8:55

3aBAa3. Analytical expressions of second harmonics in the far fields of vortex beams. Chirag A. Gokani (Appl. Res. Labs. and Walker Dept. of Mech. Eng., Univ. of Texas at Austin, P.O. Box 9767, Austin, TX 78766-9767, cgokani@arlut.utexas.edu), Randall P. Williams, and Mark F. Hamilton (Appl. Res. Labs. and Walker Dept. of Mech. Eng., Univ. of Texas at Austin, Austin, TX 78766-9767)

Second harmonics generated by acoustic vortex beams are difficult to describe analytically due to mathematical complications introduced by the dependence of the field on the azimuthal angle ϕ. However, for a spherically spreading wave with wavenumber k, directivity D, and velocity amplitude u_0 at radius $r = a$, the complex pressure of the second harmonic for $kr \gg 1$ and $|\nabla D| \ll k$ is $p_2 = i\beta\rho_0 {u_0}^2 k a^2 \ln(r/a) D^2 e^{-2i\omega\tau}/2r$, where β is the coefficient of nonlinearity, ρ_0 is the ambient fluid density, ω is angular frequency, and τ is retarded time [Westervelt and Radue, *JASA* **33**, 1672 (1961)]. For a Gaussian velocity source with orbital number $\ell > -2$, $D(\theta, \phi) = \pi^{1/2}(ka)^3 \sin(\theta) e^{-\chi} [I_{(\ell-1)/2}(\chi) - I_{(\ell+1)/2}(\chi)] e^{i\ell(\phi-\pi/2)}/8$, where I_ν is the νth-order modified Bessel function, $\chi = (ka \sin\theta)^2/8$, and θ is the polar angle. For a circular piston with the same phase dependence, $D(\theta, \phi) = F_\ell(ka \sin\theta) e^{i\ell(\phi-\pi}/2)/\sin^2\theta$, where F_ℓ is given by Eq. (7) of Gokani *et al.*, *JASA-EL* **4**, 124001 (2024). Comparison with numerical solutions of the Westervelt equation shows that p_2 accurately predicts the vortex ring amplitudes and radii of the second harmonics for $z \gtrsim 2z\mathrm{R}$, where $z_\mathrm{R} = ka^2/2$, despite the presence of near-field effects in that region. The expressions become increasingly accurate for $\ln(z/z_\mathrm{R}) \gg 1$.

9:10

3aBAa4. Multi-feature acoustic vortex characterization and automated quality classification via physics-informed ensemble model. Chadi Ellouzi (Dept. of Mech. Eng., Rowan Univ., 201 Mullica Hill Rd., Rowan Hall 212, Glassboro, NJ 08028, chadie17@rowan.edu), Farhood Aghdasi, and Chen Shen (Dept. of Mech. Eng., Rowan Univ., Glassboro, NJ 08028)

Acoustic vortices carrying orbital angular momentum are central to emerging technologies in particle manipulation, acoustic trapping, imaging, and high-capacity communication. However, objective and repeatable evaluation of vortex quality remains an open challenge, with current practices relying on visual inspection or isolated metrics that are highly sensitive to fabrication defects and measurement noise. This work presents a physics-informed, automated framework for the quantitative assessment of acoustic vortex quality. A compact six-parameter descriptor set is introduced to capture vortex geometry, symmetry, phase continuity, and angular momentum distribution in a physically interpretable manner. Using a combination of simulated and experimentally measured fields, a statistically consistent synthetic dataset comprising 2000 vortex realizations is generated to span a wide range of quality conditions. A supervised random forest model trained on this dataset achieves 98.45% classification accuracy across four defined vortex-quality categories. Validation using independent experimental measurements demonstrates strong robustness to noise and structural asymmetries. The proposed framework provides a standardized and scalable solution for acoustic vortex metrology, enabling real-time diagnostics and quality control in vortex-based manipulation, imaging, and orbital angular momentum communication systems.

9:25–9:40 Break

Invited Papers

9:40

3aBAa5. Preliminary results of kidney stone comminution using acoustic vortices. Sergio Maldonado-Ortega (Instituto de Instrumentación para Imagen Molecular (i3M), Universitat Politècnica de València (UPV)—Consejo Superior de Investigaciones Científicas (CSIC), Camino de Vera S/N, València 46022, Spain, smalort@upv.es), Enrique González-Mateo, Alejandro Cebrecos (Instituto de Instrumentación para Imagen Molecular (i3M), Universitat Politècnica de València (UPV)—Consejo Superior de Investigaciones Científicas (CSIC), Camino de Vera S/N, 46022, València, Spain), Brenda Morant-Ferrando (Instituto de Investigación Sanitaria La Fe (IIS La Fe), València, Spain), Cesar D. Vera-Donoso (Universidad Católica San Vicente Mártir, València, Spain), Alicia Carrión, Francisco Camarena, and Noé Jiménez (Instituto de Instrumentación para Imagen Molecular (i3M), Universitat Politècnica de València (UPV)—Consejo Superior de Investigaciones Científicas (CSIC), Camino de Vera S/N, 46022, Valencia, Spain)

Ultrasound-based therapies such as extracorporeal shock wave lithotripsy (ESWL) or burst wave lithotripsy (BWL) are used for kidney stone comminution. However, these techniques employ conventional focused beams of mechanical waves. In this work, we explore the use of focused acoustic vortex beams for kidney stone fragmentation. Unlike conventional focused beams, acoustic vortices exhibit helical phase distribution with embedded phase dislocations that carry pseudo-orbital angular momentum. These fields can be generated with spherical phased-array systems, enabling beam steering and control of the vortex topological charge. An experimental study was conducted in a water tank using a 128-channel therapeutic phased-array transducer operating at 1.1 MHz. Excitation consisted of short sinusoidal bursts of 20 cycles delivered at a repetition rate of 200 Hz. Real-time targeting and monitoring were achieved using a confocal 128-element imaging probe, while a camera recorded the fragmentation process. Both artificial stone phantoms (BegoStone) and human calculi were tested. Fragmentation outcomes obtained with single-topological-charge vortices were compared with those produced by standard BWL under conditions of equal peak rarefaction pressure and equal acoustic energy. The vortex-based approach consistently reduced fragmentation time by at least half for all stone types. Furthermore, the distributed focal structure of vortex beams resulted in a lower mechanical index, suggesting a reduced likelihood of damage to surrounding tissue.