Method for increasing the view field of THz holograms

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Abstract. In this paper we demonstrate the method of widefield amplitude-phase object images reconstruction from the spatially-limited broadband terahertz wavefield spectral components distributions in the Fresnel diffraction zone, based on the wave propagation equations iterative solution algorithm. Using of this method allows one to overpass the spatial resolution limit of an object image, reconstructed from the digital pulse terahertz hologram in low-frequency components of the THz radiation, used in the research. In its turn the created software allows to simulate the process of holograms registration in case of limited detector aperture and to reconstruct the full images of an object.

Keywords: Pulsed terahertz holography, Abbe's criterion, Noise suppresion, Resolution increase.

1. Introduction

Terahertz (THz) spectrum of electromagnetic radiation is represented by the frequencies between 0.3 and 3 THz and, consequently, by the sub millimeter wavelengths range between 1 and 0.1 mm. Though a great research has been made since it was discovered, it still remains unexplored enough, despite being interesting to scientists all over the world because of lots of its potential practical uses. Terahertz waves are perfectly suitable for nondestructive testing [1], including quality control [2], biomedical and chemical research and diagnostics [3, 4], other imaging purposes [5, 6], including security applications [7, 8]. This is possible due to the ability of THz waves to provide high resolution and penetration depth, get the spectroscopic information of an object, which features are covered by this range, for example, explosives [9], polymers, organic molecules. Because of such big wavelength, comparing with visible light, it is diffracted by much more huge objects. Finally, THz radiation applications often don't require optics, meaning that the optical aberrations will be minimal. But, howbeit, most of the technologies and methods, used nowadays to implement the THz radiation practical applications, mentioned above, suffer from low signal-to-noise ratio and inability to be used in all the variety of THz frequencies. So do one of the most common and universal of them - THz pulse time domain holography (PTDH) [10, 11]. Trying to at least partially overcome the mentioned problems we have carried out series of experiments.

2. Previous experiment

2.1. Preparations

Simulating the real conditions we added a noise of radiation source and detector to the created clean THz impulse. As an initial amplitude object a mask imitating the two closely placed pinholes was used. Initial phase distribution was provided by “flat phase”. Then the field distribution in the resultant hologram plane was calculated in all frequency components, also with the use of THz PTDH principles (Fig. 1).

a) b) c)

Figure 1. a) Amplitude mask “2 pinholes”. b) “flat phase distribution”. c) 3D data array of amplitude distribution via frequency in hologram plane.

2.2. Multi-wavelength iterative self-extrapolation algorithm

To increase the resolution and suppress the noise a multi-wavelength self-extrapolation algorithm (MWSEA), developed for one frequency [12] and adopted by us for a broadband THz spectrum, was used. The algorithm includes four steps (Fig. 2) : (i) Hologram plane input complex field formation for the THz frequencies array. Array dimension increasing by a factor of 2 for each frequency. (ii) Back propagation to the object plane and image reconstruction. (iii) Filling in the object plane value of the field, outside central part, with zeros. (iv) Hologram recording from the obtained field in the plane of the object and replacement of the central region on the field from the hologram plane of the original input data array. Repeating the cycle according to the desirable number of iterations.

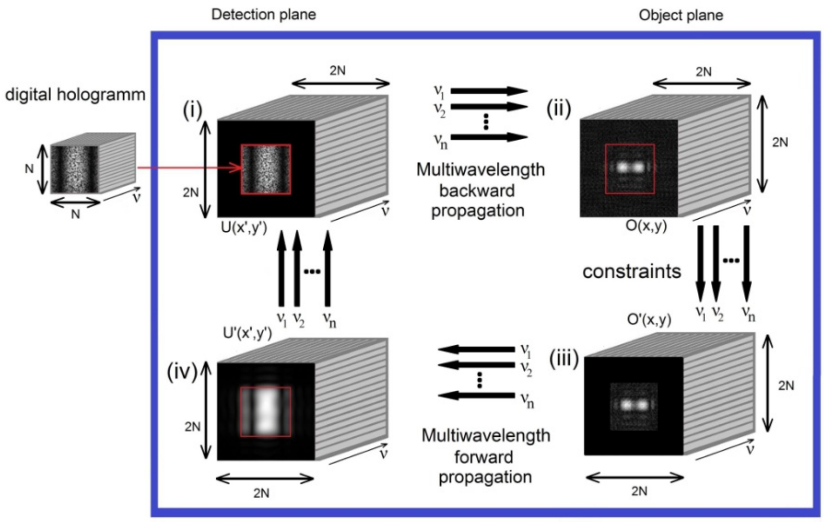


Figure 2. The algorithm 4 steps for each iteration.

2.3. Intermediate results

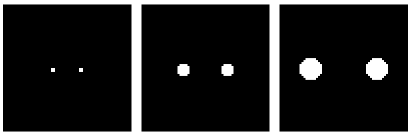
As a result of the first experiment we obtained the best noise suppression and resolution increasing on some low frequencies at the fifth iteration. But the question still remained with no answer due to the minimal variations of amplitude masks used: what are the limits for the applied algorithm – a distance between the pinholes, their diameter, a number of iterations for each variation? To get an answer we have carried out the second experiment.

3. The second experiment

3.1 Preparation and carrying out

In the second experiment we used the same methods for noise addition and its suppression and resolution increasing, but used 100 amplitude masks like one described before, step-by-step varying the distance between pinholes (L) and their diameter (D) from 14 and 2 to 32 and 11 pixels respectively (Fig. 3).

One pixel is equal to 0.6 mm^2, meaning that each of its sides has a length of 0.78 mm. As an initial phase distribution we took a white 64x64 pixels square. As a result after implementation of noise addition and MWSEA with 6 iterations we obtained 600 amplitude pictures of an object on each THz frequency used.



(a) (b) (c)

Figure 3. Some amplitude masks used. a) D = 2px, L = 14px. b) D = 6px, L = 22px. c) D = 11px, L = 32px.

3.2 Results

We noticed that the maximum number of iterations for each object remained equal to 5 and the algorithm is workable in all the range of distances and diameters used. We achieved noise suppression and resolution increasing in about X THz for L = 14 and D = 2 and Y THz for L = 32 and D = 11. It is clearly demonstrated on the Fig.4 below.

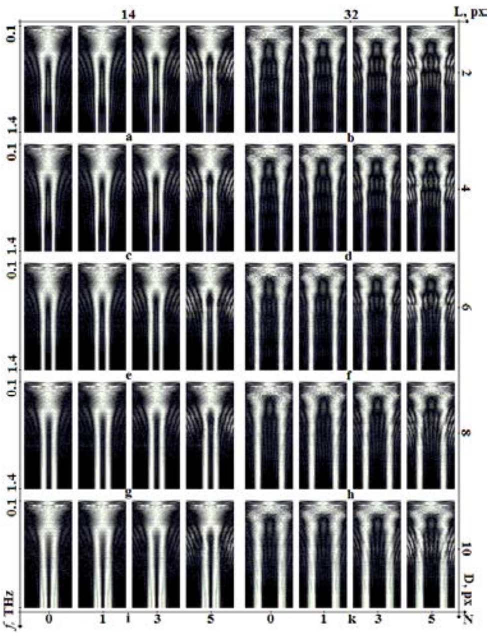


Figure 4. Amplitude images of an object for each frequency, D, L and number of iterations

4. Conclusion

We have shown that the MWSEA is workable in a wide range of distances and diameters. It allows increasing the resolution on low frequencies for lots of objects of different sizes and using of THz PTDH methods in a wider range of frequencies and samples. In its turn use of lower frequencies makes possible to apply THz radiation features more efficiently, because lower frequencies are scattered less. With all the potential applications of THz PTDH and other THz radiation methods it can increase the depth of penetration for signal, leading to more efficient, productive, accurate scanning for security reasons, quality control, nondestructive testing, chemical and biological researching and diagnostics.

5. References

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