S7-I2

Terahertz technology: novel photonic detectors, metamaterial modulators, and waveguide optics

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In this talk, we will discuss recent developments in the area of photonic terahertz (THz) detectors, metamaterial-based modulators, and waveguide technology.

First, we will highlight current trends in the area of photonic THz detection. A recently discovered quantum phenomenon that we called the “in-plane photoelectric effect” (IPPE effect) [1], Fig. 1, will be discussed. In this effect, which enables efficient THz detection in a gated 2D electron gas (2DEG), electrons absorb THz photons and jump on an artificially created, electrically tuneable potential step within the plane of a degenerate 2DEG. The detection mechanism can yield a more than 10-times higher response than previously known mechanisms. Based on this phenomenon, we develop novel photoelectric tuneable-step (PETS) detectors. The planar nature of the devices, combined with field-effect transistor-compatible fabrication and opportunities for in-situ impedance matching, enables easy integration of the detectors into integrated circuits. We will also discuss various aspects of the physics of the quantum photodetection mechanism [2].

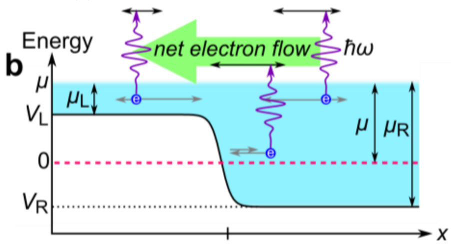

Fig. 1: Principle of the IPPE effect.

In the area of THz modulation, we will dive into the world of metamaterial-based modulators. In particular, a novel approach to terahertz modulation using graphene-metal metamaterials will be discussed. Instead of the common way of resistive shunting of the metamaterial antenna gaps, we exploit graphene patches for capacitive tuning of the LC-resonance of the unit cells [3]. The device, a “tuneable capacitance modulator,” enables modulation depths in excess of 40 dB and a speed that is several orders of magnitude higher than seen in previous modulators with a high modulation depth. The device exhibits the highest experimentally demonstrated modulation depth for a non-integrated graphene-based terahertz metamaterial, and the approach is compatible with GHz-speed modulation which is necessary for communication applications.

In the area of THz optics, the talk will showcase how cylindrical multimode waveguides can be used to deliver and simultaneously focus THz radiation – without any external focusing elements such as lenses or parabolic mirrors [4] (Fig. 2). The effect is based on multimode interference, and the results represent the first practical demonstration of the Talbot effect in cylindrical multimode waveguides at THz frequencies. The phenomenon can be well explained by a ray-optical model, which shows remarkable agreement with wave-optical calculations and can be applied both within the waveguide and beyond its end. This opens up opportunities for THz radiation delivery into confined spaces such as cryostats, and applications such as non-destructive testing of machinery or medical endoscopic imaging.

Fig. 2: Waveguide focusing effect.

REFERENCES

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