Quantum to classical behavior of exciton-polarons

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In this work we present our theoretical investigations on finite temperature exciton-polaritons in two-dimensional doped transition-metal dichalcogenides. We apply the quantum virial expansion to the many-body Green's function, which provides a systematic expansion in the low density and high-temperature limit, and allows for the exact calculation of the absorption spectrum and photoluminesence [1].

In ultracold atom systems the virial expansion is a powerful theoretical tool used to precisely describe the thermodynamic properties of strongly correlated gases [2]. The theoretical method is based on the perturbative expansion in the high-temperature regime of the thermodynamic properties through a small parameter, namely the fugacity $z = e^{\mu/T}$, where μ is the chemical potential and T defines the temperature of the system. The virial expansion has been used successfully to elucidate the thermodynamic properties of ultracold gases and is used to fit the thermometry in ultracold experiments [3].

Motivated by recent experimental work measuring the recoil of electrons in doped two-dimensional semiconductors [4], we apply the virial expansion to the high temperature regime and derive a consistent theoretical model of dressed exciton states at finite temperature. We find the virial photoluminesence gives excellent agreement with experiment, where it can explain key features, such as the strongly temperature dependent asymmetric exponential tail, splitting in quasiparticle peaks, and resolving the trion and polaron pictures. Furthermore, we find the polaronic quasiparticle is destroyed in the high temperature limit, however the role of quantum statistics is important in understanding the increased trion energy.

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