Chiral emission of giant atoms in 2D

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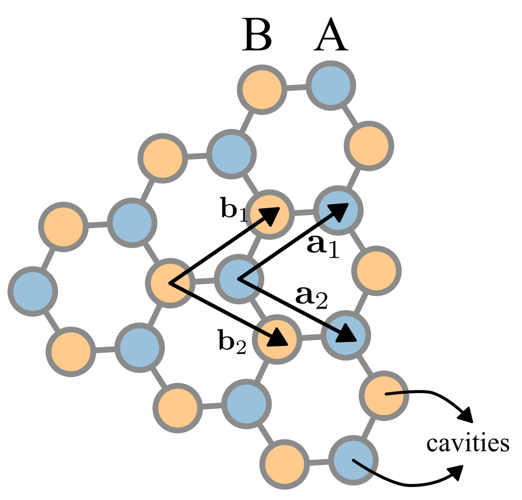
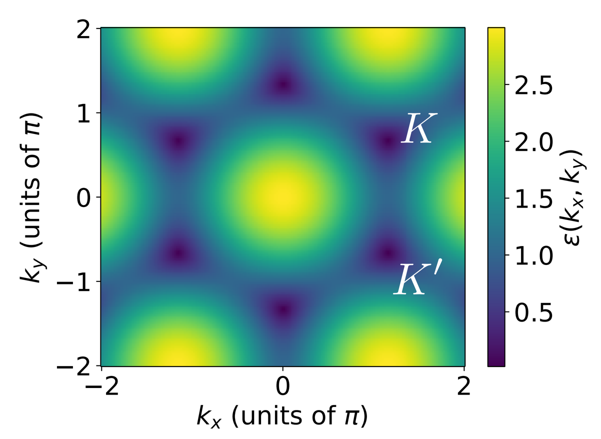
ABSTRACT

A giant atom is a quantum emitter that can be coupled to the field non-locally at a set of coupling points [1]. Such new generation of emitters can nowadays be implemented in circuit QED setups, where some spectacular effects - unachievable with normal atoms - have already been observed. One of this is the possibility to enable chiral (i.e. fully uni-directional) emission upon proper engineering of coupling-point complex phases [2,3], which can have important applications for quantum communication. Here, for the first time we investigate emission properties of a giant atom coupled to 2D honeycomb photonic lattice. This allows combining the intrinsically anisotropic light emission across lattices [4] with the topology of coupling points and their phase-difference pattern. Such phases can be used to control the distribution of emitted light among a set of different directions.

PHOTONIC GRAPHENE



$$\mathbf{n}_A = n_1\mathbf{a}_1 + n_2\mathbf{a}_2$$
$$\mathbf{n}_B = n_1\mathbf{b}_1 + n_2\mathbf{b}_2$$

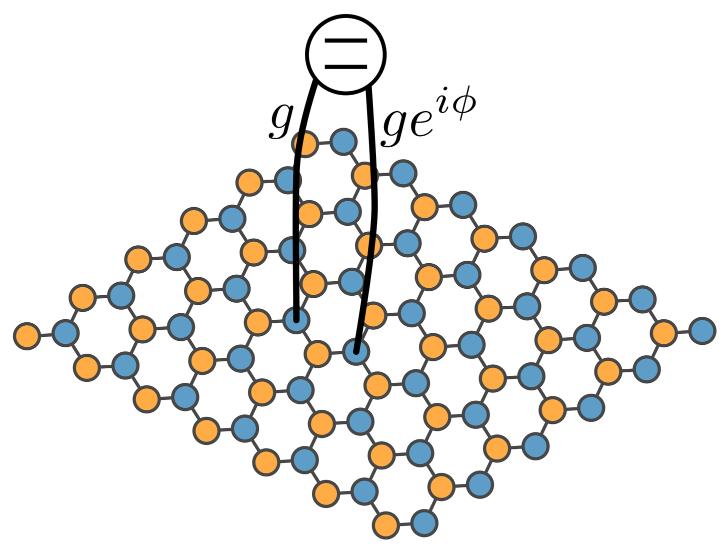


The Hamiltonian reads

$$H_A = \Delta\sigma_+\sigma_-$$
$$H_{bath} = J\sum\left(\hat{a}^\dagger_{\mathbf{n}_A}\hat{b}_{\mathbf{n}_B} + \text{H.c.}\right)$$
$$H_{int} = g\left(\hat{a}^\dagger\sigma_- + \text{H.c.}\right)$$

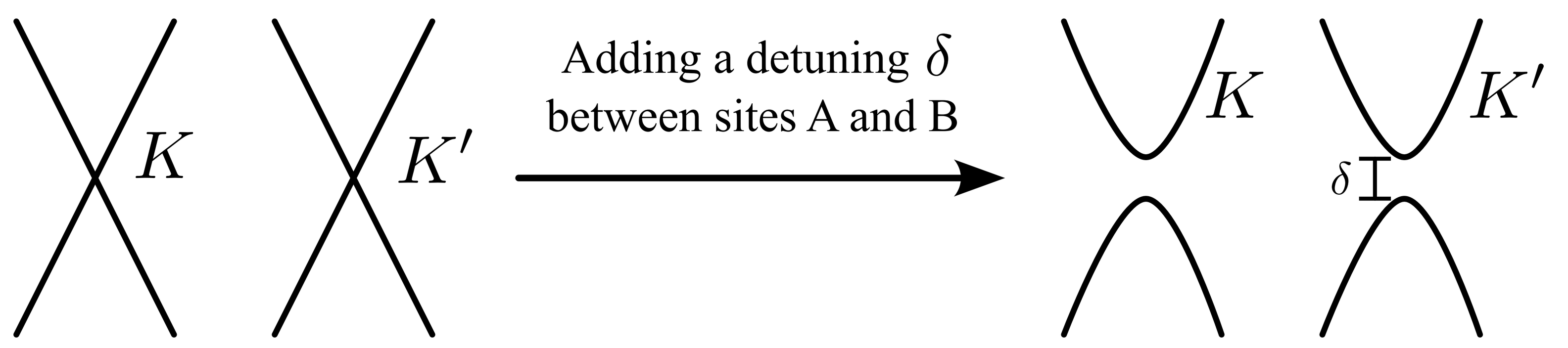
$$H = H_A + H_{bath} + H_{int}$$

INTRODUCING A *GIANT* ATOM (NON-LOCAL COUPLING)



The giant atom is coupled to *two* cavities of the same sublattice.

DECOUPLING FROM ONE VALLEY



While a normal atom couples to both valleys K and K', a giant atom will predominantly couple to valley K' or K only if:

$$\phi = \frac{\pi}{3} \qquad \text{or} \qquad \phi = \frac{5\pi}{3}$$

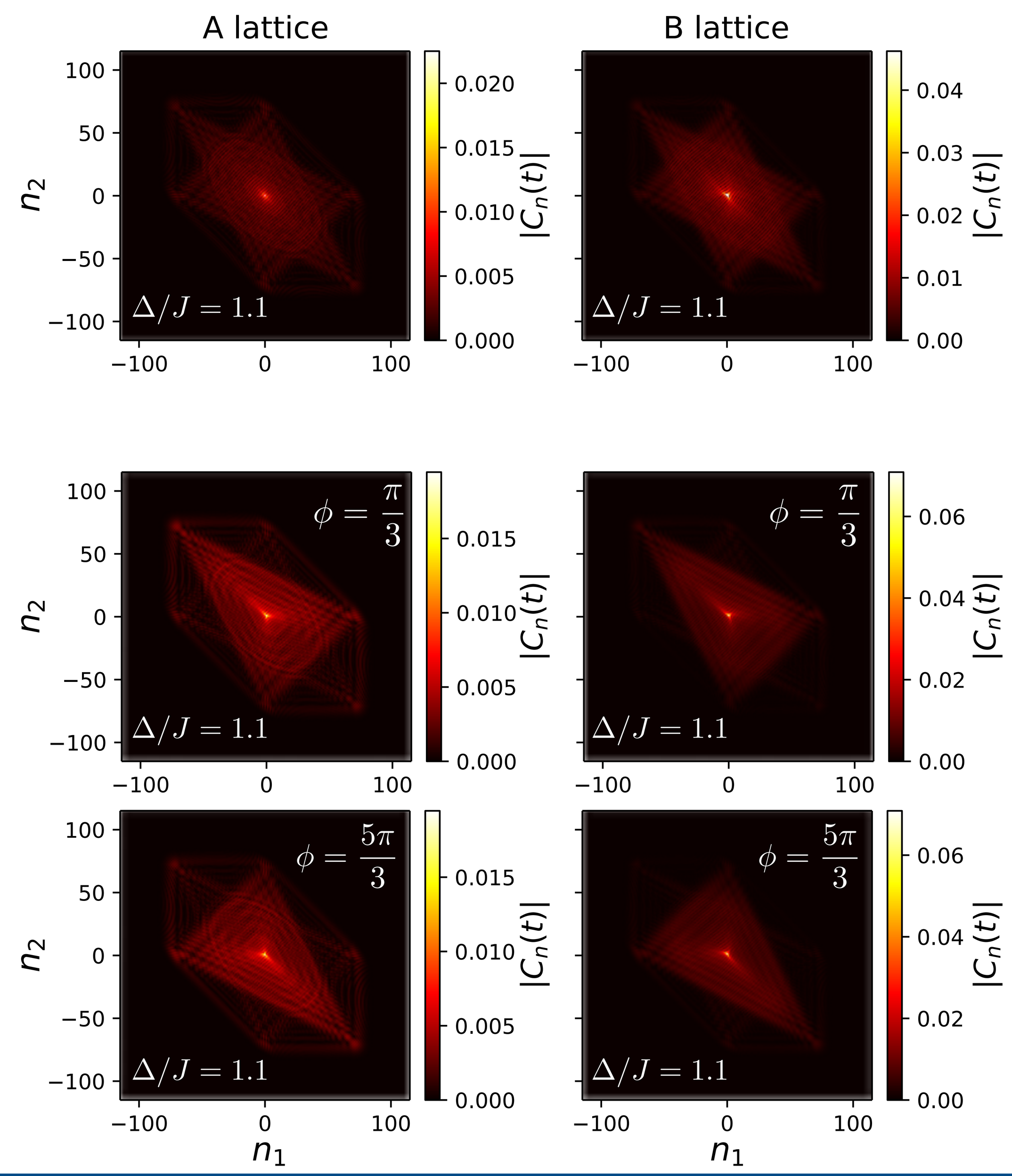
Decoupling from one valley will give rise to a Berry curvature Ω:

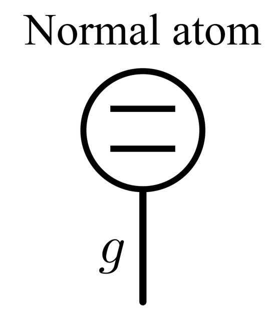
$$\Omega(k) = -\hat{z}\frac{2a^2J^2\delta}{(4a^2J^2k^2 + \delta^2)^{3/2}}\tau_z$$

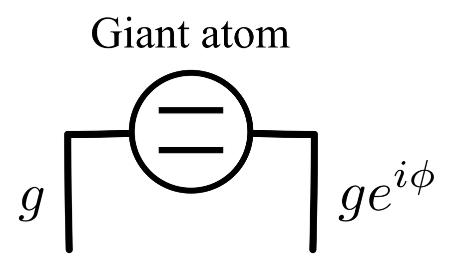
This non-zero Berry curvature in the presence of an electric field will yield an anomalous velocity:

$$\mathbf{v}_a \propto \mathbf{E}\times\Omega$$

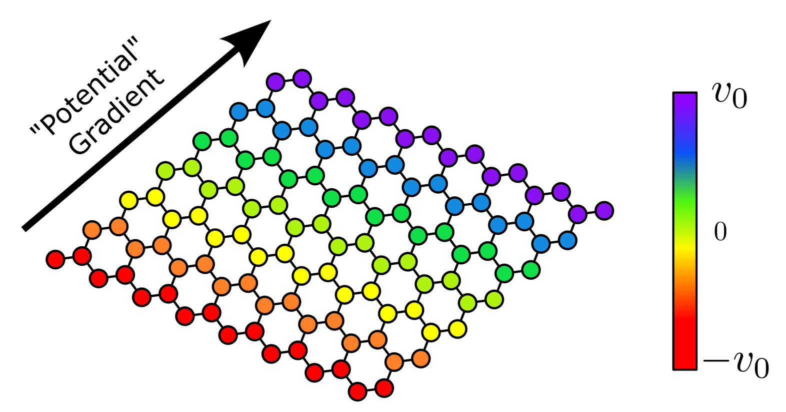
EMITTED FIELD







SYNTHETIC ELECTRIC FIELD

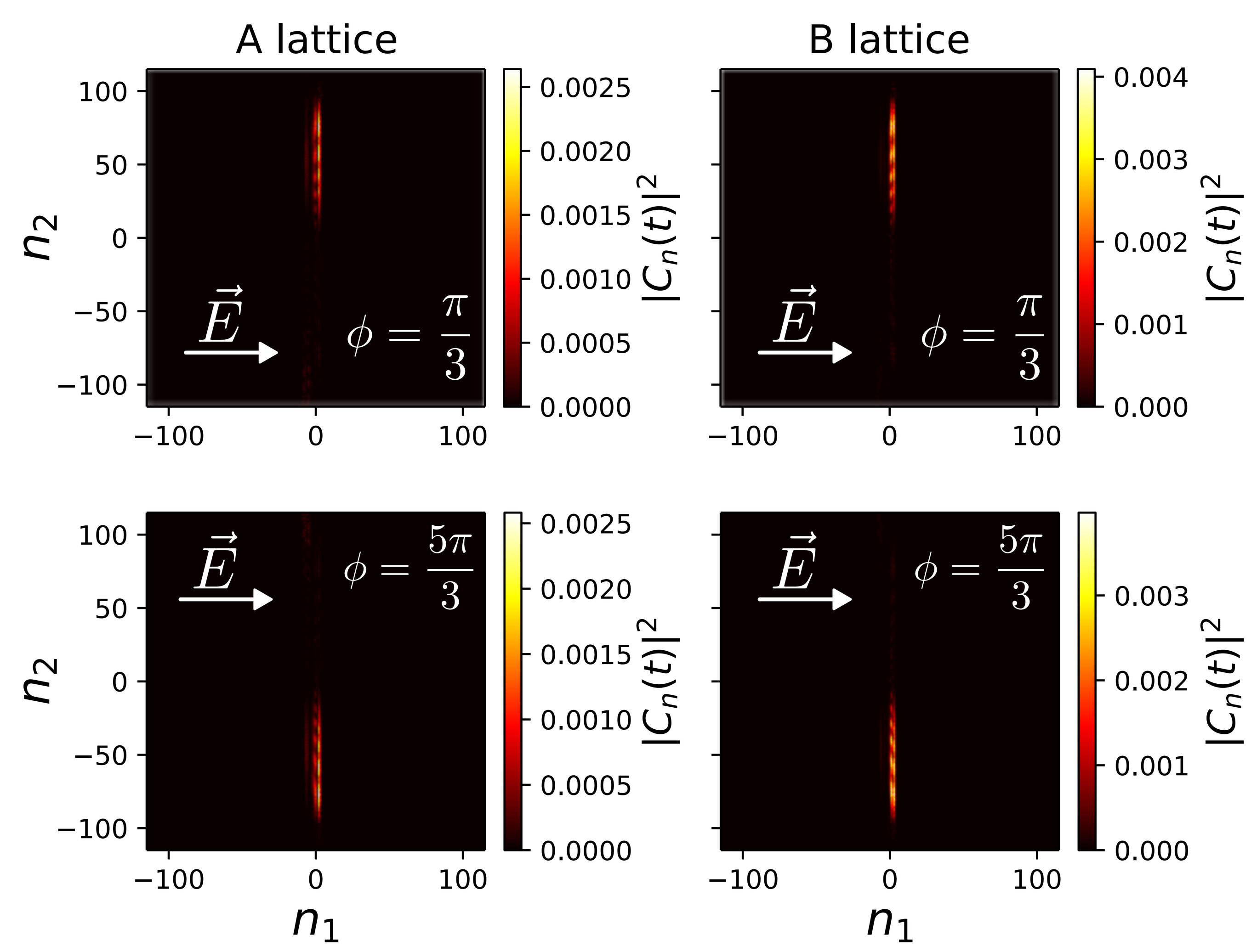


We can create a synthetic electric field by adding a potential (embodied by a pattern of cavity frequencies)

$$U(x_i) = -Ex_i$$

the electric field will be along the direction of the gradient.

CHIRAL EMISSION



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