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# Simultaneous Generation of Multiple Annular Rings and its Application to In-Plane Image Slicing and Communication

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**Abstract -** *In this paper, the aim is to generate multiple annular beams simultaneously, and later describe its usefulness in data bit generation and eventually having an application in the communication domain. Apart from this, a simple scheme for 2-D image in-plane slicing using the proposed beam pattern has also been demonstrated. This paper is basically a simulation-based paper, which is highly promising and compatible for an experimental work based on this approach in future.*

***Key Words***: image slicing, communication, Fourier optics, image processing, annular rings

## 1. INTRODUCTION

Optical imaging and optical communication are two major pillars of the modern life. In-plane slicing of an image and co-existence of the serial and the parallel data transfer facilities are quite rare. The present paper proposes a simple method to generate highly customizable multiple annular beam-pattern generation and its application to in-plane slicing of an image as well as the application of this beam-pattern to generate an approach, suitable for both serial and parallel data transfer. This present method is also suitable for modulation and demodulation required for communication. The two-dimensional distribution of data in this technique is also highly appropriate for facilitating the option of wider spatial distribution of signal and positional uncertainty introduction for secure data communication.

## 2. LITERATURE SURVEY

Some literature survey has been done before proceeding with the present work. Optical techniques have already proven their values in the domain of imaging and communication. Uchida et al. [1] and Li et al. [2] used chaotic random laser for random bit generation. Apart from this, Most of the conventional image slicing techniques are bit-plane slicing [3]. Color segmentation is an important tool for practical image processing [4]. An important concept used in this paper is arranging axicons in matrix arrangement. Similar arrangements of holes or lenslet arrays in matrix form are very useful other fields of optics like wavefront sensing and adaptive optics [5,6]. Optics has also important in case of free space communication [7]. Kahn did a detailed study on modulation and detection techniques in optical communication [8]. The method presented in this method is highly suitable for free space communication, remote communication and modulation.

## 3. THEORY OF BEAM GENERATION

An axicon is very useful for annular beam generation for different applications of optics and image processing. An axicon matrix of four axicons in a 2X2 arrangement is shown in Fig - 1.

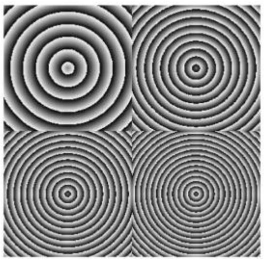

**Fig -1**: Axicon matrix with four axicons with different phases

Each axicon's radius and phase can be controlled individually, hence providing control over each annular ring in the Fourier domain, shown in the Fig – 2 (a) below. Now, Fourier transform of the axicon matrix pattern with four axicon elements is taken to form the four brightest rings, which is dominant compared to the much feeble higher order patterns in the Fourier domain. They have been extracted from the background by a certain threshold value to form an annular beam pattern shown in Fig - 2 (b). The number of rings in the annular beam pattern can be controlled by varying the number of axicon matrices to be considered. Also, by varying the phase of individual axicon patterns, the diameter of the corresponding rings can be controlled.

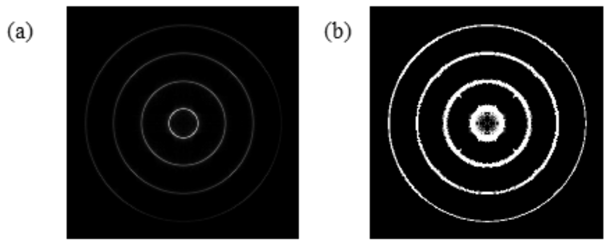


**Fig -2**: (a) Combination of annular rings generated from the Fourier transform of the axicon matrix and (b) the rings after setting a threshold value

The Fig - 2 (a) shows the combined annular ring patterns obtained by the Fourier transform of the axicon matrix without using any threshold value. Fig - 2 (b) is the result of setting a certain threshold value in Fig - 2 (a). In Fig - 2 (b) the brightness values of rings are flattened compared to Fig - 2 (a) obtained by eliminating the change in data values because of the natural variation in the intensity values of the different annular rings. The pattern without threshold setting can be used if the absolute value of the data is not needed but only the existence of the light or brightness is required. Variable number of rings with variable diameter can be generated randomly in this scheme, making it suitable for introduction to certain uncertainties for any encryption application where it would be difficult to guess the number of rings and/or the diameter value at one go.

## 4. PROPOSED APPLICATIONS

Here, the image in-plane slicing simulation using our beam pattern has been tried first. Initially, the image is illuminated using the beam pattern with multiple rings. Each individual radius of a particular beam pattern corresponds to a particular annular region of image and the illuminated parts of the image using this ring can be taken out as a slice. Then, by varying the radii of the other rings, several other subsequent slices or frames can be generated and in this way the image can be scanned radially. The complete image can be broken down to different frames, each containing some information about the original image. Again, the diameters and the numbers of the rings are highly customizable. The certain sections of the image are extracted in this method and the remaining part of the image which has not been illuminated by the annular beam pattern is also kept. In simulation, this residual portion of the image can be obtained by multiplying the image with the complement of the combination of all the bright annular rings. Finally, at the time of reconstruction, all the extracted sections are added up along with the residual part to obtain the final image. If any of the pieces are missing, complete reconstruction of the image is not possible which may have a future scope of encrypting the data using the similar beam. In the bottom figure, the extracted sections, residual frame and the reconstructed image from the information from each channel are shown. The below pictures describe the in-plane slicing using the beam and finally reconstructing the image from the in-plane sliced frames. The original figure shown in Fig - 3 (a) is multiplied with three sets of annular ring-patterns – each set being generated from the Fourier transform of the axicon matrix-pattern with each ring being the contribution of each of the axicon elements. The results of these three multiplications are shown in Fig - 3 (b) to Fig - 3 (d). Thus, in-plane slicing has been done on the original image. Different sets like these three slices can be generated by varying the number and the diameter of the annular rings by controlling the phase values of each of the axicon elements of the axicon matrix shown in Fig - 1. Extracted in-plane sections of the image can be distributed among different users as keys. After taking out all the slices from the image, the residual image is shown in Fig - 3 (e) as a master key which can be retained by the admin. Now, when the reconstruction of the image is needed, all the slices and the residual part of the image are recombined together to retrieve the reconstructed image as shown in Fig - 3 (f). Hence, all the individual slices and the residual image are needed for the complete reconstruction of the image. It shows that apart from the image reconstruction, the proposed scheme is also suitable for cases where the presence of all the pieces or members are needed for certain events like meetings, tender openings, question paper opening etc. In the presence all the required members. On the other hand, this proposed method is very useful for radial scanning.

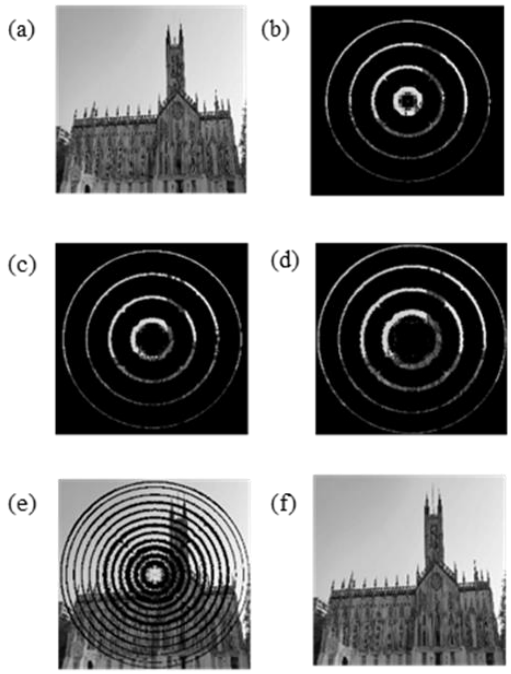


**Fig -3**: (a) Sample image, (b-d) three sets of extracted radial sections from the original image using the collections of the three sets of combined annular rings generated from the Fourier transform of the axicon matrix, (e) residual image after taking out all the segments and (f) reconstructed image by combining the residual part and all the extracted sections

Apart from this, the four rings can be considered as 4 different channels suitable for generation and transmission of data bits in a communication system. If an axicon pattern is on, then the corresponding ring is visible and represents the 1 with the dimension of the ring being controlled by the phase pattern of the axicon element. By turning off the phase pattern, the annular ring can be extinguished representing the 0 state. The four rings can be considered as four bits. By modulating the rings with the variation of the axicon element phases, these bits can be controlled. Here, at one go four bits can be controlled together facilitating parallel data transfer. Alternatively, each of the four channels can be used for transferring or generating bit streams. Here, four different bit streams can be passed independently through the four rings. This is the serial data transfer. The bits are read by noting the pixel values of four points on the four rings. Again, a huge number of channels with wide variations of the diameters can be generated. Like conventional bit patterns Least Significant Bit (LSB) and Most Significant Bit (MSB) can be assigned to two rings in the parallel combination scheme. Also, one terminal ring can be turned ON or OFF to indicate the start and end of a data packet when multiple packets are coming continuously.

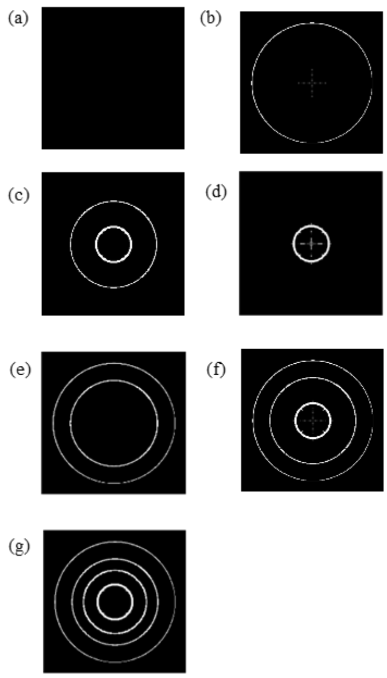


**Fig -4**: (a) Bit pattern 0000, (b) bit pattern 0001, (c) bit pattern 1010, (d) bit pattern 1000, (e) bit pattern 0011, (f) bit pattern 1011 and (g) bit pattern 1111.

## 5. CONCLUSIONS

In this paper, we discussed the generation of a special beam pattern using axicon matrix. The main advantage of this beam is that the number of rings in the beam pattern can be increased by increasing the number of axicons as per our need and the individual ring radius can also be regulated. Some of the simulation based application of the beam in image in-plane slicing and bit pattern generation have also been discussed. The scheme of image in-plane slicing can further be extended in the encrypted communication domain with each single sliced frame acting as a key, distributed randomly in terms of distribution instance (i.e. and/or various spatial positions of the ring and finally reconstructed to obtain the original image). Encryption of each single frame with unique intensity masks can also be thought of. The bit pattern generation scheme can also be extended to a proper communication method. Due to lack of resources in this pandemic the stated future prospect of these schemes could not be carried out. But, as the future work or research interest, the domain of communication and encryption will be explored further. The proposed future probable research areas are: 1) Experimental generation of the beam using SLM, 2) Using the image in-plane slices to develop an encrypted communication scheme, 3) Develop the bit pattern generation into a full-fledged data bit communication scheme.

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