



Półmagnetyczne, niskowymiarowe struktury na bazie GaN

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Plan prezentacji

- Motywacja
- Studnie kwantowe i warstwy na bazie GaN – pomiary z podświetleniem
- Kropki kwantowe GaN/AlGaN i GaN_c/GaN_w (?)
- Podsumowanie

Motywacja

- Kontrola koncentracji nośników w półmagnetycznych studniach kwantowych na bazie GaN poprzez podświetlenie
Cel : sprzężenie ferromagnetyczne jonów w studni

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Observation of a Ferromagnetic Transition Induced by Two-Dimensional Hole Gas in Modulation-Doped CdMnTe Quantum Wells

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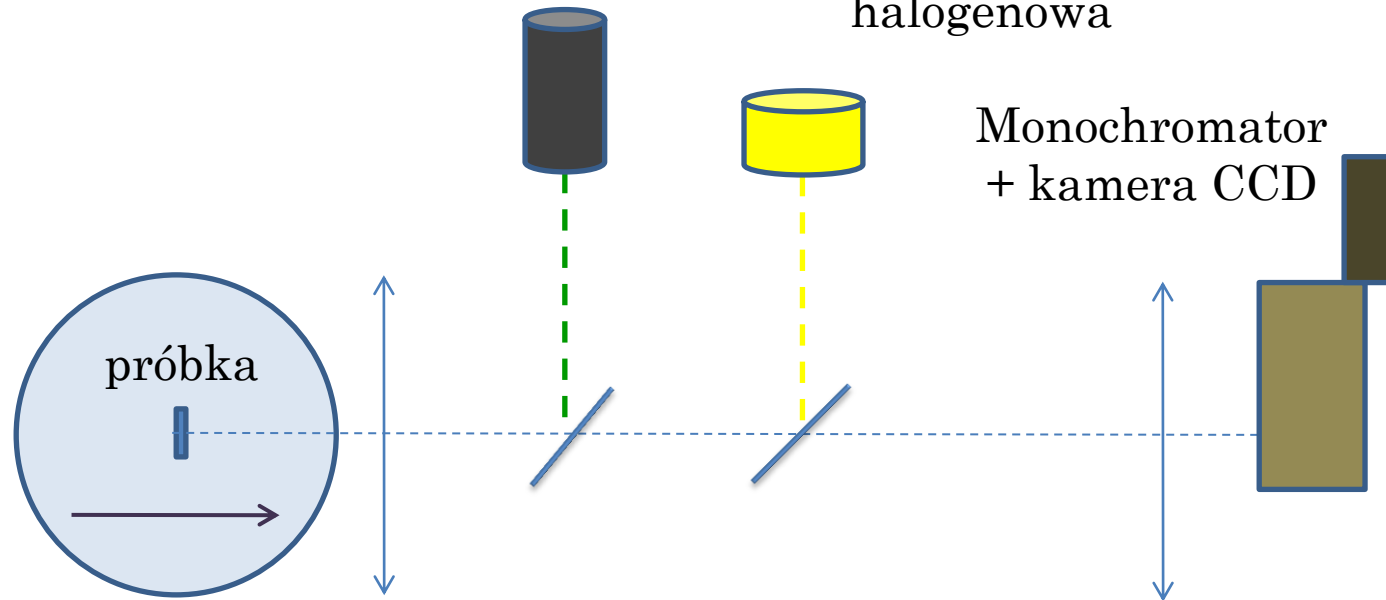
- Kropki kwantowe GaN z manganem dla spintroniki
przy okazji: kropki GaNc/GaNw (?)

Pomiary z podświetleniem

Układ doświadczalny

Podświetlenie: cw 325 nm, 442 nm, 532 nm,
OPO 550 nm, 625 nm

Lampa
halogenowa

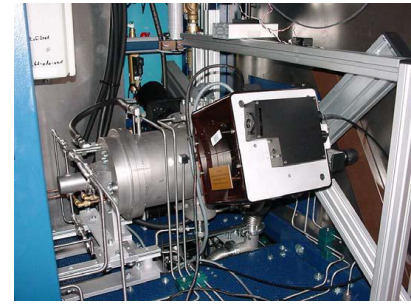


Monochromator
+ kamera CCD

Rozmiar plamki
<0.5 mm

Próbki

- MOVPE, podłoże: szafir, bufor: 1000 nm GaN



Warstwy (Ga,Fe)N

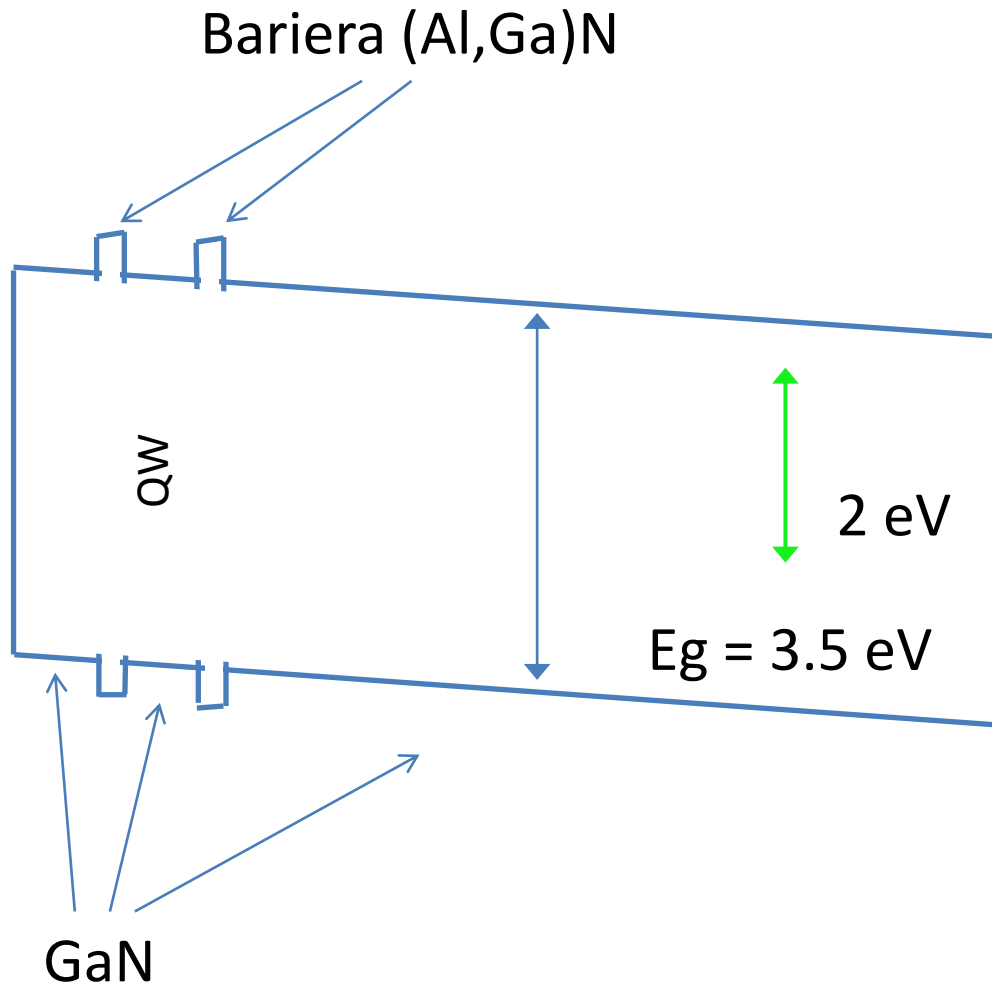
Sample	TMGa (sccm)	Cp2Fe (sccm)	GaN:Fe layer thickness (nm)	Fe _{para} (10 ¹⁹ cm ⁻³)	Fe _{ferro} (10 ¹⁹ cm ⁻³)	T _{growth} (°C)
687	5	300	760	7.6	4.2	850
689	5	100	900	6.2	0.6	800
691	5	300	560	6.4	6.8	950



Studnie kwantowe: GaN i jednorodny (Ga,Fe)N

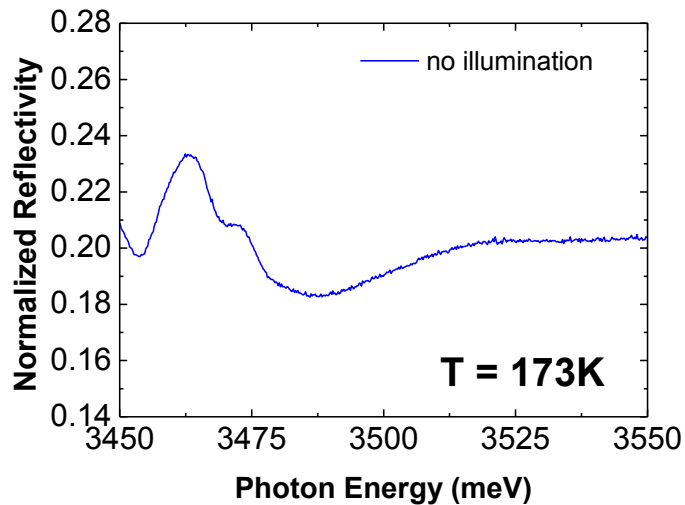
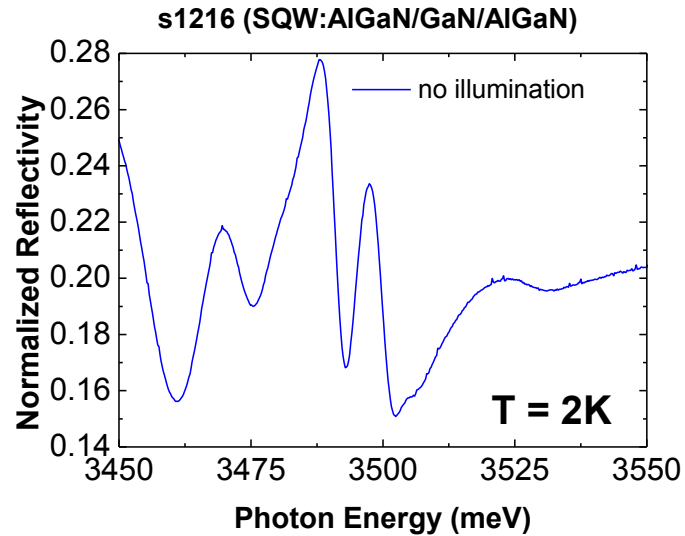
Sample	Structure	Thickness (nm)	GaN cap (nm)	Magn. ion concentr. (10 ²⁰ cm ⁻³)	T _{growth} (°C)
1216	AlGaN/GaN/AlGaN	30/40/30	100	0	820
1218	AlGaN/(Ga,Fe)N/AlGaN	30/40/30	100	1.8	820

Struktura energetyczna próbek ze studniami

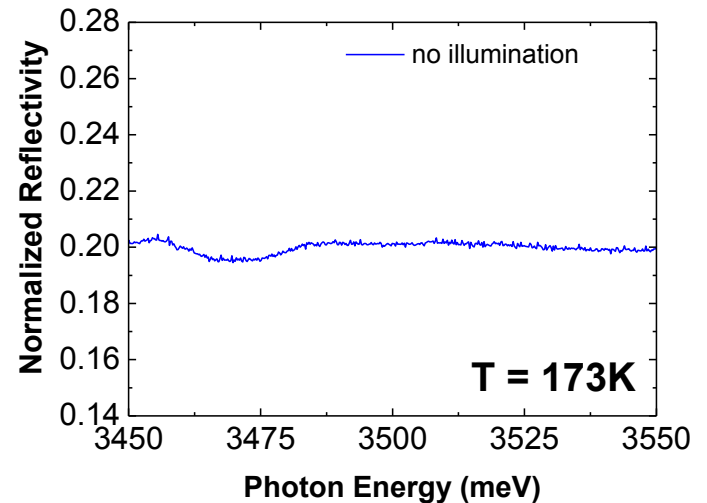
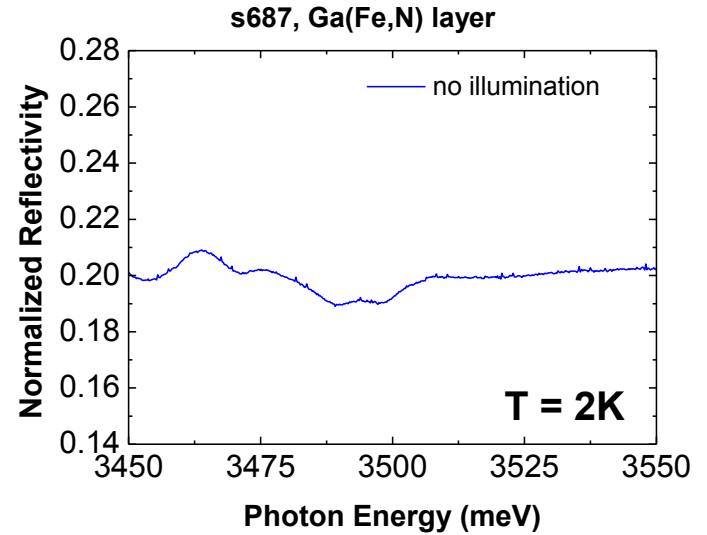


Wpływ podświetlenia na widmo odbicia

Struktura ze studnią

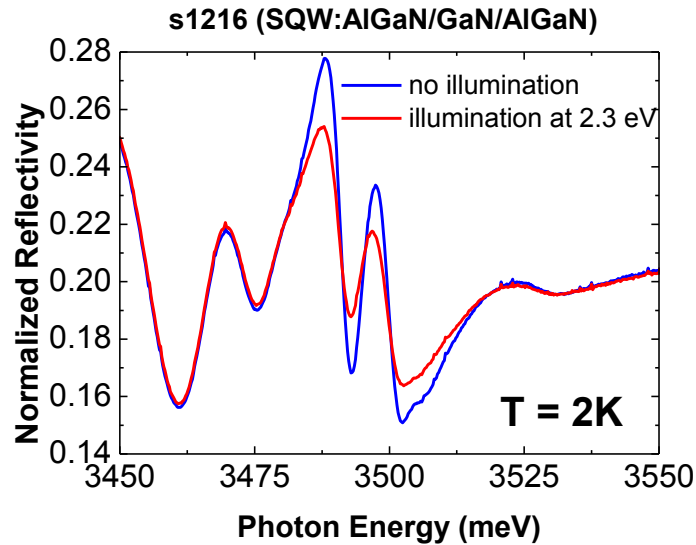


Warstwa

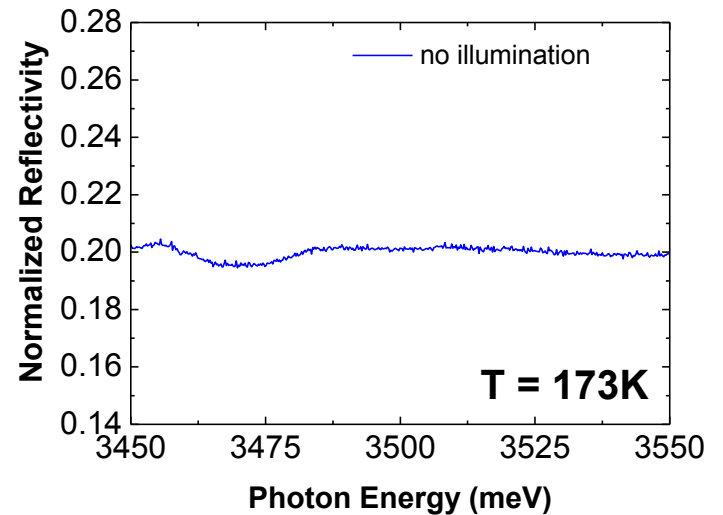
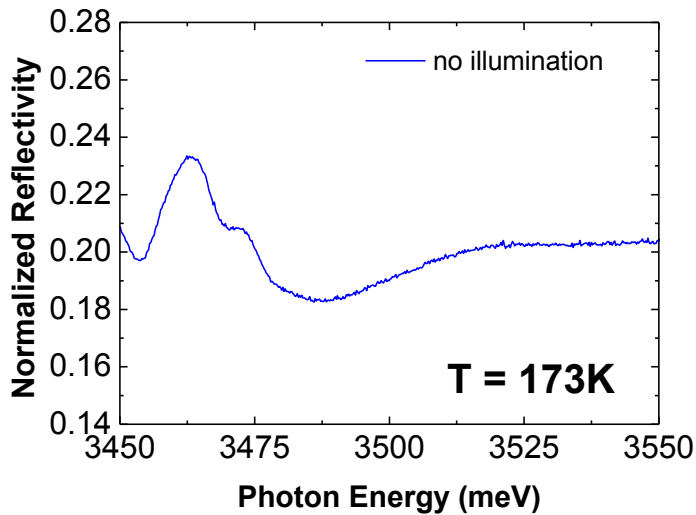
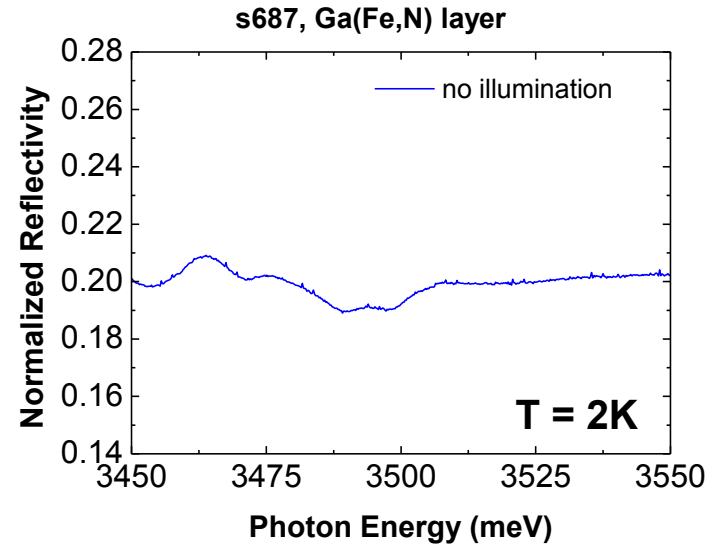


Wpływ podświetlenia na widmo odbicia

Struktura ze studnią

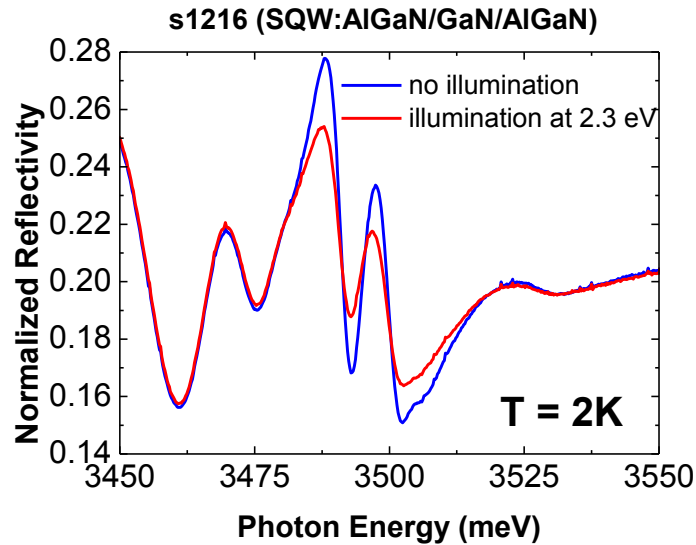


Warstwa

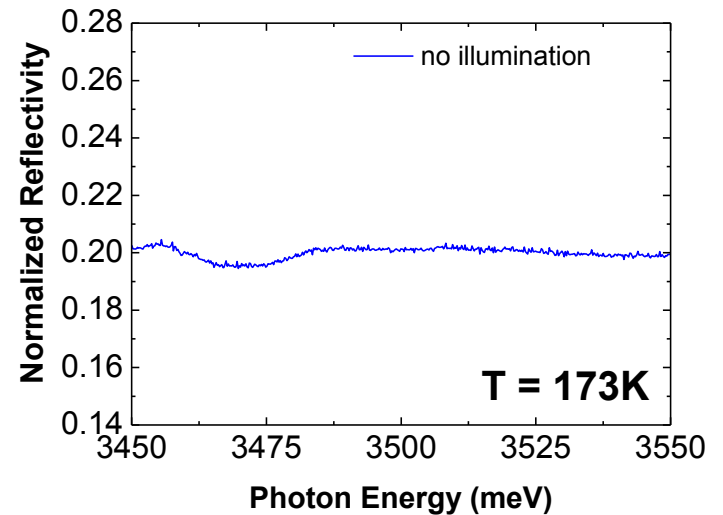
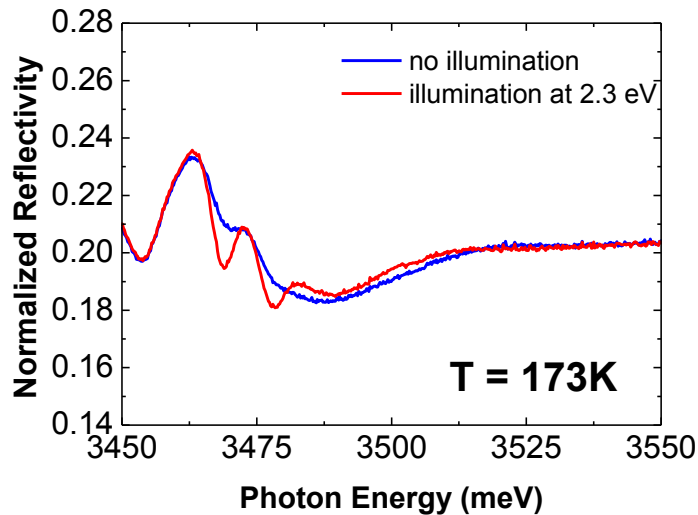
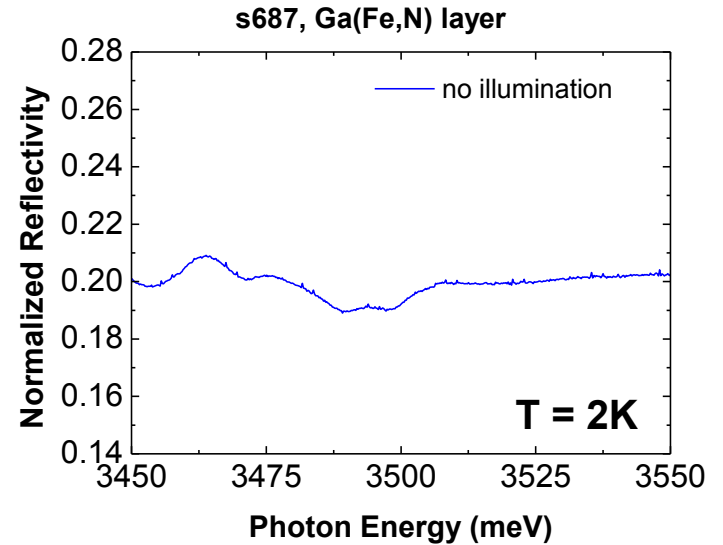


Wpływ podświetlenia na widmo odbicia

Struktura ze studnią



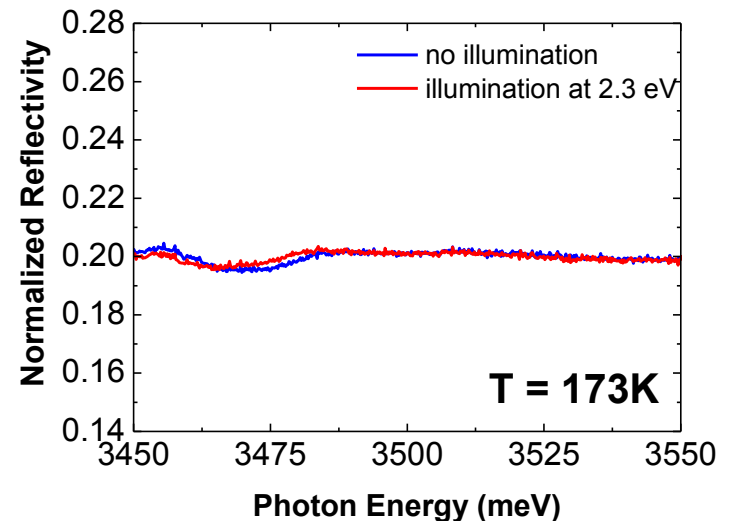
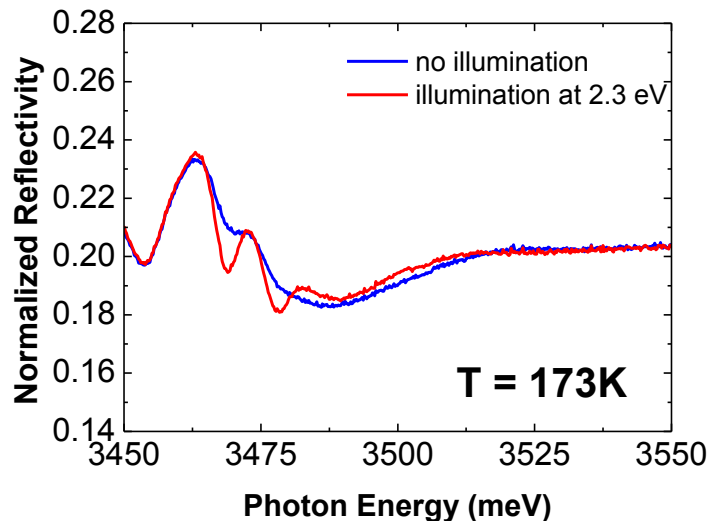
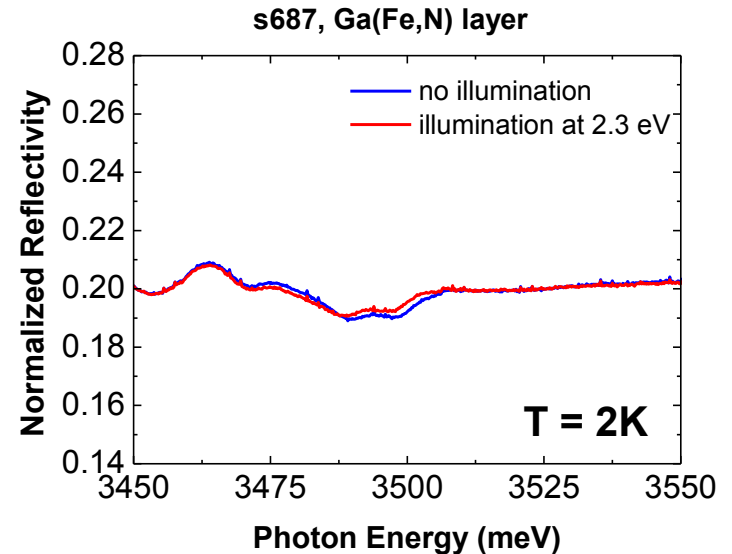
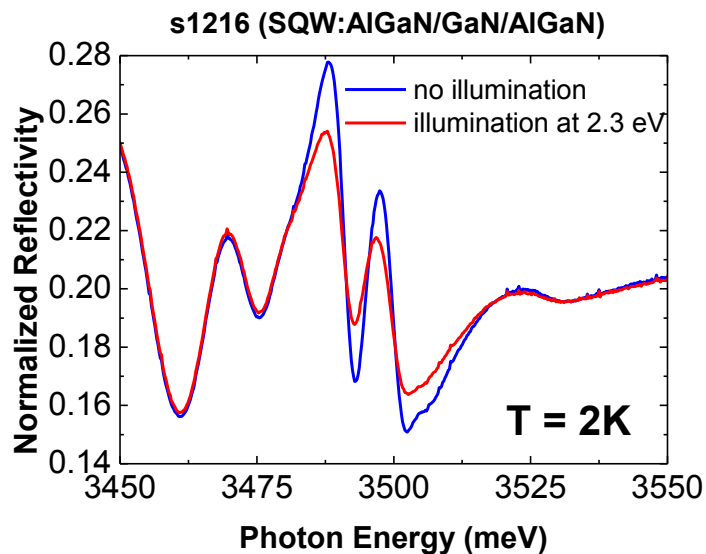
Warstwa



Wpływ podświetlenia na widmo odbicia

Struktura ze studnią

Warstwa

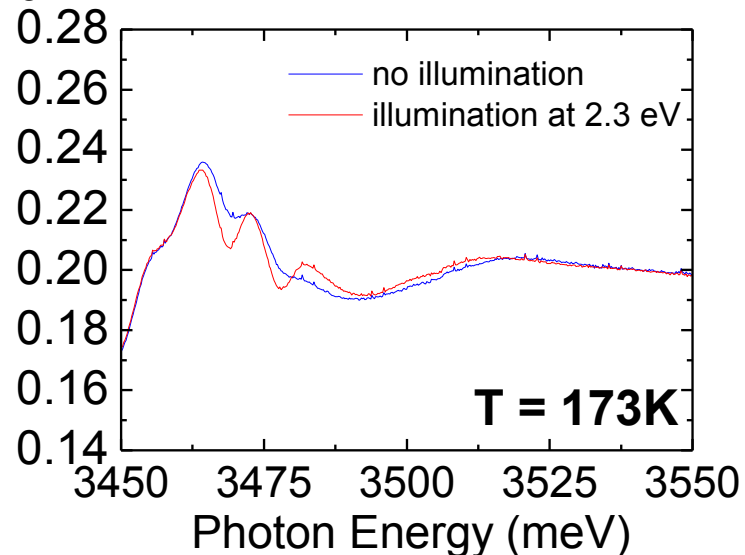
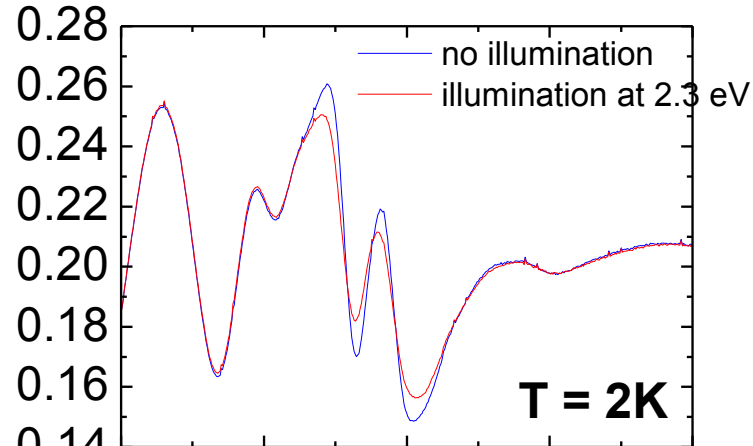


- efekt podświetlenia silniejszy w przypadku struktury ze studnią kwantową niż w przypadku warstwy

Wpływ podświetlenia na widmo odbicia

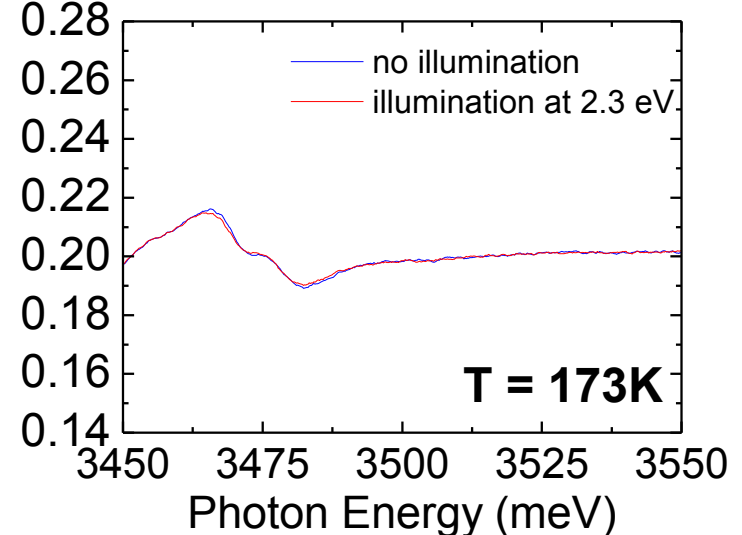
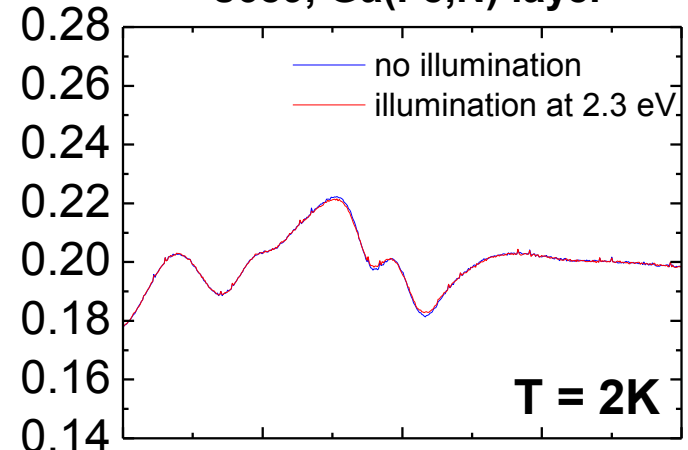
Struktura ze studnią

s1218 (SQW:AlGa_N/Ga(Fe,N)/AlGa_N)



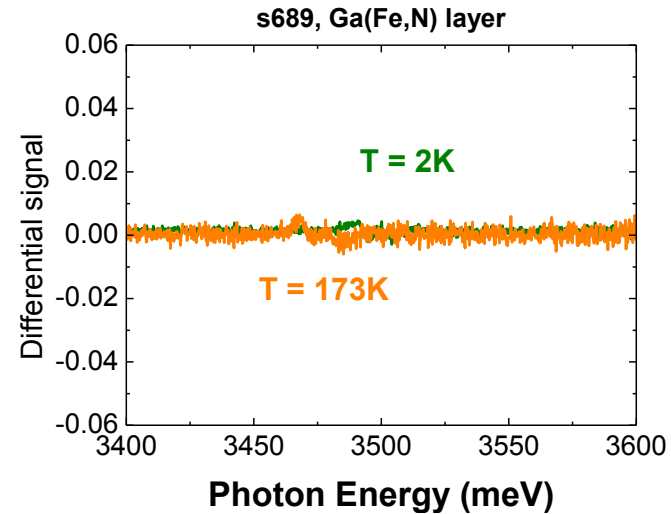
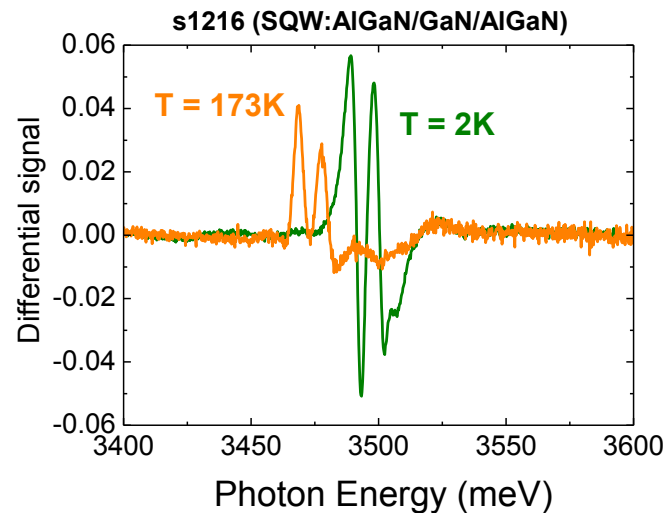
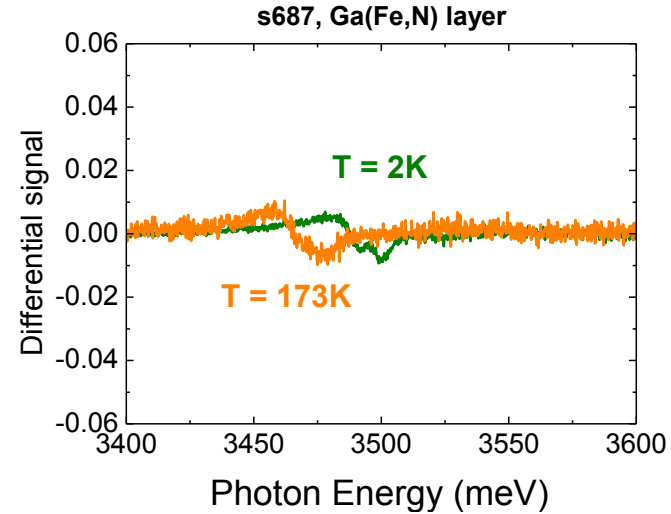
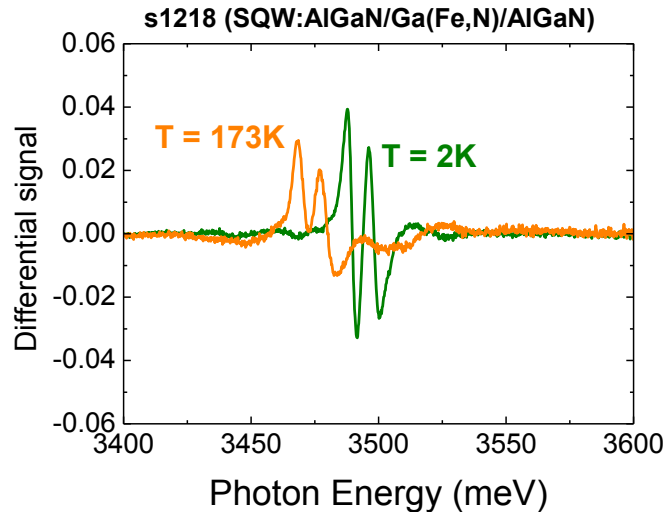
Warstwa

s689, Ga(Fe,N) layer



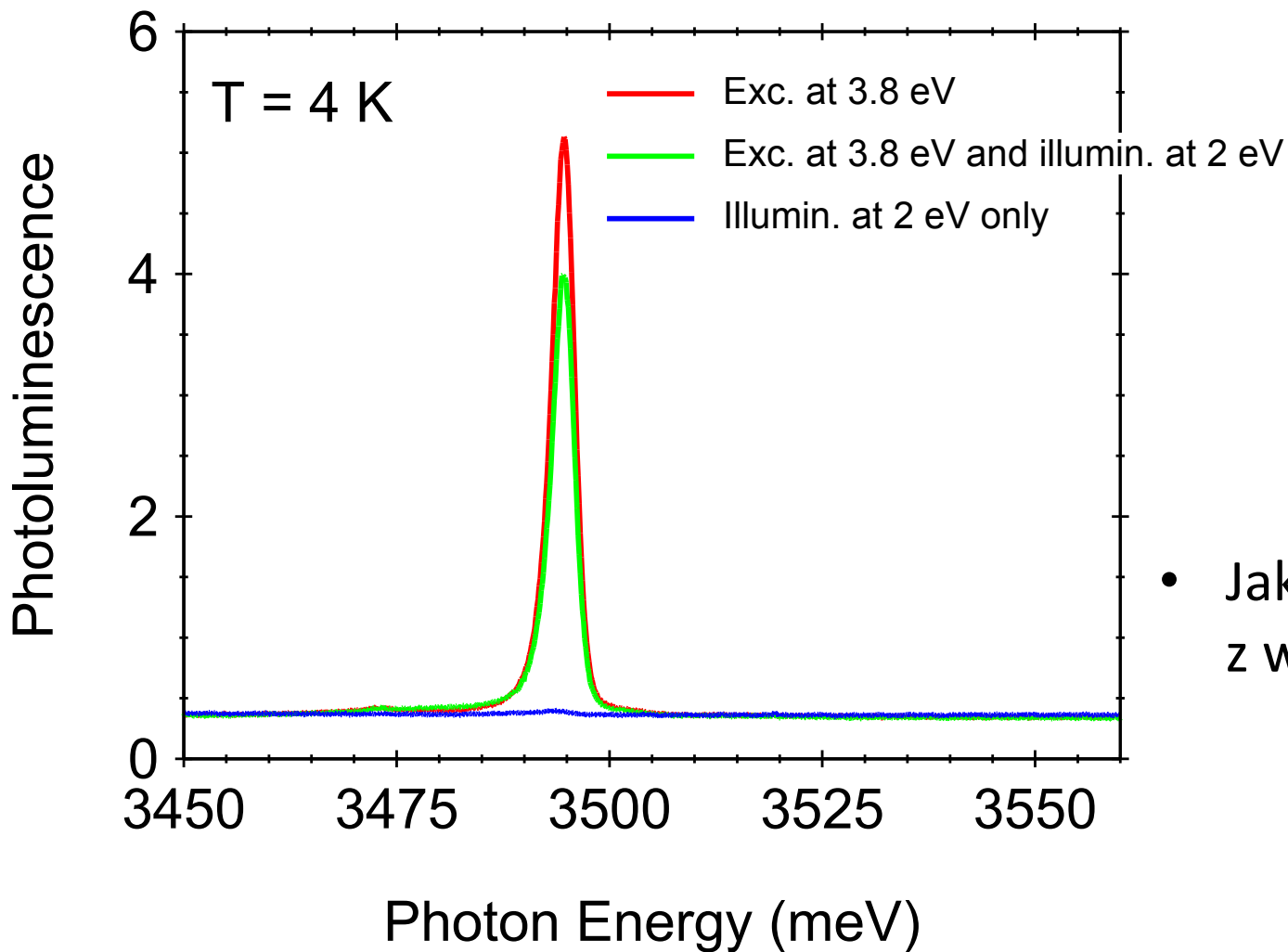
- podświetlanie w T = 2K zmniejsza, a w T = 173K zwiększa intensywność przejść ekscytonowych

Wpływ podświetlenia na widmo odbicia



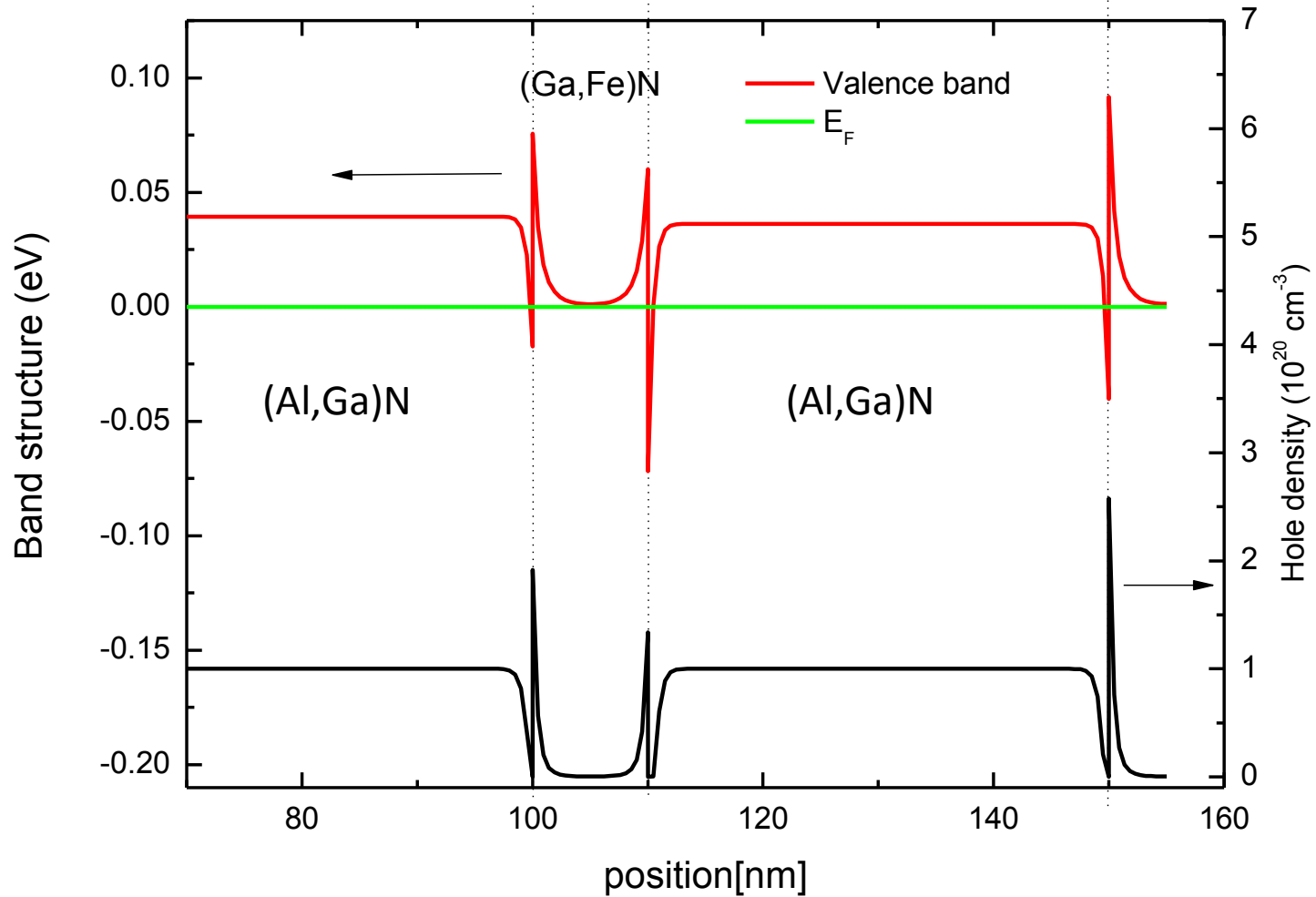
- Natężenie efektu podświetlenia większe w T = 2 K niż w T = 173 K

Wpływ podświetlania na widmo luminescencji s1216

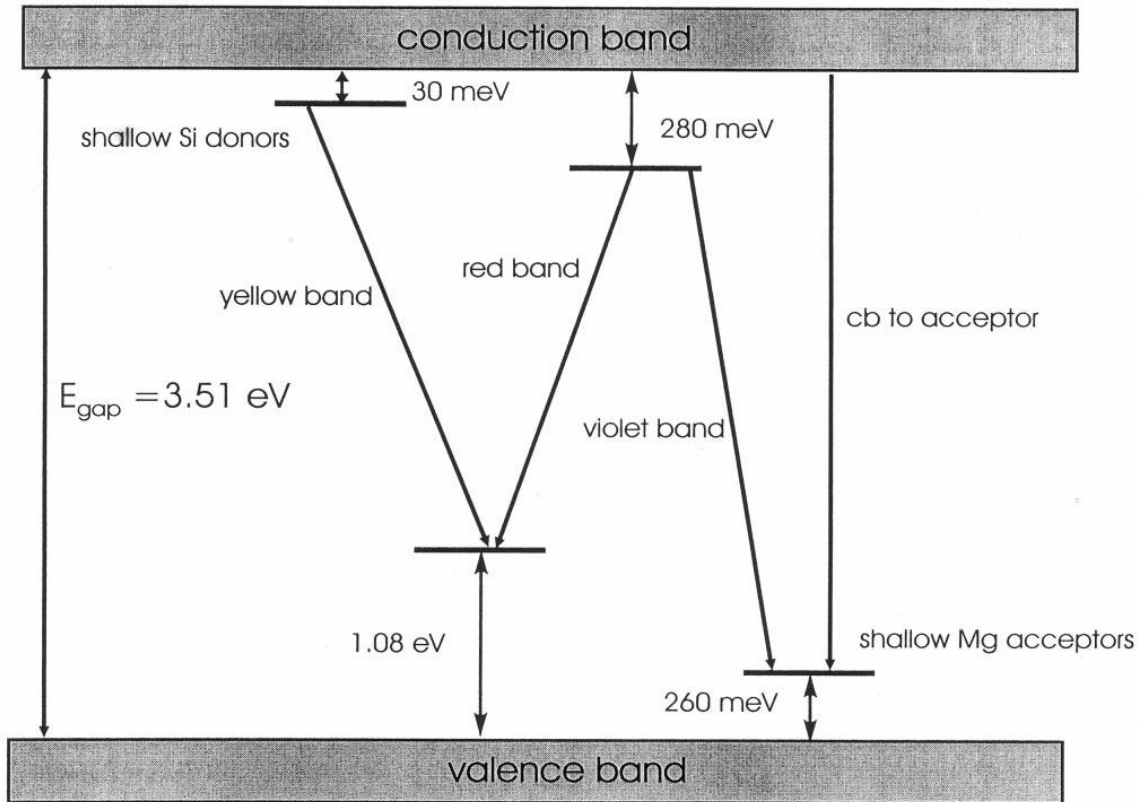


- Jakościowa zgodność z wynikami odbicia

Struktura energetyczna pasma walencyjnego



Domieszki w GaN



Meyer et al., PRB'2000

Mechanizm wpływu podświetlania w energii pod przerwą na widmo odbicia:

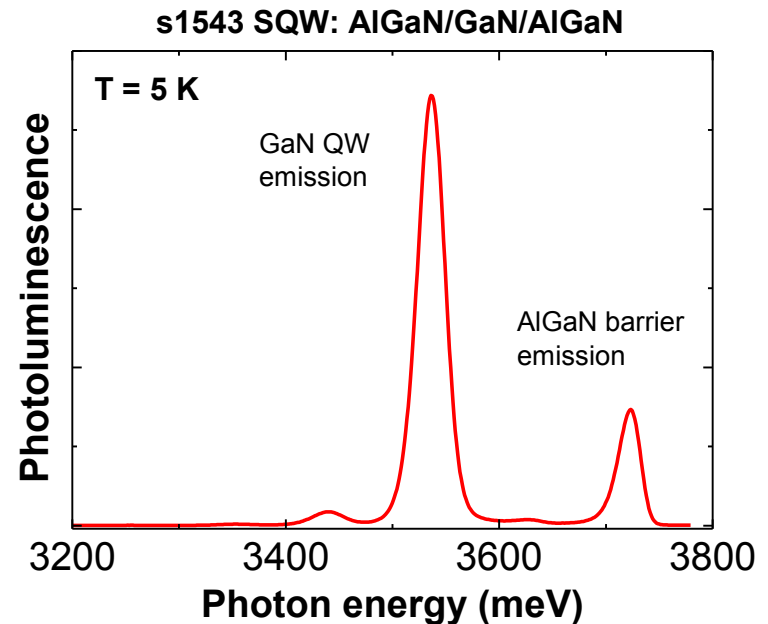
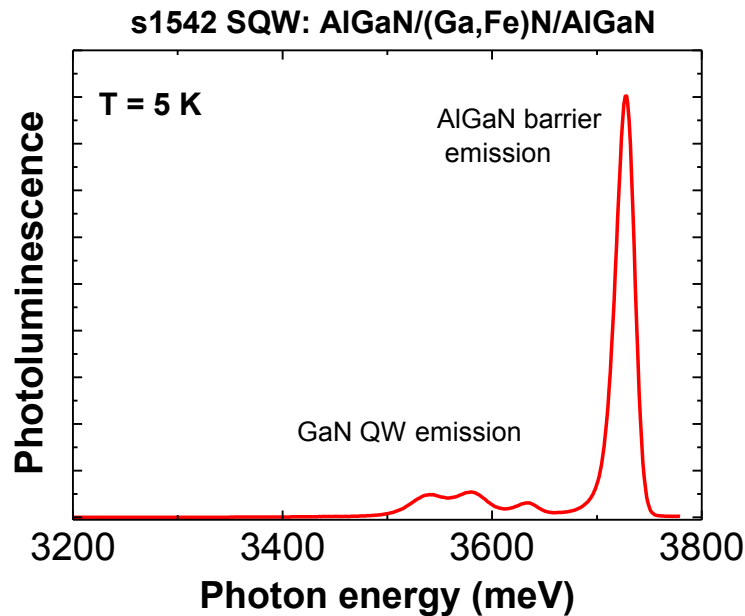
- Fotoaktywacja nośników ze stanów domieszkowych
- Zmiana koncentracji nośników w studni (i na międzypowierzchniach GaN/AlGaN)
- „W niskiej temperaturze (część) procesów fotojonizacyjnych zablokowana?”
- Wyganianie” nośników ze studni i zlokalizowanych na międzypowierzchniach GaN/ AlGaN

Podsumowanie

- Wydajna regulacja koncentracji nośników w strukturach z GaN/AlGaN poprzez podświetlanie w energii poniżej przerwy GaN

Plany

- Nowe próbki, domieszkowane w barierze + podświetlenie:
 - Studnie GaN/AlGaN i (Ga,Fe)N/AlGaN na buforze AlGaN
 - Węższe studnie (2-5 nm)



Semipolarne kropki kwantowe
GaN/AlGaN i GaN_c/GaN_w (?)

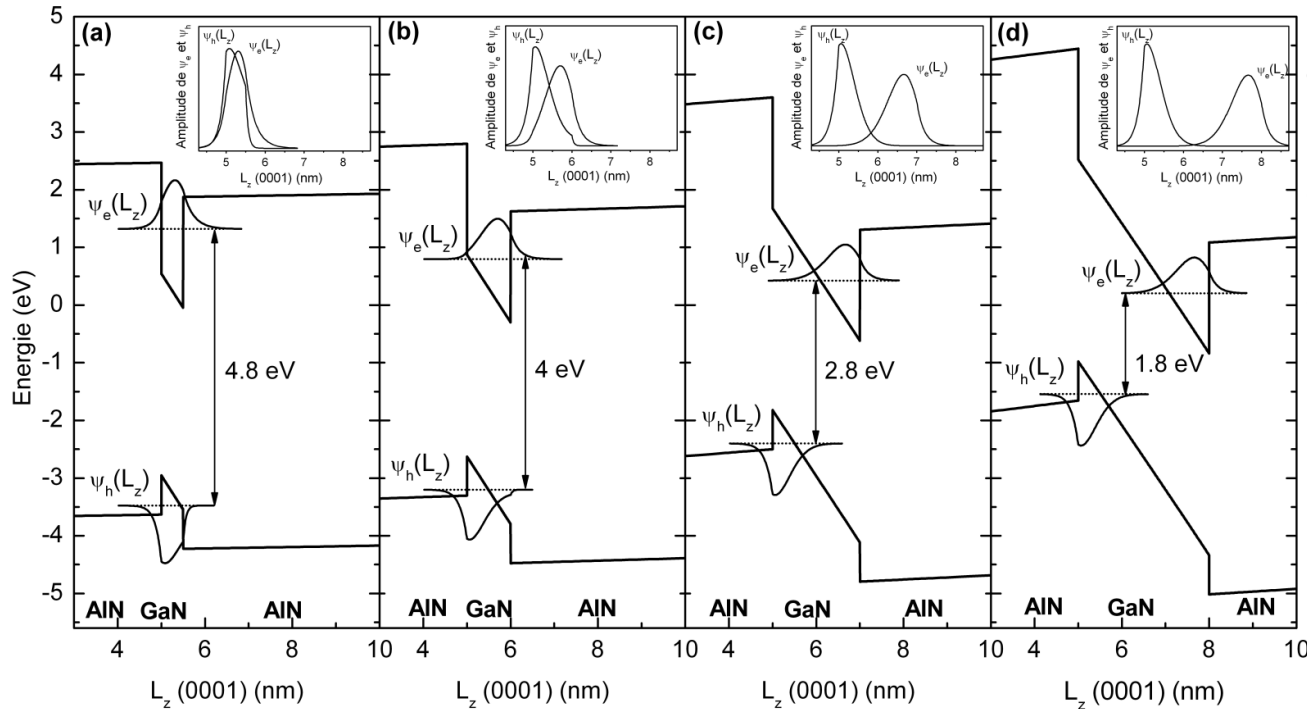
Introduction

Lz = 0.5 nm

1 nm

2 nm

3 nm

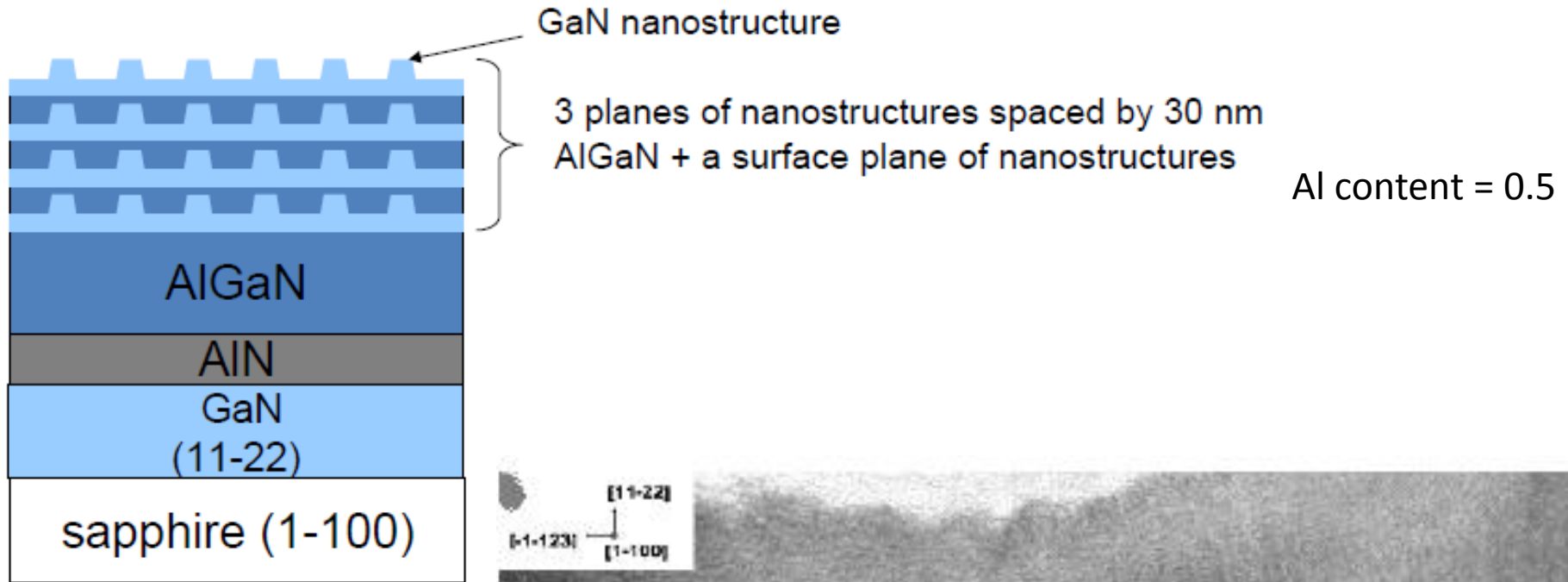


GaN/AlN
polar QWs

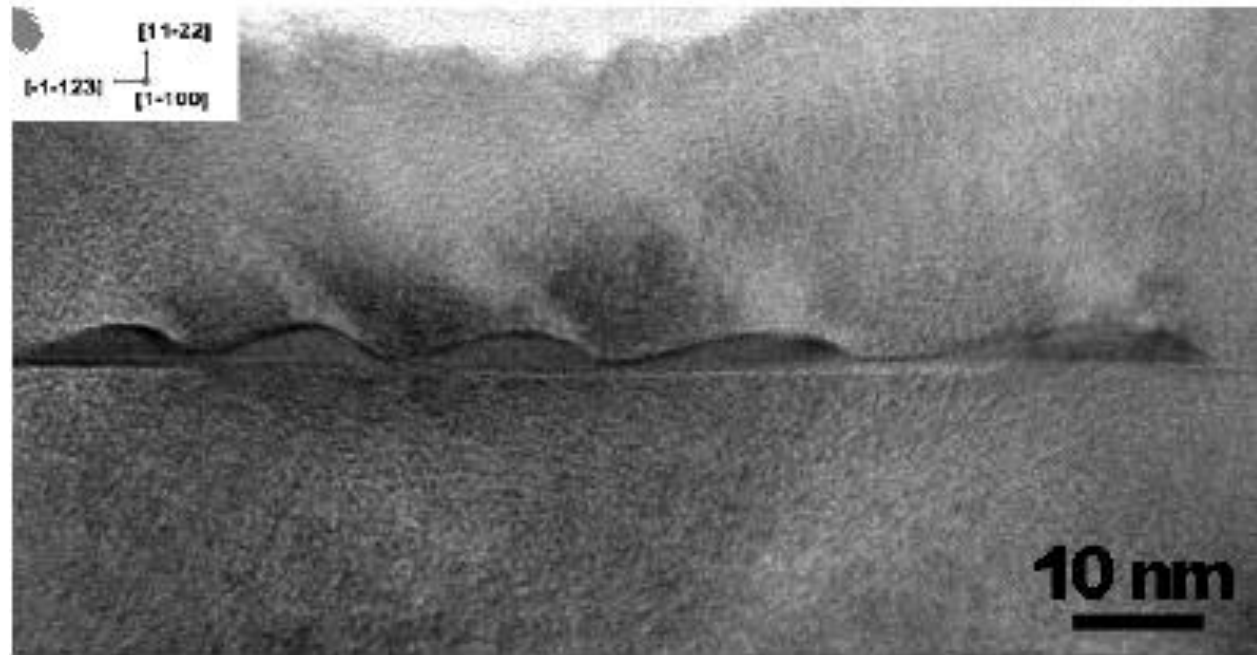
Fabian Rol, PhD Thesis 2007

Effects of piezoelectric field reduce confined exciton oscillator strength →
Growth on non-polar directions appealing

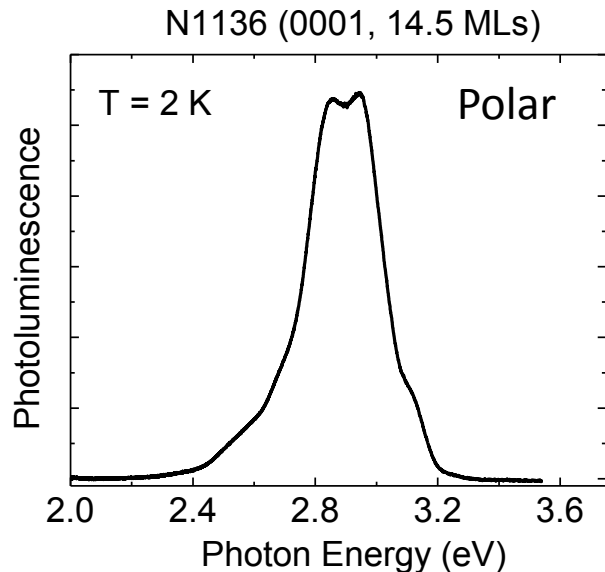
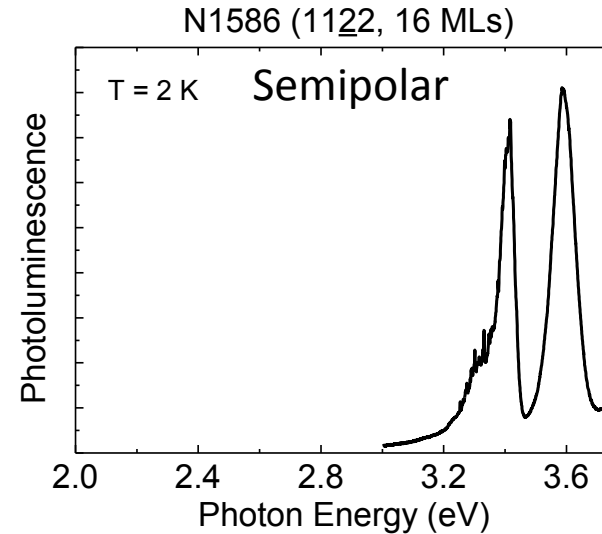
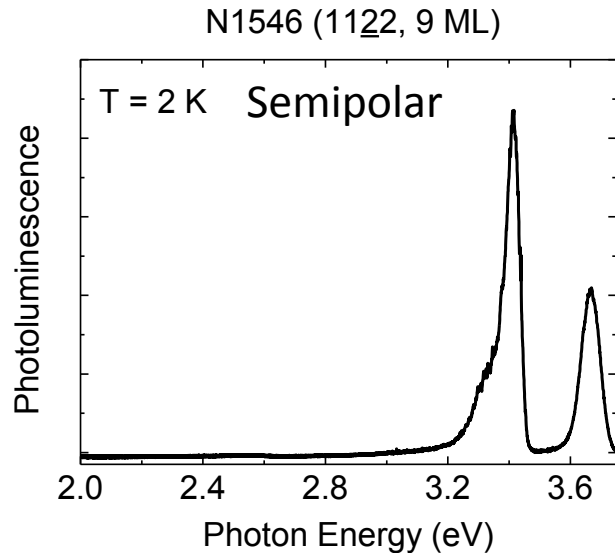
Samples



Próbki na
kierunku 11-22
i jako referencja 0001



Photoluminescence spectra



Semipolar QDs:

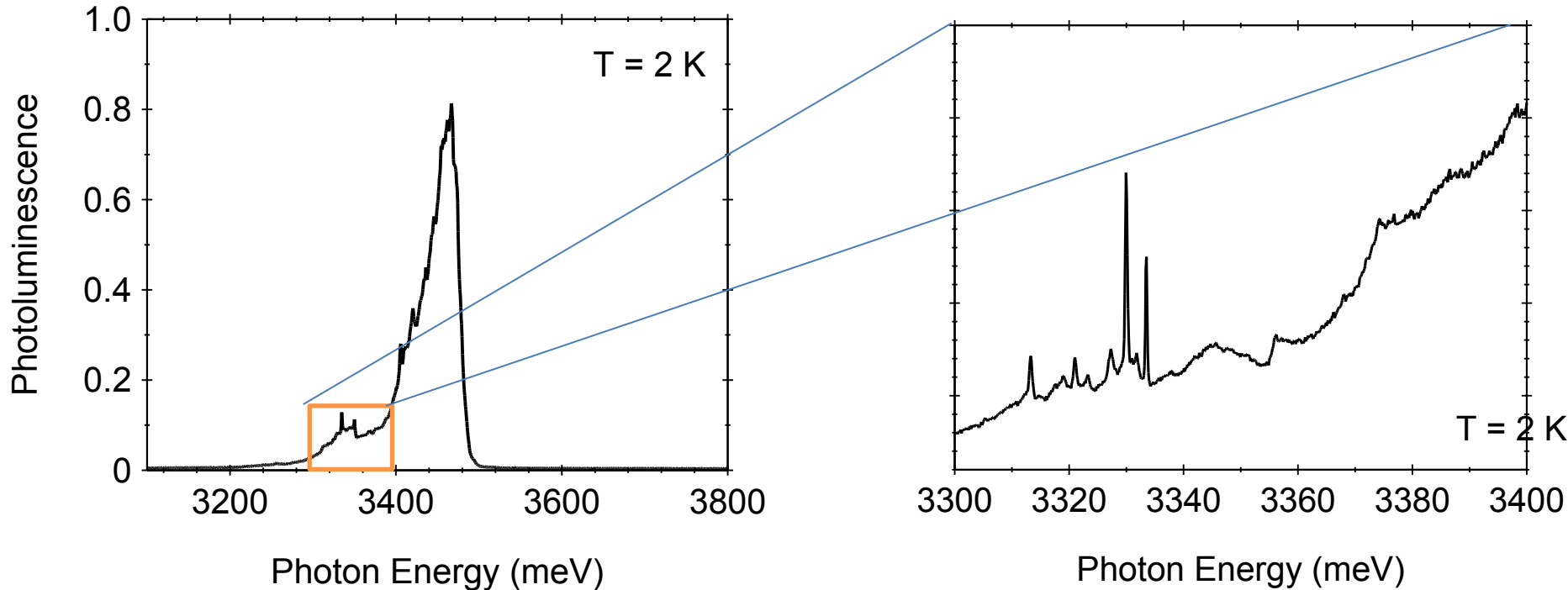
Emission centered at 3.6-3.7 eV, FWHM ~ 0.1 eV

Origin of the emission $\sim 3.25 - 3.45$ eV?

Polar QD:

Emission centered at 2.9 eV, FWHM ~ 0.3 eV

Photoluminescence spectra of GaN template on sapphire



- An evidence for narrow, discrete emission lines!

An origin of the ~3.25-3.45 eV emission band?

- Donor-acceptor assisted e-h recombination

$$E_{\text{photon}} = E_g - E_A - E_D + \sim a/r^2$$

- Defects, stacking faults, dislocations...
- Cubic GaN inclusions in wurtzite GaN

An origin of the $\sim 3.25\text{-}3.45$ eV emission band?

- Donor-acceptor assisted e-h recombination

$$E_{\text{photon}} = E_g - E_A - E_D + \sim a/r^2$$

- Defects, stacking faults, dislocations...
- **Cubic GaN inclusions in wurtzite GaN**

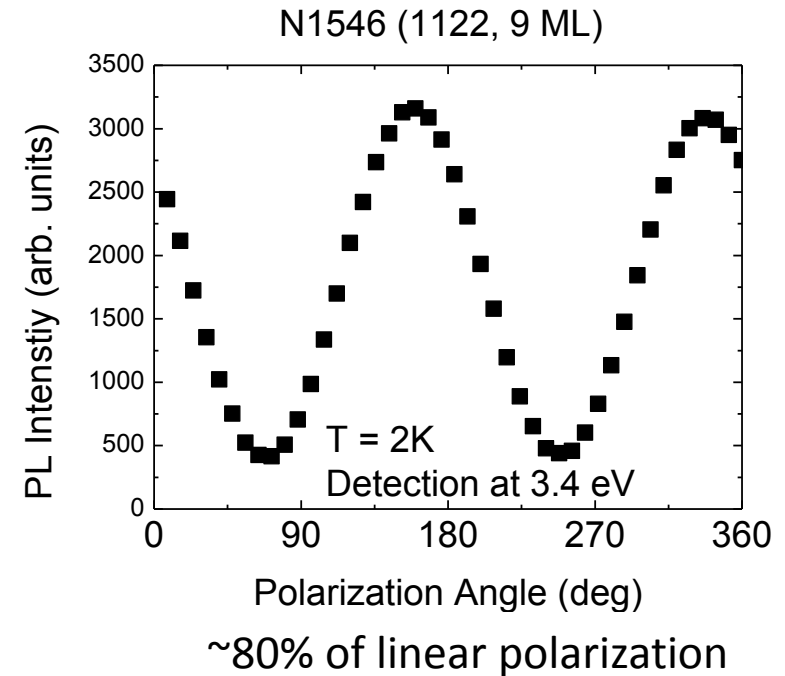
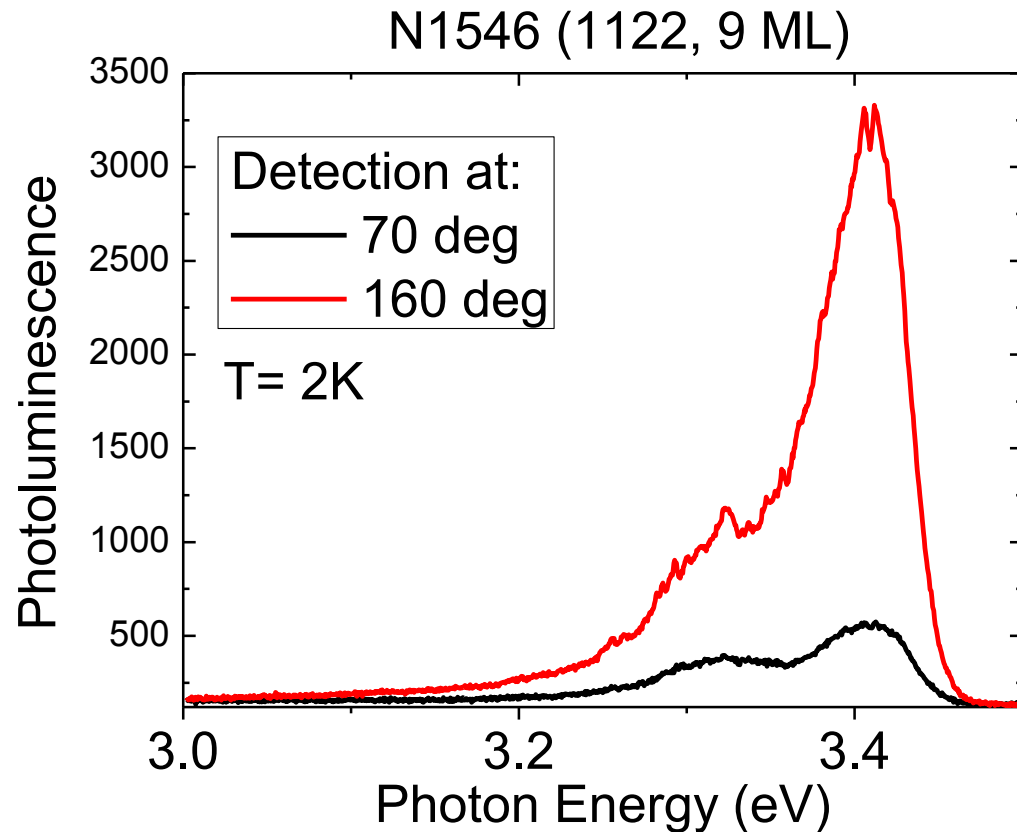
Cubic GaN vs wurtzite GaN

Structure	Zinc blende	Wurtzite
Lattice constant at 300 K	0.450 nm	$a_0 = 0.3189$ nm $c_0 = 0.5185$ nm
Energy Gap at ~ 0 K	3.30 eV Ramirez-Flores et al., 1994, Ploog et al., 1995	3.50 eV Dingle et al., 1971 Monemar 1974

- Energy of emission (~ 3.25 - 3.45 eV) agrees reasonably with an expectation for cubic GaN inclusions in wurtzite GaN

Polarization of the emission

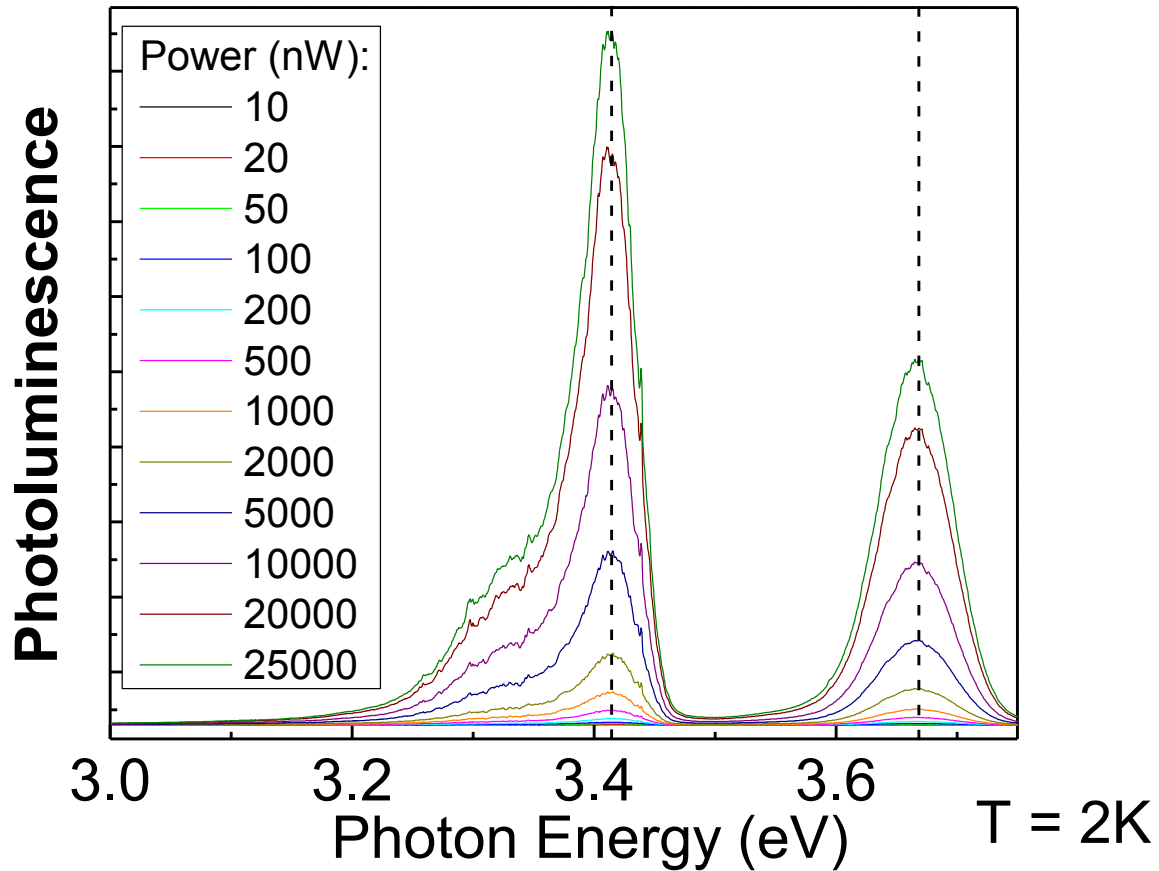
- Emission of the band **not polarized** in the case of **GaN template** on sapphire



- Strongly **polarized** emission of the band in the case of **AlGaIn covered GaN template**
→ Indication for strain induced anisotropy, thus for finite dimensions of the emitter

Emission vs Power

N1546 (1122, 9 ML)



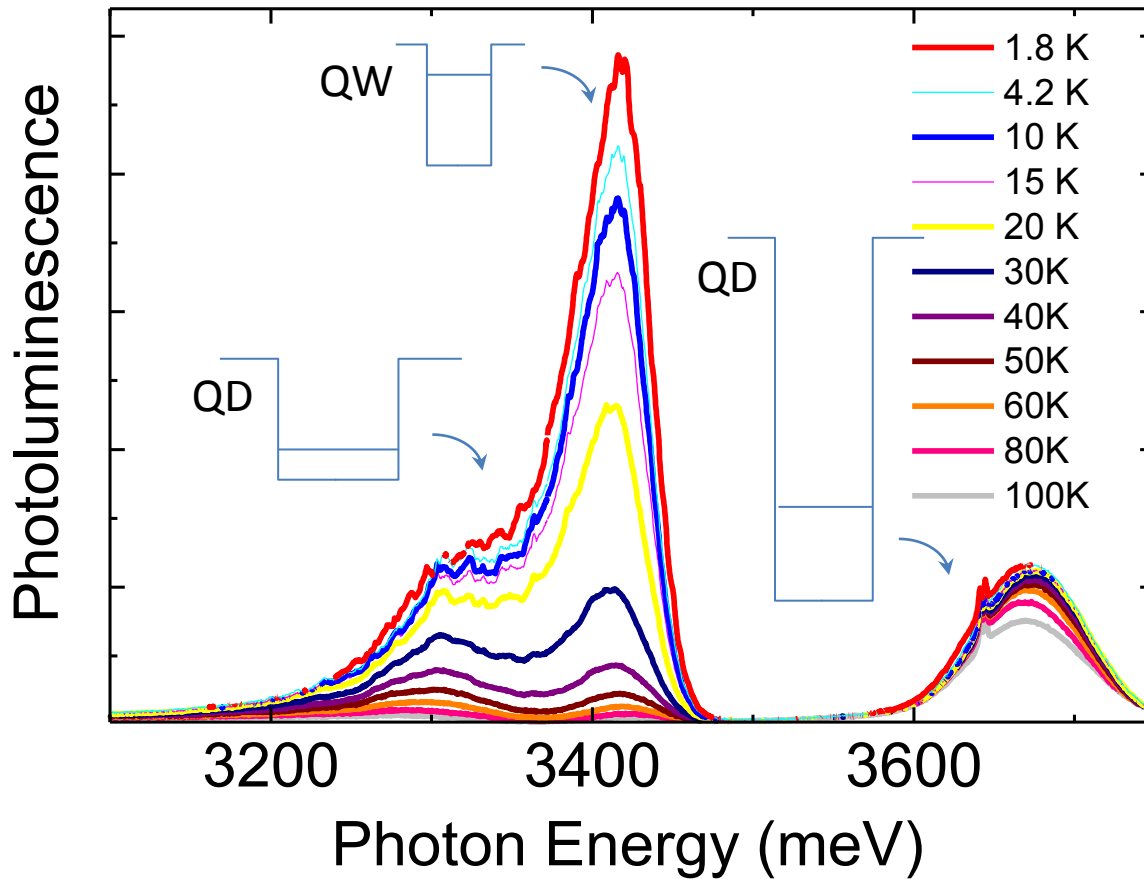
The lack of the spectral shift towards higher energies when power increased:

→ a hint against donor-acceptor recombination

→ negligibly small electric field in the structure:
spontaneous polarization compensated by piezo polarization in a cubic material

Photoluminescence vs temperature

N1546 (1122, 9 MLs)



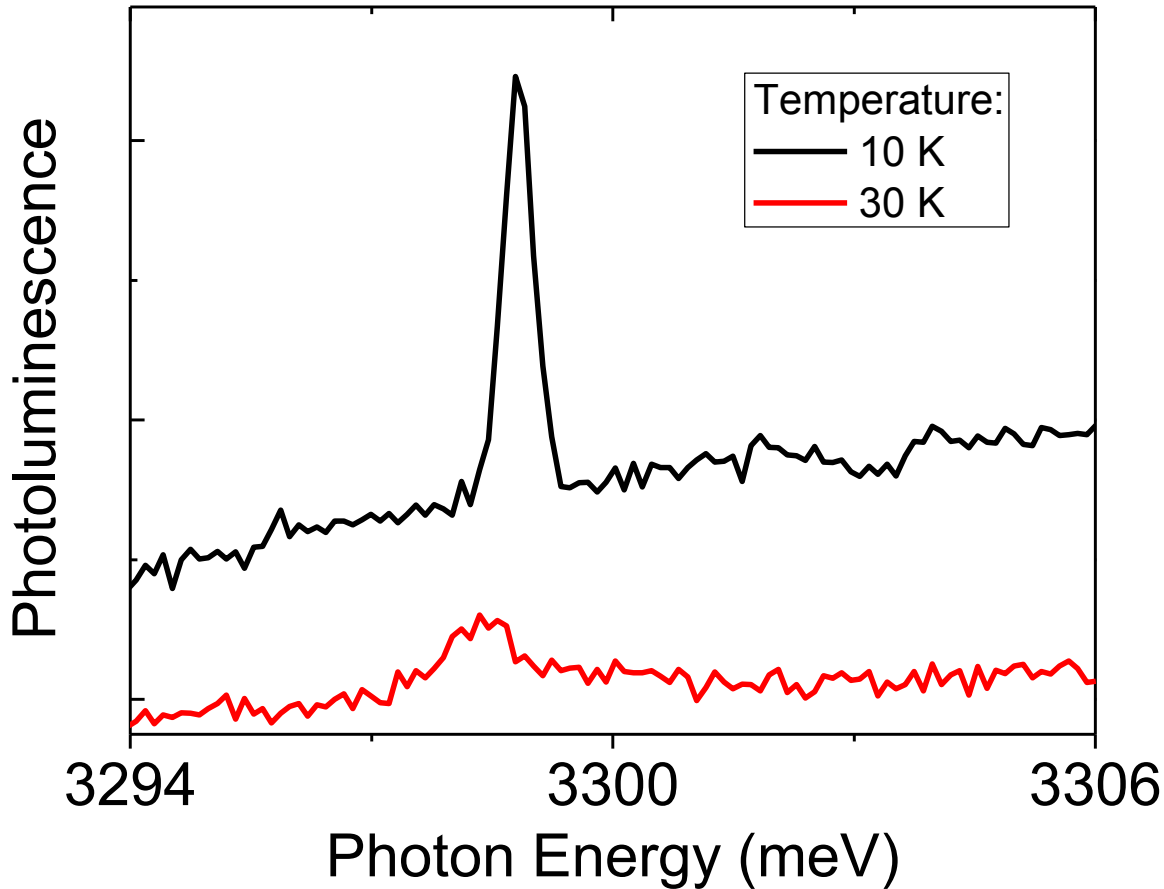
GaN/AlGaN QDs:
Deep confining potential

GaNc/GaNw QDs:
Shallow potential

An evidence for a wetting layer?

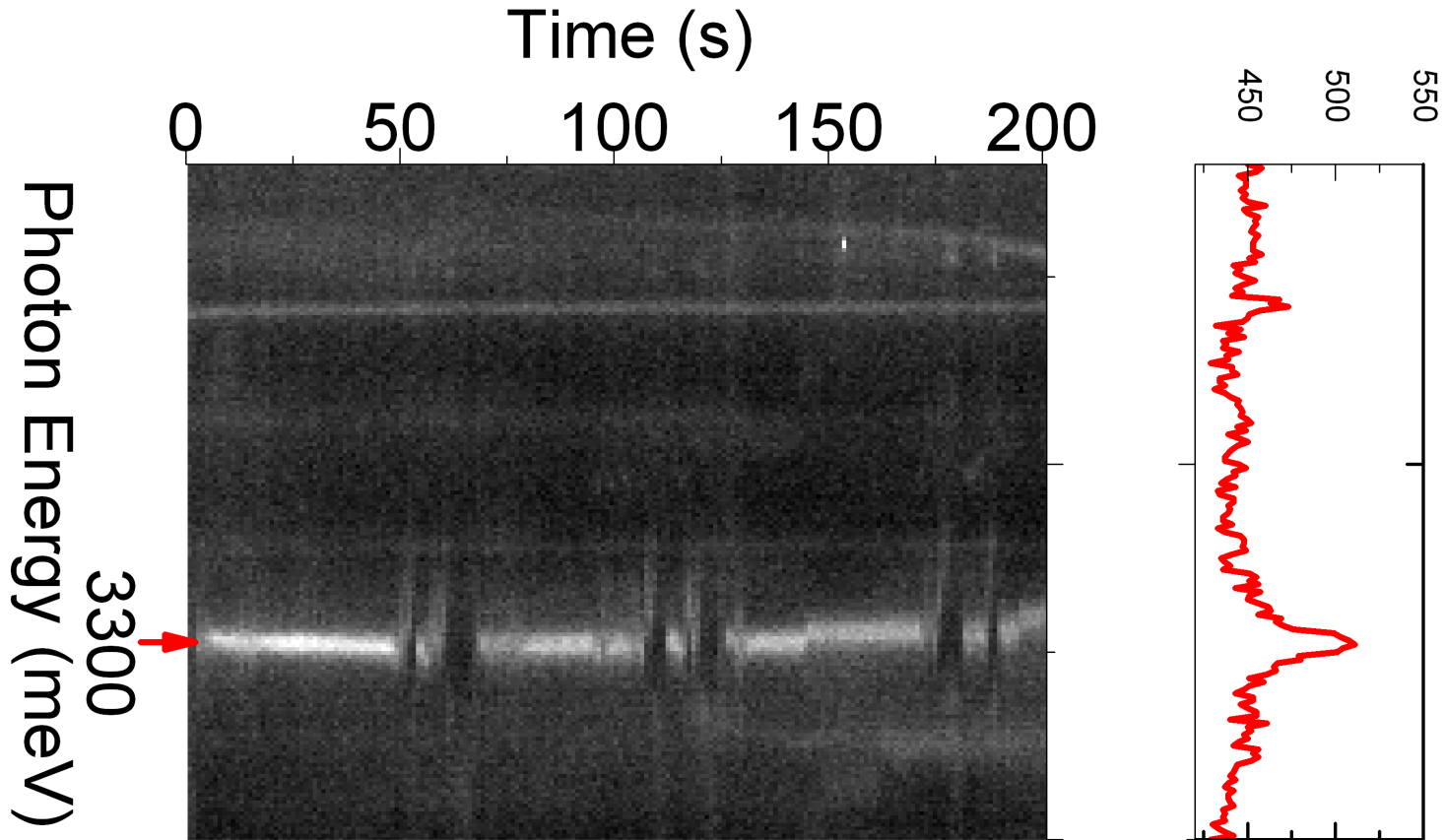
Photoluminescence vs temperature

N1546 (1122, 9 MLs)



- Shift towards lower energies and line broadening with increasing temperature

Spectral wandering



- The emitter is sensitive to a fluctuating electric field in its vicinity

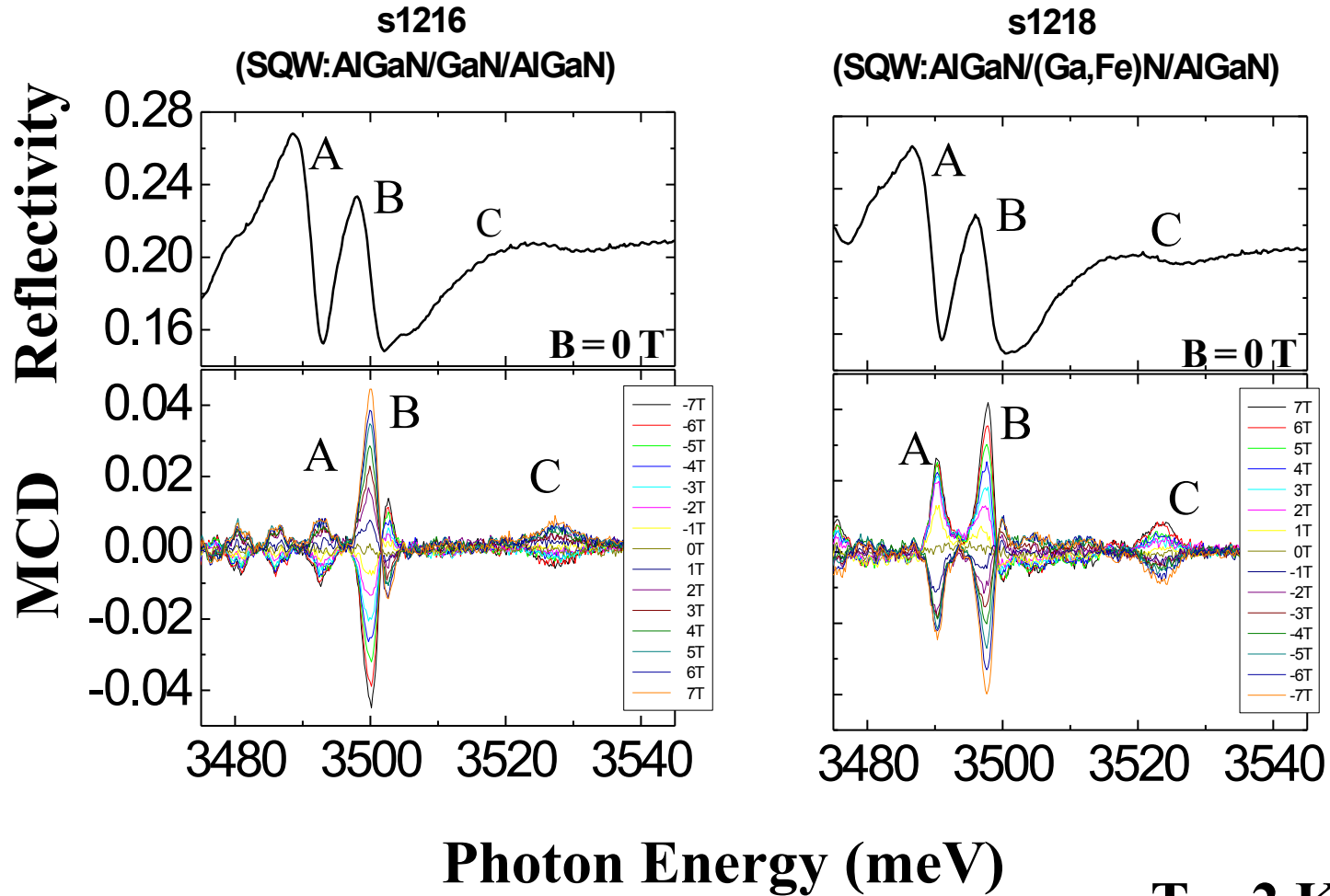
Summary

- Transitions from 3.25 – 3.45 emission band exhibits several features typical for semiconductor QD emission:
 - Linear polarization of emission due to the strain induced anisotropy
 - Spectral shift towards lower energies and broadening with increasing temperature
 - Spectral wandering (?)
 - No spectral shift towards higher energies when excitation power increased

Indications for cubic GaN in wurtzite GaN inclusions (formed out from a cubic GaN wetting layer?)

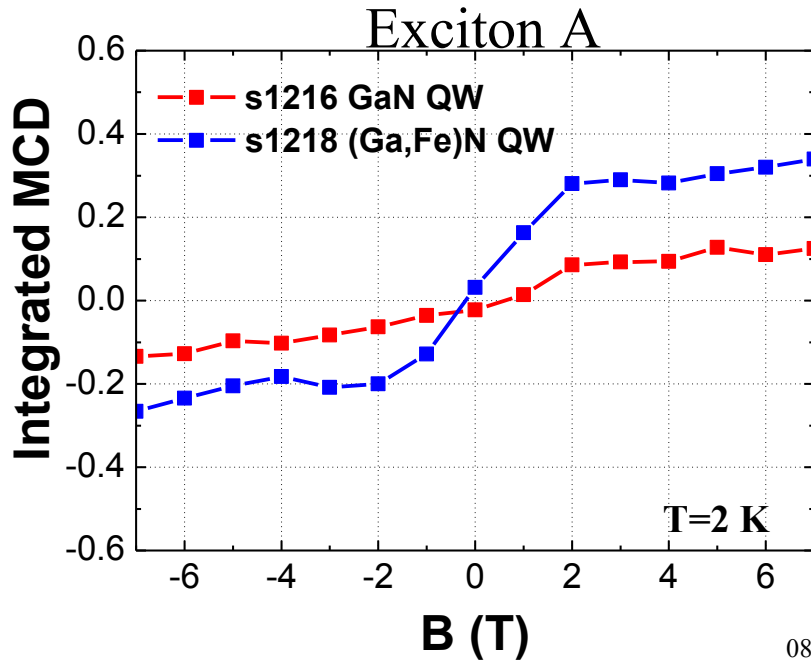
- Energy of the emission
- Negligible electric field within the inclusion (PL vs power)

MCD struktur ze studniami GaN i (Ga,Fe)N

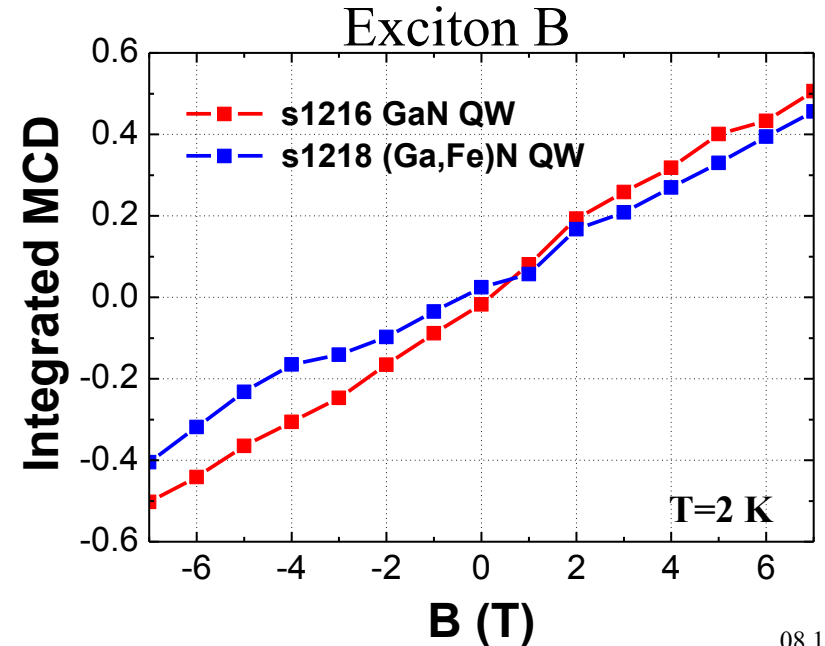


- Szerokie studnie →
- Słaby wpływ związania kwantowego na energię poziomów w studni
- Niezerowe natężenie MCD w rejonie spektralnym ekscytonów A, B i C

Natężenie MCD w funkcji pola B - ekscytony



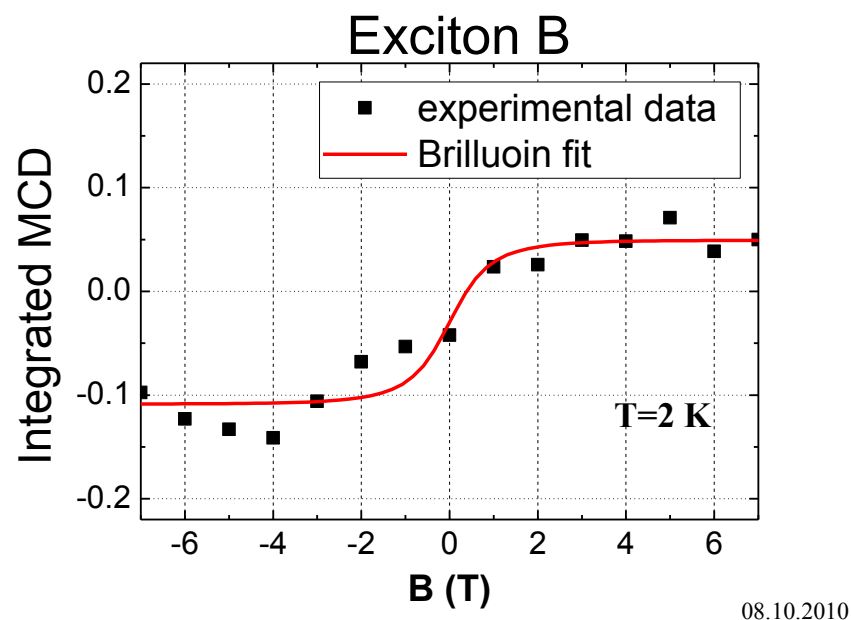
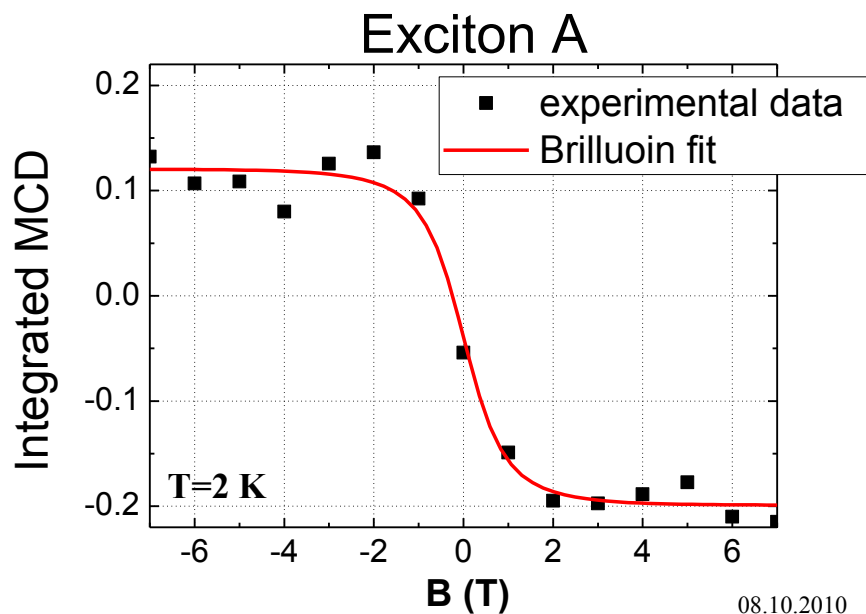
08.10.2010



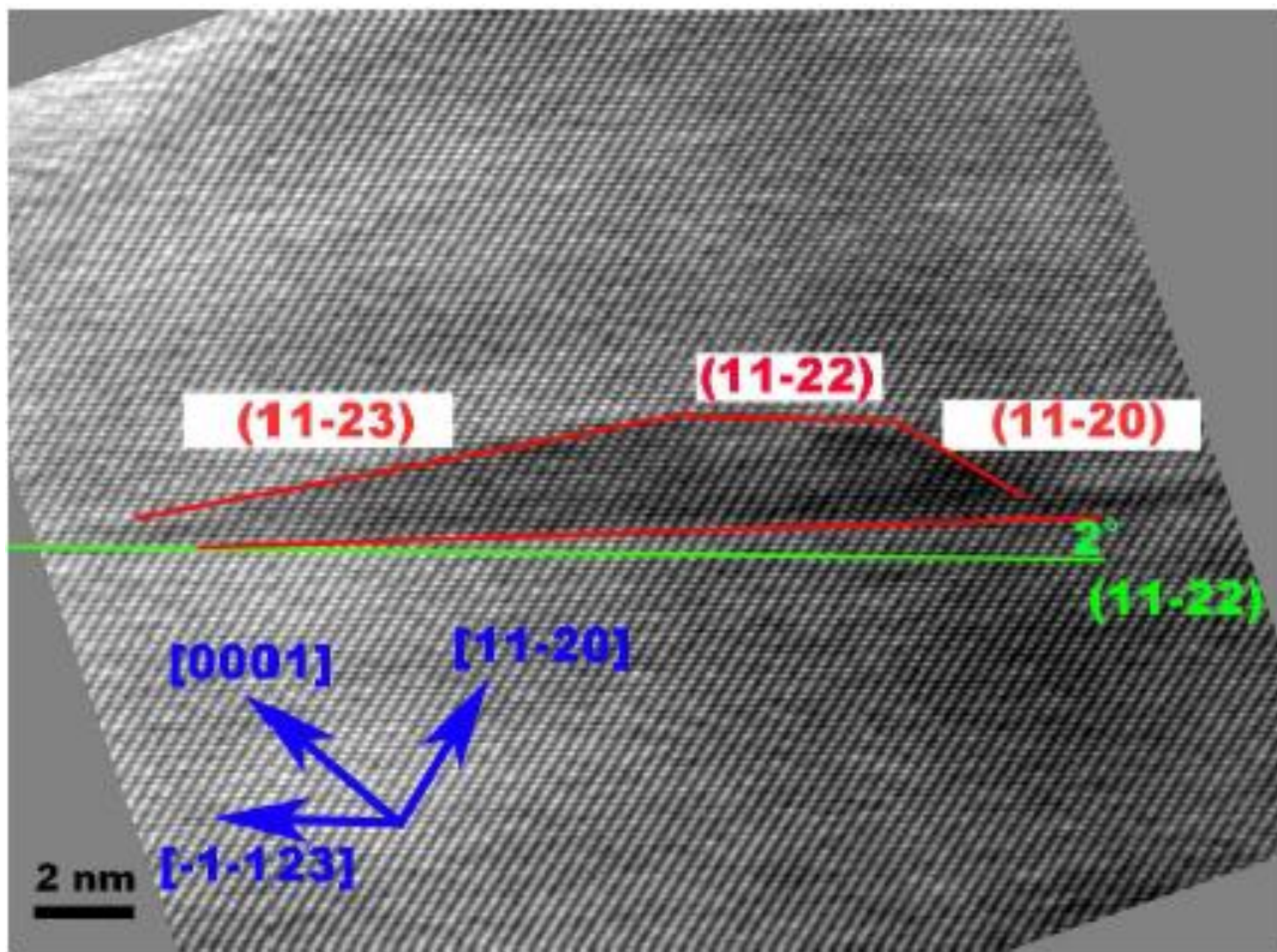
08.10.2010

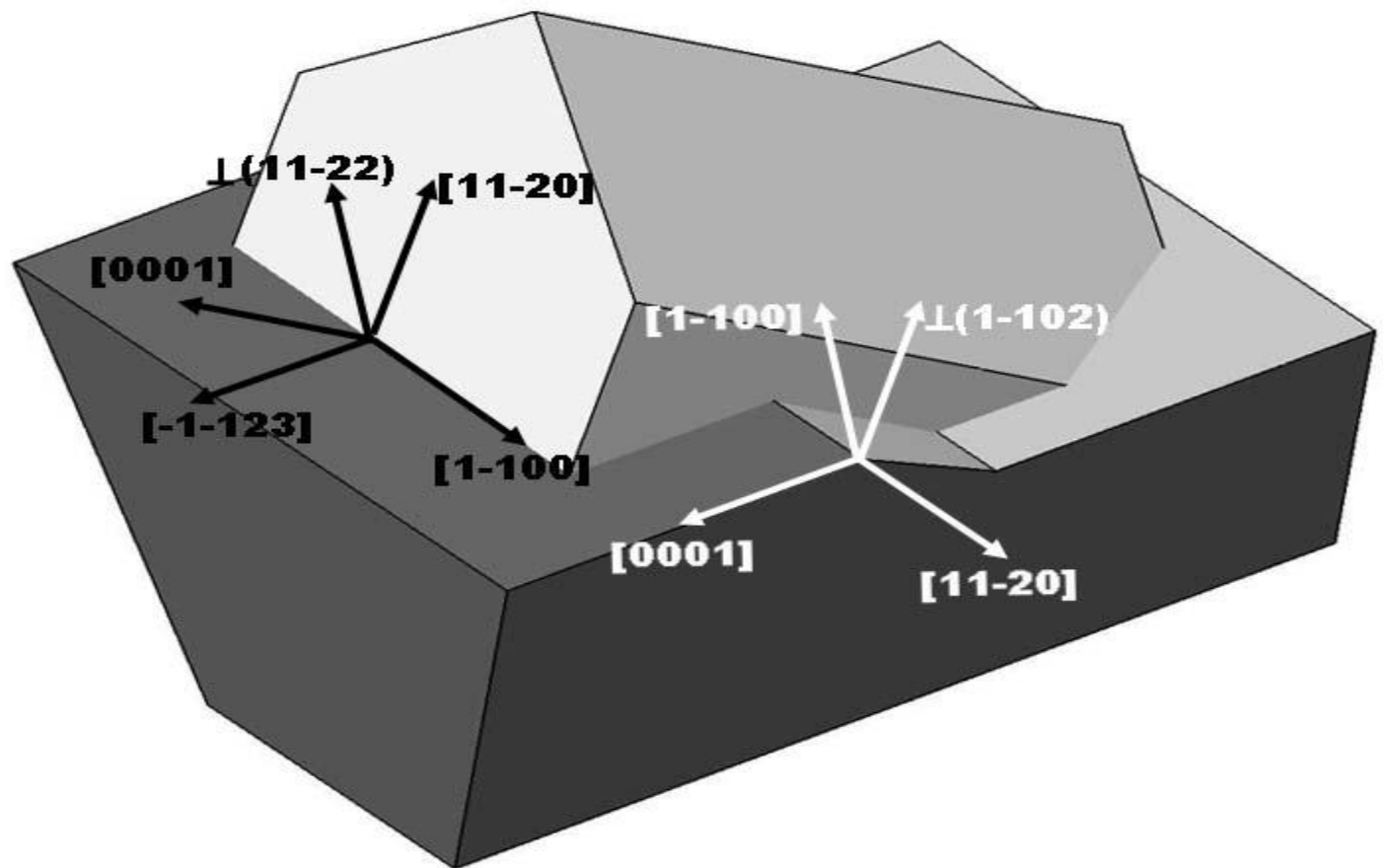
- Dwa wkłady do sygnału MCD w obszarze ekscytonowym:
 - dominujący od bufora GaN
 - od studni GaN

Obserwacja oddziaływania s,p-d w studni (Ga,Fe)N

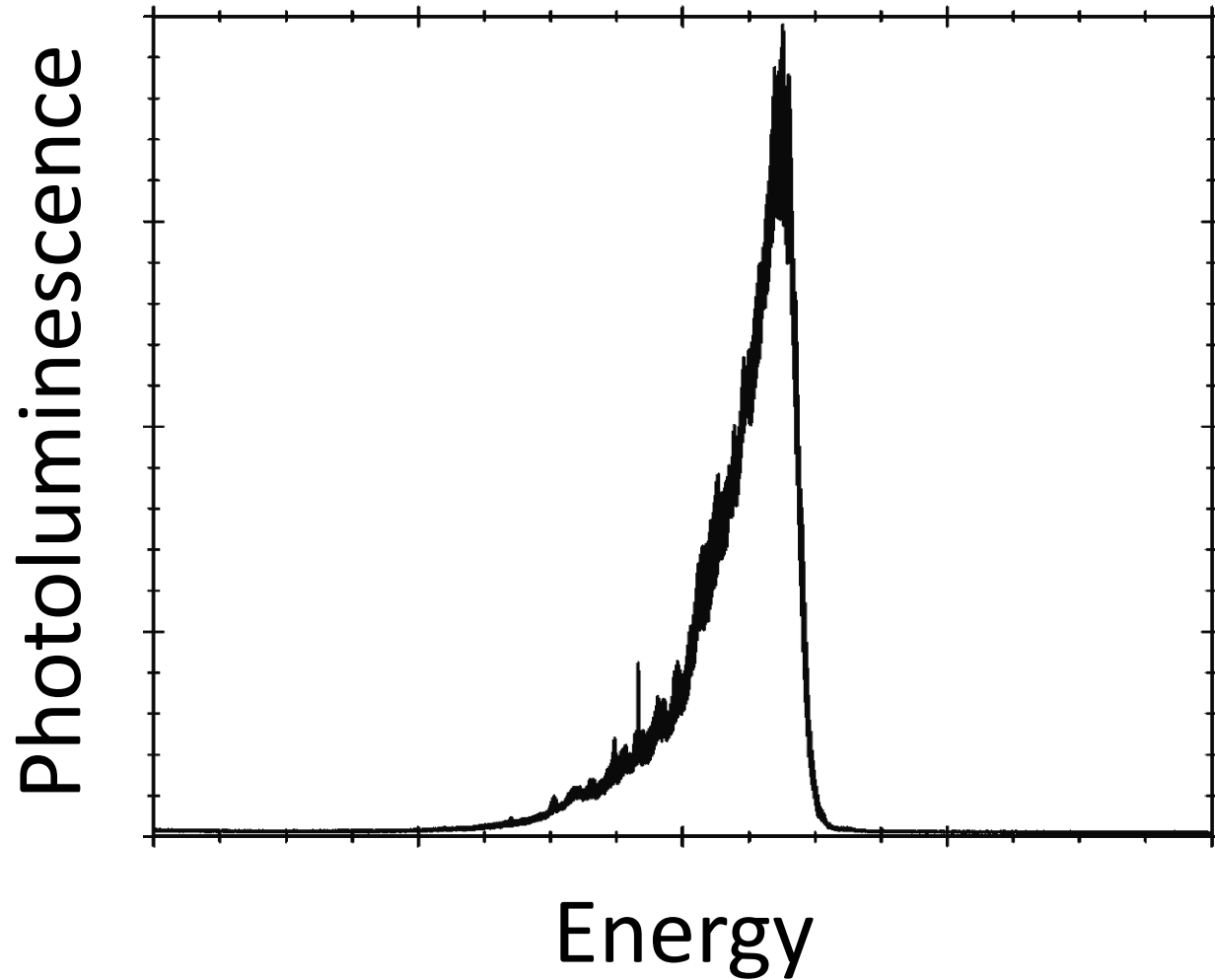


Obserwacja sygnału paramagnetycznego od studni (Ga,Fe)N jakościowo zgodna z oczekiwaniem



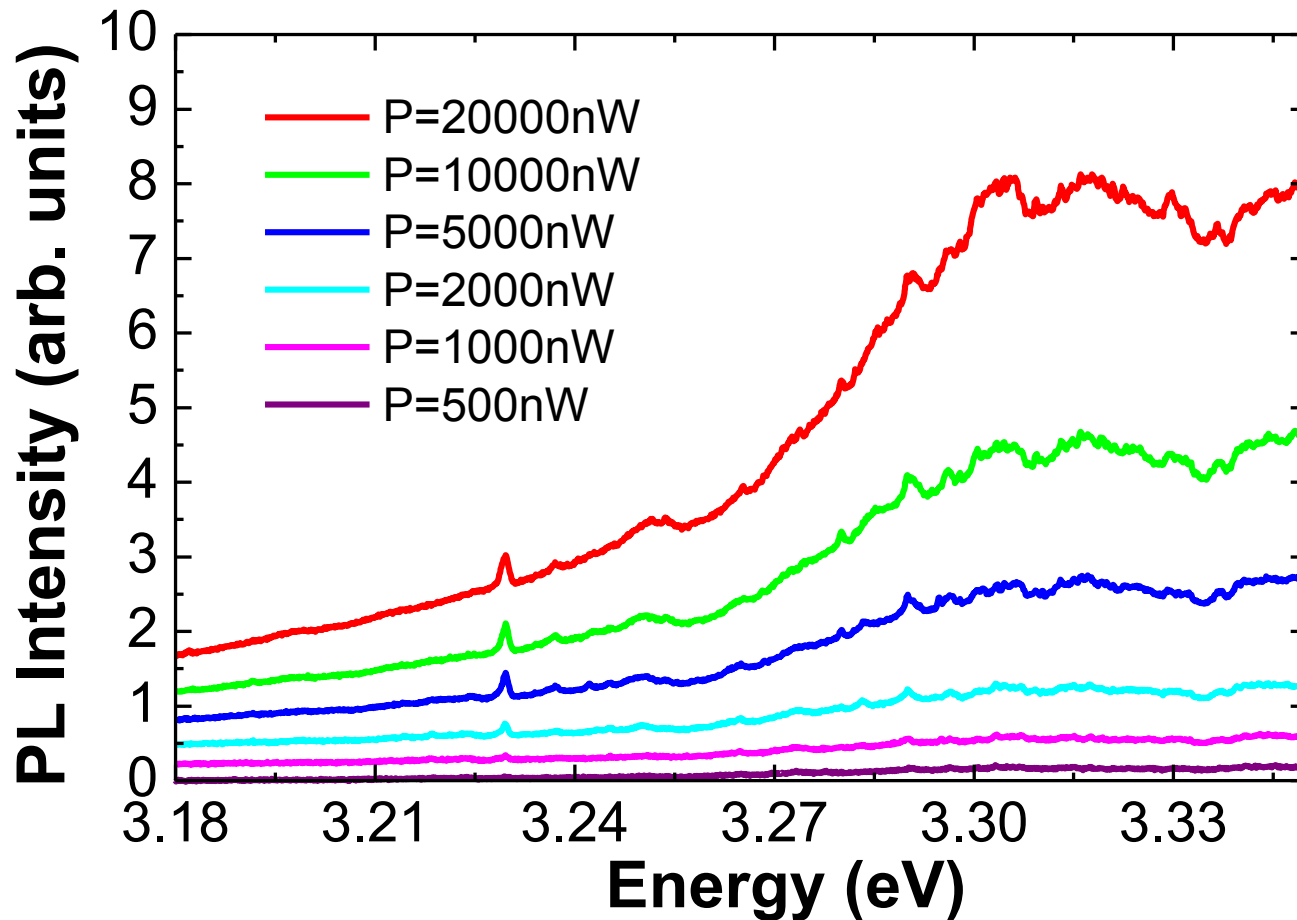


Polarization – GaN template

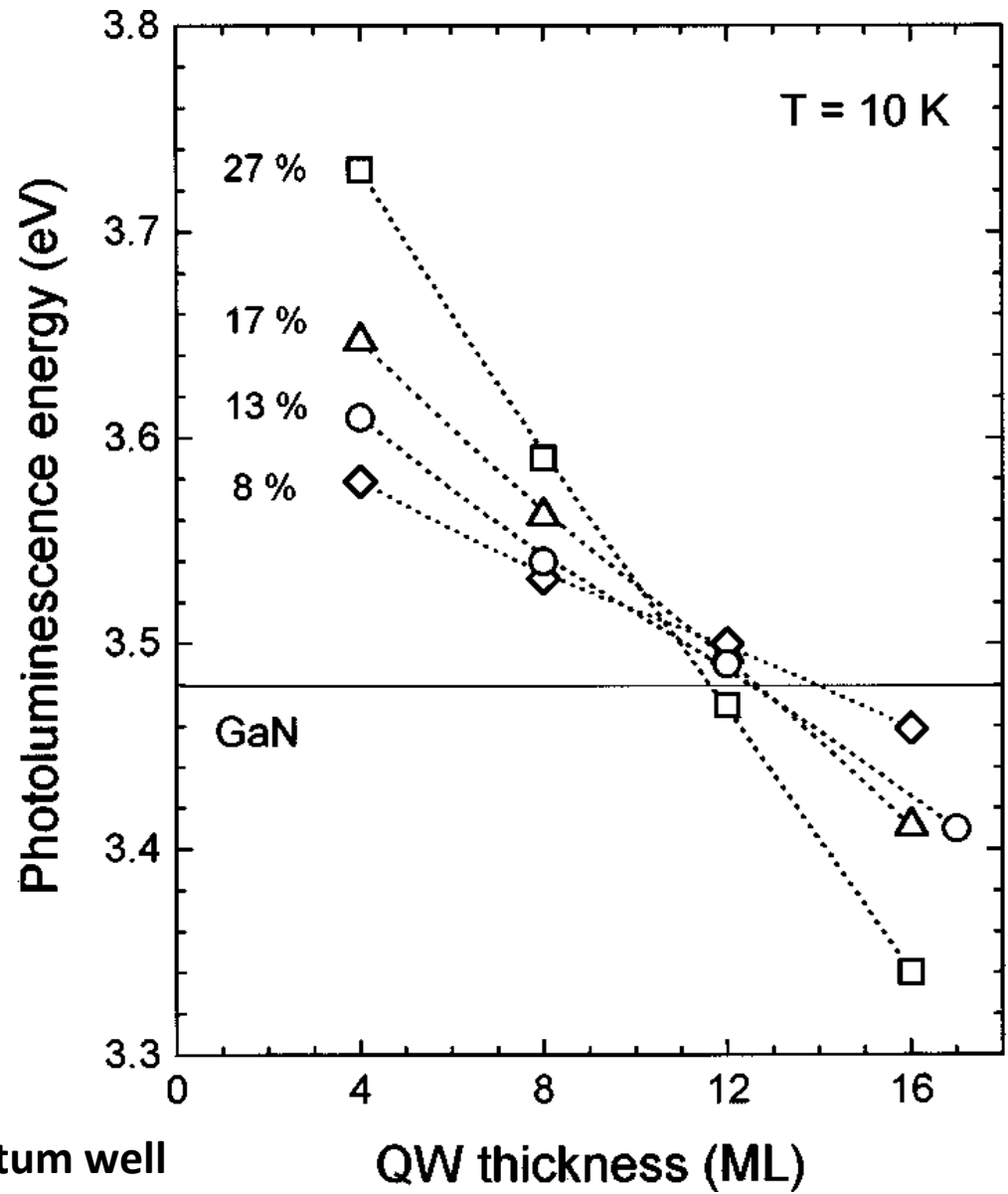


PL vs power – individual line

N1546 GaN/AlGaN (1122) 9 MLs



- An evidence for a saturation of the individual QD line



Self-limitation of AlGaIn/GaN quantum well energy by built-in polarization field

N. Grandjean, J. Massies, and M. Leroux, Appl. Phys. Lett. **74**, 2361 (1999);