北京郵電大學
BEIJING UNIVERSITY OF POSTS AND TELECOMMUNICATIONS

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COMPUTER SCIENCE

A Reconfigurable All-Optical Logic Device Using Blue and Red Shift

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Motivation

- High-speed all-optical logic gates are key elements to realize all-optical signal processing functions.
- Reconfigurable multi-logic gates are preferred as they can provide a more flexible set of networking functions.
- The existing reconfigurable multi-logic gate designs have already been proposed have several shortcomings:
  - Increasing the cost and complexity of the system by adding an additional continuous wave (CW) input or clock signal.
  - The operation is complicated by changing the parameters of input data signals.

Paper Review

- K. Sun, J. Qiu, M. Rochette, L. R. Chen, "All-Optical Logic Gates (XOR, AND, and OR) Based on Cross Phase Modulation in a Highly Nonlinear Fiber," *Proc., European Conference on Optical Communication (ECOC)*, September, 2009.

- J. Qiu, K. Sun, M. Rochette, L. R. Chen, "Reconfigurable All-Optical Multilogic Gate (XOR, AND, and OR) Based on Cross-Phase Modulation in a Highly Nonlinear Fiber," *IEEE Photon. Technol. Lett.,* vol. 22, no. 16, pp. 1199–1201, August, 2010.

Operation Principle

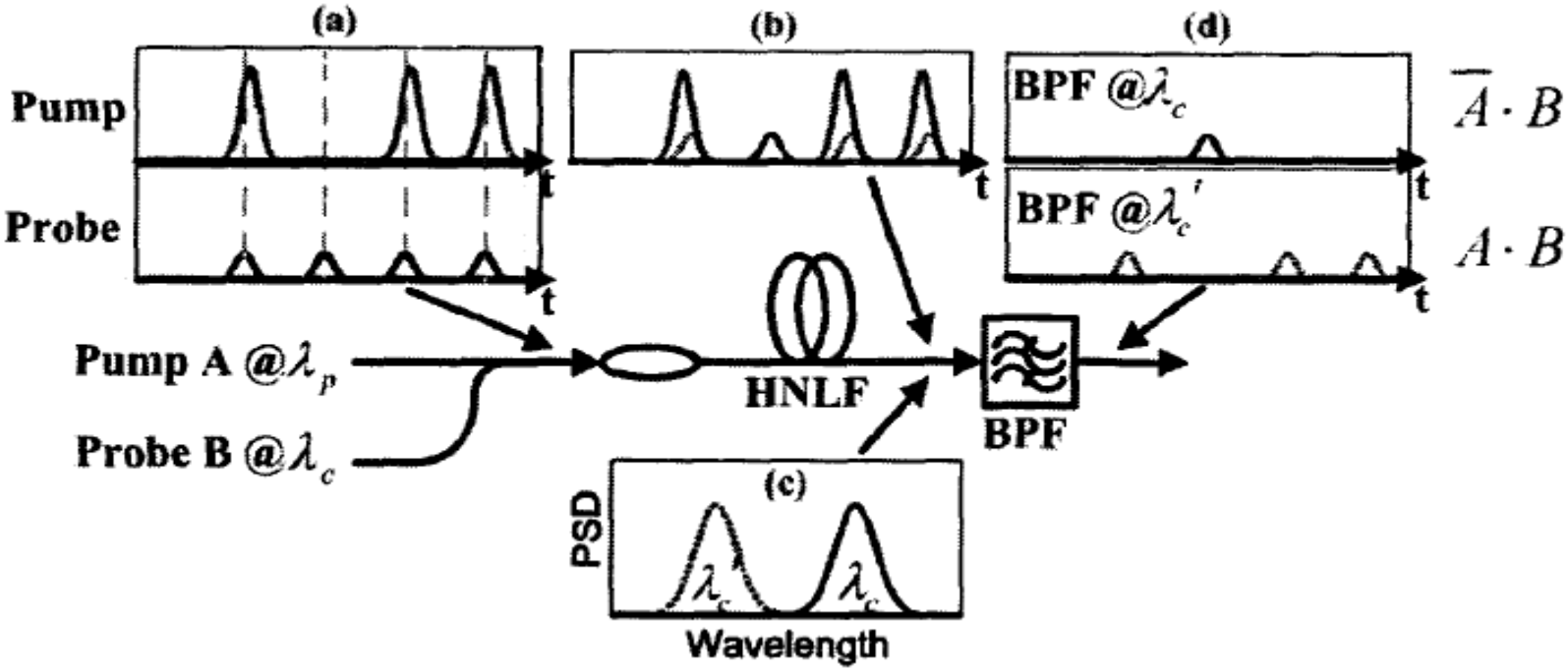

Fig. 1. Illustrating the principle of operation (Signal A acts as a pump and signal B acts as a probe). HNLF: highly nonlinear fiber, BPF: bandpass filter.

One lobe at λ_c is identical to the probe spectrum before XPM which is formed by the logical zeros of pump A, and a second lobe at λ_c' is a spectrally shifted replica of the probe spectrum, which is formed by the logical ones of pump A.

Operation Principle

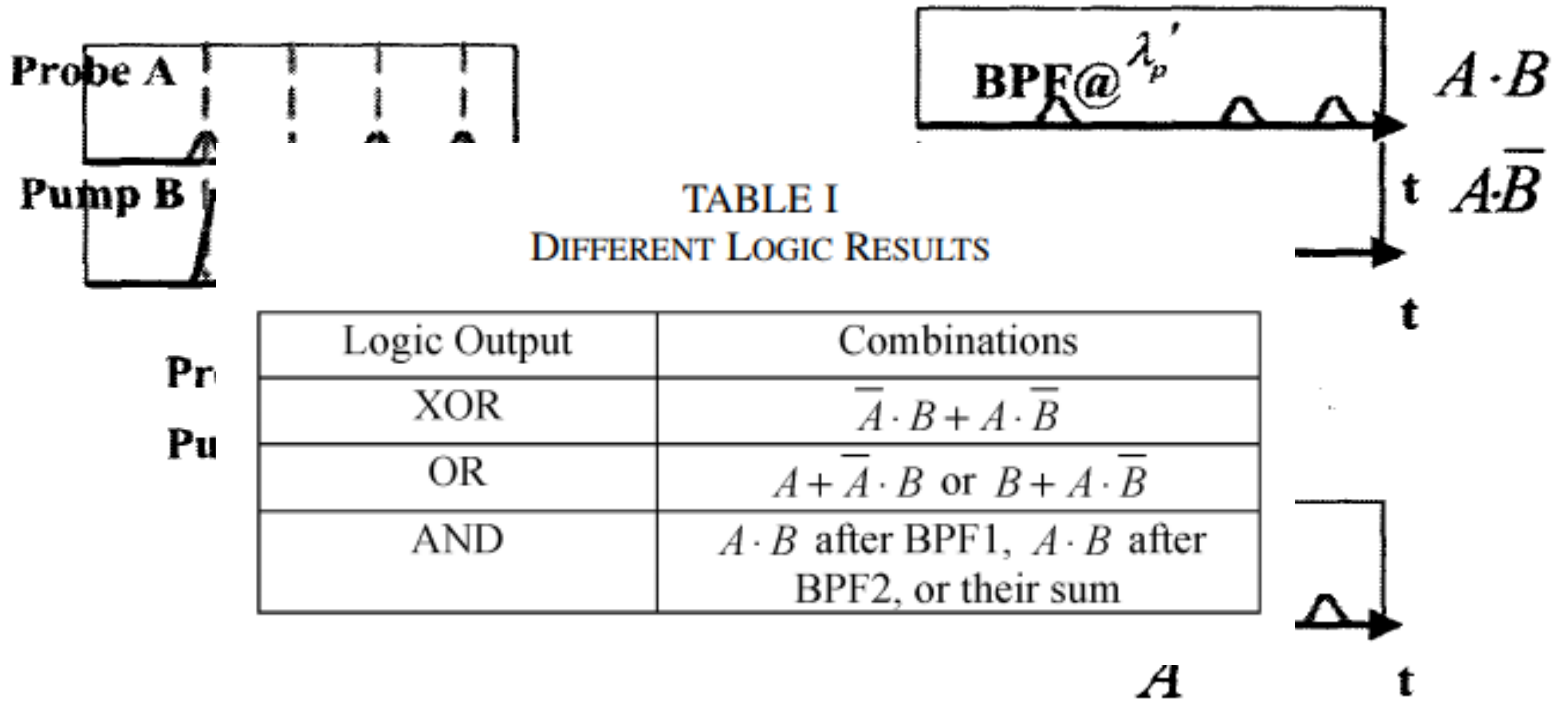

TABLE I
DIFFERENT LOGIC RESULTS

Logic Output	Combinations
XOR	$\overline{A} \cdot B + A \cdot \overline{B}$
OR	$A + \overline{A} \cdot B$ or $B + A \cdot \overline{B}$
AND	$A \cdot B$ after BPF1, $A \cdot B$ after BPF2, or their sum

Fig. 2. Illustrating the principle of operation (Signal A acts as a probe and signal B acts as a pump).

The second lobe can be red-shifted or blue-shifted, depending on which edge of the pump signal is superimposed on the probe signal.

Experimental Setup

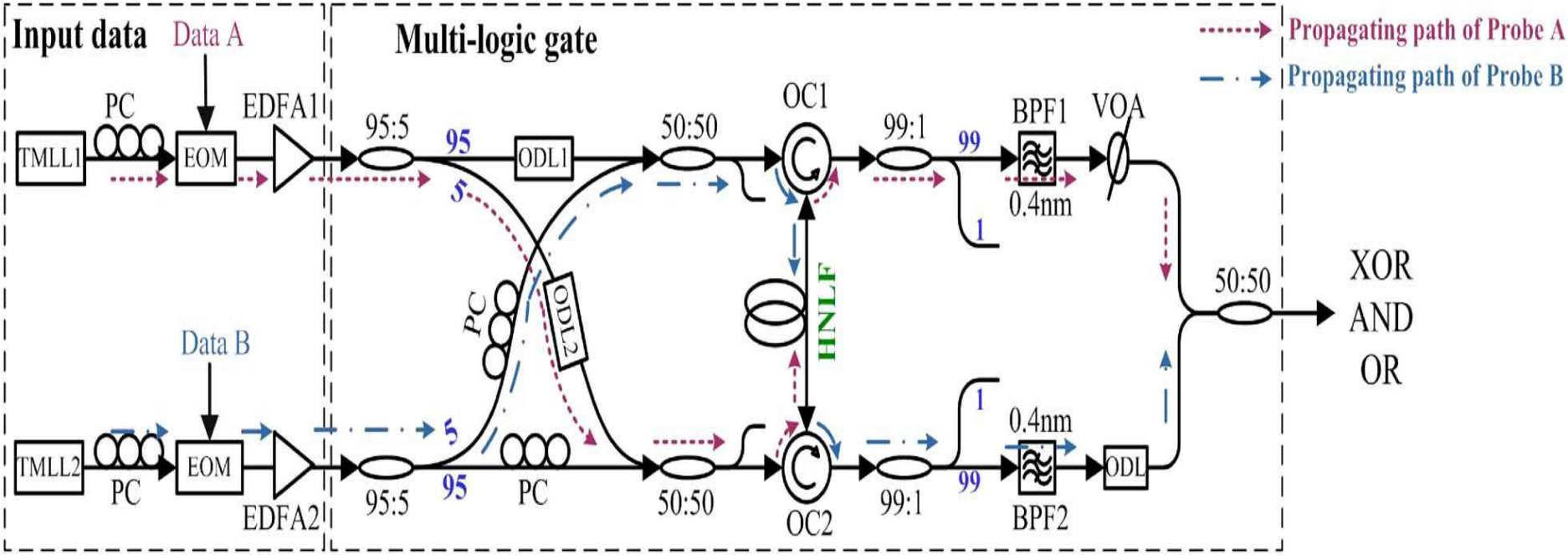

Fig. 3. Experimental setup. TMLL: tunable mode-locked laser, PC: polarization controller, EOM: electrooptical modulator, EDFA: erbium-doped fiber amplifier, ODL: optical delay line, OC: optical circulator, HNLF: highly nonlinear fiber, BPF: bandpass filter, VOA: variable optical attenuator.

The HNLF has a length of 1007 m, nonlinearity coefficient of 12.5 $W^{-1}\cdot km^{-1}$, chromatic dispersion of 0.69 ps/nm·km and dispersion slope of 0.0074 $ps/nm^2\cdot km$ at 1550.0 nm.

Experimental Setup

TABLE II
WAVELENGTH SETTINGS OF BPF1 AND BPF2 FOR DIFFERENT LOGIC OUTPUT

λ_A = 1555.24 nm, λ_B = 1541.32 nm		
Logic	λ_{BPF2}	λ_{BPF1}
XOR	1541.40 nm	1555.08 nm
AND	1538.32 nm	1558.52 nm
OR	1541.40 nm	1555.08 nm

- For the XOR gate, $A \cdot \bar{B}$ and $\bar{A} \cdot B$ are used after BPF1 and BPF2, respectively.
- For the AND gate, $A \cdot B$ can be achieved after BPF1, after BPF2, or at the combined output.
- For the OR gate, $A \cdot \bar{B}$ and B are used after BPF1 and BPF2, respectively.

Result 1

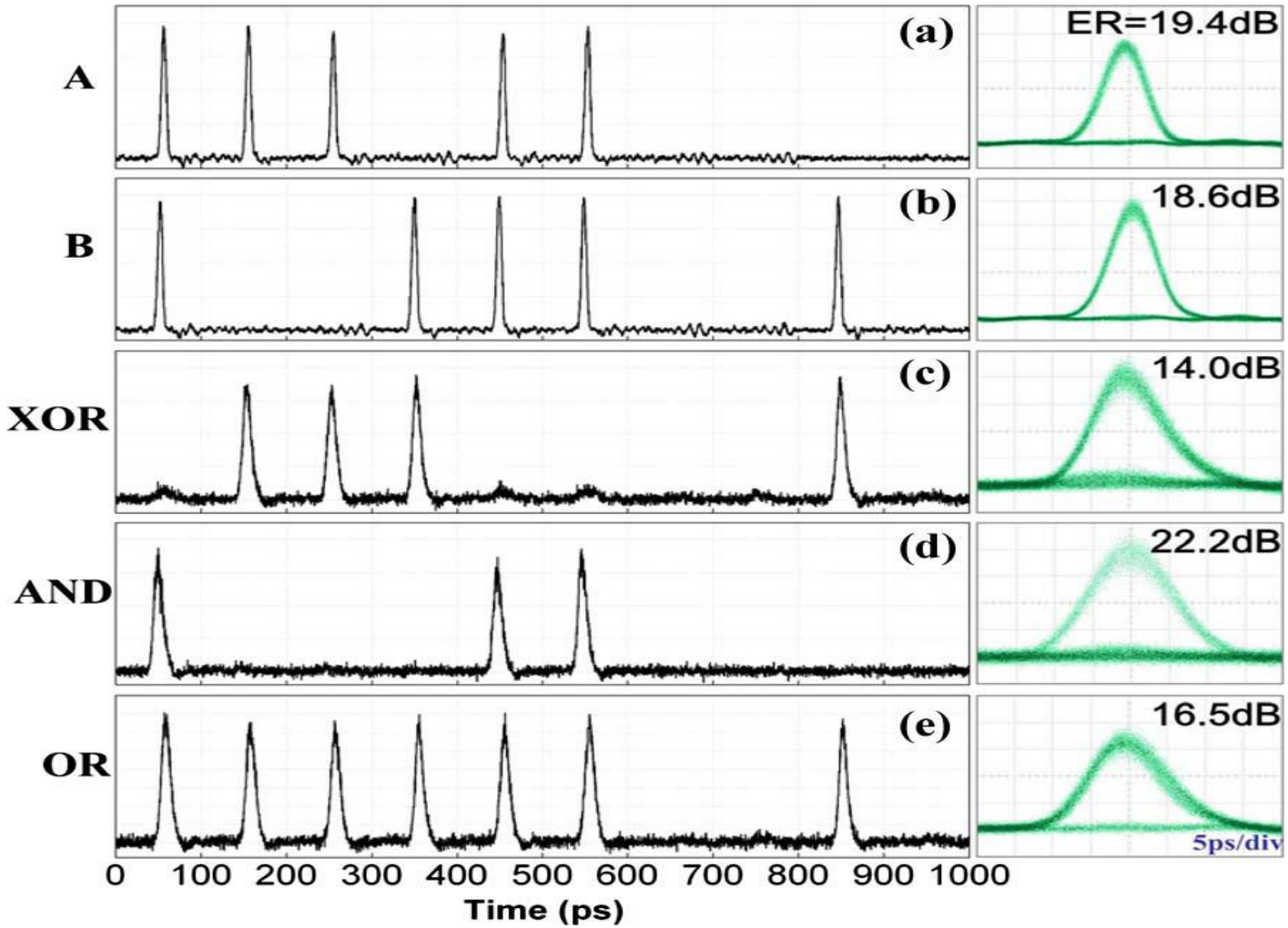

Fig. 4. Experimental results. ER: extinction ratio.

Result 2

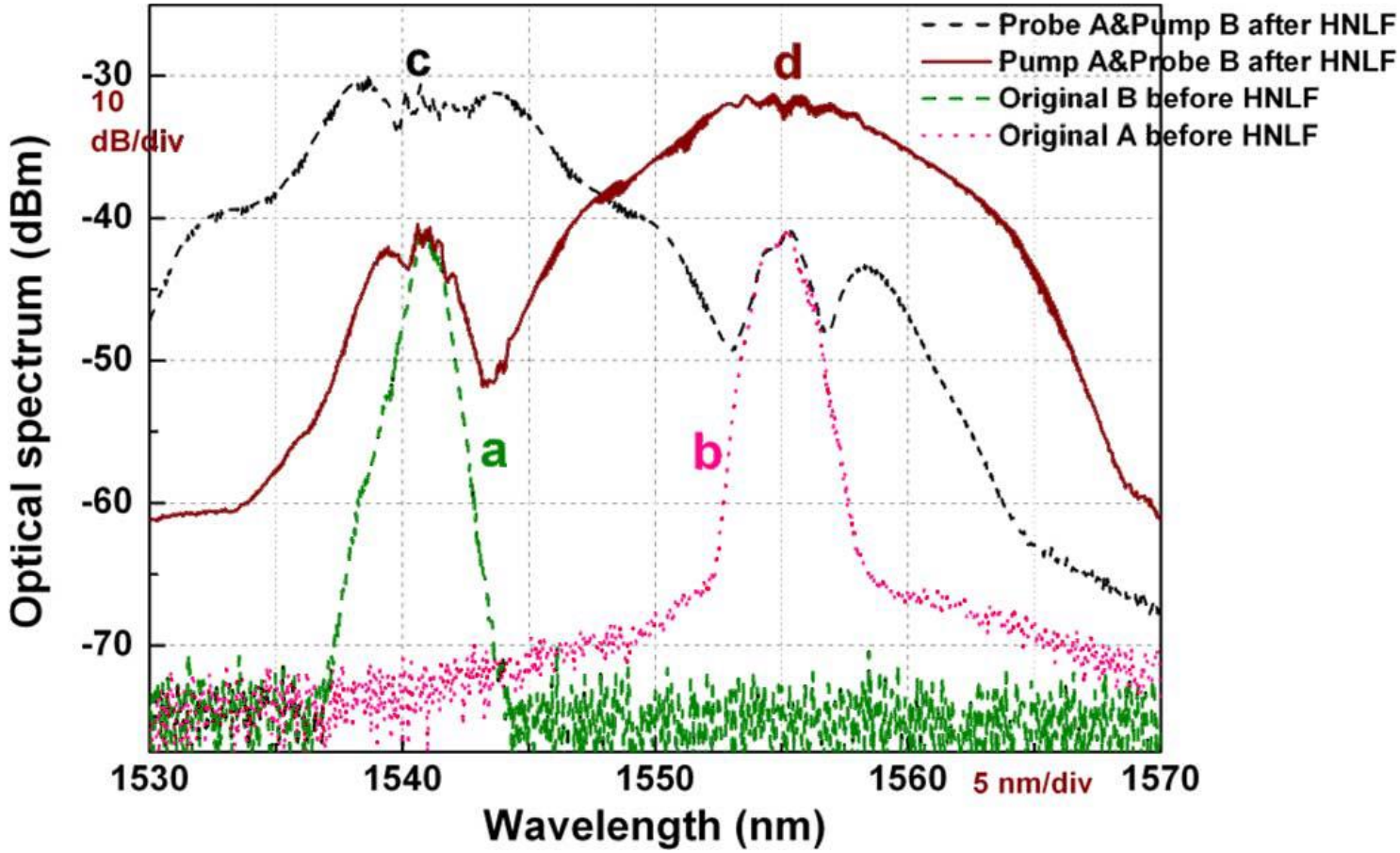

Fig. 5. Original spectrum of (a) signal *B* and (b) signal *A*. Optical spectrum after HNLF of (c) combined probe A and pump B and (d) combined pump A and probe B.

Result 3

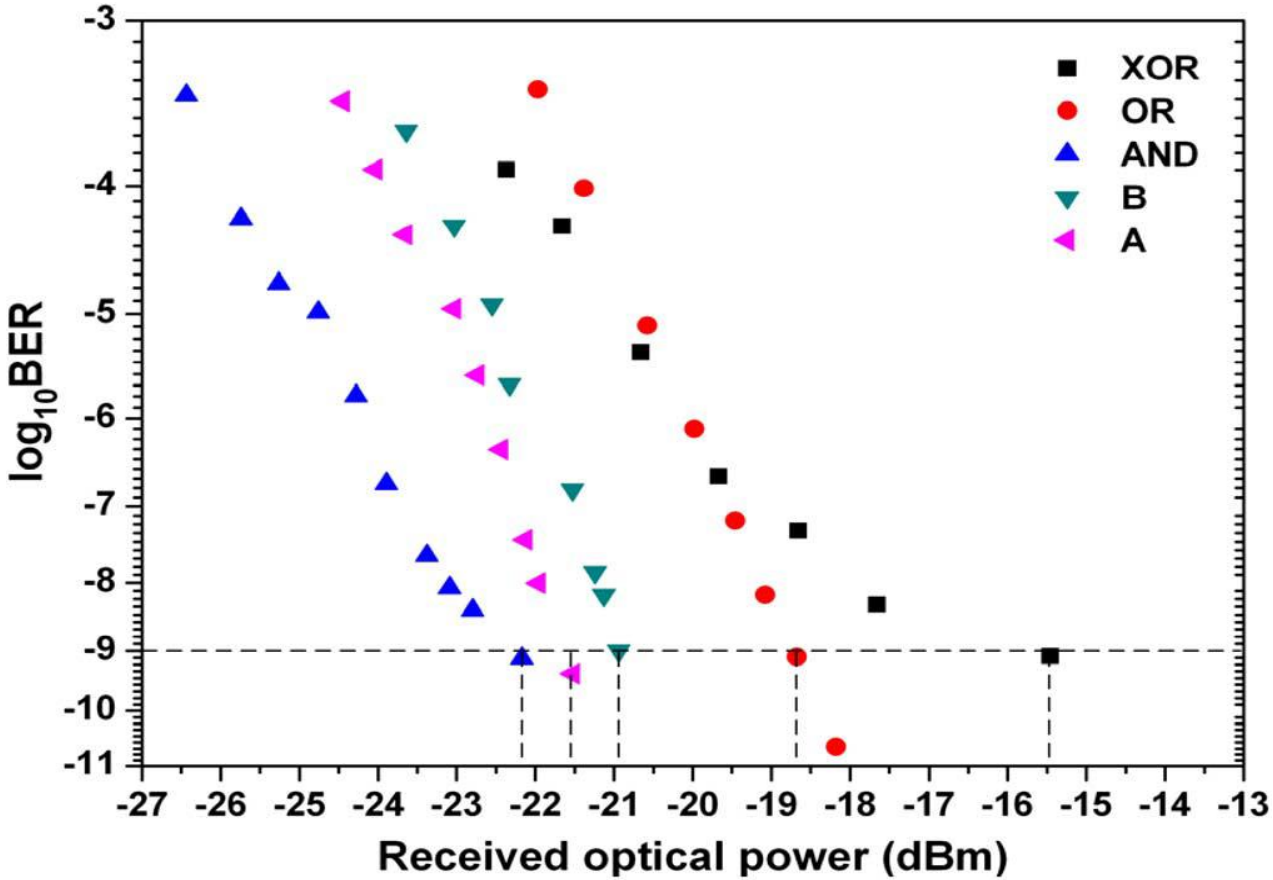

Fig. 6. BER measurements for multilogic operations and for input signals A and B.

Power penalties at a BER of 10^{-9} for XOR, AND, and OR are 5.9, -1.0, and 2.9 dB, respectively.

Discussion

A larger XPM effect is desired so that two peaks on the broadened spectrum of the probe can be clearly distinguished. Then, a larger chirp induced by XPM is preferred.

$$\Delta v_{\max} = \frac{\gamma_1 P_2 L}{\pi T_0 |\delta|} = \frac{\gamma_1 P_2 L_W}{\pi T_0}$$

Two way to maximize the XPM-induced chirp:

- Increase the power of pump P_2.
- Increase the walk-off length L_W.

There is a tradeoff between pump power and walk-off length.

Increased P_2 → overlap between signals → a larger wavelength separation → reduced L_W

Discussion

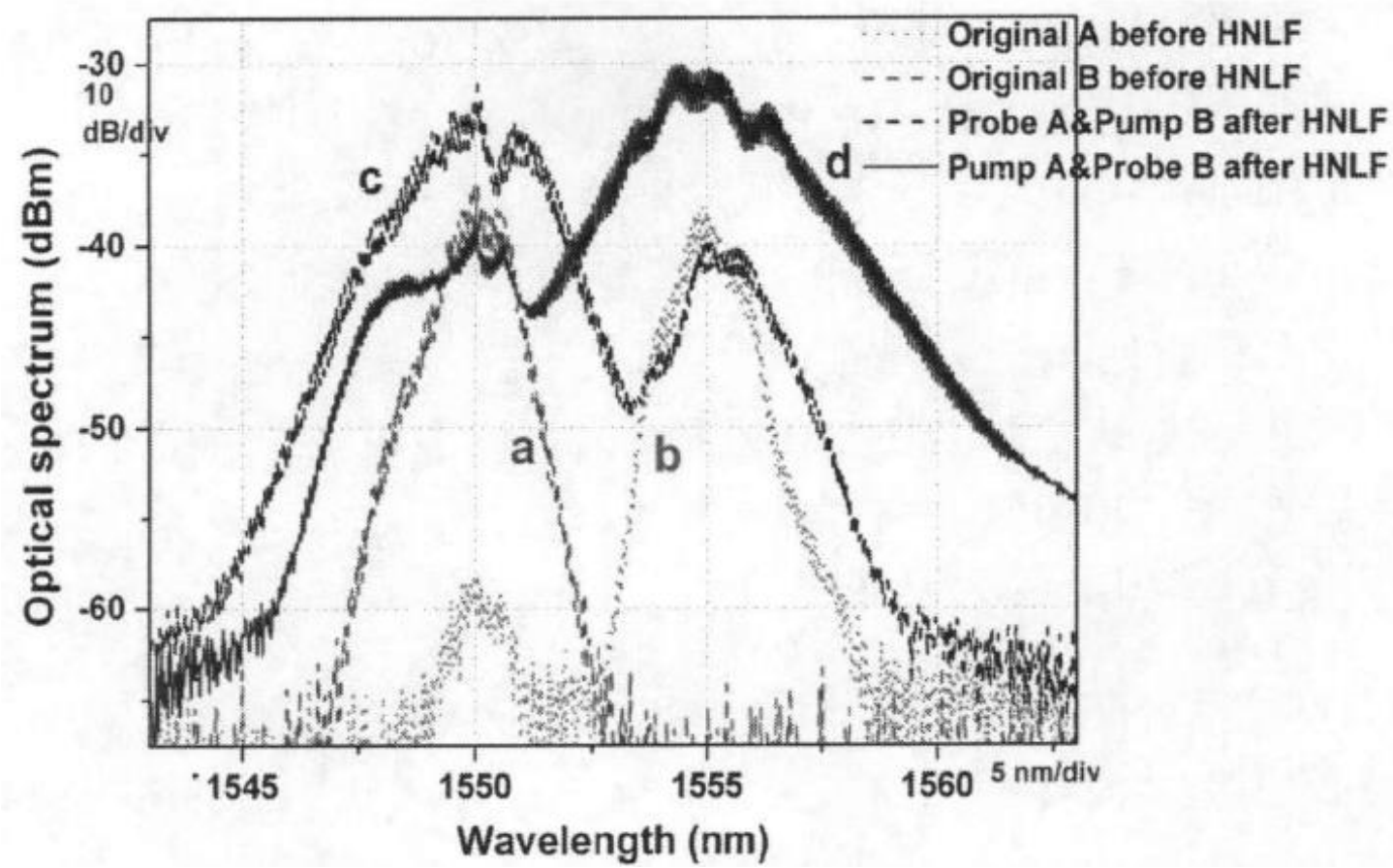

Fig. 7. Spectrum when the wavelength separation between signals *A* and *B* is 5.5 nm. (a) signal *B* and (b) signal *A*. Optical spectrum after HNLF of (c) combined probe A and pump B and (d) combined pump A and probe B.

Discussion

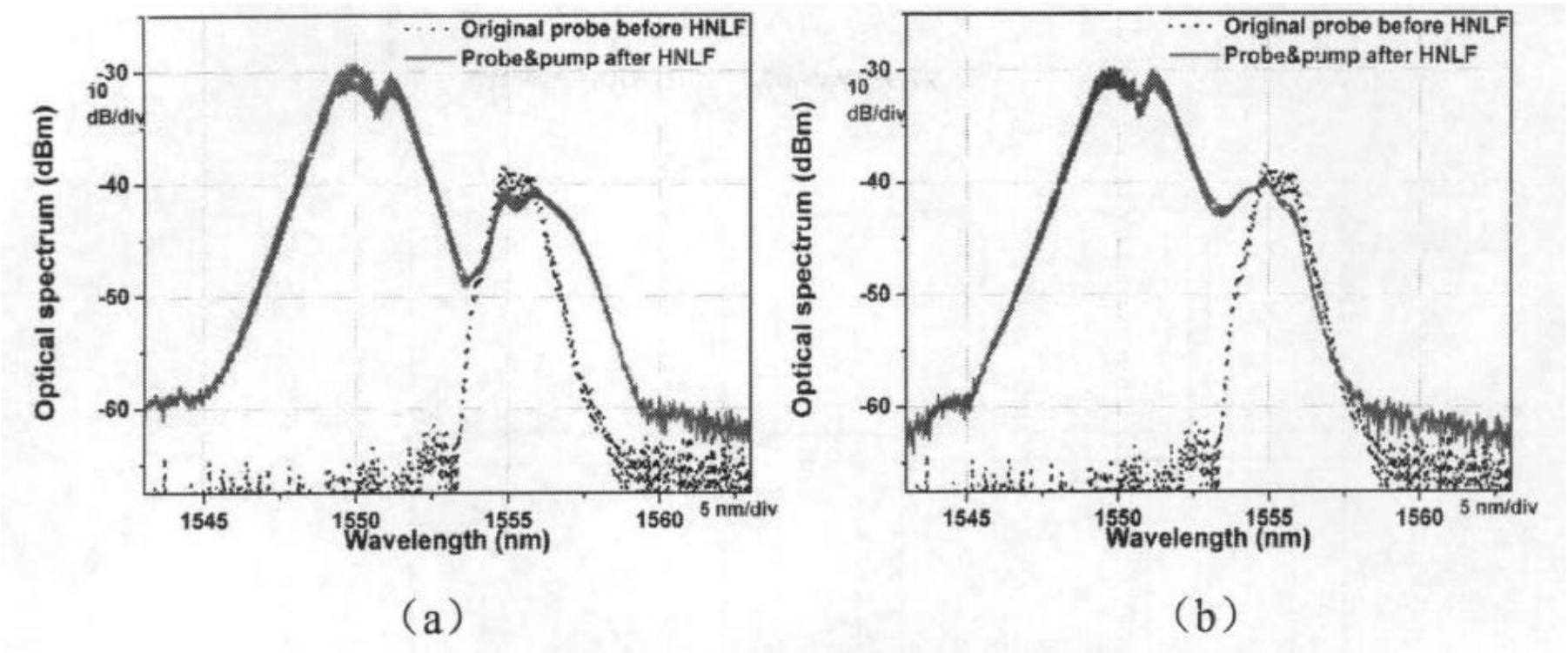

Fig. 8. Spectrum broadening induced by XPM. (a) red shift (b) blue shift.

The broadened spectrum induced by XPM varies with the delay between the pump and the probe. When the wavelength of probe is larger than that of pump, the red shift is more suitable.

Conclusions

- A simple and novel reconfigurable all-optical multilogic device which uses a single HNLF without any additional input operating at 10 Gb/s is experimentally demonstrated.
- The experiment can obtain error-free performance, a receiver sensitivity less than -15.0 dBm for a BER = 10^{-9} , and power penalties of 5.9, -1.0, and 2.9 dB for XOR, AND, and OR operations, respectively.
- All gates are believed to operate successfully beyond 100 Gb/s based on the fast time response of the Kerr effect.

Thank you for your attention!

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