Experimental generation of ring-shaped beams with random sources

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We have experimentally reproduced ring-shaped beams from the scattered Laguerre–Gaussian and Bessel–Gaussian beams. A rotating ground glass plate is used as a scattering medium, and a plano–convex lens collects the scattered light to generate ring-shaped beams at the Fourier plane. The obtained experimental results are supported with the numerical results and are in good agreement with the theoretical results proposed by Wang et al. [Opt. Express 17, 22366 (2009)]. © 2013 Optical Society of America

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Ring-shaped or dark hollow beams have found applications in guiding cold atoms [1] and trapping of low refractive index particles [2]. Such beams can be generated through multimode light wave guides [3], spiral phase plates [4], multimode fibers [5], and computer-generated holograms [6].

Optical vortices or the Laguerre–Gaussian (LG) beams with zero radial index have attracted a great deal of attention due to their applications in optical manipulation, optical communication, and quantum information [7,8]. These beams are recognized with a dark core in their intensity profile and a helical wavefront [9,10]. We have considered LG beams with zero radial index throughout this Letter. Bessel beams, owing to their interesting properties of propagation without an apparent spreading due to diffraction, have also been a subject of study for more than two decades [11]. Usually in a laboratory, the Bessel beams are generated using a Gaussian laser beam and termed as Bessel–Gaussian (BG) beams. In this Letter, we demonstrate the generation of ring-shaped beams from the scattered LG and BG beams.

The scattered light of a Gaussian laser beam through a rotating ground glass (RGG) plate can be modeled as a Gaussian Schell model (GSM) beam [5]. This GSM beam is partially coherent light which has Gaussian intensity distribution and Gaussian spectral degree of coherence. Recently, a lot of applications of partially coherent beams have been suggested in diverse areas [12]. Wang et al. [13] have introduced partially coherent LG beams of all orders. The temporal coherence properties of partially coherent beams generated by the scattering of optical vortices through a RGG plate have also been studied [14,15]. It has been shown that the decay of coherence becomes sharper with increase in the order of LG beam incident on the RGG plate. A similar type of behavior has been observed theoretically in the Fourier transform of the spatial correlation function of the Laguerre–Gaussian Schell model (LGSM) and the Bessel–Gaussian Schell model (BGSM) beams [16]. It has been stated that the beams have a rotational symmetry in the Fourier transform of their spatial correlation function and zero value on the beam axis can generate a dark core in the far field intensity distribution. Mei and Korotkov [16] generated ring-shaped beams with an arbitrary beam (including Gaussian beam) by introducing LG correlation function through a phase screen. We have experimentally generated ring-shaped beams with LG (BG) beams by introducing Gaussian correlation function through a RGG plate. The obtained experimental results are simulated by using the expression of cross-spectral density of the partially coherent beams generated by a Schell model source, and at z = 0 it is given by [13]

\[ W_{\mathbf{K}_1,\mathbf{y}_1;\mathbf{x}_2;\mathbf{y}_2;0} \propto \int_{\mathbf{K}_2,\mathbf{y}_2;0} \mathbf{K}_1 - \mathbf{x}_2;\mathbf{y}_1 - \mathbf{y}_2;0 \]

(1)

Here, \( L_{1}[\mathbf{K}_1,\mathbf{y}_1;0] \) and \( L_{2}[\mathbf{K}_2,\mathbf{y}_2;0] \) are the intensity distributions at the positions \( [\mathbf{K}_1,\mathbf{y}_1;0] \) and \( [\mathbf{K}_2,\mathbf{y}_2;0] \) respectively; \( \rho(\mathbf{K}_1 - \mathbf{x}_2;\mathbf{y}_1 - \mathbf{y}_2;0) \) is the spectral degree of coherence.

Our experimental setup for the generation of ring-shaped beams is shown in Fig. 1. An intensity-stabilized He–Ne laser beam of maximum power 1 mW and beam waist 0.3 mm is used to generate LG and BG beams. These beams are produced with computer-generated holography technique using a spatial light modulator (SLM). Different computer-generated holograms for generating different LG and BG beams are introduced to the

Fig. 1. Experimental setup for the generation of ring-shaped beams. M, mirror; BS, beam splitter; SLM, spatial light modulator; A, aperture; L1, L2, plano–convex lens.

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