Nonlinear Dyn (2022) 107:1215–1222
https://doi.org/10.1007/s11071-021-07027-5

ORIGINAL PAPER

Nonlinear control of logic structure of all-optical logic devices using soliton interactions

Qin Zhou · Tianyi Wang · Anjan Biswas · Wenjun Liu

Received: 14 October 2021 / Accepted: 25 October 2021 / Published online: 13 November 2021

Abstract The all-optical logic device is the key component in the all-optical communication system and all-optical computing. The research based on the all-optical logic device is important to improve the communication efficiency. In this paper, using optical solitons, all-optical logic devices are investigated theoretically. Three-soliton solutions are presented through solving the coupled nonlinear Schrödinger equations. The condition for forming all-optical logic devices (AOLDs) is discussed. Besides, the performance of the AOLD is analyzed. Results of this paper have theoretical research significance for the application of the AOLD.

Keywords Optical solitons · Nonlinear control · All-optical logic devices · Coupled nonlinear Schrödinger equation

Q. Zhou
School of Mathematical and Physical Sciences, Wuhan Textile University, Wuhan 430200, China

T. Wang, W. Liu (✉)
State Key Laboratory of Information Photonics and Optical Communications, and School of Science, Beijing University of Posts and Telecommunications, P. O. Box 122, Beijing 100876, China
e-mail: jungliu@bupt.edu.cn

A. Biswas
Department of Applied Mathematics, National Research Nuclear University, 31 Kashirskoe Hwy, Moscow 115409, Russian Federation

A. Biswas
Mathematical Modeling and Applied Computation (MMAC) Research Group, Department of Mathematics, King Abdulaziz University, Jeddah 21589, Saudi Arabia

A. Biswas
Department of Mathematics and Applied Mathematics, Sefako Makgatho Health Sciences University, Medunsa 0204, Pretoria, South Africa

A. Biswas
Department of Physics, Chemistry and Mathematics, Alabama A&M University, Normal, AL 35762-4900, USA

1 Introduction

All-optical logical devices (AOLDs) play a significant role in the all-optical technique and cause in-depth investigations around the world [1,2]. The research of the AOLD not only has great significance in all-optical communication systems, but also has a profound impact on the application of the all-optical computing [3,4]. In addition, the AOLD can work as a switcher, which switch optical signals and make signals output from different transmission paths [5,6]. The switch function makes the AOLD have an irreplaceable status in optical field. To realize an all-optical communication network so that signals can be transmitted in the optic fiber, the participation of the AOLD is indispensable, which will affect the quality of optical communications [7,8].

Generally speaking, the AOLDs refer to the optical devices that implement logic operations by changing signal transmission to the medium [9,10]. They are now divided into two types: semiconductor-based optical amplifiers (SOA) and nonlinear optical fibers. The advantage of SOA of long working band makes it become a hot spot in the study of nonlinear materials for the AOLD. Compared with the SOA, the advantage of the nonlinear optical fibers is the fast respond speed (about a few femtoseconds) [11,12]. The AOLDs based on them use nonlinear effects of nonlinear optical fibers to work under normal circumstances. Those optical devices utilize their switching characteristics to distribute the energy of optical pulses, so as to realize the logic results [13,14].

Optical solitons, as a product of dispersion and nonlinear balance, have been applied to the research of the AOLD based on nonlinear optical fibers, and some results have been obtained [15–28]. Bright and dark solitons can be used to study the switching characteristics of nonlinear directional coupler, and researchers have analyzed the broadening and compression of different optical solitons [29–32]. The AOLDs have been demonstrated. Besides, researchers have studied the transmission characteristics of the optical solitons in the asymmetric coupler when the dispersion coefficient has been decreased and discovered the optical logic function of the asymmetric coupler during the research process [33]. In 2011, an in-depth study has been conducted on the pulse transmission characteristics of the AOLD [34].

Here, we will use optical solitons to study the AOLD. The interactions among optical solitons are supported by the coupled nonlinear Schrödinger (CNLS) equations as follows [35],

$$\begin{aligned} & iU_{1,t} + U_{1,xx} + 2\left(\rho_1 |U_1|^2 + \rho_2 |U_2|^2\right) U_1 \\ & \quad + i\varepsilon \Big[U_{1,xxx} + 3\left(\rho_1 |U_1|^2 + \rho_2 |U_2|^2\right) \\ & \quad \times U_{1,x} + 3\left(\rho_1 U_1^* U_{1,x} + \rho_2 U_2^* U_{2,x}\right) U_1 \Big] = 0, \\ & iU_{2,t} + U_{2,xx} + 2\left(\rho_1 |U_1|^2 + \rho_2 |U_2|^2\right) U_2 \\ & \quad + i\varepsilon \Big[U_{2,xxx} + 3\left(\rho_1 |U_1|^2 + \rho_2 |U_2|^2\right) \\ & \quad \times U_{2,x} + 3\left(\rho_1 U_1^* U_{1,x} + \rho_2 U_2^* U_{2,x}\right) U_2 \Big] = 0, \quad (1) \end{aligned}$$

where U_1 and U_2 are both the soliton intensities of x and t. ρ_1 and ρ_2 are related to optical fiber nonlinearity. ε is a small parameter, which is a real number. The symbol "*" is the complex conjugate. In ref. [35], rogue waves were studied using the Darboux transformation. Breathers and dark-bright semi-rational solitons were also obtained [36]. Furthermore, soliton fusion and fission was demonstrated [37].

Solutions for Eq. (1) will be derived in Sect. 2. Discussions about the properties of all-optical logic devices will be made in Sect. 3. Conclusion will be derived at last.

2 Analytical solutions of Eq. (1)

To obtain the three-soliton solutions of Eq. (1), the bilinear forms of it can be get at first. The detail forms are [37],

$$\begin{aligned} & \left(iD_t + D_x^2 + i\varepsilon D_x^3\right) G \cdot F = 0, \\ & \left(iD_t + D_x^2 + i\varepsilon D_x^3\right) H \cdot F = 0, \\ & \quad D_x^2 F \cdot F = 2\left(|G|^2 + |H|^2\right), \end{aligned} \quad (2)$$

where "D_x" and "D_t" are the Hirota bilinear operators [38]. G, H and F are the functions of x and t to be determined with the coefficient constraints $\rho_1 = \rho_2 = 1$.

We assume that

$$\begin{aligned} G &= \epsilon G_1 + \epsilon^3 G_3 + \epsilon^5 G_5, \\ H &= \epsilon H_1 + \epsilon^3 H_3 + \epsilon^5 H_5, \\ F &= 1 + \epsilon^2 F_2 + \epsilon^4 F_4 + \epsilon^6 F_6, \end{aligned} \quad (3)$$

where ϵ is the formal parameters, and G_1, G_3, G_5, H_1, H_3, H_5, F_2, F_4 and F_6 are the undetermined functions. Next, we will get the exactly expression of those functions through Eq. (2).

For simplicity, we set that

$$\begin{aligned} G_1(x,t) &= e^{\varphi_1} + e^{\varphi_2} + e^{\varphi_3}, \\ H_1(x,t) &= -e^{\varphi_1} + e^{\varphi_2} - e^{\varphi_3}, \end{aligned} \quad (4)$$

where

$$\begin{aligned} \varphi_j &= k_j x + \omega_j t + \xi_j \\ &= (k_{j1} + ik_{j2})x + (\omega_{j1} + i\omega_{j2})t \\ &\quad + \xi_{j1} + i\xi_{j2}, (j = 1, 2, 3). \end{aligned} \quad (5)$$

Substituting expressions (4) into Eq. (2), we can get the following coefficient relationship,

$$\begin{aligned} \omega_{j1} &= 3\varepsilon k_{j1} k_{j2}^2 - 2k_{j1}k_{j2} \\ &\quad - \varepsilon k_{j1}^3, \ \omega_{j2} \\ &= k_{j1}^2 - k_{j2}^2 - 3\varepsilon k_{j2} k_{j1}^2 + \varepsilon k_{j2}^3. \end{aligned} \quad (6)$$

Assuming that

$$F_2(x,t) = A_1 e^{\theta_1 + \theta_1^*} + A_2 e^{\theta_1 + \theta_3^*}$$

$$+A_3 e^{\theta_2+\theta_2^*}$$
$$+A_4 e^{\theta_3+\theta_1^*}$$
$$+A_5 e^{\theta_3+\theta_3^*}, \tag{7}$$

we can obtain

$$A_1 = \frac{1}{2k_{11}^2},$$
$$A_2 = \frac{2}{(k_1+k_3^*)^2},$$
$$A_3 = \frac{1}{2k_{21}^2},$$
$$A_4 = \frac{2}{(k_1^*+k_3)^2},$$
$$A_5 = \frac{1}{2k_{31}^2}. \tag{8}$$

Assuming that

$$G_3(x,t) = B_1 e^{\theta_1+\theta_2+\theta_1^*}$$
$$+B_2 e^{\theta_1+\theta_2+\theta_2^*} + B_3 e^{\theta_1+\theta_2+\theta_3^*} + B_4 e^{\theta_1^*+\theta_1+\theta_3}$$
$$+B_5 e^{\theta_3^*+\theta_1+\theta_3} + B_6 e^{\theta_2+\theta_3+\theta_1^*}$$
$$+B_7 e^{\theta_2+\theta_3+\theta_2^*} + B_8 e^{\theta_2+\theta_3+\theta_3^*},$$
$$H_3(x,t) = C_1 e^{\theta_1+\theta_2+\theta_1^*}$$
$$+C_2 e^{\theta_1+\theta_2+\theta_2^*} + C_3 e^{\theta_1+\theta_2+\theta_3^*} + C_4 e^{\theta_1^*+\theta_1+\theta_3}$$
$$+C_5 e^{\theta_3^*+\theta_1+\theta_3} + C_6 e^{\theta_2+\theta_3+\theta_1^*}$$
$$+C_7 e^{\theta_2+\theta_3+\theta_2^*} + C_8 e^{\theta_2+\theta_3+\theta_3^*}, \tag{9}$$

we can get

$$B_1 = C_1 = \frac{i(k_1-k_2)(2i+3\varepsilon(k_1^*-k_2))}{2k_{11}^2(k_1^*+k_2)(2+3i(k_1+k_2)\varepsilon)},$$
$$B_2 = -C_2 = \frac{i(k_1-k_2)(2i+3\varepsilon(k_2^*-k_1))}{2k_{21}^2(k_1+k_2^*)(2+3i(k_1+k_2)\varepsilon)},$$
$$B_3 = C_3 = \frac{2i(k_1-k_2)(2i+\varepsilon(k_3^*-k_2))}{(k_1+k_3^*)^2(k_2+k_3^*)(2+3i(k_1+k_2)\varepsilon)},$$
$$B_4 = -C_4 = \frac{-(k_3-k_1)^2}{2k_{11}^2(k_1^*+k_3)^2}, \; B_5$$
$$= -C_5 = \frac{-(k_3-k_1)^2}{2k_{31}^2(k_1+k_3^*)^2},$$
$$B_6 = C_5 = \frac{2i(k_3-k_2)(2i+3\varepsilon(k_1^*-k_2))}{(k_1^*+k_3)^2(k_2+k_1^*)(2+3i(k_2+k_3)\varepsilon)},$$
$$B_7 = -C_7 = \frac{i(k_3-k_2)(2i+3\varepsilon(k_2^*-k_3))}{2k_{21}^2(k_3+k_2^*)(2+3i(k_3+k_2)\varepsilon)},$$
$$B_8 = C_8 = \frac{i(k_3-k_2)(2i+3\varepsilon(k_3^*-k_2))}{2k_{31}^2(k_3^*+k_2)(2+3i(k_3+k_2)\varepsilon)}. \tag{10}$$

Assuming that

$$F_4(x,t) = D_1 e^{\theta_2+\theta_1+\theta_1^*+\theta_2^*}$$
$$+D_2 e^{\theta_1+\theta_2^*+\theta_2+\theta_3^*} + D_3 e^{\theta_1+\theta_3+\theta_1^*+\theta_3^*}$$
$$+D_4 e^{\theta_3+\theta_1^*+\theta_2+\theta_2^*} + D_5 e^{\theta_2+\theta_3+\theta_2^*+\theta_3^*}, \tag{11}$$

we substitute Eqs. (4), (7), (9) and (11) into Eq. (3) and can get that

$$D_1 = \frac{4-12\varepsilon(k_{12}+k_{22})+9((k_{11}-k_{21})^2+(k_{12}+k_{22})^2)\varepsilon^2}{4k_{11}^2k_{21}^2|(k_1+k_2^*)(3(k_1+k_2)\varepsilon-2i)|^2}((k_{11}-k_{21})^2+(k_{12}-k_{22})^2),$$
$$D_2 = \frac{(k_1-k_2)(k_2^*-k_3^*)(3\varepsilon(k_1-k_2^*)-2i)(3\varepsilon(k_2-k_3^*)-2i)}{k_{21}^2(k_1+k_2^*)(k_1+k_3^*)^2(k_2+k_3^*)(3\varepsilon(k_1+k_2)-2i)(3\varepsilon(k_2^*+k_3^*)+2i)},$$
$$D_3 = \frac{((k_{11}-k_{31})^2+(k_{12}-k_{32})^2)^2}{4k_{11}^2k_{31}^2((k_{11}+k_{31})^2+(k_{12}-k_{32})^2)^2},$$
$$D_4 = \frac{(k_1^*-k_2^*)(k_2-k_3)(3\varepsilon(k_1^*-k_2)+2i)(3\varepsilon(k_2^*-k_3)+2i)}{k_{21}^2(k_1^*+k_2)(k_1^*+k_3)^2(k_2^*+k_3)(3\varepsilon(k_1^*+k_2^*)+2i)(3\varepsilon(k_2+k_3)-2i)},$$
$$D_5 = \frac{4-12\varepsilon(k_{22}+k_{32})+9((k_{21}-k_{31})^2+(k_{22}+k_{32})^2)\varepsilon^2}{4k_{21}^2k_{31}^2|(k_2+k_3^*)(3(k_2+k_3)\varepsilon-2i)|^2}((k_{21}-k_{31})^2+(k_{22}-k_{32})^2). \tag{12}$$

Moreover, we can assume that

$$
\begin{aligned}
G_5(x,t) &= E_1 e^{\theta_1+\theta_2+\theta_1^*+\theta_2^*+\theta_3} \\
&\quad + E_2 e^{\theta_1+\theta_2+\theta_1^*+\theta_3^*+\theta_3} \\
&\quad + E_3 e^{\theta_1+\theta_2+\theta_3+\theta_2^*+\theta_3^*}, \\
H_5(x,t) &= E_4 e^{\theta_1+\theta_2+\theta_1^*+\theta_2^{*+\theta_3}} \\
&\quad + E_5 e^{\theta_1+\theta_2+\theta_1^*+\theta_3^*+\theta_3} \\
&\quad + E_6 e^{\theta_1+\theta_2+\theta_3+\theta_2^*+\theta_3^*},
\end{aligned} \tag{13}
$$

and then, we can derive

$$
\begin{aligned}
E_1 &= \frac{(4-12\varepsilon(k_{12}+k_{32})+9((k_{11}-k_{21})^2+(k_{12}+k_{32})^2)\varepsilon^2)(k_1-k_3)}{4Mk_{11}^2k_{21}^2(k_{21}+k_{31})^2(k_1^*+k_3)(3(k_1+k_3)\varepsilon-2i)} \\
&\quad \times ((k_{21}-k_{31})^2((k_{11}-k_{21})^2+(k_{12}-k_{32})^2))(3\varepsilon(k_1^*-k_3)+2i) = E_4, \\
M &= |(k_1+k_{21}-ik_{32})(3(k_1+k_{21}+ik_{32})\varepsilon-2i)|^2, \\
E_2 &= \frac{(4-12\varepsilon(k_{12}+k_{32})+9((k_{11}-k_{31})^2+(k_{12}+k_{32})^2)\varepsilon^2)(k_1-k_{21}-ik_{32})}{4Nk_{11}^2k_{31}^2(k_1^*+k_{21}+ik_{32})(3(k_1+k_{21}+ik_{32})\varepsilon-2i)} \\
&\quad \times ((k_{21}-k_{31})^2((k_{11}-k_{31})^2+(k_{12}-k_{32})^2))(3\varepsilon(k_1^*-k_{21}-ik_{32})+2i) = E_5, \\
N &= (k_{21}+k_{31})^2|(k_1+k_3^*)(3(k_1+k_3)\varepsilon-2i)|^2, \\
E_3 &= \frac{(k_{21}-k_{31})^4(k_1-k_{21}-ik_{32})(k_3-k_1)(2i-3\varepsilon(k_1-k_3^2))}{4Lk_{21}^2k_{31}^2(k_{21}+k_{31})^4(k_1+k_{21}-ik_{32})(k_1+k_3^*)(3\varepsilon(k_1+k_3)-2i)}(2i-3\varepsilon(k_1-k_{21}+ik_{32})) = -E_6, \\
L &= (3(k_1+k_{21}+ik_{32})\varepsilon-2i).
\end{aligned} \tag{14}
$$

At last, we assume

$$
F_6(x,t) = E_7 e^{\theta_1+\theta_2+\theta_3+\theta_1^*+\theta_2^*+\theta_3^*}; \tag{15}
$$

the coefficient E_7 can be obtained as

$$
\begin{aligned}
E_7 &= \frac{P+Q}{2(k_{11}+k_{21}+k_{31})^2}, \\
P &= |B_3|^2+|B_6|^2+B_2B_5^*+B_5B_2^* \\
&\quad +B_4B_7^*+B_7B_4^*+B_1B_8^*+B_8B_1^*+E_5+E_6, \\
Q &= 2A_4D_2(k_{32}-k_{12}+ik_{21})^2+2A_2D_4(k_{12} \\
&\quad +ik_{21}-k_{32})^2-2A_5D_1 \\
&\quad \times(k_{11}+k_{21}-k_{31})^2 \\
&\quad -2A_3D_3(k_{11}-k_{21}+k_{31})^2 \\
&\quad -2A_1D_5(k_{21}+k_{31}-k_{11})^2.
\end{aligned} \tag{16}
$$

We assume $\varepsilon = 1$. Finally, solutions for Eq. (1) are obtained as

$$
\begin{aligned}
U_1 &= \frac{G_1+G_3+G_5}{1+F_2+F_4+F_6}, \\
U_2 &= \frac{H_1+H_3+H_5}{1+F_2+F_4+F_6},
\end{aligned} \tag{17}
$$

where $G_1, G_3, G_5, H_1, H_3, H_5, F_2, F_4$ and F_6 are presented in expressions (4), (7), (9), (11), (13) and (15).

3 Discussion

Expressions (17) are analytical solutions of Eq. (1). To analyze the three-soliton interactions, we set $\varepsilon = 0.05$ and select the relevant parameters as shown in Fig. 1 to realize the effective control of the logic structure of the AOLD with soliton interactions. As shown in Fig. 1(a) and (d), the intensities of optical solitons on the left are amplified when $k_{11} = 1.9$. Increasing the value of k_{11}, such as $k_{11} = 2.5$ in Fig. 1(b) and (e), the intensities of signals can be further increased on the left. Adjusting the value of k_{11}, such as $k_{11} = 1.2$ in Fig. 1(c) and (f), the logic structure of the AOLD is changed to amplify another signal. The intensities of solitons on the right are increased. Therefore, by adjusting the value of k_{11}, the signal on and off functions can be realized, so as to effectively increase the processing speed of the AOLD.

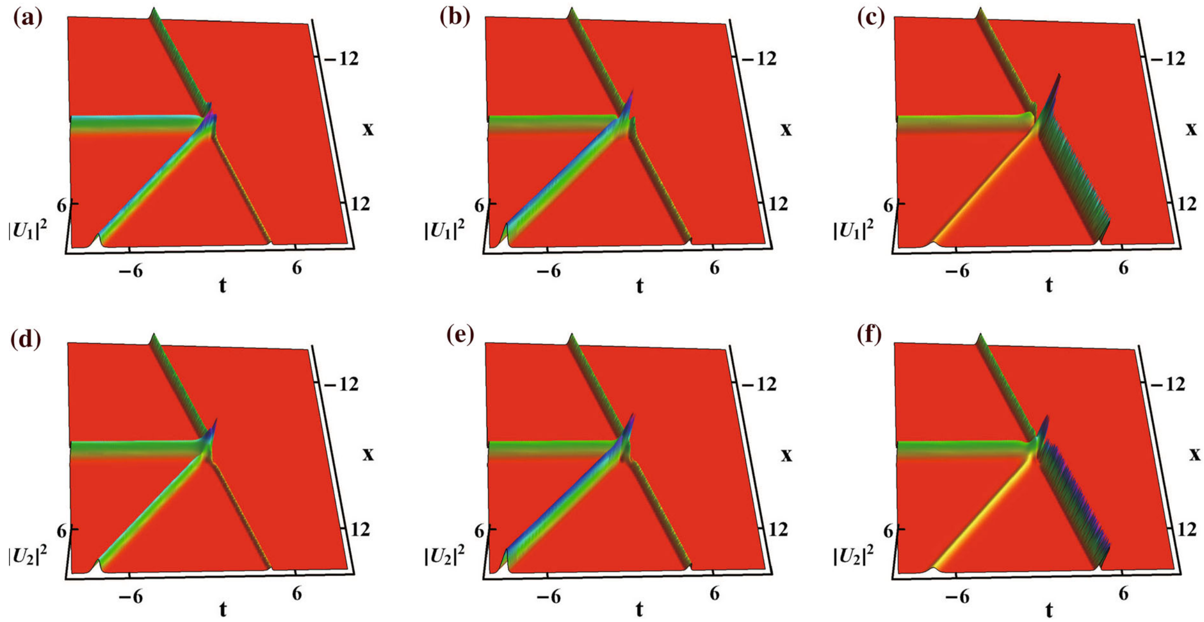

Fig. 1 Effective control of logic structure of the AOLD with soliton interactions. Relevant parameters are: $k_{21} = -1.8$, $k_{31} = -1.6$, $k_{12} = -1$, $k_{22} = -0.1$, $k_{32} = 3$, $\xi_{11} = -2$, $\xi_{12} = -1$, $\xi_{21} = 2$, $\xi_{22} = 2$, $\xi_{31} = -3$, $\xi_{32} = 3$ with **a** $k_{11} = 1.9$; **b**) $k_{11} = 2.5$; **c** $k_{11} = 1.2$; **d** has the same value as **a**; **e** has the same value as **b**; and **f** has the same value as **c**

Next, we will discuss the influences of k_{21} on the properties of the AOLD. Compared with Fig. 1, the sign of the values of k_{11} and k_{21} is opposite in Fig. 2. At first, we assume that $k_{21} = 2.7$ and can find that the energy exchange occurs between optical solitons, but the effect is not obvious due to the small change of intensities of optical solitons in Fig. 2(a) and (d). Decreasing k_{21}, such as $k_{21} = 2$ in Fig. 2(b) and 2(e), interactions among solitons can be weakened, and the switch effect is obvious after interactions. On the contrary, by increasing the value of k_{21}, such as $k_{21} = 3$ in Fig. 2(c) and (f), we can see that the signal light becomes stronger, the control light becomes weaker, and the interactions among them become more intense. In this case, we should minimize the value of k_{21}, so as to realize the effective control of the AOLD.

In Fig. 3, we will analyze the parameter k_{31} on the AOLD performance. The values of k_{11} and k_{21} are negative. In Fig. 3(a) and (d), when $k_{31} = 2.6$, there is more energy exchange after the interactions of optical solitons, and the optical switching effect is obvious, which can effectively realize the function of signal on and off. Increasing the values of k_{31}, such as $k_{31} = 2.8$ in Fig. 3(b) and (e), we can find that the signal light is amplified, which is benefit to the realization of the "on" function of the AOLD. When we decrease the value of k_{31}, such as $k_{31} = 2.5$ in Fig. 3(c) and (f), the intensities of the signal are reduced, while the intensities of the pump increase. This is conducive to the realization of the "off" function of the AOLD. Therefore, by adjusting the value of k_{31}, we can realize the effective control of the logic structure of the AOLD.

4 Conclusion

The AOLDs have been investigated through solving the CNLS Eq. (1) analytically. Three-soliton solutions (17) have been obtained using the bilinear method. Interactions among three solitons have been discussed. The AOLDs have been demonstrated based on the soliton interactions. The influences of k_{11}, k_{21} and k_{31} on the AOLD performance have been analyzed. Parameters k_{11} and k_{31} have the significant impact on the performance of the AOLD. By adjusting the relevant parameters, the logic structures of the AOLD have been obviously controlled to realize the "on" and "off" functions of different optical signals. Results are benefit to the development of the AOLD to improve optical switching

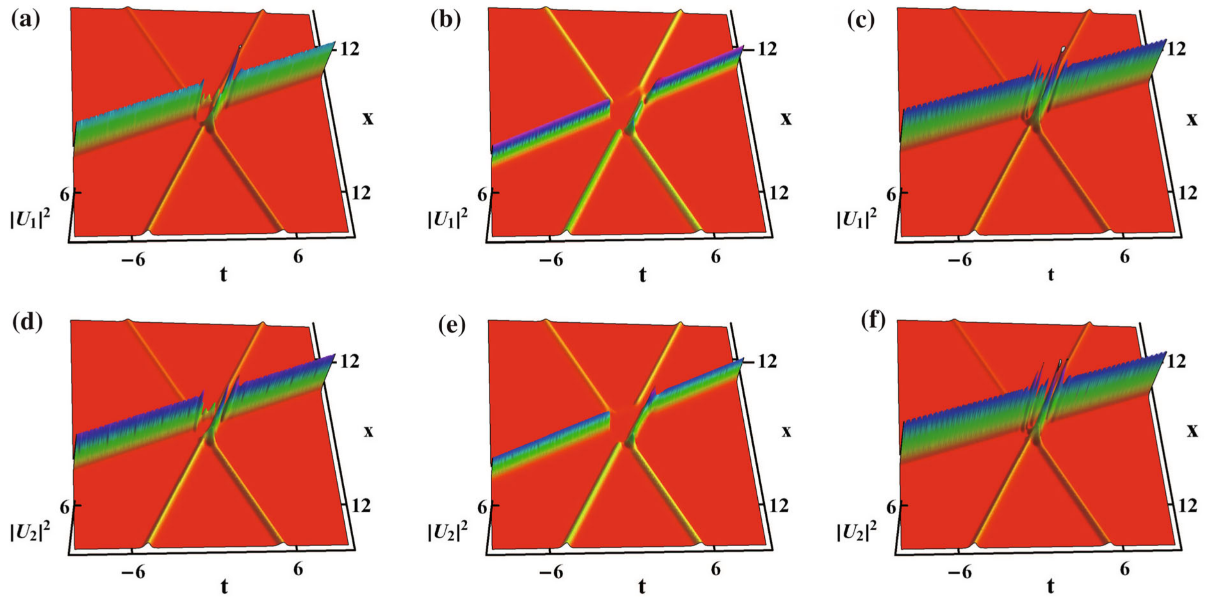

Fig. 2 Effective control of logic structure of the AOLD with soliton interactions. Relevant parameters are: $k_{11} = -1.2$, $k_{31} = -1.6$, $k_{12} = -1.5$, $k_{22} = -0.5$, $k_{32} = 2$, $\xi_{11} = 2$, $\xi_{12} = 1$, $\xi_{21} = 2$, $\xi_{22} = 2$, $\xi_{31} = 1$, $\xi_{32} = 3$ with **a** $k_{21} = 2.7$; **b** $k_{21} = 2$; **c** $k_{21} = 3$; **d** has the same value as **a**; **e** has the same value as **b**; and **f** has the same value as **c**

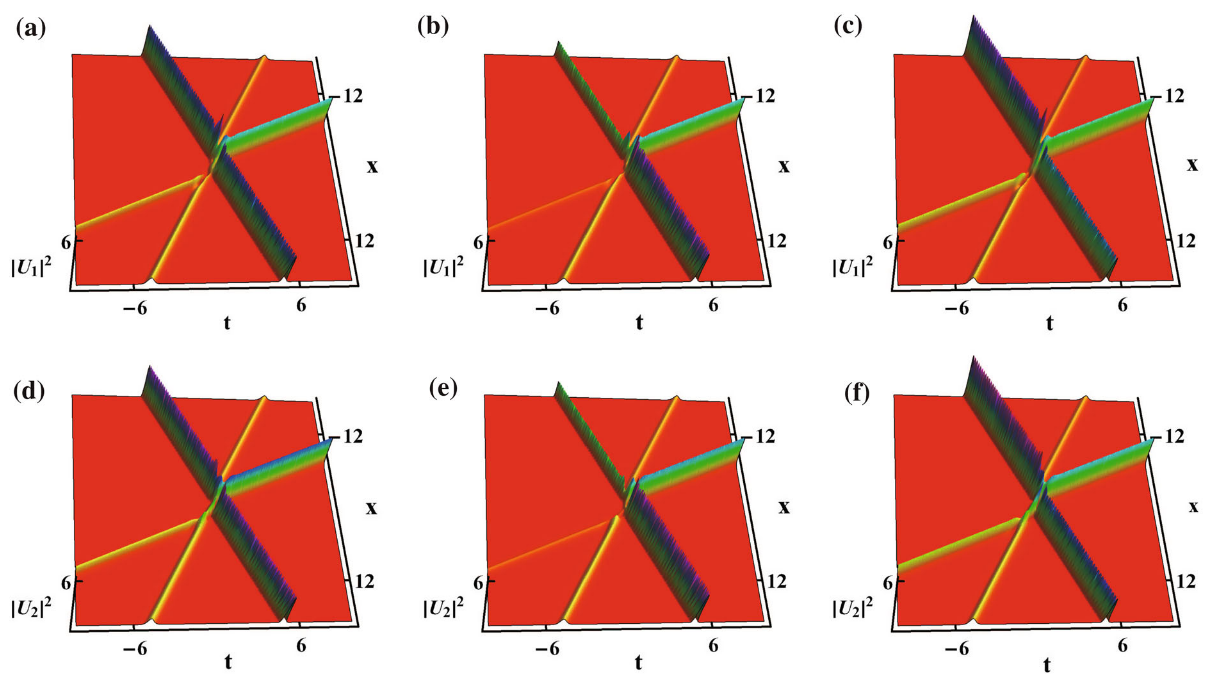

Fig. 3 Effective control of logic structure of the AOLD with soliton interactions. Relevant parameters are: $k_{11} = -1$, $k_{21} = -2.2$, $k_{12} = -1.5$, $k_{22} = -0.5$, $k_{32} = 2$, $\xi_{11} = 2$, $\xi_{12} = 1$, $\xi_{21} = 2$, $\xi_{22} = 2$, $\xi_{31} = 1$, $\xi_{32} = 3$ with **a** $k_{31} = 2.6$; **b** $k_{31} = 2.8$; **c** $k_{31} = 2.5$; **d** has the same value as **a**; **e** has the same value as **b**; and **f** has the same value as **c**

efficiency and transmission stability of communication systems.

Acknowledgements We acknowledge the financial support from the National Natural Science Foundation of China (grant 11975172).

Availability of data and material The authors declare that all data generated or analyzed during this study are included in this article.

Declarations

Conflict of interest The authors declare that they have no conflict of interest concerning the publication of this manuscript.

Ethical approval The authors declare that they have adhered to the ethical standards of research execution.

References

1. Taraphdar, C., Chattopadhyay, T., Roy, J.N.: Mach-Zehnder interferometer-based all-optical reversible logic gate. Opt. Laser Technol. **42**(2), 249–259 (2009)
2. Dimitriadou, E., Zoiros, K.E.: All-optical XOR gate using single quantum-dot SOA and optical filter. J. Lightwave Technol. **31**(23), 3813–3821 (2013)
3. Wu, L.M., Yuan, X.X., Ma, D.T., Zhang, Y., Huang, W.C., Ge, Y.Q., Song, Y.F., Xiang, Y.J., Li, J.Q., Zhang, H.: Recent advances of spatial self-phase modulation in 2D Materials and passive photonic device applications. Adv. Sci. **16**(35), 2002252 (2020)
4. Jandieri, V., Khomeriki, R., Onoprishvili, T., Erni, D., Chotorlishvili, L., Werner, D.H., Berakdar, J.: Band-gap solitons in nonlinear photonic crystal waveguides and their application for functional all-optical logic gating. Nat. Photon. **8**(7), 250 (2021)
5. Liu, W.J., Yang, D.Q., Shen, G.S., Tian, H.P., Ji, Y.F.: Design of ultra compact all-optical XOR, XNOR, NAND and OR gates using photonic crystal multi-mode interference waveguides. Opt. Laser Technol. **50**, 55–64 (2013)
6. Silvi, S., Constable, E.C., Housecroft, C.E., Beves, J.E., Dunphy, E.L., Tomasulo, M., Raymo, F.M., Credi, A.: All-optical integrated logic operations based on chemical communication between molecular switches. Chem. Eur. J. **15**(1), 178–185 (2009)
7. Pal, A., Ahmed, M.Z., Swarnakar, S.: An optimized design of all-optical XOR, OR, and NOT gates using plasmonic waveguide. Opt. Quantum Electron. **53**(2), 84 (2021)
8. Zhang, Y.B., Murata, M., Takagi, H., Ji, Y.S.: Traffic-based reconfiguration for logical topologies in large-scale WDM optical networks. J. Lightwave Technol. **23**(10), 2854–2867 (2005)
9. Chen, Y., Cheng, Y.K., Zhu, R.B., Wang, F.F., Cheng, H.T., Liu, Z.H., Fan, C.X., Xue, Y.X., Yu, Z.C., Zhu, J.K., Hu, X.Y., Gong, Q.H.: Nanoscale all-optical logic devices. Sci. China-Phys. Mech. Astron. **62**(4), 044201 (2019)
10. Wu, Y.D., Chen, M.H., Chu, C.H.: All-optical logic device using bent nonlinear tapered Y-junction waveguide structure. Fiber Integrated Opt. **20**(5), 527–524 (2001)
11. Saidani, N., Belhadj, W., Abdelmalek, F.: Novel all-optical logic gates based photonic crystal waveguide using self imaging phenomena. Opt. Quantum Electron. **47**(7), 1829–1846 (2015)
12. Goswami, K., Mondal, H., Sen, M.: A review on all-optical logic adder: Heading towards next-generation processor. Opt. Commun. **483**, 126668 (2021)
13. Yahalomi, E.M.: All-optical devices based on three-wave mixing for logic and information processing. Laser Part Beams. **19**(2), 215–218 (2001)
14. Lovkesh, Sharma, V., Singh, S.: The design of a reconfigurable all-optical logic device based on cross-phase modulation in a highly nonlinear fiber. J. Comput. Electron. **20**(1), 397-408 (2021)
15. Wazwaz, A.M.: Bright and dark optical solitons for (3+1)-dimensional Schrödinger equation with cubic-quintic-septic nonlinearities. Optik **225**, 165752 (2020)
16. Wazwaz, A.M.: New integrable (2+1)-dimensional sine-Gordon equations with constant and time-dependent coefficients: Mult. Opt. Kink. Wave Sol. Optik. **216**, 164640 (2020)
17. Wazwaz, A.M.: Multiple optical kink solutions for new Painlevé integrable (3+1)-dimensional sine-Gordon equations with constant and time-dependent coefficients. Optik **219**, 165003 (2020)
18. Wazwaz, A.M.: Higher dimensional nonlinear Schrödinger equations in anomalous dispersion and normal dispersive regimes: Bright and dark optical solitons. Optik **222**, 165327 (2020)
19. Wu, Y.D.: New all-optical switch based on the spatial soliton repulsion. Opt. Express **14**(9), 4005–4012 (2006)
20. Ghadi, A., Sohrabfar, S.: All-optical multiple logic gates based on spatial optical soliton interactions. IEEE Photon. Technol. Lett. **30**(6), 569–572 (2018)
21. Khawaja, U., Al-Marzoug, S.M., Bahlouli, H.: All-optical switches, unidirectional flow, and logic gates with discrete solitons in waveguide arrays. Opt. Express **24**(10), 11062–11074 (2016)
22. Bigo, S., Leclerc, O., Desurvire, E.: All-optical fiber signal processing and regeneration for soliton communications. IEEE J. Sel. Top. Quant. **3**(5), 1208–1223 (1997)
23. Wang, L.L., Liu, W.J.: Stable soliton propagation in a coupled (2+1) dimensional Ginzburg-Landau system. Chin. Phys. B **29**(7), 070502 (2020)
24. Yan, Y.Y., Liu, W.J.: Soliton rectangular pulses and bound states in a dissipative system modeled by the variable-coefficients complex cubic-quintic Ginzburg-Landau equation. Chin. Phys. Lett. **38**(9), 094201 (2021)
25. Li, W.Y., Ma, G.L., Yu, W.T., Zhang, Y.J., Liu, M.L., Yang, C.Y., Liu, W.J.: Soliton structures in the (1+1)-dimensional Ginzburg-Landau equation with a parity-time-symmetric potential in ultrafast optics. Chin. Phys. B **27**(3), 030504 (2018)
26. Liu, W.J., Yang, C.Y., Liu, M.L., Yu, W.T., Zhang, Y.J., Lei, M., Wei, Z.Y.: Bidirectional all-optical switches based on highly nonlinear optical fibers. EPL **118**(3), 34004 (2017)

27. Liu, W.J., Zhang, Y.J., Pang, L.H., Yan, H., Ma, G.L., Lei, M.: Study on the control technology of optical solitons in optical fibers. Nonlinear Dyn. **86**(2), 1069–1073 (2016)
28. Liu, W.J., Lei, M.: All-optical switches using solitons within nonlinear fibers. J. Electromagnet Wave. **27**(18), 2288–2297 (2013)
29. Longobucco, M., Cimek, J., Pysz, D., Buczynski, R., Bugar, I.: All-optical switching of ultrafast solitons at 1560 nm in dual-core fibers with high contrast of refractive index. Opt. Fiber Technol. **63**, 102514 (2021)
30. Ghadi, A.: Phase sensitive, all-optical and self-integrated multi-logic AND, OR, XOR, and NOT gates. Phys. Lett. A **384**(22), 126432 (2020)
31. Anbardan, S.R., Eslami, M., Kheradmand, R.: Fast and localized all-optical frequency switch based on synchronization of cavity solitons: A numerical study. Opt. Commun. **474**, 126093 (2020)
32. Mandal, B., Chowdhury, A.R.: Compression splitting and switching of bright and dark solitons in nonlinear directional coupler. Chaos Soliton Fract. **27**, 103–113 (2006)
33. Fraga, W.B., Menezes, J.W.M., Silva, M.G.: Logic gates based in asymmetric couplers: Numerical analysis. Fiber Integrated Opt. **26**(4), 217–228 (2007)
34. Liu, M., Chiang, S.K.: Nonlinear switching of ultrashort pulses in multicore fibers. IEEE J. Quantum Electron. **47**(12), 1499-1505 (2011)
35. Ding, C.C., Gao, Y.T., Su, J.J., Deng, G.F., Jia, S.L.: Vector semirational rogue waves for the coupled nonlinear Schrödinger equations with the higher-order effects in the elliptically birefringent optical fiber. Wave Random Complex. **30**, 1483092 (2018)
36. Du, Z., Tian, B., Chai, H.P., Zhao, X.H.: Dark-bright semirational solitons and breathers for a higher-order coupled nonlinear Schrödinger system in an optical fiber. Appl. Math. Lett. **102**, 106110 (2020)
37. Wang, T.Y., Zhou, Q., Liu, W.J.: Soliton fusion and fission for the high-order coupled nonlinear Schrödinger system in fiber lasers. Chin. Phys. B https://doi.org/10.1088/1674-1056/ac2d22 (2021)
38. Hirota, R.: Exact envelope-soliton solutions of a nonlinear wave equation. J. Math. Phys. **14**(7), 805–809 (1973)