Propagation

Ince-Gaussian Beams: The Third Family of Eigenmodes of Stable Laser Resonators

Miguel A. Bandres, Ulrich T. Schwarz and Julio C. Gutiérrez-Vega

Hermite–Gaussian beams (HGBs) and Laguerre–Gaussian beams (LGBs) have been studied extensively for more than 40 years.[1] Their numerous applications in science and engineering make them highly relevant and useful. HGBs and LGBs exhibit three important features: they are transverse eigenmodes of stable laser resonators; they constitute two complete families of exact and orthogonal solutions of the paraxial wave equation (PWE); and they do not change transverse shape on propagation, i.e., they are structurally stable. Because of the general relevance of Gaussian beams in optics, it is important to identify other orthogonal modes of stable laser resonators with no rectangular or circular symmetry.

In recent papers the existence of Ince–Gaussian beams (IGBs), which constitute the third complete family of transverse eigenmodes of stable resonators, was theoretically[2–4] and experimentally[5] demonstrated. These new modes are exact and orthogonal solutions of a PWE in elliptic coordinates and can be considered continuous transition modes between HGBs and LGBs. The transverse distribution of IGBs is described by Ince polynomials. Most of the propagating and resonating characteristics of HGBs and LGBs can be extended to IGBs. In addition to wavelength λ and waist size w_0 at plane $z = 0$, IGBs are characterized by two indices (p,m), the parity (even or odd), and a free continuous parameter ε that adjusts the ellipticity of the transverse shape of the beam.

Building on the theoretical research reported in Refs. 2 and 3, we have been able to produce IGBs experimentally with high fidelity.[5] To create IGBs, we used a self-built diode-pumped solid-state laser, the active medium of which was a $Nd:YVO_4$ crystal pumped at 808 nm. Output power was approximately $P_{out} = 20$ mW at an emission wavelength of $\lambda_0 = 1{,}064$ nm. To generate IGBs we slightly broke the symmetry of the resonator by shifting the output coupler sideways by several tens of micrometers. The intensity patterns shown in Fig. 1(a) and Ref. 5 provide, for the first time to our knowledge, experimental verification of this new class of beams. Note the excellent agreement with the theoretical patterns shown in Fig. 1(b). The patterns exhibit an inherent elliptical structure. Index m defines the number of hyperbolic nodal lines, and $(p - m)/2$ is the number of elliptic nodal lines.

A suitable superposition of even and odd IGBs with the same pair of indices (p, m) makes it possible to construct helical IGBs the phase of which rotates elliptically around the line that joins the foci of the ellipses; see Fig. 1(c). A field of this kind carries orbital angular momentum and exhibits multiple vortices. Both are attractive properties for potential applications in optical tweezers and particle trapping. Our results extend the fundamental theory of high-order Gaussian beams by adding the new IGBs to the well known HGBs and LGBs.

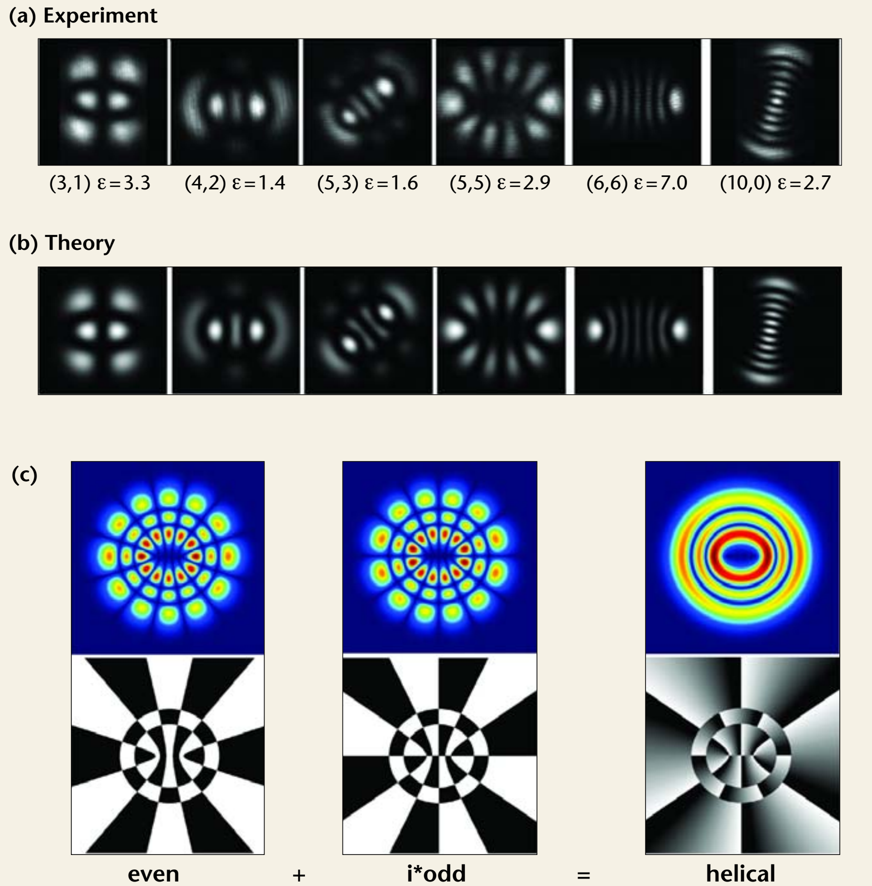

Figure 1. (a) Experimental and (b) theoretical intensity patterns of even IGBs. (c) Transverse amplitudes and phases of stationary even and odd IGBs ($p = 10$, $m = 6$) at the waist plane and the corresponding helical IGB.

Miguel A. Bandres and Julio C. Gutiérrez-Vega (juliocesar@itesm.mx) are with the Photonics and Mathematical Optics Group, Tecnológico de Monterrey, México. Ulrich T. Schwarz is with Naturwissenschaftliche Fakultät II-Physik, Universität Regensburg, Regensburg, Germany.

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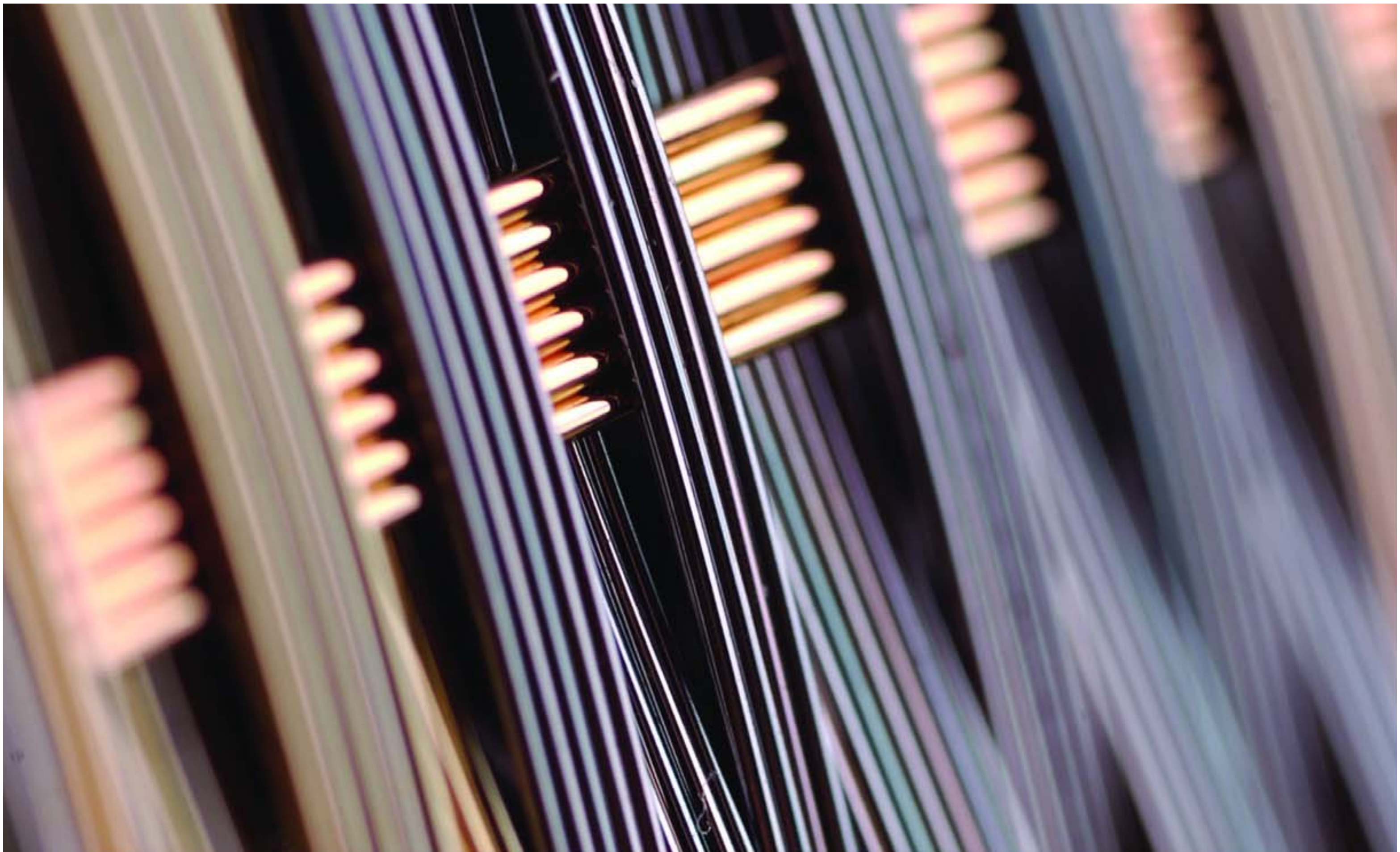

Optics in 2004

Guest Editors: Bob D. Guenther
David Hardwick, Changsheng Li and R. John Koshel

The December *Optics & Photonics News* (OPN) is a special issue that highlights the most exciting research to emerge in the preceding 12 months in the fast-paced world of optics.

"Optics in 2004" offers readers a unique opportunity to access, in a single source, descriptions of cutting-edge optics research reported in the peer-reviewed press. The areas covered in this year's special issue range from semiconductor optics to nanophotonics and from optical engineering to ultrafast technology. This year's issue comprises 31 summaries that represent the work of 155 authors.

A record number of research groups submitted summaries to "Optics in 2004": there were 104 submissions this year, representing the work of 414 authors. This was a significant increase over the total of 61 submissions to "Optics in 2003."

This year as in previous ones, submissions were judged on the basis of the following requirements:

- the accomplishments described had to have been published in a refereed journal in the year prior to publication in OPN;
- the work had to be illustrated in a clear, concise manner, readily accessible to the at-large optics community.

In addition, the authors were asked to describe the topical area as a whole and to detail the importance of their work in that context.

Although OPN makes every effort to ensure that achievements in all optics subfields are recognized, there are no requirements in the selection process for inclusion of specific topical areas. When a large number of submissions is received for a specific area, it is taken as evidence that the topic has been fertile ground for activity and research. OPN strives to ensure that engineering, science and technology are all represented. The number of papers accepted overall is limited by space.

OPN and OSA would like to thank the hundreds of researchers from around the world who submitted summaries of their peer-reviewed articles to "Optics in 2004."

OSA and the OPN staff would like to take this opportunity to express their heartfelt thanks to the panel of OPN Editorial Advisory Committee members who vetted submissions to "Optics in 2004": Bob D. Guenther (Optics in 2004 Panel Chair), Physics Department, Duke University; David Hardwick, Confluent Photonics Corporation; Changsheng Li, Hong Kong Polytechnic University; R. John Koshel, General Dynamics C4 Systems.

(*Background image*) Each fiber in the spectrometric fabric is a photodetector sensitive to external illumination at a particular wavelength range. Credit: Greg Hren Photography-RLE/Fink Lab, Massachusetts Institute of Technology. [From Nature **431**, 826-9, Oct. 2004.]