Zeitschrift: Helvetica Physica Acta
Band: 62 (1989)
Heft: 6-7

Artikel: Dissipative mechanics in granular superconductors
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DOI: https://doi.org/10.5169/seals-116088

DISSIPATIVE MECHANISMS IN GRANULAR SUPERCONDUCTORS

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Abstract: The role played by dissipation in the coherent transition of granular superconductors is approached from a new viewpoint stressing the link between local and global properties of the system.A novel kind of free energy functional is presented.

1. Introduction

In accounting for the role of dissipation in the physics of a single Josephson Junction(SJJ),it is well known that starting from different dissipative mechanisms we are led to a non completely overlapping understandings of the superconductor-insulator transition,which rests,moreover,on limiting values of some constrains[1].At present the extension to arrays does not look to be equally well developed and to this end the knowledge gained in the theory of granular superconductors(GS)[2]and related experiments[3] offers as a promising starting point.Indeed,in a GS, coherence results from the competition between the Josephson coupling,that determines the ordering of the phases of the single grain superconductive order parameters(singled out by a non vanishing value of an ordering field Ψ)and the electrostatic effects responsible for quantum fluctuations,dissipative tunneling suppressing this last leading to coherence.

It is our purpose to investigate the mutual interplay between the SJJ and the global transitions,stressing the role of dissipation in the former,by a novel kind of free energy accounting on the same footing for the respective ordering fields.

2. The Free Energy functional

The Euclidean effective phase action obtained in [2] describing a Josephson array exibits the feature that, besides the spatial Josephson coupling between the single grain phases ϕ_i, dissipation couples on the imaginary time axis the differences of the phases ϕ_{ij} across every SJJ. The spatial decoupling is performed by introducing the Hubbard-Stratonovich field $\Psi_i(\tau)$ conjugated to $\exp(i\phi_i)$. We introduce a novel field $\Phi_{ij}(\tau)$, in order to perform "temporal" decoupling, conjugated with $\exp(i\phi_{ij})$. Integrating out the phase degrees of freedom, after a cumulant expansion in power of the two fields, we pervent to the following free energy functional form:

$$F|\Psi_i,\Phi_{ij}| = \Sigma_{ij}\Sigma_n|\Psi_i(\omega_n)K^{-1}_{ij}\Psi_j(\omega_n) - g(\omega_n)\delta_{ij}\Psi_i(\omega_n)\Psi_j(\omega_n)| +$$
$$\Sigma_{ij}\Sigma_n||\Phi_{ij}(\omega_n)|^2 - 2\alpha(\omega_n)g(\omega_n)|\Phi_{ij}(\omega_n)|^2| +$$
$$F_1(\Psi^4) + F_2(\Phi^4) + F_3(\Psi^2\Phi^2)$$

where K_{ij} is the Josephson matrix and g is the phase-phase correlation function (details are omitted for brevity, they will appear in a forthcoming paper [4]). The fourth order coupling term $F_3(\Psi^2\Phi^2)$ provides to the aimed link in the sense that it can be viewed as a second order term for the effective free energy describing the Ψ or the Φ transition as alone. The structure of the involved propagators obliges recursion to the RG methodology in accounting for the Φ transition [4] whereas a mean-field approximation is known to lead to reasonable findings as about the phase diagram of the Ψ transition.

3. References

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