Spatial-Polarization State Scrambling for Image Encryption Obtained with Subwavelength Gratings

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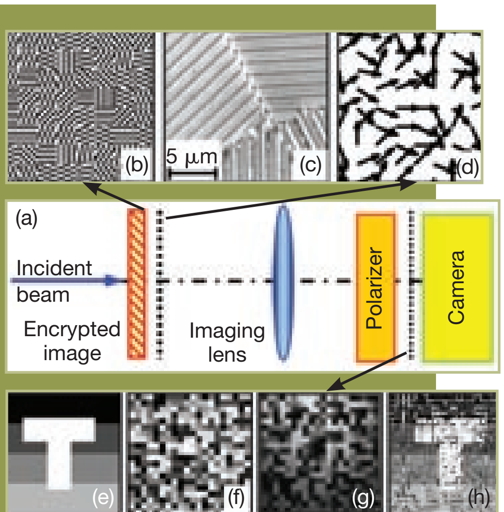
Researchers, policymakers and the public have become increasingly interested in data security over the past few years, and there has been a growing need for improved methods for data encryption. The demand for better and faster security devices is a result of the problems created by unauthorized users and commercial spies gaining access to communications networks. One of the processes that has been extensively investigated is the optical encryption technique.

Recently, polarization encryption has garnered a great deal of attention. Polarization encryption provides additional flexibility in key encryption designs by adding a polarization-state manipulation to conventional phase and amplitude manipulations. We propose an approach for polarization encryption using geometrical phase modification.[1,2]

We recently demonstrated the formation of complex polarization-state manipulation by using computer-generated space-variant subwavelength gratings (SWGs).[2,3] We have also shown that such polarization-state manipulations inevitably lead to a phase modification of geometrical origin.[2,4,5]

Geometrical phase encryption, which is realized by using an SWG, results in a robust and stable encryption scheme. The method is suitable for chip integration and can be applied to personal security cards such as credit or identification cards.

To encrypt a primary image, we needed to form an SWG that encodes the image intensity while incorporating a random key function. The SWG, which is a space-variant rotating wave plate, imprints the image intensity along with the random key function in the local orientation of the wave plate's fast axes. Decryption is then performed by illuminating the encrypted element with circularly polarized light and retrieving the primary image by analyzing the emerging Stokes parameters using the correct key [part (a) of the figure]. Alternatively, instead of using the function of the correct key in the analysis, we can insert an SWG in the optical setup to serve as a decryption key.[1]



(a) Schematic representation of the concept of geometrical phase encryption. (b) Subwavelength grating mask of the central region of the SWG. (c) Scanning electron microscope (SEM) image of the encrypted element taken from a small region in the element. (d) The measured polarization state of the beam emerging from the encrypted element taken from the central region. (e) Primary image intensity to be encrypted. (f) The wave plate's orientation function of the key element shown in grayscale. (g) A picture of the measured intensity obtained by the decryption process with the polarizer oriented at 0°. (h) Decrypted image achieved by the decryption process.

Part (b) is a magnified illustration of the subwavelength grating mask of the encrypted image. The primary image is shown in part (e). The encrypted element was comprised of 20 × 20 pixels, with each pixel having dimensions of 500 μm × 500 μm. The SWG was fabricated on a 500-μm-thick GaAs wafer to a nominal grating depth of 2.5 μm, with a 2 μm subwavelength period [part (c)].

Following the fabrication, we illuminated the encrypted element with a right-handed circularly polarized light at 10.6 μm wavelength. The beam emerging from the encrypted element was then transmitted through a polarizer at three different orientations (0°, 45° and 90°) [part (g)]. The decrypted image shown in part (h) was attained by calculating the Stokes parameters while applying the intensities and the correct geometrical phase key [part (f)].

Part (d) shows the measured space-variant polarization directions emerging from the encrypted SWG. As can be seen, the orientation of the arrows is completely random. The emerging field, which is a result of the vectorial self-interference, is a space-varying polarized field.

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