Low cost technique developed to speed up encryption & decryption

Researchers at Raman Research Institute (RRI), Bangalore, an autonomous institute under the Department of Science & Technology, along with collaborators from University of Rennes, France, demonstrated a new technique of decrypting encrypted information through optical technology.

In many fields, including telecommunications and TV broadcasting, information is encrypted or modulated by the sender and is retrieved by the receiver by the process of "demodulation." Demodulation is extracting the original information-bearing signal from a carrier wave. The demodulation is done electronically, which in the case of images, has to be done pixel by pixel. This requires time, which for most purposes, may be small enough to be ignored. However, for certain applications, like aircraft navigation, even the tiny amount of time taken for demodulation makes the technique unsuitable for practical use.

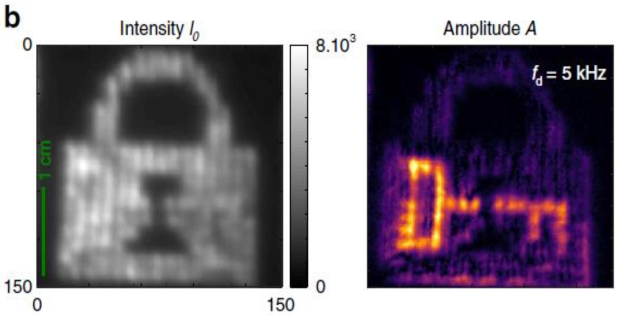
Prof. Hema Ramachandran, along with a team of scientists at the Light and Matter Physics group at RRI and collaborators, has provided a means of demodulation optically rather than electronically. This speeds up the process significantly, and full demodulated images are obtained instantaneously upon recording a single frame using an ordinary digital camera.

The technology is called – FAST-QUAD (Full-field All-optical Single-shot Technique for Quadrature Demodulation). The all-optical technique that has been developed has two components – the concept and the device. A prototype of the FAST-QUAD has also been built and demonstrated.

The techniques currently being used for the demodulation of optical signals at radio frequencies and higher face numerous practical challenges like the need for phase synchronization, timing jitters, inability to perform snapshot operation, and difficulty in frequency tuning. These issues have only been partially addressed by a few existing laboratory demonstrations of full-field demodulation, based on image intensifiers, Time-of-Flight (ToF) sensors, or lidar systems. While fast intensity-modulated light sources are easily available, full-field demodulation of images at high frequencies still awaits a viable solution. This radically new approach to modulation and demodulation imaging developed by Prof. Ramachandran bypasses these challenges by performing the demodulation optically, making use of the polarization of light. This technique is compatible with high-frequency operation up to the radio frequency range.

When any signal is transmitted over a medium, be it air, or water, or even electrical cables, it becomes noisy due to various environmental factors. Often, as is the case in free-space broadcast, the signal becomes very weak and is buried in noise. Thus, at the receiver, it becomes necessary to filter out the noise and amplify the signal. One commonly used method to distinguish a signal from noise is to modulate the signal in a periodic fashion, say by altering its intensity from high to low to high, repeatedly, at a known rate. As the noise is random, the signal can now be distinguished from the noise due to its periodic rise and fall in intensity. Thus, by picking up and amplifying only the periodically varying part at the receiver, the signal can be extracted from the noise. This is the basic idea of demodulation.

This concept is widely used in communications, where the demodulation is performed by special electronic circuits. These circuits have their own 'local oscillators' that generate a periodic signal at the desired frequency, and compare it with the noisy incoming signal, looking for a variation at the matching frequency. This is done by a circuit that performs an operation equivalent to mathematically multiplying two signals and integrating them. The output of this circuit is proportional to the strength of the periodic component that one is looking for.



Using FAST-QUAD, the picture on the left was transmitted, which has encrypted in it the picture of a key and is not normally visible. Upon demodulation at the correct frequency, the image of the key is retrieved.

In the present work, instead of electronic circuits, birefringent elements are used. These materials, like naturally occurring calcite crystals, or manufactured electro-optic crystals, can separate light beams with different polarisations. The birefringent property of the electro-optic crystals can be controlled by means of applied electric current and can be periodically varied as fast as a billion times per second. In FAST-QUAD, the noisy input signal is polarised and then passed through an electro-optic crystal whose polarisation properties are periodically varied. This performs an operation equivalent to mathematical multiplication. The signal passes through further polarisation elements and then is acquired by a digital camera. This is equivalent to the mathematical operation of integration.

The entire process of demodulation (multiplication and integration) is performed optically, and over the entire field of view, eliminating the need for pixel-by-pixel demodulation. This offers an enormous speedup and provides a demodulated image with a single snapshot of the camera.

Prof. Hema Ramachandran and her team have been working for more than two decades on techniques of imaging through random media. The French collaborators have been working on modulation and demodulation techniques. During this period, several techniques were developed, and experiments carried out in the real fog, both in France and in India. The endeavour has been to devise low-cost techniques and to speed up the processing time.

These scientists were each working on other research areas, and the idea of all-optical demodulation emerged over numerous discussions, where each scientist brought in ideas from allied research fields. Their work has been published in Nature Communications, and two related international patents have been filed which are in the finals stages of processing.

This technique has great potential for application – it can be used for encrypting and decrypting images, surveillance, navigation under poor visibility, optically imaging through tissues and underwater vision. In addition, the technique is likely to open up possibilities for 3D ranging and imaging, optical communications, food quality analysis, and specialized scientific instrumentation.