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Self-assisted complete maximally hyperentangled state analysis via the cross-Kerr nonlinearity

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We present two complete maximally hyperentangled state analysis protocols for photons entangled in the polarization and spatial-mode degrees of freedom. The first protocol is a hyperentangled Bell state analysis scheme for two photons, and the second is a hyperentangled Greenberger-Horne-Zeilinger (GHZ) state analysis scheme for three photons. In each scheme, a set of mutually orthogonal hyperentangled basis states are completely and deterministically discriminated with the aid of cross-Kerr nonlinearities and linear optics. We also generalize the schemes to unambiguously analyze the N-photon hyperentangled GHZ state. Compared with previous protocols, our schemes greatly simplify the discrimination process and reduce the requirements on nonlinearities by using the measured spatial-mode state to assist in the analysis of the polarization state. These advantages make our schemes useful for practical applications in long-distance high-capacity quantum communication.

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