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Mach-Zehnder interferometer with quantum beamsplitters

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Coherent control of single-photon emission, absorption and transport opens promising perspectives for quantum communication and information processing: photons can act as flying quantum bits between distant atomic nodes in a quantum network. A key element of these single-photon networks is the quantum beamsplitter (QBS). The QBS is the most elementary version of a beamsplitter, consisting of a single two-level system coupled to a one-dimensional continuum of electromagnetic modes (as in a one-dimensional waveguide, for instance). The QBS may not only refract and reflect, but also absorb and then reemit a single photon. This raises the question of whether a single-photon pulse, once split by a first QBS, could be made to interfere with a second one.

Here, we propose and theoretically analyze a quantum Mach–Zehnder interferometer (QMZ) as formed by two concatenated QBSs. The distinctive feature of our QMZ is its considerable saturability for a single photon, arising from the broadband nature of the pulse. We show that, depending on the photon pulse shape and detunings with the two QBSs, the interference pattern can either reproduce classical features or reveal rich non-classical behavior, providing a versatile platform for applications in quantum technologies.

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