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Correlation measurements of the ground state of light

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In analogy to the ground state of the quantum harmonic oscillator, the quantum ground state of light contains non-zero energy, the vacuum energy. On average, the ground state photon number is zero, but the existence of fluctuations in the electromagnetic field can be interpreted as the creation and destruction of virtual photons. Mathematically, the average field expectation value of the ground state vanishes while its variance is non-zero, corresponding to the field fluctuations. Direct measurements of the vacuum field by absorption are impossible because the energy extraction from the ground state is unphysical. However, the manifestation of the vacuum field in the Casimir effect, spontaneous emission, or the Lamb shift allows for indirect measurements of the vacuum state.

In this work, we present an approach using electro-optic sampling, which enables the direct measurement of the electric field fluctuations caused by the vacuum field. Electro-optic sampling (EOS) is based on the interaction of electric fields in the THz to the mid-infrared regime with a near-infrared probe signal in a non-linear crystal. The non-linear interaction of a probe pulse with the vacuum field in the crystal results in a detectable polarization change of the former. Consequently, the altered polarization offers information about the electric vacuum field amplitude. By performing this measurement using not only one but two separate probe beams having a certain time delay, the technique allows for the investigation of the temporal correlation function of the vacuum electric field. Additional spatial displacement of the probe beams enables us to access the spatial correlation function. Tuning both the temporal and spatial displacements allows for the characterization of the vacuum field at different space-time points, promoting the understanding of causal and non-causal connections of the vacuum electric field.

Category

Other

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