Waveguiding in Mathieu photonic lattices

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Abstract: We exploit single Mathieu beams (MB) as lattice-writing light to fabricate discrete waveguide structures and investigate their nonlinear self-action in these structures, leading to morphing discrete diffraction. Nonlinear self-action of elliptic MB in SBN breaks this sensitive equilibrium and we demonstrated a new type of rotating beam formation arises with high-intensity filaments corresponding to the energy flow in an enforced preferential direction. This process is beneficially applied to realize chiral twisted photonic refractive index structures with a tunable ellipticity.

Experimental setup for investigation of single and Elliptic MB

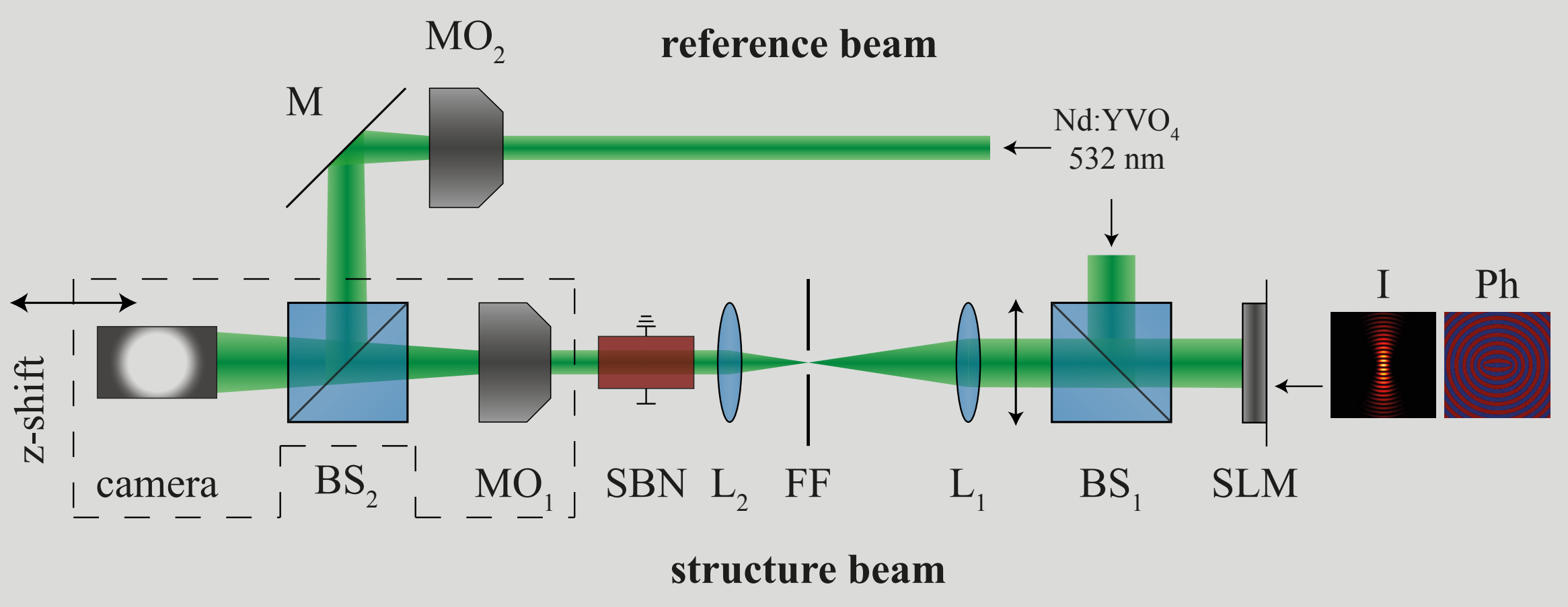


***Fig. 1**.* Setup scheme for optical induction in a photorefractive SBN crystal: BS: beam splitter, FF: Fourier filter, L: lens, M: mirror, MO: microscope objective, SLM: spatial light modulator.

Theoretical model

Nonlinear light propagation in photonic structures is simulated by numerically solving the nonlinear Schrödinger equation:

$$i\partial_z A(r) + \frac{1}{2}\Delta_\perp A(r) + \frac{1}{2}\Gamma E(|A(r)|^2)A(r) = 0$$

Owing to the biased SBN crystal, we use an ***anisotropic approximation*** *to calculate the refractive index modulation and solve the potencial equation:*

$$\Delta\Phi_{sc} + \nabla\Phi_{sc}\nabla\ln(1+I) = E_{ext}\partial_x \ln(1+I)$$

Even *E_m and* ***Odd*** *O_m* ***MB*** *are matematically described as a product of radial ce_m, se_m and angular Je_m, Jo_m Mathieu functions of order m:*

$$E_m(\xi,\eta;q) = C_m(q)Je_m(\xi;q)ce_m(\eta;q)$$

$$O_m(\xi,\eta;q) = S_m(q)Jo_m(\xi;q)se_m(\eta;q)$$

where $q=f^2k_t^2/4$ is parameter of ellipticity, $k_t=2\pi/a$ is transvese wave number and a is the characteristic structure size. ***Elliptic MB*** *$A_m(\xi,\eta)$ are matematically described as a complex linear superposion of even and odd MB of the same order m:*

$$A_m = E_m + iO_m$$

Experimental characterization of a 0th order lattices fabricating even MB

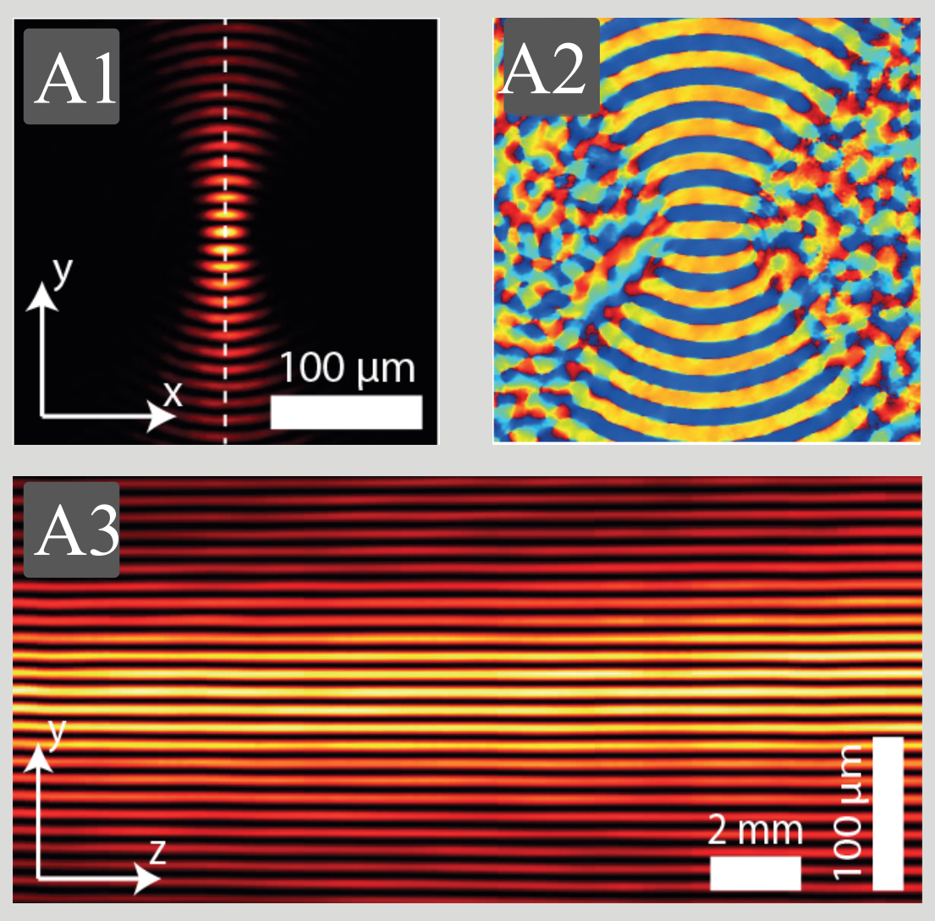


Fig. 2. Transverse intensity (A1) and phase (A2) distributions, (A3) linear yz cross-section trougthe intensity volume (A1) in SBN crystal 15mm long.

Morphing diffraction of MB with transition from 1D to 2D

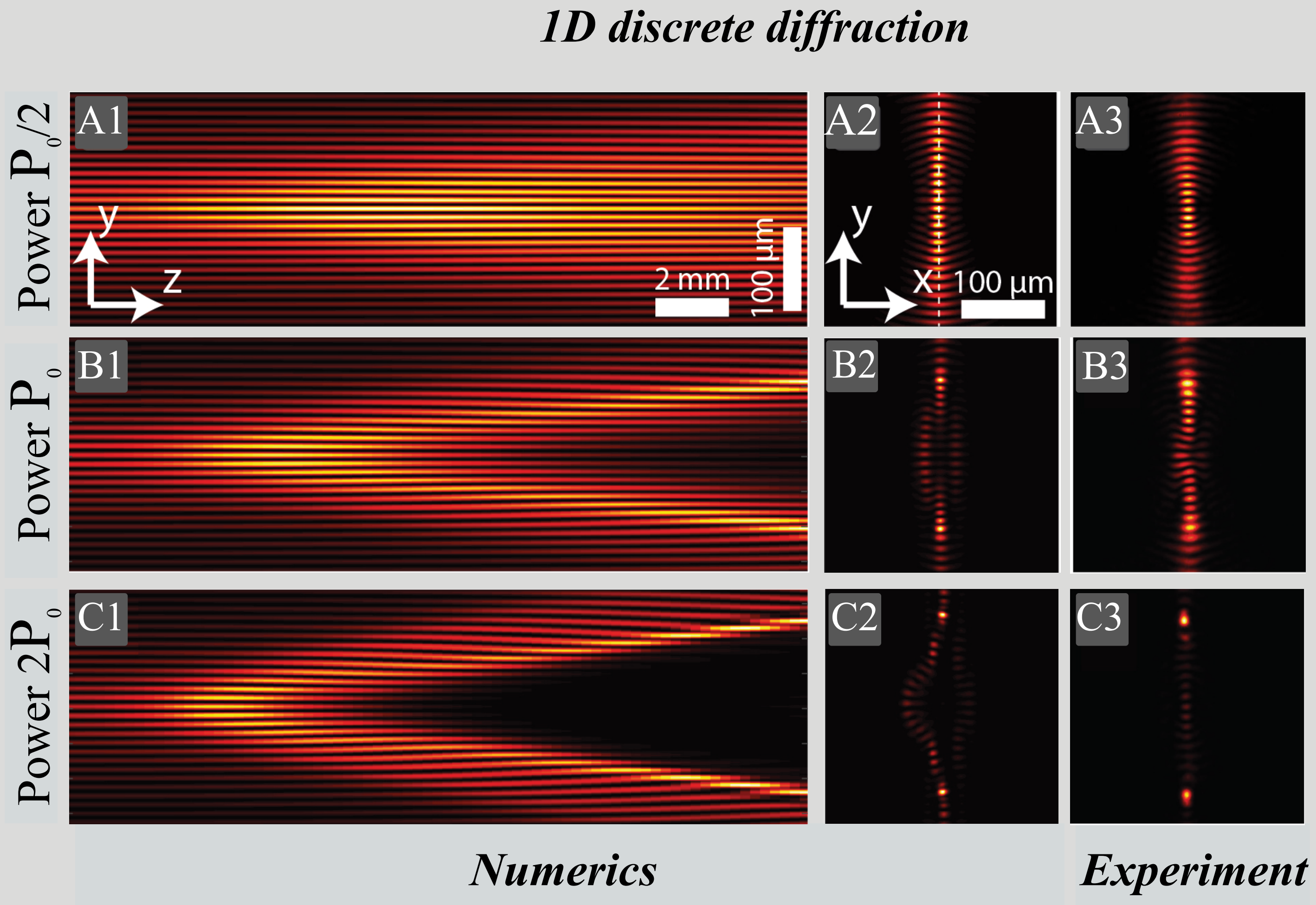


Fig. 3. Nonlinear propagation of even ***0th-order MB*** (q=25) in SBN crystal, nonlineary inscribed with incrising beam powers (P_0=20μW).

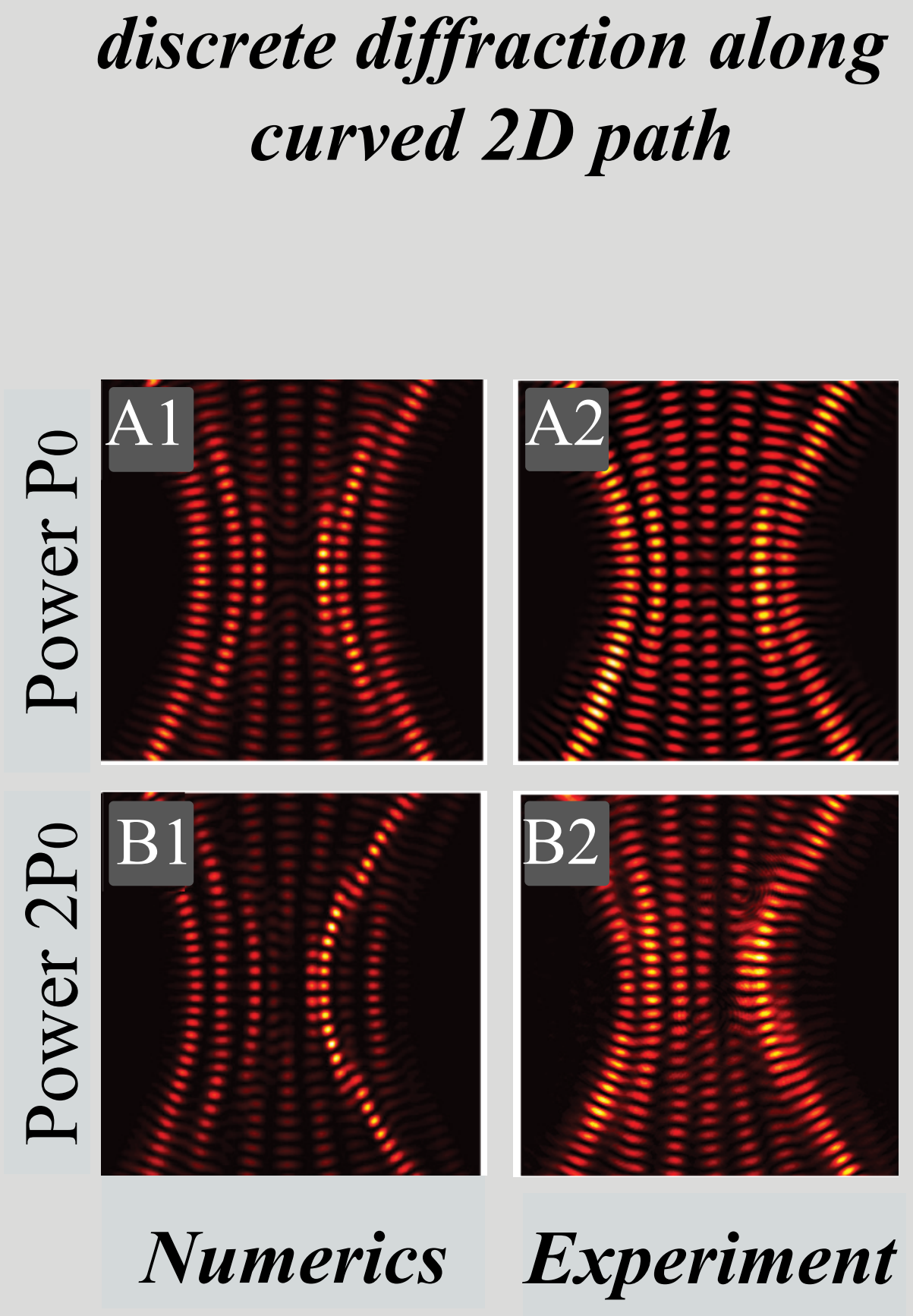


Fig. 4. Nonlinear propagation of even ***6th-order MB*** (q=325) in SBN crystal, nonlineary inscribed with incrising beam powers (P_0=20μW).

Linear propagation of the narrow Gaussian probe beam in Mathieu lattices

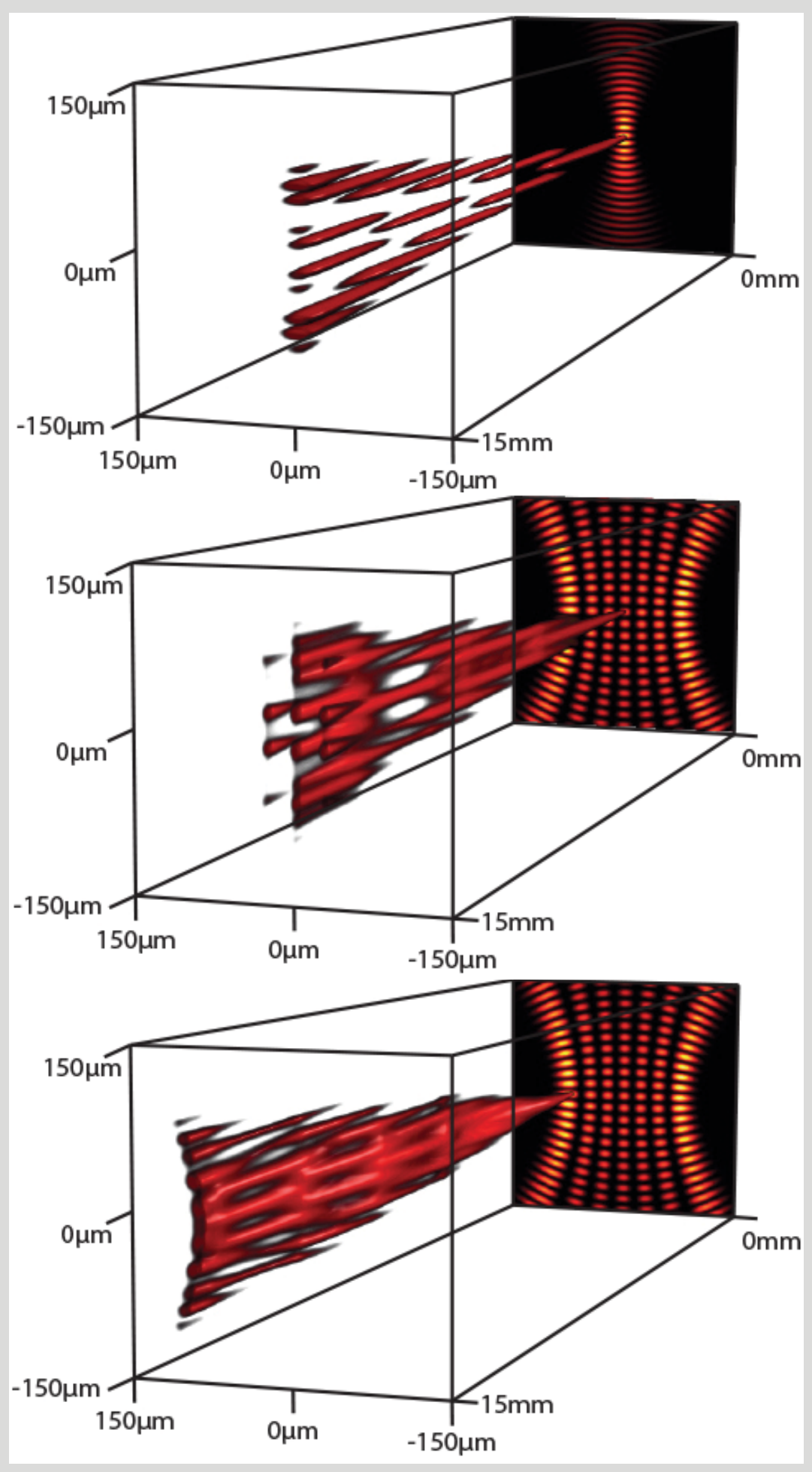


Fig. 5. Intensity distribution of a Gaussian probe beam inside the Mathieu lattices.

Characterization of Elliptic MB

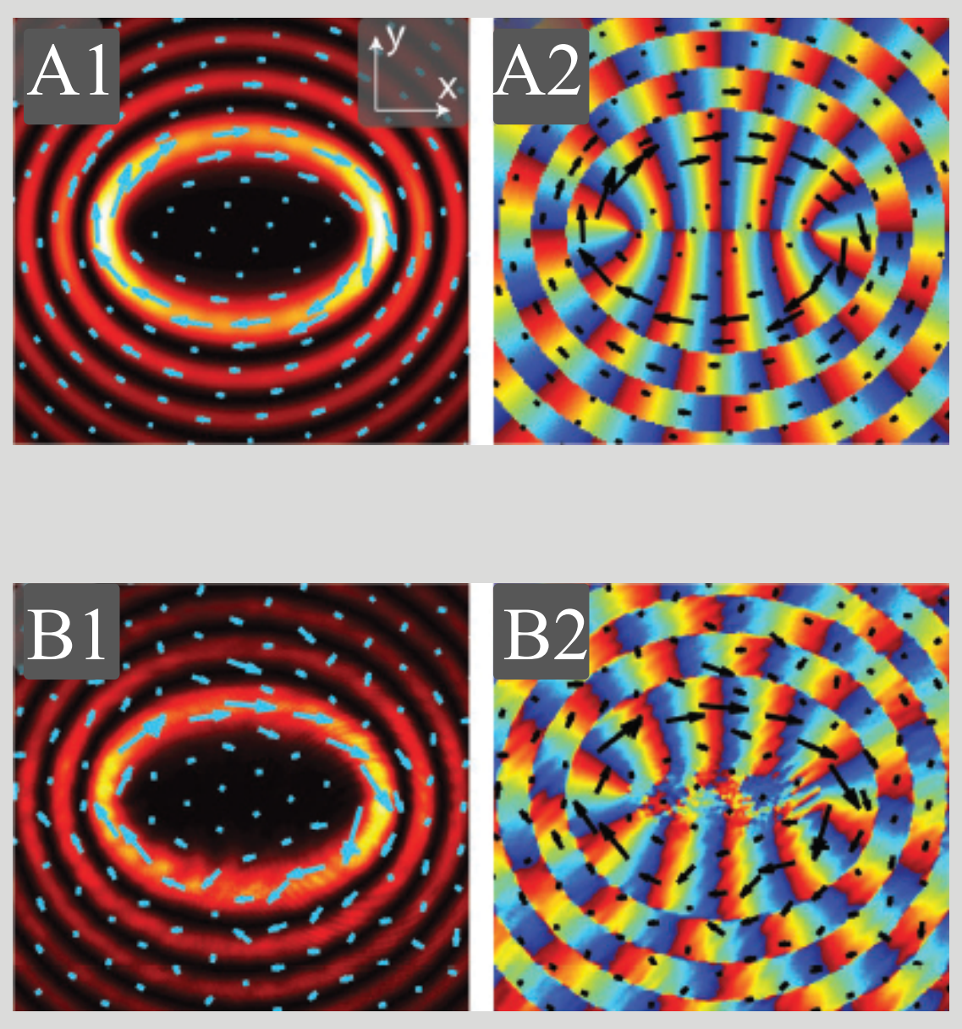


Fig. 6. Elliptic MB of order ***m=10*** with an ellipticity of ***q=25***. Arrows indicate the ***Pointing vector***.

Tailored, Nonlinear Mathieu lattices

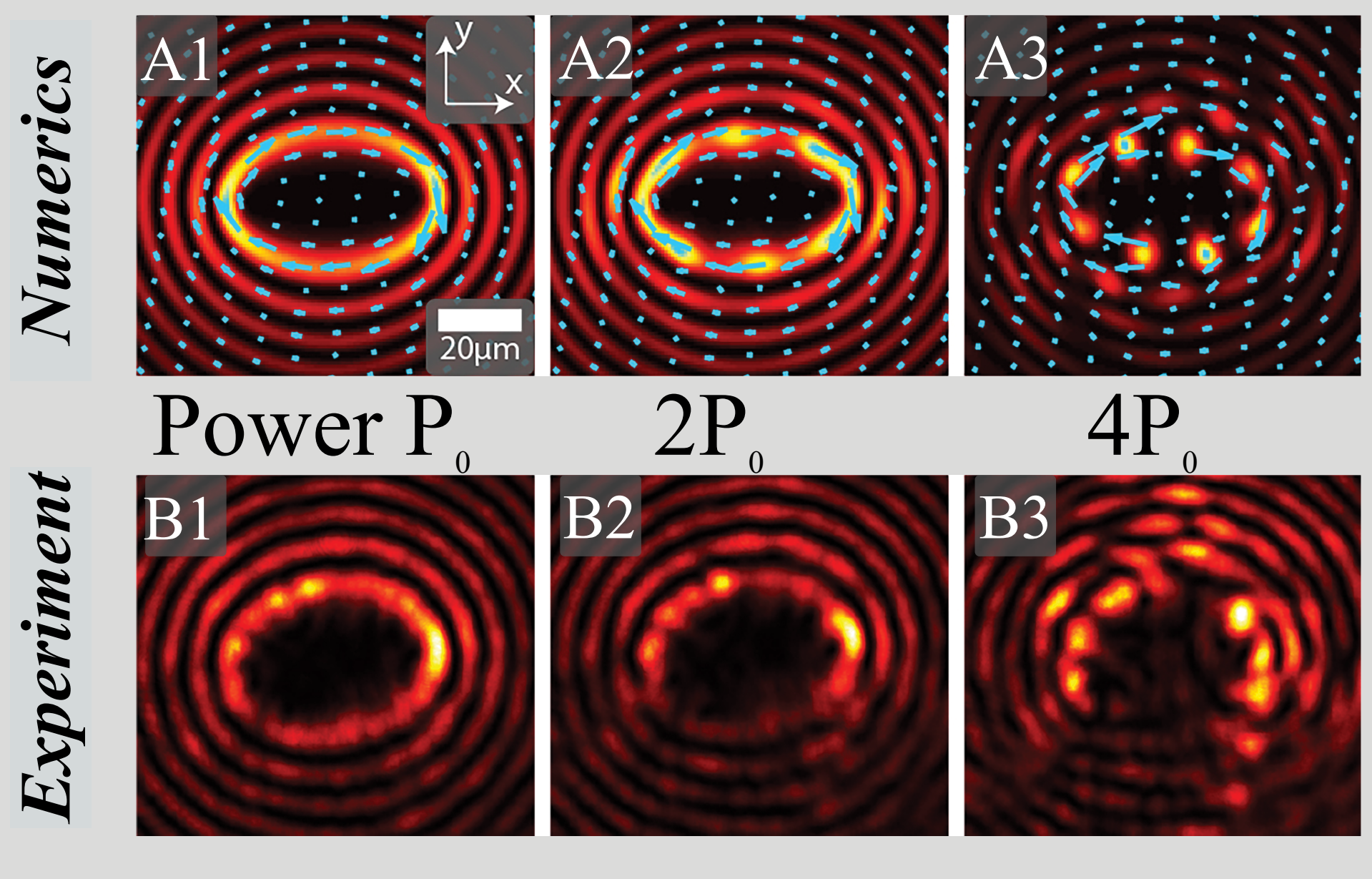


Fig. 7. Transverse intensity distribution of elliptic MB (a=15μm) at the back face of the SBN crystal, nonlineary inscribed with incrising beam powers (P_0=20μW).

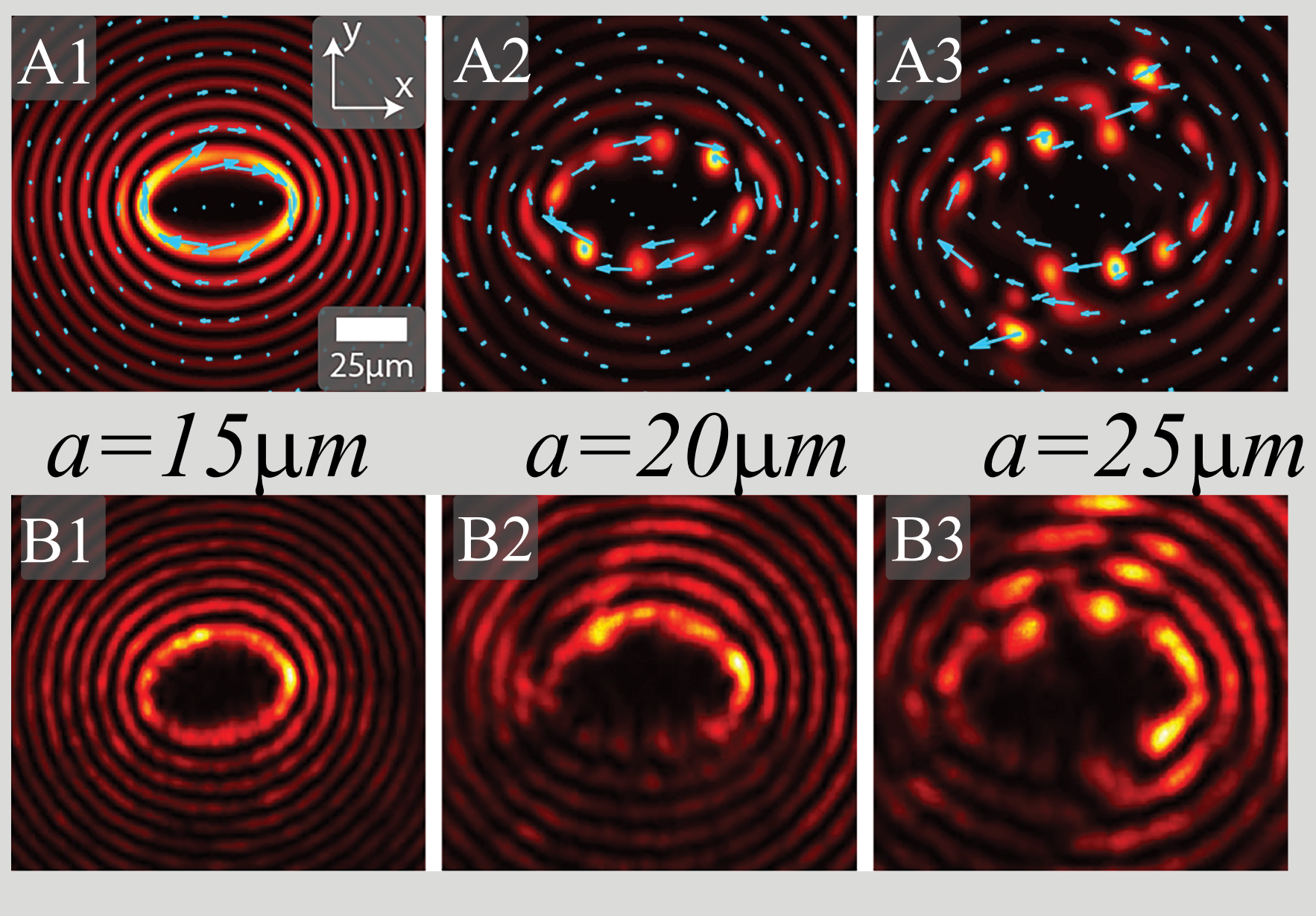
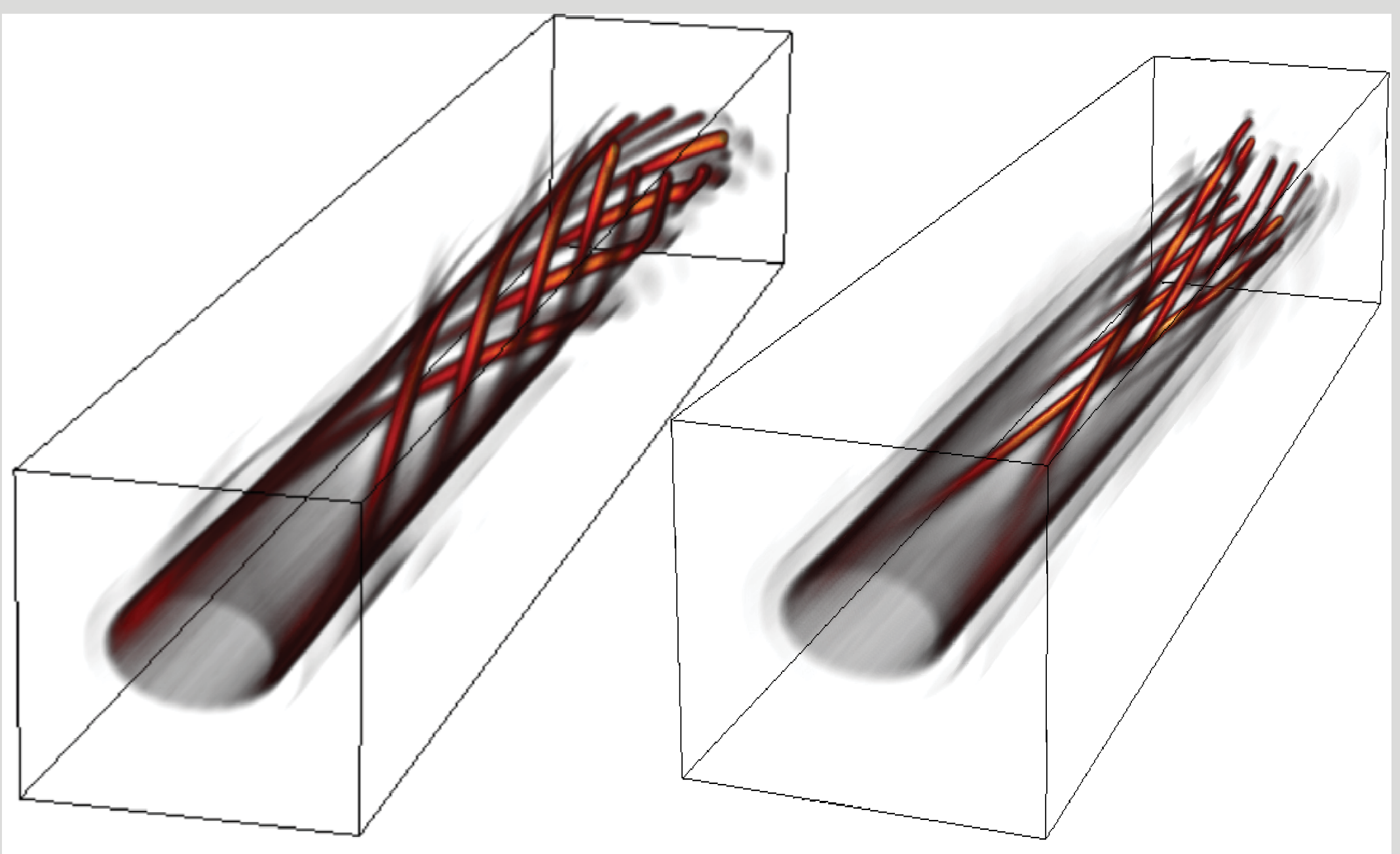


Fig. 8. Transverse intensity distribution at the back face of the SBN crystal after nonlinear propagation of elliptic MB (P_0), for beams with different structure size a.

Chiral lattices



The nonlinear self-action of elliptic MB leads to the formation of high-intensity filaments.

Filaments are rotating in the direction determined by the energy flow.

These twisted refractive index formation could act as chiral waveguides.

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