Controlling bosonic effects in light intersubband-excitation coupling in nanostructures

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Abstract— This paper demonstrates that the coupling between light and intersubband excitations in semiconductors is fundamentally different from the well understood coupling to interband transitions that leads to excitonic polaritons. It is shown that bosonic approximations required for a Hamiltonian theory can be manipulated and turned ``on/off'' in the regime of excitations where the signatures of the coupling are stable and well defined. The novel concept of ''intersubband antipolaritons is introduced.

***Index Terms*— semiconductor heterojunctions, intersubband optics, polaritons, intersubband antipolaritons, many-body effects.**

I. INTRODUCTION

EXCITONS and polaritons play a major role in interband optics and since in the last decade semiconductor optics has been steadily evolving towards the less explored field of intersubband transitions, it is of general interest to understand how light couples with an intersubband excitation. A recent theory predicted the possibility of intersubband polaritons for oblique incidence by means of a cavity created by total internal reflection at the air interface.[1] Indeed the microcavity polarity splitting of intersubband transitions has been observed experimentally.[2,3] Stimulated by the striking good agreement between theory and experiments, a Hamiltonian approach based on a bosonic approximation for the intersubband excitation has been developed to treat the quantum vacuum properties of the interusbband cavity polariton field.[4] However, this paper demonstrates that the coupling between light and intersubband excitations in semiconductors is fundamentally different from the well understood coupling to interband transitions that leads to excitonic polaritons.

The approach summarized here is a step forward in the microscopic understanding of the coupling between light and intersubband transitions and a more general ``intersubband antipolariton'' concept is introduced. [5]

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II. MAIN RESULTS PRESENTED

The microscopic Keldysh Green's functions formalism leads to analytical expressions for the quasi-particle dispersion including many body effects under nonequilibrium conditions. It consistently reproduces dispersion relations found experimentally if light is absorbed due to intersubband transitions [2-3] and yields unique features not found in the literature so far: [5]

(i) Anomalous dispersions under population inversion conditions that cannot be described a Hamiltonian theory based on bosonic approximations are predicted.

(ii) The limit of validity of the conventional polariton as a bosonic quasi-particle concept is demonstrated numerically for the intersubband case and a simple recipe to control bosonic effects and turn them on and off by selective excitation of the subbands is presented.

(iii) The influence of the dominating many body corrections on the dispersion of both passive (absorption) and active (inverted gain media) is discussed.

III. CONCLUSION

In conclusion, the theory sumarized here is a step forward towards understanding the microscopic interaction between light and interband transitions and provides a recipe to control bosonic effects that may play a role in novel intersubband-based nanophotonic device concepts.

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