Towards Large-Scale Entanglement-Based Quantum Networks

Ronald Hanson⁽¹⁾

⁽¹⁾ QuTech and Kavli Institute of Nanoscience, Delft University of Technology, The Netherlands, r.hanson@tudelft.nl

Abstract We report on our latest progress towards large-scale quantum networks, including exploring protocols on a multi-node entanglement-based quantum network in the lab, extending the distance between quantum network nodes using deployed fibre and work on qubits systems compatible with large-scale photonic integration. ©2023 The Author(s)

Introduction

Future quantum networks [1] may harness the unique features of entanglement in a range of applications, exciting such as quantum computation and simulation. secure communication, enhanced metrology for astronomy and time-keeping as well as fundamental investigations. To fulfill these promises, a strong worldwide effort is ongoing to gain precise control over the full quantum dynamics of multi-particle nodes and to wire them up using quantum-photonic channels.

Entanglement-based quantum network in the lab

Here, we report recent progress towards quantum large-scale entanglement-based networks. First, we discuss recent work on the recently realized three-node entanglementbased quantum network based on diamond NV centers in the lab. On this novel network, we have demonstrated several quantum network protocols without post-selection: the distribution of genuine multipartite entangled states across the three nodes, entanglement swapping through an intermediary node [2], and qubit teleportation between non-neighbouring nodes [3]. This work establishes a platform for exploring, testing, and developina multi-node quantum network protocols and a quantum network control stack.

Increasing the distance between small quantum processors

Second, we will discuss future challenges and prospects for quantum networks, in particular on increasing the distance between the nodes to metropolitan scales. We will report on the most recent progress on connecting small quantum processors via tens of kilometers of deployed optical fiber. One critical element for achieving long-distance connectivity is quantum frequency conversion of the photons at the wavelength native to the qubits to a wavelength in a telecom band [4].

Vision towards large-scale integration

Finally, we will touch upon the role of nextgeneration integrated devices, with an eye on potential large-scale photonic integration. Our most recent results on controlling novel qubits compatible with such integration will be discussed.

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