Quantum materials for terahertz nonlinear photonics

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Nonlinear optical phenomena play a key role in many fundamental processes and are highly relevant for a wide range of applications, including quantum technologies, optical computing, and advanced spectroscopies. Many excellent materials are available for nonlinear optics in the visible and infrared part of the electromagnetic spectrum.

Until a few years ago, this was not the case for the terahertz regime, where only moderate nonlinearities were obtained with quantum well systems. This situation changed dramatically with the observation of highly efficient harmonic generation in quantum materials with massless Dirac fermions – charge carriers with a linear energy-momentum dispersion relation – such as graphene [1] and topological insulators [2].

In this talk, I will discuss our most recent results, obtained with a large group of collaborators, including researchers at TELBE (Germany), the University of Manchester (UK), Bielefeld University (Germany), ICFO (Spain), ICN2 (Spain), and several more. In particular, I will present ways of obtaining enhanced THz nonlinearities using quantum materials (see Fig. 1). These approaches include *a)* enhancing the THz nonlinearity of quantum materials through electrical control of the Fermi energy [3], *b)* using metal grating structures with micrometer-sized gaps that lead to local field enhancement [4]; and *c)* circumventing the saturation of harmonic generation that occurs in graphene due to heat accumulation by exploiting "Coulomb cooling" that provides enhanced electronic dissipation [5,6,7].

References

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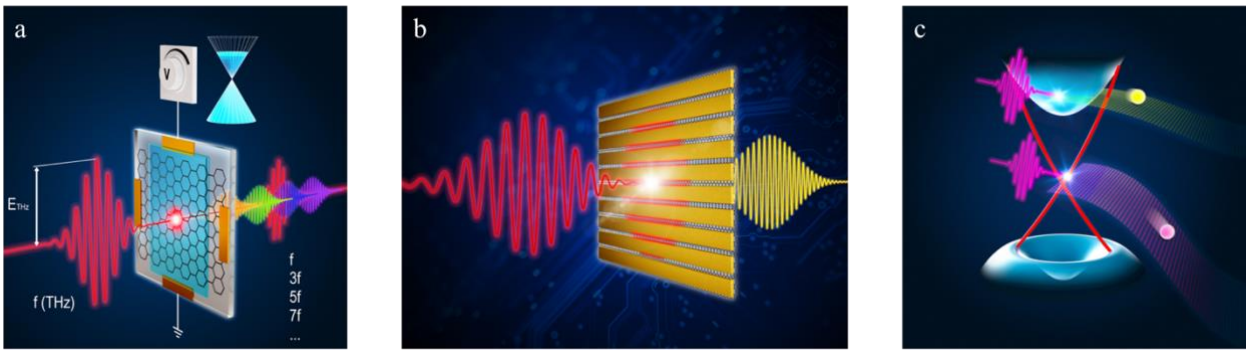

Fig. 1. **a)** Terahertz harmonic generation control and enhancement via electrostatic gating of a graphene-electrolyte system [3]. **b)** Grating-graphene metamaterial with strongly enhanced nonlinear susceptibilities due to field enhancement [4]. **c)** Band structure of topological insulator with faster cooling of surface state electrons [5,7], leading to enhanced harmonic generation [6]. All three images by HZDR.