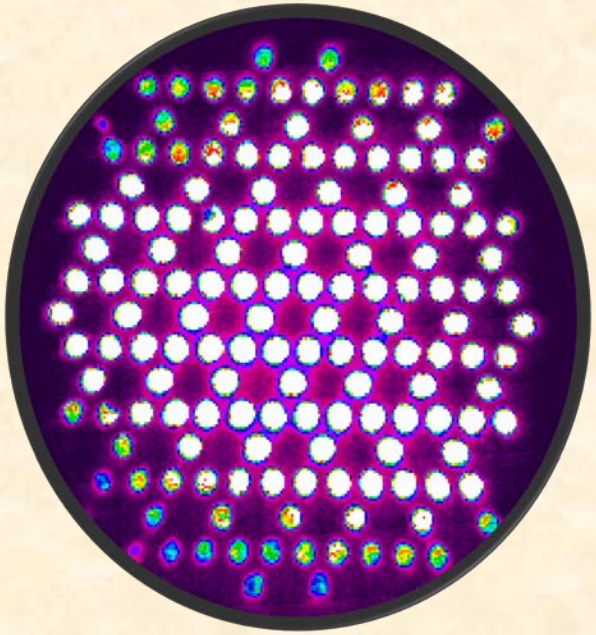
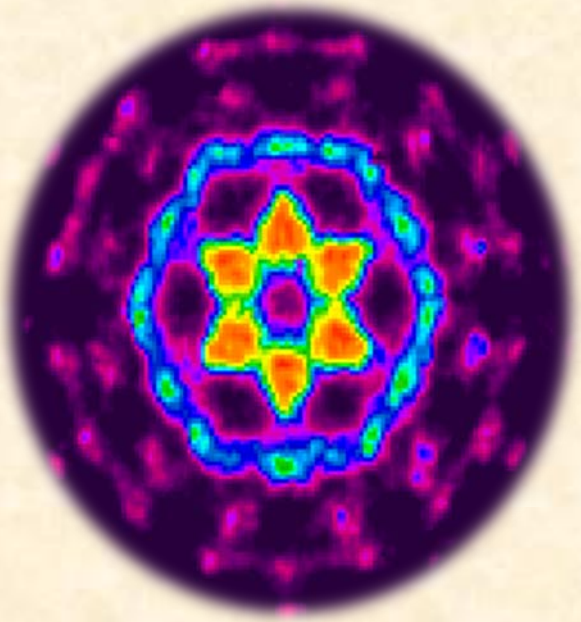
Frustration in a 2D Kagome lattice of coupled lasers

Near Field



Far Field



Nir Davidson

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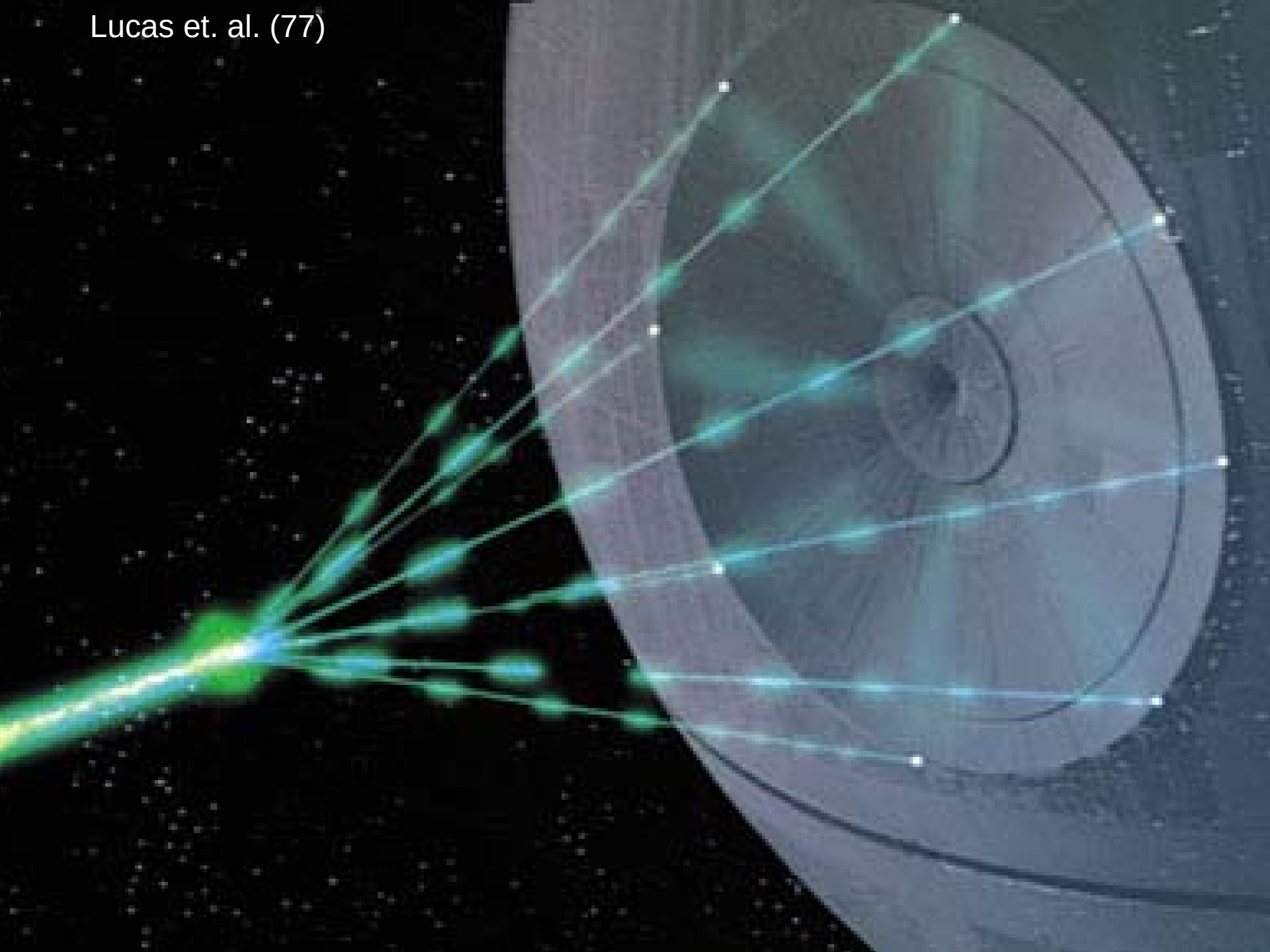
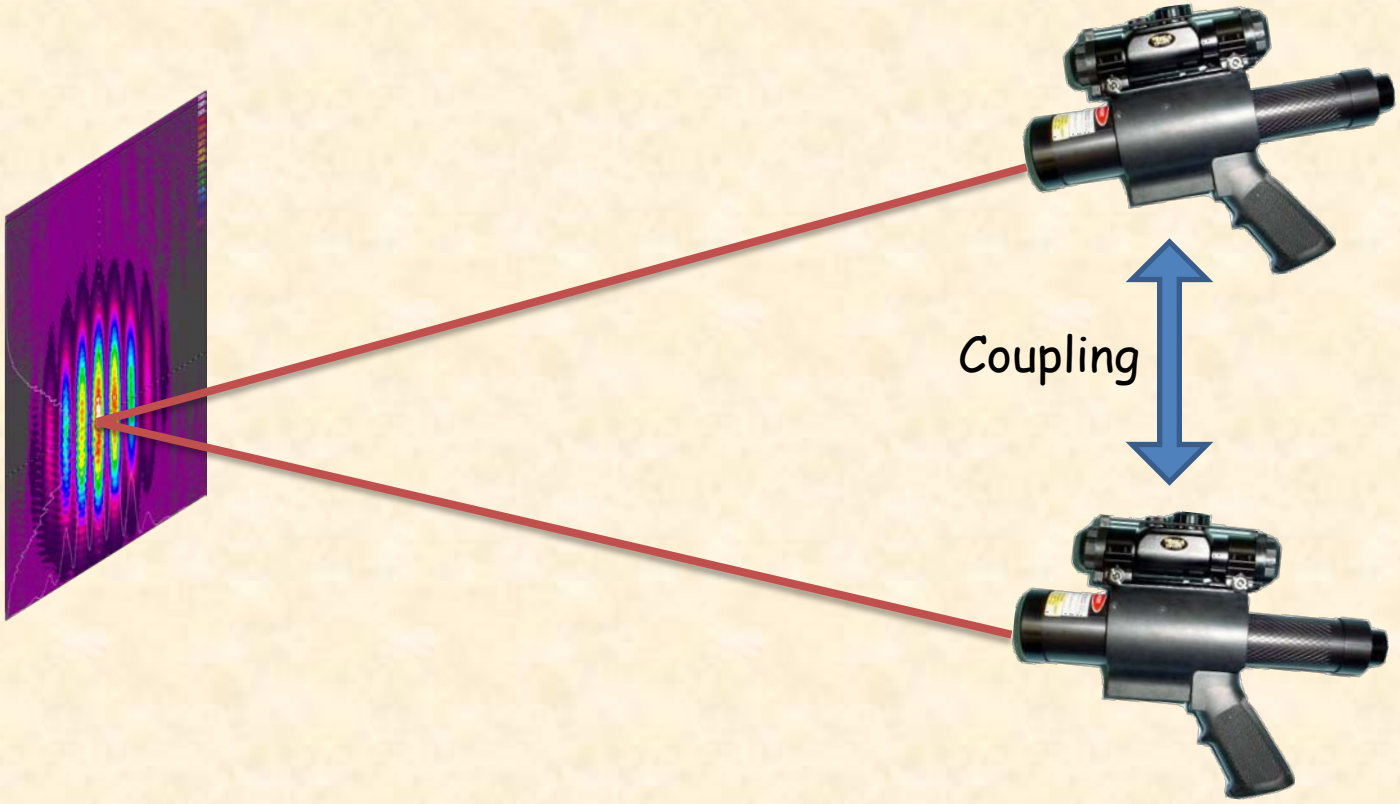

Lucas et. al. (77)

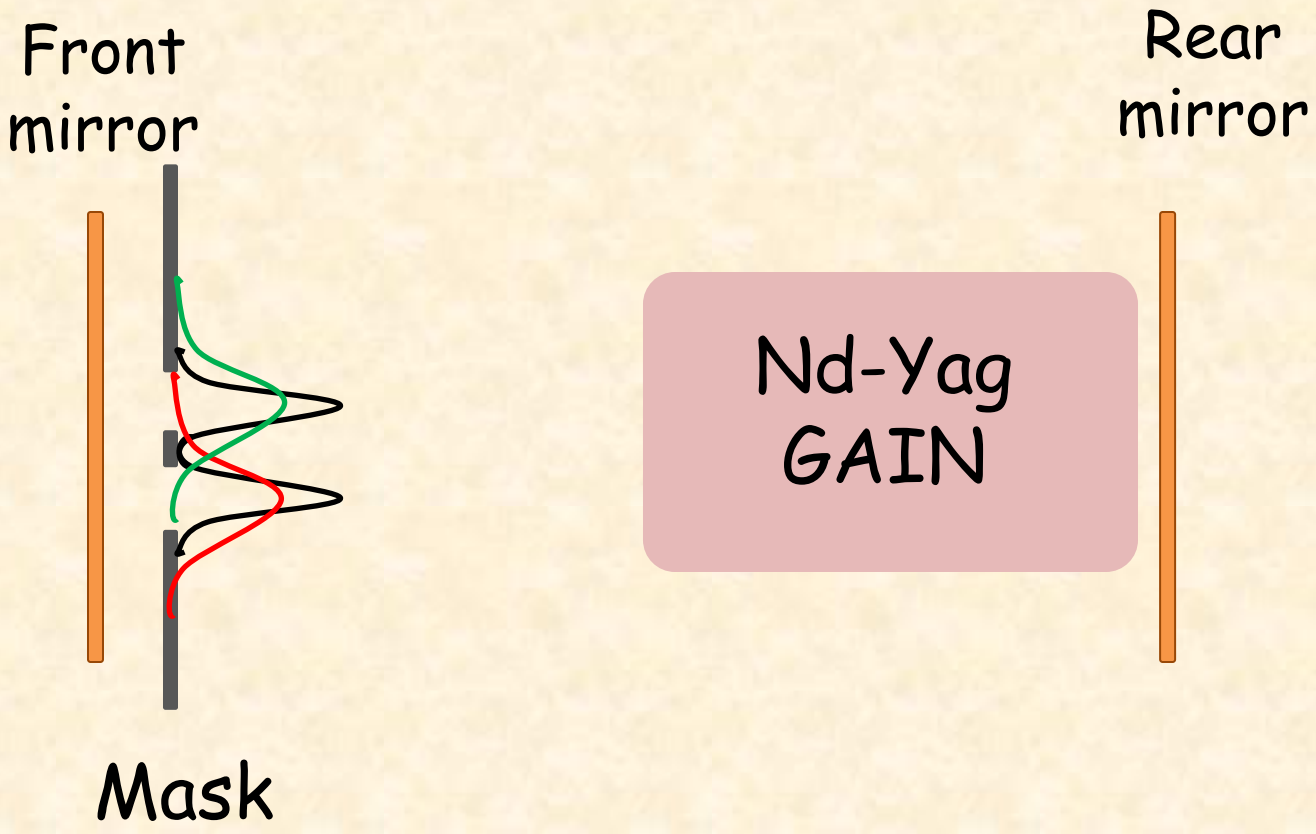
Introduction

What is phase locking ?



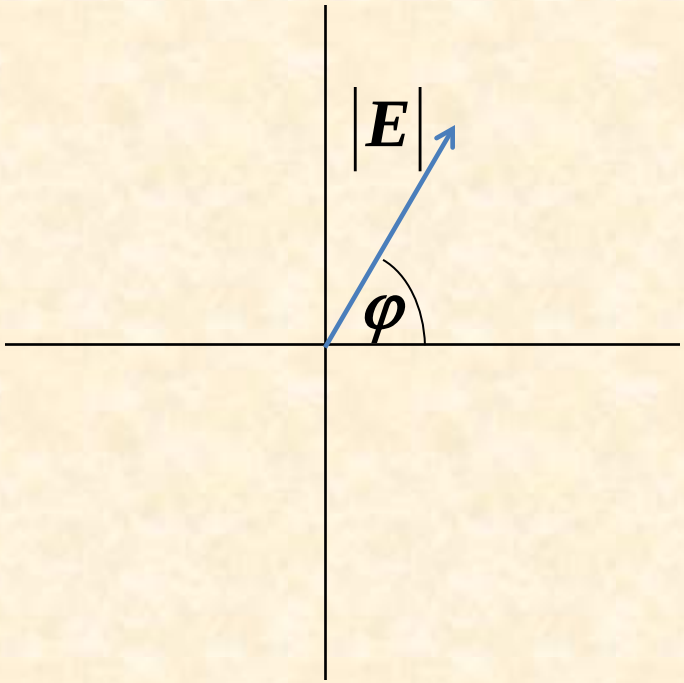
$$\Delta\varphi(t) = \varphi_2(t) - \varphi_1(t) = const$$

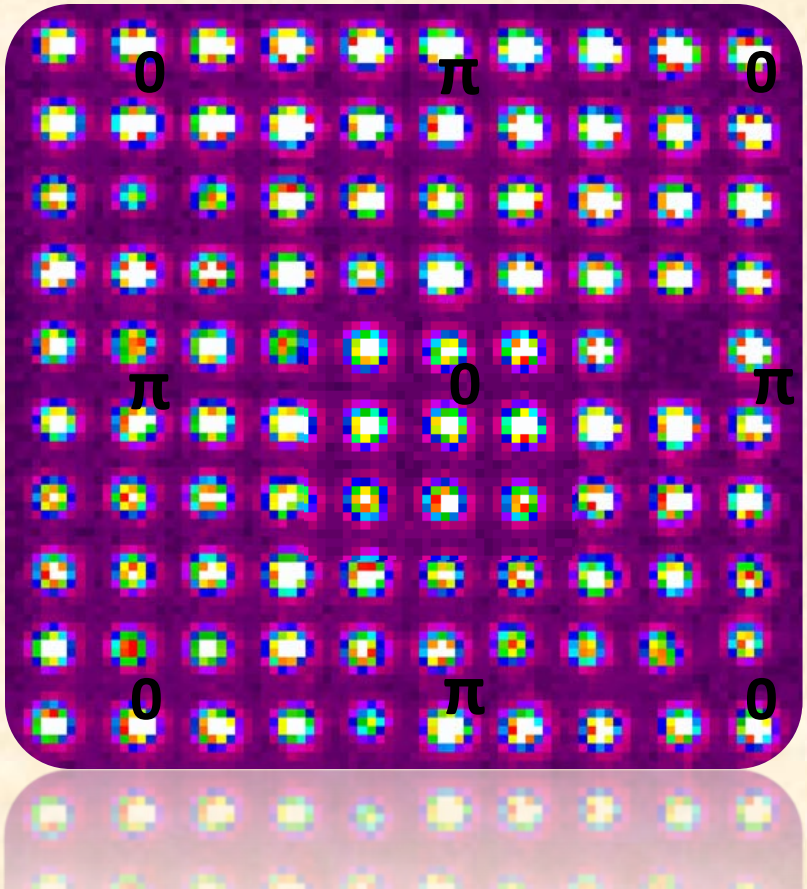
Diffraction (evanescent field) coupling



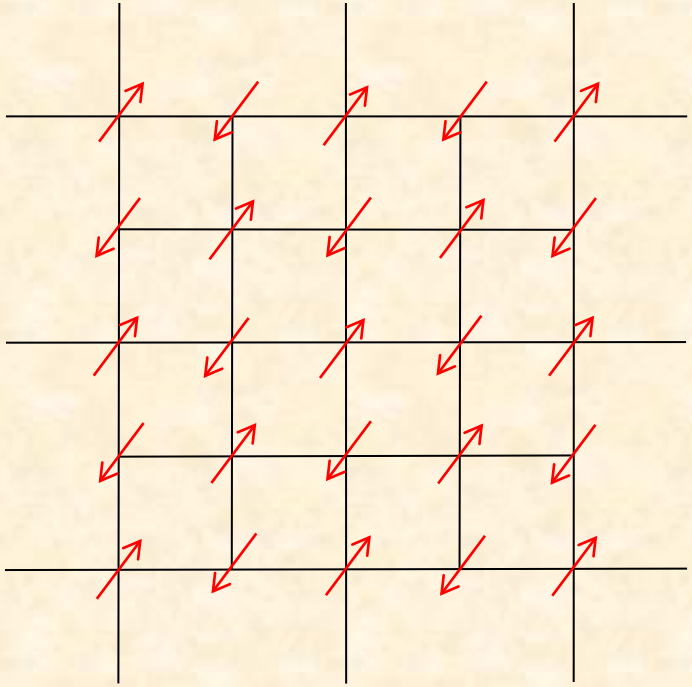
Negative Coupling

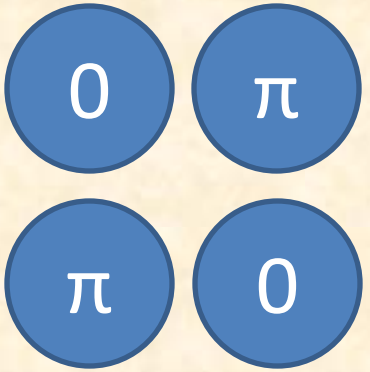
$$\boldsymbol{E_1 = -E_2 \rightarrow \Delta\varphi = \pi}$$





Negative Coupling

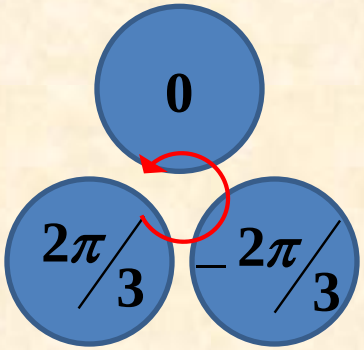




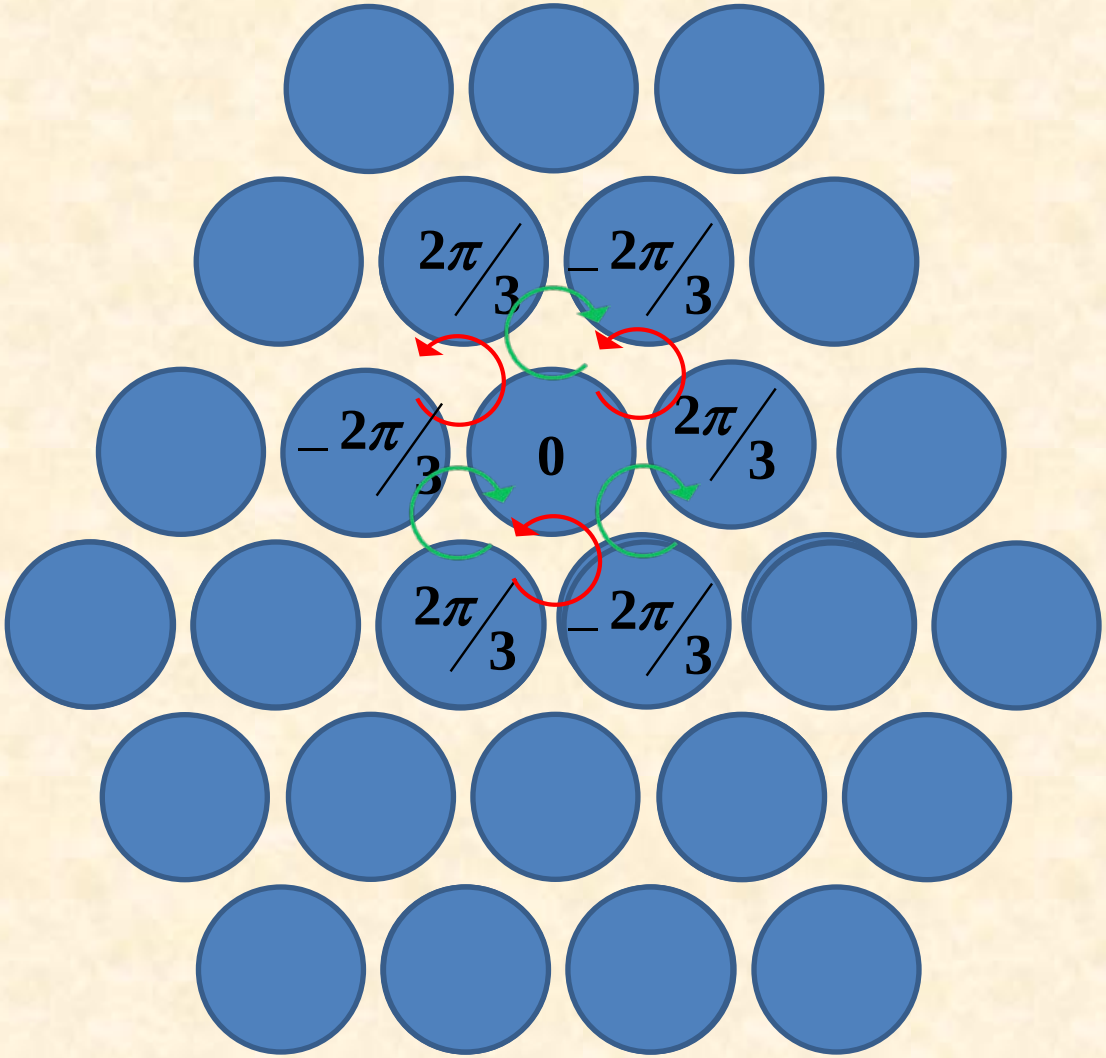
XY model with anti ferromagnetic interactions

$$\mathrm{H} = J \sum_{i \neq j}^{n} \vec{\sigma}_i \cdot \vec{\sigma}_j$$

Triangle Array

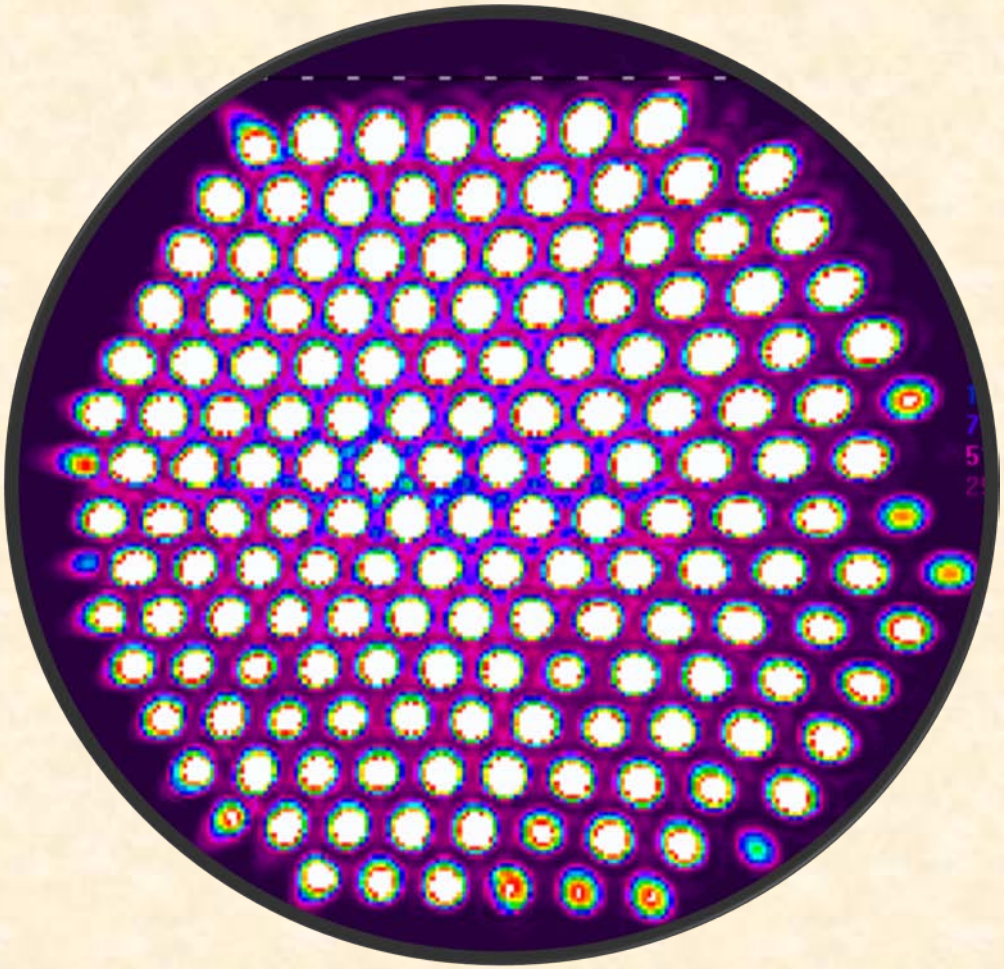


Triangle Array

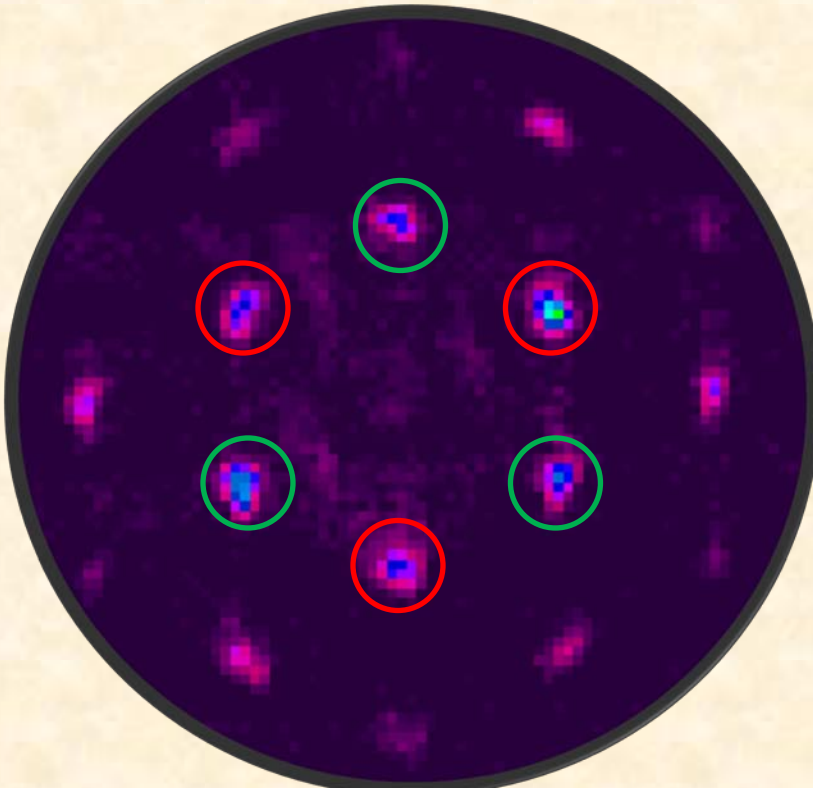


Triangle Array

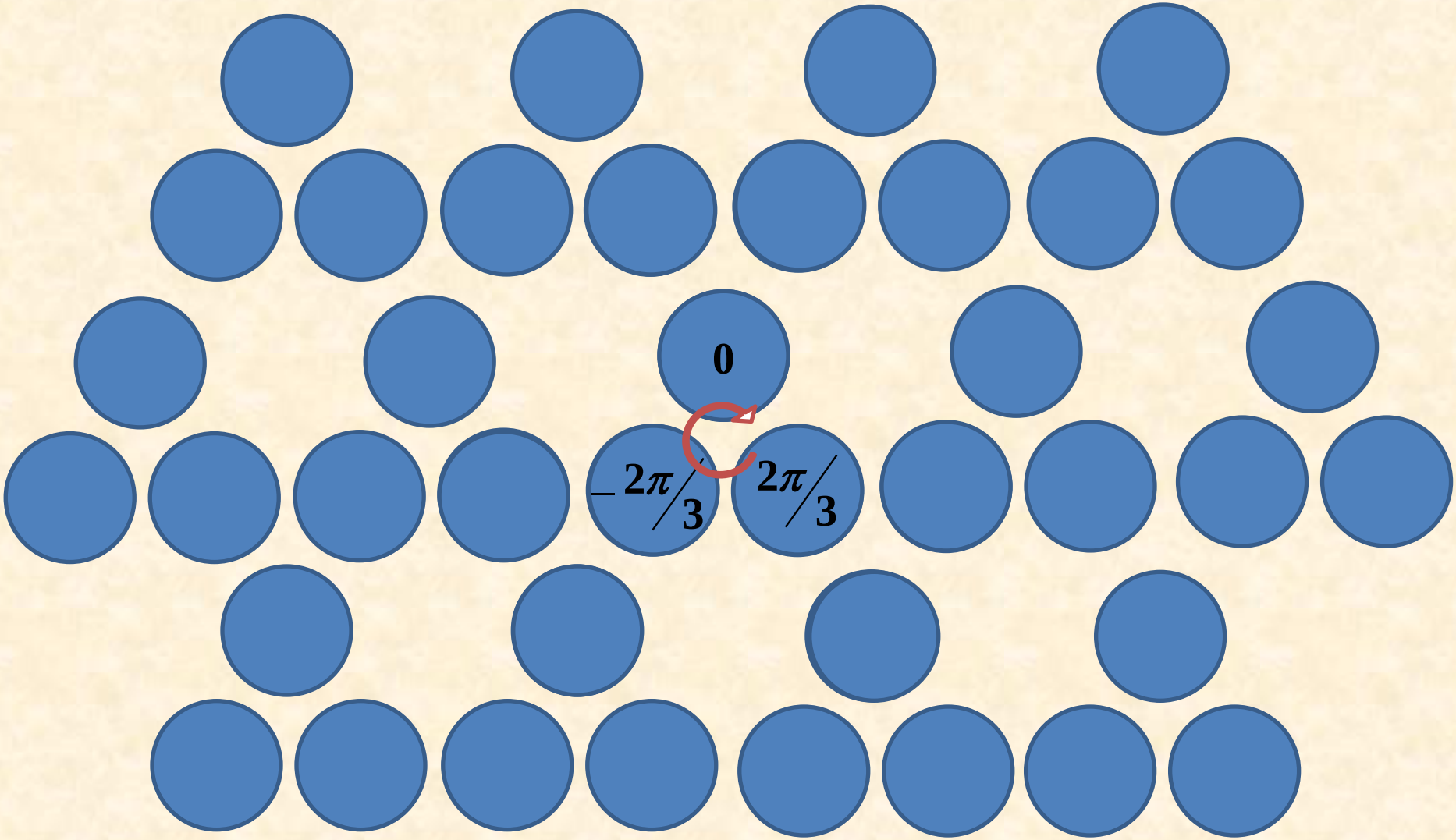
Near Field



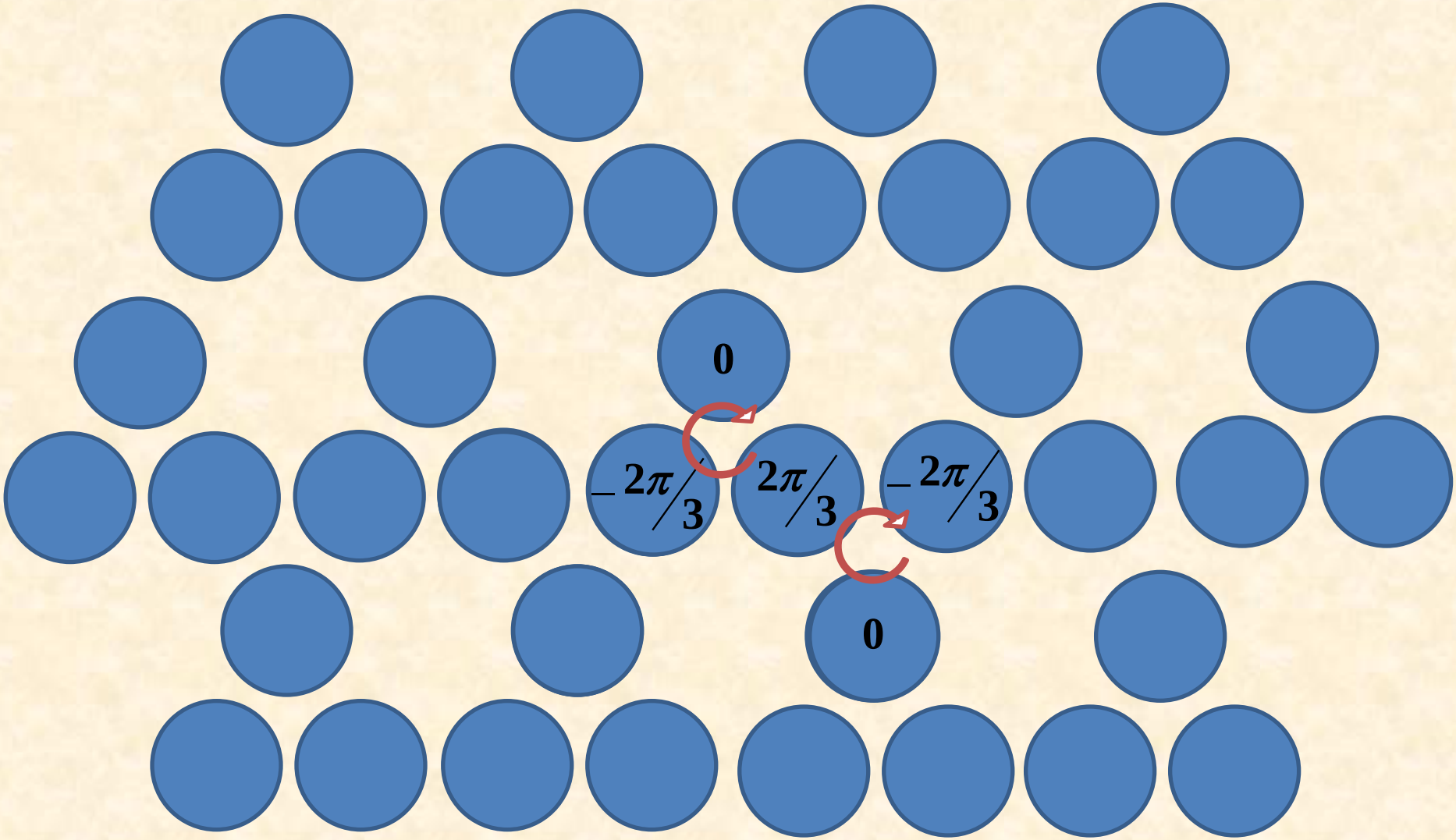
Far Field



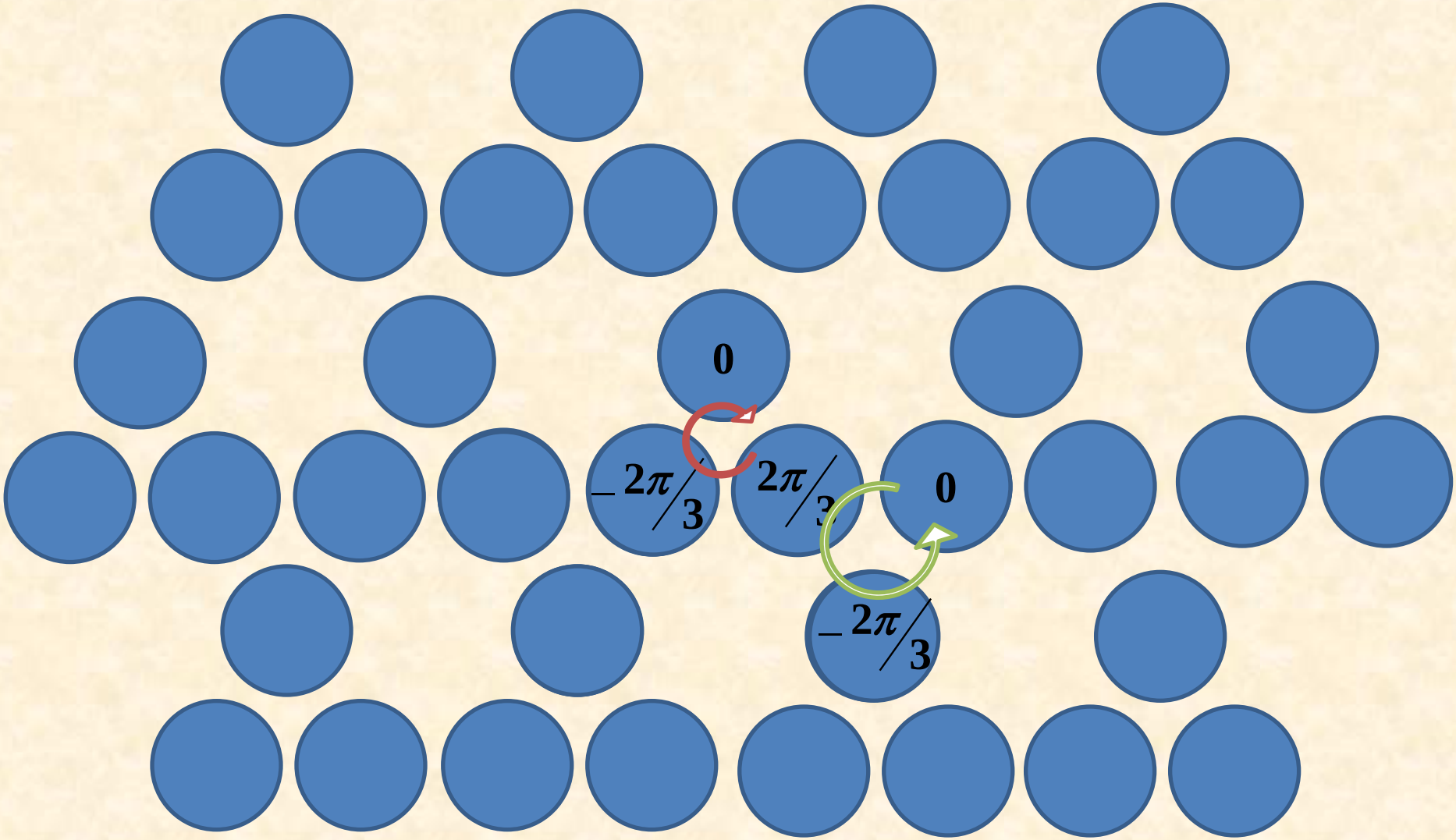
Kagome Array



Kagome Array

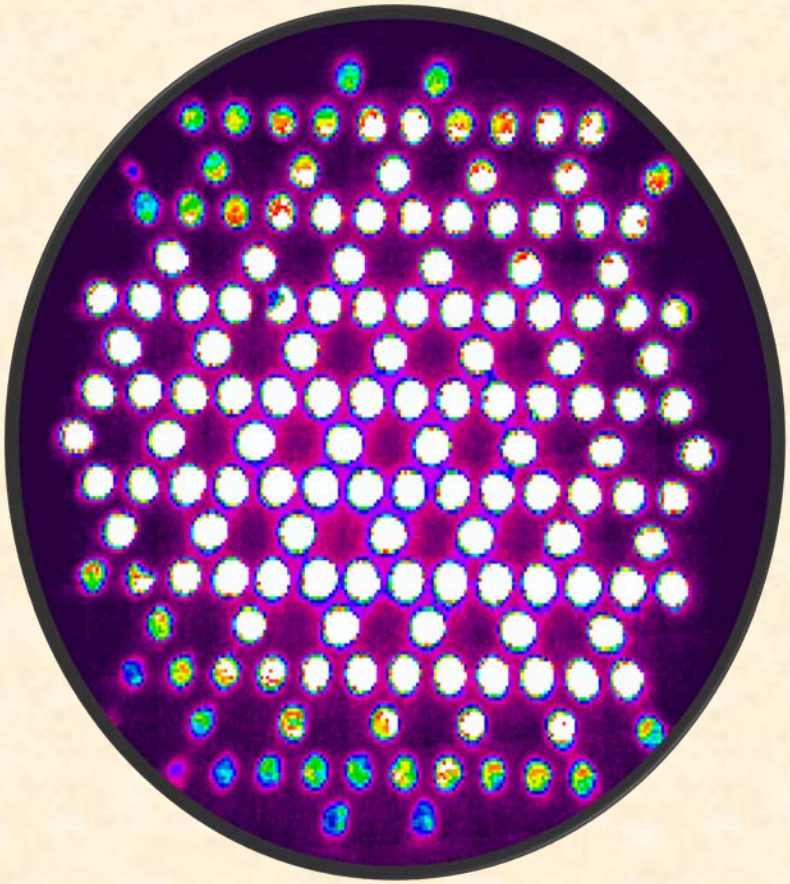


Kagome Array

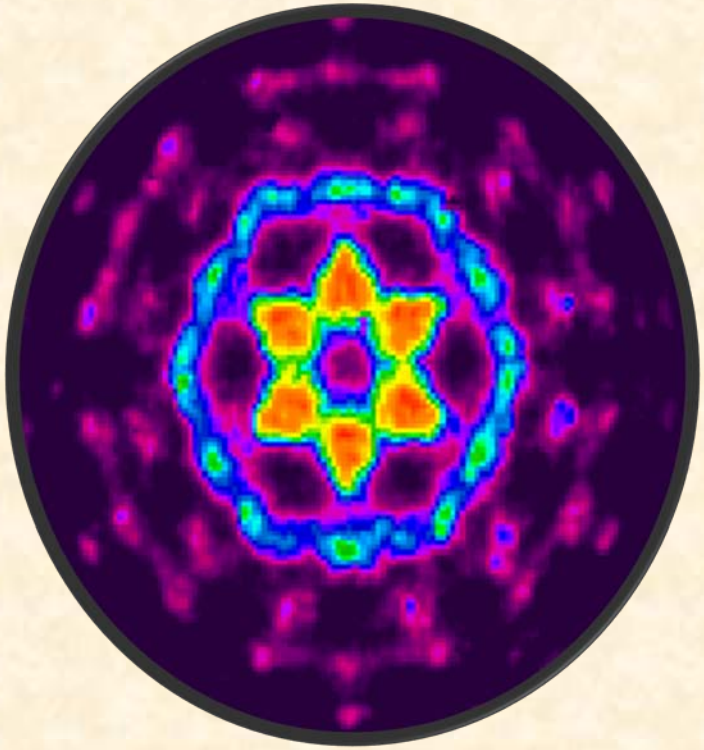


Kagome Array

Near Field

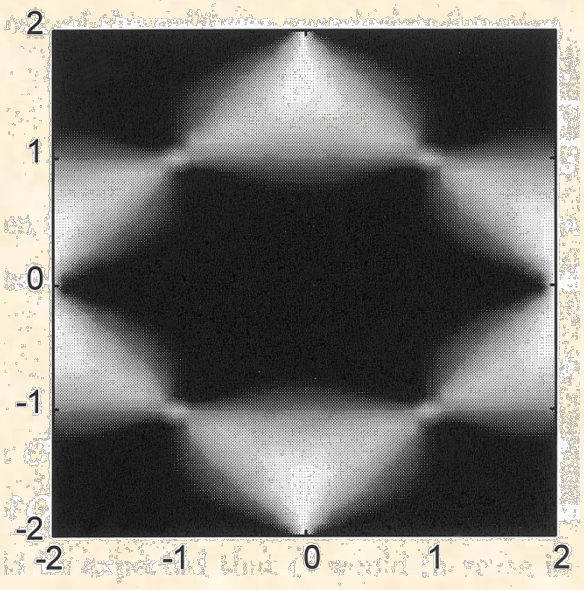


Far Field

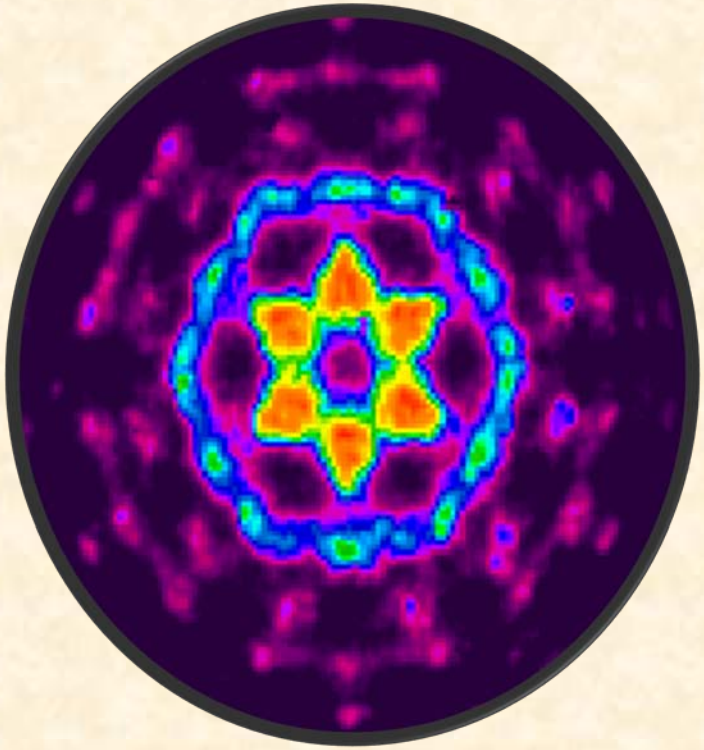


Kagome Array

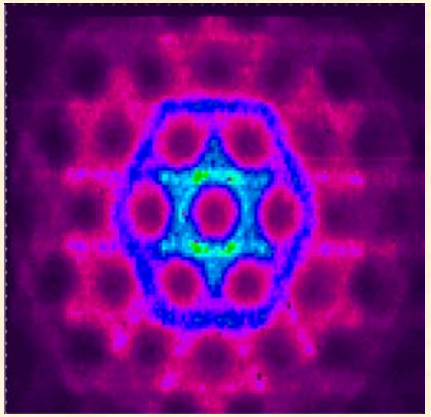
Moessner and Chalker *"Low-temperature properties of classical geometrically frustrated antiferromagnets"*, *Phys. Rev.* B **58** 12049 (1998)



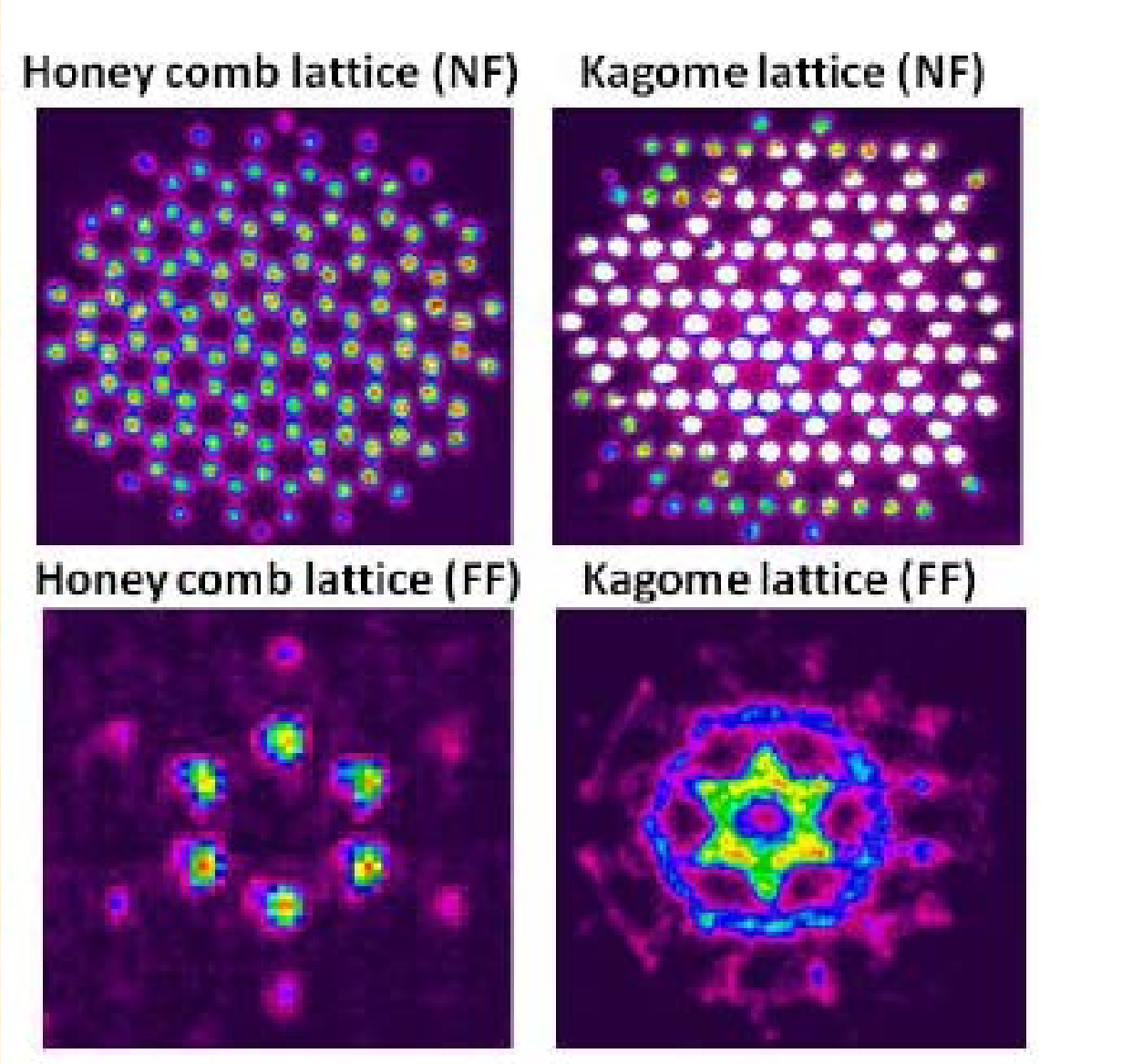
Far Field



Kagome lattice
with >1000 lasers



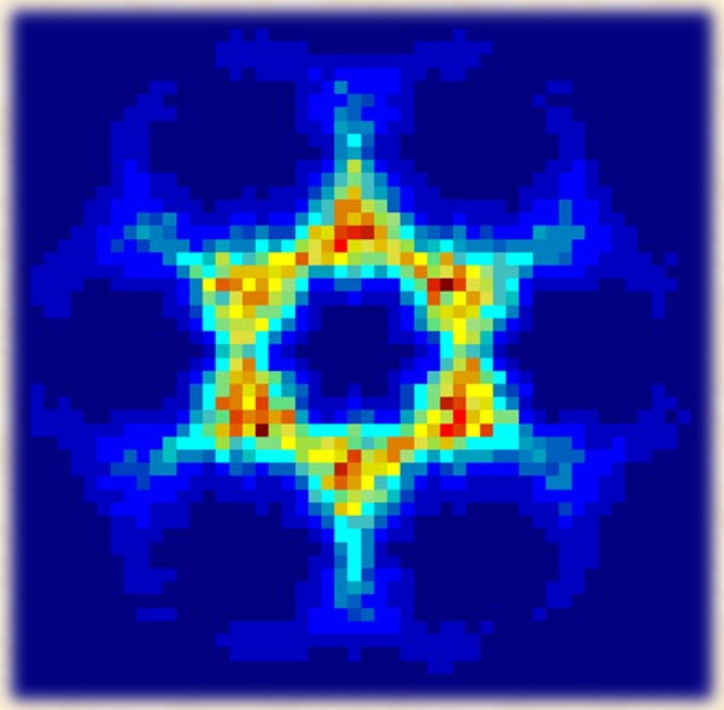
Honeycomb vs Kagome



Numerical Models

- Laser rate equations

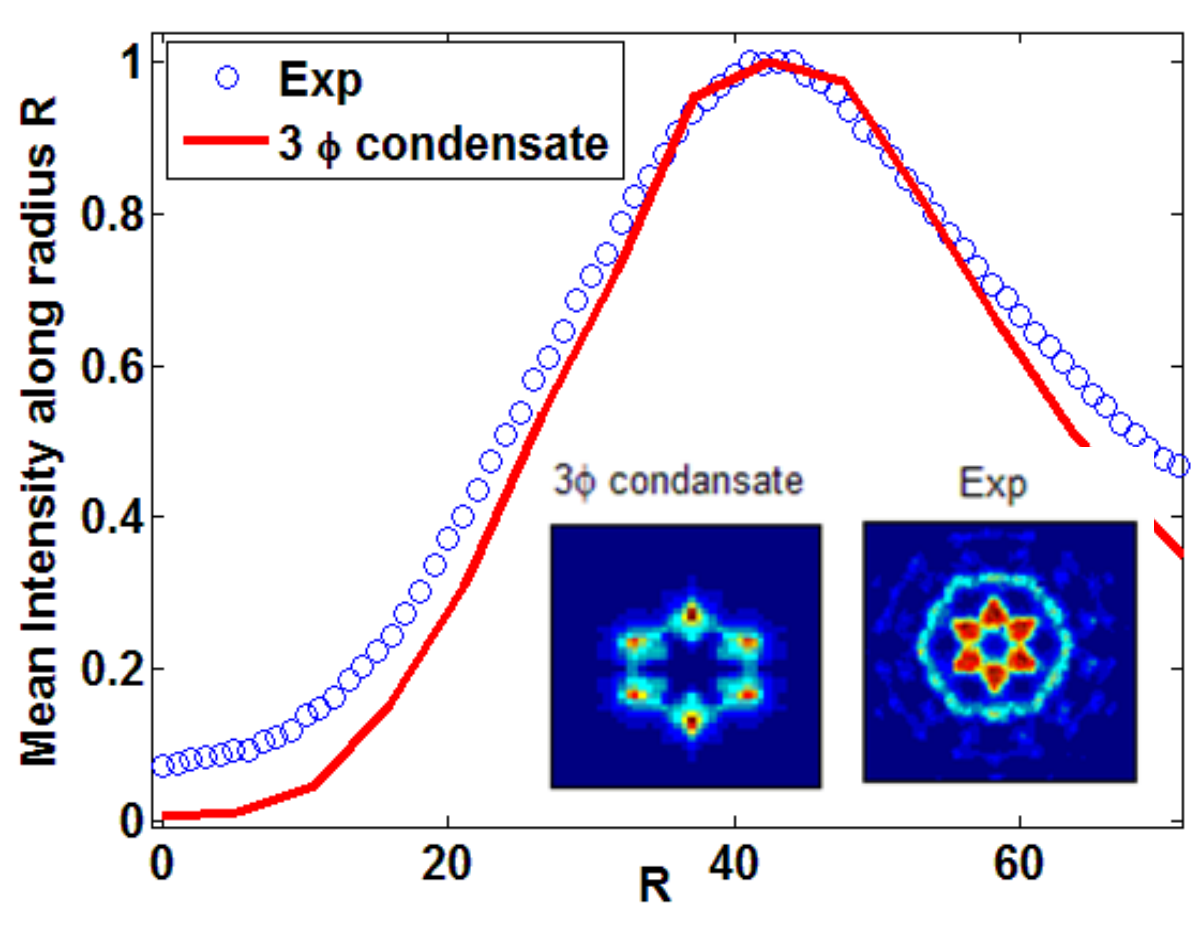
$$\frac{d\varphi_i}{dt} = \kappa \sum_{j=nn\{i\}} \sin(\varphi_j - \varphi_i)$$



- Lee-Fox iterations to find cavity lowest mode

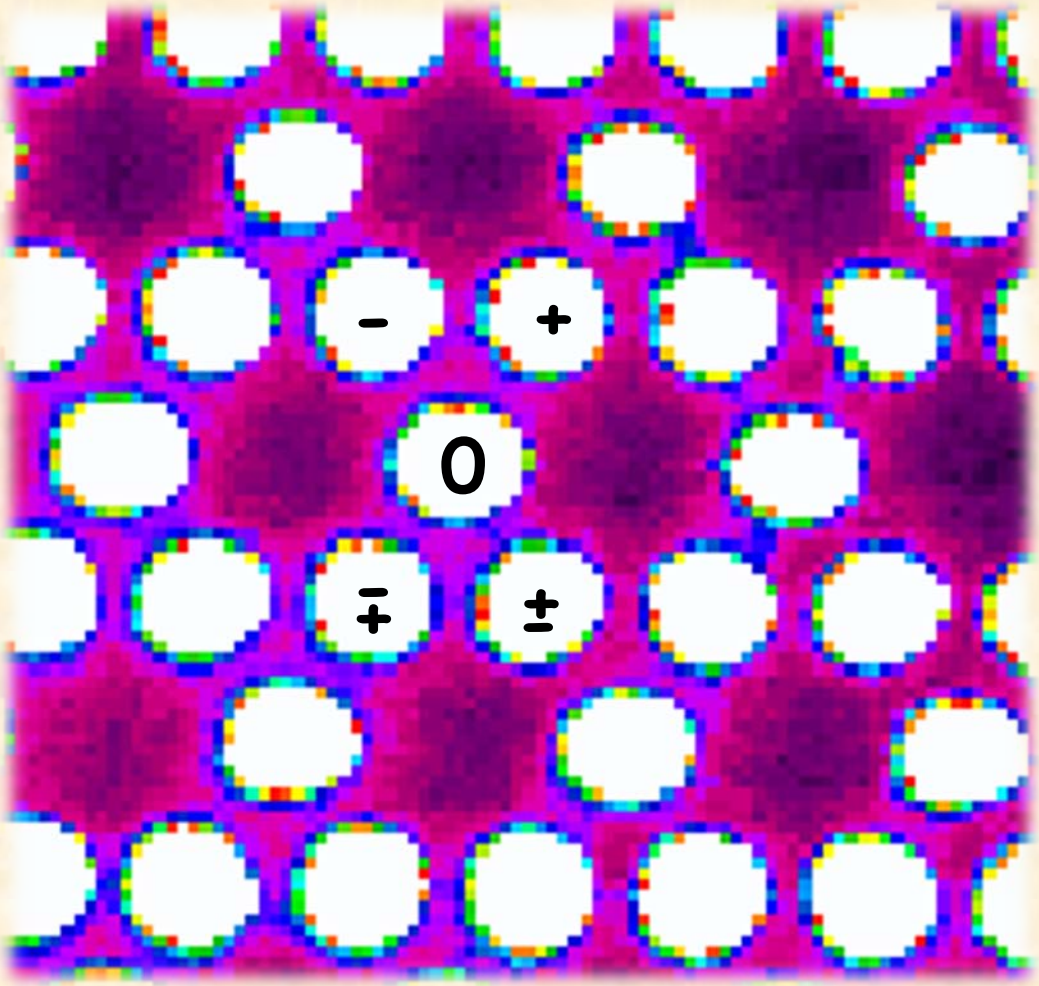
- Minimizing XY Hamiltonian with MC simulation

Is this a 3φ "condensate" ?

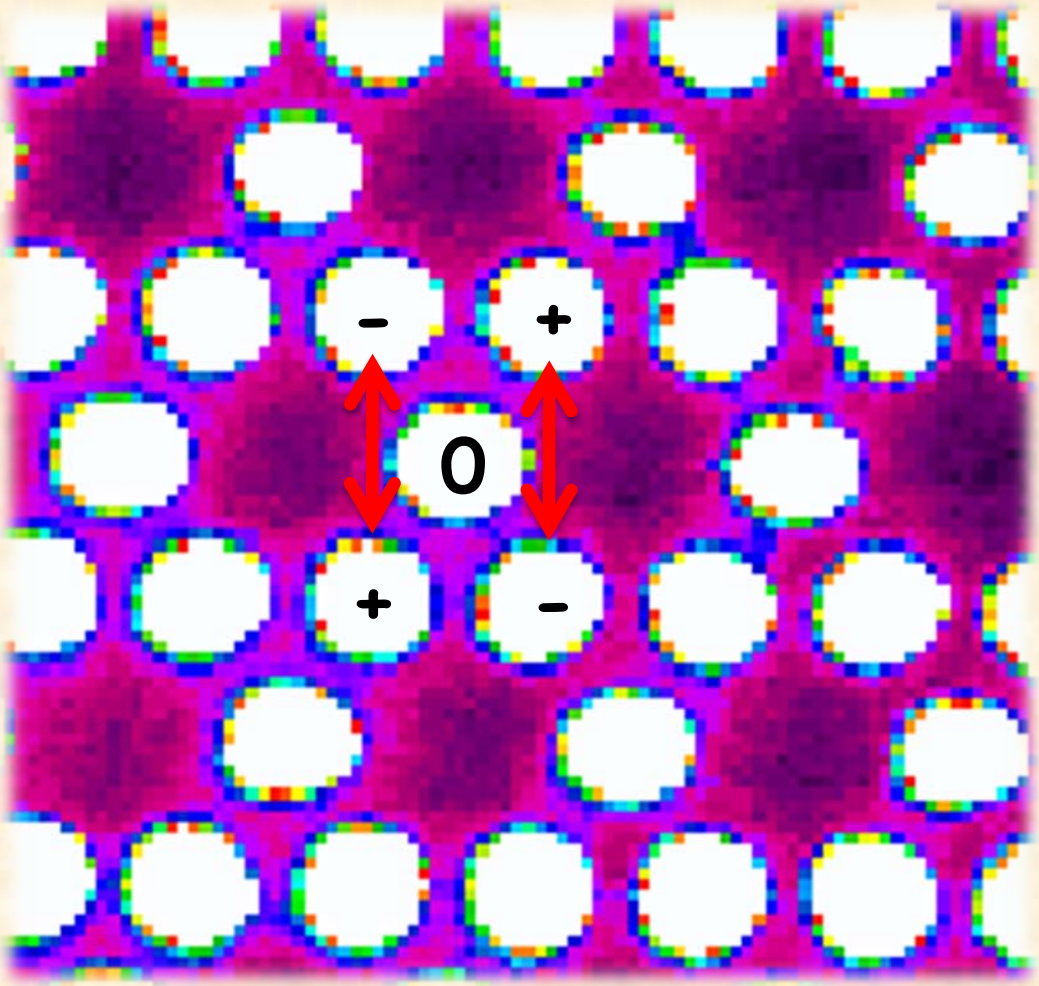


Simulations: averaged over many realizations of 3Φ condensate g.s. using MC simulations for minimizing the energy of the spins.

Kagome Array with Next Nearest Neighbor Coupling



Kagome Array with Next Nearest Neighbor Coupling

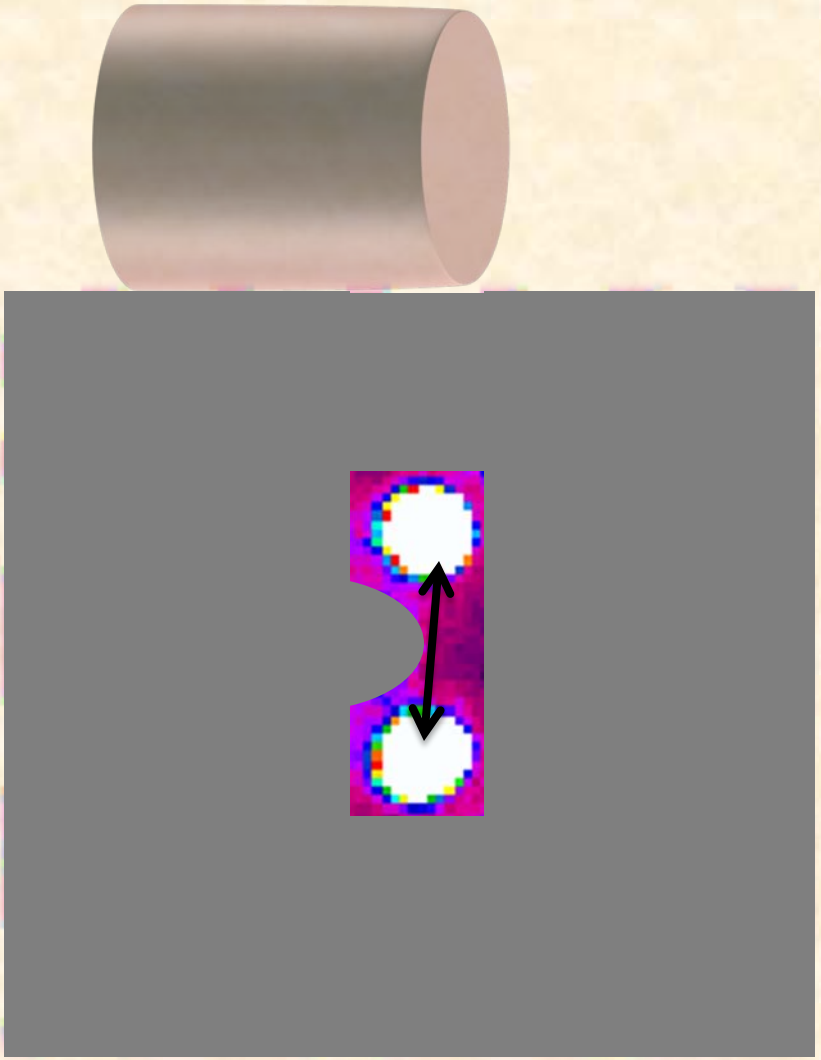


Output coupler (R=80%)

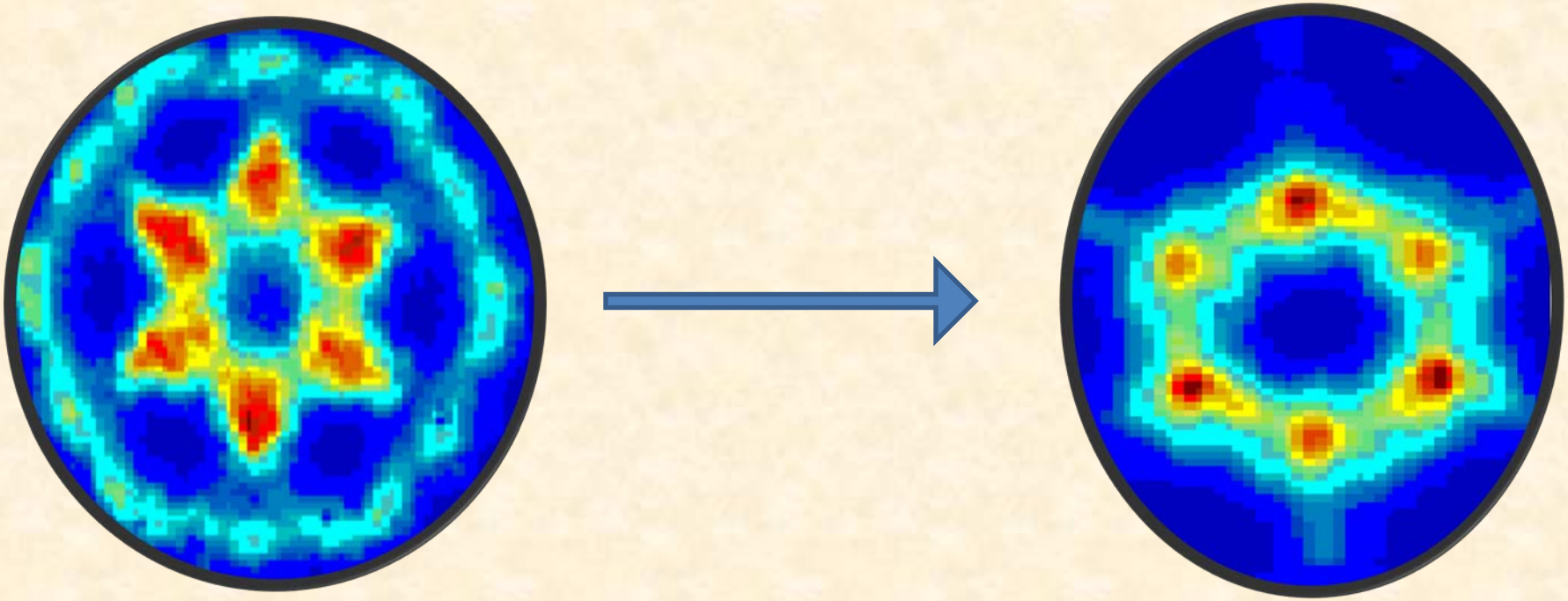
Mask

D

GAIN

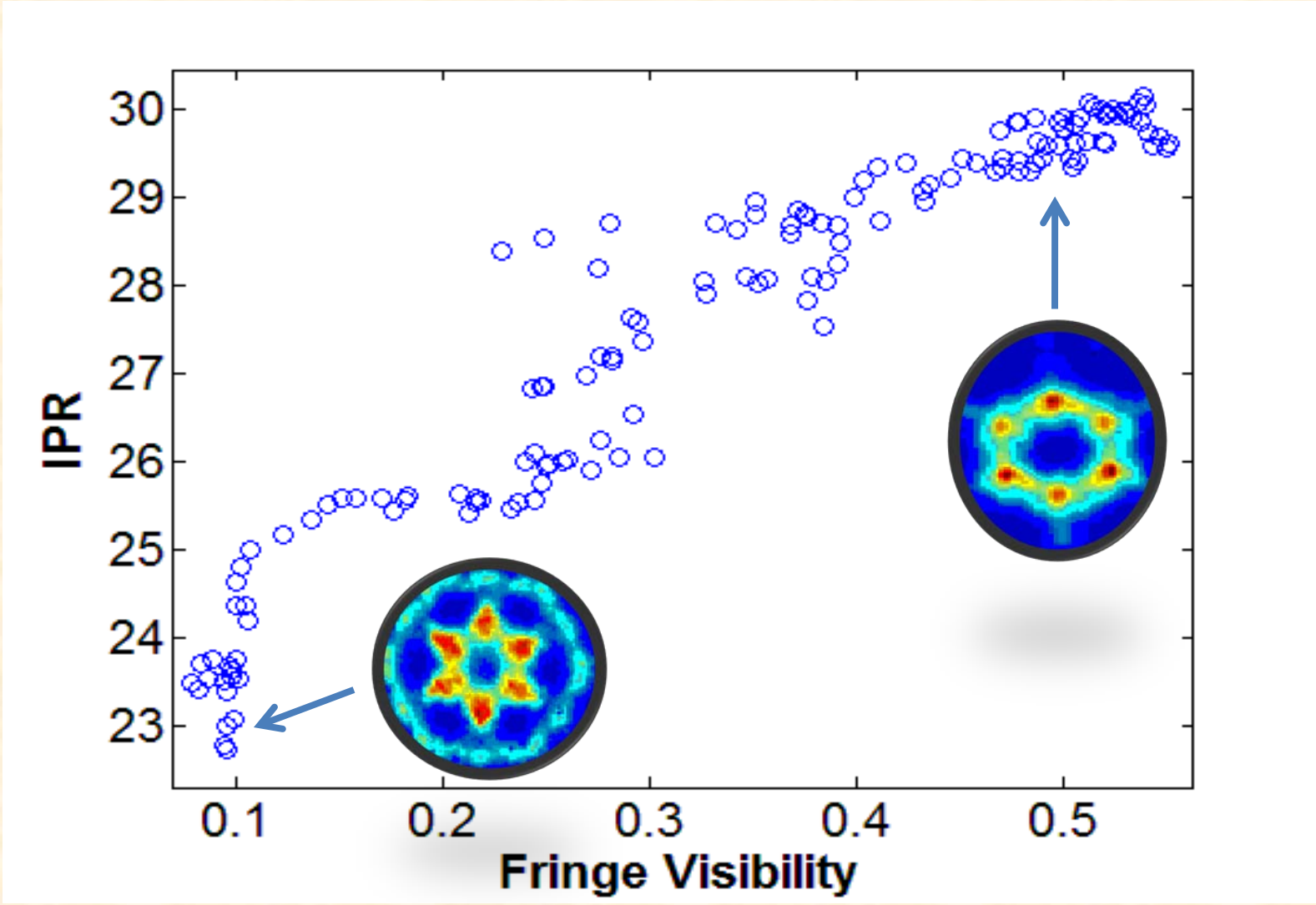


Kagome Array with Next Nearest Neighbor Coupling

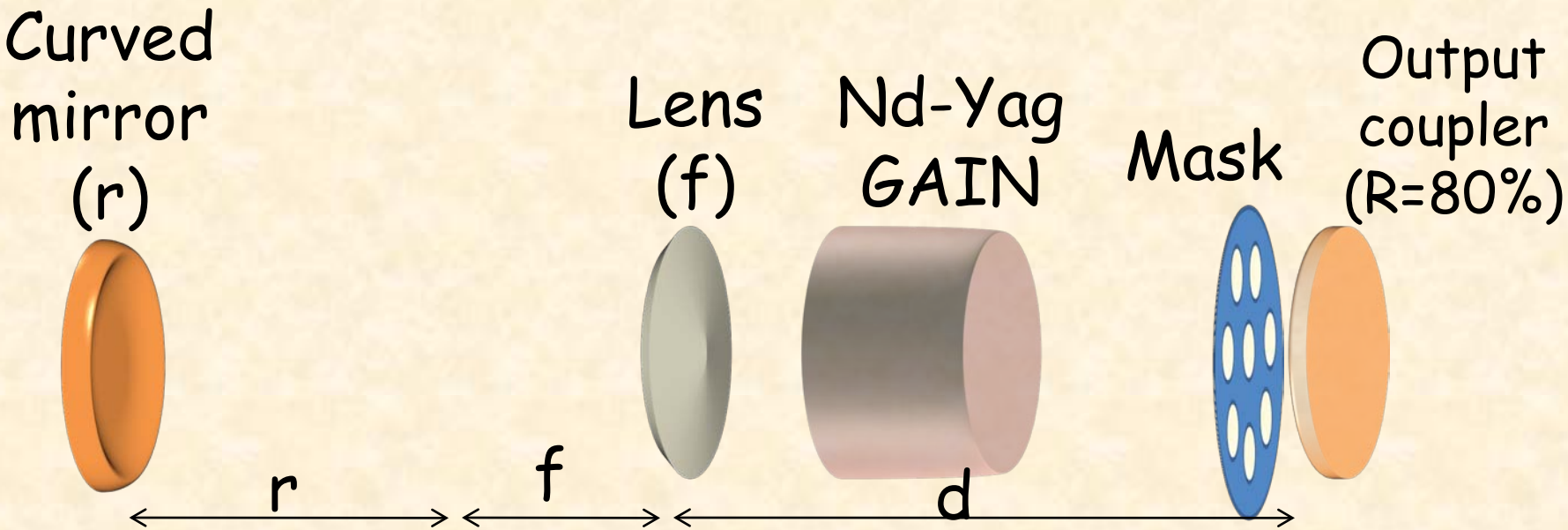


$$IPR = \frac{\langle I(x,y)^2 \rangle}{\langle I(x,y) \rangle^2}$$

Kagome Array with Next Nearest Neighbor Coupling



Degenerate cavity



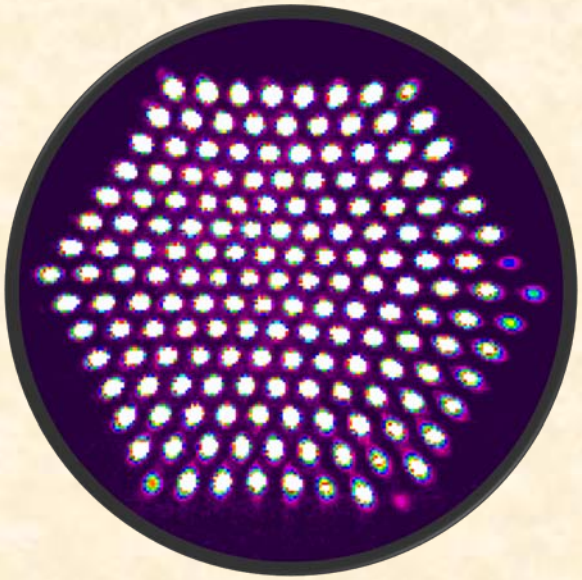
$$\mathcal{F}\{E\}e^{i\varphi} \leftarrow E(x,y)$$

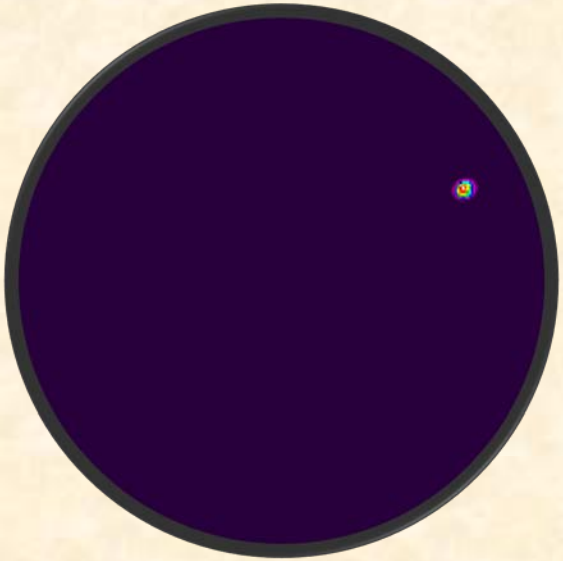
$$\mathcal{F}\{E\}e^{i\varphi+i\psi} \rightarrow E(x,y)$$

$$d = f \cdot (1 + f / r)$$

No phase locking

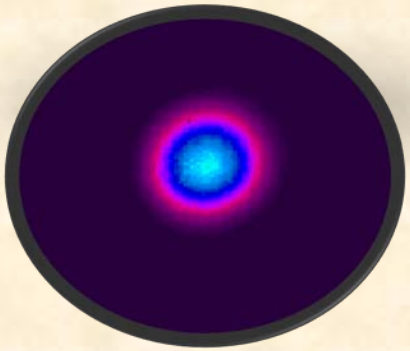
Near field of 169 lasers



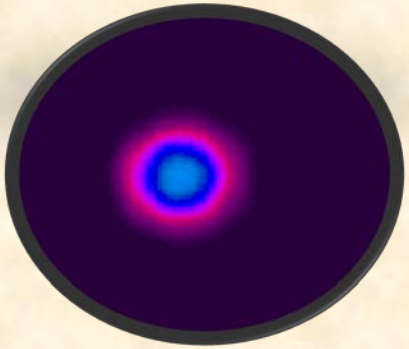


Near field of 1 laser

Far field of 169 lasers

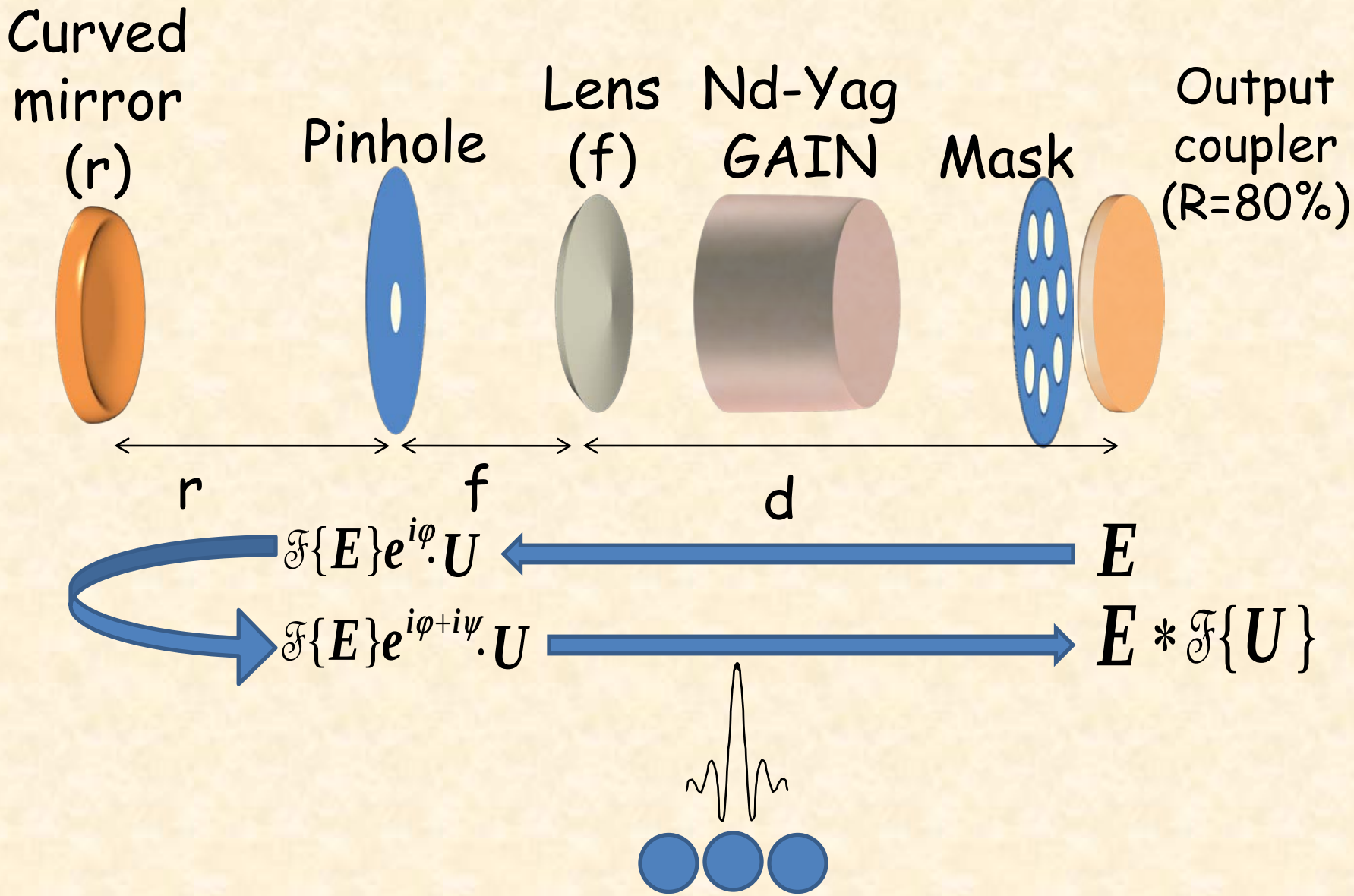


Overlapping crossections

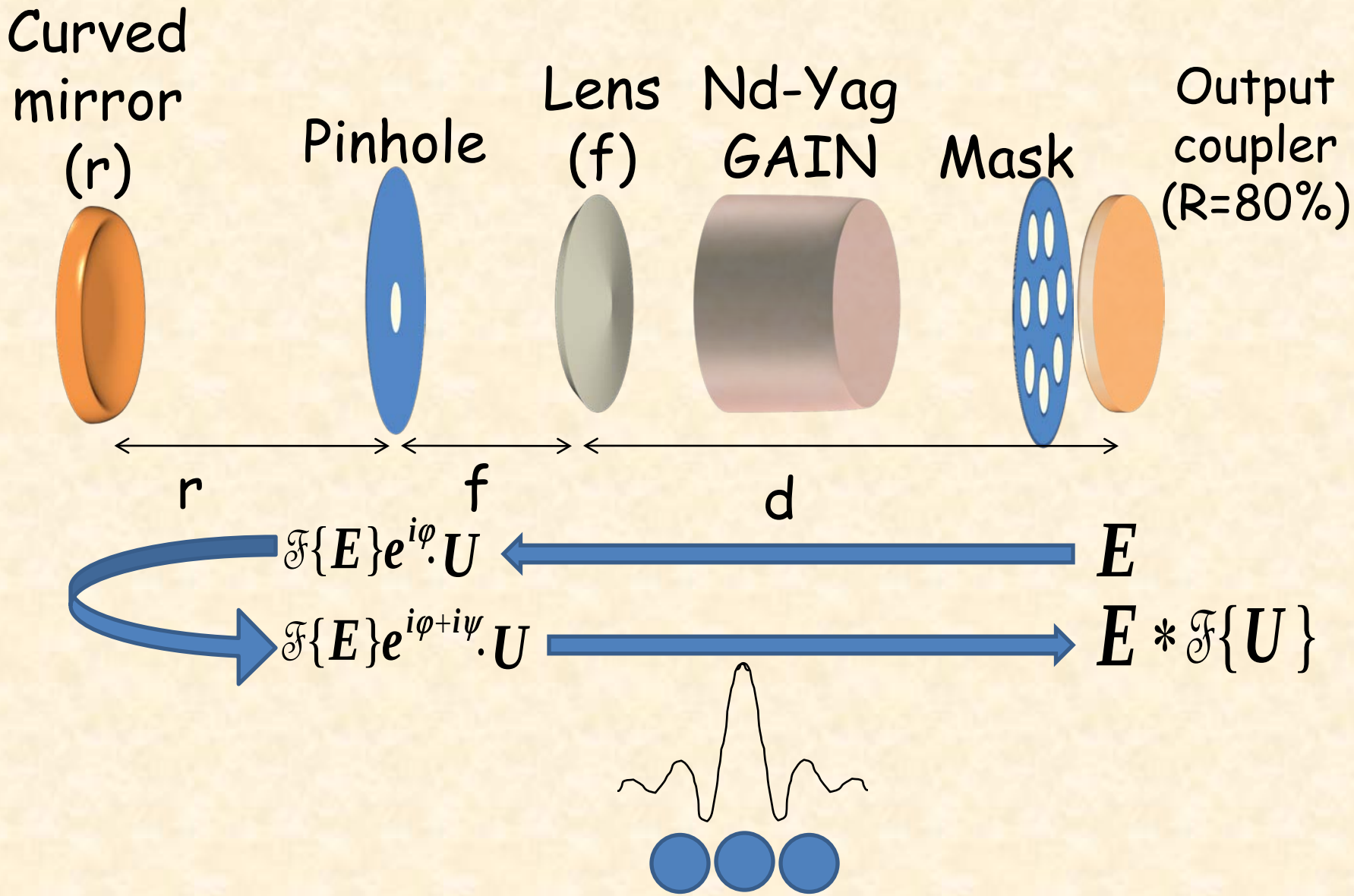


Far field of 1 laser

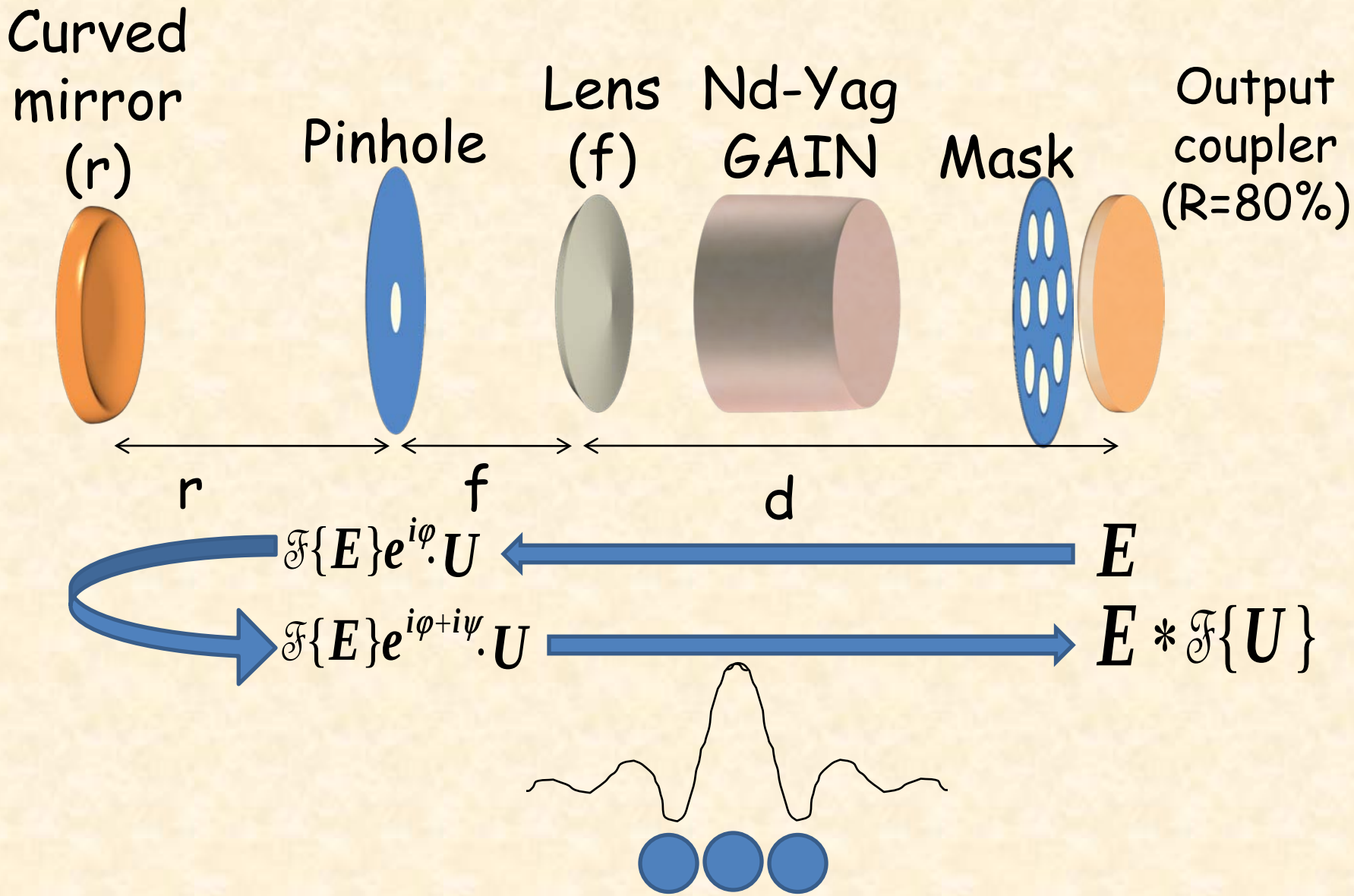
Degenerate cavity

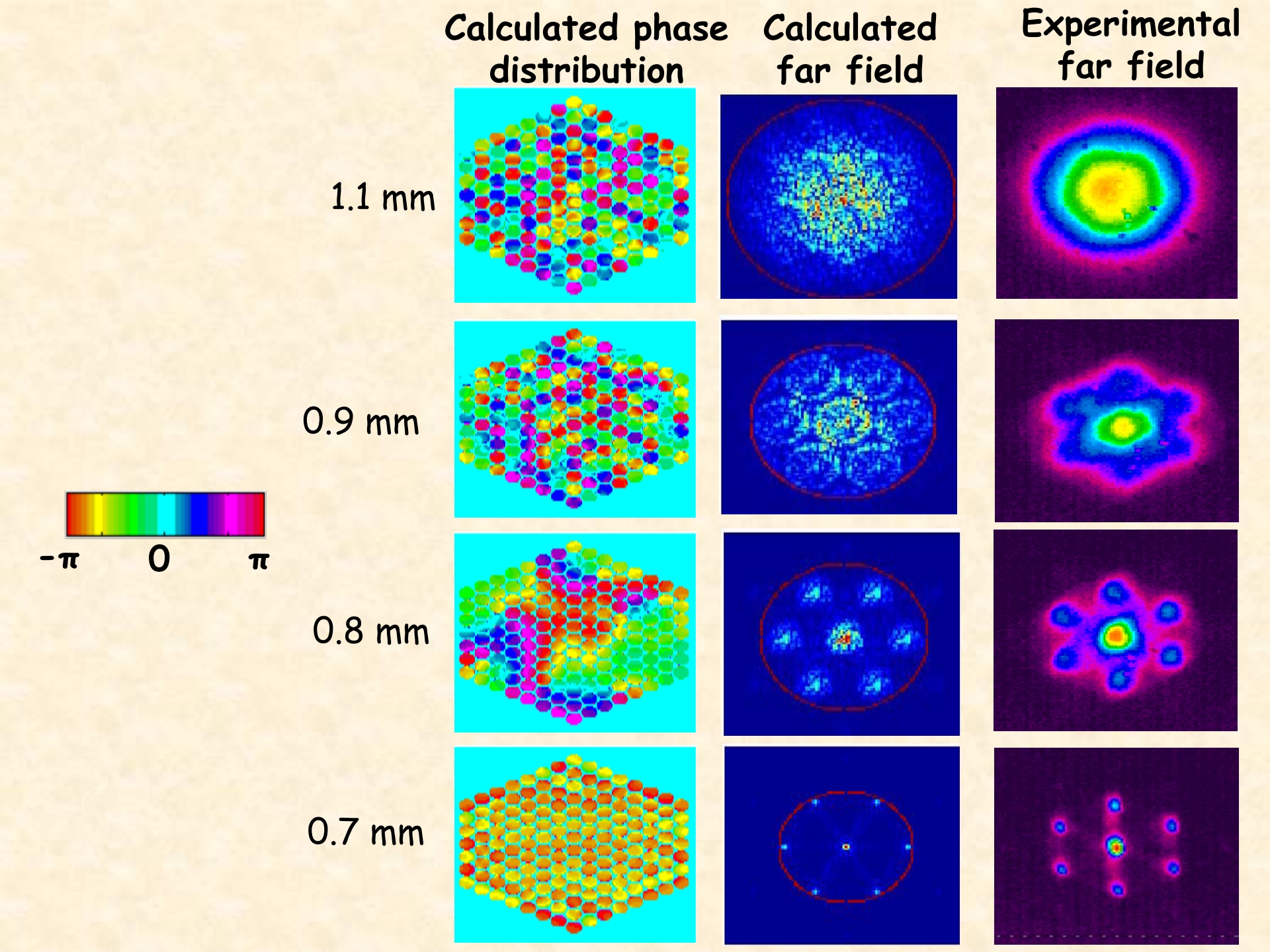


Degenerate cavity

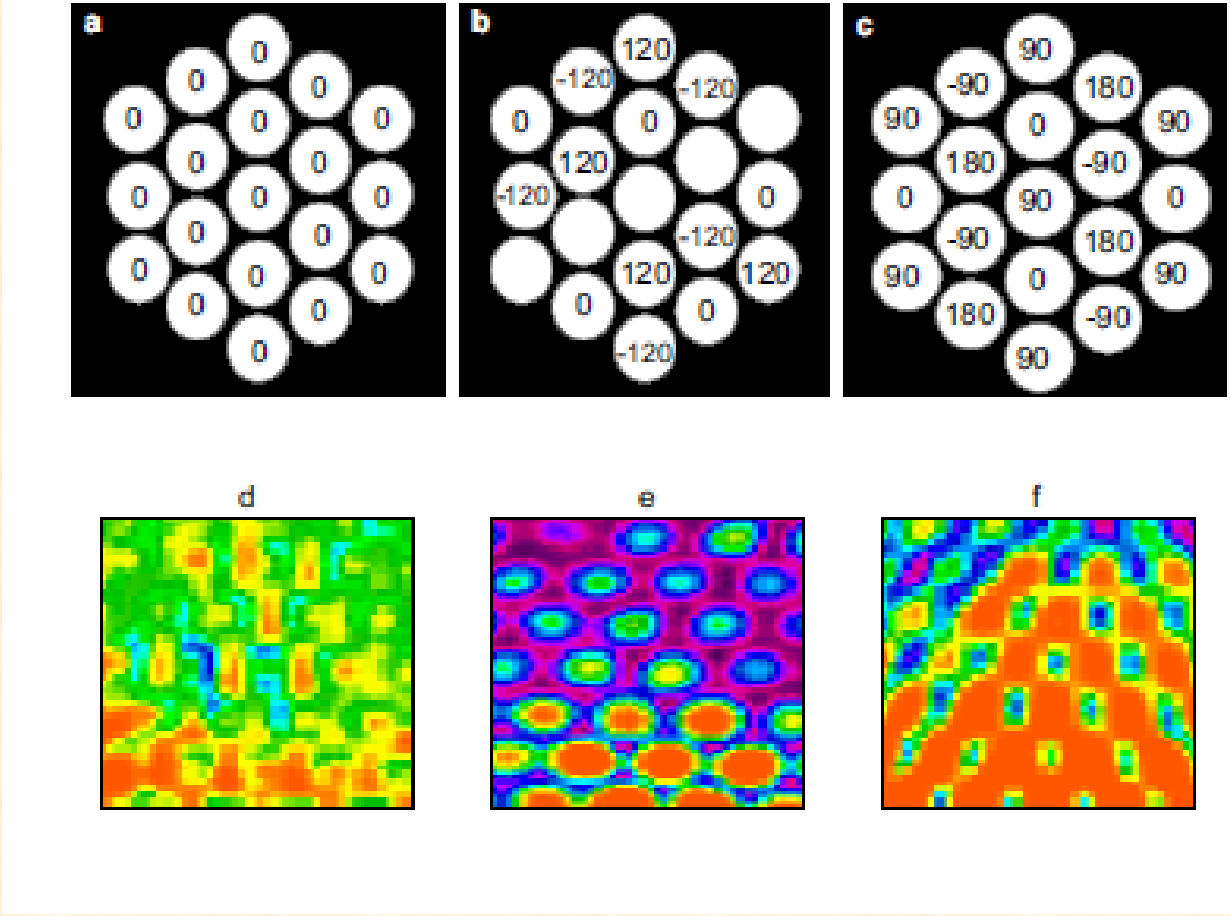


Degenerate cavity



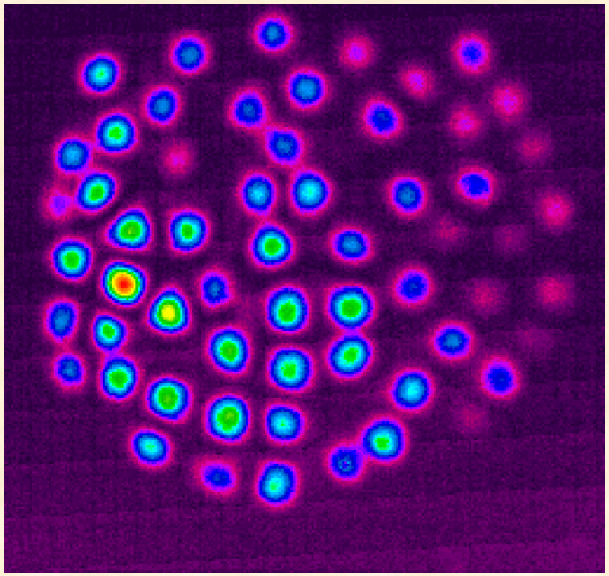

Calculated phase distribution
Calculated far field
Experimental far field
1.1 mm
0.9 mm
0.8 mm
0.7 mm
-π
0
π

Verifying phase structures in “mid field” diffraction

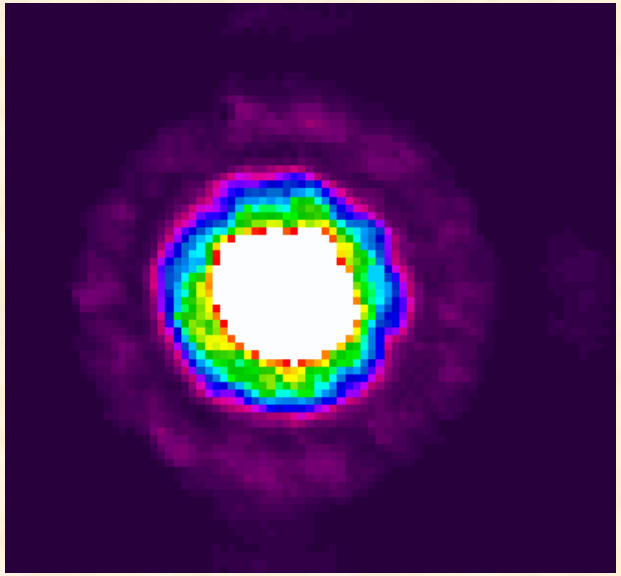


Phase locking of random array

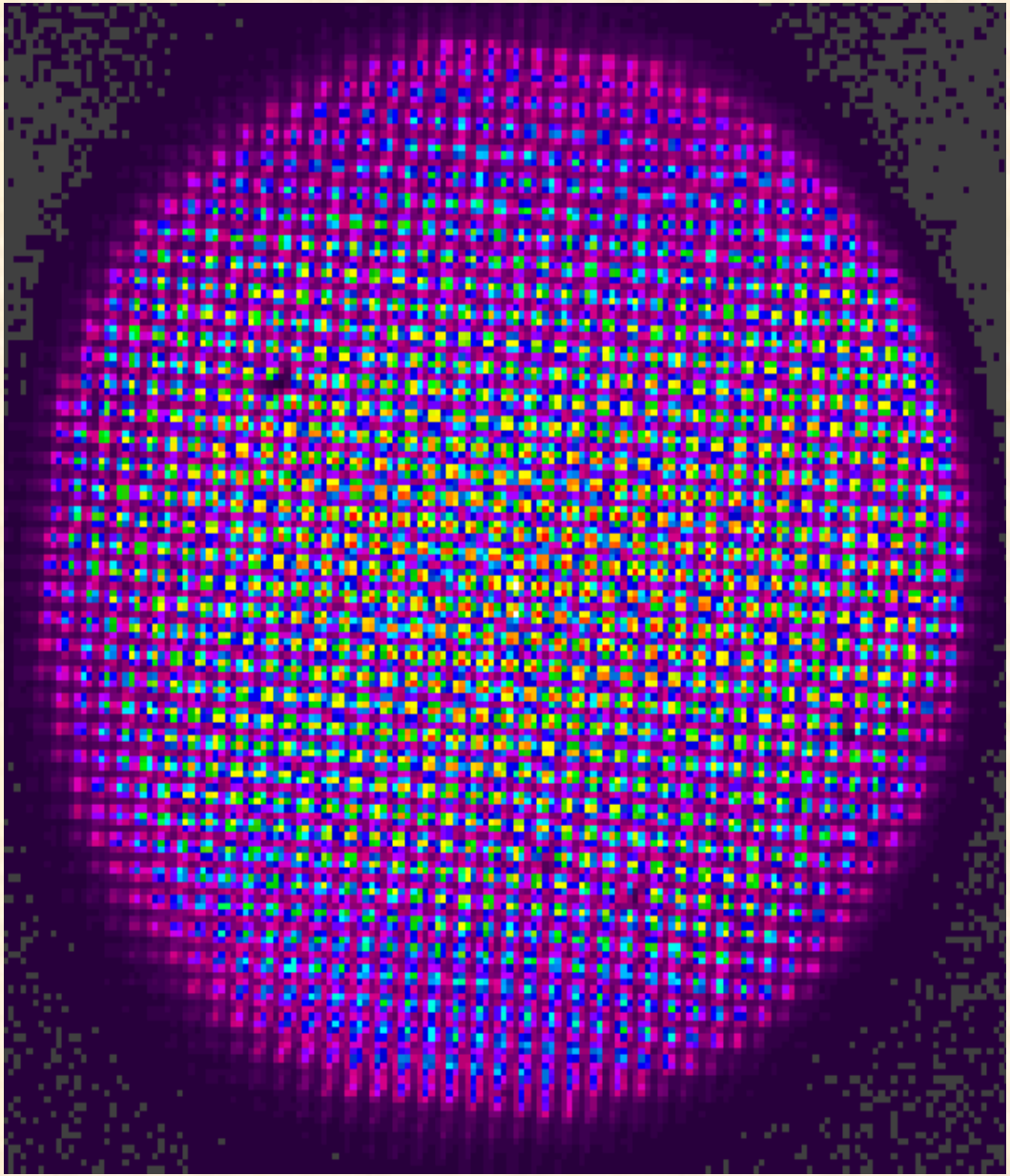
Near field



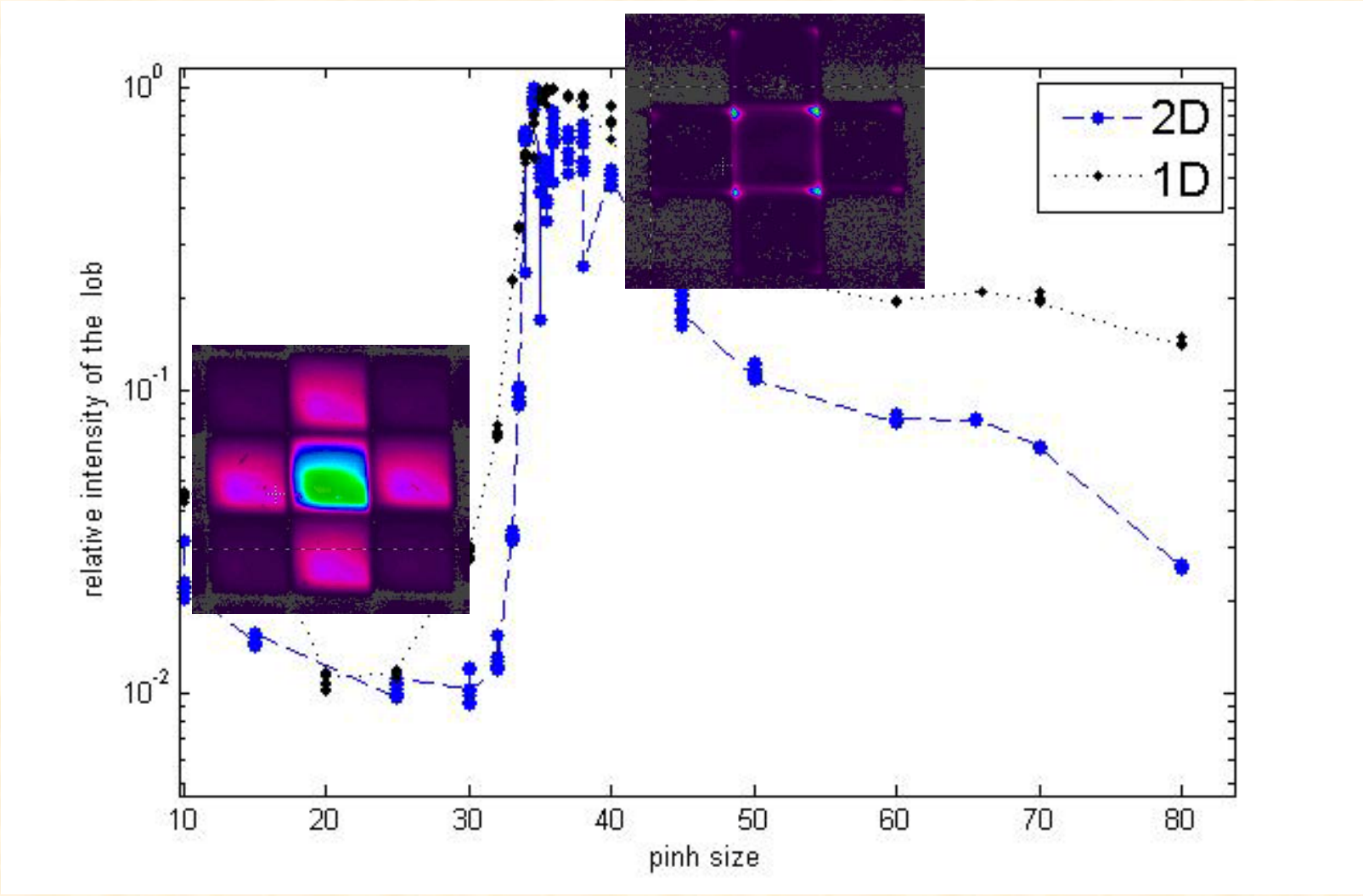
Far field



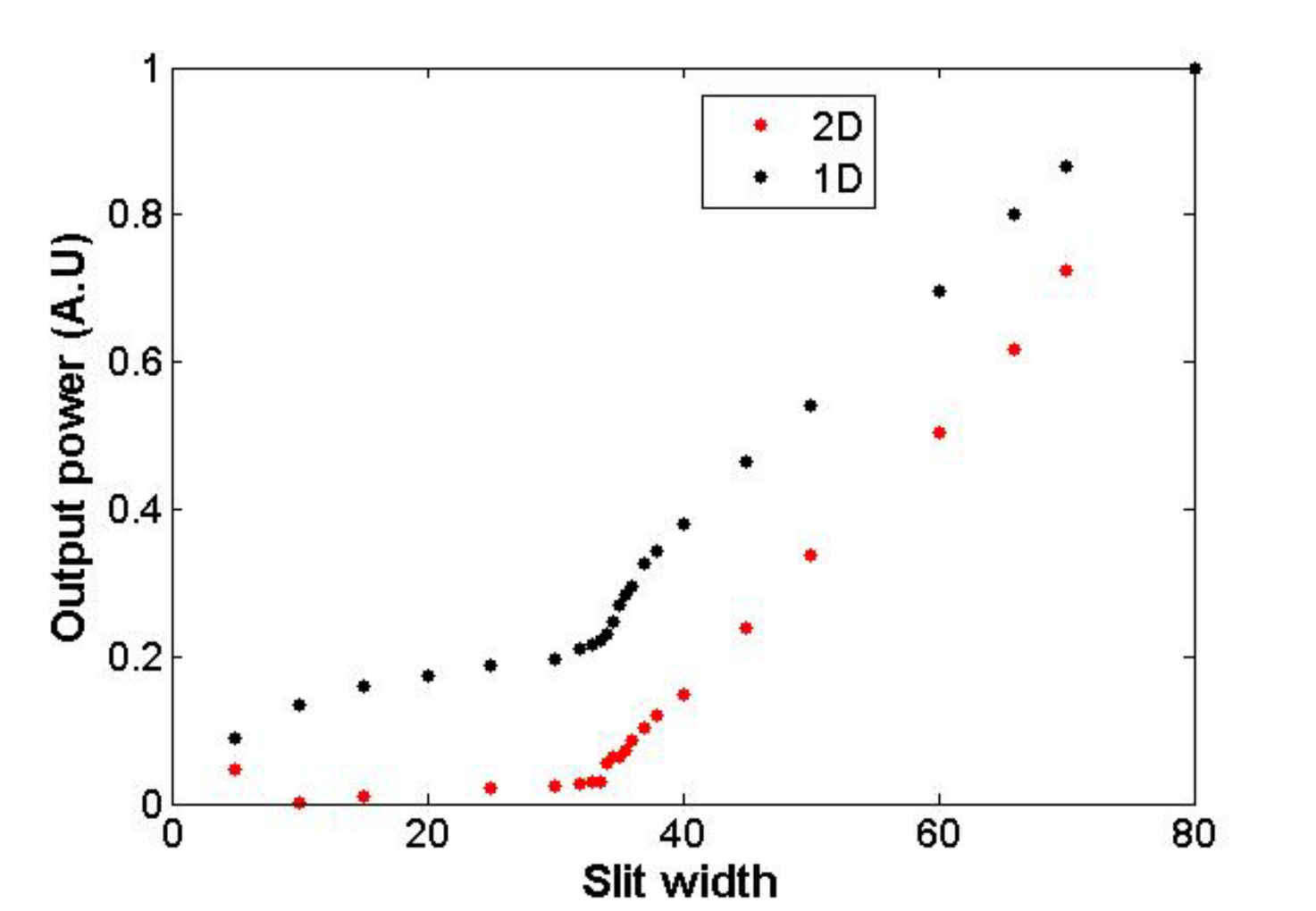
Very large square arrays



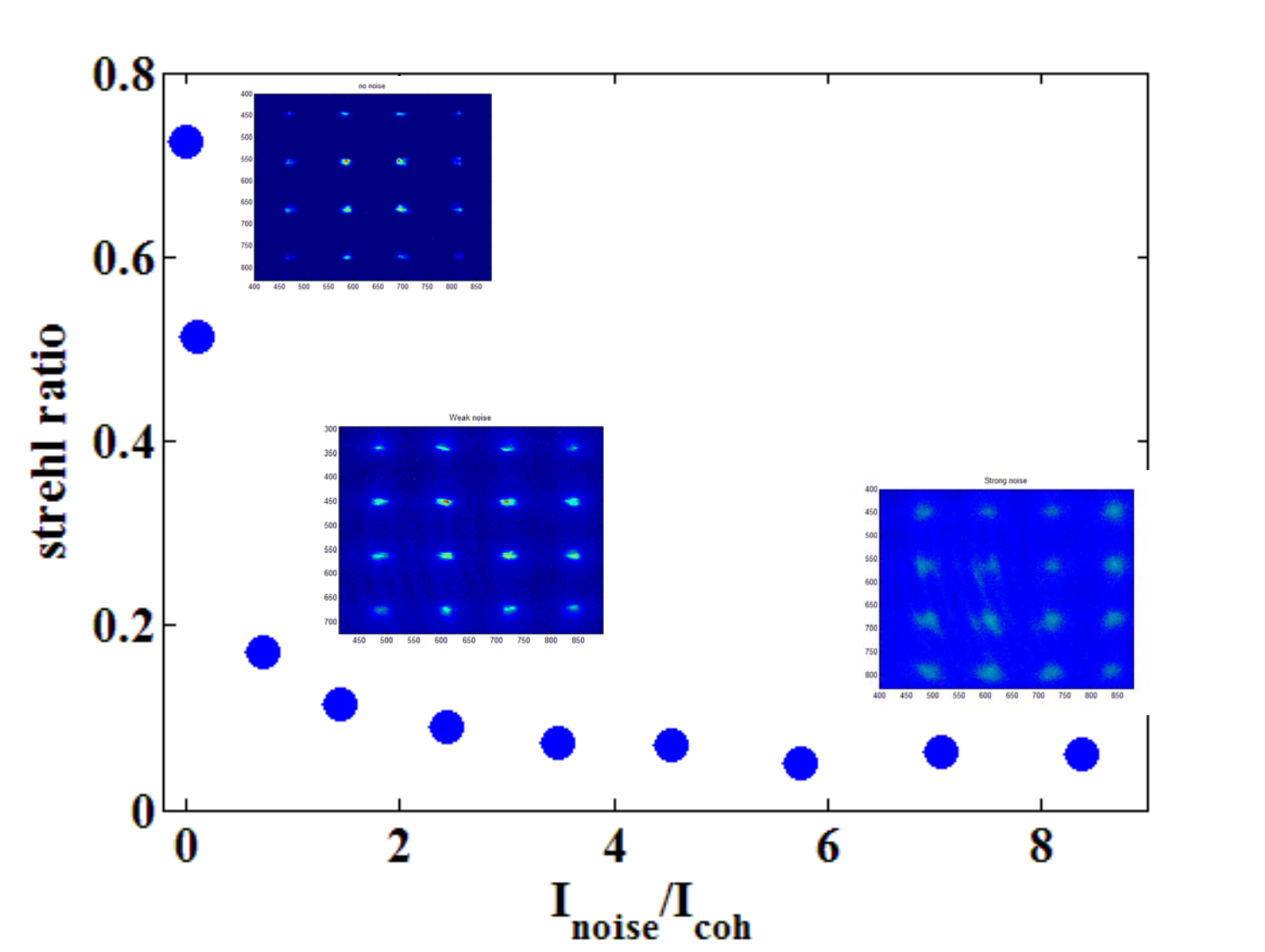
Sharp “phase transition”



“kink” in output power



Effects of finite “temperature” in square array



Very large 1d arrays