J. S. Redinha
J. da Providência
A. J. C. Varandas
Editors

Quantal Aspects in Chemistry and Physics

A tribute to the memory of Professor Couceiro da Costa

IMPRENSA DA UNIVERSIDADE DE COIMBRA
COIMBRA UNIVERSITY PRESS

COIMBRA 2011

4. Spontaneous Symmetry Breaking in Quantum Physics [1]

J. da Providência[*]

CFT, Department of Physics, University of Coimbra, Coimbra, Portugal

Following a classification due to Sir Rudolf Peierls, two possible types of spontaneously broken symmetries are discussed, namely, *spontaneously broken symmetry of first kind*, when a symmetric ground state is degenerate with an asymmetric one, and *spontaneously broken symmetry of second kind*, when the ground state belongs to a representation of the relevant symmetry group other than the identical one. *Symmetry breaking approximation* is also considered. In this case, in order to take into account in a simple manner important correlations between the particles of the system, a symmetric ground state of a quantal system is described by an approximation method which violates the symmetry. However, great care should then be exerted in order to insure that the approximation scheme does not break the symmetry to such an extent that the relevant physical properties are distorted. Color superconductivity is an example of such a case which is here discussed in detail.

A novel BCS-type formalism is constructed in the framework of a schematic QCD inspired quark model, having in mind the description of color symmetrical superconducting states. The physical properties of the BCS vacuum (average numbers of quarks of different colors) remain unchanged under an arbitrary color rotation. In the usual approach to color superconductivity, the pairing correlations affect only the quasi-particle states of two colors, the single particle states of the third color remaining unaffected by the pairing correlations. As a consequence, the average numbers of quarks depend apparently on the color, which is an unphysical and undesirable feature. The $SU(3)$ symmetry should not be violated to such an extent. In the theory of color symmetrical superconductivity here proposed, the pairing correlations affect symmetrically the quasi-particle states of the three colors so that vanishing net color-charge is automatically insured. It is found that the ground state energy of the color symmetrical sector of the Bonn model is well approximated by the average energy of the color symmetrical superconducting state proposed here.

[1] Talk based on joint work with H. Bohr and C. Providência

[*] Email address: providencia@teor.fis.uc.pt