Phase-space non-separability and optical beam shifts

A classically non-separable state of light involves entanglement of, at least, two degrees of freedom of a light field. For instance, one can have a superposition of two orthogonal polarizations and two orbital angular momentum (OAM) states of light, such that the optical field. This is the essence of classical entanglement which is **local** because we speak of non-separability (entanglement) of different degrees of freedom of **the same optical field**. Employing classically entangled optical fields makes it possible to simulate many quantum communications/imaging protocols with classical fields so long as no **quantum non-locality** is required. We have recently discovered a hitherto unrecognized manifestation of classical entanglement in phase space whereby the momentum (magnitude and direction) of a photon depends on its location within a wave packet of light which we dub **phase-space non-separability** [OL, **46** 5958 (2021)]. We have discovered that phase-space non-separability of incident wave packets profoundly affects optical shifts of the packets upon their reflection form an interface separating optical media of different refractive indices (Fig.1). Specifically, the phase-space separability can cause giant optical shifts [PRL, **135**, 193801 (2025)], or cancel the shifts altogether [PRA **114**, L011501 (2026)].

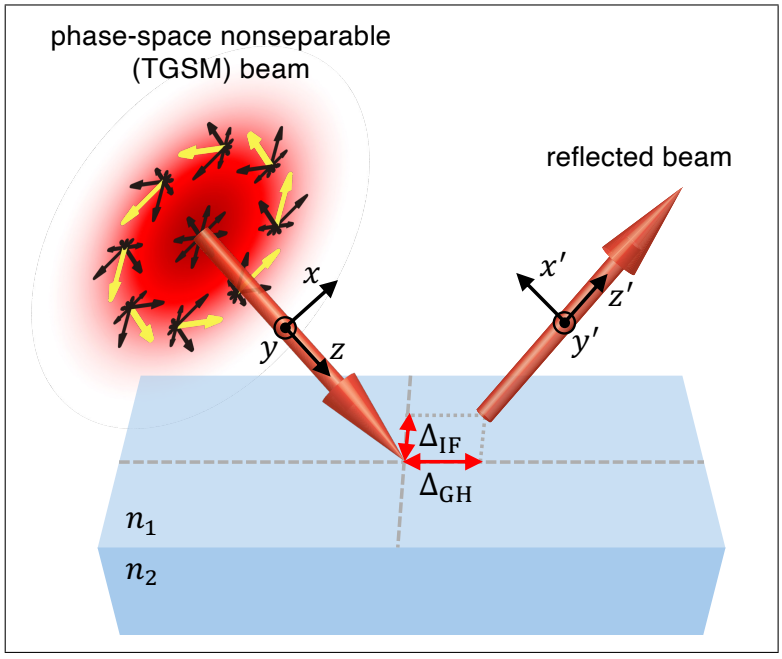


FIG. 1. Illustrating optical shifts upon reflection of phase-space nonseparable wave packets of light.