Microscopic Insights into Superconducting Transition from Type I to Type II

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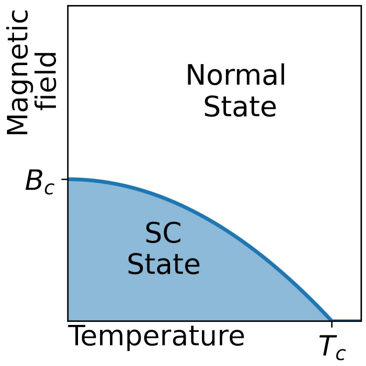
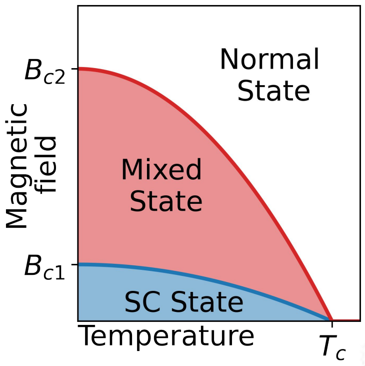
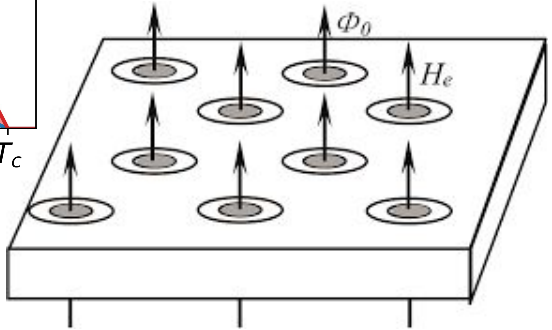
- Introduction
  - Type I-II
  - Superconductivity between type I and II

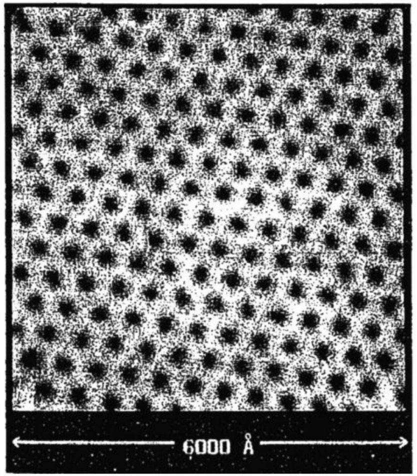
Type I and Type II superconductors

- Based on their magnetic properties, superconductors are divided into Type I and Type II superconductors
- A magnetic field penetrates into a type II superconductor in the form of vortices
- In Type II the vortices repel each other and form a triangular Abrikosov lattice









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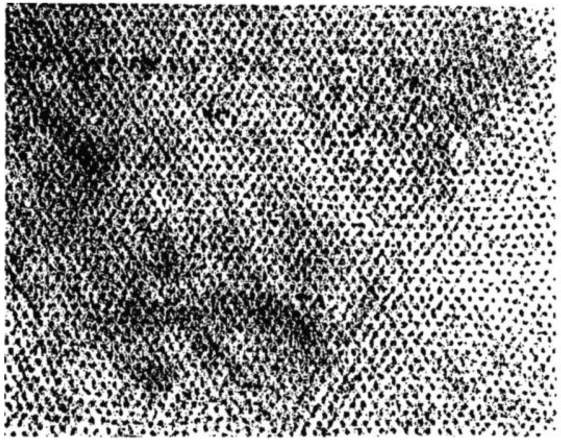
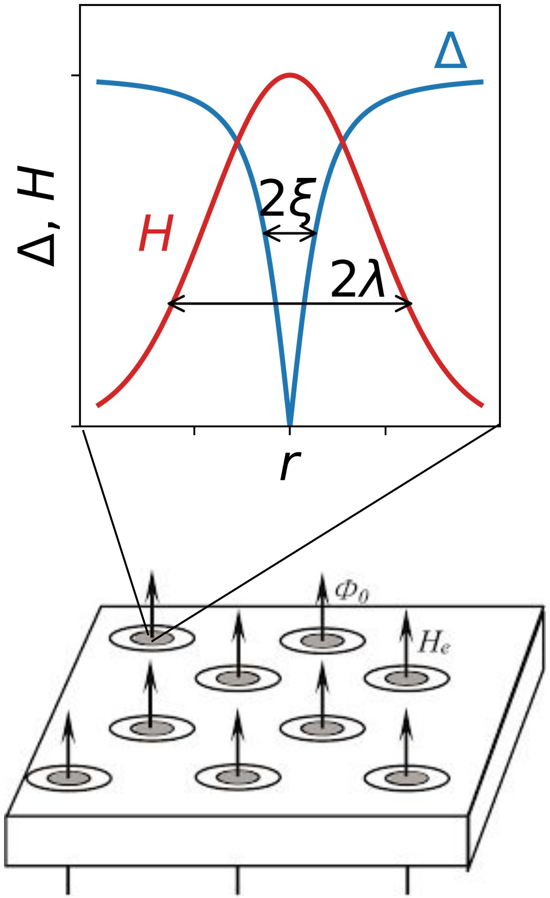
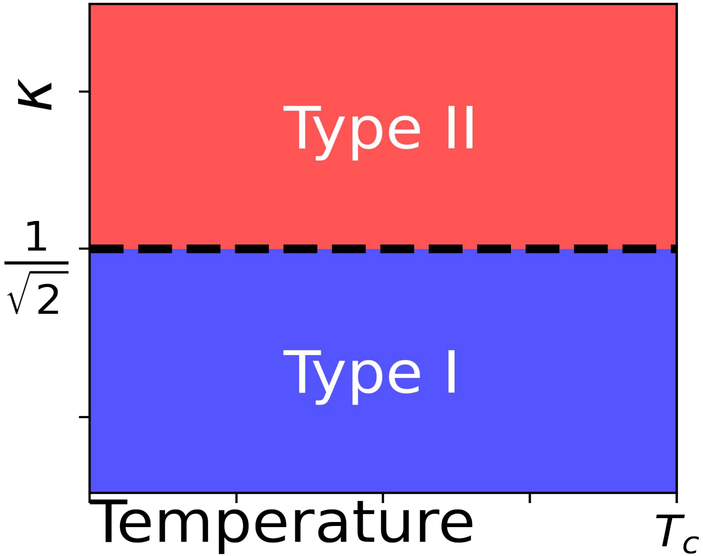




GL - parameter

$$\kappa = \lambda / \xi$$

GL - theory



GL-theory and *κ*-dependence

- GL theory predicts the existence of two types of superconductivity depending on the value of the GL parameter
- The standard GL theory is not able to describe the existence of an intertype regime between type I and type II superconductivity

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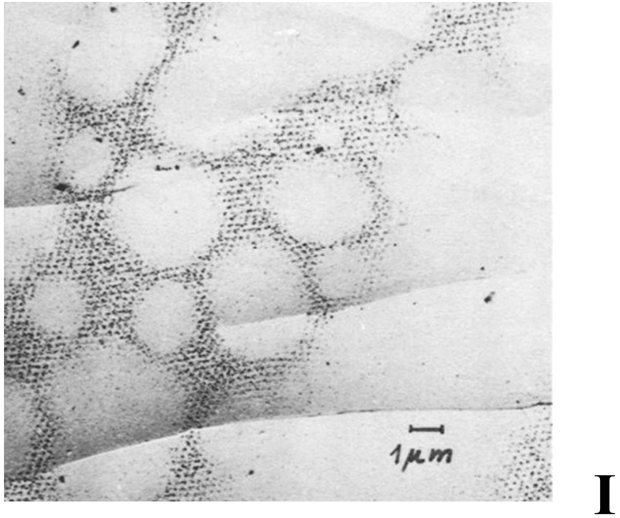

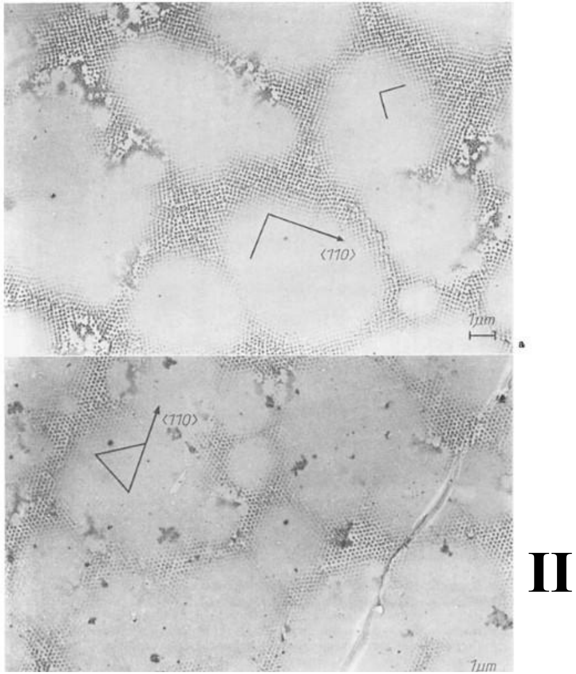

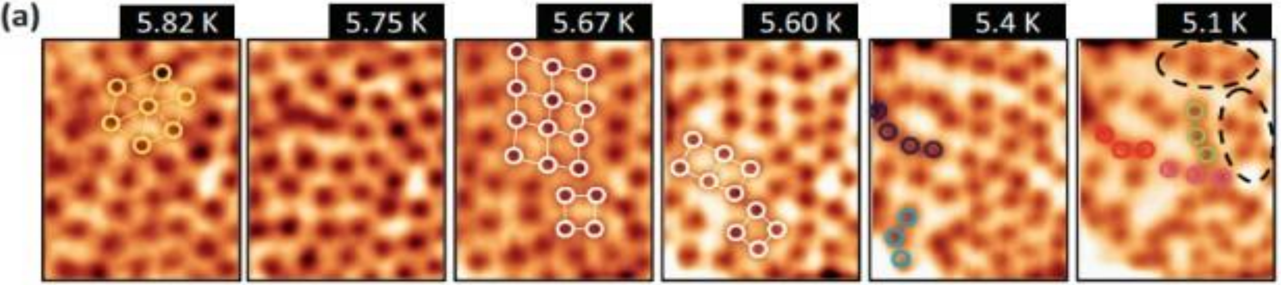

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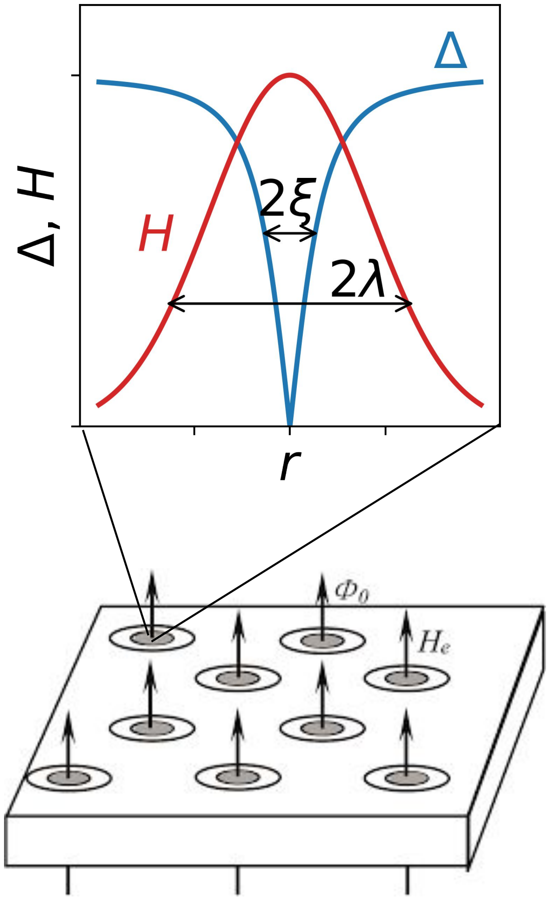
Intertype superconductors

- There are superconducting materials into which magnetic field penetrates in an exotic way
- The Abrikosov vortex lattice is destroyed and various patterns of vortices are formed

GL-theory and κ-dependence

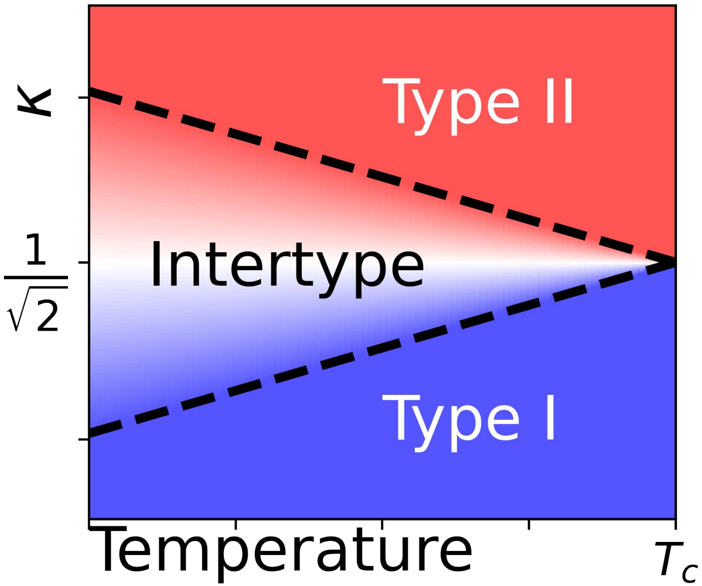
- GL theory predicts the existence of two types of superconductivity depending on the value of the GL parameter
- The distinction between the type I and type II of superconductors is determined by GL-parameter κ, the ratio of two crucial lengths.



GL - parameter

$$\kappa = \lambda / \xi$$

Extended theory



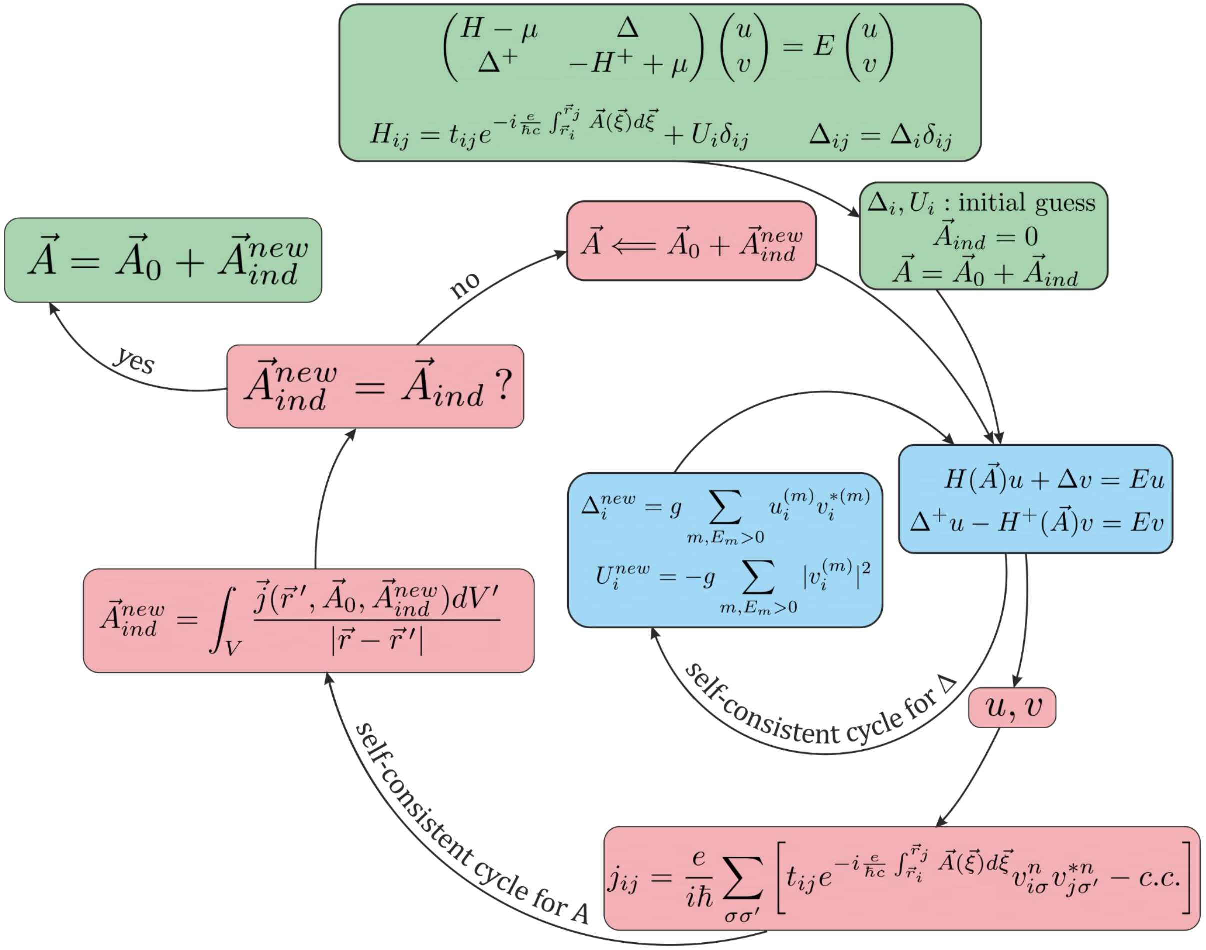
What do we want to know?

- How does the structure of vortices change in the model during the transition from type II to type I?
- How wide on the phase diagram is the range of the intertype regime for zero temperature?
- What is the form of the interaction potential between vortices in the intertype regime? Is this potential a fully pairwise or is there a many-body interaction?

The Idea

with fully microscopic treatment of magnetic field in Bogoliubov – de Gennes approach to get insights into superconducting transition from Type I to Type II

- **Method**
  - BdG equations
  - Induced magnetic field

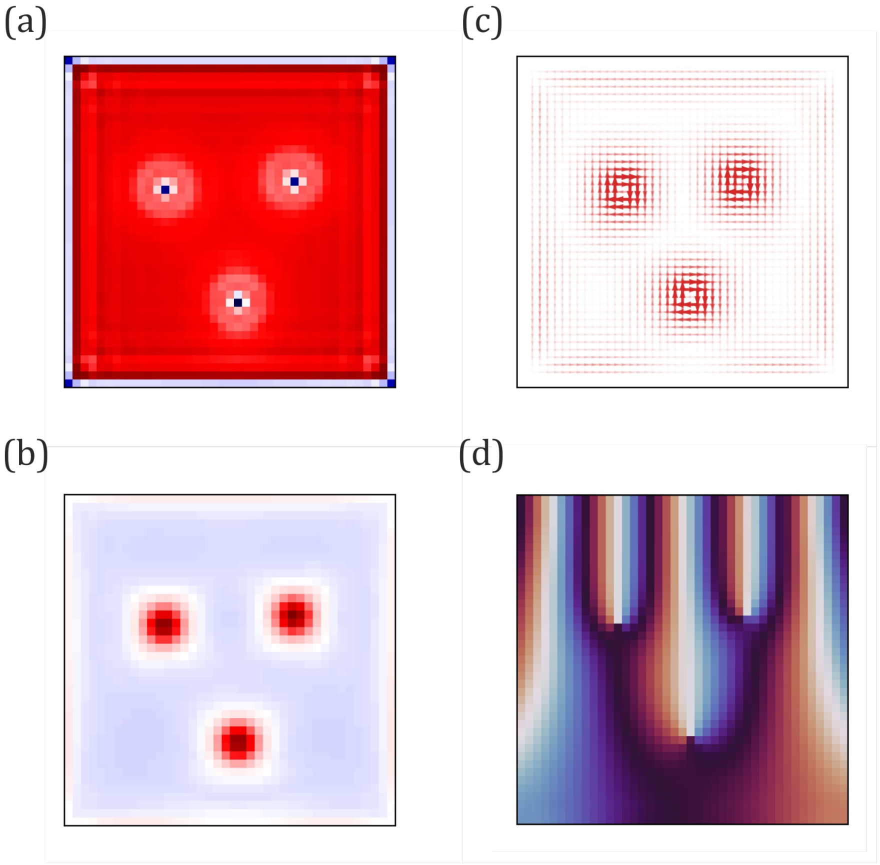


Bogoliubov-de Gennes equations

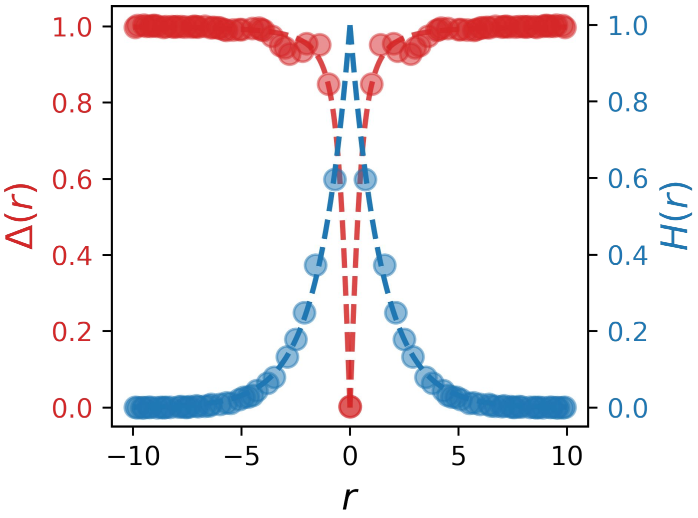
The main difference between the developed method and analogues presented in other works is the presence of another self-consistency cycle in the magnetic field, which allows us to take into account the influence of the induced magnetic field on the system. The connecting link in the cycle of self-consistency in the magnetic field is the solution of the Maxwell equation for the vector potential in integral form, taking into account the formula for the microscopic current for the Bogoliubov-de Gennes equations.

- # Results
  - Abrikosov lattice
  - Intertype superconductivity
    - Magnetic field
    - Many-body physics

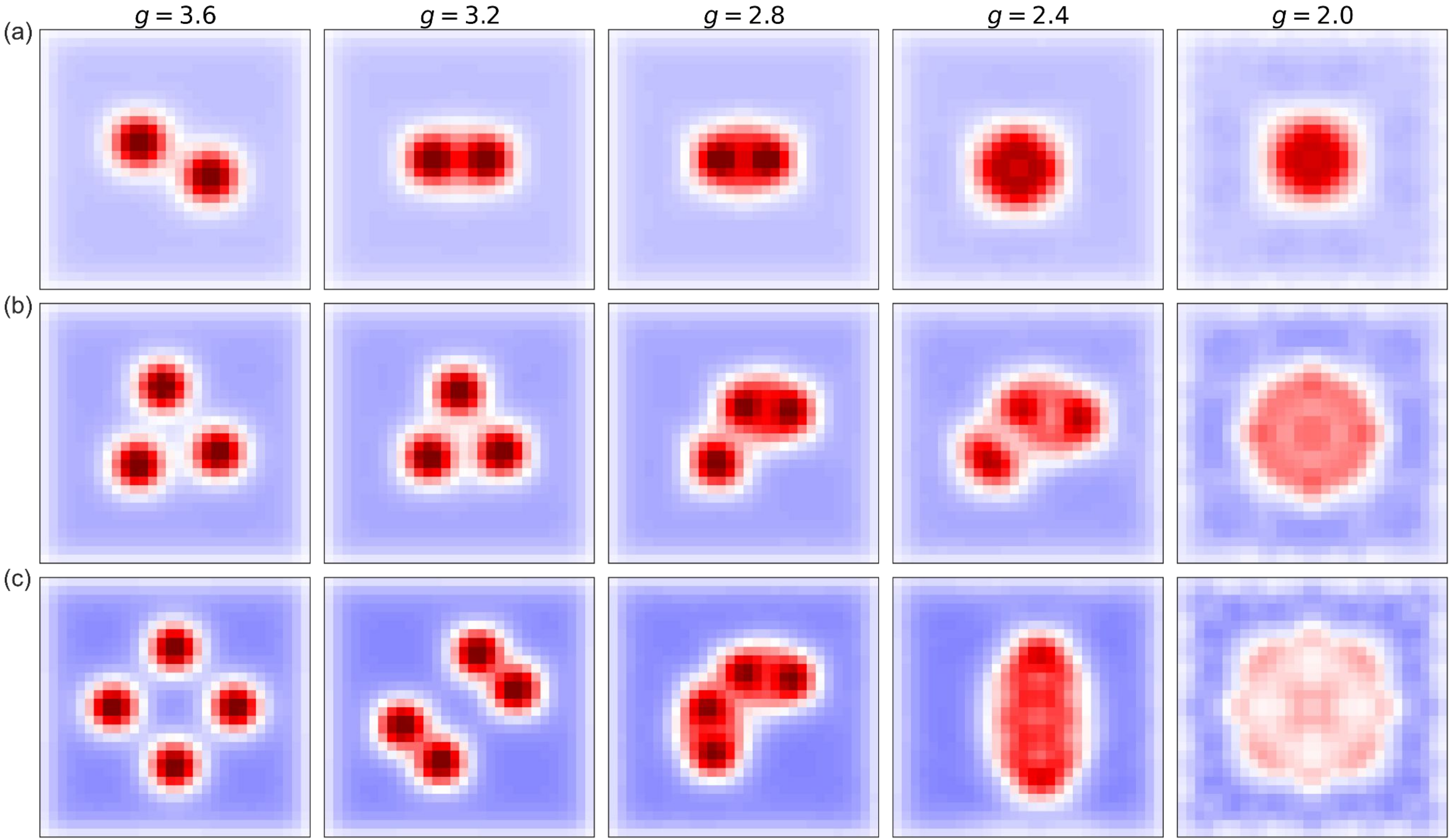
Abrikosov lattice



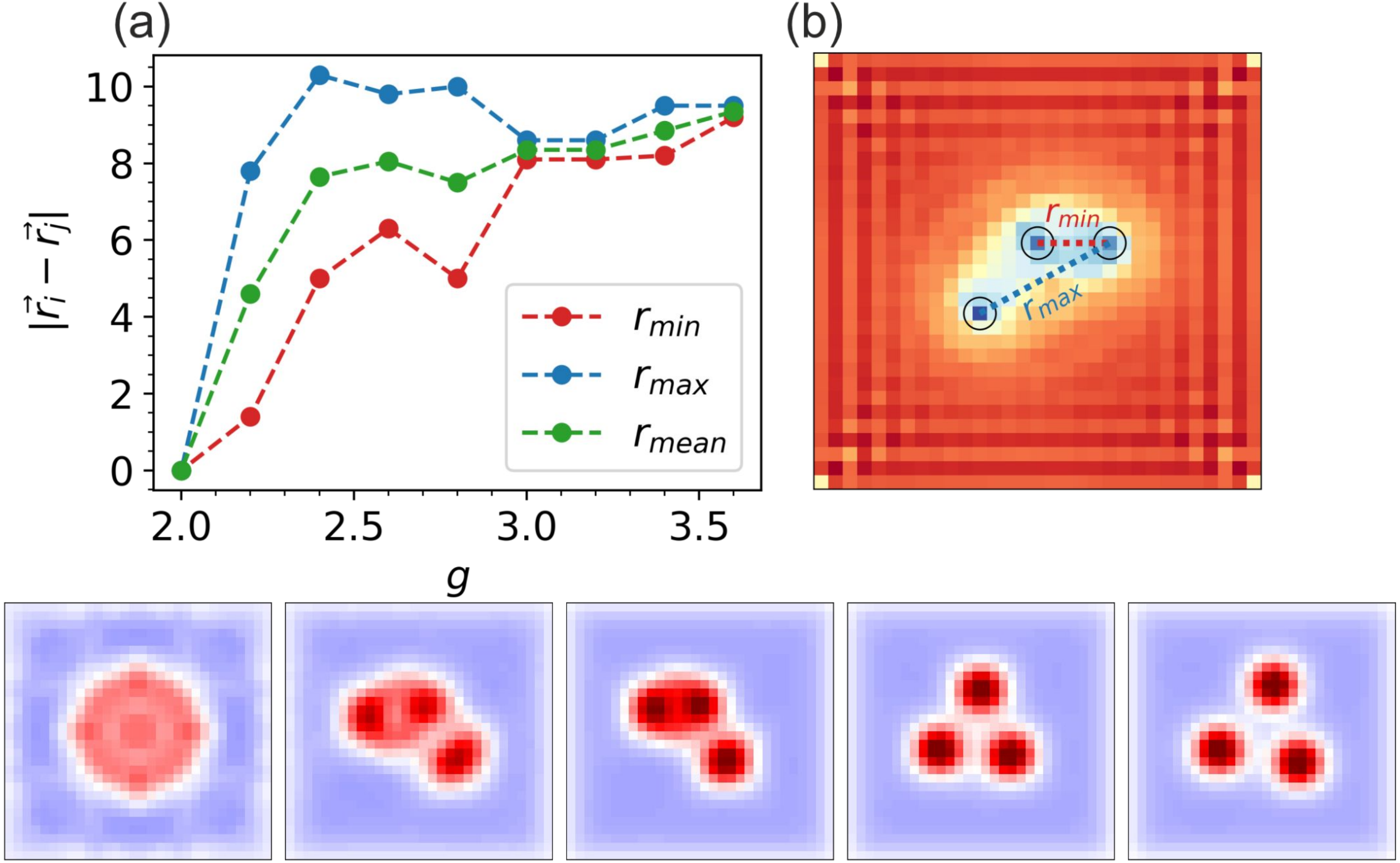
$$\kappa = \lambda / \xi \approx 3$$



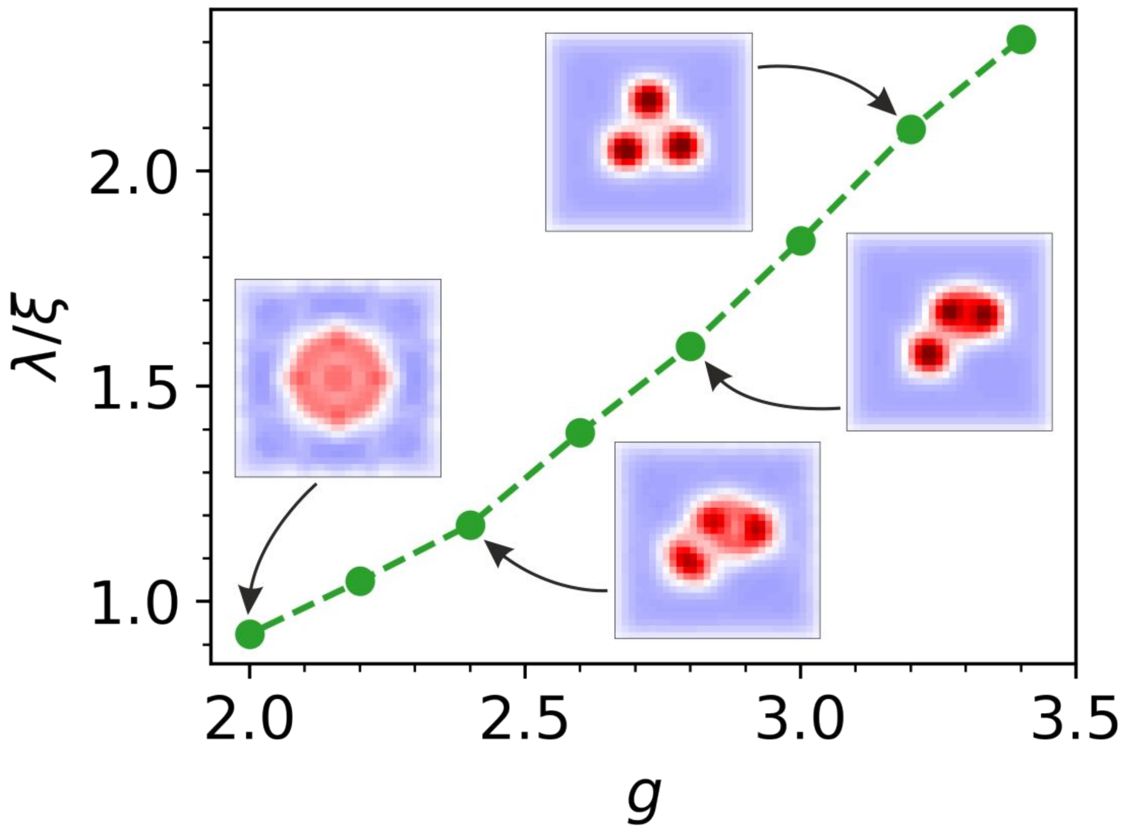
Intertype superconductivity

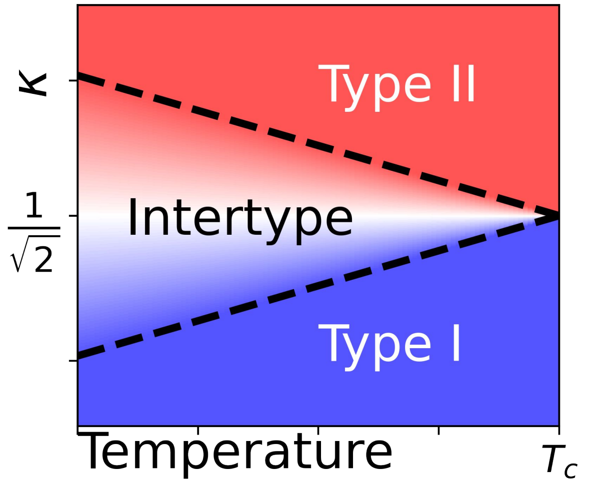


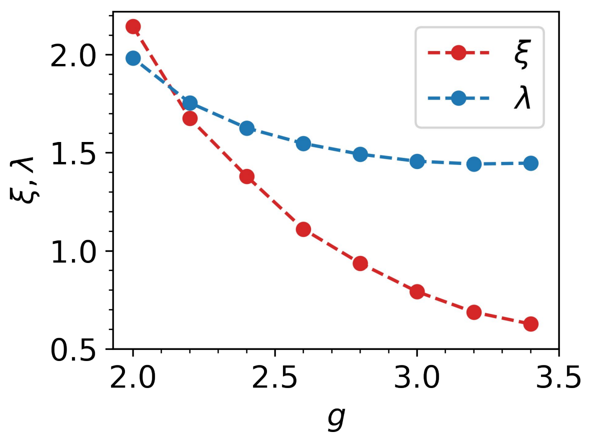
Many-body physics



κ - dependence







- Conclusions

Conclusions

What did we want to know?

- How does the structure of vortices change in the model during the transition from type II to type I?
- How wide is the range of the intertype regime for zero temperature?
- What is the form of the interaction potential between vortices in the intertype regime? Is this potential a fully pairwise or is there a many-body interaction?

Answers

- ❖ As the parameter κ decreases, the Abrikosov lattice begins to disintegrate into cluster formations, then chains (or worms) of vortices are formed, which subsequently form one giant vortex
- ❖ The upper edge of the intertype regime is slightly less than $\kappa = 2$ for zero temperature, the lower edge is difficult to obtain due to the size effects of the problem
- ❖ Using the example of three vortices, it is shown that the structures formed in the intertype regime cannot be described by a pairwise potential, which indicates the presence of a nontrivial many-vortex interaction