Fundamental specifications of reconstruction in terahertz pulsed time-domain holography

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Abstract

This work is a detailed study of the hologram reconstruction quality in pulsed terahertz time-domain holography. It was performed with both single wavelength and broadband spectrum. The study presents the dependences of the transverse and longitudinal spatial resolution, as well as the reconstruction contrast on the solid angle at which the hologram is observed, and the frequency of the used terahertz radiation for both amplitude and phase objects. Comparison of the obtained results with theoretical estimations shows that pulsed terahertz time-domain holography provides ample opportunities for contactless visualization and non-destructive testing.

Keywords

Digital holography, terahertz holography, resolution, contrast

1. Introduction

One of the most promising methods of using THz radiation is pulsed terahertz time-domain holography (THz PTDH) [1]. It provides coherent detection of a THz field in time domain and, therefore, direct wavefront inversion and subsequent reconstruction of the spectral properties of amplitude and phase objects. However, its important properties such as resolution, contrast and quality of reconstruction have not been thoroughly studied.

2. Object of study

For the numerical study of the properties of the method, an axial referenceless recording setup was used. To evaluate the quality of reconstruction, amplitude and phase objects were taken (Fig. 1(a-d)), the process of recording and reconstruction of wavefront was modeled with the THz PTDH methods [1] at solid angles from 0.0375 to 0.16 steradians, varied by the hologram area or propagation distance. Further, the dependences of the transverse resolution of the reconstructed amplitude and phase objects, as well as the contrast for amplitude objects and the longitudinal resolution for phase ones, were estimated.

3. Results

To estimate the transverse resolution of the reconstruction, the solid angle at which the hologram is observed was varied. The results of the numerical evaluation of the resolution are shown in Fig. 1(a-d). Comparison with the theoretical estimation of reconstruction resolution shows good correlation with the results of numerical simulation (Fig. 2).
The results of modeling the reconstruction of phase objects are shown in Fig. 1(c-d).

4. Conclusions

Numerical evaluations are given for the transverse resolution of amplitude and phase objects, as well as the contrast for the reconstructed amplitude and longitudinal resolution of phase objects. The results show that both physical parameters (solid angle, wavelength) and numerical (number of pixels) affect the quality of reconstruction.

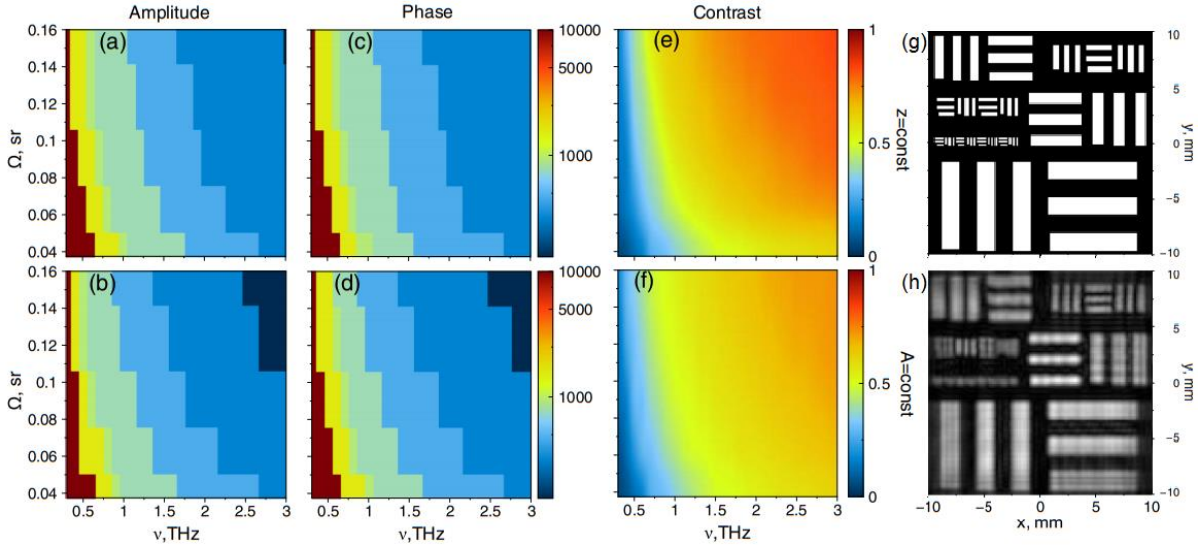

Figure 1: Transverse spatial resolution (a, b) and contrast (e, f) of a binary amplitude object reconstructed with THz PTDH methods at different solid angles, varied either by distance (A=const) or by hologram area (z=const). Resolution of a binary phase object reconstruction (c, d). Initial (g) and reconstructed (h) object

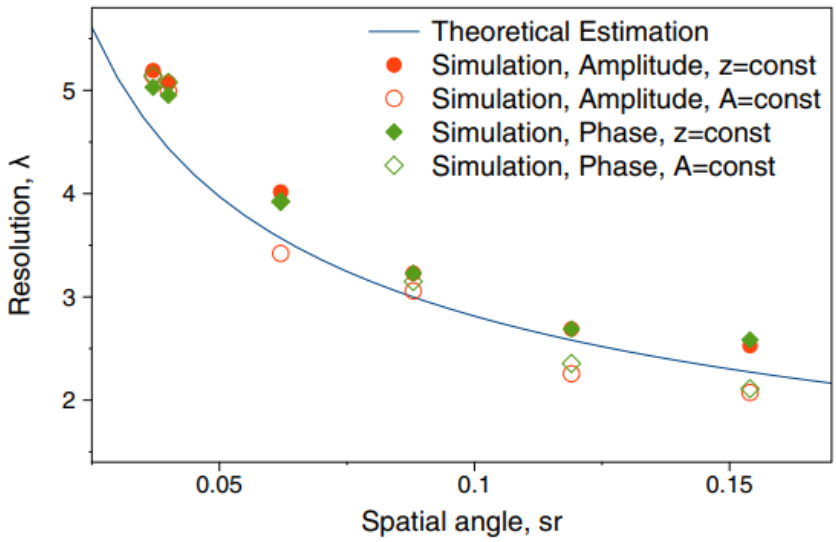

Figure 2: Theoretical estimation (blue line) of the resolution in inline PTDH and numerical transverse spatial resolution dependence on the solid angle varied by different methods for amplitude and phase objects

5. References

[1] Petrov, N.V. Application of terahertz pulse time-domain holography for phase imaging / N.V. Petrov, M.S. Kulya, A.N. Tsypkin, V.G. Bespalov, A.A. Gorodetsky // IEEE transactions on terahertz science and technology. – 2016. – Vol. 6(3). – P. 464-472.