High Harmonics Generation in Solids by Bright Squeezed Vacuum

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High harmonic generation (HHG) is an extreme nonlinear process which results in the emission of high-frequency photons by strongly light-driven matter, such as noble gases or solids [1]. The spectrum of emitted photons reflects the attosecond electron dynamics inside the material and allows all-optical reconstruction of energy band structure [2]. Until now only classical laser light (Glauber's coherent state) was considered as the main driver for strong-field light-matter interaction. Meanwhile, recent theoretical works [3-5] extended the description of HHG considering quantum light as a driver of the process, predicting extension of the HHG spectrum, modification of the electron dynamics and quantum squeezing in the extreme ultraviolet spectral range. Bright squeezed vacuum (BSV) [6] is a macroscopic quantum state of light which represents the strongly amplified quantum fluctuations of the electromagnetic field. BSV has zero mean electric field and oscillation of electric field variance at double carrier frequency, which is in striking contrast with the classical light.

In our work [7], we show experimentally, for the first time, HHG by BSV in solid-state samples. We generate 25-fs BSV at 1600 nm reaching 10 TW/cm^2 of peak intensity. We register up to the 7th harmonic from thin-film lithium niobate and amorphous silicon. We observe a 10-fold enhancement of the harmonics yield in case of BSV compared to coherent light with the same peak intensity. By measuring joint photon-number statistics between input pump and output harmonic, we can recover the power scaling of the harmonic generated by BSV without changing the mean photon number of the pump. We observe that harmonic power scaling in the case of BSV has higher exponent compared to coherent light indicating the enhancement of multiphoton transitions. Besides, we can probe the extreme nonlinearities of the material due to the fluctuating nature of BSV, which is not possible with coherent light even at low repetition rate.

In future, the free-carrier dynamics in solids driven by strong-field BSV will be studied in more detail, as it has more information about many-body correlations, and potentially shaping electron wavefunction will bring a new tool for quantum state engineering.

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