Bosonic Lattice Double Ring Under A Gauge Field

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With
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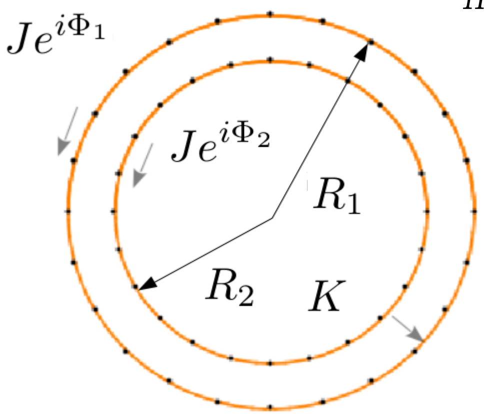
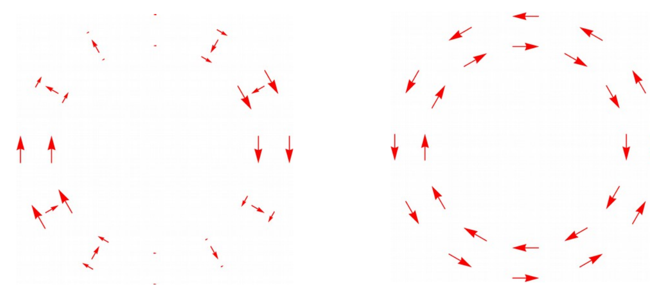


$$\hat{H} = -\sum_{l=1,p=1,2}^{N_s} J_p \left(a_{l,p}^{\dagger} a_{l+1,p} e^{i\Phi_p} + a_{l+1,p}^{\dagger} a_{l,p} e^{-i\Phi_p} \right) - K \sum_{l=1}^{N_s} \left(a_{l,1}^{\dagger} a_{l,2} + a_{l,2}^{\dagger} a_{l,1} \right) + \frac{U}{2} \sum_{l=1,p=1,2}^{N_s} a_{l,p}^{\dagger} a_{l,p}^{\dagger} a_{l,p} a_{l,p}$$

$U = 0$ Two phases : Meissner and Vortex



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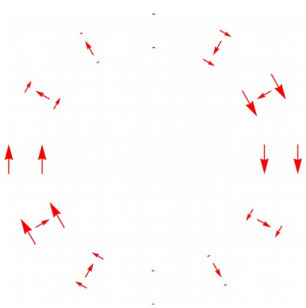
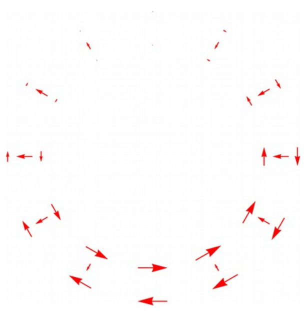
Finite size effect

$$\Phi = \frac{\Phi_1 + \Phi_2}{2}$$

Number of vortices depends on the parity of the mean flux Φ

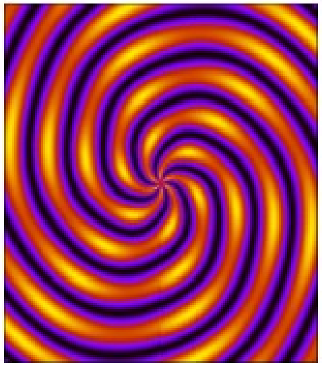


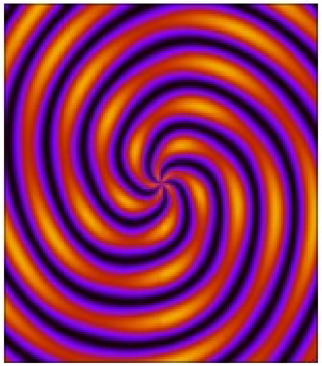


Φ Even

Φ Odd

Experimental way of seeing vortices

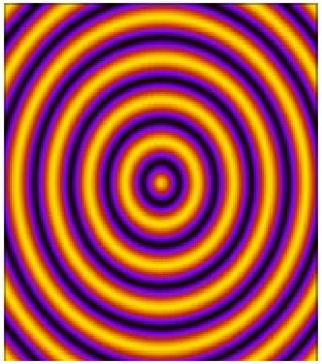




Vortex phase

Φ Even

Φ Odd



Meissner phase

Mean field regime – New phases appear

Discrete coupled non linear Schrödinger equations

$$i\partial_t \Psi_{l,1}(t) = -J\Psi_{l+1,1}(t)e^{i(\Phi+\phi/2)} - J\Psi_{l-1,1}(t)e^{-i(\Phi+\phi/2)} - K\Psi_{l,2}(t) + U|\Psi_{l,1}(t)|^2\Psi_{l,1}(t)$$

$$i\partial_t \Psi_{l,2}(t) = -J\Psi_{l+1,2}(t)e^{i(\Phi-\phi/2)} - J\Psi_{l-1,2}(t)e^{-i(\Phi-\phi/2)} - K\Psi_{l,1}(t) + U|\Psi_{l,2}(t)|^2\Psi_{l,2}(t)$$

We see new phases that break $\mathbb{Z}_2$ and rotational symmetry of the system