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Use of Multichannel Bessel Beams For Holographic Encryption

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Abstract—
Microwave encryption may make advantage of holography, which offers a way to reconstruct the intensity and phase distribution. Using a multichannel Bessel beam as the encryption key and the phase distribution of special characters conveying information as the output, we provide a holographic encryption system in this study. The two quasi-optical mirrors that make up the bulk of the system are optimized for deformation using a tweaked version of the Katsenelenbaum-Semenov algorithm. Commercial software simulation allows one to acquire the output field of a system with varied inputs. Simulation confirms the practicability and good security of this encryption approach. Terms like "quasi-optical mirror," "multichannel Bessel beam," and "holographic encryption" come to mind.

I. INTRODUCTION

Holography, which has been used with optical, electron, and X-ray beams, offers a crucial method for reconstructing intensity and phase information [1]. Separate information channels for high-capacity holographic systems have been implemented by using the various physical dimensions of microwave, such as polarization, wavelength, and time. As a crucial physical aspect of microwaves, orbital angular momentum (OAM) has also garnered a lot of interest. The helical phase factor, $\exp(il\theta)$, is a common way to express OAM. Here, l is the helical mode index and θ is the azimuthal angle of a helical wavefront. The potential information-carrying capabilities of this degree of freedom are overlooked since traditional digital holograms do not disclose OAM selectivity [2]. Achieving OAM holography, where the helical phase may be used as an information carrier, requires presenting OAM selectivity in the reconstruction of the corresponding holographic pictures while preserving the OAM feature.
The authors of this work simulated holographic encryption using a multichannel Bessel beam. Using the Katsenelenbanum-Semenov (K-S) technique, we are able to get the target image's mirrors with multimode OAM. It is clear from the simulation findings that the holographic encryption technique is feasible for electromagnetic encryption. Clear reconstruction of the target picture is possible for certain multichannel Bessel beams; otherwise, fuzzy reconstruction is possible.

II. PRINCIPLE AND DESIGN METHOD

In Fig. 1, we can see the Bessel beam being used as an input to generate the target field's phase. The mirrors are illuminated by the predicted Bessel beam, which allows for the generation of a field at the target point with a distinctive phase distribution that carries the unique information. In contrast, the target field's phase distribution becomes distorted and unidentifiable when the incorrect beam is used to light the mirrors.

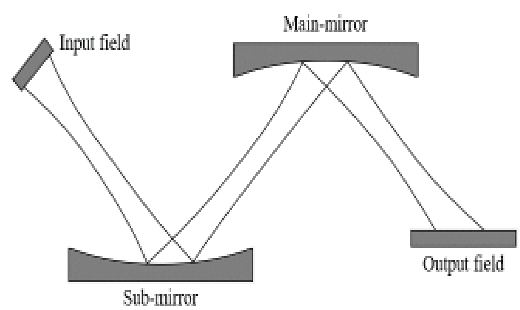

Fig. 1. Schematic diagram of holographic encryption system.

A. Multichannel Bessel beam
Scale field propagation in a homogeneous medium is described by the Helmholtz equation, which is widely known [3]. You may find the Helmholtz equation as:

$$(\nabla^2 - \frac{1}{v^2}\frac{\partial^2}{\partial t^2})\psi(\vec{r},t)=0 \qquad (1)$$

The variables φ, r⃗, v, and t represent the scale field, position vector, phase velocity, and time, respectively, of the wave. Among the several answers to (1), non-diffracting waves or beams—also known as localized waves—proceed without divergence and have their energy spatially confined. The Bessel beam, a solution to (1) in cylindrical coordinates, is one kind of confined wave. The following is the formula for a monochromatic wave solution:

$$\psi(x,y,z,t) = A_0 J_n(k_\rho \rho) e^{i(\beta z - \omega t)} \qquad (2)$$

This is where the amplitude A0 is, the radial and longitudinal components of the wave vector (____) are denoted by kρ and β, respectively, the angular frequency ϋ is, the polar coordinates ρ and φ are, and the Bessel function of the first type of order n is Jn(). They are connected through:

$$\beta^2 + k_\rho^2 = \left(\frac{\omega}{c}\right)^2 = k_0^2 \qquad (3)$$

where the angle between them is axicon angle, δ, given by:

$$\delta = \arctan\left(\frac{k_\rho}{\beta}\right) \qquad (4)$$

The opening angle of a cone with an equation (3)-defined value of 2δ is given by (4). B. The Holographic Encryption Network's Architecture The asymmetrical mirror is the primary component of the holographic security system. As shown in Figure 1 [4], when the input and output fields are known, the modified K-S method is a useful tool for optimizing the quasi-optical mirrors. Here, the holographic encryption system is designed using the K-S algorithm. Figure 2 shows that the source field's relative location,

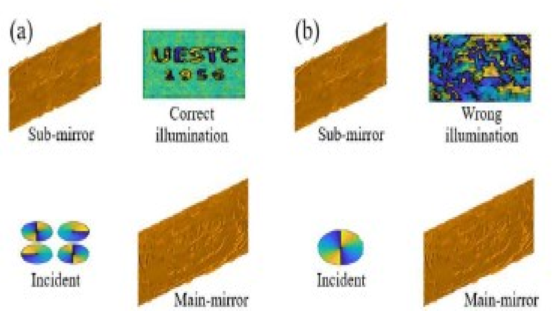

Fig. 2. The process of phase generation of target field with the Bessel beam as input. (a) The expected input. (b) The wrong input.

Prior to iteration, the geometric optical approach determines the target field and the mirrors. To describe the algorithm's iterative procedure, we may say:

1. Apply the inverse scalar diffraction formula to determine the field on the Main-mirror after setting the target field with the "UESTC 1956" phase distribution.
2. Optimize the Sub-mirror by calculating its field from the Main-mirror and comparing it to the input field of the multichannel Bessel beam.
3. Find the desired field, compare it to the field calculated from the Sub-mirror to the Main-mirror, and then optimize the Main-mirror.
4. Verify that the output field matches the target field that has been specified. Put an end to the loop if the vector purity is met; keep going if not.

Part III: Concept and Outcomes

Figure 3 displays the final product and the steps used to create the mirrors. In this setup, the source field and encryption key are two of four Bessel beams that have various modes but are identical in intensity. A Bessel beam is used to split the target picture into four halves, allowing for simple identification following iteration and a clear target image overall. Hence, in order to get the phase information of the relevant component, the preset Bessel beam must be used as an input. Plus2, minus1, plus 1, and minus 2 are the four predefined Bessel beam modes.

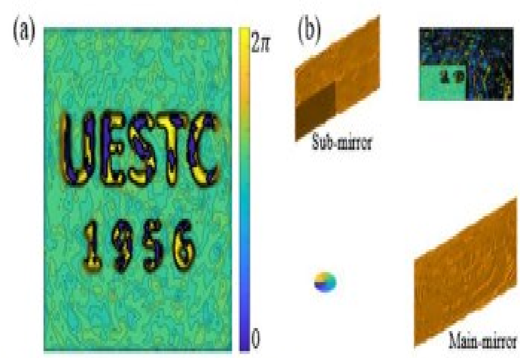

Fig. 3. (a) The target image. (b) The design process of mirrors.

Then, to get the sub-mirrors for each component, the preset Bessel beam is supplied independently. Figure 3(b) shows an example of how to generate a partly clear phase picture by transferring Mode +1 from the shaded portion of the Sub-mirror to the Main-mirror. The same procedure also yields the other three Sub-mirror components. One more cycle yields the Main-mirror deformation, which is achieved by concurrently using four beams as inputs. In TABLE I, you can see the primary elements' parameters.

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TABLE I. Parameters of the Main Elements

	Size(mm)	Theta(degree)	Center position(mm)
Source plane	140×140	0	(0,0,0)
Sub-mirror	200×200	157.5	(0,0,280)
Main-mirror	240×240	157.5	(280,0,0)
Observation plane	200×200	0	(280,0,300)

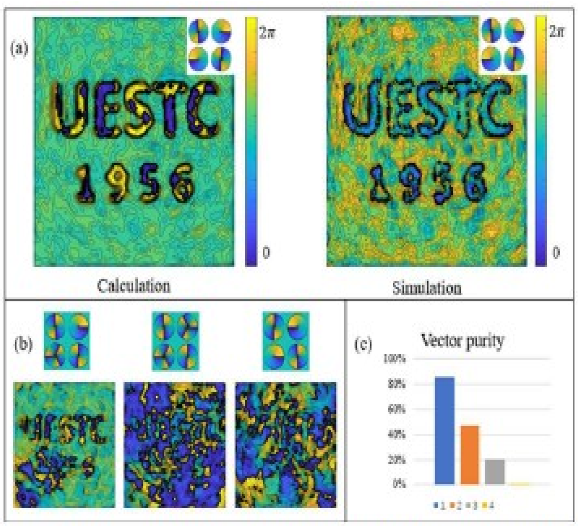

Fig. 4. Analysis of target image under different inputs. (a) The calculation and simulation results with the correct input. (b) The output with the wrong input. (c) The vector purity of the target field in four cases.

As seen in Figure 4, a crystal clear "UESTC 1956" and a vector purity of 85.3% may be achieved with the appropriate multichannel Bessel beam illumination. Consistent with the computed outcome, the target picture is acquired via the use of commercial software simulation. The result is examined under three distinct inputs to confirm the security. Changing the third input from +1 mode to +3 mode has an effect on the target image's overall resolution and reduces the vector purity to 46.7%. Second, just 20.5% of the vector remains pure when the second and third inputs are modified. You can't even make out the intended phase distribution when you switch about the four input types' rotation directions. There is evidence of some level of security in the system from the simulation findings.

IV. CONCLUSION

Using multichannel Bessel beam illumination, we propose the approach for designing a mirror holographic encryption system in this study. Holography determines the precise deformation of the mirrors when the target picture and source field information are pre-designed. By simulating various input scenarios, we can ensure that the encryption system is secure, and that the target picture can be decoded using the appropriate Bessel beam illumination.

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