Optical Nonlinear Effects of Resonantly Excited Excitons on Excitons in GaAs Multiple Quantum Wells

GaAs 다중 양자 우물 구조에서 공명 여기된 엑시톤들에 의한 광학적 비선형성의 연구

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We investigate the effect of resonantly excited excitons on the optical-absorption of the n=1hh and n=2hh exciton resonances in GaAs quantum wells. Under quasistationary excitation condition using the pump and probe beam at low temperature, we report the first observation of long range Coulomb screening by two dimensional exciton-exciton interaction, and discriminate unambiguously exciton bleaching between by long range Coulomb screening and the Pauli exclusion principle. In addition, the relative strength of absorption bleaching effect by long range Coulomb screening is about 2 times weaker than the Pauli exclusion principle and theoritical consideration is in good agreement with the experimental data. In semiconductor multiple quantum wells, the quantum confinement of carriers enhances excitonic behavior, resulting in the persistence of strong and well-resolved excitonic absorption peaks up to high temperatures. With increasing densities of the photogenerated carriers, the Coulomb interaction between electrons and holes is screened and eventually lose their oscillator strengths. On the other hand, the Pauli exclusion principle, i.e., phase-space filling and exchange effect causes directly a reduction of the exciton oscillator strength and a modification of the electron-hole interaction, as the conduction- and valence-band states near the band edge become occupied. In experiments on exciton bleaching by photogenerated free carriers or excitons with bulk and quasi two dimensional muliple quantum well structures, contradictory results have been obtained regarding the relative importance of long range Coulomb screening and effects of the Pauli exclusion principle. Furthermore, the bleaching effectiveness of various states of photogenerated carriers, i.e., hot or cold plasma or excitons has been the subject of numerous investigations during the past decade and seems to be a disagreement between theory and experiment. P.C. Becker et al. reported the relative bleaching strength of excitonic absorption by cool free carriers and cold excitons in II-VI CdZnTe/ZnTe MQWs. In those measurements, the absorption bleaching strengths of cold neutral excitons is stronger than that of the same density of cool uncorrelated charged electron-hole pairs, in disagreement with the theoritical predictons. Knox et al. observed that the bleaching effect of excitons on excitons was stronger than that of the same density of warm free carriers in GaAs MQWS. However, the studies of absorption bleaching are

limited to the relative strength between by excitons and the same number of free electron-hole pairs, i.e. hot or cool, which are ionized from the resonantly excited excitons. One interesting question is how strongly can excitons, which are electrically neutral but consist of electrons and holes, self-screen the exciton. In bulk GaAs Fehrenbach et al. observed that the screening of excitons by excitons is very weak, compared to the screening of excitons by free carriers. Up to now no experimental data on long range Coulomb screening of excitons by excitons in two dimensional MQWs are available in the literature. In this letter, we report the first direct observation of long range Coulomb screening by two dimensional exciton-exciton interaction, and discriminate unambiguously the relative bleaching strength of exciton absorption peaks by long range Coulomb screening and the Pauli exclusion principle. For our investigation we measure the optical absorption change of the n=1hh (heavy-hole) and n=2hh exciton resonances simultaneously, using GaAs /AlGaAs MQWs at low temperature(=10K). For quasistationary pump and probe experiment, broadband probe pulses covering both n=1 and n=2hh exciton resonances are employed to elucidate the absorption change of respective subbands. Pump pulses are fixed accurately to create only n=1 hh excitons to the resonance energy of n=1hh using pulsed-N_2-laser-pumped dye-laser system, which (laser linewidth) ΔE_{laser} < (exciton linewidth) ΔE_{exc} . In the case of the spectrally narrow exciting pulse centered at n=1hh exciton resonance at low temperature, the excited excitons are restricted to the exciton ground state. It is important to note that long range Coulomb screening affects excitons of all subbands, i.e. n=1hh, n=2hh and etc., and the Pauli exclusion principle are restricted to the occupied subband n=1hh exciton. Surprisingly, we observe the bleaching effect of neutral excitons excited at n=1hh excitons on excitons at n=2hh. This result strongly confirms that long-range Coulomb screening is present in quasi two dimensional system. At the same time we have measured absorption bleaching at n=1hh exciton resonance affected both the Pauli exclusion principle and long range Coulomb screening. We are able to discriminate between the Pauli exclusion principle and long range Coulomb screening. Moreover the relative strength of absorption bleaching effect by the Pauli exclusion principle is two times stronger than long range Coulomb screening, which agrees well with estimates from our theoretical consideration.

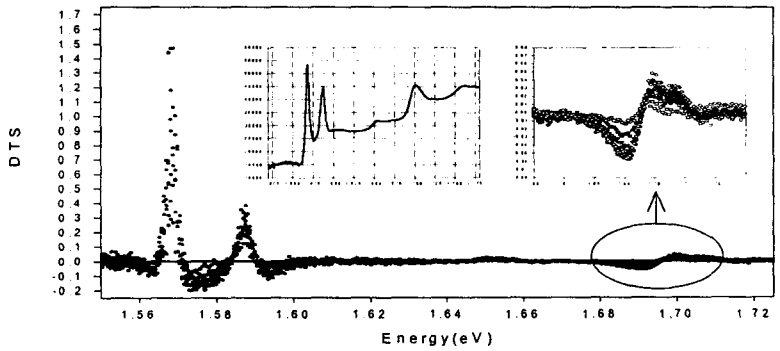

Fig. 1 Linear absorption spectra and Differential Transmission Signals varying excited carrier densities at low temperature