high-image-density particle image velocimetry allows the instantaneous and phase-averaged patterns to be referenced to passage of the free-surface of the wave. These patterns are interpreted for a range of Keulegan-Carpenter number KC = 7 to 18 at a fixed value of the Stokes number beta = 164. The wavelength, peak vorticity, and circulation of the three-dimensional structures are related to variations of KC and, despite this complex structure, the quasi-two-dimensional patterns of vorticity and streamline topology exhibit a number of features in close accord with those obtained in previous investigations using qualitative flow visualization.

16:38

JH 7 Fluidic-Driven Ducted Heat Ejector* DONAVON GERTY, RAGHAV MAHALINGAM, ARI GLEZER, *Georgia Institute of Technology* A high-aspect ratio miniature air duct is developed for forced convection heat rejection from electronic hardware within sealed enclosures. Relatively high heat transfer coefficient is achieved at low volume flow rates by a thin oscillating reed that is mounted across the span of the duct, parallel to its (wide) walls. The flow is induced by the time-periodic shedding of tip vortices at the edge of the reed which continue to propagate downstream along the duct. The interaction of these vortices with vorticity concentrations along the duct surfaces and the structure of the ensuing flow are investigated using high-resolution phase-locked and time-averaged particle image velocimetry. The dependence of the global flow and heat transfer from the duct walls on the frequency and amplitude of the reed motion are also characterized.

*Supported by NSF.

16:51

JH 8 Viscous critical layer analysis of vortex normal modes STÉPHANE LE DIZÈS, *IRPHE, 49 rue F. Joliot Curie, B. P. 146, F-13384 Marseille cedex 13, France* The properties of viscous and inviscid approximations of 3D normal modes of an axisymmetrical vortex with axial flow are examined in the limit of large Reynolds numbers. These approximations are known to exhibit critical point singularities. In this work, these singularities are resolved in a viscous critical layer. We demonstrate that the viscous critical layer analysis is similar to what has been done for stratified shear flows with unitary Prandtl number. The analysis provides the matching conditions of the different approximations across the critical points, as well as the Stokes multipliers. The results are applied to the Batchelor vortex. As an illustration, it is shown how approximations of viscous centre modes can be constructed.

17:04

JH 9 Particle transport by a vortex soliton YOSHI KIMURA, *Graduate School of Mathematics, Nagoya University* SOUJI KOIKARI, *Theory and Computer Simulation Center, National Institute for Fusion Science* Motions of fluid particles advected by a 3D vortex soliton are studied. In the moving frame which makes the vortex soliton steady in space, the motion of a particle is governed by a differential equation that includes the Biot-Savart integral. We can observe that particles are confined in a torus near the loop of the vortex soliton for a wide range of three parameters that characterize the shape and the strength of the soliton. The transported volume, defined as the volume surrounded by the outmost torus, is calculated numerically as a function of these parameters. The torus is composed of groups of invariant surfaces around periodic trajectories. Although the system is not a Hamiltonian, similar phenomena can be observed with the KAM tori for non-integrable Hamiltonian systems. To extract and model the essential mechanism of the transport properties, an ODE dynamical system is proposed which is named ''chopsticks model.'' This model can explain the qualitative features of the transport phenomena well.

17:17

JH 10 Vortex dynamics of particle-wall collisions THOMAS LEWEKE, *IRPHE-CNRS, Marseille, France* MARK C. THOMPSON, *Monash University, Melbourne, Australia* KERRY HOURIGAN, *Monash University, Melbourne, Australia* We present results from an experimental and numerical study of the flow generated by a particle impacting onto a solid wall at low Reynolds numbers. Experimentally, a 3/4″ bronze sphere attached to an inelastic string was lowered onto a Plexiglas plate inside a glass tank, using a stepper motor. Direct Numerical Simulations were carried out using either an axisymmetric or a fully 3D spectral-element code. The parameters varied were the running distance before impact, the sphere Reynolds number during motion, and the stopping distance away from the wall. For running lengths less than 7.5 diameters, the sphere wake remains axisymmetric in the form of an attached vortex ring. At impact, this ring overtakes the sphere and spreads out along the wall. When the sphere stops more than 0.3 diameters away from the wall, the secondary vorticity generated at the sphere surface rolls up into a second vortex ring persisting over a long time. At Reynolds number above 1000, the flow after impact exhibits a 3D instability with azimuthal wave numbers of around 20. Flow visualizations, vorticity fields, and quantitative information on the flow topology will be shown to illustrate the different regimes. The effect of a rebound of the sphere is also discussed.

17:30

JH 11 Instability of a columnar vortex in stratified fluid BENJAMIN CARITEAU, JAN-BERT FLOR, *LEGI-CNRS, Grenoble, France* We experimentally investigate the stability of a monopolar columnar vortex in a linearly stratified fluid. The vortex was generated by a single flap of which the rotation about the vertical axis was accelerated and subsequently decelerated, resulting in an approximately Gaussian vorticity profile. The Reynolds number Re =UR/n was of order O(1000), with U the maximum azimuthal velocity and R the corresponding radius, while the Froude number Fr=U/(RN), with N the buoyancy frequency, ranged between 0.5 and 5. Though these vortices are centrifugally and elliptically stable for Fr<2, they are unstable due to a resonant interaction between inertial and gravitational oscillations that occur near the radius where the angular velocity approaches N. This instability is apparent as a helical wave, of which the wavelength varies monotonically with F. To our knowledge this instability has not been observed before, and differs from the so-called zigzag instability observed by Billant and Chomaz (2000).

17:43

JH 12 KINEMATIC AND THERMAL CONTROL OF VORTEX BREAKDOWN MIGUEL A. HERRADA, *Escuela Superior de Ingenieros, Universidad de Sevilla, Sevilla, Spain* VLADIMIR SHTERN, *Department of Mechanical Engineering, University of Houston, Houston, TX 77204-4006, USA* It is shown that a combination of additional near-axis swirl and temperature gradients can efficiently control vortex breakdown (VB). The numerical analysis of a flow in a cylindrical container driven by a rotating bottom disk reveals the underlying mechanisms of such kinematic and thermal control. The analysis explains experimen-