Electronic Raman Scattering Study of "122"-type Iron Based Superconductors

By

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Abstract

Superconducting materials have great commercial potentials for applications in industry and human daily life. Below the superconducting transition temperature T_c, the electrons near Fermi energy in the superconductor become paired and form a Cooper pair, they gain phase coherence and enter into the superconducting ground state. It is of significance to deepen the understanding of the electron pairing mechanism for unconventional superconductors and the coupling between different degrees of freedom in condensed matter physics.

In this dissertation, we systematically study the normal state, superconducting gaps and in-gap collective mode in typical "122" system of iron-based superconductors by electronic Raman scattering. It contains three parts:

1. Electronic Raman scattering study of c-axes As vibration mode across the structural phase transition T_S and magnetic phase transition T_N to investigate the magneto-elastic coupling. (1) We detected a forbidden A_g-symmetry As vibration mode in the XY scattering geometry below the structure phase transition temperature T_S, demonstrating the existence of the electronic polarizability anisotropy along X and Y directions in the orthorhombic phase. (2) By measuring the intensity of the As vibrational mode in different iron-based superconductors, we found that the intensity of A_{1g}(As) in the XY scattering geometry is closely related to magnetism. In the tetragonal phase, the intensity of A_{1g}(As) mode is zero in the XY scattering geometry. In the orthorhombic phase, the intensity of A_{1g}(As) in the XY scattering geometry is very weak. In the magnetic phase, the intensity of A_{1g}(As) in the XY scattering geometry is greatly enhanced. (3) We find that the ratio of the intensity of A_{1g}(As) phonon in the XY scattering channel and the XX scattering channel is proportional to the square of the ordered magnetic moment at low temperature. (4) In the Au-doped $BaFe_2As_2$ system, we systematically studied the Fano lineshape of the A_{1g}(As) phonon. This asymmetric phonon lineshape reveals that the As c-axes vibration mode is coupled to the magnetic B_{2g}-like electronic continuum. We

demonstrate that the anomalous behavior of the A_g(As) phonon mode in the XY scattering geometry can be consistently described by a Fano model involving the A_g(As) phonon mode interacting with the B_{2g} symmetry-like magnetic continuum in which the magneto-elastic coupling constant is proportional to the magnetic order parameter.

2. In the Au-doped $BaFe_2As_2$ system, we systematically studied the temperature evolution of the nematic fluctuations and explored the origin of nematic fluctuations by electronic Raman scattering. (1) We found that the static Raman susceptibility increases gradually above the structural phase transition temperature T_S, following the Curie-Weiss law. (2) There was only a slight decrease in static Raman susceptibility between T_S and T_N. (3) Below T_N, the static Raman susceptibility decreased rapidly, which is closely related to the opening of a spin density wave gap below T_N. (4) Our observation can be explained by the orbital fluctuations.

3. In the K-doped $BaFe_2As_2$ system, we systematically studied the nematic fluctuations, the superconducting pair breaking peaks and the in-gap collective modes by electronic Raman scattering. (1) In the sample studied, we observed a quasi-elastic peak, which originates from nematic fluctuations, in the normal state in the B_{2g} channel in a large doping range. (2) In the superconducting state, we observed two different superconducting Cooper pairs breaking peaks which corresponds to the two different superconducting gaps. The peak with larger energy corresponds to a larger superconducting gap while the one with smaller energy corresponds to a smaller superconducting gap. (3) In the B_{2g} channel, below T_c, we detected a collective in-gap mode whose energy lie in between the larger SC gap and the smaller SC gap. We carefully studied the temperature evolution and doping evolution of this mode and presented different scenarios to the origin of the collective in-gap mode.

The structure of the dissertation is as follows: The first chapter is an introduction, the second chapter and the third chapter are introductions to the Raman theory and Raman experiment, respectively. The fourth chapter, the fifth chapter and the sixth chapter introduce the research of phonon, nematic

fluctuations and superconducting collective in-gap mode by Raman scattering in iron-based superconductor, respectively. The seventh chapter is a summary and prospect.

Keywords: iron-based superconductors, electronic Raman scattering, phonon Raman Scattering, nematic order, nematic fluctuations, electronic paring gap, collective mode, magneto-elastic coupling, Fano lineshape