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Optical Nonlinear Propagation Dynamics in Silicon Photonic Wire Waveguides

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Extended Abstract

Photonics in silicon-on-insulator (SOI) platform has been the focus of a considerable number of research works in the past decades as it is seen as a key technology enabling the integration of highly complex optical circuits for making inexpensive optical devices. Moreover, silicon nanowire waveguides exhibit one of the largest nonlinear third order coefficient ($\approx$300 $\mathrm{W^{-1}m^{-1}}$), making them ideal candidates for efficient integrated nonlinear devices, or as a platform for studying nonlinear propagation dynamics of optical waves. Here we report on our recent works, performed in silicon nanowire waveguides, on the generation of optical supercontinuum (SC) at telecommunication wavelengths around 1550 nm, as well as on the nonlinear interaction between waves in the general framework of optical analogs of event horizons.

Supercontinuum generation (SCG) is a fascinating nonlinear process that gives rise in the extreme case to octave-spanning spectra [1]. It finds numerous applications in the fields of frequency metrology, spectroscopy, optical communications, or medical imaging. The potential of SCG for integrated broadband or few-cycle pulse sources in the near-IR around the telecommunication C-band or in the mid-IR, led to its on chip experimental demonstration in various platforms such as chalcogenide, SiN, InGaP, amorphous silicon or silicon photonic wires. At telecommunication wavelengths, silicon waveguides suffer from two-photon absorption (TPA) that generates free carriers. We have demonstrated that TPA plays a major role in SC generation in the femtosecond regime, as it is the perturbation that governs the fission of high order solitons, a mechanism at the heart of SCG. Moreover, we have shown that TPA is responsible for the generation of highly coherent SC regardless of the pulse duration or the input power [2]. Broader SC are nevertheless obtained when the nonlinear loss is reduced. This can either be achieved by increasing the input pulse wavelength or by making use of materials of larger energy bandgap. In this respect, hydrogenated amorphous silicon (a-Si:H) is a good candidate. The direct comparison of SCG in similar a-Si:H and crystalline silicon waveguides shows largely broader output spectra in a-Si:H, but at the expense of slightly degraded coherence properties [3]. For waveguides with low nonlinear loss, very short input pulses are required for generating highly coherent and very broad spectra. We have shown that another useful strategy is to judiciously vary the dispersion properties along the waveguide length instead of using fixed width waveguides [4]. By nature, an optical soliton induces a moving refractive index perturbation in the nonlinear medium. In waveguides with appropriate dispersion properties, this perturbation interacts with other waves in a manner that mimics the interactions at event horizons of black and white holes. In this context, we have experimentally investigated the frequency shift occurring when waves are scattered by the soliton. Different properties are observed for interacting co-and cross-polarized waves [5]. Regarding potential applications of this phenomenon, the major difference with its silica fiber counterpart is that temporal solitons do not suffer from Raman induced self-frequency shift.

References

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