Optical Analogue of the Event Horizon

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The quantum physics of black holes cannot be observed in astrophysics, but laboratory analogies may, literally, shed light on it. In this lecture I describe the state of the art in establishing optical analogues of the event horizon. What is it about? Stephen Hawking [1] predicted in 1974 that black holes are not black as a consequence of quantum physics, but send out thermal radiation. Hawking's prediction is consistent with Jacob Bekenstein's ideas on black-hole thermodynamics [2] and has been one of the intellectually most influential results of theoretical physics: it gives a tantalising view into a possible connection between general relativity, quantum physics and thermodynamics. Unfortunately, the thermal radiation of realistic black holes is much too feeble to be observable in astrophysics, and so Hawking radiation seemed destined to remain theory, were it not for recent ideas and experimental progress on analogues of the event horizon. These are not real black holes, but analogues that behave similar to the event horizon. Such analogues have been inspired by William Unruh [3] in 1981, but only recently they entered a stage where direct experimental observations are possible. In my opinion, the most promising analogues of the event horizon are optical ones, because the quantum features of light are the easiest to detect. In 2004 I developed an idea of using nonlinear fiber optics for creating analogues of the even horizon. Here an ultrashort light pulse acts like a moving medium, establishing horizons when the speed of the pulse matches the group velocity of a probe wave. Hawking radiation is created when the pulse also exceeds the phase velocity of another partner wave that shares the same frequency in the co-moving frame. In 2008 we published the idea and first experimental steps [4]. In 2010 Daniele Faccio's group observed a first indication of radiation created by the pulse exceeding the phase velocity of light [5], which, however was most probably due to an optical undulation instability. In 2012 both his and my group observed the creation of light with negative frequencies [6], an effect closely related to Hawking radiation. The lecture shall explain these ideas and experiments.

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