EPJ Web of Conferences **267**, 02022 (2022) https://doi.org/10.1051/epjconf/202226702022
EUROPHOTON 2022

Self-phase modulation in periodically-poled thin-film lithium niobate waveguides

Gamze Gul[1], Kamal Abdelsalam[2], Sasan Fathpour[2,3], Kim F. Lee[4], Gregory S. Kanter[4], and Prem Kumar[1,4]

1. *Graduate Program in Applied Physics, Northwestern University, 2145 Sheridan Road, Evanston, Illinois 60208, USA*
2. *CREOL, The College of Optics and Photonics, University of Central Florida, Orlando, Florida 32816, USA*
3. *Department of Electrical and Computer Engineering, University of Central Florida, Orlando, Florida 32816, USA*
4. *Center for Photonic Communication and Computing, Department of Electrical and Computer Engineering, Northwestern University, Evanston, Illinois 60208, USA*

Thin-film lithium niobate (TFLN) waveguides have been one of the most popular elements for integrated photonics in recent years. The design of the waveguide and the high refractive index contrast create strong field confinement and enable low power nonlinear interactions. The periodic-poling provides quasi-phase-matching (QPM) for the second-order ($\chi^{(2)}$) nonlinear processes. Periodically-poled TFLN waveguides have been employed in various applications such as supercontinuum generation [1], third-harmonic generation [2], and photon-pair generation [3] in a much more efficient way with low powers due to the cascaded $\chi^{(2)}$ effect. Although cascaded interactions are more effective near the phase-matching wavelength, their effect can still be observed through self-phase modulation, which is originally a third-order ($\chi^{(3)}$) nonlinear effect [4,5].

Here we investigate the self-phase modulation (SPM) of sub-picosecond telecom wavelength light pulses due to the cascaded second-order nonlinear processes in periodically-poled TFLN waveguides when the spacing between the wavelength of the input pulse and the phase-matching wavelength is large. The experiments are performed on x-cut 1-cm long waveguides with a 1-mm long poled region in the middle with grating periods of 2.7 and 2.76 μm, respectively. The free-space output from an IMRA Femtolite laser is coupled into the waveguides with a 40x microscope objective to avoid any dispersion or nonlinear effects on the pulses before the waveguide. We collect the output light with a lensed fiber and calculate the change in the spectral bandwidth $\Delta\omega_{\mathrm{rms}}$. We also used a split-step Fourier method to simulate the propagation of pulses in the presence of nonlinearities in the waveguides, the lensed fiber, and fiber patch cords in the setup under the condition of an undepleted pump.

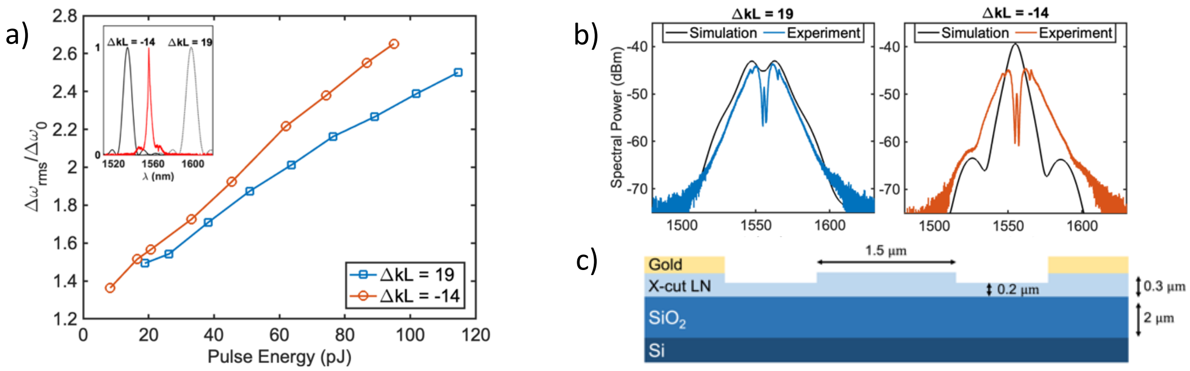

Fig. 1: a) Spectral broadening as a function of input pulse energy for two waveguides with different poling periods. (Inset) Simulated phase matching curves for the waveguides (black) and normalized power spectrum of the input laser (red). b) Simulated and experimentally observed output spectra of pulses for 40 pJ input pulse energies. c) Cross-section of the ridge TFLN waveguide.

We experimentally studied the spectral broadening in periodically-poled TFLN waveguides at telecom wavelengths. We observed a 2.6-factor spectral broadening for <90 pJ when phase-mismatching is negative (cf. Fig. 1(a)). This value decreases to 2.3 for the other waveguide with positive phase-mismatching. Figure 1(b) shows that the simulation performed with a 400 fs FWHM sech^2 type pulse agrees with the experimentally observed spectra for the lower pulse energies whereas in the middle of the spectra it fails to match the experimental spectra. The effect of cascaded $\chi^{(2)}$ on spectral broadening can be further analyzed by adding $\chi^{(3)}$ effects to the simulation. Such details and more experimental results under various operating conditions will be presented at the conference.

References

[1] M. Jankowski *et al*., "Quasi-static optical parametric amplification," Optica **9**, 273 (2022).
[2] A. S. Solntsev *et al*., "Cascaded third harmonic generation in lithium niobate nanowaveguides," Appl. Phys. Lett. **98**, 231110 (2011).
[3] B. S. Elkus, K. Abdelsalam, S. Fathpour, P. Kumar, and G. S. Kanter, "Quantum-correlated photon-pair generation via cascaded nonlinearity in an ultra-compact lithium-niobate nano-waveguide," Opt. Express **28**, 39963 (2020).
[4] R. H. Stolen and C. Lin, "Self-phase-modulation in silica optical fibers," Phys. Rev. A **17**, 1448 (1978).
[5] R. Schiek, "Self-phase modulation in lithium niobate waveguides," in 2014 International Conference Laser Optics (2014).