Binding of quasi two-dimensional biexcitons

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oscillations back and forth in 2D momentum space can be interpreted as quantum beats resulting from the Coulombic attraction, which causes a change in the relative momentum $p$ up to the values $-1/a_w$. Complicated quantum interference given by Eq. (1) destroys the oscillations within a few periods. The transient coherent stage of PL explains the finite rise-time of PL and allows to estimate the $m$ binding energy straightforwardly by $E_b = \hbar/\tau$, where $\tau$ is the time of the first maximum of the PL signal.

The recently developed bipolaron model is adopted to analyze the coherent stage of PL. We conclude that the main 'hidden' channel of the $m$ decay is dissociation into two outgoing surface polaritons rather than an observable decay into bulk radiative modes. A spatial anisotropy of transient PL is also analyzed.

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The relaxation of a degenerate gas of excitons (\(\chi\)'s) coupled to an LA-phonon bath toward Bose–Einstein condensation (BEC) is analyzed within the kinetic equations. The optical processes, i.e., the radiative decay and the polariton effect, are included explicitly.

The observation of high quantum degeneracy and the asymptotic approach of BEC have been reported for a Bose gas of ortho-\(\chi\)'s in \(\text{Cu}_2\text{O}\). In these experiments, both the resonant and LO-phonon assisted ortho-\(\chi\) recombinations give an observable optical signal. However, the radiative renormalizations of the ortho-\(\chi\) dispersion strongly influence the relaxation kinetics. Recent experiments clearly demonstrate a well-developed polariton effect for the quadrupole-dowered ortho-\(\chi\)'s in \(\text{Cu}_2\text{O}\) at \(T = 2\) K. The corresponding polariton coupling is given by \(\Omega(p) = (\hbar c p^2/\epsilon_0)^{1/2}\), where \(\epsilon_0 = 6.5, f = 3.7 \times 10^{-3}\), and \(p\) is the polariton wave vector. The anomalously weak ortho-\(\chi\)'s - LA-phonon interaction in \(\text{Cu}_2\text{O}\) does not destroy the polariton effect.

Quasi-equilibrium BEC may coexist with the polariton effect under the following criterion:

\[
\epsilon_{\text{rad}}(p, \omega) \gg \Omega(p, \omega),
\]

where \(\epsilon_{\text{rad}}\) is the wave vector of the resonant x-photon transition and \(M_\omega\) is the x mass (see Fig. 1). For ortho-\(\chi\)'s this condition is broken because \(\epsilon_{\text{rad}}(p, \omega) = 9.7\) \(\mu\)eV and \(\Omega(p, \omega) = 123.7\) \(\mu\)eV. In this case, the ortho-\(\chi\)'s relax to the bottleneck region of the lower polariton branch rather than accumulate at state \(p = 0\) of the upper polariton branch. Our numerical simulations clearly demonstrate such a relaxation kinetics, explain the low-energy tail in phonon-assisted ortho-\(\chi\)'s recombination, and show an unusual relaxation kinetics along the lower polariton branch.

We conclude that the quantum degeneracy is high both for the high-energy tail of the distribution function (chemical potential \(\mu \rightarrow 0\)) and within the bottleneck region, but the quasi-equilibrium BEC at \(p = 0\) cannot develop for ortho-\(\chi\)'s in \(\text{Cu}_2\text{O}\).

The polariton effect is absent for the para-\(\chi\)'s. Therefore we analyze the relaxation kinetics within the standard kinetic equations for Bose particles with quadratic dispersion. For \(T \gg T_c\), the adiabatic cooling of the quasi-equilibrium \(\chi\)'s gas from \(T + \Delta T\) to \(T\) is exponential: \(\Delta T = \Delta T \exp[-1/t_\chi^2]\) (see Fig. 2). However, the kinetics slows down considerably if \(T \rightarrow T_c\). In this case, \(\Delta T = \Delta T/[1 + t/\tau_\chi^2]\). The number of condensed \(\chi\)'s at state \(p = 0\) grows very slowly \(\propto [1 + t/\tau_\chi^2]^2\). This nonexponential kinetics implies that a

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**References**