Supercontinuum generation in hydrogenated amorphous silicon waveguide

Jassem Safioui[1], Bart Kuyken[2], Shankar Kumar Selvaraja[2], Wim Bogaerts[2], Dries Van Thourhout[2], Gunther Roelkens[2], Philippe Emplit[1], Roel Baets[2] and Serge Massar[3]

[1]Service OPERA-Photonique, Université Libre de Bruxelles (ULB), 50 Avenue F. D. Roosevelt, CP 194/5, B-1050 Bruxelles, Belgium
[2]Photonics Research Group, INTEC Department, Ghent University—IMEC, Sint-Pietersnieuwstraat 41, 9000 Ghent, Belgium
[3]Laboratoire d'Information Quantique (LIQ), ULB, 50 Avenue F. D. Roosevelt, CP 225, B-1050 Bruxelles, Belgium

Abstract: We report supercontinuum (SC) generation centered on the telecommunication C-band (1550nm) in CMOS compatible hydrogenated amorphous silicon waveguide. A broadening of 200nm is obtained in a 1cm long waveguide using as pump 1.6ps pulses with on chip peak power of 4,5W and 45W.

OCIS codes: (190.0190); (190.4390)

1. Introduction

Since the first report of supercontinuum (SC) generation in borosilicate glass by Alfano and Shapiro in 1970, many others demonstrations have been successfully reported as for example in single mode fibers [1], photonic crystal fibers [2] and more recently in integrated guiding structures [3].

For the generation of a SC in integrated waveguides both strong nonlinearity and high figure-of-merit (FOM) are required. In crystalline silicon (c-Si) at telecom wavelengths two photon absorption (TPA) clamps the maximum propagating power in the chip and hence reduces dramatically the FOM, which limits the maximum achievable spectral broadening. This problem is overcome by using hydrogenated amorphous silicon (a-Si:H) as nonlinear medium [4].

The high FOM of a-Si:H wires [5] allowed the demonstration of many nonlinear functions such as parametric amplification frequency [4], all-optical signal processing [6], and more recently low power continuous-wave frequency conversion [7]. Here, we present the first demonstration of SC generation in a-Si:H waveguides using telecommunication 1.6-picosecond-long pump pulses.

2. Experiment and results

The a-Si:H waveguides are fabricated in 220-nm-thick hydrogenated amorphous silicon deposited on top of silicon dioxide layer using a low temperature Plasma Enhanced Chemical Vapor Deposition (PECVD) process. The a-Si:H film was formed by plasma decomposition of silane (SiH_4) gas and combined with Helium (He) for dilution. Waveguides of varying lengths L (1 to 7cm) were fabricated using 193 nm optical lithography and dry etching. The cross-section of these waveguides is 500×220 nm^2. To allow an effective injection and extraction of the light from the photonic nanowires, broadband grating couplers are added at the input and the output. Thanks to a cutback measurement at low power we estimate propagation losses for TE polarization of about 3dB/cm.

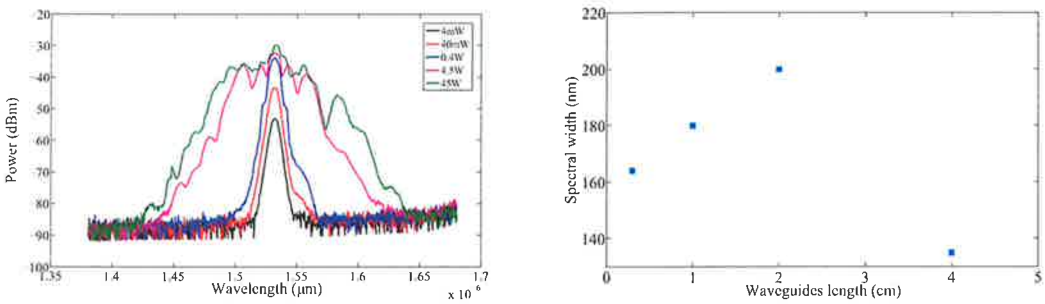

Figure 1: (a) Transmission spectra as function of on chip peak pump power at the exit of a 1cm long waveguide. (b) Spectral width of the supercontinuum as a function of the waveguide length (P_{peak}=45W).

For the supercontinuum generation experiment, a picosecond pulse train (FWHM ~ 1.6ps, repetition rate = 10 MHz) generated by a tunable optical fiber cavity is used as the pump. The coupling loss between the cleaved fiber and the waveguides through the in/out grating coupler is estimated to be 6-7dB. The output beam is sent into an optical spectrum analyzer (OSA). The polarization is aligned with the TE mode of the waveguide with the help of polarization controllers.

Figure 1(a) shows the dependence of the output spectrum as a function of on chip peak pump power at pump center wavelength of λ_{pump}=1530nm. At low pump power, the spectral width varies only slightly. However, above a threshold pump power the spectral width increases sharply until at the highest power, 45W, the spectral width has increased to reach a value close to 200nm. The measured spectral broadening is restricted by the bandpass output grating coupler (200nm at -20dB), and that the spectral broadening on chip may be much larger. We note that the spectral width is determined from the intersection of the signal with the noise level of our OSA.

To understand the nonlinear processes involved in this widening, we investigate the evolution of the output spectrum as a function of the pump power. At an input peak power of 4.5W, the pump has undergone self-phase modulation and two modulation instability sidebands have appeared detuned by approximately 65nm around the pump wavelength of 1530nm (fig. 1a). At the highest peak power of 45W, cascaded four wave mixing (FWM) has broadened and flattened the spectrum further.

Using the intensity of the converted signal in a continuous wave FWM experiment [8], we estimated the nonlinear coefficient ($n_2=1.7\times10^{-17}m^2/W$) and dispersion coefficient ($\beta_2=2ps^2/m$) of the waveguide. This implies a nonlinear length L_{NL}=83μm and soliton fission length $L_{Fission}$=1.03cm [2]. These values confirm that the FWM is the main process in our supercontinuum generation.

Finally we investigated the influence of the waveguide length (L) on supercontinuum generation using L=3mm, 1cm, 2cm and 4cm long waveguides (fig. 1b). We observe that the spectral broadening increases with waveguide length until L=4cm, where the linear losses are very high which clamps output spectrum widening.

3. Conclusion

We have demonstrated SC generation in 1cm long CMOS compatible hydrogenated amorphous silicon waveguides. We measured broadening of 200nm is a lower bound on the width of the supercontinuum as it is limited by the bandpass of the output grating coupler. In the future experiments with no output grating coupler will be performed to reveal the maximum width of the SC.

4. References

[1] K. Mori, H. Takara, and S. Kawanishi, *"Analysis and design of supercontinuum pulse generation in a single-mode optical fiber,"* J. Opt. Soc. Am. B **18**, 1780-1792 (2001).

[2] J. M. Dudley, G. Genty and S. Coen, *"Supercontinuum generation in photonic crystal fiber,"* Rev. Mod. Phys **78**, 1135-1184 (2006).

[3] I-Wei Hsieh, X. Chen, X. Liu, J. I. Dadap, N. C. Panoiu, C.-Y. Chou, F. Xia, W. M. Green, Y. A. Vlasov, and R. M. Osgood, *"Supercontinuum generation in silicon photonic wires,"* Opt. Express **15**, 15242-15249 (2007).

[4] B. Kuyken, S. Clemmen, S. K. Selvaraja, W. Bogaerts, D. V. Thourhout, P. Emplit, S. Massar, G. Roelkens, and R. Baets, *"On-chip parametric amplification with 26.5dB gain at telecommunication wavelengths using CMOS-compatible hydrogenated amorphous silicon waveguides,"* Optics letters **36**, 552-554 (2011).

[5] C. Grillet, L. Carletti, C. Monat, P. Grosse, B. Ben Bakir, S. Menezo, J. M. Fedeli, and D. J. Moss, *"Amorphous silicon nanowires combining high nonlinearity, FOM and optical stability,"* Opt. Express **20**, 22609-22615 (2012).

[6] B. Kuyken, H. Ji, S. Clemmen, S. K. Selvaraja, H. Hu, M. Pu, M. Galili, P. Jeppesen, G. Morthier, S. Massar, L.K. Oxenløwe, G. Roelkens, and R. Baets, *"Nonlinear properties of and nonlinear processing in hydrogenated amorphous silicon waveguides,"* Optics express **19**, B146-B153 (2011).

[7] K.Y. Wang and A. C. Foster, *"Ultralow power continuous-wave frequency conversion in hydrogenated amorphous silicon waveguides,"* Optics letters **37**, 1331-1333 (2012).

[8] J. Matres, G. C. Ballesteros, P. Gautier, J-M Fédéli, J. Martí, and C. J. Oton, *"High nonlinear figure-of-merit amorphous silicon waveguides,"* Opt. Express **21**, 3932-3940 (2013).

CONTROL ID: 1705996

CURRENT CATEGORY: Nonlinear Media

PRESENTATION TYPE: Oral or Poster Acceptable

TITLE: Supercontinuum generation in hydrogenated amorphous silicon waveguide

AUTHORS (FIRST NAME, LAST NAME): Jassem Safioui[1], Bart Kuyken[2], Shankar Kumar Selvaraja [2], Wim Bogaerts[2], Dries Van Thourhout[2], Gunther Roelkens[2], Philippe Emplit[2], Roel Baets[2], Serge Massar[3]

INSTITUTIONS (ALL): 1. OPERA photonique ULB, Brussels, Belgium.
2. Photonics Research Group, Ghent, Belgium.
3. Laboratoire d'Information Quantique, Bruxelles, Belgium.

ABSTRACT BODY:
Abstract (35 Word Limit): We report supercontinuum (SC) generation centered on the telecommunication C-band (1550nm) in CMOS compatible hydrogenated amorphous silicon waveguide. A broadening of 200nm is obtained in a 1cm long waveguide using as pump 1.6ps pulses with on chip peak power of 4,5W and 45W.

KEYWORDS: Nonlinear optics: 190.0190, Nonlinear optics: 190.4390 Nonlinear optics, integrated optics.

Nonlinear Optics (NLO)
The Fairmont Orchid, Kohala Coast
21 - 26 July 2013 : Hawaii, USA

Browse the Program
View Your Itinerary
Society Home Page

Welcome to the Online Program. To begin, either click the plus "+" icon to e "Search Program" area. Please note there are additional filters to the right of

To add items to your itinerary, click the check box to the right of each item y Itinerary" box will add all items in that session to your itinerary.

When done, click the "View Your Itinerary" link from the left menu to view ;

You must login in order to create or save your itinerary for later. To simply b

Search Program: Supercontinuum generation Search Presenters Only ŀ

Enter a name, institution, Final ID, and/or words from the session or presentation title. Separate mult with a semicolon to narrow your search. Separate multiple items with an OR to broaden your search.

Advanced Search

MONDAY, JULY 22, 2013

NM3A. Frequency Combs and Supercontinuum Generation
Presider(s): Steven Cundiff (University of Colorado at Boulder JILA)
7:30 PM - 9:30 PM; Plaza II & III

9:00 PM - 9:15 PM	NM3A.6. Infrared supercontinuum generation in soft-glass pho *Grzegorz J. Sobon; Jaroslaw Sotor; Karol Krzempek; Dariusz ı Tadeusz Martynkien; Krzysztof M. Abramski; Ryszard Buczyns* View Presentation
9:15 PM - 9:30 PM	NM3A.7. Supercontinuum generation in hydrogenated amorph *Jassem Safioui; Bart Kuyken; Shankar Kumar Selvaraja ; Wim Roelkens; Philippe Emplit; Roel Baets; Serge Massar* View Presentation

TUESDAY, JULY 23, 2013

No matching results.

WEDNESDAY, JULY 24, 2013