Commun. Math. Phys. 120, 177–193 (1988)

Communications in
Mathematical
Physics

On the Mean Field Instability of a Random Model for Disordered Superconductors

K. Ziegler*
Service de Physique Théorique, CEN Saclay, F-91191 Gif-sur-Yvette cedex, France

Abstract. A phenomenological model for a strongly disordered superconductor is considered. This is a modification of the Bardeen–Cooper–Schrieffer approach for a system with random phonon-electron interaction. We show that the instability of its mean field theory cannot be fitted by a power law with a positive exponent, in contrast to a recent result based on perturbation theory.

1. Introduction

Theoretical investigations of the effect of disorder in superconducting materials started soon after the invention of the famous Bardeen–Cooper–Schrieffer (BCS) theory in 1957 [1]. As expected from experiments, the presence of a weak random potential in this theory, describing weak disorder, does not alter essentially the superconducting properties [2]. In particular, the gap of the density of states, characterizing the superconductor below the transition point, is stable against a perturbation by the weak random potential [3]. More recent experiments with strongly disordered superconducting materials, exhibiting unusual properties, have motivated extending work in this field. In contrast to the earlier results, one is interested in the description of new properties probably caused by disorder. For instance, strong fluctuations of the gap width have been observed in experiments with various alloys. On the other hand, measurements at very low temperature ($T \approx 1K$) indicate a linearly increasing specific heat with temperature like in normal metals. Therefore, it was argued that this type of disordered superconductors is gapless.

The observation of a strongly fluctuating gap width leads to the construction of a phenomenological modification of the BCS theory [4]. Suppose that the Cooper pairs, the central objects of the BCS theory, are also the supercurrent carrying states of the disordered superconductor. Then it is natural to introduce an external field ϕ which couples with the Cooper pairs. As in the BCS theory, this field can be fixed by its saddle point value which, in turn, results in a

* Supported in part by the Deutsche Forschungsgemeinschaft