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# Image Encryption based on Optical Coherence Multiplexing Technique

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**Abstract:** We present a novel encryption method based on the path-difference multiplexing technique and consists in adding a key-random-image to the target image. Both images are encoded randomly as an optical path-difference greater than the coherence length of the light source. We will discuss its performance in terms of Peak-to-Correlation Energy (PCE).

## 1. Introduction

Optical image encryption has received a great deal of attention [1]. Most of the proposed methods are based on double-random phase encoding [2,3]. Recently, Alfalou *et al.* proposed a new method based on Stokes-Mueller formalism [4]. Other methods using nonlinear optical techniques [5] and quantum imaging [6] have been reported. None of these methods has exploited the properties of coherence modulation of light for image encryption, although this approach has already been used for signal encryption processing by Wacogne *et al.* [7].

In this paper, we propose a novel approach of optical image encryption based on modulation coherence of light that allows several signals to be multiplexed as an optical path-difference (OPD) larger than the coherence length of the light source. This method has readily been implemented in a wide range of applications, including optical sensing, acousto-optic signal processing, and real-time optical image addition and subtraction [8]. The proposed encryption technique enables two levels of security to be carried out simultaneously, on the principle and on the experimental implementation.

## 2. Theory

The main advantage of the coherence modulation of light is that it permits the multiplexing of several signals in a single light beam which allows real-time all optical arithmetic operations between two 2-D signals [10]. Using this advantage, we will show how to encrypt a target image.

The coding system is schematically shown in Fig.1. The images  $f_1(x, y)$  and  $f_2(x, y)$  are encoded by two-dimensional coherence modulators (CM's) in series and illuminated by a broadband light source  $s$ . The OPD of the CM's is greater than the source coherence length  $\Delta_i \gg L_c$  with  $L_c = \lambda_0^2 / \Delta\lambda$  ( $\lambda_0$  is the center wavelength and  $\Delta\lambda$  is the spectral width of the source).

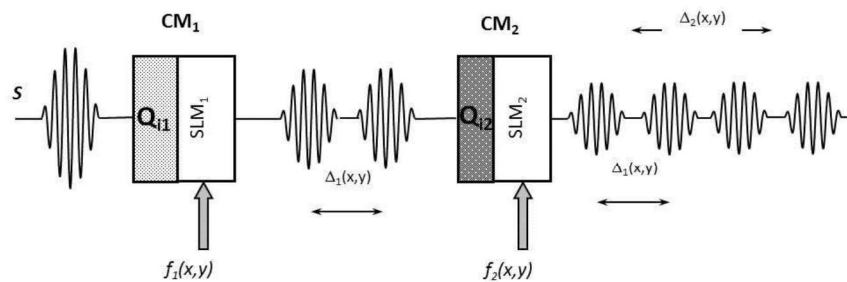


Fig.1. Schematic of the encryption setup

Each CM is composed of a birefringent plate ( $Q_i$ ) and a spatial light modulator ( $SLM_i$ ) which permits to encode every pixel  $(x, y)$  of the images  $f_i(x, y)$  as an optical path delay given by

$$\Delta_1(x, y) = \Delta_{01} + Kf_1(x, y) \quad \Delta_2(x, y) = \Delta_{02} + Kf_2(x, y) \quad (1)$$

where  $f_1(x, y)$  is the target image,  $f_2(x, y)$  is the key-random-image,  $K$  is a constant related to the SLM,  $\Delta_{01}$  is the OPD introduced by  $Q_1$  which is randomly variable around  $\Delta_0$ .  $\Delta_{02}$  is the OPD introduced by  $Q_2$  so that  $\Delta_{01} + \Delta_{02}$  is always a constant. At the output of system, the intensity is given by,

$$I_{out}(x, y) = \frac{1}{4} \int_{\Delta\sigma} P(\sigma - \sigma_0) \cdot [1 + \cos 2\pi\sigma\Delta_1(x, y)] [1 + \cos 2\pi\sigma\Delta_2(x, y)] \cdot d\sigma \quad (2)$$

where  $\sigma$  is the wave number and  $P(\sigma - \sigma_0)$  is the power-spectrum of the source centered at  $\sigma_0$ .

The decoding system consists in using an interferometer with an OPD  $d = \Delta_{01} + \Delta_{02}$ , and the intensity of the encrypted image is then given by,

$$I(x, y) \approx \frac{I_0}{8} \{1 + K\pi\sigma_0 [f_1(x, y) + f_2(x, y)]\} \quad (3)$$

### 3. Numerical results

Fig.2. shows the target image (a), the key-random-image (b) and the encrypted image (c) which are (100,100) pixels 256-gray-level-amplitude images.

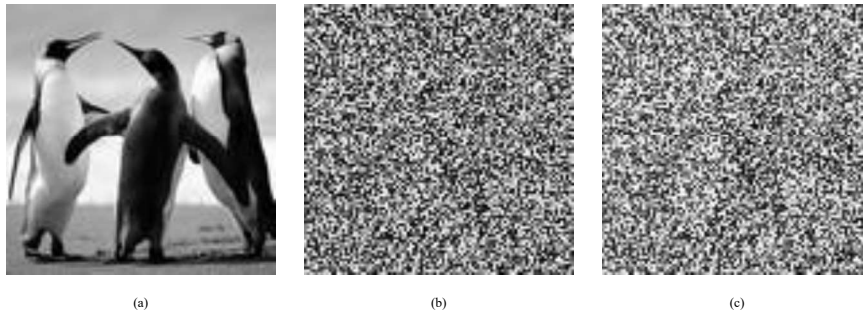


Fig.2. The target image (a), key-random-image (b) and the encrypted image (c).

To evaluate the encryption level of our method, we used a histogram analysis which describes the distribution of pixel values in both target and encrypted images. Then we have compared the two images using a phase-only-filter (POF). Finally, we have performed a correlation technique between adjacent pixels. All these methods have shown that the target image has successfully been encrypted.

### 4. Conclusion

To conclude, we have proposed a novel technique for real-time optical image encryption based on coherence modulation of light. We have presented the theoretical study and numerical simulation then evaluated the encryption level of our method using several techniques. The experimental verification of the proposed technique is in progress.

### 5. References

- [1] B. Javidi, et al., "Roadmap on optical security", *J. Opt.* **18**, 083001 (2016).
- [2] K. Nakano, M. Takeda, H. Suzuki, and M. Yamaguchi, "Encrypted imaging based on algebraic implementation of double-random-phase encoding", *Appl. Opt.* **53**, 2956-63 (2014).
- [3] E. Pérez-Cabré, H. C. Abril, M. S. Millán and B. Javidi, "Photon-counting double-random-phase encoding for secure image verification and retrieval", *J. Opt.* **18**, 094001 (2012).
- [4] A. Alfalou and C. Brosseau C, "Dual encryption scheme of images using polarized light", *Opt. Lett.* **35** (13), 2185 (2010).
- [5] S. K. Rajput and N. K. Nishchal, "Fresnel domain nonlinear optical image encryption scheme based on Gerchberg-Saxton phase-retrieval algorithm", *Appl. Opt.* **53**, 418-425 (2014).
- [6] A. Markman and B. Javidi, "Full-phase photon-counting double-random-phase encryption", *J. Opt. Soc. Am. A* **31**, 394-403 (2014)
- [7] Wacogne B and Jackson D A 1996 Enhanced security in a coherence modulation system using optical path difference corruption *IEEE. Photonics Technology Letters.* 8 947.
- [8] S. Elwardi, M. Zghal and B.-E. Benkelfat, "Coherence Modulation of Light for Mathematical Operations", *IEEE International Conference on Electronics, Circuits and Systems (Institute of Electrical and Electronics Engineers, New York, 2008)*, pp. 878-881.