Demonstration of an optical event horizon in a silicon nanophotonic waveguide

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The optical analog of an event horizon, in which an intense optical soliton propagating in a nonlinear waveguide prevents a weak probe wave travelling at a different velocity from passing through it, has recently attracted a lot of attention for theoretical similarities with general relativity as well as for potential applications [1,2]. Among others, it has been shown that the strong light-light interaction occurring at the optical event horizon can be exploited for high efficient frequency conversion [3] or for the realization of useful all-optical transistors [4]. Here we demonstrate, to the best of our knowledge, the first optical analog of an event horizon in integrated photonic nonlinear structures, through the reflexion of a continuous wave (CW) on an intense pulse.

We use a 7 mm-long, 800 nm-wide silicon-on-insulator waveguide with standard 220 nm silicon thickness, which has a zero dispersion wavelength located around 1710 nm. At the input, we launch an intense pump pulse (200 fs, 82 MHz) at 1940 nm together with a weak continuous probe wave at 1540 nm. The later wavelength is chosen close to the wavelength that is group velocity matched with the soliton at 1940 nm [~1550 nm, see in Fig. 1(b)]. Experimental output spectra are plotted in Fig. 1(a) in the range 1.2-1.7 µm, i.e. up to the wavelength cut-off of our optical spectrum analyzer. As previously shown [5], pulses propagating at high input peak power in the anomalous dispersion region lead to the generation of supercontinua (SC) through self-phase modulation and soliton splitting around the pump wavelength, and through dispersive wave generation in the normal dispersion region (at 1325 nm in our experiment, see blue curve). When the weak CW wave (black curve) is added, we clearly observe a frequency conversion from the probe wave to an idler wave at 1564 nm (red curve), i.e. on the other side of the group velocity matched wavelength. This frequency conversion is in agreement with the nonlinear interaction predicted to take place at optical event horizon [see Fig. 1(b) where the wavenumber (D), expressed in the soliton moving reference frame, has been plotted]. Note that in our experiment, the probe wave is CW. The frequency conversion is thus not expected to be efficient [3]. Moreover, as theoretically shown in Ref. [2], the resonance condition setting the frequency conversion yields to the interchangeability of the probe and the idler. This is remarkably shown in the results reported in Fig. 1(c), where the probe wavelength is set to 1540 nm and 1564 nm, and the reflexion observed at 1564 nm and 1540 nm, respectively.

These results confirm the experimental demonstration of the optical analog of an event horizon. They are of great interest for future realizations of low power all-optical functionalities in integrated photonic chips.

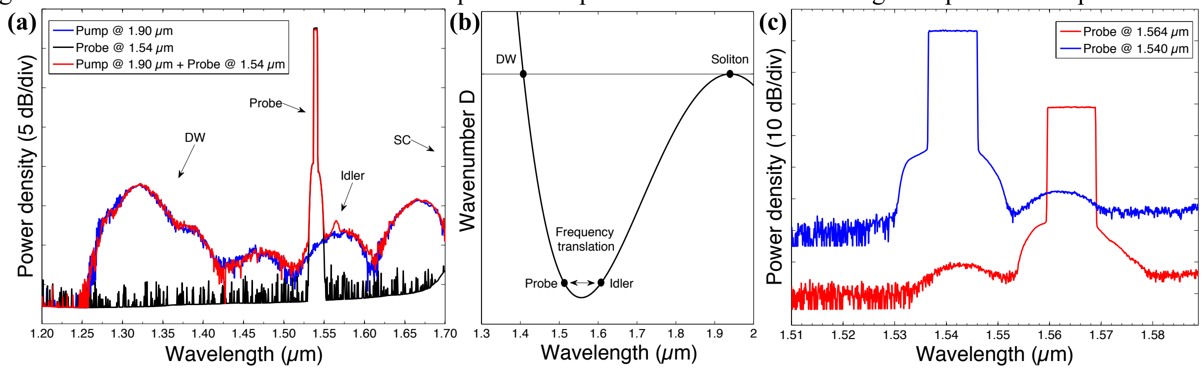

Fig. 1 (a) Experimental output spectra for the demonstration of the optical analog of an event horizon. (b) Wavenumber D as a function of the wavelength computed from the theoretical dispersion curve. (c) Experimental spectra highlighting the intercheangability of probe and idler. Note that the blue spectrum has been shifted by 20 dB for clarity.

References

[1] T. Philibin, C. Kuklewicz, S. Robertson, S. Hill, F. König, and U. Leonhardt, "Fiber-optical analog of the event horizon," Science, **319,** 1286 (2001).

[2] K. E. Webb, M. Erkintalo, Y. Xu, N. G. R. Broderick, J. M. Dudley, G. Genty, and G. Murdoch, "Nonlinear optics of fibre event horizons," Nat. Commun. **5**, 4969 (2014).

[3] L. Tartara, "Frequency shifting of femtosecond pulses by reflection at soliton," IEEE J. Quant. Elec., **48,**1439 (2012).

[4] A. Demircan, Sh. Amiranashvili, and G. Steinmeyer, "Controlling light by light with an optical event horizon," Phys. Rev. Lett., **106,** 163901 (2011).

[5] F. Leo, S.-P. Gorza, J. Safioui, P. Kockaert, S. Coen, U. Dave, B. Kuyken, and G. Roelkens, "Dispersive wave emission and super-continuum generation in a silicon wire waveguide pumped around the 1550 nm telecommunication wavelength," Opt. Lett., **39,** 3623 (2014).

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