Nonlinear Waves along a Torus of Fluid

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Linear and nonlinear waves have been extensively studied both experimentally and theoretically in the context of straight geometries. On the other hand, curved interfaces such as toroidal drops are ubiquitous in nature, but are unstable, making them difficult to control. They have been observed under laboratory conditions, such as Leidenfrost levitation, but in a non-stationary regime. By means of an original technique we have achieved a stable and stationary torus of liquid, deposited on a superhydrophobic substrate which allows for a systematic study of waves along its inner and outer border under both curved and periodic conditions [1,2].

In order to study linear waves, the torus is excited using a Teflon wavemaker connected to a shaker, and the forcing frequency is linearly varied in time from 0 to 20 Hz. The torus is recorded from above and using a border detection algorithm the displacements $\eta(\theta, t)$ of the two borders are extracted. The Fourier transform of the displacements, $\tilde{\eta}(k_\theta, \omega)$ allows us to study the dispersion relation of the torus, yielding a rich spectral signature in the form of varicose, sinuous and sloshing modes [1]. We have been able to discern from this a dispersion relation for gravity-capillary waves along the torus borders.

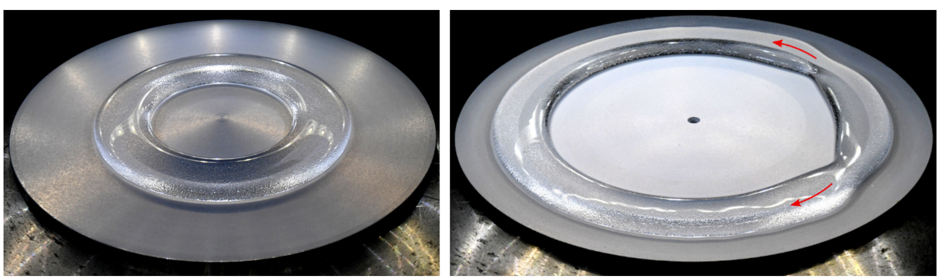

Figure 1. Left : A stationary torus of fluid of outer radius $R_o = 4.8$ cm on a superhydrophobic substrate. Right : Two counter-propagating solitons along each border of a torus with radius $R_o = 7.9$ cm.

Nonlinear waves in form of solitons are found to propagate along the torus borders for sufficiently strong forcing amplitudes. By using a linear actuator instead of the shaker, we generate two counter-propagating solitons along each border. We stress the observation of subsonic elevation solitons which are due to the periodicity of the system. These effects are explained by applying periodic boundary conditions to a Korteweg-de Vries equation yielding a non-trivial and nonlinear dependence of the soliton velocity on its amplitude but also torus curvature.

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Références

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2. F. Novkoski, C.-T. Pham & E. Falcon, Experimental Periodic Korteweg-de Vries solitons along a torus of fluid, submitted to *Phys. Rev. Lett.*, (2022).