On-chip distribution of quantum information using traveling phonons

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Distributing quantum entanglement on a chip is a crucial step towards realizing scalable quantum processors. Using traveling phonons as a medium to transmit quantum states is currently gaining significant attention, due to their small size and low propagation speed compared to other carriers, such as electrons or photons. Moreover, phonons are highly promising candidates to connect heterogeneous quantum systems on a chip, such as microwave and optical photons for long-distance transmission of quantum states via optical fibers. Here, we experimentally demonstrate the feasibility of distributing quantum information using phonons, by realizing quantum entanglement between two traveling phonons and creating a time-bin encoded traveling phononic qubit. The mechanical quantum state is generated in an optomechanical cavity and then launched into a phononic waveguide in which it propagates for around two hundred micrometers. We further show how the phononic, together with a photonic qubit, can be used to violate a Bell-type inequality [1].

References

[1] Zivari, A., Fiaschi, N., Burgwal, R., Verhagen, E., Stockill, R. and Gröblacher, S., Science Advances, 2022, 8(46), p.eadd2811.

Figures

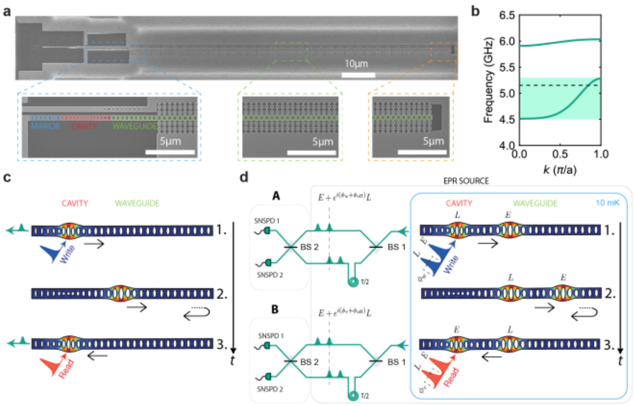

Figure 1: a) SEM of the device, showing different parts. B) band structure of the phononic waveguide. C) Sketch of various stages of the protocol for writing and retrieving a mechanical excitation from the structure. D) Simplified schematics of the time-bin entangling protocol, where we highlight the three main steps. 1. The creation of the entangled state between the photonic excitation (Stokes scattered photons) and the traveling phononic excitation in the waveguide. 2. The propagation of the mechanical qubit in the waveguide, with the reflection at the end. 3. The mapping of the phononic state onto a photonic state in order to verify the entanglement. The boxes conceptually divide Einstein–Podolsky–Rosen (EPR) source, and parts A and B, which are used to create and detect the entangled state.