Assembling of Truncated Deterministic Aperiodic Lattices with Defects Using Weber Beams

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Abstract: We present an experimental and numerical approach for generating two-dimensional truncated deterministic aperiodic photonic lattices using interference of Weber beams—non-diffracting beams with parabolic symmetry. By superimposing two such beams with tunable parameters (parabolicity, phase, spatial shift), we induce refractive index patterns in a photorefractive SBN61: Ce crystal. Numerical simulations based on a nonlinear Schrödinger-type model accurately predict lattice formation and probe beam behavior. Experiments confirm waveguiding and reveal complex defect structures, making these lattices a useful platform for studying light localization and surface effects.

Numerical Method

Beam evolution is governed by the nonlinear Schrödinger-type equation for the field $A(x, y. z)$ in the presence of the induced potential $V(I)$.

$$i\partial_z A(r) + \frac{1}{2k_z}\left[\Delta_\perp + V(I)\right] A(r) = 0$$

The anisotropic electrostatic potential equation governs the space-charge potential Φ_{sc} induced by the intensity I in the presence of the external field E_{ext}.

$$\Delta_\perp \Phi_{sc} + \nabla_\perp(1+I)\cdot\nabla_\perp\Phi_{sc} = E_{ext}\partial_x ln(1+I)$$

The paraxial scalar light field envelope A corresponds to even Weber beams defined as:

$$A = U_e(\eta, \xi; a) = \frac{1}{\pi\sqrt{2}}|\Gamma_1|^2 P_e(\sigma\xi; a)\, P_e(\sigma\eta; -a)$$

Where P_e denotes the even parabolic cylinder function, Γ is the Gamma function, $\Gamma_1 = \Gamma_1[\frac{1}{4} + \frac{1}{2}ia]$, $\sigma = (4\pi/\lambda)^{1/2}$.

Experimental Setup

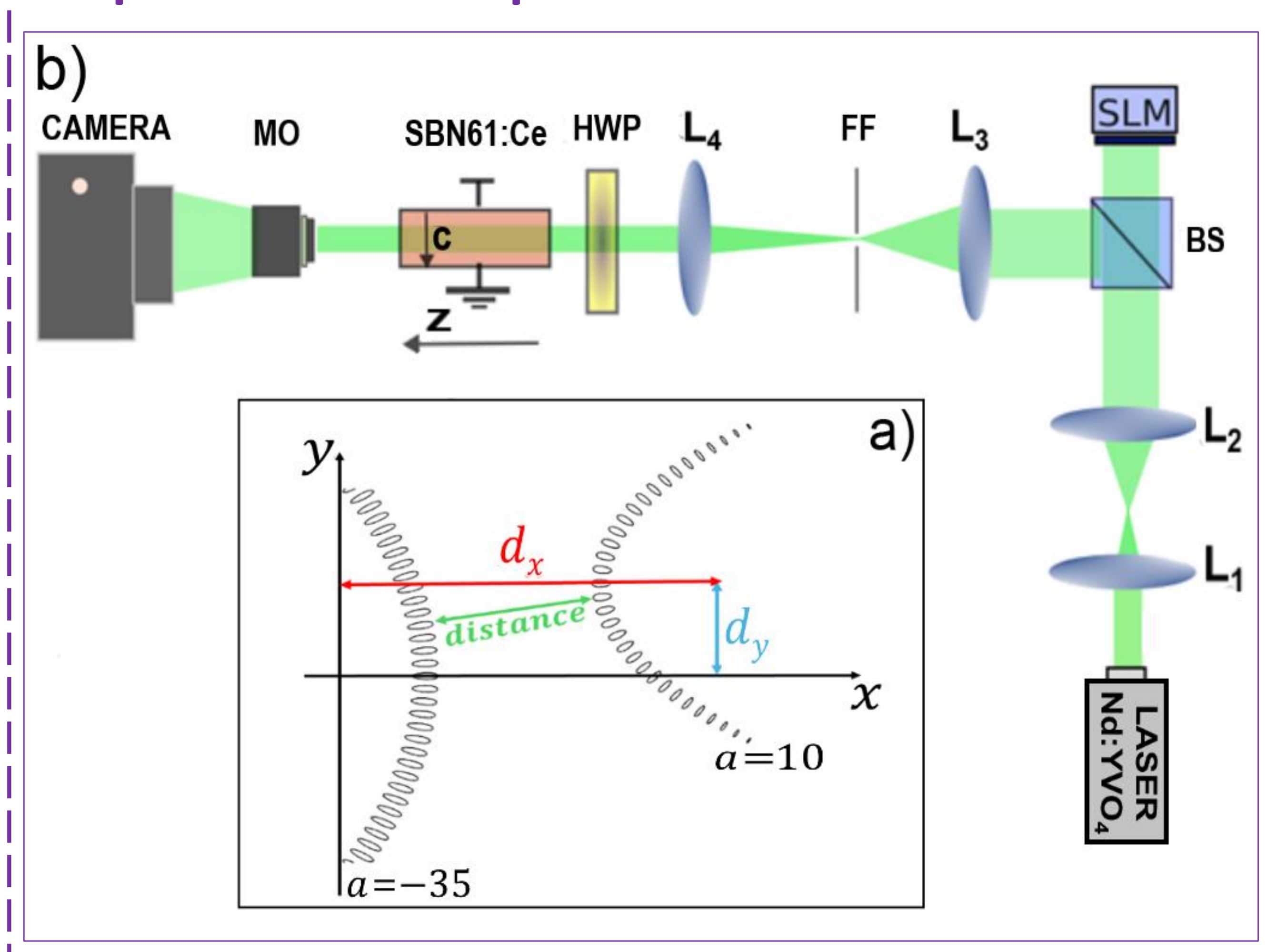

Fig.1.
(a) Geometry of two ***Weber beams*** with parabolicities - a_1, a_2 and focal points F1,F2.

(b) ***Experimental setup***:
L – lens
BS – beam splitter
SLM – spatial light modulator
FF – Fourier filter
SBN61:Ce – crystal
HWP – half-wave plate
MO – microscope objective

Results

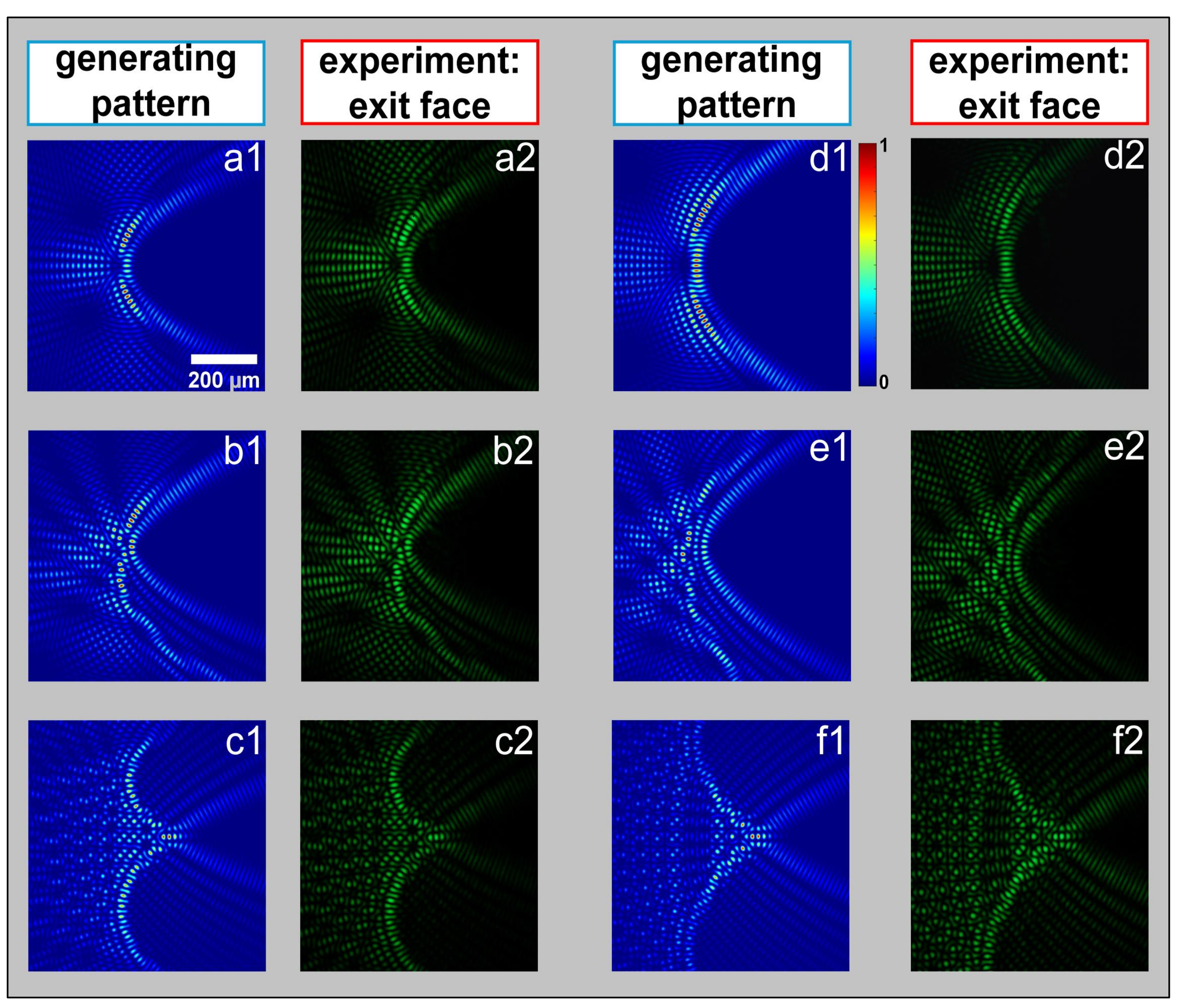

Fig. 2. Interference of two Weber beams. Transverse intensity distributions for beams with common orientation:
$(a–c)\ a_1 = 10$ and $a_2 = 15$,
$(d–f)\ a_1 = 20$ and $a_2 = 25$,
with various vertical positions: $(a),(d)\ dy = 0\ \mu m, (b)\ dy = 108\ \mu m, (c)\ dy = 378\ \mu m, (e)\ dy = 162\ \mu m,$ and $(f)\ dy = 594\ \mu m.$

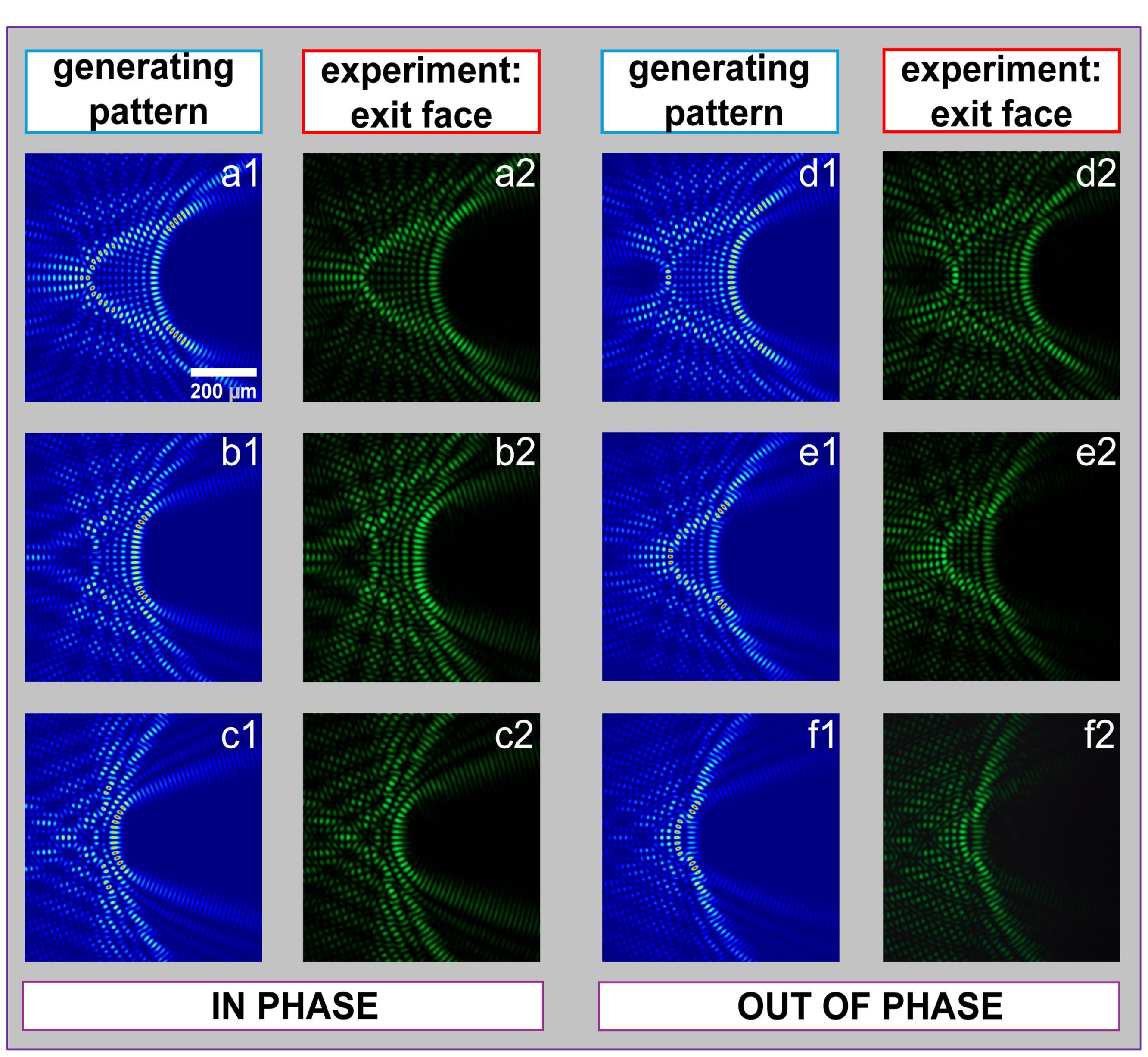

Fig. 3. *Influence of horizontal beam shift and mutual phases:* $(a,d)\ a_1 = 5, a_2 = 20, dx = 54\ \mu m;$
$(b,e)\ a_1 = 5, a_2 = 30, dx = 108\ \mu m;$
$(c,f)\ a_1 = 5, a_2 = 40, dx = 162\ \mu m;$
In-phase (the first and second columns) and *out-of-phase* (the third and fourth columns).

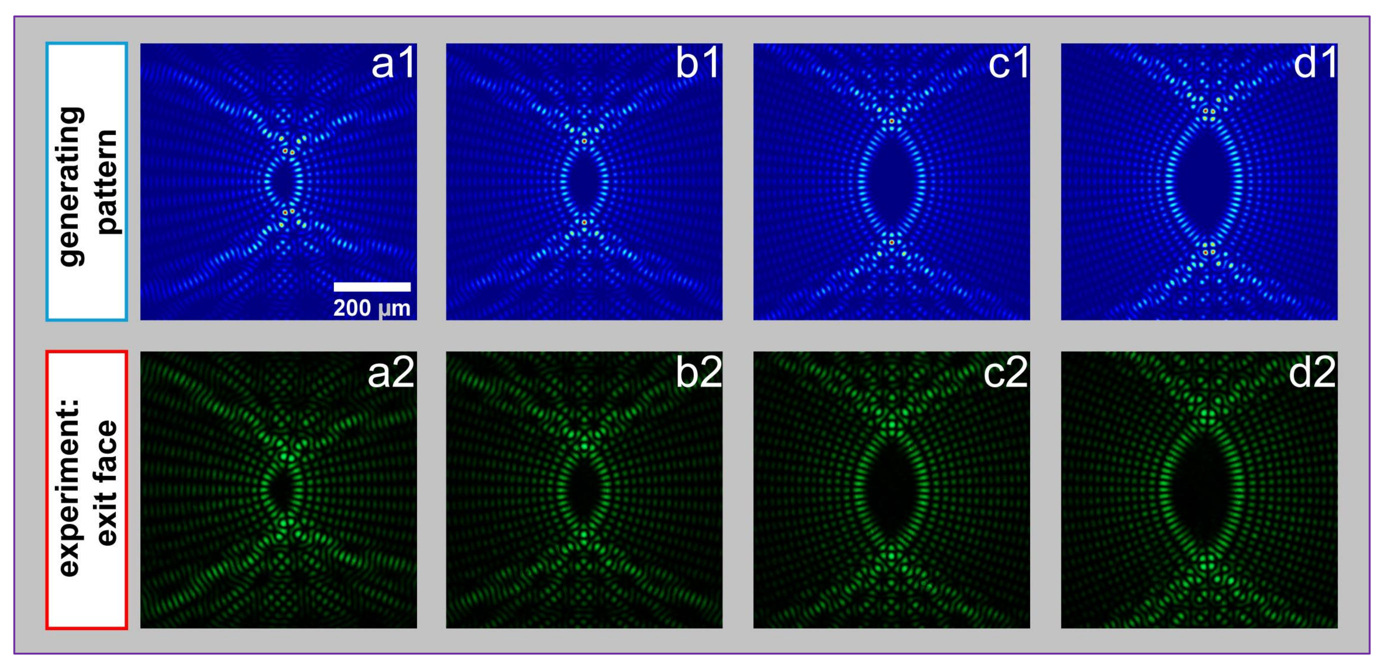

Fig. 4. *Interference of two Weber beams with **opposite-sign parabolicities**:*

$(a)\ a_1 = 5,\ a_2 = -10;$
$(b)\ a_1 = 10, a_2 = -10;$
$(c)\ a_1 = 15, a_2 = -15;$
$(d)\ a_1 = 15, a_2 = -20.$

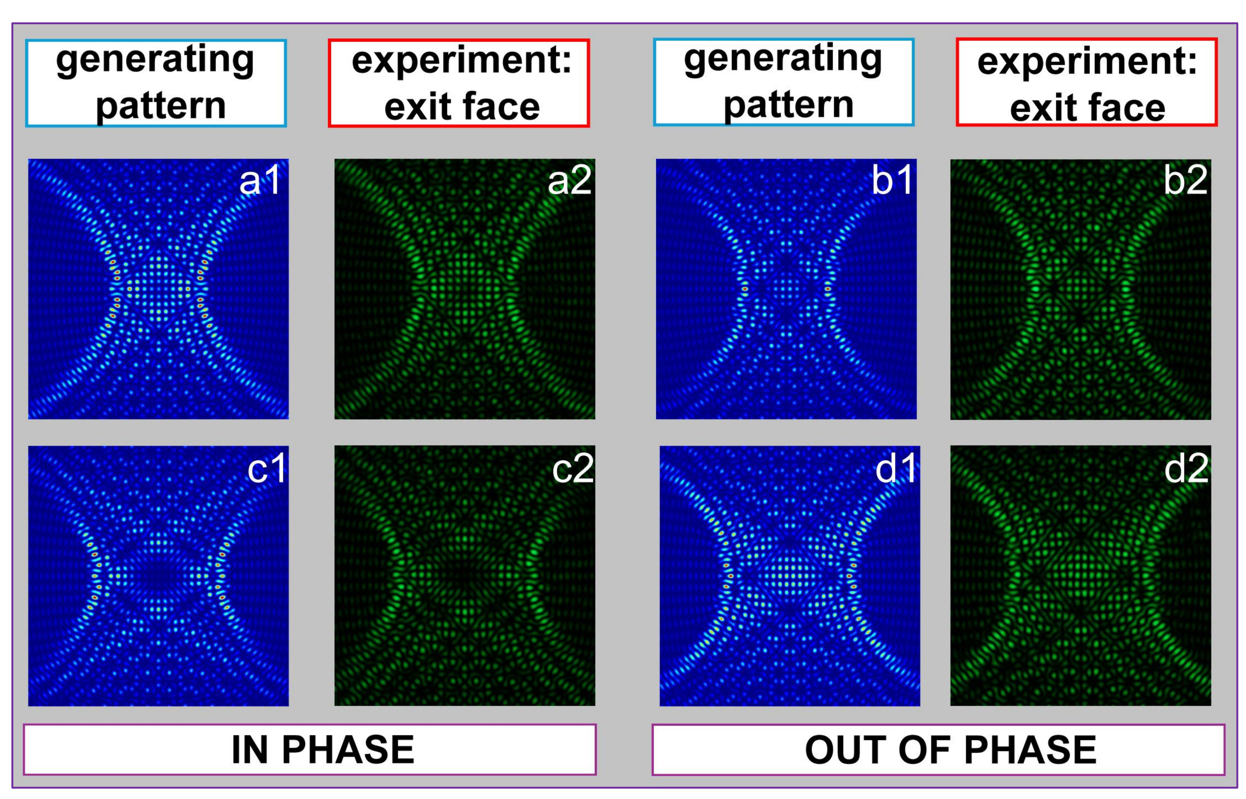

Fig. 5. Mutual influence of horizontal beam shift and opposite-sign parabolicities:
$(a-d)\ a_1 = 25, a_2 = -25$
Horizontal shifts:
$(a),(b)\ dx = 486\ \mu m;$
$(c),(d) dx = 594\ \mu m;$
The *first and second columns* show *in-phase*, and the *third and fourth columns* show *out-of-phase* configurations.

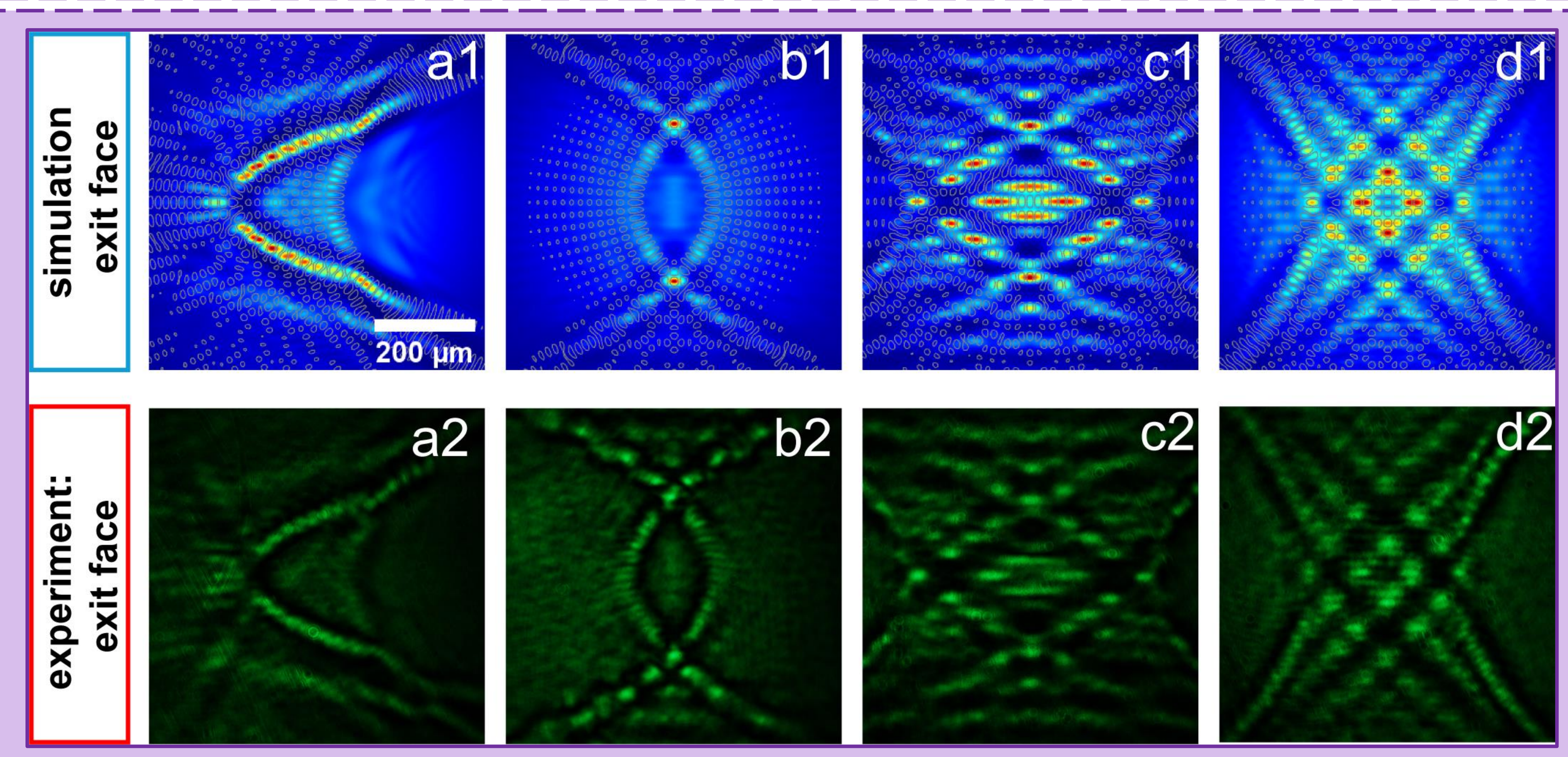

Fig.6. Waveguiding in deterministic aperiodic photonic lattice structures* corresponding to: (a) *Fig. 3(a)*, (b) *Fig. 4(c)*, (c) *Fig. 5(c)* and *Fig. 5(a).
Probe beam at the *exit face of the crystal* shown *numerically (first row)* and *experimentally (second row)*, confirming *refractive index modulation* in the form of *parabolic deterministic aperiodic structures* and demonstrating *agreement between numerical and experimental results*.

References:

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