

Abstract

Vector vortex beams (VVBs) are spatially varying polarized beams, also known as classical non-separable beams (CNSBs). They are formed by superimposing mutually orthogonally polarized beams with orthogonal orbital angular momentum (OAM) modes. In these beams, the spatial and polarization degrees of freedom (DOFs) are correlated, and a measurement in one DOF can affect the other. These beams have various applications in metrology, sensing, imaging, communications, and encryption. Several parameters have been developed to quantify the degree of classical non-separability in VVBs, with linear entropy (S_L) being the most commonly used.

The modulation of the S_L parameter in VVBs has not been extensively investigated. This thesis proposes several techniques for modulating S_L by exclusively manipulating the degree of polarization (DOP) of VVBs. The DOP of VVBs is controlled using non-uniform, birefringent, and cost-effective overhead projector (OHP) sheets. VVBs with different input polarization (IP) angles are generated through the superposition of a horizontally (H) polarized orbital angular momentum (OAM) beam and a vertically (V) polarized Gaussian beam (GB) via a common-path technique. The VVB with IP=45° and $S_L = 1$ is called the maximally non-separable VVB. The VVBs with other IP angles, excluding 0° and 90°, and with S_L value between 0 and 1 are called partially non-separable VVBs. These beams are scattered using a diffuser and then propagated through OHP sheets of non-uniform thickness, resulting in the modulation of S_L only for partially non-separable VVBs. For these partially non-separable VVBs, S_L increases as the number of OHP sheets after the diffuser increases. In contrast, for maximally non-separable VVBs, S_L remains constant regardless of the number of OHP sheets after the diffuser, due to the completely non-uniform polarization distribution.

In addition to this approach, the Brewster technique can be employed to modulate the parameter S_L of VVBs by controlling their DOP. In this method, linear (L)-basis VVBs with different IP angles are generated using a common-path scheme and reflected from a dielectric prism rotated by different angles. The modulation of S_L arises from the unequal reflected intensities of the horizontally (H) and vertically (V) polarized components. As the rotation angle of the prism (AP) increases, the peak value of S_L shifts toward lower IP angles for L-basis VVBs. The sharp variation of S_L near the Brewster angle, particularly for L-basis VVBs with small IP angles, is found to be useful for detecting small changes in the refractive index of the dielectric prism.

To investigate the effect of polarization basis on the modulation of S_L under the Brewster effect, the L-basis VVB was converted into diagonal (D), circular (C), and random linear (RL) basis VVBs using the same common-path scheme. The variation of S_L for D- and C-basis VVBs is found to be similar, but distinctly different from that of L- and RL-basis VVBs. With increasing AP, the peak value of S_L decreases only for the D- and C-basis VVBs. In contrast, for RL-basis VVBs, the peak of S_L both decreases and shifts toward lower IP angles as AP increases. This behavior indicates that RL-basis VVBs exhibit a combined effect of L- and D-basis (or equivalently C-basis) VVBs.

Furthermore, the sharpness of the S_L variation near the Brewster angle is identical for D- and C-basis VVBs across all IP angles. For RL-basis VVBs, the variation of S_L about the Brewster angle is sharper at smaller IP angles, making them particularly suitable for detecting small variations in the refractive index of the prism.

Keywords: Vector vortex beams, Linear entropy, Brewster effect, Classical non-separability, Refractive index.