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Generation of vortex beam superpositions using angular gratings

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Vortex beams form a class of beams carrying orbital angular momentum (OAM). A single photon carries $l\hbar$ OAM where l represents the OAM state and a beam with non-zero OAM state has a zero intensity at its centre and a helical phase wavefront.

Vortex beams have gained interest for their applications in optical manipulation, optical communication and quantum information [1-3]. In particular, they can enhance communication security by improving the quantum key distribution (QKD) procedure [4]. The original proposal uses the photon polarization degree of freedom, resulting in each photon carrying a single bit. Since OAM states are unbounded and mutually orthogonal, using instead the OAM degree of freedom as a basis enables far greater channel capacity. As QKD requires superpositions of states, this improved version of QKD requires superpositions of different OAM values.

There are many ways to generate vortex beams with bulk optics, such as spiral phase plates, spatial light modulators, q-plates and cylindrical lens mode converters [5-8]. However, an integrated photonic approach has advantages over bulk optics because of its scalability, stability and small size. It turns out that ring resonators with lateral grating elements, called angular gratings, radiates a vortex above the structure when on resonance [9,10]. To generate a superposition of vortex beams, we expand this idea to a single ring with two sets of gratings, one on the inside wall and one on the outside. We then show with simulations that, after post-selecting on one of the circular polarizations, we can generate OAM superposition states based on the number of grating elements for each grating.

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