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Simulating a superposition of spacetimes with optical media

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Superpositions of spacetimes have received considerable attention from the Relativistic Quantum Information community. The standard RQI protocol involves calculating the response of an Unruh-DeWitt detector that is coupled to a quantum field whose background spacetime exists in a quantum superposition of geometries. In this work, we propose a method to simulate such a superposition of spacetimes using optical media. The approach builds on the established analogy between the electromagnetic field in an arbitrary spacetime and the electromagnetic field in an equivalent optical medium. Since permittivity determines the speed of light propagation in an optical medium, controlling it allows us to mimic different spacetime geometries. By analyzing an optical cavity under quantum control—where its permittivity depends on the state of a quantum system—we analyze in-principle measurable quantities in a scenario describing a superposition of effective metrics. We draw analogies between our setup and the standard RQI protocol, and outline how such an approach could be used to simulate quantum superpositions of spacetimes in a laboratory setting.

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