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MgB_2: Novel properties due to multibands[1]

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About 40 years ago A.J. Leggett proposed a new collective mode arising from cross-tunneling of Cooper pairs residing on different Fermi surfaces of a multiband superconductor: Leggett's collective mode is caused by a counter flow of the interacting superfluids leading to small fluctuations of the relative phase of the condensates while the total electron density is locally conserved.[2] Here we present direct spectroscopic observation of the Leggett's excitation in the MgB_2 superconductor containig two pairs of Fermi surfaces resulting from π- and σ-bands. Electronic Raman scattering studies have revealed three distinct superconducting (SC) features: (i) a clean threshold of Raman intensity at 4.6 meV consistent with the π-band SC gap; (ii) the SC pair breaking coherence peak at 13.5 meV consistent with excitations above the σ-band gap; and (iii) the SC collective mode at 9.4 meV which we assign to an excitation first discussed by Leggett.[3] Our calculation of the Raman response function for MgB_2 superconductor based on multiband interaction matrices by first principle computations show good agreement with spectroscopic observations. The temperature and field dependencies for all three features (i) – (iii) have been established;[4] the effects of magnetic field on the pair cross-tunneling in multiband system will be discussed. In addition, anharmonicity and superconductivity-induced self-energy effects for the E_{2g} boron stretching phonon have been studied.[5] We show that anharmonic two-phonon decay is mainly responsible for the unusually large linewidth of the E_{2g} mode. We observe 2.5% hardening of the E_{2g} phonon frequency upon cooling into the SC state and estimate the electron-phonon coupling strength associated with this renormalization.

[1]In collaboration with A. Mialitsin, B.S. Dennis, M.V. Klein, N.D. Zhigadlo, and J. Karpinski.

[2]A.J. Leggett, Progr. Theor. Phys. **36**, 901 (1966).
[3]G. Blumberg et al., Phys. Rev. Lett. **99** (2007); arXiv:0710.2803.
[4]G. Blumberg et al., Physica (Amsterdam) **456C**, 75 (2007).
[5]A. Mialitsin et al., Phys. Rev. B **75**, 020509(R) (2007).