Session 4pPA

Physical Acoustics and Biomedical Acoustics: Interactions of Sound Beams with Objects II

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Invited Papers

1:00

4pPA1. Strongly focused vortex beams by using flat Fresnel-spiral lenses. Noé Jiménez (Instituto de Instrumentación para Imagen Molecular (I3M), Consejo Superior de Investigaciones Científicas (CSIC), Edificio 8B, Acceso N, 1[a] Planta, Camino de Vera s/n, Valencia 46022, Spain, nojigon@upv.es), Vicente Romero-Garcìa (Laboratoire d'Acoustique de la Université du Mans UMR 6613, CNRS, Le Mans cedex 9, France), Lluis M. García-Raffi (IUMPA, Universitat Politècnica de València, València, Spain), Francisco Camarena (Instituto de Instrumentación para Imagen Molecular (I3M), Universitat Politècnica de València, Valencia, Spain), and Kestutis Staliunas (ICREA, Universitat Politècnica de Catalunya, Tarrasa, Spain)

We report geometrically-optimal diffraction gratings for sharp vortex beam focusing using Fresnel-spiral curves. The lenses are built based on the Fresnel-spiral, a spiral curve that combine the focusing properties of Fresnel zone plates and the phase dislocations produced by spiral gratings. On the one hand, the constructive and destructive interferences between open and opaque zones in the grating, in analogy to the Fresnel zone plate, allow sharp beam focusing. On the other hand, the spiral shape of the grating retains the helicity, rotating the phase of the diffracted waves and creating a phase dislocation along the axis. This allows the generation of geometrically optimal focused vortex beams, enhancing the field intensity at the focus up to 170 times. In particular, this system offers a tunable topological charge of the vortex beam by using different arms in the Fresnel-spiral diffraction grating, being the topological charge equal to the number of arms. Two different Fresnel-spiral diffraction gratings with topological charge of 1 and 5 are experimentally tested showing excellent agreement with theory and simulations. These diffraction gratings will allow the design of effective wave-matter interaction systems, with direct applications in industry and biomedical engineering.

1:20

4pPA2. Bessel beam superposition for analyzing off-axial scattering, forces, and torques. Likun Zhang (Univ. of MS, 145 Hill Dr., Oxford, MS 38677, zhang@olemiss.edu)

Illumination of an arbitrary-order Bessel beam on an off-axial object is expanded as illuminations of a series of Bessel beam components of different orders on an axially centered object [L. Zhang, J. Acoust. Soc. Am. 143(5), 2796–2800 (2018)]. The expansion follows from a parallel-axis relation that is derived as a generization of Graf's addition theorem of Bessel functions. The off-axial Bessel beam expansion enables to understand the off-axial scattering, forces, and torques in terms of superposing that in the on-axial illuminations by the series of beam components. The superposition reveal negative axial radiation force and negative radiation torque in terms of contributions of different beam components in the on-axial configuration. The exact locations of the object for torque direction reversal are analytically identified for a small particle. The superposition also reveals that the off-axial radiation torque on a small particle exists even for higher-order vortex beams or vortices.

1:40

4pPA3. Expansion of linear focused sound fields using Bessel beams. Timothy D. Daniel (Phys., WSU, Phys. and Astronomy Dept., Washington State Univ., Pullman, WA 99164, timothy.daniel@email.wsu.edu), Ivars P. Kirsteins (NUWCDIVNPT, Newport, RI), and Philip L. Marston (Phys., WSU, Pullman, WA)

Previous work on scattering by Bessel beams shows that expansion of incident sound fields in term of these beams has application to scattering [P. L. Marston, J. Acoust. Soc. Am. 122, 247–252 (2007)]. In this work, we expand a focused cylindrically symmetric sound field in terms of Bessel beam components. In particular, the authors are interested in a focused beam radiated from a spherical cap source. A physical optics model is applied to sound propagation close to the source to facilitate the calculation of the Bessel beam expansion coefficients. This type of model is useful for focused scattering [P. L. Marston and D. S. Langley, J. Acoust. Soc. Am. 73, 1464–1475 (1983)]. Once the expansion coefficients are found the sound field can be evaluated by the appropriate superposition. The model gives results in agreement with O'Neil [H. T. O'Neil, J. Acoust. Soc. Am. 21, 516–526 (1949)] and Chen [X. Chen, K. Q. Schwarz and K. J. Parker, J. Acoust. Soc. Am. 94, 2979–2991 (1993)]. Comparison is also made with direct integration of a Kirchhoff integral for both on and off axis pressures with good agreement. [Work supported by ONR.]