Speckle-based hyperspectral imager using disordered metasurface

Dong-gu Lee, Gookho Song, Chunghyung Lee, Mooseok Jang*
Department of Bio and Brain Engineering, Korea Advanced Institute of Science and Technology (KAIST); Daejeon, 34141, South Korea.
**E-mail: mooseok@kaist.ac.kr*

Conventional hyperspectral imagers rely on scanning systems based on diffractive optical components, which are inherently bulky and time-consuming. To build compact and snapshot hyperspectral imagers, inverse problem approaches have been actively explored, where information is encoded using the system's spectral response and subsequently computationally reconstructed. However, the limited spectral sensitivity and instability of spectral encoders present ongoing challenges.

Here, we present a hyperspectral sensor that utilizes a disorder-engineered metasurface (1) as a spectral encoder. The disordered metasurface generates orthogonal speckles at different wavelengths, even over compact propagation distances between the metasurface and the image sensor. Additionally, since it is pre-characterized, speckles for all wavelength channels can be globally derived from a single-wavelength calibration. We have successfully constructed a reconstructive spectrometer using the characteristics of this disordered metasurface (2), and now aim to extend its application to the spatio-spectral domain.

We have built a simple system with ~4 nm spectral resolution, consisting of a disordered metasurface and an image sensor, where the spectral response appears as the point spread function with a large memory effect of the metasurface. The distance between the metasurface and the sensor is set to the optimal point of ~4 mm, where angular dispersion enhances spectral sensitivity while preserving the high transverse wavevector light components. Also, the angular spectrum of the speckle is optimized to achieve high spectral sensitivity using a genetic algorithm. We believe that speckle-based information encoding using metasurfaces represents a new frontier for replacing conventional optical elements, with this hyperspectral sensor as a starting point.

References

1. M. Jang et al., Wavefront shaping with disorder-engineered metasurfaces. Nat Photonics 12, 84-90 (2018).
2. D. Lee et al., Reconstructive spectrometer using double-layer disordered metasurfaces. Science Advances, in press.