Boosting XUV Intensity with Propagation: From High-Harmonic Generation to High-Order Frequency Mixing

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The generation of bright, coherent XUV light via frequency conversion of intense laser drivers is a problem of both fundamental and technological importance. Increasing the intensity of the generated high harmonics by raising the intensity of the driving field only works up to a point: at high intensities, rapid ionisation of the medium limits the conversion efficiency.

We identify the dominant limiting mechanism – the combined effect of phase matching and the blue shift of the driving field during its propagation through a rapidly ionising medium [1]. We introduce the blue-shift length, which sets the upper bound for the quadratic intensity growth of the harmonics.

We study analytically and numerically (solving the propagation equation coupled with the TDSE) the behaviour of the macroscopic HHG signal with propagation distance. We show that its quadratic growth is limited by the shortest of three lengths: absorption, coherence or blue-shift length. Thus, we define three regimes of HHG, corresponding to the dominant limiting mechanisms (see diagram (a) for argon).

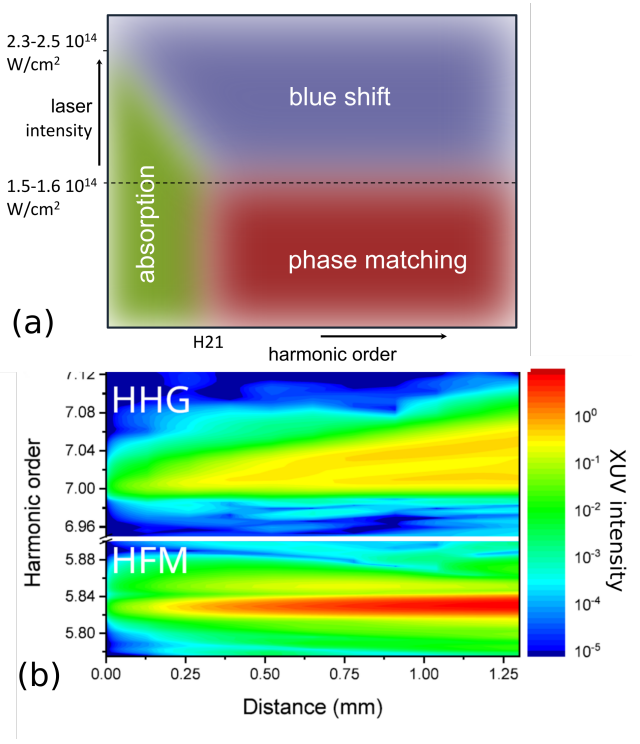

Figure 1: (a) Diagram for different regimes of the HHG marking the mechanism, which limits the optimal propagation. (b) HHG and HFM emission spectrum with propagation

Moreover, we show that this seemingly fundamental restriction can be overcome by using an additional generating weak mid-IR field. For suitable combinations of frequencies of the generating fields, the corresponding high-order frequency-mixing (HFM) process does not suffer from the blue shift of the drivers and phase mismatch [1], and thus its efficiency grows quadratically with propagation, see figure (b).

Our results open a new route for highly efficient generation of XUV light, the first step of which has been taken already via an observation of high-order parametric generation [2]. More-over, HFM offers new handles for XUV control such as the control of the carrier envelope phase of the emitted attosecond XUV pulses [3].

References

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