The following publication C. Mei, J. Yuan, Z. Kang, F. Li, X. Zhang, B. Yan, X. Sang, X. Zhou, K. Zhong, L. Wang, K. Wang, C. Yu, C. Lu, H. Y. Tam, and P. K. A. Wai, "Passive generation of parabolic similaritons in tapered hydrogenated amorphous silicon photonic wires," in Conference on Lasers and Electro-Optics, OSA Technical Digest (online) (Optica Publishing Group, 2017), paper JTh2A.84 is available at https://doi.org/10.1364/CLEO_AT.2017.JTh2A.84.

Passive generation of parabolic similaritons in tapered hydrogenated amorphous silicon photonic wires

Chao Mei[1], Jinhui Yuan[1,2,*], Zhe Kang[2], Feng Li[2], Xianting Zhang[2], Binbin Yan[1], Xinzhu Sang[1], Xian Zhou[2], Kangping Zhong[2], Liang Wang[3], Kuiru Wang[1], Chongxiu Yu[1], Chao Lu[2], Hwa Yaw Tam[2], and P. K. A. Wai[2]

[1]*State Key Laboratory of Information Photonics and Optical Communications, Beijing University of Posts and Telecommunications, P.O. Box72 (BUPT), 100876, Beijing, China*

[2]*Photonics Research Centre, Department of Electronic and Information Engineering, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, China*

[3]*Department of Electronic Engineering, The Chinese University of Hong Kong, Shatin, NT, Hong Kong.*

**Corresponding Authors: yuanjinhui81@163.com*

Abstract: We numerically study parabolic similariton generation in tapered hydrogenated amorphous silicon photonic wires. Simulation results show that initial Gaussian pulses can evolve into parabolic similaritons with the linear chirp at 1550 and 2150 nm, respectively.

OCIS codes: (190.4360) Nonlinear optics, devices; (190.4400) Nonlinear optics, materials

1. Introduction

Similaritons is a type of optical pulses that preserve their shape during propagation. Solitons are the most common examples of such pulses which exist in the anomalous dispersion region, while the counterparts in the normal dispersion region are self-similar parabolic pulses. The spectral and temporal characteristics of parabolic pulses find a wide range of applications, e.g. high-power amplification and ultrashort pulse generation [1], highly coherent continuum for optical telecommunications [2], and ultrafast all-optical signal processing [3]. Hydrogenated amorphous silicon (a-Si:H) has emerged as a robust candidate for nonlinear optics because of its large nonlinear figure of merit. Similar to c-Si photonic wires, tapered a-Si:H photonic wires (a-Si:H-PhWs) with subwavelength transverse dimension are suitable for dispersion engineering [4]. In this paper, we numerically analyze the generation of parabolic similaritons in tapered passive a-Si:H waveguides. Nonlinearity increasing waveguides (NIWs) are proposed to generate parabolic similaritons based on the self-similar theory at the telecom (λ~1550 nm) and mid-IR ($\lambda \geq 2100$ nm) wavelengths.

2. Theoretical model

The generation of parabolic similaritons in NIWs is based on the observation that nonlinear Schrödinger equation (NLSE) with uniform nonlinearity and gain can be transformed into an NLSE with increasing nonlinearity without gain. Thus, the propagation of optical pulses in NIWs can be described by

$$i\frac{\partial A}{\partial z}-\frac{\beta_2}{2}\frac{\partial A^2}{\partial t^2}+\gamma_0\varepsilon(z)|A|^2 A=0, \tag{1}$$

where $A(z, t)$ is the slowly varying envelope of the pulse, z and t are the distance along the waveguide and time, respectively. γ_0 is the nonlinear coefficient at z = 0. $\varepsilon(z)$ gives the variation of nonlinearity along propagation with $\varepsilon(0)$ = 1. $\beta_2 > 0$, is the group-velocity dispersion parameter and assumed to be a constant. We note that if $\varepsilon(z)=\exp(a_0 z)$, the gain coefficient will become a constant equal a_0. Thus, the asymptotic solutions in NIWs with an exponentially increasing nonlinearity profile is given by [5]

$$A(\mathrm{z}\to\infty,\mathrm{t})\to\begin{cases}\sqrt{P_0(z)}\left\{1-\left[t/t_0(z)\right]^2\right\}^{1/2}\exp\left[i\varphi(z,t)\right], & |t|\leq t_0(z),\\ 0, & |t|>t_0(z).\end{cases} \tag{2}$$

In the asymptotic regime, the pulse propagates self-similarly, and maintains its parabolic shape with exponentially varying power $P_0(z)$ and pulse width $t_0(z)$.

3. Waveguide design

Fig. 1(a) shows the proposed tapered a-Si:H-PhWs have rectangular cross-section buried inside silica cladding. Fig. 1(b) shows the three-dimensional sketch of the NIWs. Figs. 1(c) and 1(d) show the optical field distributions of the output facets at 1550 and 2150 nm, respectively, which show that the light energy is well confined into the core region of a-Si:H-PhWs and remain single mode transmission within the wavelength range of interest. The lengths of the waveguides are 10 mm for both of the pump wavelengths considered.

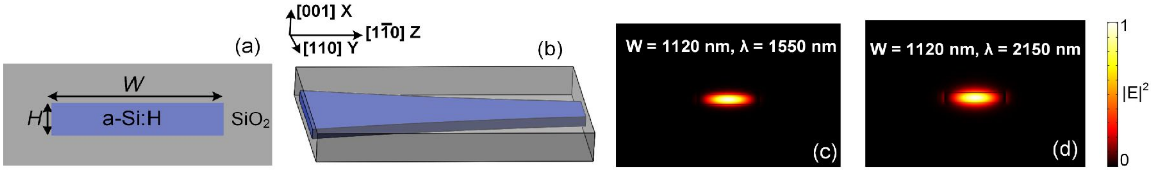

Fig. 1. (a) The cross-section and (b) 3D sketch of the tapered a-Si:H-PhWs. The optical field of output facets at (c) 1550 nm and (b) 2150 nm.

The widths of the input and output facets (at 1550 nm, from A to B, and at 2150 nm, from C to D) are 3000 and 1120 nm, respectively, as shown in Fig. 2(a). The white curve in Fig. 2(a) represents the zero-dispersion points. In Fig. 2(b), it can be seen that β_3 is relatively small, which indicates that parabolic similaritons could avoid the perturbation induced by higher-order dispersion. Figs. 2(c) and 2(d) show the real and imaginary parts of γ, respectively. β_2 and γ of the input and output ports are chosen as follows. (i) At 1550 nm, $\beta_{2,\,in}$ = 1.76 ps^2/m, $\beta_{2,\,out}$ = 1.21 ps^2/m, γ_{in} = 175.17 /W/m, and γ_{out} = 481.85 /W/m, and (ii) at 2150 nm, $\beta_{2,\,in}$ = 2.83 ps^2/m, $\beta_{2,\,out}$ = 1.53 ps^2/m, γ_{in} = 70.46 /W/m, and γ_{out} = 196.68 /W/m.

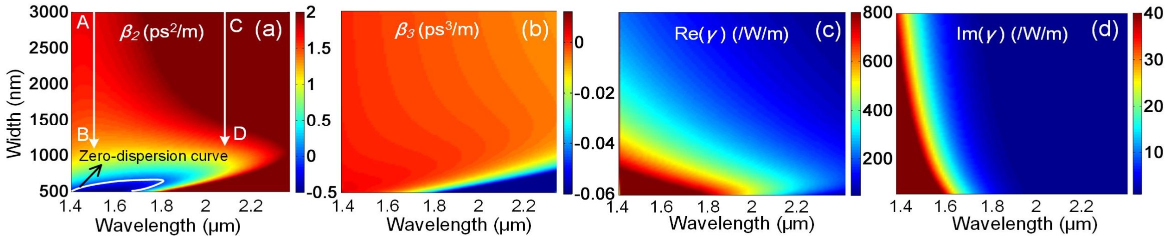

Fig. 2. Dispersion maps of (a) β_2, (b) β_3, (c) real part of γ and (d) imaginary part of γ. White arrows in (a) mark the two wavelengths considered, and the white curve in (a) represents the zero-dispersion curve.

4. Simulation results

We investigate the influence of losses including the two-photon absorption (TPA) in the similariton formation. Figs. 3(a) and 3(b) show the output pulse without and with higher-order effects and losses at 1550 nm, respectively. Fig. 3(b) shows that the output pulse deviates from the parabolic shape. Figs. 3(c) and 3(d) shows the output pulse without and with higher-order effects and losses at 2150 nm. From Fig. 3(d), the pulses remain parabolic in shape even in the presence of losses. Thus, the generated parabolic similariton at 1550 nm is affected by the TPA. We also note that the generated chirp is linear in agreement with the theoretical prediction of Ref [5].

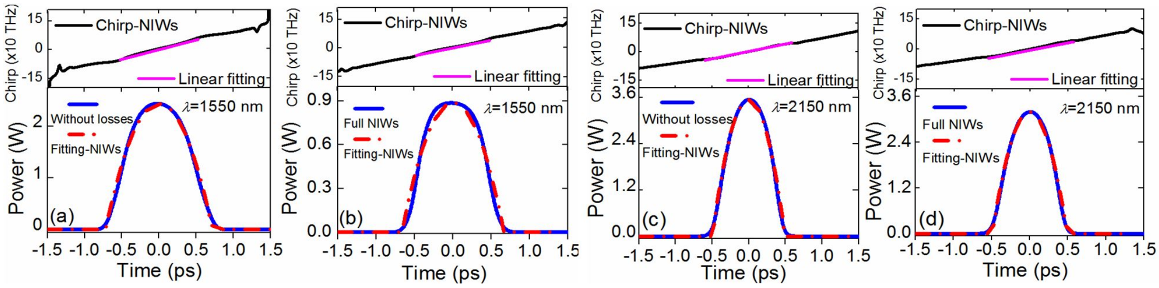

Fig. 3. Top panel: the generated chirp (black solid curve) and linear fitting (pink solid curve). Bottom panel: at 1550 nm, (a) without losses (blue solid curve) and fitting (red dashed dot curve), and (b) full NIWS (blue solid curve) and fitting (red dashed dot curve). At 2150 nm, (c) without losses (blue solid curve) and fitting (red dashed dot curve), and (d) full NIWS (blue solid curve) and fitting (red dashed dot curve).

5. Conclusion

We showed that parabolic similaritons can be generated by using tapered a-Si:H-PhWs at 1550 and 2150 nm. However, the generated parabolic similaritons at 1550 nm are degraded by losses. In contrast, the parabolic similaritons at 2150 nm are not affected by losses.

We gratefully acknowledge support from National Natural Science Foundation of China (61307109), Beijing Youth Top-notch Talent Support Program (2015000026833ZK08), Natural Science Foundation of Beijing (4152037), and Hong Kong Scholars Program 2013 (PolyU G-YZ45).

6. References

[1] D. N. Papadopoulos *et al.*, Opt. Lett. **32,** 2520-2522 (2007).
[2] C. Finot, and G. Millot, Opt. Express **12,** 5104-5109 (2004).
[3] C. Finot, *et al.*, Opt. Lett. **30,** 1776-1778 (2005).
[4] L. Shen, *et al.*, Opt. Lett. **39,** 5721-5724 (2014).
[5] M. E. Fermann, *et al.*, Phys. Rev. Lett. **84,** 6010-6013 (2000).