TERAHERTZ IMAGING USING PHASE CONTRAST METHOD

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Over the past few years, research and technology in the field of terahertz (THz) radiation has developed significantly. This is due to the non-ionising properties of this radiation, characterised by a much longer wavelength than that of the visible range. Applications of this radiation are increasingly being found in fields such as medicine, biology or safety. It is therefore a motivation to continue research into spatial filtering, with suitable personalised optical elements to enable imaging of transparent elements in this frequency range.

Spatial filtering method is a promising technique, that can be used to visualize transparent objects with the use of a 4f optical setup (Fig.1) with much larger apertures than in the previous research [1].

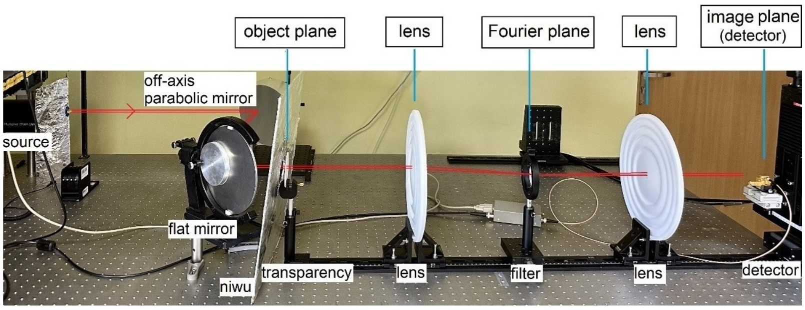


Fig. 1. A 4f optical setup consisting of: source and detector - based on Schottky diodes, reflective interference neutraliser, collimating mirror, flat mirror, transparency, two double-sided focusing HDPE lenses (focal lengths f = 300 mm) and phase filter.

It was decided to focused on two of the main spatial filtering methods. The first is the Positive Phase Contrast (PPC) method, which allows imaging after the insertion of a phase filter introducing a phase delay of $\pi/2$ into the setup in the focal plane. The second method used is the Negative Phase Contrast (NPC) method, which uses phase filters introducing a phase delay of 3/2 π, thus obtaining an image opposite to that obtained using the PPC method. The choice of these methods is due to the linear relationship between the received irradiance in the image plane and the phase shift introduced by the object in the input [1].

After performing relevant simulations to find proper sizes of filters, it was procced with analysis of suitable materials from which optical object could be made. It was important to find materials with a relatively low refractive index and a low absorption coefficient, so that obtained objects were transparent at the chosen frequency [2] and possible to manufacture by FDM method in 3D printing [3].

The experiment confirmed the performance as well as proved the suitability of this method in the THz range, the effects of which can be seen in Fig. 2. It also showed some unexpected effects associated with very long wavelengths, which inspired further research.

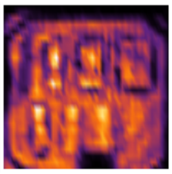
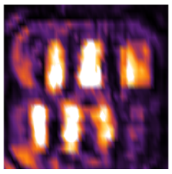
Scan	reference (without filter)	PPC (r = 3.0 mm)	NPC (r = 3.0 mm)
Waffle transparency			

Fig. 2. Normalised scans in the imaging plane for transparency: without filter, using the positive phase contrast method and a filter with radius r = 3 mm, using the negative phase contrast method and a filter with radius r = 3 mm, (scan size: 100 x 100 mm^2).

[1] SIEMION, Agnieszka, et al. Spatial filtering based terahertz imaging of low absorbing objects. Optics and Lasers in Engineering, 2021, 139: 106476.

[2] ZHANG, Xi-Cheng; XU, Jingzhou. Introduction to THz wave photonics. New York: Springer, 2010, DOI: https://doi.org/10.1007/978-1-4419-0978-7.

[3] KALUZA, Mateusz, et al. THz optical properties of different 3D printing polymer materials in relation to FTIR, Raman, and XPS evaluation techniques. In: 2022 47th International Conference on Infrared, Millimeter and Terahertz Waves (IRMMW-THz). IEEE, 2022. p. 1-2.