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Observation of local entanglement oscillation in free space

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It is well known that the entanglement of a quantum state is invariant under local unitary transfor- mations. It dictates, for example, that the degree of entanglement of a photon pair in a Bell state remains maximally entangled during propagation in free-space. Here we outline a scenario where this paradigm does not hold. Using local Bell states engineered from classical vector vortex beams with non-separable degrees of freedom, so-called classically entangled states, we demonstrate that the en- tanglement evolves during propagation, oscillating between maximally entangled (purely vector) and product states (purely scalar). We outline the theory behind these novel propagation dynamics and confirm the results experimentally. Crucially, our approach allows delivering a tunable degree of local entanglement to a distant receiver by simply altering a modal phase delay holographically, or, in essence, a tractor beam for entanglement. This demonstration highlights a hitherto unnoticed property of classi- cal entanglement and offers at the same time a device for on-demand delivery of vector states to targets, e.g., for dynamic laser materials processing as well as switchable resolution within STED systems.

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