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ELECTRONIC STATES AND OPTICAL TRANSITIONS IN UNDOPED AND MODULATION DOPED GaInAs/AlinAs QUANTUM WELLS AND SUPERLATTICES

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ABSTRACT

We briefly discuss selected fundamental properties of the electronic states and optical transitions in GaInAs/AlInAs quantum wells and superlattices either undoped or modulation doped. The results of different optical investigations are compared and we provide information on the excitonic as well as many-body states under different excitation conditions.

Recent advances in the technique of Molecular Beam Epitaxy (MBE) allow to fabricate high quality superlattices consisting of III-V semiconductors. Owing to the important opto-electronic applications the GaInAs/AlInAs material system is of particular importance. In this communication we briefly survey several recent results concerning the optical properties of MBE grown Ga In As/Al As superlattices either undoped (QW) In 0.47 0.53 0.48 0.52 or modulation doped (MDQW). It is well known that the perfect lattice matching and the interface roughness are the most critical problems for the succesful fabrication of photonic devices made of this material system. In fig.1 we show the comparison between the absorption spectra measured in narrow QWs and MDQWs. The undoped quantum wells (broken line) clearly

exhibit sharp heavy and light hole peaks positioned at the energy exciton calculated with the simple particle a box model (arrow in fig. 1). in The excitonic features are quenched in the heterostructure MDQW With sheet a 11 -2 density of 4.10 This is due to CM the screening of the Coulomb interaction which reduces the binding energy of the exciton. In addition we

observe a blue shift of the absorption edge up to the Burstein-Moss edge, due to the band filling effect, and a red shift of the luminescence due to the band gap renormalization. The quantitative analysis of these data is reported elsewhere [1].

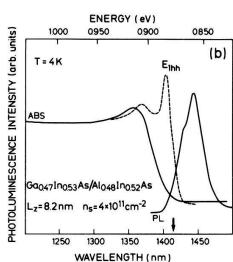
It is worth noting that the luminescence MDQW in the does not show any Fermi singularity at the edge, indicating that no relaxation of the kconservation due to localized states or impurities occurs in the investigated superlattices [2]. This 13 a clear indication of the extremely high quality the MBE grown superlattices even in of the limit of narrow well widths.

Fig. 1 ABS and PL spectrafrom the MDQW and QWis up to the Bursteinect, and a red shift of

ENERGY (eV) 1.100 1.050 1200 1,150 1.000 FES CB1-LH1 INTENSITY (arb.units) 4K 16 K 25K 35K PHOTOLUMINESCENCE 53K Ga047 In0.53 As/Al0.48 In0.52 As Lz=3.4 nm ns= 4 · 10¹¹ cm⁻² 1060 1100 1140 1180 1220 1020 1260 WAVELENGTH (nm)



The existence of a pronounced intrinsic Fermi edge singularity is observed in the photoluminescence excitation (PLE) and absorption spectra of the GaInAs MDQWs. In fig.2 we show the



dependence of the PLE spectra of a 3.4 nm MDQW temperature recorded at very low excitation intensity. The peak labeled FES, which is located at the Burstein-Moss edge, originates from the enhanced oscillator strength of the scattered electronic states. The screening of the photogenerated holes by the confined gas in the MDQW leads to a charge rearrangement in electron the modulation doping induced plasma. In doing this, the scattering processes can only have final states above the Fermi level (where empty states are available) causing the enhancement of the electron correlation above the Fermi edge. This results in the FES peak observed in the PLE spectra of fig.2. As expected from the decrease of the electron correlation this spectral feature disappears rapidly with increasing temperature, and the absorption spectrum recovers the density-of-state profile around 50 K.

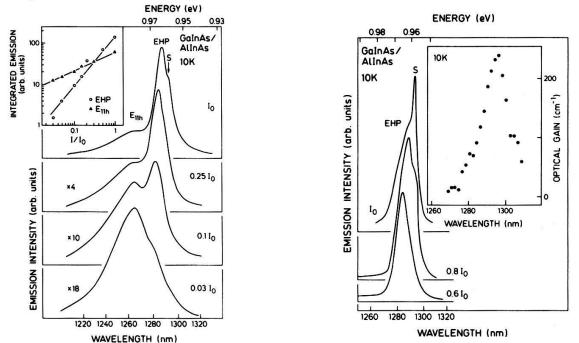


Fig.3 a) Spontaneous emission at different excitation intensities (I =1 MW/cm^2) and b) stimulated emission and optical gain for 3.6 nm QW

We next study the interesting effect of an increase of the

density of photogenerated quasi particles in the superlattice, when we apply a strong optical pumping. In fig.3a we i.e. show luminescence spectra obtained at low temperature and the under different excitation conditions from an undoped superlattice. The ordinary excitonic luminescence observed at low excitation rate (E linearly and saturates with the) grows excitation 11h intensity. superlinear emission band (EHP) arises on the 101 A energy side of the E band and becomes dominant at the highest 11h excitation intensities. Sharp stimulated emission and optical gain are observed from this band (fig.3b). The main radiative channel is now the electron-hole plasma (EHP band) recombination. detailed explanation of the emission line-shape will A be the subject of another work. The stimulated emission threshold 13 considerably higher than in GaAs/AlGaAs superlattices under identical excitation conditions, and the optical gain is of the order of 250 cm at 10 K. SAMPLE IOK

A strong improvement of the performances optical amplification is achieved in the MDQW n-type heterostructures [2]. In fig.4 we show the stimulated emission and the optical gain spectrum measured in a MDQW of 8.2 well width under the same excitation nn conditions as before. The optical gain about a factor 3 and the increases by stimulated emission arises over more

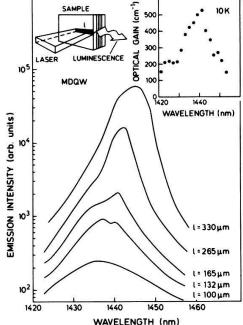


Fig. 4 Stimulated emission and optical gain in NDQW

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than three decades when the length of the optical cavity in the Mm. This effect is ascribed crystal is ranging from 100 and 330 to the presence of the dense electron-plasma which is confined in the conduction well. From the phenomenological point of view this situation allows us to achieve a population inversion state simply by photogeneration of electron-hole pairs in the superlattice [3], thus lowering the stimulated emission threshold and improving the optical amplification performances of the MDQW as compared to the undoped case.

CONCLUSIONS

have briefly discussed a few fundamental electronic We transitions occurring in undoped and modulation doped GaInAs/AlInAs superlattices. The very high quality of the investigated superlattices allowed us to study the effects of the confined electron plasma on the excitonic states and the increasing electron correlation at the Fermi edge. Under high photogeneration rates, the establishment of a dense carrier electron-hole plasma results in an optical amplification which is very promising for opto-electronic devices operating in the 1.3-1.5 Mm spectral range. We finally show that n-type modulation doping can be very useful for the improvement of these emission performances, since it allows to obtain a population inversion in the MDQW in stationary conditions.

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