Superconducting Critical Current by Design

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Motivation & GL model

- Critical current determined by long-time evolution of TDGL (to stationary flow)
- Dominated by rare events of vortex depinning, avalanches, nucleation and splitting & reconnection
- Frequency and duration of pinning/depinning depends on configurations of inclusions
- Suitable pinning configurations must be determined using geometry optimization

Pinning of Vortices

Motion of vortices leads to dissipation/resistance
- Pinning prevents this motion
- Pinning mechanism:
  - pinning defects
  - quenched noise
  - geometry/surfaces
  - intrinsic/anisotropy

Realization of pinning in GL

1. Metallic inclusions and defects are modeled by $T_1$ modulation; spatial variation of $\phi$ (positive in the superconductor, negative in the defect)
2. Quenched noise and inclusions or interfaces between different superconductors can be modeled by $T_1$ modulation as well
3. Surfaces, voids, and insulating inclusions are modeled by open-boundary conditions (or reflections)
4. Intermittent pinning due to layered structure/ anisotropy are modeled by spatially dependent diffusion coefficients.

Critical current & optimization

- Critical current depends strongly on the pinning in the superconductor
- Using the pattern generator the critical current for a fixed pinning configuration is obtained
- The latter is defined by several parameters, e.g., size & concentration of defects, angle & diameter of columnar defects, etc. and can be optimized therefor

Task: Find the values for each of the defining pinning parameters in order to achieve the best critical current!

A typical realistic system has about 10 pinning parameters -> sophisticated optimization required (poster A1)

Critical current by design: examples

Here three examples with only one or two parameters:
1. Nanorods + columnar defects
2. Columnar defects at different angles
3. Point defects in parallel field configuration

Sample realization

- Sample is realized using a regular mesh of $52x28x42$ grid points with mesh size of $L_2/2$
- 0-100 spherical inclusions (low-$T_1$) with diameter $D_0$ randomly placed -> average over different disorder realizations
- A fixed constant current applied in y-direction as the variable magnetic field

Parallel fields

- Large-scale parallel TDGL integration methods allow to make the study of mesoscopic systems including the collective behavior
- Experiments verify simulation results
- Effects from different types of inclusions are strongly non-additive
- Analysis of experimental results with numerical simulations allows prediction of new types of materials with higher critical current

Critical current by design

- Advanced vortex detection & tracking help to understand the underlying mechanism
- Discovery of new effects

Conclusion & References

- More information & videos at oscon-scidac.org
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- Analysis of experimental results with numerical simulations allows prediction of new types of materials with higher critical current
- Critical current by design
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References:
Anisotropic superconductors in tilted magnetic fields

Fluxcutting in high-Tc superconductors

Towards Superconducting Current by Design
Submitted (2015)

Parallel magnetic field suppresses dissipation in superconducting nanotubes
Submitted (2015)