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

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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. 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.

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 sech² 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