Localized modes in two-dimensional "plus" lattice

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The model

We have proposed a design for new photonic lattice which does not exist in nature but might be easily fabricated by, for example, femtosecond laser inscription technique. Unit cell of the lattice consists of five linearly coupled waveguides distributed at the edges and in the center of a "plus" sign. Existence and stability of linear and nonlinear localized modes in the lattice are numerically investigated.

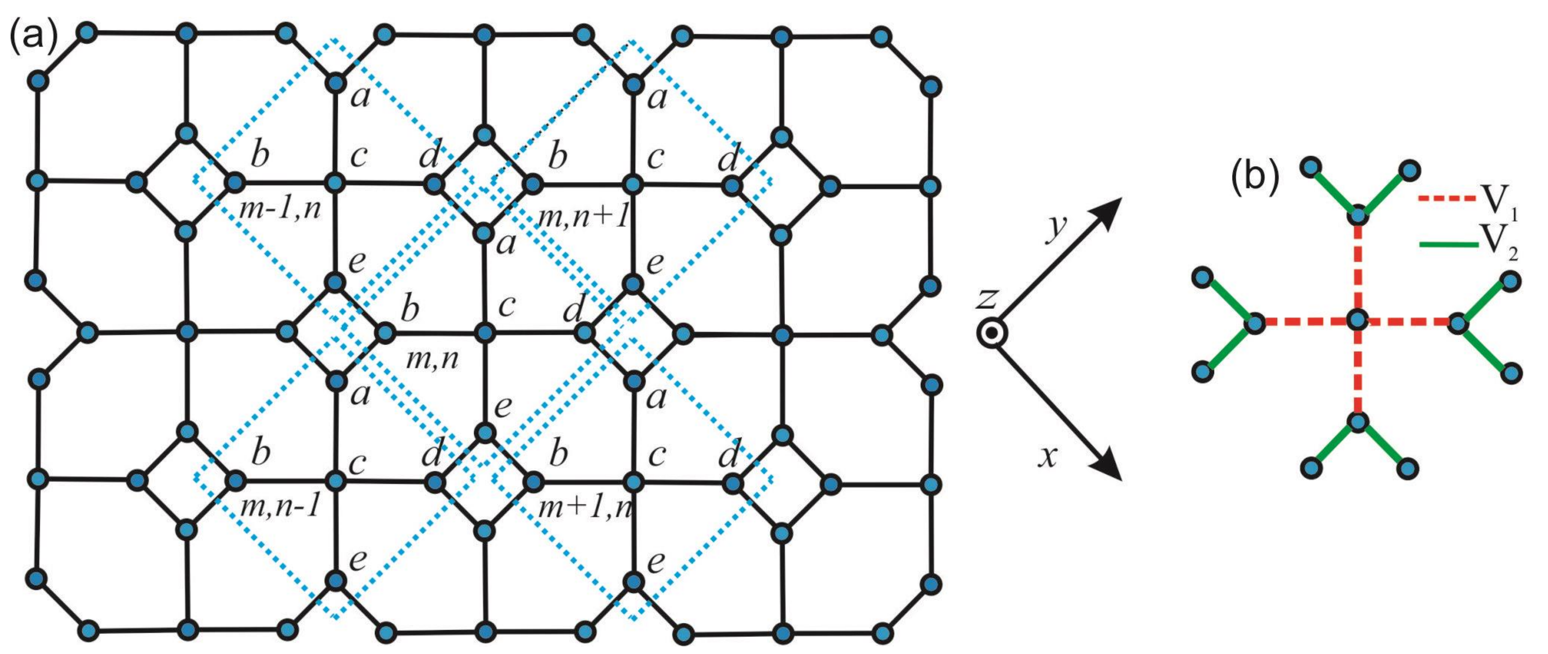

Fig.1: (a) Schematic representation of the 2D "plus" lattice; (b) Schematic presentation of couplings in the system.

$$i\partial_z a_{m,n} + V_2 b_{m,n+1} + V_1 c_{m,n} + V_2 d_{m-1,n} + \gamma |a_{m,n}|^2 a_{m,n} = 0$$
$$i\partial_z b_{m,n} + V_2 a_{m,n-1} + V_1 c_{m,n} + V_2 e_{m-1,n} + \gamma |b_{m,n}|^2 b_{m,n} = 0$$
$$i\partial_z c_{m,n} + V_1 (a_{m,n} + b_{m,n} + d_{m,n} + e_{m,n}) + \gamma |c_{m,n}|^2 c_{m,n} = 0$$
$$i\partial_z d_{m,n} + V_2 a_{m+1,n} + V_1 c_{m,n} + V_2 e_{m,n+1} + \gamma |d_{m,n}|^2 d_{m,n} = 0$$
$$i\partial_z e_{m,n} + V_2 b_{m+1,n} + V_1 c_{m,n} + V_2 d_{m,n-1} + \gamma |e_{m,n}|^2 e_{m,n} = 0,$$

z is normalized propagation axis, $a_{m,n}$, $b_{m,n}$, $c_{m,n}$, $d_{m,n}$ and $e_{m,n}$ are sites within m, n primitive cell ($m = 1,\ldots,M$; $n = 1,\ldots,N$), V_1 and V_2 are inter-cell and intra-cell coupling constants, respectively.

Different families of localized modes are found:
- linear FB compactons (due to the geometrically 'forced' destructive interference);
- nonlinear compact localized modes (on-site nonlinearity vs. geometry effect);
- nonlinear modes: gap modes (dimerization can open gaps + semi-infinite gap).

Stability of localized modes is numerically checked:
- Linear stability analysis (LSA);
- Direct numerical simulations.

Linear case (γ=0)

- One flat band [FB] [1,2]
- Four dispersive bands [DB]

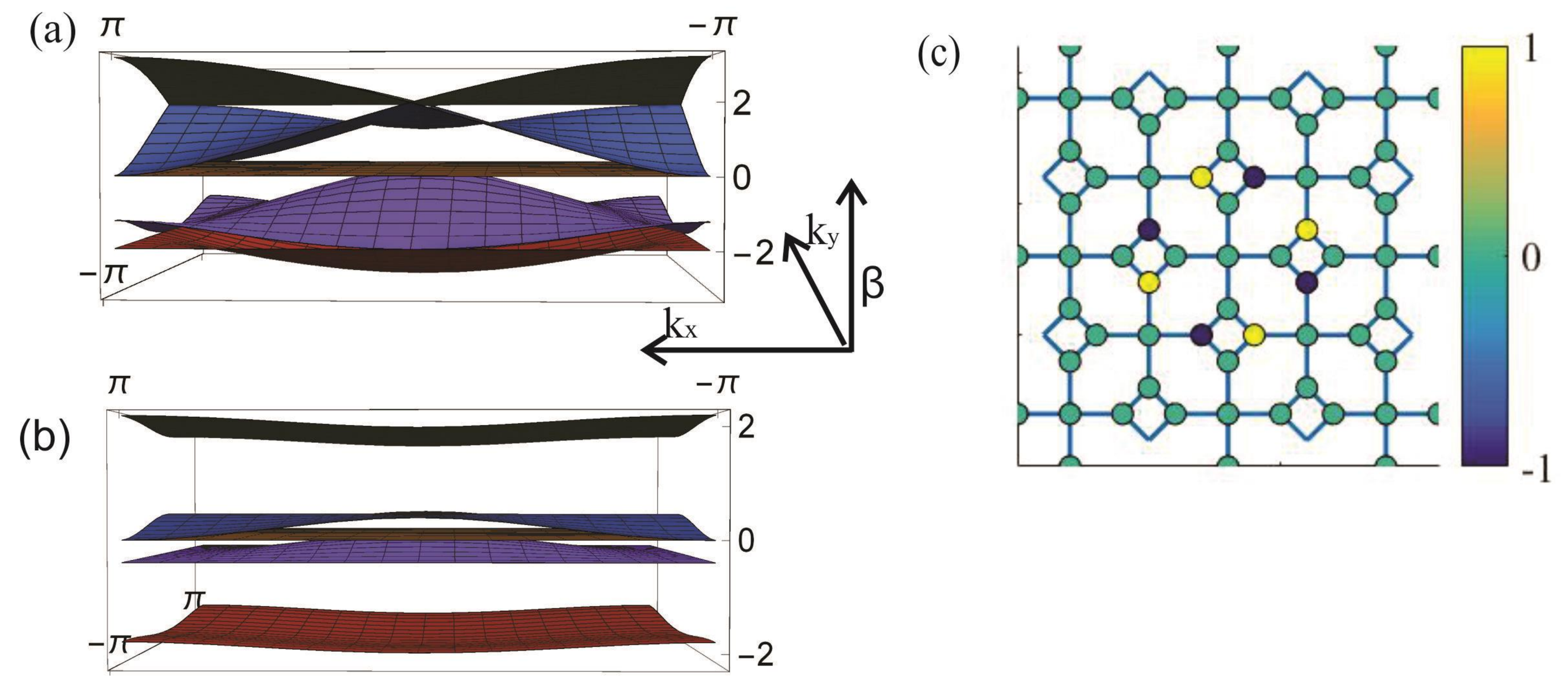

Fig. 2. Band gap diagram: (a) V1=V2=1; (b) V1=1, V2=0.2.
(c) Fundamental compacton solution for β=0 (exists for all ratios of V1 and V2).

Nonlinear (NL) case

NL 'continues' the compact localized mode branch from FB

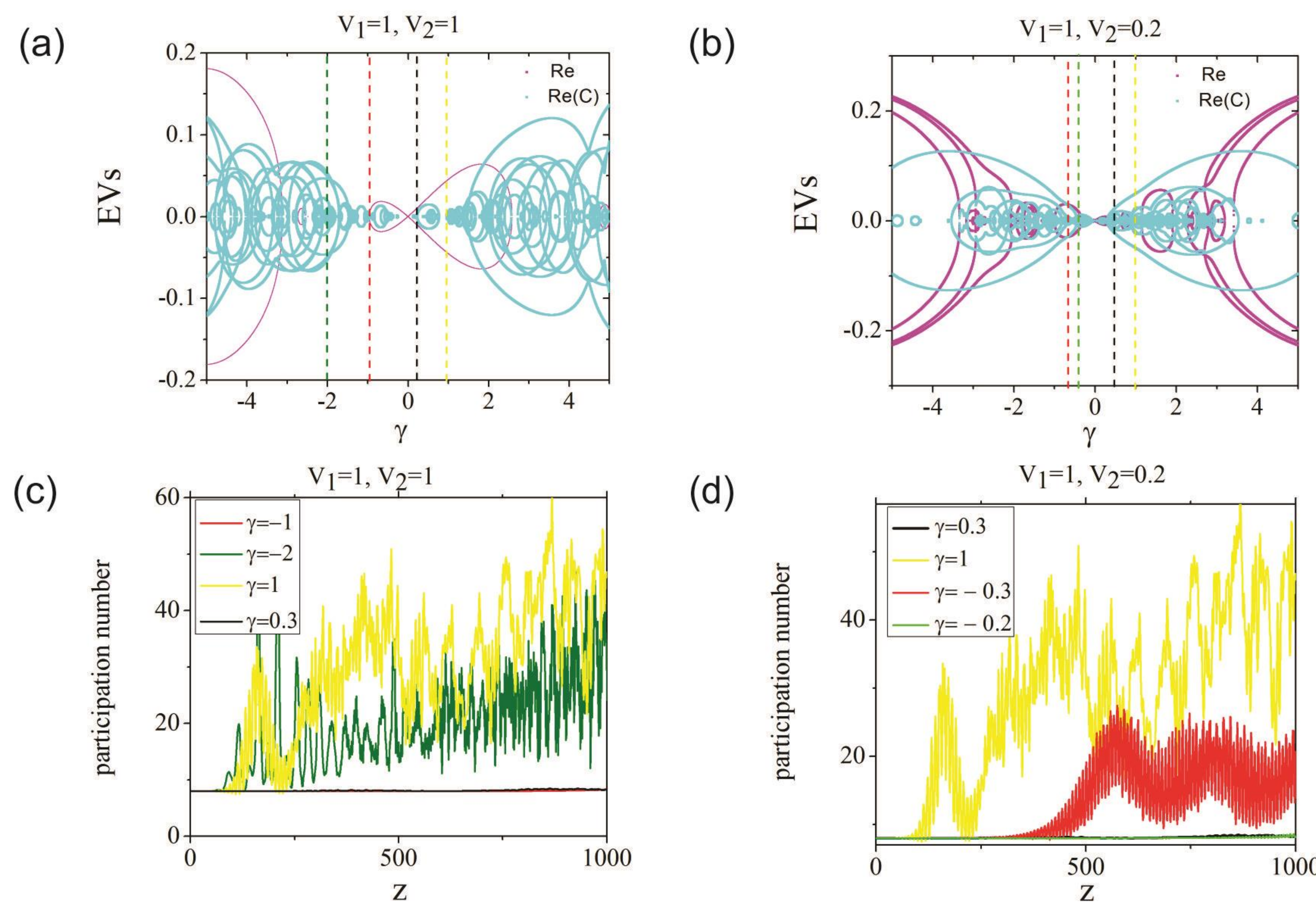

Fig. 3. Results of LSA for NL compact mode: (a) V_1=1, V_2=1 ; (b) V_1=1, V_2=0.2; Participation number for (c) V_1=1, V_2=1; (d) V_1=1, V_2=0.2. Size of the system is 5x5.
NL destabilizes compact localized mode branch.
Dynamical simulations confirm the LSA findings.

Localized modes in gaps opened by dimerisation

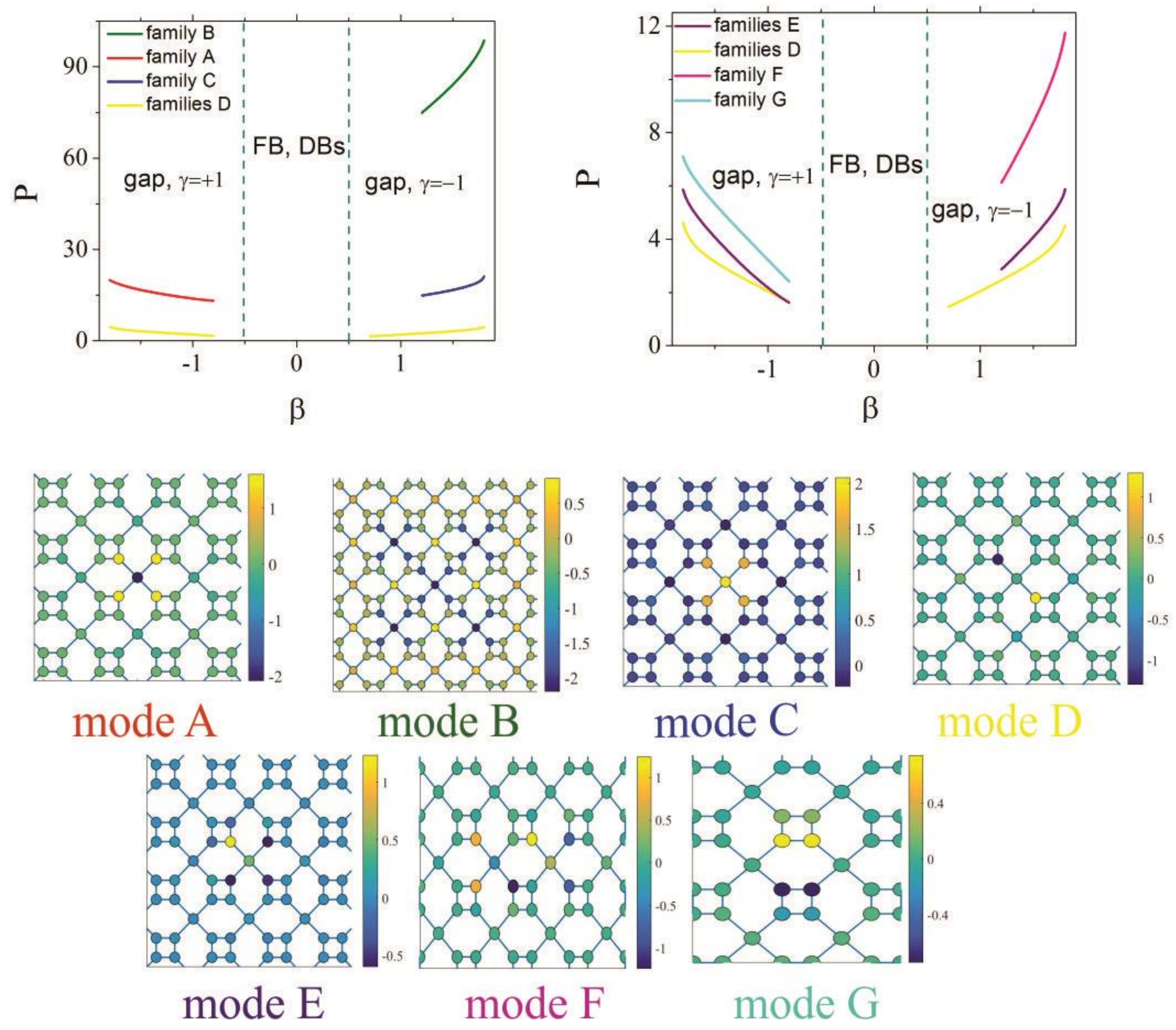

Fig. 4. P vs. β diagrams of different non-linear localized modes within the gaps with representative modes profiles.
Narrow stability regions: modes A, C, D, E

Conclusion

-Suggested design of new lattice with FB;
-Different families of localized modes are found (FB compactons, nonlinear compact and gap modes);
-Nonlinearity destabilized the compact localized modes;
-Narrow ranges of the gap mode stability;
-Challenge: edge states?

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References

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