Characteristics of Modulated-Wavefront Beams for Active Sensing through Strong Scattering Obscurants

Kang-Min Lee[1], Cristian Hernando Acevedo and Aristide Dogariu[†]
[1]CREOL, College of Optics and Photonics, University of Central Florida, Orlando, Florida 32816-2700, USA
kangmin.lee@ucf.edu

1. Abstract

Our research explores the application of modulated-wavefront beams, such as vortex beams carrying orbital angular momentum (OAM) modes and Poincaré sphere beams, for active sensing through strongly scattering media. Extracting object information from obscurants is contingent upon environmental conditions, which can limit the effectiveness of conventional coherent or incoherent source illuminations, such as Gaussian beams or LEDs. For instance, utilizing coherent sources for single-shot image retrieval requires specific constraints on the distance between the target and scattering medium, as well as the object's size, to effectively incorporate speckle modulation [1]. Imaging retrieval via optical memory effects (OMEs) in scattering media depends on speckle modulation with incoherent illumination [2]. When OME conditions are met, image retrieval from reflected signals becomes feasible. However, in dynamic scattering media, the OME effect diminishes over time, leading to potential failure in image retrieval. In such scenarios, we found that modulated-wavefront beams offer distinct advantages, as coherent noise generated by strongly scattering media becomes unavoidable [3]. We introduce the concept and experimental results of directional control over the transmitted fields after they pass through scattering media, which is expected to enhance speckle modulation [4]. Additionally, by utilizing OAMs, we propose that imaging retrieval in dynamic scattering media is achievable. This approach also aids in locating objects embedded in volumetric scattering media and improves transmission efficiency. Through this work, we present the comprehensive characteristics of modulated-wavefront beams in active sensing.

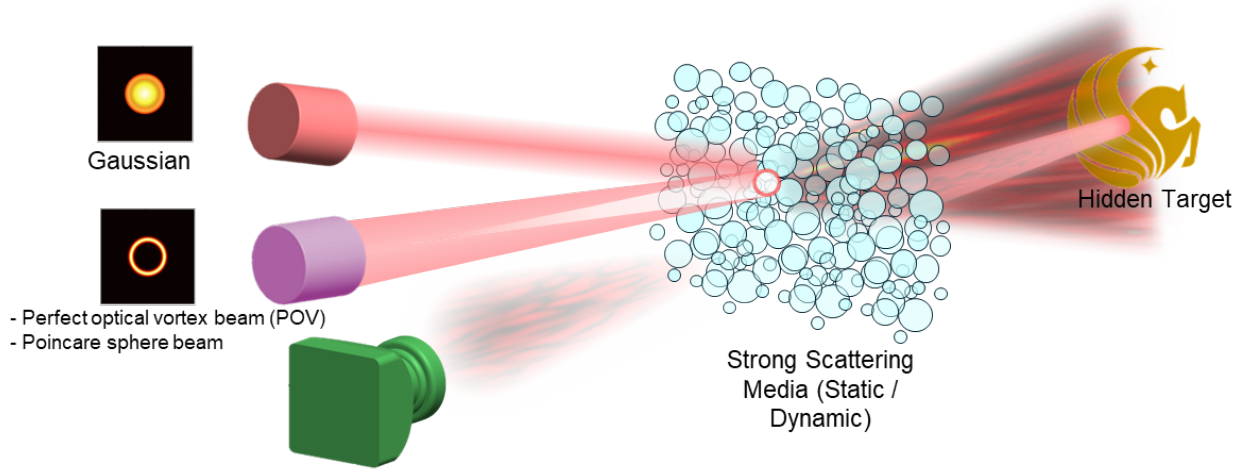

Figure 1 Schematic view of active sensing with modulated wavefront beams versus Gaussian beams through strong scattering media in reflection.

Reference

1. Pengfei Wu, Zi Liang, Xing Zhao, Lei Su, and Lipei Song, "Lensless wide-field single-shot imaging through turbid media based on object-modulated speckles," Appl. Opt. 56, 3335-3341 (2017)
2. Katz, O., Heidmann, P., Fink, M. et al. Non-invasive single-shot imaging through scattering layers and around corners via speckle correlations. Nature Photon **8**, 784–790 (2014).
3. Kang-Min Lee, Cristian Hernando Acevedo, Aristide Dogariu, "Active sensing of a hidden object using Gaussian and perfect optical vortices speckles: a comparative study," Proc. SPIE 13041, Three-Dimensional Imaging, Visualization, and Display (2024)
4. Kang-Min Lee, Cristian Hernando Acevedo, Aristide Dogariu, "Object detection through obscurants using partially coherent fields generated by perfect optical vortex beams," Proc. SPIE 13030, Image Sensing Technologies: Materials, Devices, Systems, and Applications XI (2024)