# Anomalous temperature-dependence of the free-charge-carrier concentration in modulation-doped AlGaAs/GaAs quantum well superlattices studied by fir magnetooptic generalized ellipsometry

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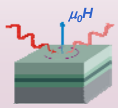
## Our message

• An anomalous temperature dependence in modulation doped n-$Al_{0.4}Ga_{0.6}As$/GaAs super-lattices: drastic *increase* of the free charge carrier concentration with *decreasing* temperature.

• A simple hydrodynamic rate model explains this behavior.

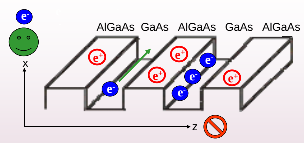
• Magnetooptic ellipsometry is used for contactless measurement of free charge carrier parameters *m, N, μ* in semiconductor layer structures




fir mo generalized ellipsometry:

## Motivation

spatial free-charge-carrier *confinement*



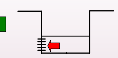

spatial confinement of modulation doped AlGaAs/GaAs superlattices at low temperatures

Fingerprints in the far-infrared optical response

Fir MO-ellipsometry

contact-less, nondestructive determination of phonon and free-charge-carrier parameters (concentration, effective-mass, mobility) in thin layer samples

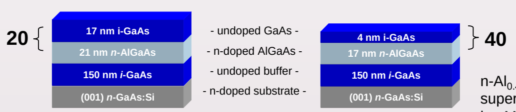
free-charge-carriers *dynamics* during the condensation process



number of activated interface states depends on the quantum-well filling

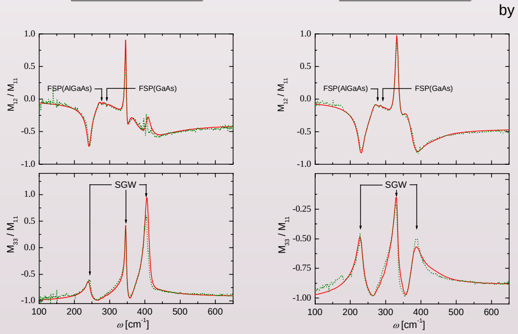
## Experimental results

### FIR ellipsometry



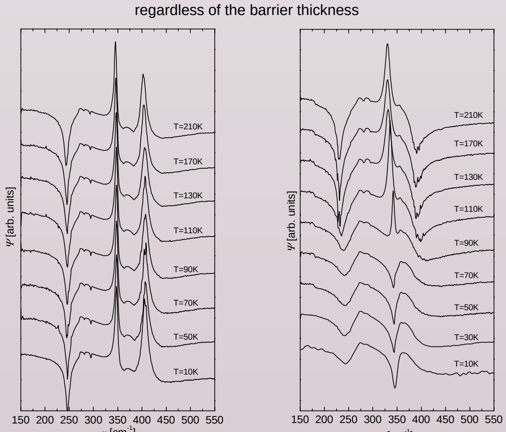

n-$Al_{0.4}Ga_{0.6}As$/GaAs-superlattice grown by MOCVD

room temperature



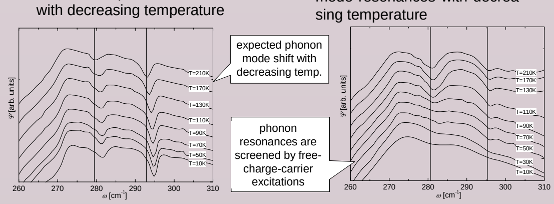

interface coupled wave resonances dominate the spectra regardless of the barrier thickness

T = 10 to 210 K

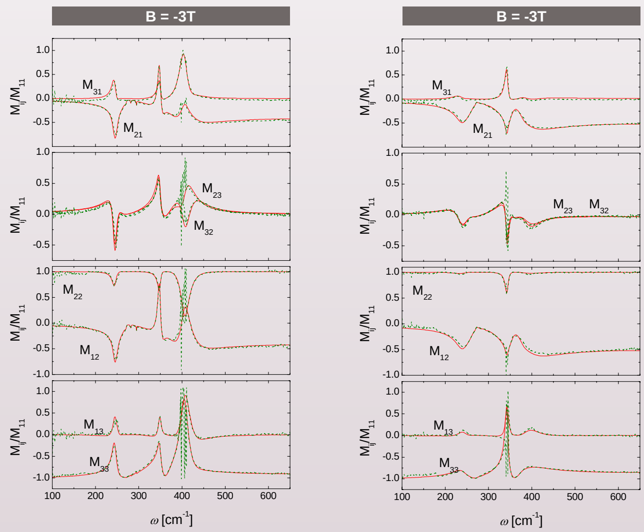



**slight** changes mainly due to shifts of the phonon resonance with decreasing temperature

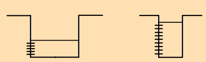
**drastic** changes of the SGW mode resonances with decreasing temperature




### FIR-MO ellipsometry at 10K




### hydrodynamic rate model



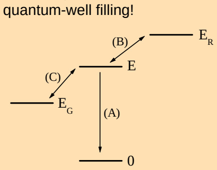
number of activated interface states depends on the quantum-well filling!

$$\dot{\rho} = -A\rho L e^{-E/kT} + B\rho_R\left(1-\frac{\rho}{N_c}\right)Le^{-E_R/kT} + C\rho\left(1-\frac{\rho}{N_c}\right)Le^{-E_G/kT}$$

emission to the host crystal

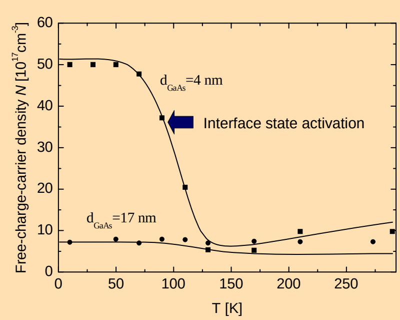
quantum-well-barrier reservoir interaction

Coulomb-activated interface-states




(A) irreversible loss
(B) reversible quantum-well-reservoir interaction
(C) reversible Coulomb activation of surface states

| | A/C [nm] | B/C [nm] | $\Delta E_{RG}$ [K] | $\Delta E_G$ [K] | $\Delta E_R$ [K] | $N_c$ [$cm^{-3}$] |
|---|---|---|---|---|---|---|
| $L_{GaAs}$=17 nm | 5 | 8 | 845 | 711 | 134 | $7.2 \times 10^{17}$ |
| $L_{GaAs}$=4 nm | 7 | 11 | 845 | 419 | 426 | $5.1 \times 10^{18}$ |





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