High harmonic generation in 2D and 3D semiconductors

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Ultrafast nano-photonics science is emerging thanks to the extraordinary progresses in nano-fabrication and ultrafast laser science. Nanotechnology enables the engineering of photonic structures at the nanometer scale for enhancing light-matter interaction, which can be exploited in a number of photonic applications. Our research is motivated by the novel fundamental processes occurring while a semiconductor is submitted to a strong laser field. Electrons start to oscillate in coherence and are accelerated by the laser field in the Brillouin zone. After recombination, high order harmonics are emitted, carrying with them precious information about the fundamental process[1-3]. Strategies to boost and control at a nanoscale this coherent phenomenon are of recent focus[4-6]. We propose new routes in boosting the non-linear response using nanostructured photonic crystals. Here, we demonstrate field amplification through light confinement in ZnO nano-structured 3D waveguides. Using our novel "nano-amplifiers", we have observed the amplification of high harmonics from mi-infrared laser-crystal interaction by up to 2 orders of magnitude. Compared to previous works[6], we extend enhancement of high harmonic to the highly non-perturbative regime. Amplification of up the 15th harmonic order is reported[7]. Nanostructuring semiconductors offers also the possible to control the high harmonic generation light properties. We will present strategies to manipulate the orbital angular momentum of light.

Finally, we investigate high harmonic generation in 2D semiconductors. Graphene has attracted significant attention in recent years due to its extraordinary mechanical, electronic and optoelectronic properties. High harmonic generation from graphene on substrate has been reported for the first very recently[8]. Here, we report for the first time on the generation of high harmonics from free-standing graphene. We study the laser polarization dependence of the harmonics to reveal the impact of the band-gap opening induced by the substrate.

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