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Entanglement from Longitudinal and Scalar Photons JAMES FRANSON, University of Maryland at Baltimore County — The covariant quantization of the electromagnetic field in the Lorentz gauge gives rise to longitudinal and scalar photons in addition to the usual transverse photons [1]. This is necessary because the vector and scalar potentials form the components of a four-vector. Quantizing only the transverse components of the field would give different results in different reference frames and is not invariant under Lorentz transformations. Here we calculate the entanglement of two atoms or harmonic oscillators due to the exchange of longitudinal and scalar photons. The form of the entangled state is found to be very different from that obtained using only transverse photons in the Coulomb gauge. Nevertheless, a generalized gauge transformation is used to show that the results are physically equivalent. A covariant treatment of photons is necessary for a fundamental understanding of quantum optics and it may have practical implications for quantum communications between satellites and ground stations, for example.

[1] For example, see C. Cohen-Tannoudji, J. Dupont-Roc, and G. Grynberg, Photons and Atoms (Wiley, New York, 1989.)

James Franson
University of Maryland at Baltimore County

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