Distinguishing elastic and inelastic scattering during the interplay of incoherent excitons with near band-edge excitations

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The interaction between charge carriers and excitons represents a cornerstone in semiconductor physics. It holds significant implications for the advancement of semiconductor-based devices such as transistors, solar cells, and lasers. In the past, scattering processes in semiconductors between charge carriers and excitons have been studied intensively using a wide variety of experimental methods, e.g., four-wave-mixing spectroscopy, time-resolved photoluminescence spectroscopy, or optical pump - optical probe spectroscopy. However, all these studies only provide information on the rate at which scattering events occur but fail to distinguish between inelastic and elastic scattering This woud require an additional measure, namely the quantitative information about the size of the exciton population which has become accessible by optical pump-terahertz probe spectroscopy. This allows to distinguish between elastic and inelastic scattering processes of excitons and charge carriers [1].

In this approach, the linewidth of the intraexcitonic resonance serves as a metric for the total scattering rate, encompassing both elastic and inelastic scattering. The change in the exciton fraction, on the other hand, is specifically sensitive to inelastic scattering processes. This study applies this approach to a high-quality semiconductor multi quantum well sample featuring a pure homogeneous broadening in its intraexcitonic transition. Our experimental setup involves the use of two optical pulses. The first pulse resonantly injects 1*s* excitons into the sample. The second optical pulse is delayed by 22 ps. Varying its energy alters the temperature of the electron-hole plasma. Probing the excitons created by the first optical pulse measures the induced THz-absorption change before and after the second optical pulse excites additional carriers which is shown in Figure 1.

We analyze electron-exciton scattering by determining the excitation-induced intraexcitonic linewidth change complimented by an analysis of the exciton fraction. This yields therespective contributions of elastic and inelastic scattering processes for different excess energies of the electron-hole plasma. For an excess energy of 9 meV - which already exceeds the exciton binding energy of 6.33 meV - virtually no inelastic scattering is observed, regardless of the number of additional carriers injected. This is because there are no final states that the electron-hole plasma can occupy when it scatters inelastically with excitons, which prohibits this scattering process according to Fermi's Golden Rule. At 40 meV excess energy, a Drude-like response associated with unbound charge-carriers arises which is indicative of an electron-hole plasma.

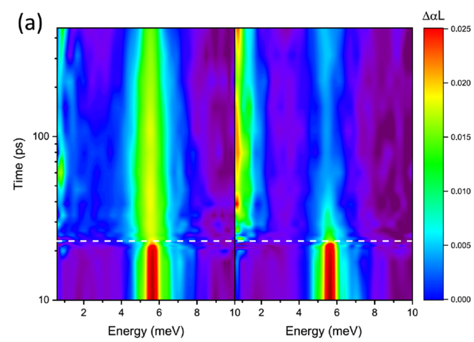

Fig.1. THz absorption change after resonant excitation with additional injected carriers at the dashed white line with 9 meV (left) and 40 meV (right) excess energies. The carrier densities are nearly identical in both cases.

The importance of excess energies and the availability of final states in governing inelastic exciton scattering with near-band edge carriers is highlighted. Despite ample excess energy, the absence of final states for unbound carriers hinders exciton breakup, limiting scattering to elastic events. These findings shed light on the nuanced interplay between energy states and scattering mechanisms, contributing valuable insights into excitonic behaviors in these systems.

References

[1] D. Anders et al., Phys. Rev. Lett. **132**, 106901 (2024).