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Transport of Indirect Excitons in Polar GaN/AlGa_xN Quantum Wells



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1 Abstract

We present spatially- and time-resolved photoluminescence experiments on polar GaN/AlGa_xN quantum well structures, showing exciton propagation distance of tens of micrometers from generation position and exciton radiative lifetimes of tens of microseconds. We study in detail the dynamics and range of their relaxation/diffusion along the growth plane, as a function of temperature.

2 Motivation

Indirect excitons
(spatially separated bound electron and hole pairs)

Long lifetime Built-in dipole moment

Use of dipole-dipole interaction for excitonic transport

Excitonic devices (e. g. exciton transistors [1,2])

GaN-based polar quantum wells (QWs):

- strong built-in electric field \sim MV/cm
- quantum Confined Stark Effect (QCSE) dominates over confinement in wide QWs $>$ 30 atomic monolayers (ML):

- fundamental optical transition below the excitonic gap of GaN

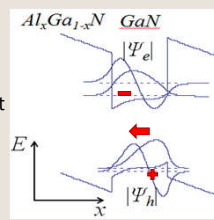
- emission energy decreases linearly with increasing QW width

- carrier lifetime \sim μ s and longer (small e-h overlap)

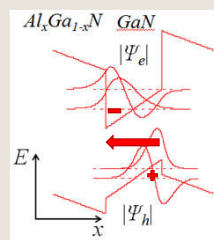
- exciton binding energy (bulk GaN is \sim 26 meV)
- exciton Bohr radius (bulk GaN is \sim 3nm)

- 2D Mott density $n_{\text{Mott}} = 2 \cdot 10^{12} \text{ cm}^{-2}$

High-exciton density, short lifetime (blueshift)



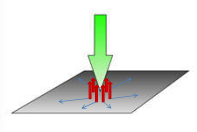
Low-exciton density, long lifetime (redshift)



3 Experimental details and sample structure

Al _{0.2} Ga _{0.8} N
GaN (6 ML)
Al _{0.2} Ga _{0.8} N (1 ML)
GaN (17 ML)
Al _{0.2} Ga _{0.8} N
Sr:Ga _{0.9999} buffer
(0001) sapphire

Creation of dipolar excitons (red arrows) by laser excitation



Using interbarrier in the QW:

- Moderate modification of the exciton binding energy
- "Pinching" of the electron-hole overlap
- larger lifetime

Spatially-resolved photoluminescence (PL):

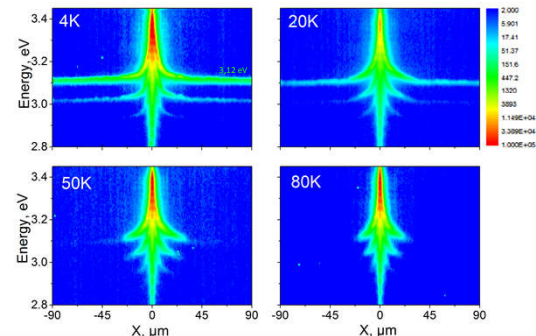
- cw excitation at 266nm
- Incident power 1-10 mW
- Excitation spot 1 μ m in diameter

Micro-time-resolved PL:

- $\lambda = 266 \text{ nm}$
- 150 fs pulses
- Incident power about 1 mW
- Repetition rate: 8 kHz (125 μ s between pulses)

4 Experimental results

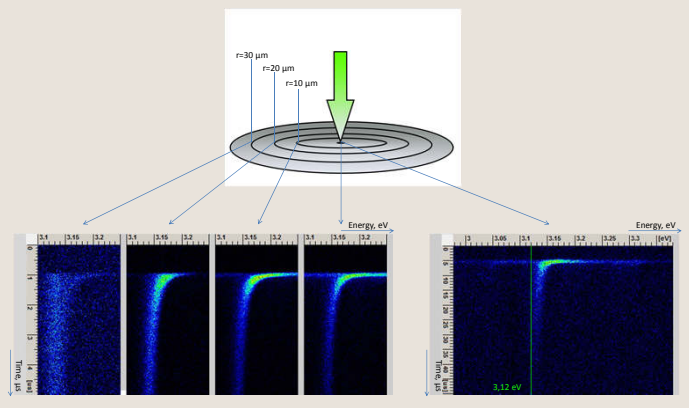
Spatially-resolved PL (dependence of emission on distance from excitation)



- Close to the excitation spot: strong blue shift of PL energy (\sim 300 meV), strong emission intensity (large carrier density and short radiative lifetime)
- At low temperature: excitonic emission observed hundreds of μ m away from excitation spot
 - Long range excitation transport (strong repulsive interaction between excitons + long carrier lifetime)
- With increasing temperature: quenching of transport (nonradiative recombination dominates over radiative), but only **above some critical distance**
- Excitonic transport is accompanied by energy relaxation and decrease of emission intensity (strong energy dependence on carrier density)
- LO-phonon replicas located 90, 180, ... meV below the main emission peak

5 Experimental results

Time-resolved PL (dependence of emission on time)



6 Conclusions

- Long range exciton transport induced by exciton-exciton dipolar repulsion at low temperatures (up to 100 μ m)
- Exciton transport is mainly dominated by drift due to the repulsive dipole-dipole interaction
- High temperature transport is hindered by nonradiative decay: mean exciton transport distance decreases with increasing temperature due to nonradiative decay (nonradiative horizon)
- Estimated speed of exciton flow in our structure is 2 m/s.

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[2] Y. Y. Kuznetsova, M. Remeika, A. A. High, A. T. Hammack, L. V. Butov, M. Hanson, and A. C. Gossard, All-optical excitonic transistor, Optics Letters, 35 (10), 1587-1589 (2010).