Original Article

Directing the shape of optical fractality in the Talbot band

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Abstract

Directing the shape of optical fractality in the talbot band In this study, using the method of changing the sensitivity of different optical paths in the range of the Fourier spectral interferometer that leads to the production of Talbot bands, and also using a near- field interferometer, behind a periodic scattering grid under parallel light patterns appear that are called Talbot carpets or quantum carpets. The present study also shows that for a specific propagation distance, at a certain radial distance, the shadow pattern changes to the near field and at another distance from the specific radius, the diffraction pattern changes from a near- field to a far-field. The results were first obtained by simulation and then confirmed by experiments.

Keywords: Talbot band, Diffraction grating, Near field, far field, quantum carpets.

Introduction

HF Talbot is best known for his work on self-imaging, published in 1836. On the other hand, another experiment in 1837 on the formation of interfering freezes in white light was performed by Mr. Talbot, which has not received as much attention as the previous work. In this experiment, Talbot showed that by placing a glass blade of suitable thickness in the path of the incoming beams to a grid so that half of the beams pass through this blade before entering the grid, interference freezers (Talbot band) can be One of the first 2 times observed diffraction [1, 2].

Until now, Talbot group experiments have often been considered as the role of temporal aspects in light interference. Experiments with Talbot strips show that it is a combination of diffraction, diffraction and refraction that has produced amazing results called "scatter management", which is an important issue for ultra-high speed signal processing time. [3, 4]

Whenever a monochromatic and coherent beam illuminates an absorption grid vertically at fixed intervals, depending on the grid step and wavelength, the intensity distribution created on the plane perpendicular to the propagation is the same as the intensity distribution on the back plate. The intensity distributions are called Talbot images or phenomena, which can be described by Fresnel diffraction theory. Spacing two consecutive images or Talbot strips for a strip parallel to the wavelength of the formula

$$L_T = \frac{d^2}{\lambda}$$

Is obtained where d is the grid step. [5]

Mathematical approch

Using the Talbot effect of the near field, the design of a spectrometer is presented, assuming that a flat wave eradiate on a grid (Figure 1), the diffraction of the grid with the periodicity d of the wave transmitted behind the grid as: [5, 6]

$$\psi_0\,(x_0,\, z{=}0)\ \textstyle\sum_n A_n \exp\{\mathrm{in}K_d\, x_0\} \qquad (1)$$

when, $A_n = \sin(n\pi f)/n\pi$, $K_d = \frac{2\pi}{d}$, n=1,2,3

Which is the Fourier transform component of the periodic lattice (opening fraction). In the near field, the wave equation at distance Z along the X axis is obtained by the Fresnel-Huygens integral.
incidence on plate xz leads to approximation in the following equation [7]

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$R \approx Z + (X-X_0)^2/2Z$

$$(X,Z) = \sqrt{\frac{i}{\lambda Z}}\int_{-\infty}^{\infty} dx_0 \exp\left\{-ik\left(z + \psi_\lambda(X,Z) = \frac{(x-x_0)^2}{2z}\right)\right\}\psi_0(x_0,0) \qquad (2)$$

According to the field ψ_0 Equation (1) is obtained

$$\psi_\lambda(X,Z) = \exp\left\{-ik\left(Z + \frac{X^2}{2Z}\right)\right\}\sum_n A_n \exp\left\{\frac{iz}{2k}\left(nK_d + \frac{kx}{z}\right)^2\right.$$

The intensity behind the net is obtained according to the Talbot effect $\psi_\lambda^*\psi_\lambda$

$$I_\lambda(x,z) = \sum_{n,m} A_n A_m \exp\left\{i\left((n-m)\frac{2\pi}{d}x + \frac{(n^2-m^2)}{L_T}\right)\right\}$$

That, $\frac{d^2}{\lambda} = L_T$ ، Is called the Talbot distance. By calculating the intensity, the near field interference pattern is obtained. By simulating the fractal pattern in Equation (4), Figure (a, b) results. In this experiment, the grid amplifies the input wave alternately by one or zero for f = .1 of the opening fraction.[8]

$A_0 = f$

$A_n = \sin(n\pi f)/(n\pi)$; for n≠0

When the screen is at even multiple distances from the Talbot, z=2n. L_T

The pattern of wave 3 in z=0, repeats the amplitude propagated by equation 1, called the Talbot carpet fractional interference freezes. [9]

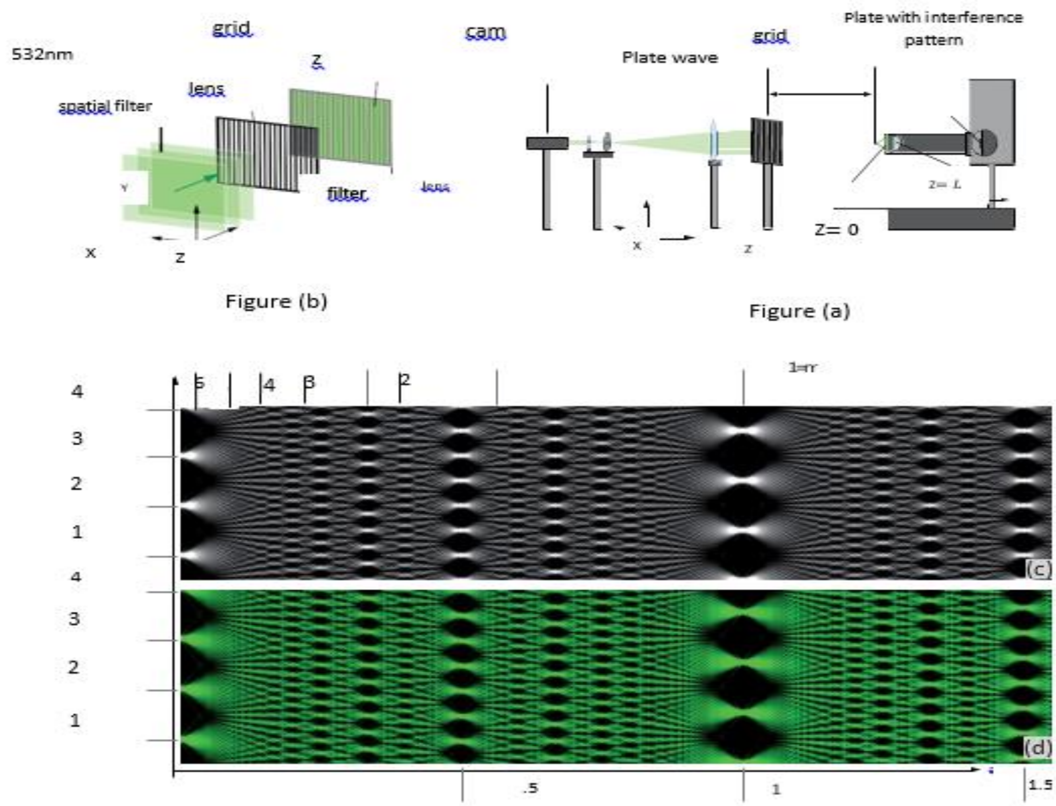

Figure 1. a) Talbot image itself using monochrome and parallel light; Figure b) Optical arrangement; (c) The pattern obtained using equation (3); (d) The fractal pattern is shown experimentally. The x-axis of the lattice period and the z-axis show the distance between the detector and the number m of the selfimage.

Experimental examination

An experimental Talbot experiment requires a parallel monochromatic flat wave. Using a 5 mW green diode laser beam (λ = 523 nm) propagated by a beam with a 20 nm diameter telescope to completely cover the grid, a 10 µm aperture at the center of the diffuser beam as a space filter To produce homogeneous light, Figures (a, b) were used. Since the final image is about 1 mm across the Gaussian distribution, the intensity of the laser light has little effect on the recorded pattern. In visible light, the grids have a period of 200 microns. Meters and the opening fraction are 10% opaque. Talbot freezes were displayed by a 108-micrometer 489 x 659-pixel camera embedded behind the grid. To see the details of the wave interference, Talbot images were magnified by short focal length lenses. (f_L=15mm).

In order to minimize light distortion in the inner walls, an aperture was made in the middle of the lens tube. The filter embedded in the laser path ($\Delta\lambda_{\frac{1}{2}} = 10 \pm 2nm$ and λ0 = 523nm) reduces the effect of deflection.

Since the grid is a completely periodic structure, we can use vertical pixels for any longitudinal position (Z) to improve the signal-to-noise ratio. For each longitudinal position z is a two-dimensional pattern I(x,z)= =$\sum_y I(x,y,z)$, I (X, Y, Z) is converted to a one-dimensional horizontal row, which is then combined for all positions z inside a single Talbot carpet I (x, z).

The result of this method is shown in Figure 1d, which fits the expected details of Figure 1c. Grid selfimages are displayed in integer multiples of Talbot length L_T=$\frac{d^2}{\lambda}$=75.5nm.

Conclusion

To have a high-resolution spectrometer, you need a grid with the smallest aperture fraction (less than 0.5). The intensity source is very limited, in addition to the aperture resolution, the image resolution is affected by the input wavelength distribution.

In this study, advanced wave optics were well demonstrated intuitively in Talbot tapes, paving the way for more complex research with ultrasound, X-rays, electrons, atoms, and molecules.

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