

Quantum control and coherence in 2D materials

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In 1961, Franken et al. first demonstrated SHG in quartz, which opened the door for non-linear optical effects. Although the NLO effects of materials are typically inherently weak, the second-order NLO susceptibility is used for various current optical devices based on bulk crystal materials (e.g. potassium dihydrogen phosphate, potassium titanyl phosphate, beta barium borate, lithium niobate), including ultrafast laser generation, ultrafast pulse measurement, optical parametric generation, and optical parametric amplification.

Today, technology is being developed towards miniaturization of photonic and optoelectronic devices for on-chip integration, e.g. on-chip nanophotonics and quantum nanophotonics, which, however, are limited by difficulties of miniaturization, compatibility and integration of traditional materials on chips. Therefore, for future photonics and optoelectronics applications, it is significantly important to discover new materials with large SHG responses that enable novel devices with high performance, small size and low cost.

Recently quantum coherence excited in the materials promises to be able to enhance nonlinear effects. In particular, the quantum engineering of light-matter interaction at the nanoscale has evolved from the existing research on exotic electromagnetic properties of materials and structures with novel shape and size. It has led not only to novel phenomenon and applications, but has opened up the exceptional potential to tailor, control and manipulate light-matter interactions for nanophotonics. Quantum coherence can drastically modify the optical properties of a media, in particular, absorption practically vanishes even at the single photon level. The changes in dispersion properties of the medium with excited quantum coherence has been initially studied theoretically and then experimentally demonstrated in atomic or molecular systems. Coherent interaction of plasmons to excitons in the strong coupling regime results in nonlinear effects.

In this talk, we report the results on experimental and theoretical studies of the second harmonic and parametric generation of two-dimensional layered materials. Strong dependence of intensity of SHG vs pump intensity has been observed. We develop a theoretical model to explain the observed features of the SHG. The model takes into account self-consistently the interaction of excitons, and it provides a qualitative agreement with the observed SHG spectra and intensity dependencies. The obtained results on the second harmonic and parametric generation of two-dimensional layered materials can be promising for many applications stretching from technology, sciences, and security because of the abilities of photon generation, manipulation, transmission, detection, and imaging for the applications to on-chip nanophotonic devices.