北京郵電大學
BEIJING UNIVERSITY OF POSTS AND TELECOMMUNICATIONS

UC DAVIS COMPUTER SCIENCE

Photonic Logic Gates based on XPM in SOA and HNLF

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11/1/2019

Kerr effect & SPM

Kerr effect: It is a change in the refractive index of a material in response to an applied electric field. The induced index change is directly proportional to the square of the electric field.

$$\bar{n}(w, |E|^2) = n(w) + n_2|E|^2$$

↑ None-linearity coefficient

Self-phase modulation (SPM): It refers to the self-induced phase shift experienced by an optical field during its propagation in optical fibers.

$$\phi = \bar{n}k_0L = (n + n_2)|E|^2k_0L$$

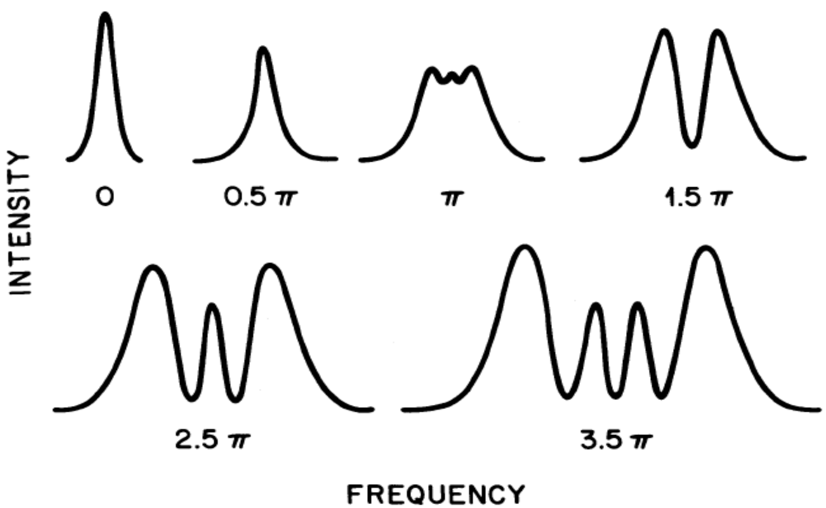
where $k_0 = 2\pi/\lambda$ and L is the fiber length. The intensity-dependent nonlinear phase shift $\phi_{NL} = n_2k_0L|E|^2$ is due to SPM.

XPM

Cross-phase modulation (XPM): It is a nonlinear optical effect where one wavelength of light can affect the phase of another wavelength of light through the optical Kerr effect. When the optical power from a wavelength impacts the refractive index, the impact of the new refractive index on another wavelength is known as XPM.

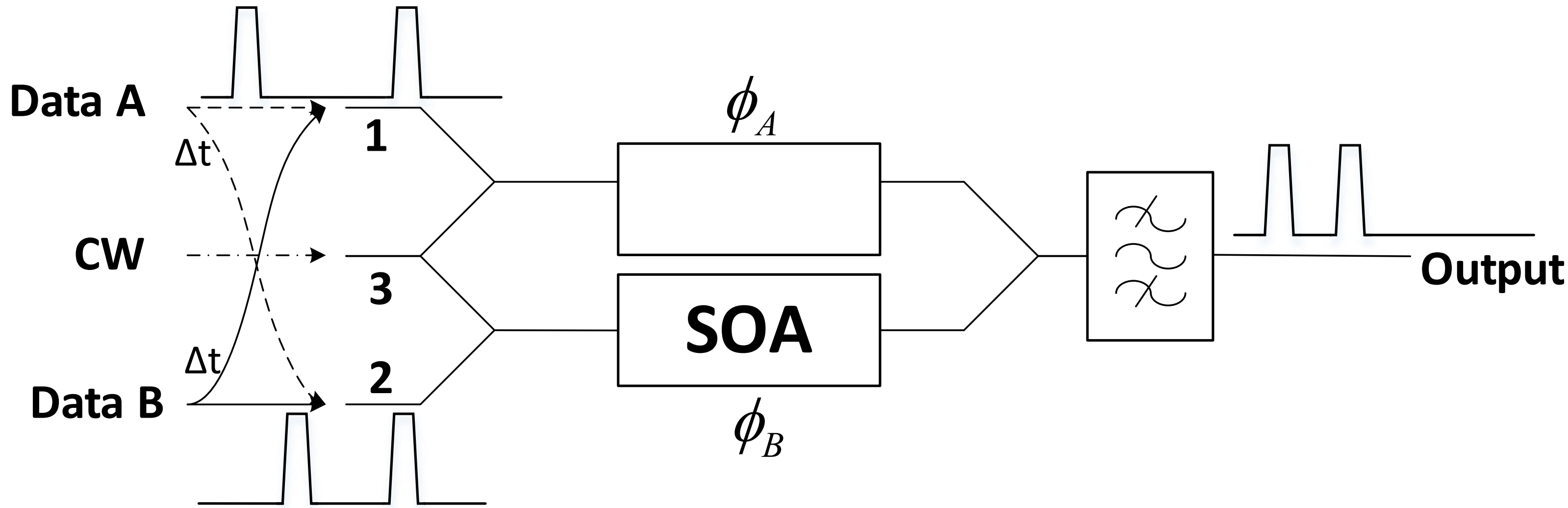
$$\phi_{NL} = n_2 k_0 L(|E_1|^2 + 2|E_2|^2)$$

SPM ($|E_1|^2$) — XPM ($2|E_2|^2$)



SPM-broadened spectra are labeled by the maximum nonlinear phase shift

XPM in SOA



Schematic diagram of XOR gate based on SOA-MZI

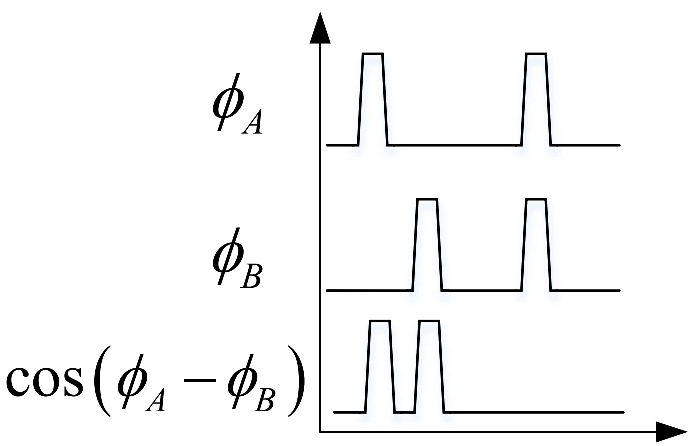
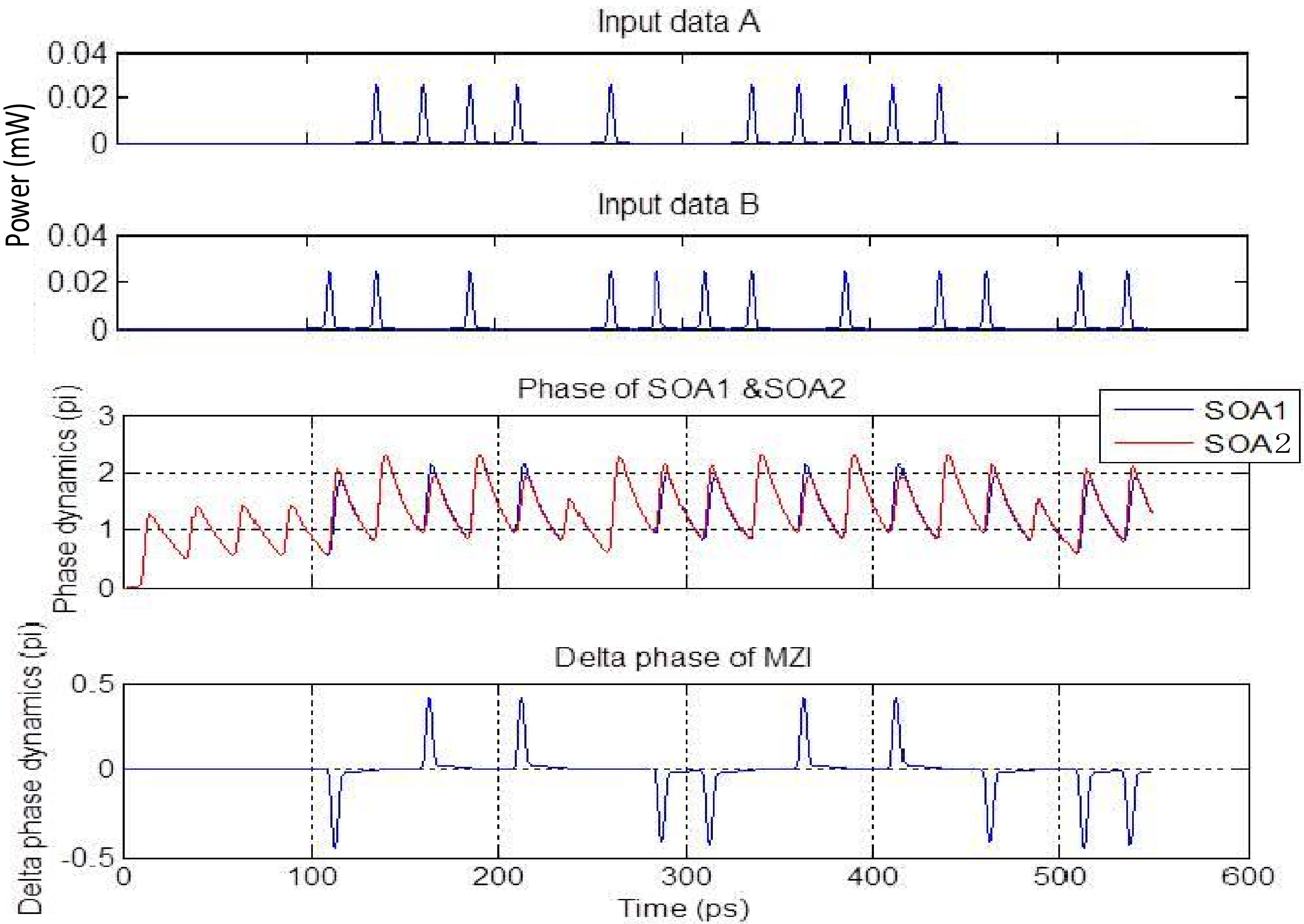


Illustration detailing principle of XOR operation

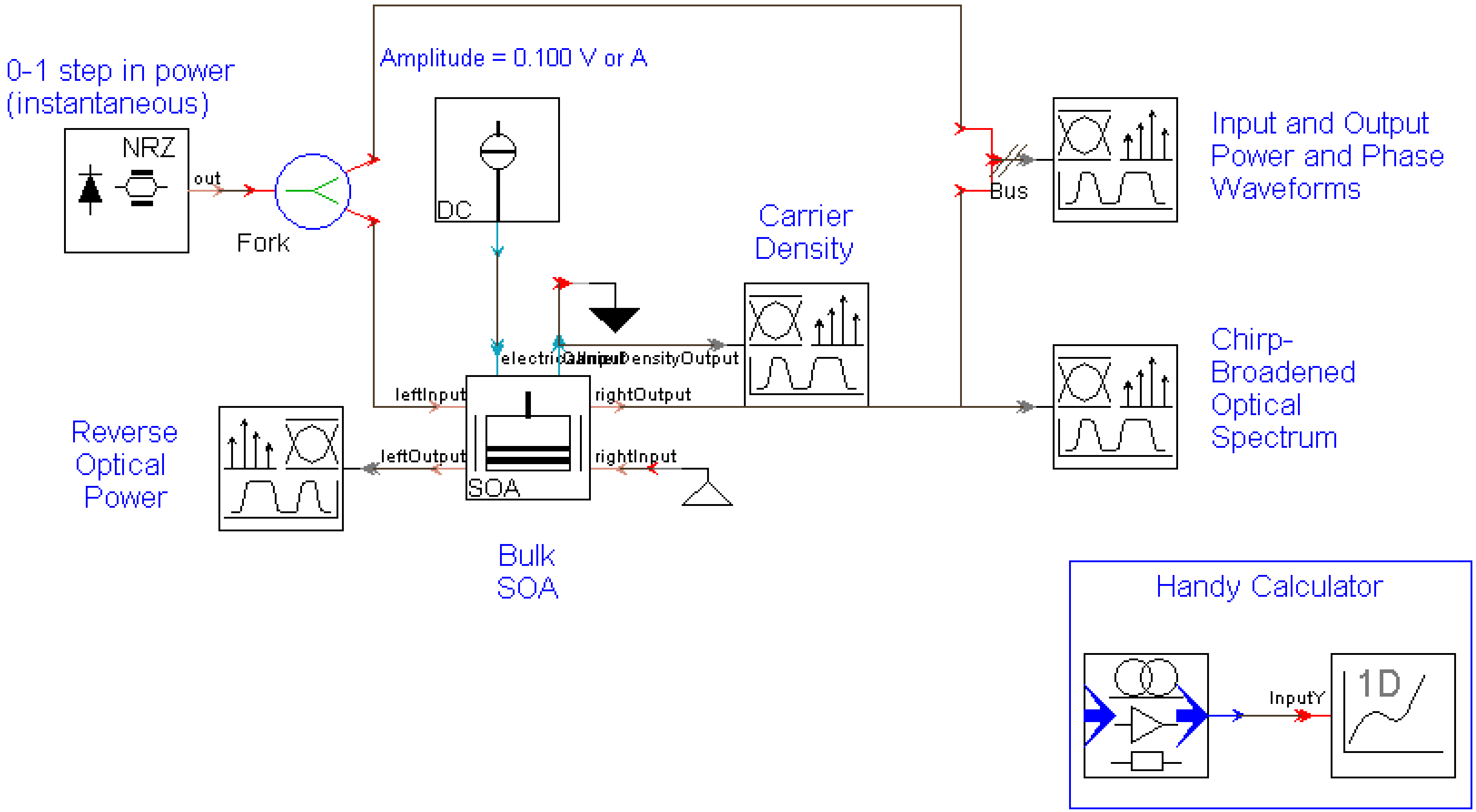
Port Number		
1	2	4
0	0	0
0	1	1
1	0	1
1	1	0

XOR True Table

Phase shift in SOA

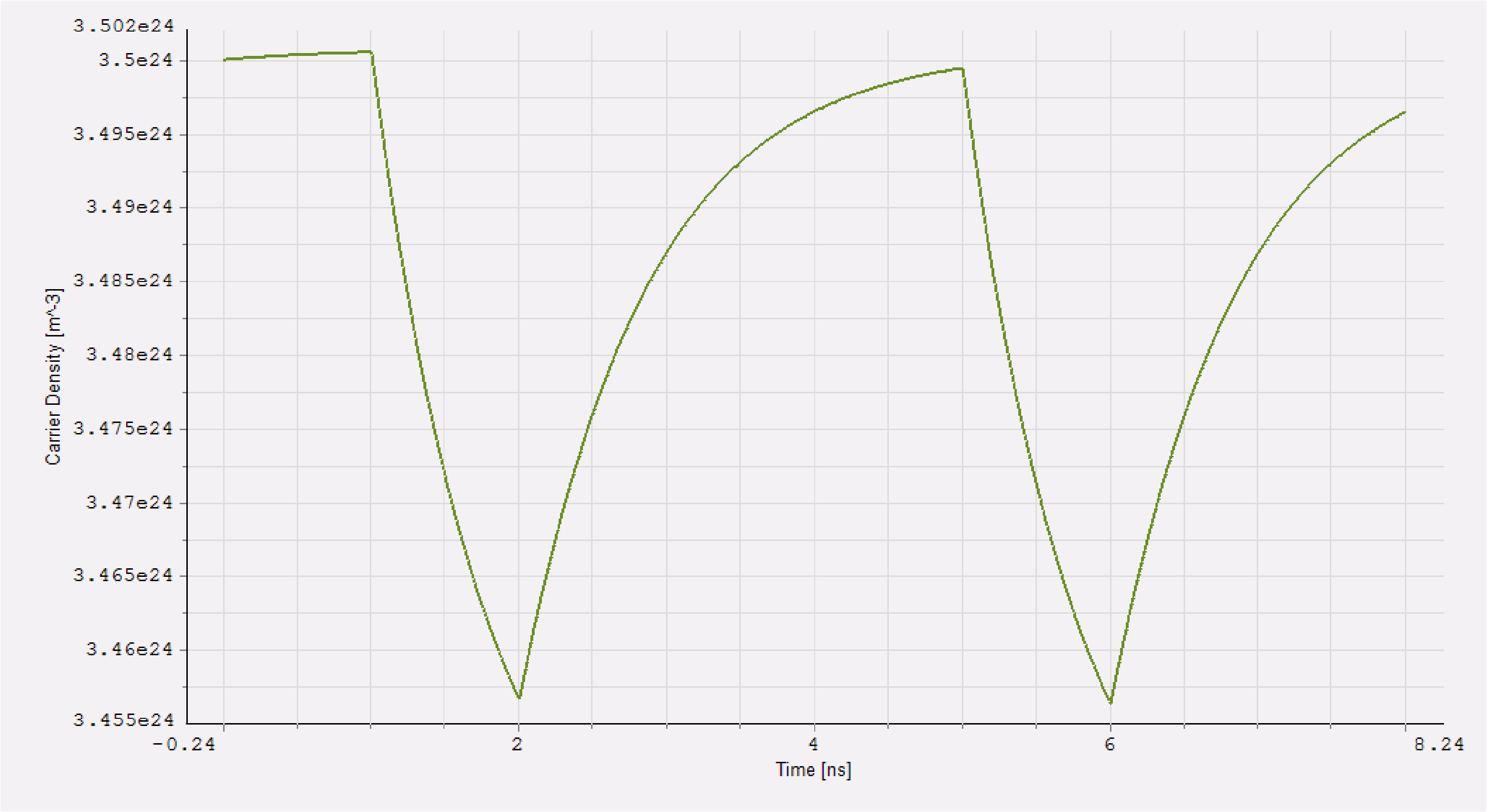


SOA carrier density



Schematic diagram of SOA carrier density shift

Performance analysis



- The input signal is 10001000 with a data rate of 1 Gbps.
- The carrier density of SOA drops rapidly when the light is input. When the light is over, the carrier density will gradually recover.

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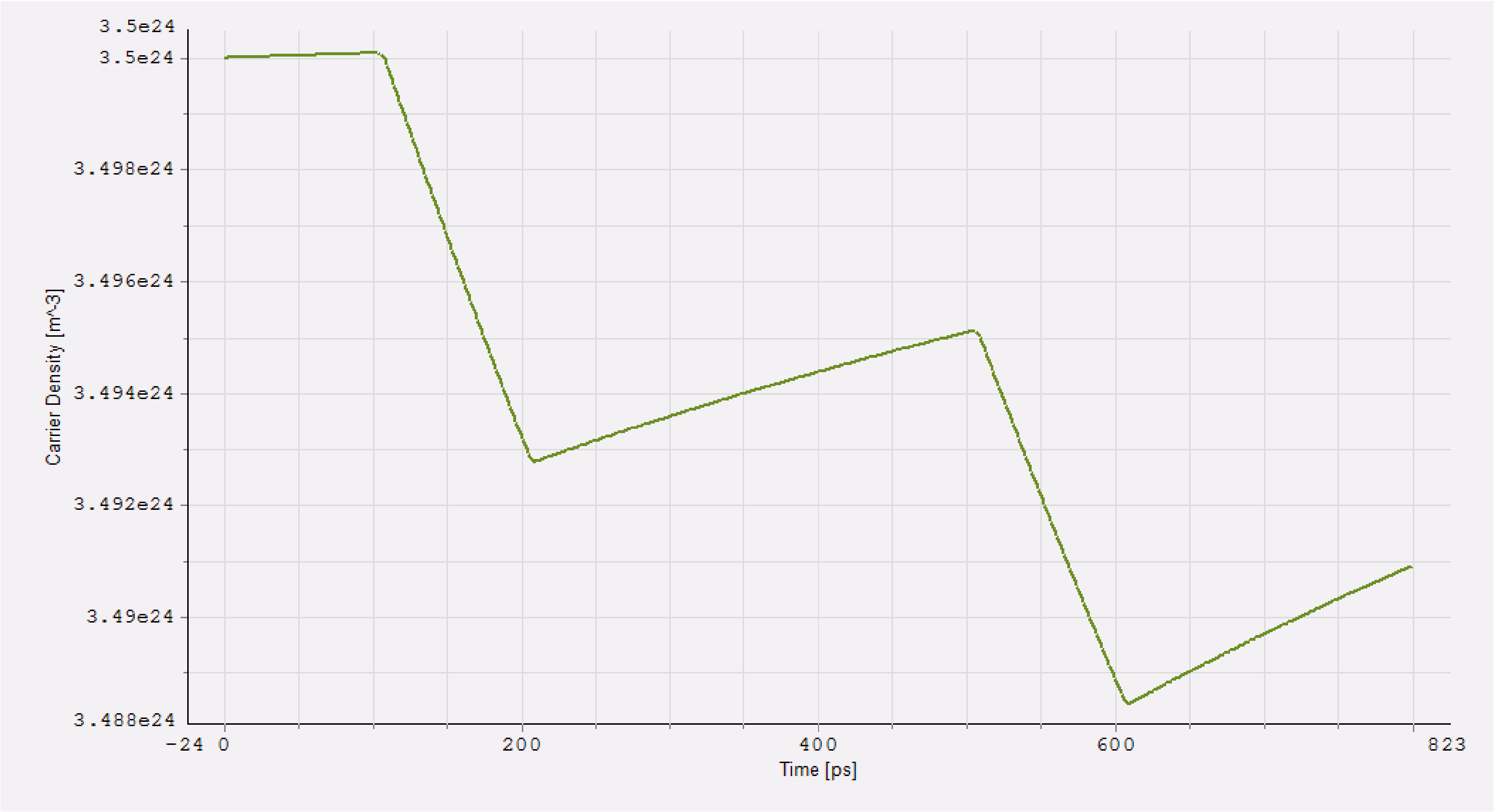
Performance analysis



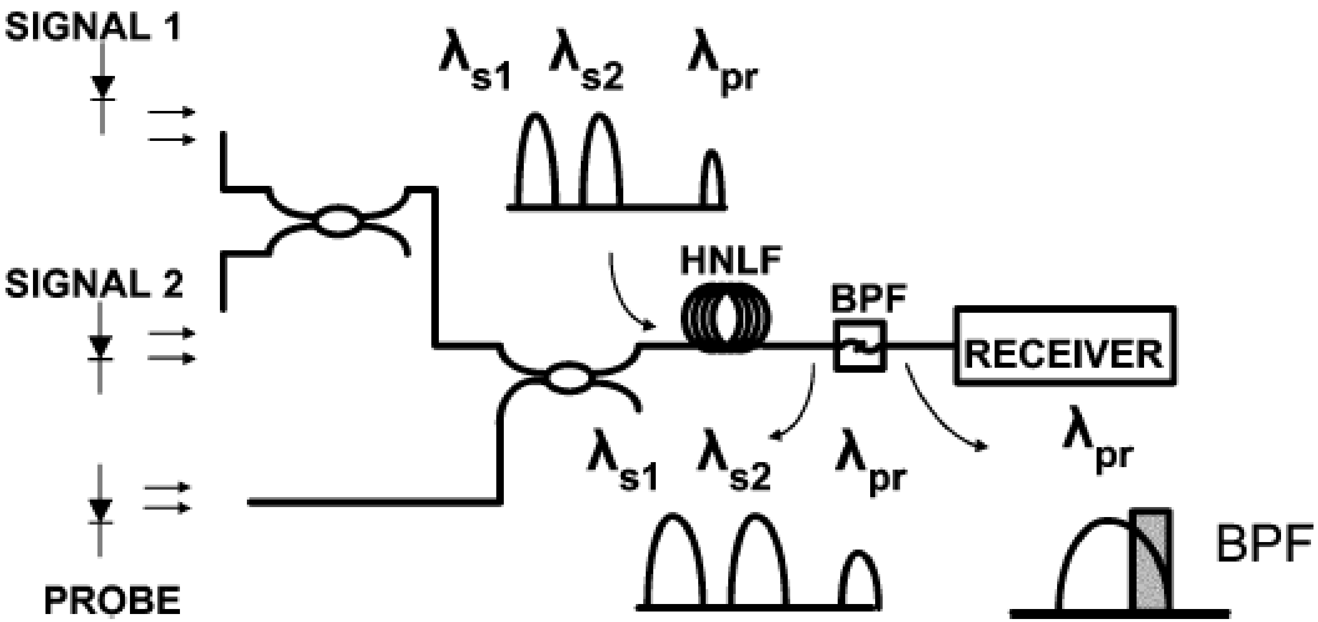
- The input signal is 10001000 with a data rate of 10 Gbps.
- The emergence of mode effect in SOA .

Why we use HNLF?

- The conventional techniques using SOA-MZI can not operate a speed above 40 Gbps.
- The response time of non-linear effect in HNLF is usually very short, enabling optical signal operating at 1 Tbps.
- Fiber-based device is easily coupled to the fiber link, which can reduce the coupling losses and simplify the architecture.
- HNLF is a passive device so that no additional noise is induced during signal processing.

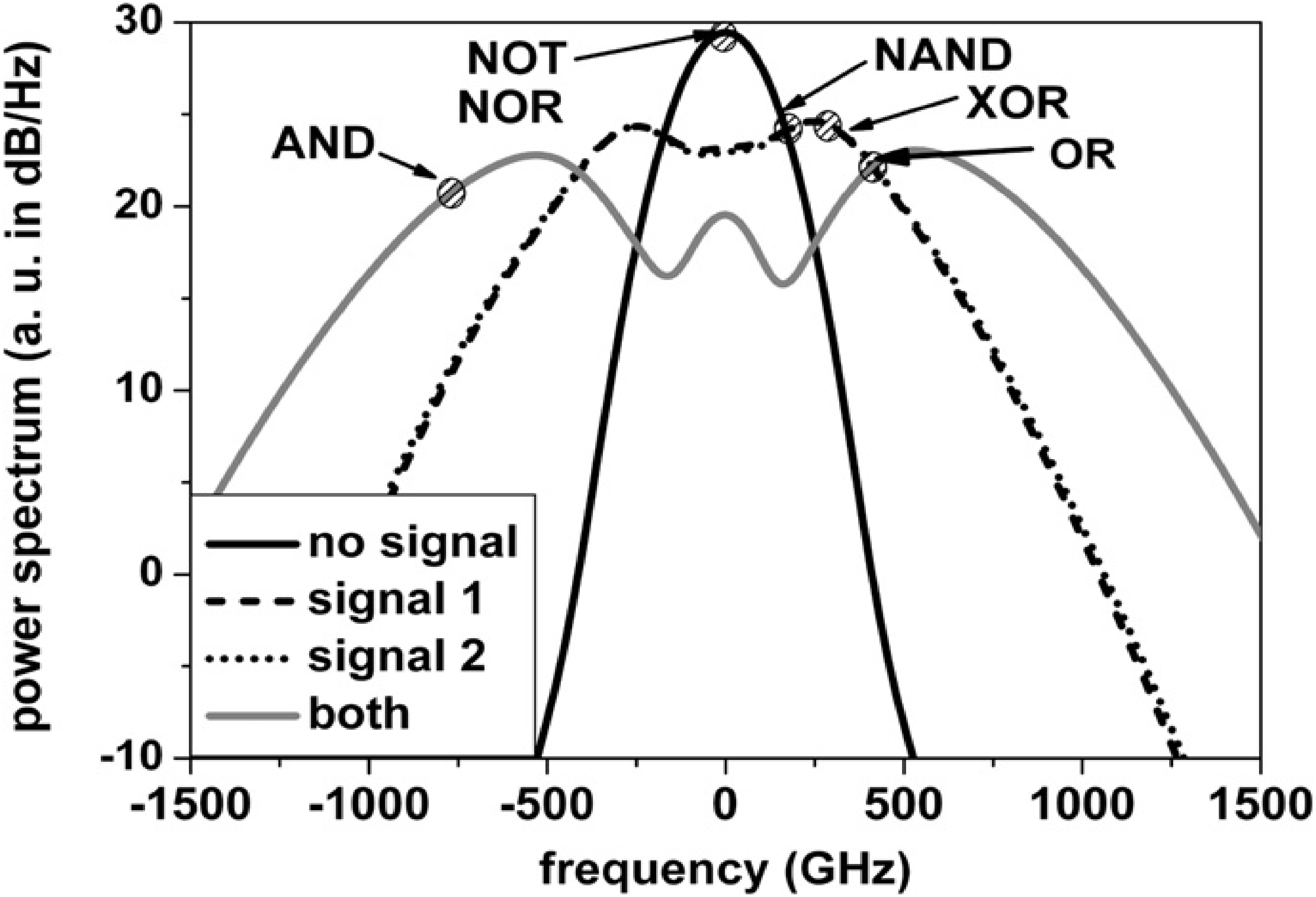
Logic Gates achieved with HNLF

Signal 1 and signal 2 are two strong modulated optical return-to-zero signal, and the power of probe signal is weak. They are positioned at different wavelengths respectively.



Adonis Bogris, Pantelis Velanas, Dimitris Syvridis, "Numerical Investigation of a 160-Gb/s Reconfigurable Photonic Logic Gate Based on Cross-Phase Modulation in Fibers," *IEEE Photon. Technol. Lett.*, vol. 19, no. 6, pp. 402–404, Mar. 15, 2007.

Logic Gates achieved with HNLF



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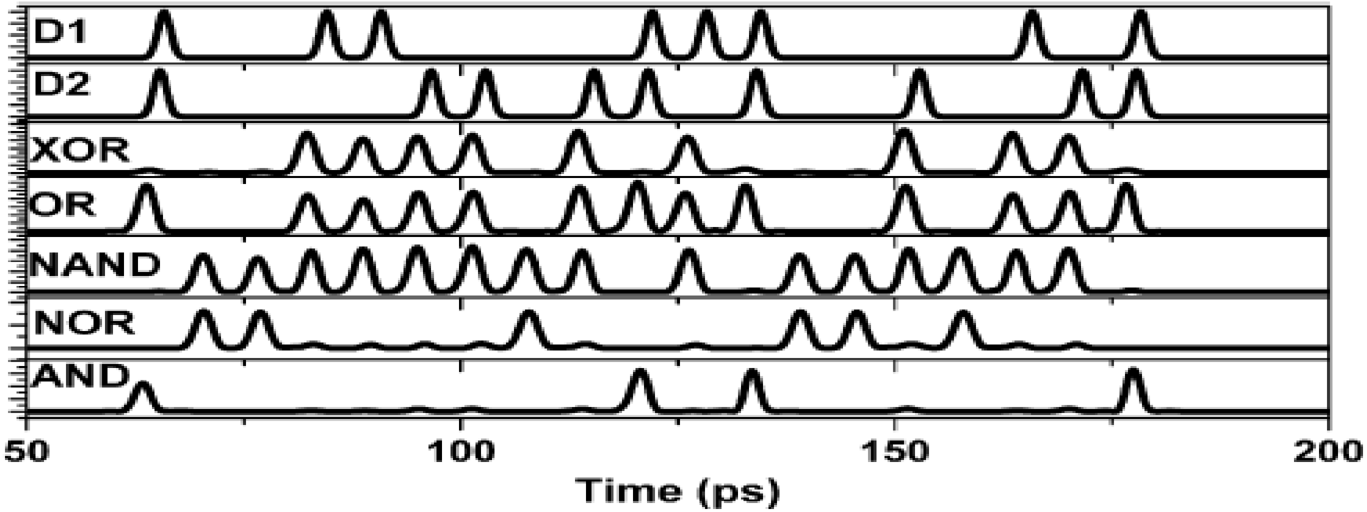
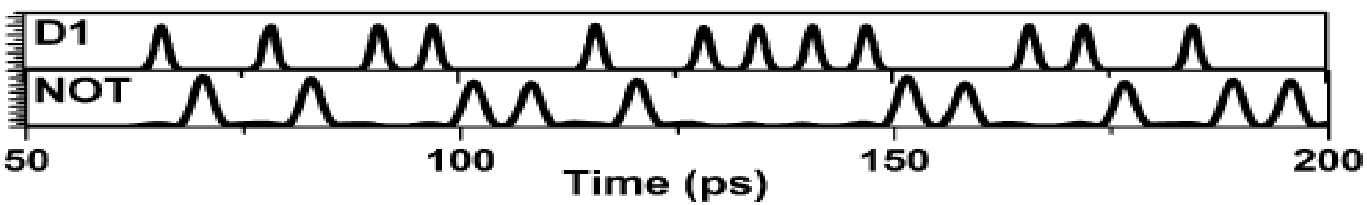
Results

The pulse's width is chosen to be equal to 1 ps, short enough to support 160 Gbps.



(a)



(b)

Adonis Bogris, Pantelis Velanas, Dimitris Syvridis, "Numerical Investigation of a 160-Gb/s Reconfigurable Photonic Logic Gate Based on Cross-Phase Modulation in Fibers," *IEEE Photon. Technol. Lett.*, vol. 19, no. 6, pp. 402–404, Mar. 15, 2007.

Conclusions & future works

Conclusions:

- XPM: input power → refractive index → velocity → phase.
- Explain how the XOR gate is completed in SOA and its limitation.
- A reconfigurable photonic logic gate based on XPM in HNLF.

Future works:

- Make clear the relationship among the input power of pump signals, data rate of three signals and the power spectrum of probe signal.
- Main factors in HNLF affecting the shape of output spectrum.
- Do simulations to achieve the logic gates.

Thank you!

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