Hyperbolic Quantum Processor

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Achieving strong, coherent interactions between spatially separated qubits remains a central challenge in quantum science, fundamentally limited by the mismatch between emitter size and photon wavelength, which suppresses long-range coupling.

Here we show that this limitation can be overcome in hyperbolic materials, where optical polariton modes provide a qualitatively new interaction channel. In this regime, interactions are mediated by strongly confined electromagnetic modes supported by the anisotropic dispersion, enabling strong and highly directional coupling between distant qubits.

As a result, coherent interactions can be sustained over distances far exceeding the free-space wavelength, with dynamics governed by optical timescales. Such interactions enable high-fidelity quantum gate operations in platforms supporting low-loss hyperbolic polaritons, including van der Waals materials such as hexagonal boron nitride.

These results establish hyperbolic media as a platform for long-range quantum interactions, with applications to quantum information processing, nonlinear quantum optics, and many-body quantum systems.