

# Probing gravitational waves with the orbital angular momentum of light

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We introduce an alternative approach to gravitational-wave (GW) detection in which GW information is encoded in the orbital angular momentum (OAM) states of photons. Starting from the propagation of vortex light in linearized gravity, we show that interaction with a GW induces transitions from an initial photon OAM state to neighboring OAM sidebands, providing a different optical observable of spacetime perturbations. Building on this interaction, we develop a GW detection framework in which the complex amplitudes of the induced OAM sidebands are measured using parametrized quantum state tomography. A V-shaped configuration provides sufficient independent degrees of freedom to resolve all seven wave parameters characterizing a GW. We further investigate the detectability of this approach by constructing a noise budget over the frequency range from 1 mHz to 100 Hz. The symmetry properties of the OAM states allow the GW signal to appear predominantly in the differential mode, while technical noise enters primarily through the common mode, enabling its suppression through balanced detection. Our analysis further shows that a compact, short-arm configuration can reduce mode-crosstalk noise without sacrificing the GW response. Together, these results establish a framework for probing GWs through the spatial-mode Hilbert space of light and motivate OAM-based sensing as a complementary approach to future GW detection.

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