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Spatial Talbot Effect: Generation Of Wide Beam Divergence Coherent Source

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Abstract:
The application of spatial Talbot effect in mask lithography has been studied and reported elaborately in the literature. In this work, we report the application of spatial Talbot effect in generating coherent optical sources with wider beam divergence. Single slit Fresnel diffraction technique has been considered. A HeNe (Helium Neon) red wavelength broad beam divergence source with angular spread of 1.43^{o} has been reported.
Key Word: *Beam Divergence, HeNe laser, Spatial Talbot Effect, Fresnel diffraction*

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I. Introduction

The Talbot effect was first observed and reported by Henry Fox Talbot in 1836 [1]. Talbot discovered beautiful colourful patterns by utilising two right angled prisms (crown or flint glass) pressed closely against each other to form a cube with a hair inserted in the plane joining these two prisms. In the near field, due to Fresnel diffraction pattern, he saw multiple bands (the self-imaging phenomenon) of the incident beam of intense solar light.

In 1881, Rayleigh performed a similar experiment using diffraction gratings and gave a detailed mathematical analysis of the coloured Talbot interference bands in the near field regions and calculated the wavelengths of red and green coloured optical waves with significant accuracy [2].

Literature suggests that the spatial Talbot effect has now been utilized in various applications including mask lithography [3-7], quantum optics [8,9], non-linear optics [10], and classical optics [11]. In this work we have explored another area of research where we can employ spatial Talbot effect to realize coherent optical source with wide beam divergence.

II. Theory

In order to understand Talbot effect, one needs to first study Fresnel zone plates. Fresnel zone plates utilize diffraction, instead of the reflection or refraction phenomenon, to focus light, creating images similar to those produced by a convex lens. A zone plate consists of concentric half period rings called ‘zones’, alternating between opaque and transparent, whose thicknesses are calculated according to Fresnel's principle [12-14]. The diffracted light constructively interferes at specific distances away from the zone plate, hence giving rise to the self-imaging phenomenon.

Whereas instead of circular zone plate, when an N-slit diffraction grating is considered, it has been shown that in the Fresnel region, the interference of the diffracted beams gives rise to beautiful Talbot designs which have found numerous applications.

In this research article we have considered a red He-Ne laser source and passed it through a single rectangular slit and observed the diffraction pattern in the near field (Fig. 1). Table 1 consolidates the details of the He-Ne laser and the output of the experiment performed.

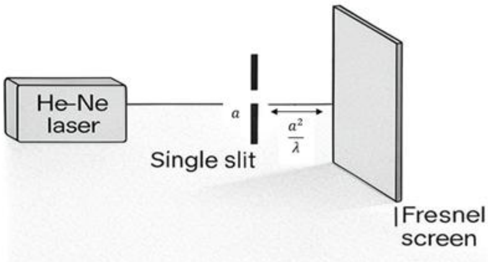

Fig. 1: Experimental setup

Table 1: Details and the results of the experimental set-up of Fig. 1

S. No.	Parameter	Value
1.	He-Ne laser wavelength	633nm (red colour)
2.	Beam divergence before Fresnel Grating	0.0087^{o}
3.	Beam divergence after Fresnel grating	1.43^{o}
4.	Width of rectangular slit	15µm

III. Results

Figure 2 shows the diverged monochromatic coherent beam as recorded on the near field screen with propagation distance varying from 0 till 20mm measured from the position of the slit for the experimental set-up of Fig. 1. The Calculations reveal that the beam divergence achieved at the output plane is 1.43^{o} as compared to 0.0087^{o} which is available directly at the output of the HeNe laser.

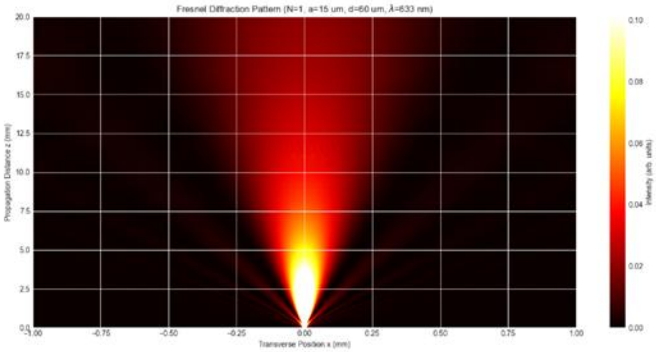

Fig. 2. Diverged monochromatic coherent beam as recorded on the near-field screen of the experimental set-up

IV. Conclusion And Discussion

We have proposed a wide beam divergence laser source which will find applications in flow cytometry, wherein the coherent source analyses the physical properties such as size, shape, and fluorescent labels on cells for the detection cancer and other infectious diseases. Other applications include broadcasting the signal so as to reach large number of receivers.

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