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Femtosecond Supercontinuum Generation in a Silicon Wire Waveguide at Telecom Wavelengths

François Leo,[1,2,*] Simon-Pierre Gorza,[3] Jassem Safioui,[3] Pascal Kockaert,[3] Stéphane Coen,[4] Utsav Dave,[1,2] Bart Kuyken,[1,2] and Gunther Roelkens[1,2]

[1] *Photonics Research Group, Department of Information Technology, Ghent University-IMEC, Ghent B-9000, Belgium*
[2] *Center for nano- and biophotonics (NB-photonics), Ghent University, Belgium*
[3] *OPERA-Photonique, Université Libre de Bruxelles (ULB), 50 Av. F. D. Roosevelt, CP 194/5, B-1050 Bruxelles, Belgium*
[4] *Physics Department, The University of Auckland, Private Bag 92019, Auckland 1142, New Zealand*
* *Corresponding author: francois.leo@intec.ugent.be*

Abstract: We demonstrate femtosecond supercontinuum generation in a silicon waveguide. Despite the strong nonlinear absorption inherent to silicon at telecom wavelengths, we experimentally demonstrate that the compression and subsequent splitting of higher order solitons remains possible.

OCIS codes: (130.4310) Integrated optics, Nonlinear

1. Introduction

Supercontinuum generation trough fission of higher order solitons has been the subject of many studies since the advent of photonic crystal fibers [1]. The high confinement, leading to high nonlinearities, low losses and the possibility to tailor the zero dispersion wavelength has led to the generation of supercontinuums spanning over an octave, which benefits the many applications requiring broadband sources [1]. Recent results demonstrating ultra-short pulse generation on chip [2] allow to envision the integration of supercontinuum sources. On-chip supercontinuum generation was performed in chalcogenide [3], Si_3N_4 [4] and silicon waveguides [5]. In the latter however, the broadening at telecom wavelengths is limited. This is most likely due to working far from the zero dispersion wavelength, which prevents the emission of dispersive waves (DW). Such resonant radiation is emitted by solitons perturbed by higher order dispersion [6]. It has been intensely studied in the context of supercontinuum generation as in most cases, the supercontinuum is bound by the DW in the normal dispersion regime [7]. The soliton fission process can be simulated with the well known generalized nonlinear Schrödinger equation. This equation can be solved through simple split step methods and very good agreement between experiment and numerical simulations is achieved in photonic crystal fibers [8]. Using a similar model, Yin et al predicted the emission of DWs and hence the generation of a broad supercontinuum in a silicon wire at telecom wavelength [9] but an experimental study is still missing. Here we report the first, to the best of our knowledge, experimental generation of DWs, leading to the generation of a broad supercontinuum in a silicon wire waveguide at telecom wavelengths.

2. Waveguide

We use 7 mm long silicon-on-insulator waveguides with a standard 220 nm silicon thickness. In this case, the group velocity dispersion is negative at telecom wavelengths when working with a width below 800 nm. Since we are interested in regions of small group velocity dispersion, we work with two waveguides of width 700 and 750 nm, with the zero dispersion wavelength located at 1425 nm and 1510 nm respectively.

3. Experiment and simulations

The experiment is performed with an OPO (spectra physics OPAL) emitting pulses at 1565 nm with an 150 fs full-width-at-half-maximum. We couple in the waveguide with a microscope objective (x60, NA = 0.65) and couple out with a lensed fiber (NA = 0.4). The experimental output spectra for peak powers of 32 W are shown on Figure 1. Our results show clear width dependent broadening and hence confirm the importance of the dispersion profile on the supercontinuum process in a silicon wire. In order to gain further insight in the observed spectral broadening, we perform simulations using the generalized nonlinear Schrödinger equation proposed in [9]. Our results are displayed on Figure 1 and compared to our experimental results. A good agreement is found between measured and simulated

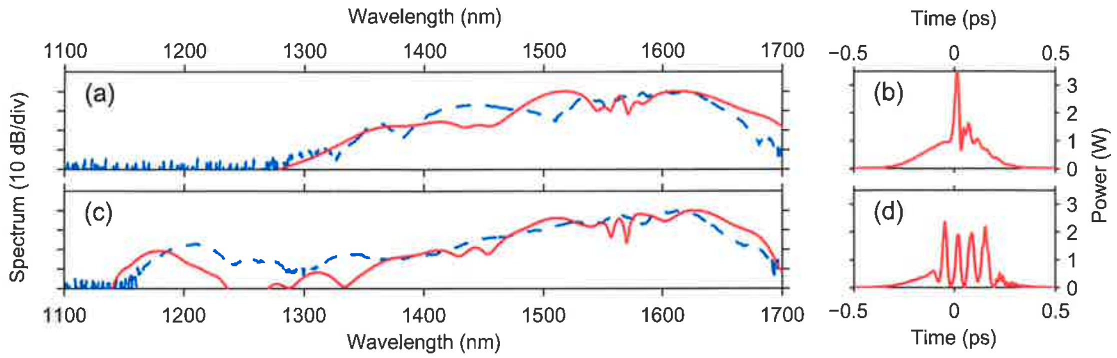

Fig. 1. Experimental (blue) and simulation (red) results results for a input peak power of 32 W for a 7 mm long waveguide with a width of 750 nm (a) and 700 nm (c). The temporal profile corresponding to the spectrum (a), resp (c) is shown in (b), resp (d).

spectra, in particular the broadening is very well reproduced by simulations. In both cases, simulations display the temporal compression and subsequent splitting of the input pulse, along with the emission of resonant radiation, which is similar to the known fission process happening in photonic crystal fibers. The spectral position of the DWs lie in the normal dispersion regime and highly depend on the dispersion profile, as expected from theory [7]. In the 700 nm wide waveguide, the DWs allow for the generation of a supercontinuum spanning from 1150 nm to 1700 nm, almost twice what was previously reported in silicon at telecom wavelengths [5].

4. Conclusion

In conclusion we have experimentally and numerically studied soliton fission, dispersive wave generation and supercontinuum generation in a silicon photonic wire. Despite the strong two- photon absorption inherent to the telecom region in silicon, we generated a supercontinuum spanning from 1150 nm to 1700 nm.

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