Physica C 185–189 (1991) 1431–1432
North-Holland

PHYSICA C

OPTICAL CONDUCTIVITY OF HIGH - TEMPERATURE SUPERCONDUCTORS: EXACT SOLUTION FOR A "SPIN - BAG" MODEL

Michael V. SADOVSKII, Andrei A. TIMOFEEV

Institute for Electrophysics, USSR Academy of Sciences, Ural Branch, Sverdlovsk, 620219, USSR

Exact summation of all Feynman diagrams for two-particle Green's function is performed for the one-dimensional Gaussian model of static fluctuations of short-range (antiferromagnetic) order with Lorentzian correlator analogous to "spin-bag" model of Schrieffer et al. We obtain the general picture of frequency dependence of conductivity for different ranges of correlation length of short-range order. For specific values of parameters we get good qualitative agreement with experimental data on optical absorption in high-Tc superconductors.

1. INTRODUCTION

It is well known by now that the superconducting state in high-T_c oxides is realized on the phase diagram quite close to region of antiferromagnetic (AFM) insulator. Antiferromagnetic short-range order is being observed also in superconducting phase[1]. Among different theoretical schemes we address ourselves to "spin-bag" model of Schrieffer et al[2] which is based upon the Hubbard model with intermediate electronic correlations U. For half-filled band the free-electron spectrum satisfies the nesting condition $\varepsilon_{\mathbf{p}+\mathbf{Q}}=-\varepsilon_{\mathbf{p}}$ where $\mathbf{Q}=(\pi/a,\pi/a)$, which leads to the spin density wave (SDW) instability with the wave-vector $\mathbf{Q}$ [2]. For non half-filled case AFM order is being destroyed, while short-range order SDW-fluctuations may persist in relatively wide region of phase diagram. For this case only few results were obtained.

2. THE MODEL AND ITS EXACT SOLUTION

In the adiabatic (static) limit, when spin fluctuations are slow in comparison with characteristic electronic frequencies, general spin susceptibility $\chi(\mathbf{q},\omega)$ is given by[2]:

$$\chi(\mathbf{q},\omega)=\lambda^2\, 2\pi i\delta(\omega)\sum_{\mathbf{Q}}\kappa/((\mathbf{q}-\mathbf{Q})^2+\kappa^2)$$

where λ is some coupling constant, $\kappa^{-1}=\xi_{SDW}$ is the correlation length of SDW-fluctuations. In case of incommensurate fluctuations $\mathbf{Q}=(\mp 2p_F,\mp 2p_F)$ (p_F-is the Fermi momentum). In the following we assume the Gaussian nature of these fluctuations which is reasonable not very close to SDW-instability. We shall consider only the one-dimensional model of these fluctuations which allows an exact solution. Apparently this model is not very bad for the two-dimensional system in case of perfect nesting.

The structure of an exact solution[3] obtained by summing all Feynman diagrams reduces to Dyson equation in the following form:

$$G^{-1}(\varepsilon,\mathbf{p}) = \varepsilon-\xi_{\mathbf{p}} - \Delta^2 v(1)G_1(\varepsilon,\mathbf{p})$$

where $\xi_{\mathbf{p}} = \varepsilon_{\mathbf{p}} - \mu \simeq v_F(|\mathbf{p}| - p_F)$

$$G_k(\varepsilon,\mathbf{p})=\{\varepsilon-(-1)^k(\xi_{\mathbf{p}}+ikv_F\kappa\,\mathrm{sign}\,\xi_{\mathbf{p}})- -\Delta^2 v(k+1)G_{k+1}(\varepsilon,\mathbf{p})\}^{-1}$$

$\Delta \approx \sqrt{\lambda}U$-fluctuation energy (pseudo gap) scale, v(k)-combinatorial factor[3]

These recursion expressions give exact continuous-fraction representation of single-particle Green's function. Results of the degradation of pseudo gap for diminishing correlation length of the electronic density of states were given in Ref. 3. Here we present an exact solution for the vertex-function determining the frequency dependence of conductivity and the general picture of optical absorption in case of pseudo gap in density of states. The response of our system to the variation of external scalar potential $\delta\varphi_{q\omega}$ is given by:

$$\delta G(\varepsilon,\mathbf{p})/\delta\varphi_{\mathbf{q}\omega}=G(\varepsilon,\mathbf{p})G(\varepsilon+\omega,\mathbf{p}+\mathbf{q})J_0^{RA}(\varepsilon\mathbf{pq}\omega)$$

where the vertex part $J_0^{RA}(\varepsilon\mathbf{pq}\omega)$ is determined by recursion formula

$$J_{k-1}^{RA}(\varepsilon\mathbf{pq}\omega)=e+\Delta^2 v(k)G_k^A(\varepsilon,\mathbf{p})G_k^R(\varepsilon+\omega,\mathbf{p}+\mathbf{q})* *\{1+2ikv_F\kappa/(\omega-(-1)^k v_F q+v(k+1)\Delta^2* *(G_{k+1}^A(\varepsilon,\mathbf{p})-G_{k+1}^R(\varepsilon+\omega,\mathbf{p}+\mathbf{q})))\}J_k^{RA}(\varepsilon\mathbf{pq}\omega)$$

Details of this solution can be found in Ref. 4. Remaining analysis can be done numerically: we cut the continuous fractions for G-functions at some far away denominator, where we take $G_{k+1}=0$, and assume $J_k=e$, then we can sum everything to the limit of k=0. Conductivity is calculated in units $\omega_{pl}^2/4\pi\Delta$ (ω_{pl}- plasma frequency)

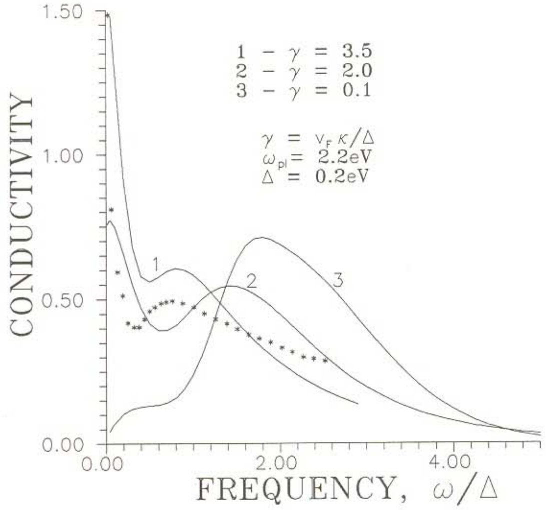

FIGURE 1
Frequency dependence of real part of conductivity - incommensurate case. Points - experimental data (Ref. 5).

3. CONCLUSION

Thus the picture of soft pseudo gap qualitatively explains the non-Drudean behavior of optical absorption in high T_c systems.

REFERENCES

1. G. Shirane et al. Phys. Rev. Lett. **59**, 1613 (1987)

2. A. Kampf, J.R. Schrieffer Phys. Rev. **B41**, 6339; **B42**, 7967 (1990)

3. M.V. Sadovskii. JETP **77**, 2070 (1979)

4. M.V. Sadovskii, A.A. Timofeev Superconductivity: Physics, Chemistry, Technology **4**, 11 (1991)

5. G.A. Thomas et al. Phys. Rev. Lett. **61**, 1313 (1988)