Parametric Model for High-Order Harmonic Generation with Quantized Fields

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During the process of high-order harmonic generation (HHG) [1,2], a secondary electromagnetic field is emitted from the irradiated sample, containing frequencies that are around integer multiples that of the driving pulse. These secondary pulses, when interfering coherently, may produce bursts of duration in the attosecond range [3,4]. Traditionally, the theoretical description of the phenomenon relies on the semiclassical approximation, *i.e.*, on the assumption that the exciting radiation (driving) can be treated as a classical, time-dependent field [5,6]. Recently, Hanbury Brown – Twiss type intensity correlations revealed the nonclassical nature of certain HH modes [7]. As reported *e.g.* in [8], by measuring the photon statistics of a strong, mid-IR pulse after the interaction with matter, the back-action of the material system on the exciting field is observable on the quantized level.

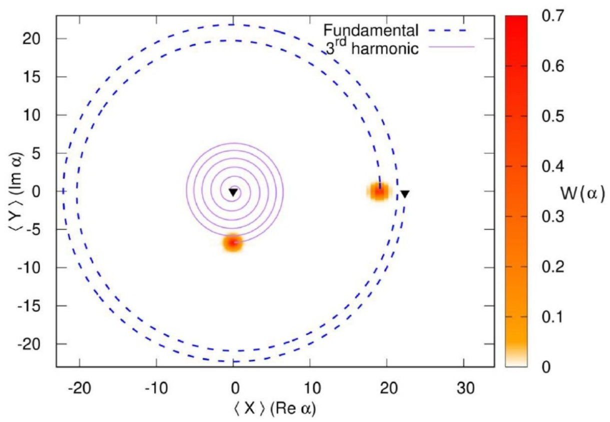

Figure 1: The time evolution of the Wigner function for the exciting mode and its third harmonic. Two optical cycles of the excitation is shown, the lines correspond to the expectation values of the quadrature operators, black triangles mark the initial points, and the Wigner functions are also shown at the end of the time evolution [12]

Following our early [9] and more recent [10-11] theoretical results, we introduced a model in which both the exciting field and the high harmonic modes are quantized, while the target material appears via parameters only [12]. As a consequence, the model is independent from the excited material system to a large extent, and allows us to focus on the properties of the electromagnetic fields. Technically, the Hamiltonian known for parametric down-conversion is adopted, where photons in the nth harmonic mode are created in exchange of annihilating n photons from the fundamental mode. This model predicted that modes that are initially in a coherent state, will remain approximately coherent during a few optical cycles (see Fig. 1), but later photon number distributions get broader, and – as it was shown by Wigner functions – localization in the phase space becomes less pronounced.

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