Exchange interaction: correction to the effective mass of the yellow exciton in Cu_2O

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One of the fundamental properties of an exciton is the exchange interaction between electron and hole. The electron-hole exchange interaction is normally approximated as a spin-spin interaction, which is independent of the wave vector (**k**). This represents a severe simplification of the exchange interaction omitting much of the lattice properties. We demonstrate that electron-hole exchange indeed depends on the wave vector [1]. In studies with sub-μeV spectral resolution the exchange fine structure of the yellow 1S orthoexciton in Cu_2O is probed for various orientations of **k**. The data show that the orthoexciton triplet, which was assumed to be degenerate so far, shows a complex fine structure.

In agreement with theory this fine structure is identified as electron-hole exchange scaling with $\mathbf{k}^2$. The exchange splittings are on the order of few μeV. Despite the fact that these splittings are small, they have severe consequences also for studies with low spectral resolution.

A long standing discrepancy can be explained, when looking at the full exchange fine structure. In resonant Raman experiments the effective exciton mass is found to be much larger than the sum of the hole and electron mass. As the exchange discussed here scales as $\mathbf{k}^2$ it acts as a correction to the effective mass. The exchange splitting is of the same magnitude as the kinetic energy of the exciton at the exciton-photon resonance. This gives a straightforward explanation for the discrepancies in the measurements of the effective exciton mass. Further the exchange induced effective mass is anisotropic in **k**, hence one expects a direction-dependent exciton mass.

The 1S excitons in Cu_2O are extensively studied as they are candidates for the Bose-Einstein condensation of excitons. The critical density for such collective coherence scales linearly with the degeneracy of the exciton state. Hence, taking the wave vector dependent exchange into account, this critical densities are found to be three times lower than previously assumed.

[1] G. Dasbach, D. Fröhlich , H. Stolz, R. Klieber, D. Suter, and M. Bayer, Phys. Rev. Lett. 91, 107401 (2003).