Electron-hole plasma influence on band edge and Rydberg exciton lines in cuprous oxide

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Since their first experimental confirmation [1], Rydberg excitons have proven to be fascinating quantum objects with interesting properties (signatures of quantum coherence [2], quantum chaos [3], to name only two examples). Recently it has been shown that a surrounding plasma of free carriers (electrons and holes) has a significant influence on the absorption spectrum, in particular on the position of the band edge, even though its density is very low [4]. There have been, however, some features of the absorption lines that remained still quite unclear, e.g. the temperature dependence of the maximum observable principal quantum number $n_{\max}$. Moreover, no shifts of the exciton lines could be found so far in spite of the sufficient spectral resolution.

We introduce a many-body approach to the behaviour of bound (exciton) states and the band edge in a surrounding electron-hole plasma and discuss several approximations for the band edge. Measurements of the absorption spectrum are presented and a careful analysis of the exciton lines and the band edge is performed. The comparison of calculated and measured line and band edge shifts rules out widely used models for the latter quantity. It is shown that the shifts cannot be consistently explained by semiclassical models like the Debye approximation. Moreover, the temperature dependence of the maximum observable principal quantum number can only be explained by the improved band edge model.

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