Spontaneous emission in optical analogue gravity systems

Friedrich Koenig[a*] and Maxime Jacquet[a,b]

a. School of Physics and Astronomy, SUPA, University of St. Andrews, North Haugh, St. Andrews, KY16 9SS, United Kingdom
b. Vienna Center for Quantum Science and Technology, Faculty of Physics, University of Vienna, Boltzmanngasse 5, Vienna, A-1090, Austria

* fewk@st-andrews.ac.uk'

Quantum fluctuations in curved space-time cause the emission of particles. Under certain conditions, event horizons can create one-way doors, as in the case of black holes. Here we investigate and demonstrate the role of event horizons for the production of entangled pairs in a dispersive analogue system. We find that horizons lead to an order of magnitude increase in the pair production, strong and purified quantum correlations, and a characteristic shape of the photon emission spectrum.

We consider a moving refractive index perturbation in an optical medium, which exhibits optical event horizons. Based on the field theory in curved space-time we formulate an analytical method to calculate the scattering matrix that completely describes mode coupling leading to the emission of photon pairs in various configurations. We quantify the emission by the emission spectrum and the spectrally resolved photon number correlations, as they would be observed in the laboratory. Moreover, we apply our method in a case study, in which we consider a moving refractive index step in bulk fused silica. We calculate the emission flux in the moving frame as well as in the laboratory frame. The flux from horizons is particularly enhanced and carries a signature spectral shape. In both frames, we observe significant spectral quantum correlations between modes of opposite norm, evidence of their vacuum origin. If the modes form horizons, the correlation with the partner photon mode increases and approaches unity. These methods and findings pave the way to the observation of particles from the event horizon in optical systems. Furthermore, they will be relevant in a number of other optical and non-optical systems exhibiting horizons.