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Photon total angular momentum manipulation

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Abstract. As an inherent degree of freedom, total angular momentum (TAM) of photons consisting of spin angular momentum and orbital angular momentum has inspired many advanced applications and attracted much attention in recent years. Probing TAM and tailoring beam's TAM spectrum on demand are of great significance for TAM-based scenarios. We propose both theoretically and experimentally a TAM processor enabling tunable TAM manipulation. Such a processor consists of a set of quasi-symmetric units, and each unit is composed of a couple of diffraction optical elements fabricated through polymerized liquid crystals. Forty-two single TAM states are experimentally employed to prove the concept. The favorable results illustrate good TAM state selection performance, which makes it particularly attractive for high-speed large-capacity data transmission, optical computing, and high-security photon encryption systems.

Keywords: vortex beams; orbital angular momentum; spin angular momentum; total angular momentum tailoring.

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1 Introduction

The pioneering works of Beth and Mechanical¹ and Allen et al.² illustrated that photons can possess two distinct forms of angular momentums (AMs), spin angular momentum (SAM), and orbital angular momentum (OAM). SAM has two eigenvalues $\sigma = \pm 1$, corresponding to the right and left circular polarizations of a macroscopic beam,¹ while the eigenvalue l of OAM, also known as topological charge, can be any integer. The eigenvalue l determines the helical wavefront as $\exp(il\varphi)$, where φ is the azimuthal angle.^{2,3} Originally, researchers focused more on OAM beams, namely, optical vortices, due to their enormous potential in large-capacity data transmission,⁴⁻⁷ optical tweezers,⁸ rotation detection,⁹ and other applications.¹⁰⁻¹² Recently, photon total angular momentum (TAM),¹³ the sum of SAM and OAM under paraxial approximation, came into view. The most well-known TAM carried beam is a vectorial vortex beam featuring anisotropic polarization distribution and a complex wavefront.^{14,15} Currently, TAM has inspired many advanced applications, ranging from classical to quantum physics such as laser processing¹⁶ and motion detection.¹⁷ Moreover, TAM

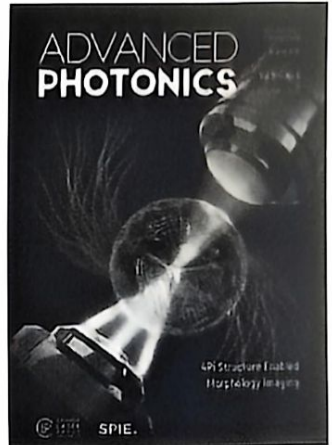
provides 2 degrees of freedom (DoFs), SAM and OAM; thus it is of great significance in achieving higher-dimensional entanglements.^{18,19}

Processing TAM components on demand is a crucial basis for TAM applications. In other words, for a TAM beam, one can extract corresponding TAM photons and drop out irrelevant TAM photons selectively, which can be regarded as a TAM filter, analogous to a common wavelength/frequency filter. Such manipulation is of great significance, especially as the receiver for TAM-based communications, remote detection, and optical computing. TAM filtration can be accomplished through simultaneous SAM and OAM filtration. SAM filtration is simple and can be implemented through polarization elements such as wave plates, whereas OAM filtration is intricate. In the past two decades, much effort has been devoted to excavating more effective schemes for OAM probing and extraction, for instance, by probing and recognizing OAM modes through diffraction optical elements (DOEs),²⁰⁻²⁵ interferometers,²⁶ neural networks,^{27,28} and so on. Various OAM sorters have also been developed such as the Mach-Zehnder interferometer²⁹⁻³¹ and log-polar transformation-based elements,³²⁻³⁶ enabling the tunable OAM filter.³⁷ Recently, metamaterials with polarization modulation characteristics have been introduced for photon SAM and OAM

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摘要

As an inherent degree of freedom, total angular momentum (TAM) of photons consisting of spin angular momentum and orbital angular momentum has inspired many advanced applications and attracted much attention in recent years. Probing TAM and tailoring beam's TAM spectrum on demand are of great significance for TAM-based scenarios. We propose both theoretically and experimentally a TAM processor enabling tunable TAM manipulation. Such a processor consists of a set of quasi-symmetric units, and each unit is composed of a couple of diffraction optical elements fabricated through polymerized liquid crystals. Forty-two single TAM states are experimentally employed to prove the concept. The favorable results illustrate good TAM state selection performance, which makes it particularly attractive for high-speed large-capacity data transmission, optical computing, and high-security photon encryption systems.

关键词

作者关键词: vortex beams; orbital angular momentum; spin angular momentum; total angular momentum tailoring
Keywords Plus: VECTOR BEAMS; POLARIZATION; GENERATION; SORTER; STATES; PHASE

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