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Experiments with non-uniformly correlated laser beams propagating underwater

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Abstract: Generation and underwater propagation of recently developed non-uniformly correlated laser beams is presented. The experimental set-up and initial observations of the beam intensity after a short underwater path are given.
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1. Introduction

In 2011, Lajunen and Saastamoinen introduced the first non-uniformly correlated partially coherent source [1]. These sources can self-focus [1-3] and experience lower scintillation and achieve higher peak irradiances than coherent and uniformly correlated (Schell-model) sources making them potentially useful for both free-space and underwater optical communications [4]. As a result, research into these special partially coherent sources has since blossomed: electromagnetic non-uniformly correlated beams [2, 5], circularly coherent sources [3, 6, 7], and high-order non-uniformly correlated beams [8]. Techniques to synthesize them have also been developed [7, 9].

Most of the work to date involving non-uniformly correlated sources has been theoretical. The experimental work that has been performed has dealt with synthesizing and then validating the desired non-uniformly correlated source. Here, we propose an experimental study aimed at validating the suitability of using these beams for free-space or underwater optical communications, namely, that they experience lower scintillation and achieve higher peak irradiances than their coherent and uniformly correlated counterparts. In this work, we present the initial results of our study. Using the synthesis technique discussed in [9], we generate a non-uniformly correlated beam using a spatial light modulator (SLM) and propagate it in both free space and calm water. We discuss our experimental set-up, present measured irradiance results for both free space and underwater propagations, and discuss future work.

2. Experimental set-up

A stabilized 2 mW 632.8 nm He-Ne laser was expanded (see Fig. 1a.) to fill an SLM window with a spatial resolution of 256 x 256 pixels and a sensor area of 6.14 mm x 6.14 mm. Eight thousand screens with prescribed statistics to define non-uniform correlation and cycling at a rate of 333 Hz were used to generate the laser beams. A 4f system/spatial filter was used to isolate the desired first order and translate the SLM (i.e., the source) plane to the water tank entrance. The 4f system, shown in Fig. 1a, consisted of two 400 mm lenses and a mechanical iris.

After exiting the 4f system, the light was split (see Fig. 1b) to allow imaging of the laser intensity using camera 1 before propagating through the water tank. The initial experiment was conducted using a 1 m long underwater propagation path with the intention to switch to a 10 m underwater link in the next iteration of this study. Camera 2 (not shown below) was located at the exit point from the water tank and it recorded the laser beam intensity directly. The camera's integration time was set at 100 ms, producing 10 frames per second and allowing averaging approximately 30 cycled screens from SLM. Neutral density filters were used to attenuate the laser light incident on the camera sensor. To observe the laser light intensity distribution and account for the variations introduced by SLM cycling and randomization of the beam maximum intensity location, the cameras recorded 220 images, lasting about 20 seconds.

3. Results

This initial investigation included the generation of non-uniformly correlated laser beams with the following parameters $\sigma = 1$ mm, $\delta = (\sigma/2)^2$, $\gamma_x = (0.6)\sigma$, and $\gamma_y = (0.6)\sigma$. Figure 2a shows the simulated intensity of the near-field propagation of a non-uniformly correlated laser beam over 220 realizations. Figure 2b shows the image of the recorded light intensity distribution averaged over 220 frames. The beam clearly demonstrates the randomized motion along the major axis with skewed maximum value. Note that the recorded image is off center and the beam has a wider spread. This effect is in part due to the length of the propagation path to the sensor and due to the slight mismatch of the camera sensor size and the simulation area.

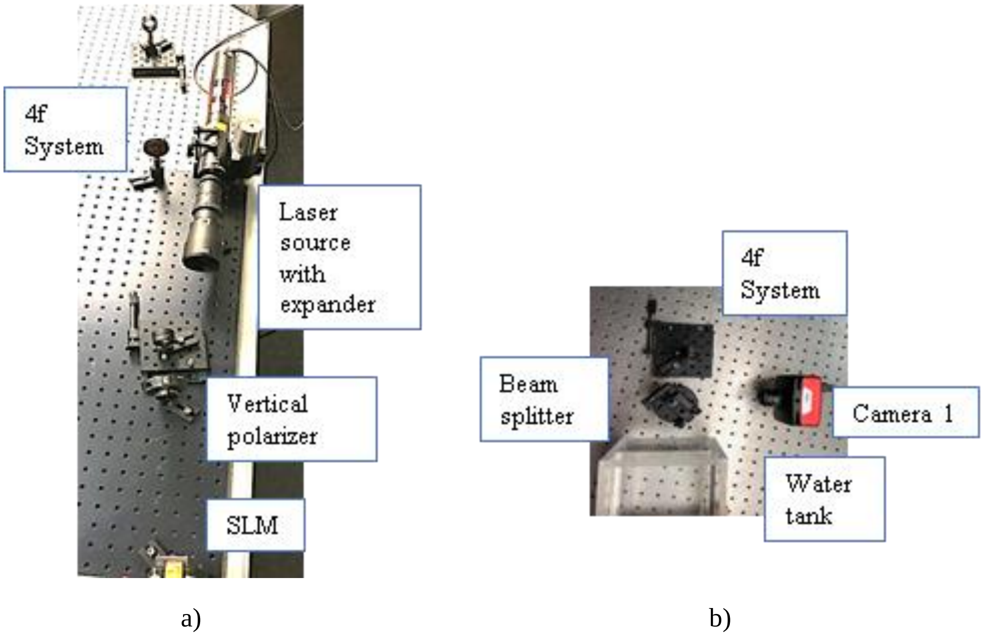

Figure 1. Experimental set-up—a) optical set up for beam generation and b) generated beam intensity disturbing recording.

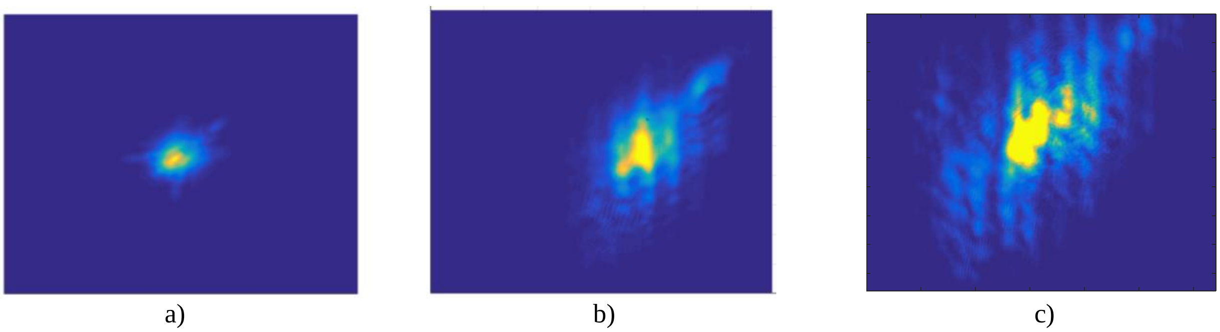

Figure 2. Light intensity distribution for non-uniformly correlated laser beam—a) simulation of the generated beam, b) recorded image before, and c) recorded image after underwater propagation.

The laser light intensity distribution recorded after propagating underwater is shown in Fig. 2c. Note that the camera sensors have equal size and the light was projected directly onto the sensor in both cases, but the neutral density filters did not have the same intensity attenuation in both cases. Clearly after propagating underwater, even over a short distance, the beam exhibits wider spread in the high intensity region. A more detailed study will be conducted to evaluate the performance of non-uniformly correlated beams propagating under water and the results will be presented in future publications.

4. References

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