Controllable waveguiding structures induced by diffracting Bessel beams in a nonlinear medium

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Introduction

Due to their unique profiles and fascinating propagating phenomena, unconventional beams like Airy beams are good candidates for photo-inducing waveguiding structures in for example a photorefractive medium. Bessel beams (BBs) share similar features with Airy beams, such as diffraction-free, multi-lobes profiles, and self-trapping properties under nonlinear conditions. Thus, several studies on waveguides induction using non-diffracting BBs under weak nonlinearity have been developed [1]. Instead, our recent work unveiled that diffracting BBs propagating under high nonlinear conditions provide more advantages and opportunities for fully controllable waveguiding structures.

Results and discussion

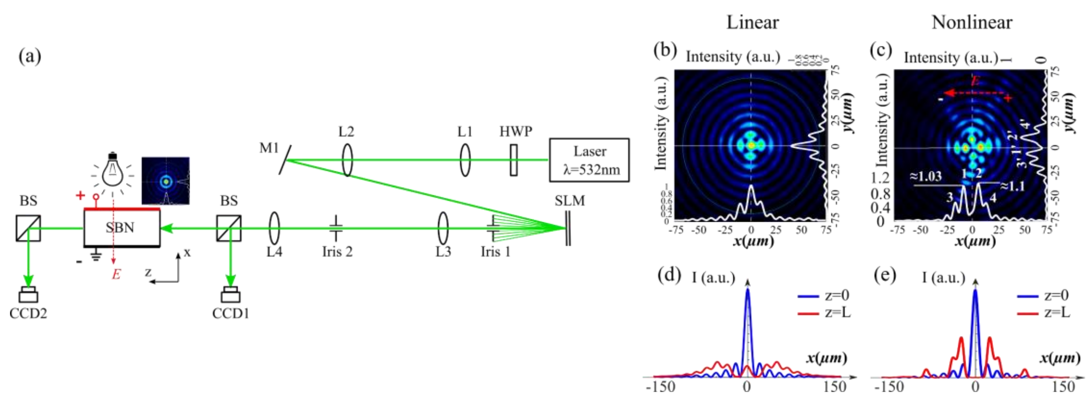

Figure 1: (a) Experimental setup: HWP, half-wave plate; L, lens; M, mirror; SLM, spatial light modulator; BS, beam splitter. (b)(c): Output profiles of a 6 µm zero-order BB propagating under (b) linear conditions and (c) nonlinear conditions. (d)(e) Corresponding numerical results of the diffracting BB.

Our experiment consists of propagating a single zero-order BB in a PR strontium barium niobate crystal (SBN: Ce) with the dimension of $0.5 \times 0.5 \times 1$ cm, as depicted in Fig. 1(a). The BB is generated by a SLM and reduced by lenses (L3, L4) then launched into the SBN crystal. An external electric field is applied along the crystallographic c axis of the crystal for activating the nonlinearity. The input and output profiles are monitored by the CCD1 and CCD2 cameras. Figures 1(b) and 1(c) are the output profiles of a 6µm BB propagating in the biased SBN crystal [2]. The profile in Fig. 1(b) is no longer the same as the input BB profile, suggesting that the BB diffracts and distorts during its linear propagation in the 1cm crystal. When we apply the electric field to the crystal, as shown in Fig. 1(c), the central peak disappears, and the optical energy shifts to the adjacent lobes (1, 2, 3, 4). On the other hand, we developed the 1D numerical model to verify our experimental results and investigated more interesting waveguiding structures. We restricted the BB in the 1D situation where the transverse direction corresponds to the c axis of the PR crystal. The propagation of the BB in the crystal is described by $i\partial_Z F + \partial^2{}_X F = \Gamma E_0 F,$ where Γ is the nonlinear strength [3]. Figures 1(d) and 1(e) show the 1D profiles of a diffracting BB propagating under linear and nonlinear conditions. We notice that our experimental results are in good agreement with our 1D numerical results.

It is worth noting that our all-optical platform owns several parameters such as BB size, BB order, BB truncation, the external electric field, input Bessel beam intensity, and background illumination. By adjusting these parameters, we can tailor the photo-induced waveguiding structures. For example, in the experiments, as shown in Fig. 2(a), we obtain the waveguiding structures with 5, 9, and 8 potential addressable outputs as increasing the nonlinearity. Moreover, when we fix the electric field at 3.8 kV/cm and increase only the input intensity, as shown in Fig. 2(b)-2(d), the intensity difference between outputs (1,2) tends towards 0. In this case, the guiding efficiency of each photo-induced channel is tailored by the input intensity.

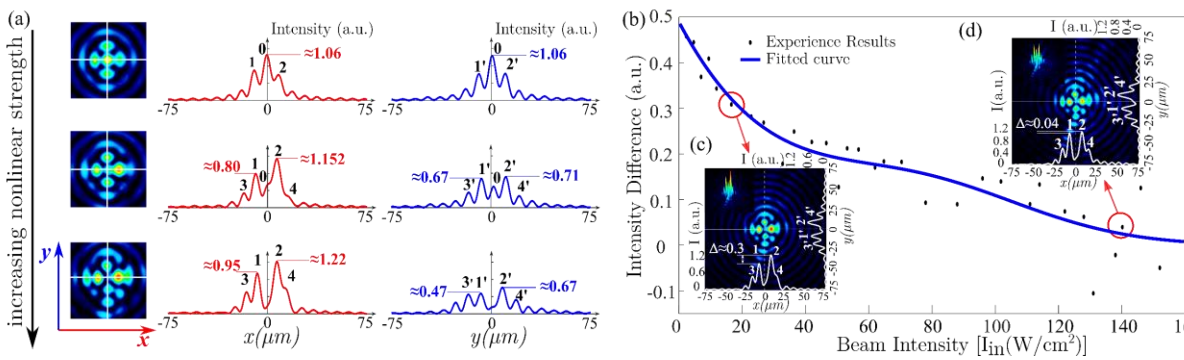

Figure 2: (a) 2D intensity distributions of the outputs, their corresponding profiles along x and y directions when a 6μm BB propagates for increasing nonlinearity. (b) Difference of the intensities between outputs (1,2) versus the input intensity. (c)(d) Two examples for low and high input intensities.

Conclusion

We numerically and experimentally demonstrated that a single diffracting BB could induce the waveguiding structures with multiple channels in a biased PR crystal. By varying the parameters of the BB and the nonlinearity of the crystal, our platform can tailor the output numbers, the guiding efficiency, and the stability of the waveguiding structures. These results provide more complex waveguiding structures and further possibilities for all-optical interconnects.

References

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