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All-optical logic device using bent nonlinear waveguide structure

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ABSTRACT

We propose an all-optical logic device made of a bent waveguide with a Kerr-like nonlinear interface. It could provide an OR gate, exclusive-OR (XOR) gate and AND gate. We could obtain different transmission results by modifying the bending angle. The numerical simulation results show that the device functions as OR, XOR and AND gates.

Keywords : All-optical logic device, bent nonlinear Y-junction waveguide, Kerr-like nonlinear interface, nonlinear medium, spatial soliton.

1.INTRODUCTION

The interest in nonlinear waveguide designs and their applications has been growing rapidly in recent years. It has been well displayed that all-optical switching and logic gates have potential applications in optical communication and ultrafast signal processing.¹⁻³ For logic functions, many novel optical devices using nonlinear waveguide technologies have been discussed extensively.⁴⁻⁸ In 1991, Ogusu⁹ and Chang et al.¹⁰ studied the evolution of the TE waves propagating along the nonlinear dielectric interfaces. The numerical results are related to the spatial structure of dielectric interface. Their structures are potentially useful for digital applications such as optical threshold devices.

In this paper, we design an all-optical logic device using a bent nonlinear waveguide structure. The

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proposed device is based on the propagating characteristics of the nonlinear waveguide. This device could implement three all-optical logic functions (AND, OR and XOR) by adjusting the structure parameters. The numerical results appeared in this paper are calculated by using the beam propagation method (BPM).¹¹

2. NUMERICAL METHOD

The proposed structure is shown in Figure 1. The branching angle between the waveguide is 2ϕ in the input section, and the bending angle is θ in the output section. The two input ports A and B must be adequately separated so that the fields in each port do not overlap. Separation distance between input ports A and B is s and the film thickness is $2d$.

We consider the case of TE waves as $\varepsilon(x, z, t) = E(x, z) \exp[j(\beta k_0 z - \omega t)]$, where β is the effective index of refraction, k_0 is the wave number in the free space. We have taken the field to be homogeneous in the y direction. Taking into account the slowly varying envelope approximation, we obtain the following equation for $E(x, z)$:

$$2j\beta k_0 \frac{\partial E}{\partial z} + \frac{\partial^2 E}{\partial x^2} + k_0^2 [n^2(x, z, |E|^2) - \beta^2] E = 0 \quad , \quad (1)$$

The square of the refractive index for the Kerr-like nonlinear medium is expressed as

$$n_j^2(x, z, |E|^2) = n_{Lj}^2 + \alpha_j |E|^2 \quad I=s, c \quad , \quad (2)$$

where n_{Lj} is the linear refractive index of the nonlinear medium and α_j is the nonlinear coefficient. The subscripts s and c in Eq.(2) are used to denote the substrate and cladding, respectively. For the linear medium in the film, the refractive index n_f is constant.

3. RESULTS AND DISCUSSIONS

All numerical results presented here were calculated with the values: refractive index $n_f=2.2888$, $n_{sL} = n_{cL} = 2.2885$, $d=3 \mu m$, $s=24 \mu m$, $\phi=0.275^\circ$, $\alpha_j = 1 \times 10^{-8} m^2/V^2$, free space wavelength $\lambda=0.6 \mu m$, waveguide length $l_1=2500 \mu m$, $l_2=1500 \mu m$, $l_3=2000 \mu m$, input power $P_{in} = 25mw/mm$. P_0 is defined as the normalized output power when only one input port is excited. Figure 2 shows the propagating condition of the wave along the nonlinear waveguide for the bending angle $\theta=0.3^\circ$. When only port A is excited, the result is shown in Fig.2(a). The waves propagating along the waveguide are almost well confined in the output port C. With only port B excited, the result is shown in Fig.2(b). It is similar to that of Fig.2(a). Figure 2(c) shows the propagation results when both ports A and B are excited. The optical waves propagating along the waveguide are also well enclosed in the output port C.

Figure 3 shows the propagating condition of the wave along the nonlinear waveguide for the bending angle $\theta = 0.7^\circ$. With either port A or B excited, the results are shown in Figs.3(a) and 3(b), respectively. Those are resembling to that of Figs.2(a) and 2(b) for the bending angle $\theta = 0.3^\circ$. Figure 3(c) shows that the spatial soliton is producing in the nonlinear medium and propagates in the output port D when two input ports A and B are excited simultaneously.

4.CONCLUSIONS

We have designed an all-optical logic device using a bent nonlinear waveguide and the numerical results show that the device functions as AND, OR and XOR gates by simply modifying the bending angle. The proposed device has potential application in all-optical signal processing systems.

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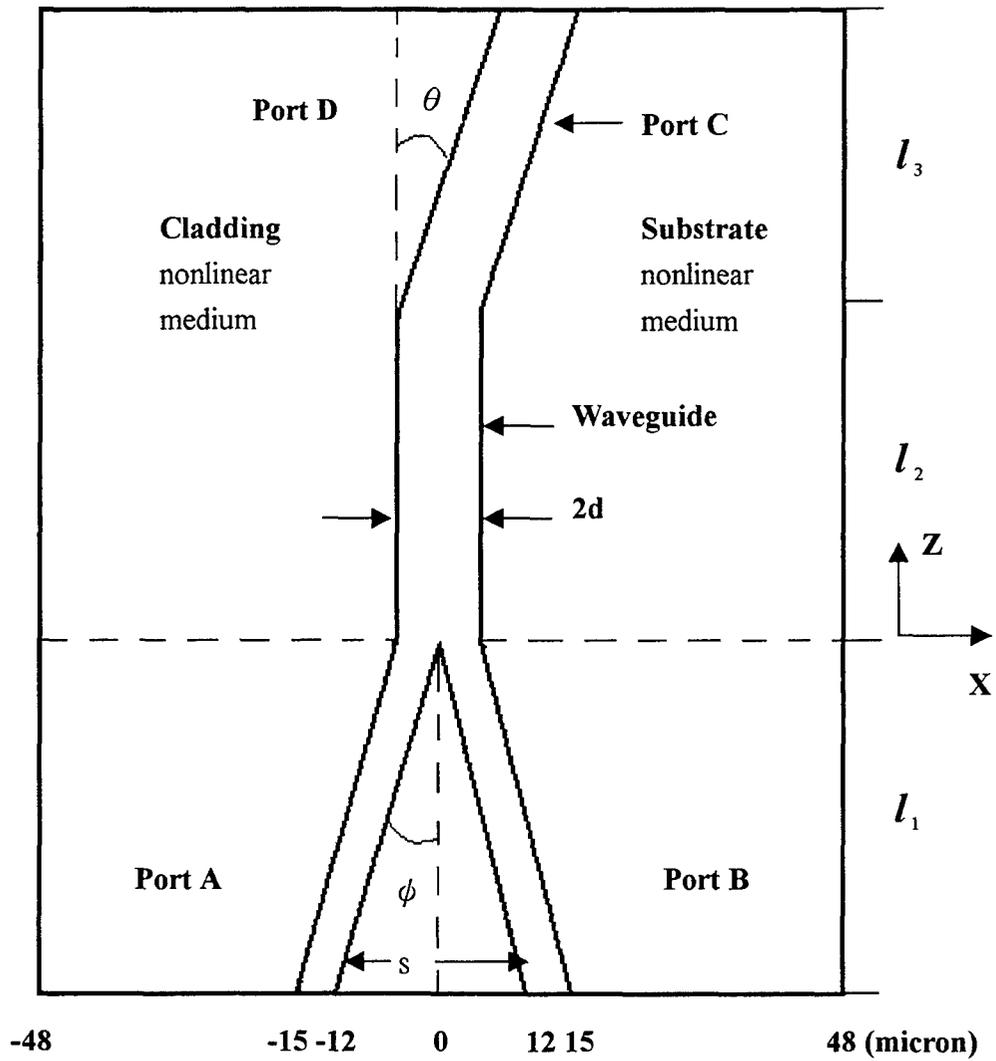
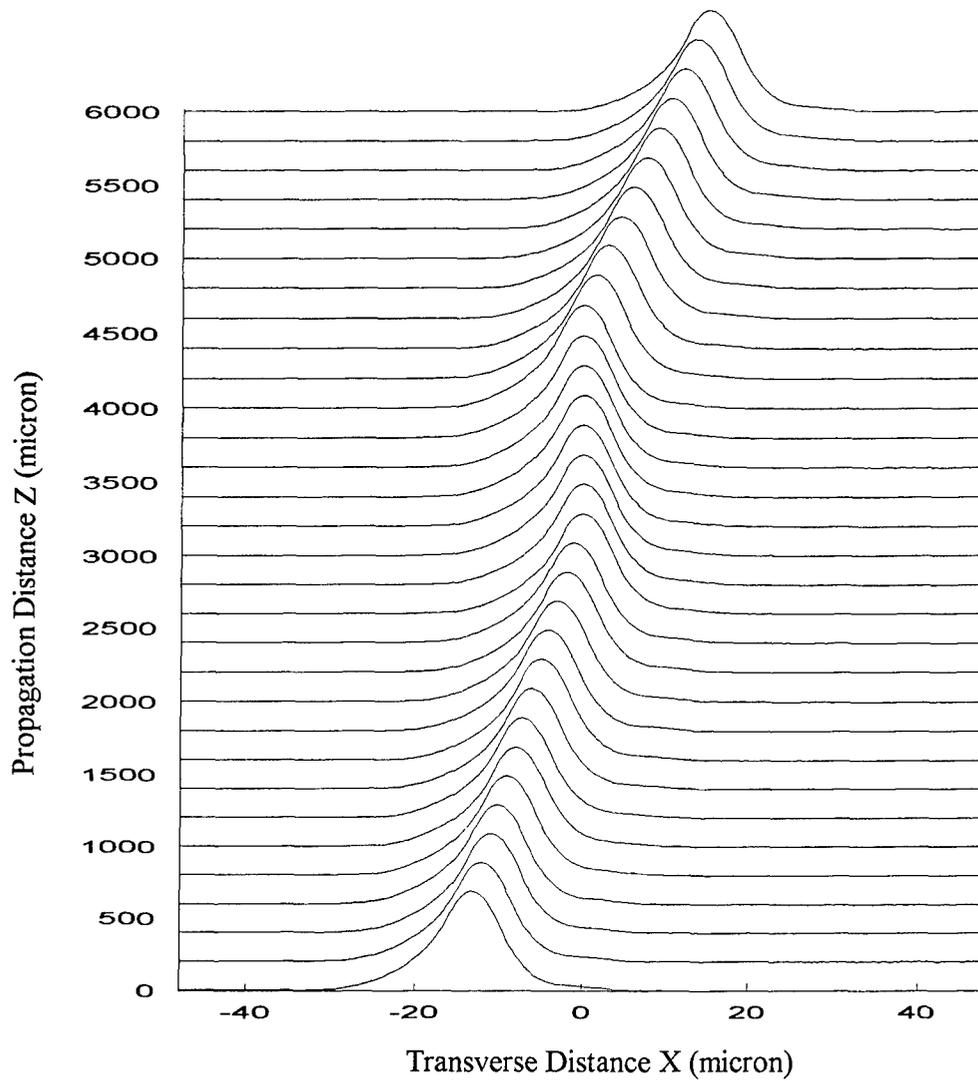
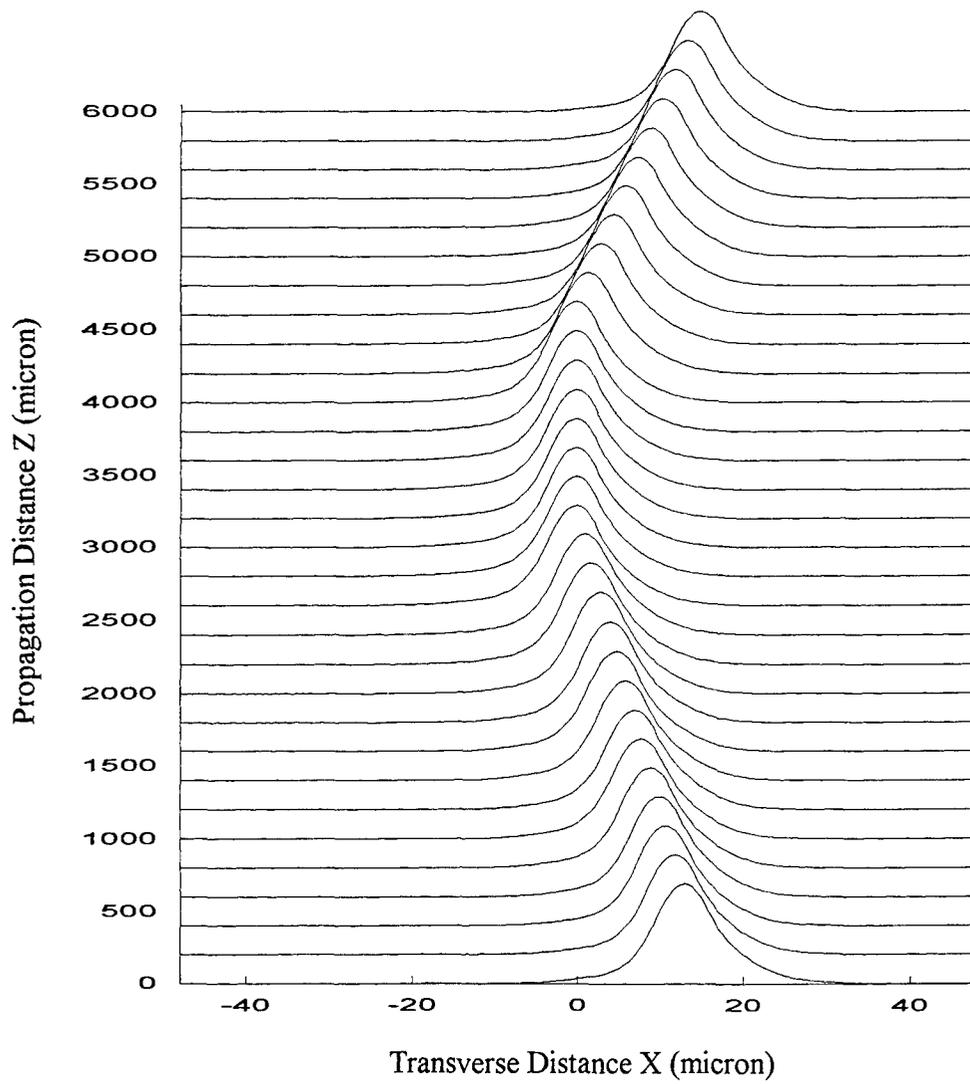


Figure 1. The schematic of the proposed bent nonlinear waveguide structure.

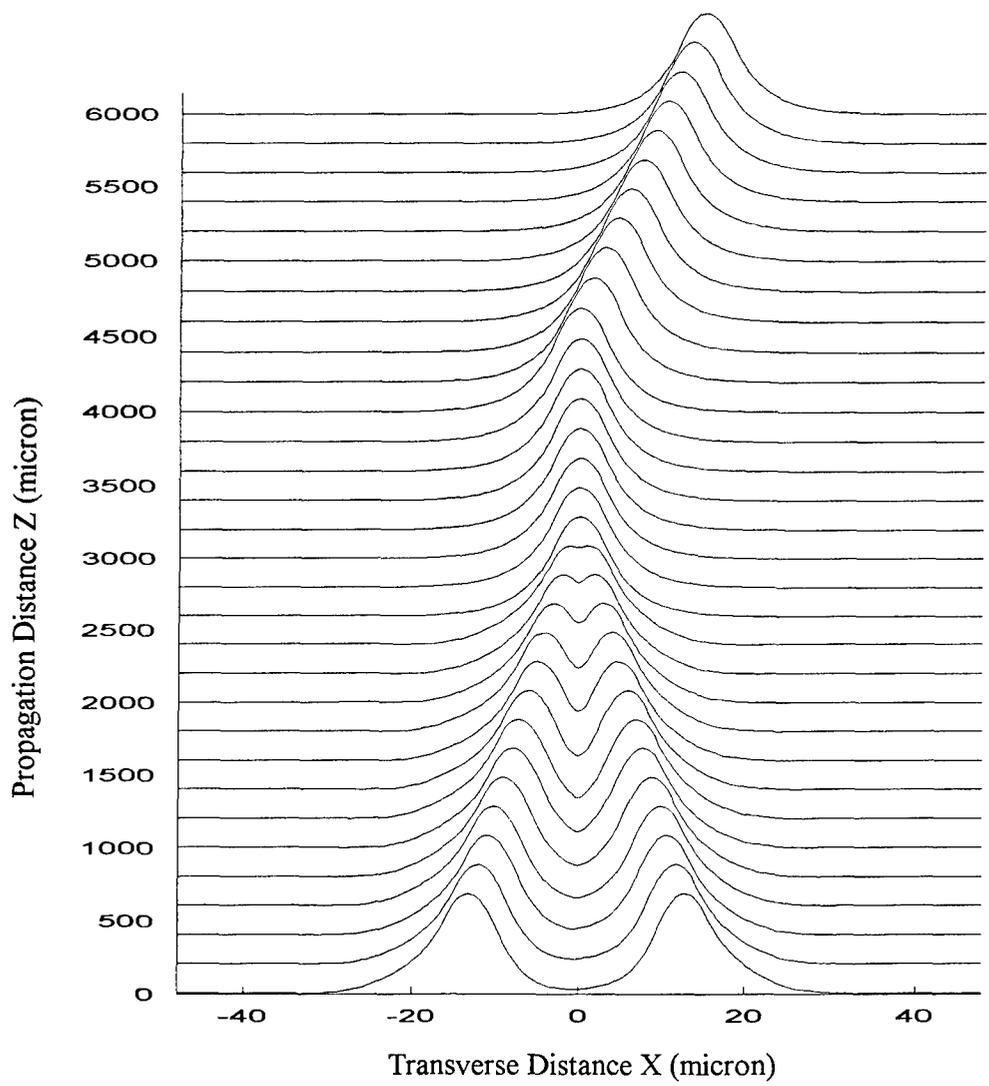


(a)

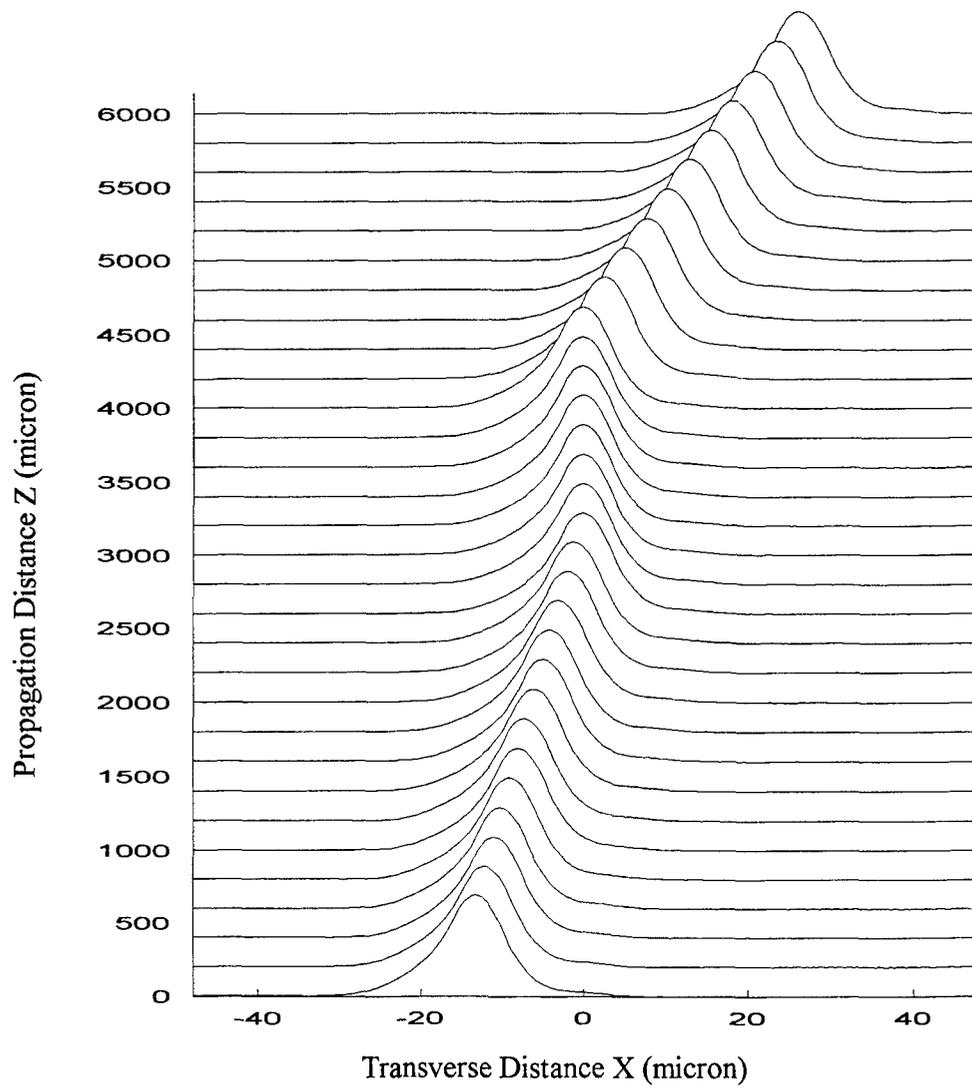
Figure 2. The typical evolution of the wave along the nonlinear waveguide for the bending angle $\theta = 0.3^\circ$ (a) Input : A, (b) Input : B, (c) Input : A and B.



(b)

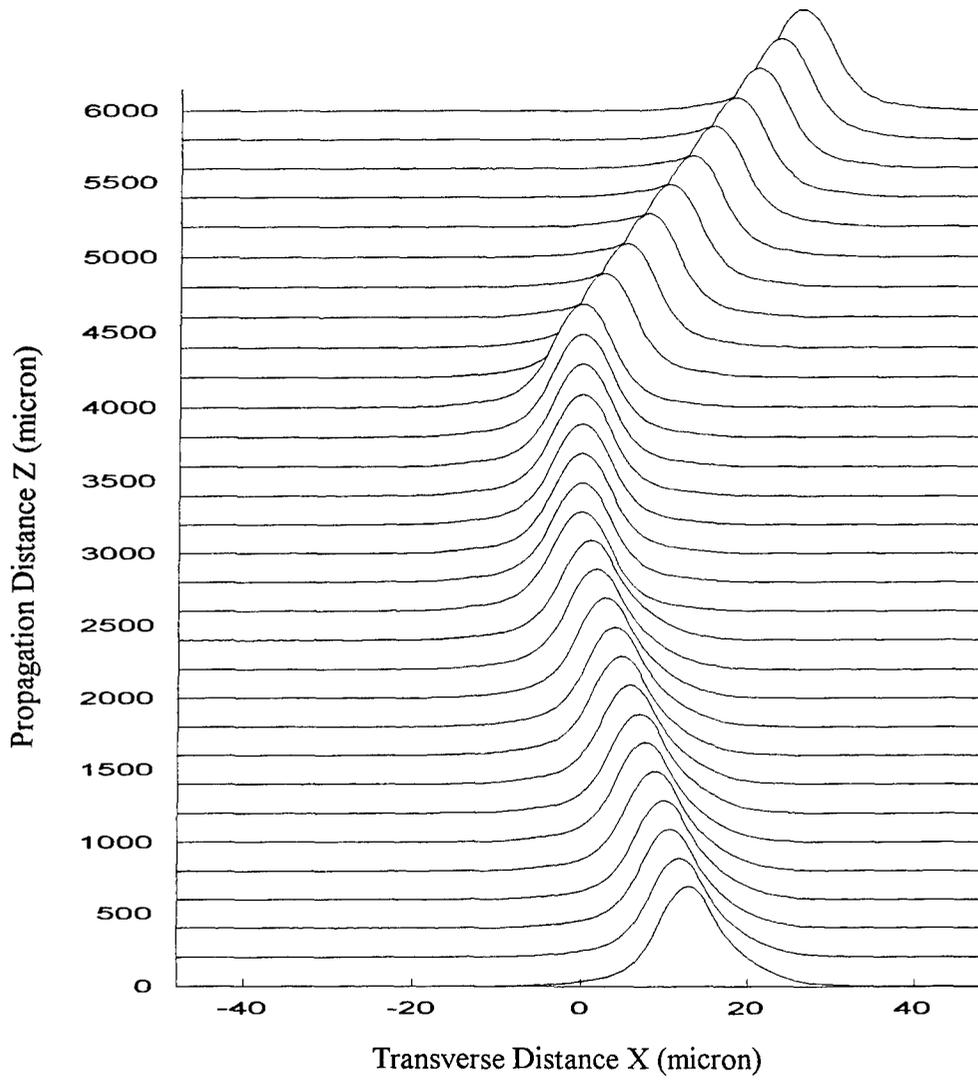


(c)

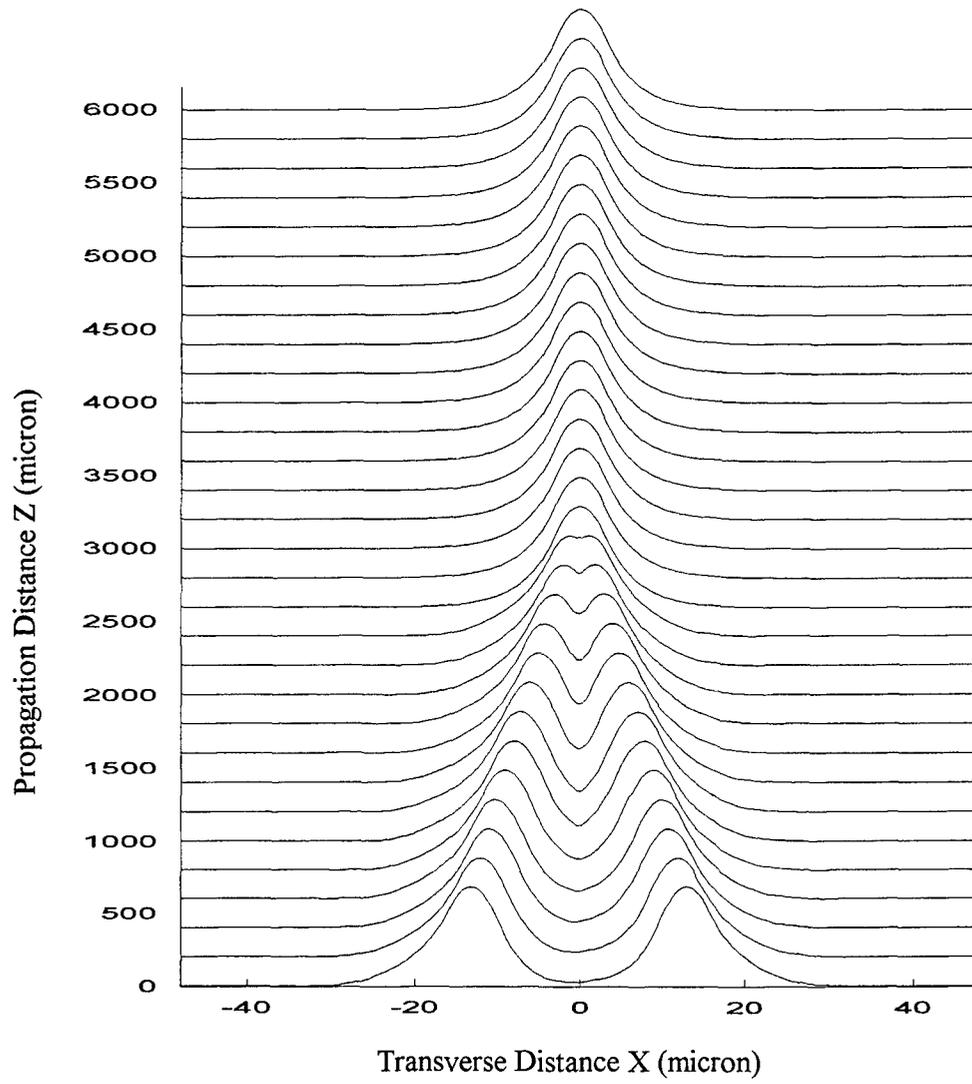


(a)

Figure 3. The typical evolution of the wave along the nonlinear waveguide for the bending angle $\theta=0.7^\circ$ (a) Input : A, (b) Input : B, (c) Input : A and B.



(b)



(c)