Sub-wavelength-resolution imaging of biological tissues using THz solid immersion microscopy

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***Abstract*—We have proposed a method of THz solid immersion microscopy, which yields imaging soft biological tissues with the sub-wavelength resolution up to 0.2-wavelengths. To achieve this advanced resolution, it employs a solid immersion phenomenon – i.e. a reduction in the dimensions of the THz beam caustic by its formation on a small distance behind the medium featuring high refractive index. We have assembled an experimental setup, which realizes the principles of the THz solid immersion microscopy, and proposed an approach for handling the soft tissue at the object plane. This setup uses a backward-wave oscillator, as a source of continuous-wave THz radiation, and a Golay cell, as a detector of the THz field intensity. We have examined the resolution of the THz solid immersion microscopy using both numerical simulations and experimental studies. Finally, in order to highlight the prospective of the proposed THz imaging modality, we have applied the experimental setup for imaging of representative examples of biological tissues.**

Keywords—terahertz radiation, terahertz technology; terahertz imaging; terahertz microscopy; solid immersion microscopy; biological tissues, sub-wavelength spatial resolution.

I. Introduction

Since biological tissues feature strongly sub-wavelength scales compared to the wavelength of terahertz (THz) radiation [1], achieving the sub-wavelength spatial resolution of THz spectroscopy and imaging is of high importance in THz biology and medicine [2,3]. Recently, several approaches for bringing the resolution of THz spectroscopy and imaging to the essentially sub-wavelength scales have been proposed. Among these approached, we would particularly notice the THz imaging relying on aspherical optics [3] and exploiting tera-jets [4], the THz holography [5] and synthetic aperture imaging [6], the THz near field imaging relying on the sub-wavelength apertures [7] or cantilever (needles/tips) [8]. At the same time, these modalities of sub-wavelength-resolution THz imaging do not allow for solving all the problems posed by the THz sub-wavelength-resolution THz imaging of biological tissues.

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II. Results

In our work, we developed a THz solid immersion microscopy – a method of sub-wavelength resolution THz imaging, which relies on the solid immersion phenomenon – i.e. a reduction in the dimensions of the THz beam caustic formed on a small distance ($<\lambda$) behind the medium possessing high refractive index [9]. We assembled an experimental setup realizing the principle of the solid immersion microscopy and proposed an approach for handling the object of interest (including, the soft tissues) at the object plane of imaging system [10,11]. As a source of the continuous THz waves and a detector of the THz field intensity, the setup uses a backward-wave oscillator [12] and a Golay cell (an opto-acoustic detector) [13].

We combined numerical simulations, using the finite-difference time-domain (FDTD) method for solving the Maxwell's equations, and experimental studies, using the razor blade imaging, to demonstrate the advance sub-wavelength resolution (up to 0.2λ) of the propose THz imaging configuration. Finally, we have applied the experimental setup for THz imaging of biological tissues and objects.

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