

Nonlinear hydrodynamics on a chip: wave breaking and multisoliton fission in a superfluid waveflume

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In this poster I will present research interfacing cavity optomechanics and superfluid physics for the study of nonlinear wave phenomena.

Building upon our previous work in superfluid optomechanics [1], I will present a novel sensor architecture formed by covering nanofabricated silicon photonic crystal beams with a thin superfluid helium-4 film. This creates an optically addressable quasi-one-dimensional wave tank containing a few femtoliters of superfluid helium, upon which waves can be generated, propagate and be readout.

Superfluid helium's characteristics present a unique opportunity for the study of nonlinear wave propagation. Indeed, thanks to superfluid helium's vanishing viscosity, the depth of the film h can readily be made as small as a few nanometers without wave attenuation—something impossible to do with classical fluids. Our platform thus enables us to generate waves whose aspect ratio (defined as the wavelength over depth λ/h) exceeds 10,000:1, two orders of magnitude larger than that achievable in the world's largest wave tanks and exceeding that of the most extreme terrestrial phenomena such as tsunamis. This, combined with our recently developed ability to engineer strong fountain pressure forces [2], now allows us to combine within a single device high spatial and temporal resolution along with strong actuation capabilities.

Leveraging these unique characteristics, I will show how our superfluid wave tank enables us to generate and measure (within a sub-millimetre-sized device in a laboratory setting) a rich variety of superfluid nonlinear wave phenomena for the first time, including wavebreaking, multisoliton fission and optomechanical dissipative solitons [3] - opening up the way for the study of extreme regimes of nonlinear hydrodynamics on a chip.

[1] X. He et al., *Nature Physics* 16, 4 (2020); Y. P. Sachkou et al., *Science* 366, 1480 (2019), G. Harris et al, *Nature Physics* 12, 8 (2016) ; W. W. Wasserman et al., *Opt. Express* 30, 30822 (2022) ; C. Baker et al., *New J. Phys* 18, 123025 (2016)

[2] A. Sawadsky et al., *Science Advances* 9, eade3591 (2023)

[3] J. Zhang et al., *Optomechanical Dissipative Solitons*, *Nature* 600, 75 (2021)