University of New Orleans, New Orleans, LA, 70148, USA, [6]Joint Quantum Institute, National Institute of Standards and Technology and University of Maryland, 100 Bureau Drive, Gaithersburg, MD, 20899, USA., [7]Concordia Institute for Information Systems Engineering, Concordia University, Montreal, QC, H3G 1M8, Canada, [8]Joint Center for Quantum Information and Computer Science, University of Maryland, College Park, MD, 20742, USA, [9]Quside Technologies S.L., Castelldefels (Barcelona), Spain, [10]ICFO-Institut de Ciencies Fotoniques, The Barcelona Institute of Science and Technology, 08860 Castelldefels (Barcelona), Spain., [11]ICREA - Instituci´o Catalana de Recerca i Estudis Avan¸cats, 08010, Barcelona, Spain, [12]Physical Measurement Laboratory, National Institute of Standards and Technology, Boulder, CO, 80305, USA, [13]Computer Security Division, National Institute of Standards and Technology, Gaithersburg, MD, 20899, USA, [14]Applied and Computational Mathematics Division, National Institute of Standards and Technology Boulder, CO, 80305, USA, [15]Center for Theory of Quantum Matter, University of Colorado, Boulder, CO, 80305, USA [16]Quantum Engineering Initiative, Department of Electrical, Computer, and Energy Engineering, University of Colorado, Boulder, CO, 80309, USA

Accurately localizing a party to a target spacetime region is a cornerstone of modern security protocols, and further plays a crucial role in commercial, automotive, and cryptographic industries. Classical protocols achieve this with ranging techniques, where trusted "verifiers" send signals to and from an untrusted "prover" to determine the maximum roundtrip travel time between them. From there, the "verifiers" establish a bounded spacetime region from which the "prover" is communicating. This classical protocol, however, can always be spoofed in the presence of colluding adversaries. Quantum position verification (QPV) protocols harden this technique with the no-cloning property of qubits, but current proposals are infeasible with existing hardware. Here, we provide our results from the first experimental implementation of QPV by developing a new protocol based on a loophole-free photonic Bell test. In our demonstration, two Verifiers are separated 200 meters apart with a Prover located centrally between them. A pair of polarization-entangled photons are produced, where one half of the pair is sent to the Prover. The Verifiers then require the Prover to run a protocol with the photon that an honest prover can pass with high probability, but adversaries outside a target region have a low probability of passing. The protocol is fully device-independent, so it is immune to side-channel attacks and does not rely on assumptions about the devices involved. With this protocol, we demonstrate a 78% improvement in the three-dimensional localization performance of our quantum protocol compared to the most accurate theoretical region achievable with classical ranging techniques [1].

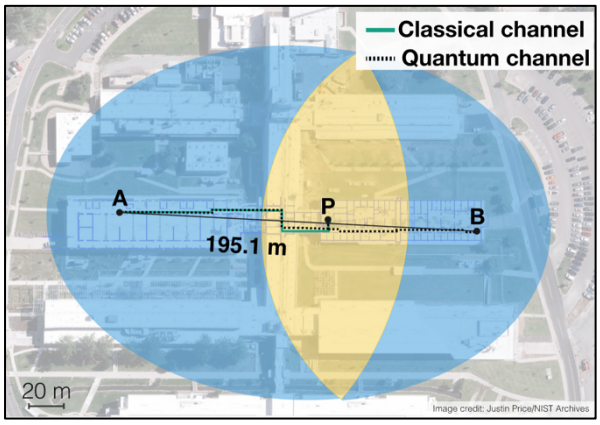

Figure 1: 2D localization regions for classical protocols (blue) and our QPV demonstration (yellow).

References

[1] Kavuri, G. A., et al, e-print arXiv:2601.16892 (2026).