Polariton Fluids as Quantum Field Theory Simulators on Tailored Curved Spacetimes

K. Falque,* J. Hameury , M. Jacquet, K. Guerrero, E. Giacobino

Laboratoire Kastler Brossel, Sorbonne Université, CNRS, Ecole Normale Supérieure PSL, Collège de France. 4 Place Jussieu, 75005 Paris. France

Quantum field theory (QFT) in curved spacetimes predicts the amplification of field excitations and the occurrence of classical and quantum correlations, as in the Hawking effect for example [1]. This raises the interest for experiments in which the curvature of spacetime can be controlled and amplification measured, as in fluids going from sub- to supersonic speeds where acoustic excitations are effectively trapped inside an acoustic horizon. [2] Quantum fluctuations of the acoustic field are predicted to yield entangled emission across the horizon, as in black holes. Here we introduce such a QFT simulator in a one-dimensional polaritonic fluid of light. We demonstrate the unique tunability of our system by engineering smooth and steep horizons, which respectively have quasi-thermal, but weak, and strong Hawking radiation. We measure the spectrum on either side of the horizon and evidence the excitation of negative energy waves in fluids of light for the first time. Notably, we explicitly show that, beyond phononic excitations as in other systems, our simulator also supports excitations with a massive, relativistic dispersion. In the future, quantum optics techniques offer the possibility to measure entanglement in unexplored regimes, giving insight in this outstanding prediction of relativistic QFT.

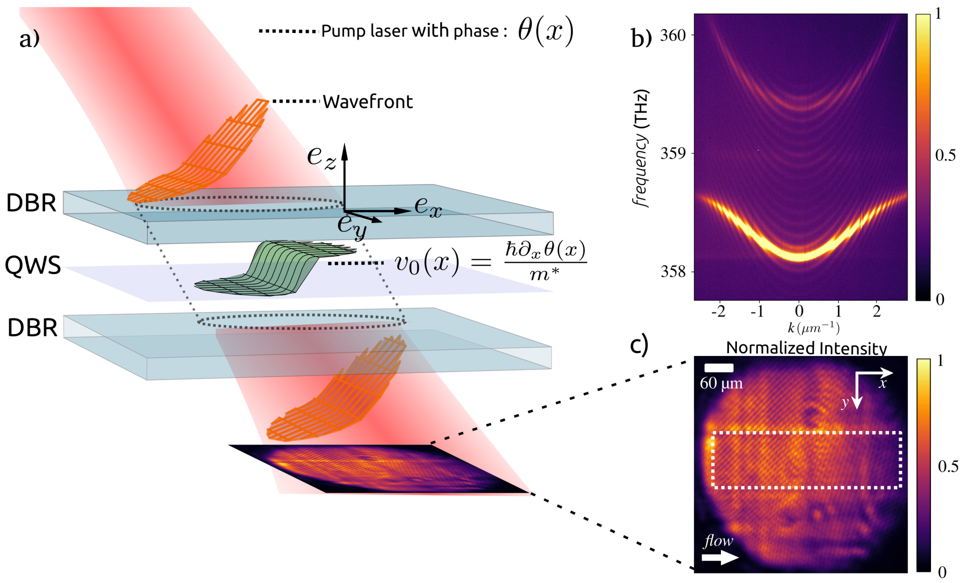

Figure 1: Simplified scheme of the generation of a transonic fluid. a) The pump laser is shapped with the target phase profile and sent on the microavity The corresponding fluid velocity field is represented by the black surface lying on the Quantum Wells (QWs). c) The outgoing photons are collected and the sample plane is imaged on a CCD camera to obtain the fluid density map. b) Measured Lower and Upper polariton dispersion at the working point $C6-D6$ at which the experiment was run. By fitting this dispersions, the effective LP mass can be extracted = 7.0×10^{-35} kg

References

[1] R.M Wald Qunatum field theory in curved Space-Time and black hole thermodynamics Chicago lecturs in physics (1995)

[2] W.G Unruh , Experimental black hole evaporation . Phys Review Letters. 46,1351 (1981)

*E-mail: alberto.bramati@lkb.umc.fr