Terahertz beam engineering in imaging: from designs to applications

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Laser beam engineering is one of the main techniques widely used in microfabrication and laser ablation, therefore, its management possibilities play essential role aiming to optimize a large variety of laser-material processing applications [1].

Room temperature terahertz (THz) imaging is a powerful tool for non-destructive inspection covering different kind of materials, security checks, or medical scanning [2]. However, practical implementation of compact THz imaging and spectroscopy systems in real outside laboratory environment still meets significant obstacles because of low powers of THz emiters, reliability of sensitive THz detectors and effective solutions in design and technology of planar optical components. In particular, it gains a significant importance if the aim is alignment-free THz imaging systems. Therefore, design solutions in passive optical THz components in reducing their dimensions remains one of the main topics in THz photonics. As a rule, investigated objects are bulky, hence, bearing in mind the fact that image quality is strikingly sensitive to the sample position in respect to diffractive optical elements, obtained images can be blurred resulting in complication to resolve the recorded data.

In this lecture, we present silicon-based THz beam profile engineering via planar optics solutions providing both compact focusing as well as extended focus geometry in THz imaging and enabling thus precise inspection of thick objects with weak sensitivity of the object position.

We have revealed recently that thin silicon based multilevel phase Fresnel lenses are suitable solution for optical components for the entire THz range [3]. It was exposed that at least 4 and up to 8 phase quantization levels are required for efficient diffractive element compromising the performance and fabrication complexity of phase structures. We extended the silicon optics approach to so-called Fibonacci or bifocal THz imaging and Bessel THz imaging employing diffractive zone plates fabricated by laser ablation technology [3,4]. Zone plates simulated by 3D finite-difference-time-domain method displayed bifocal focusing operation. Features of the performance were studied both theoretically and experimentally via spatial profiles, distances between the foci and the focal depth at frequencies of 0.3 THz and 0.6 THz. Terahertz images of various packaged objects at 0.6 THz frequency were simultaneously recorded with the spatial resolution of the wavelength in two different planes of the packaged volume. It is worth noting that Bessel zone plates provide a $2\times\lambda$ resolution at 0.6 THz frequency with weak dependence of the object positioning between the diffractive elements [5].

THz beam engineering properties using flexible materials shaped in zone plates with integrated filters will be considered.

Further steps in development of THz beam profile engineering in imaging and its application for investigation of carbon-based materials will be discussed as well.

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