Optical properties of InGaAsN/GaAs heterostructures grown by molecular beam epitaxy

N.V. Kryzhanovskaya

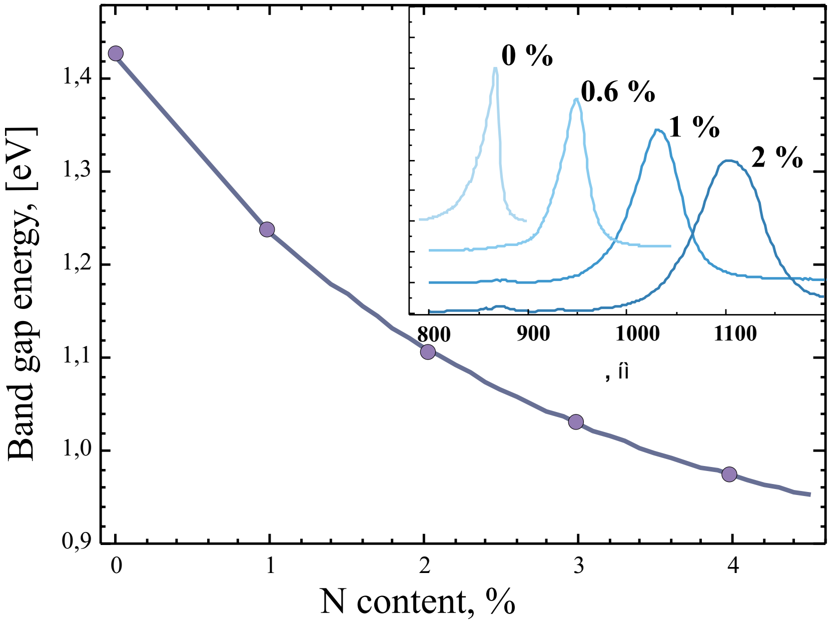
- ✓ Optical properties of GaAsN/GaAs heterostructures
- ✓ Band alignment of GaAsN/InGaAs heterojunctions
- ✓ Optical properties of InGaAsN/GaAs heterostructures

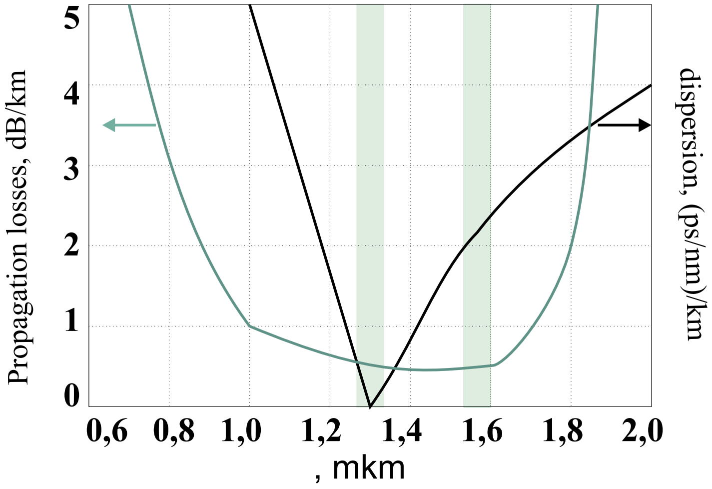
16.12.2002 г

GaAsN layers: basic properties and applications

✓ Raft decrease of band gap of GaAsN with increasing of N content

Using in active layer of light emitting devices on range of *1.3* , *1.55* mkm





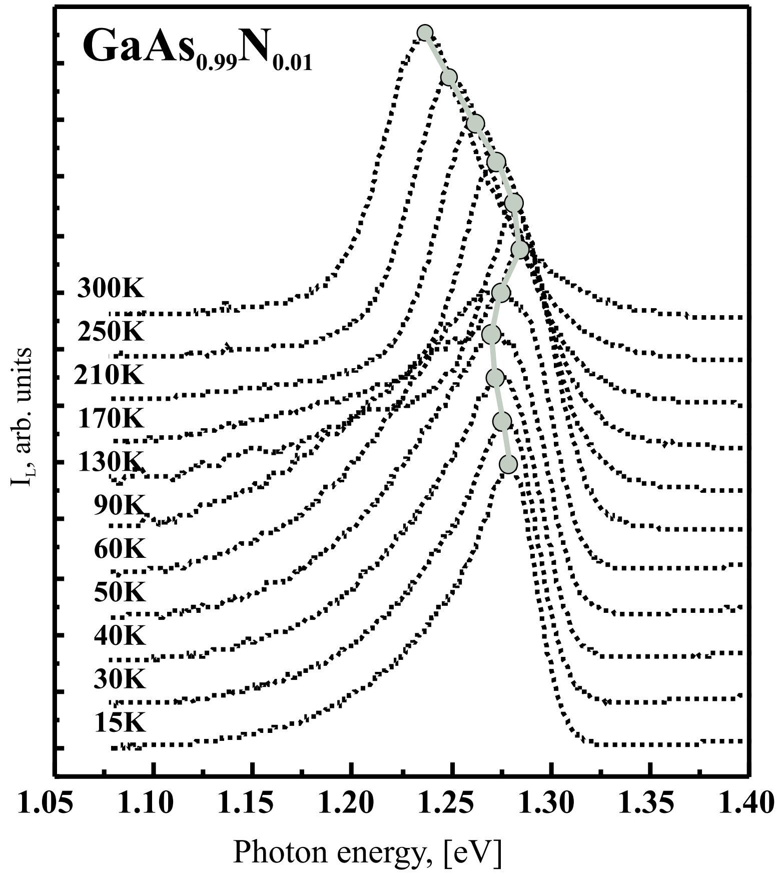
✓ High difference of *N* (~*0.72* À) and *As* (~*1,23* À) diameters

✓ High electronegativity of N atoms

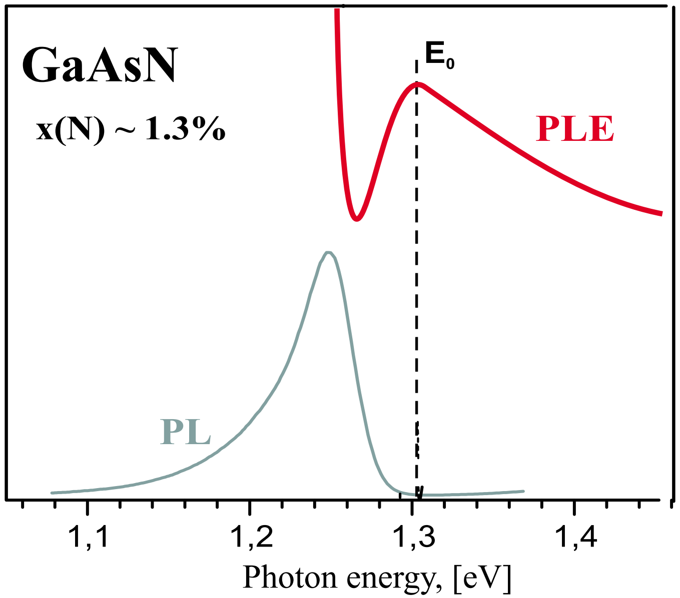
Imbedding of small content of nitrogen highly
alters GaAsN properties

Optical properties of thick GaAsN layers grown in GaAs matrix

Temperature dependence of PL



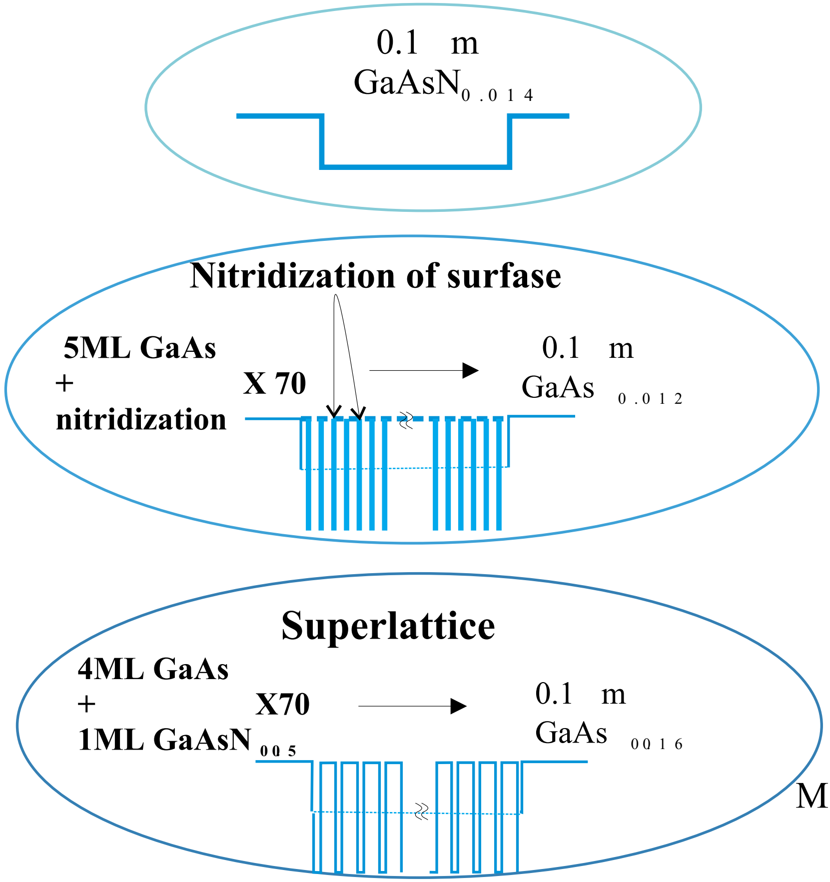
Stoke`s shift between PL and PLE maxima



The optical properties at low temperature recombination is determined by the carrier recombination via localized states related to a strong composition inhomogeneity and the carrier localization energy.

Methods of growing ultra thin GaAsN layers in GaAs

The conductance band alignment scheme of the structures studied.



0.1 m
GaAsN$_{0.014}$

Nitridization of surfase

5ML GaAs
+
nitridization
X 70

0.1 m
GaAs$_{0.012}$

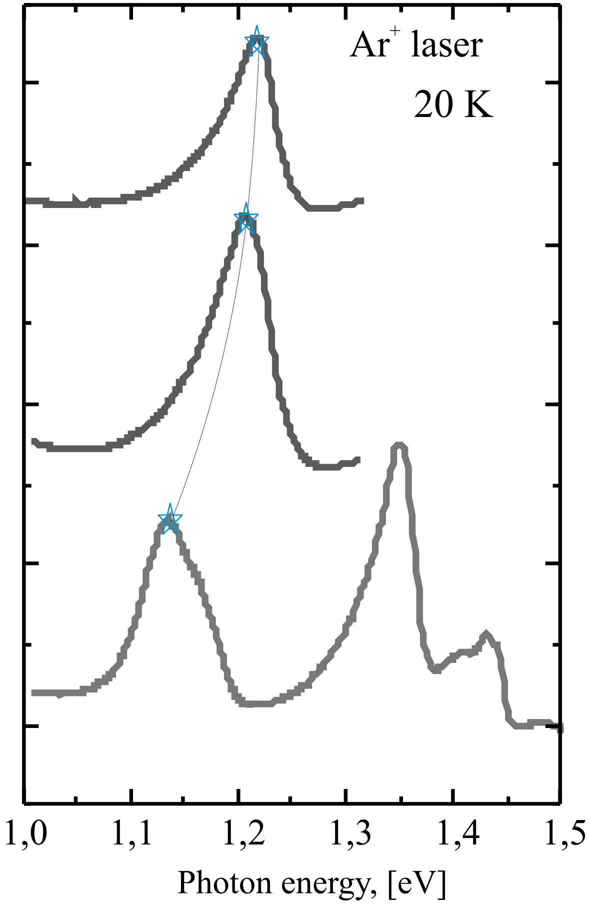
Superlattice

4ML GaAs
+
1ML GaAsN$_{0.05}$
X70

0.1 m
GaAs$_{0.016}$

Mechanism of stimulated formation high-N content areas.

PL spectra taken at 20K

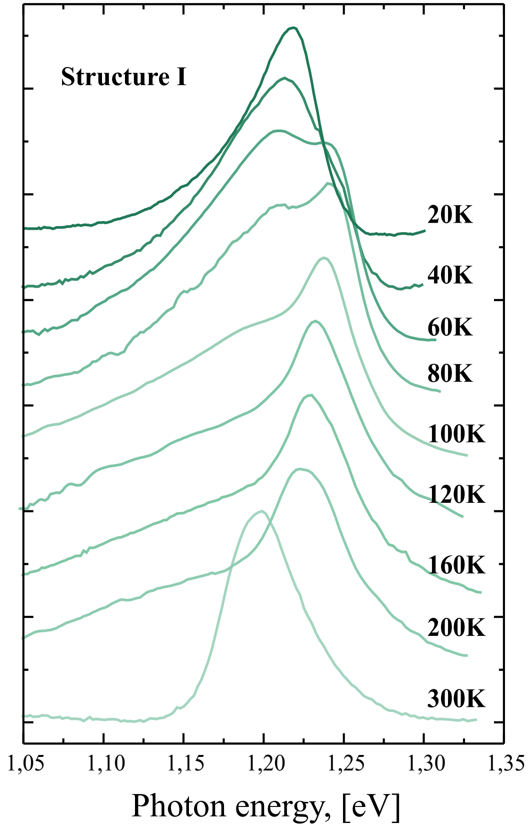


Use of short-period superlattice *GaAsN/GaAs* allows to increase emission wavelength as compared with thick GaAsN layer .

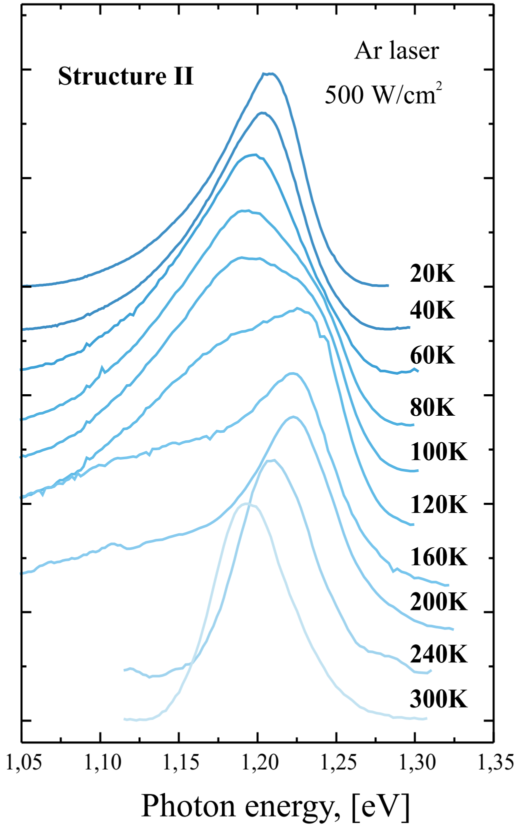
Influence of growth methods on properties of GaAsN layers.

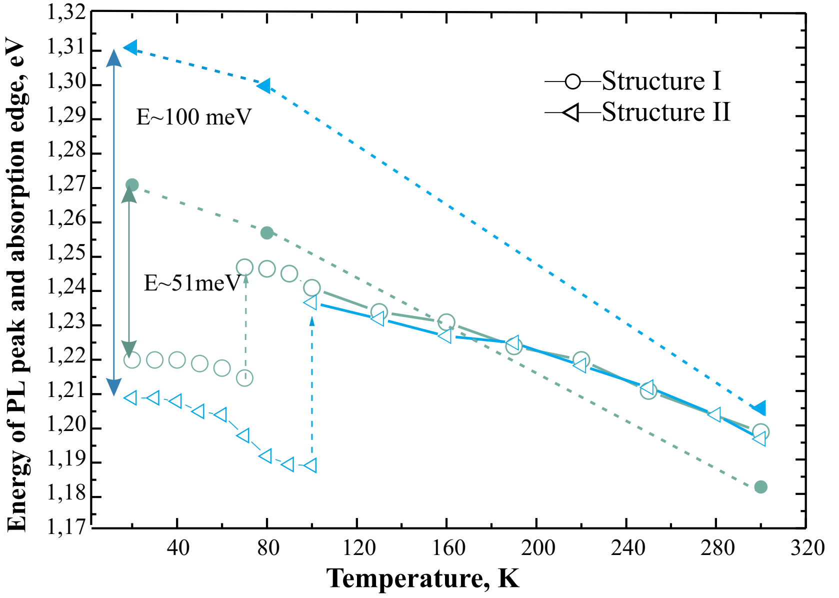
PL spectra recorded at different temperatures

Uninterrupted growth of GaAsN layer



Growth with appliyng nitridation procedure



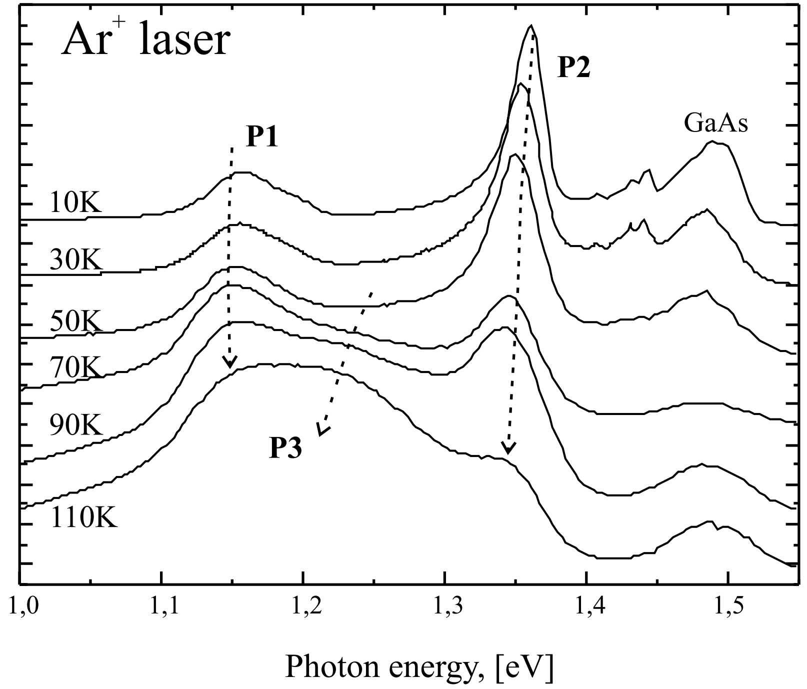


The largest Stockes shift (~100 meV) is for Sample 2 - nitridation growth mode.
Reduction of the temperature energy shift of the absorption edge with increasing of the N composition.

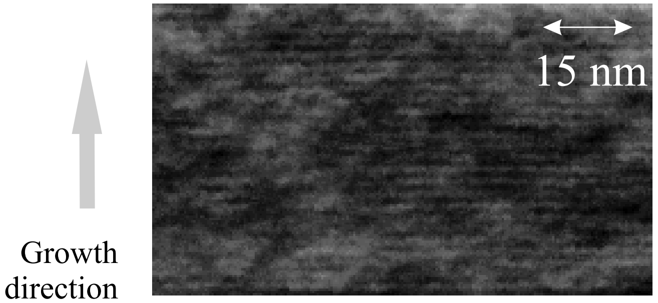
S -shaped behaviour of the dependence of PL maximum on temperature is explained by dominated role of localized states in emission at low temperatures.Enchanced formation of localized states takes place in case of applying nitridation growth mode.

Investigation of density of states in *GaAsN/GaAs* superlattice

PL spectra of GaAsN/GaAs superlattice
recorded at different observation temperatures



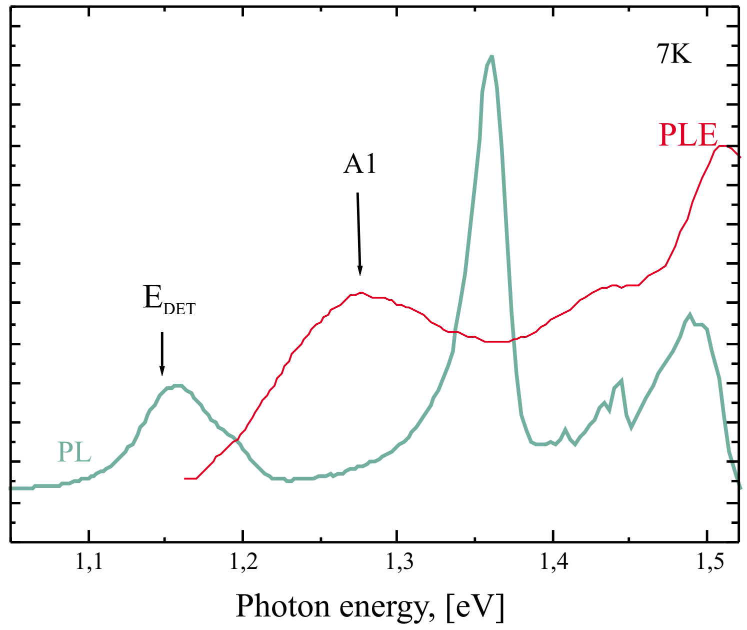
BF cross sectional TEM micrographs
of formed superlattice



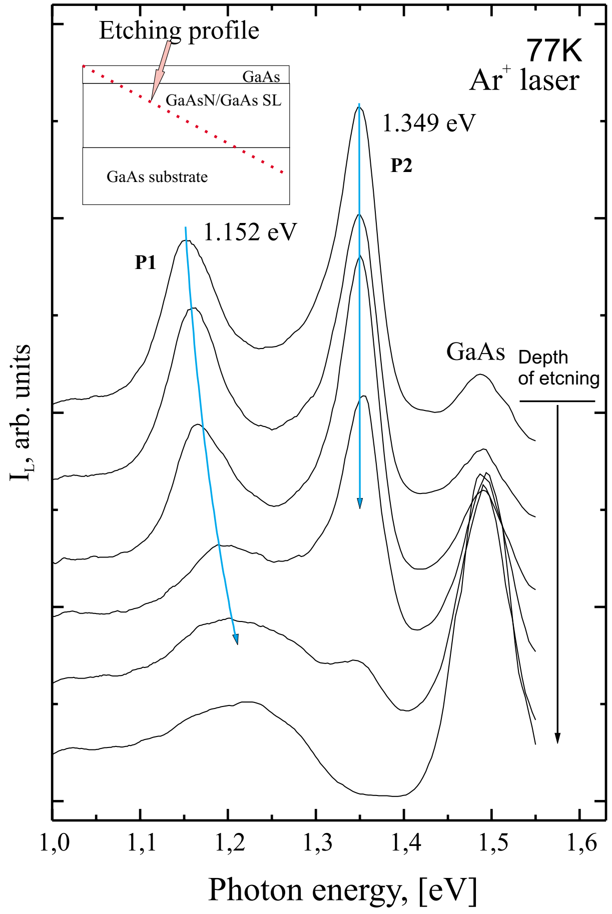
Existence of maximums in DOS spectra which
correspond to areas with different N content

Formation of N-rich areas

Aditional maximum in DOS



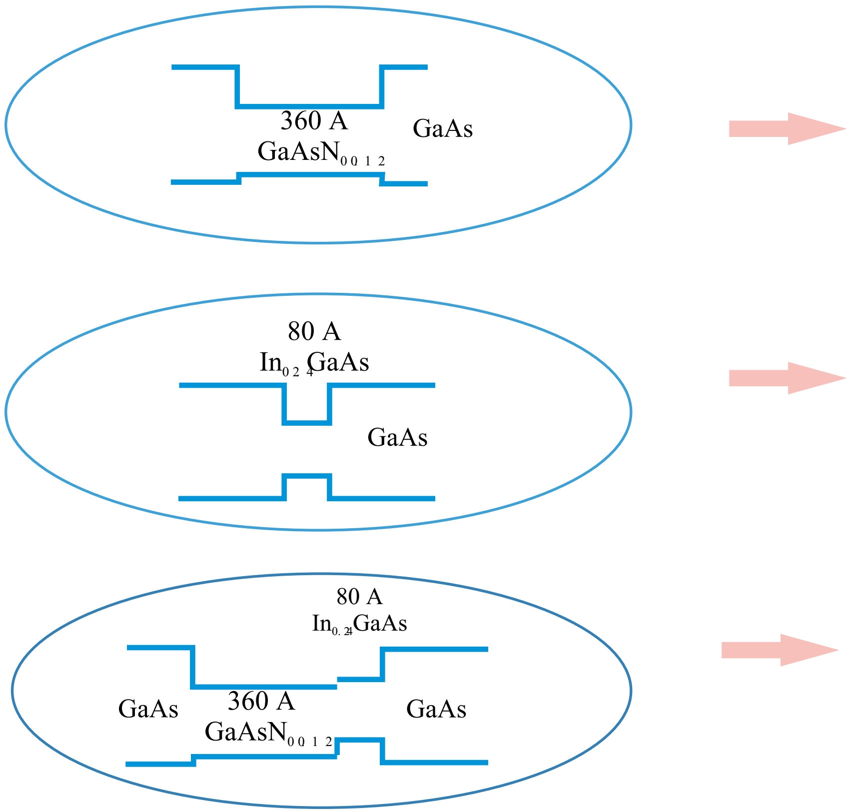
PL spectra taken after skewing etching

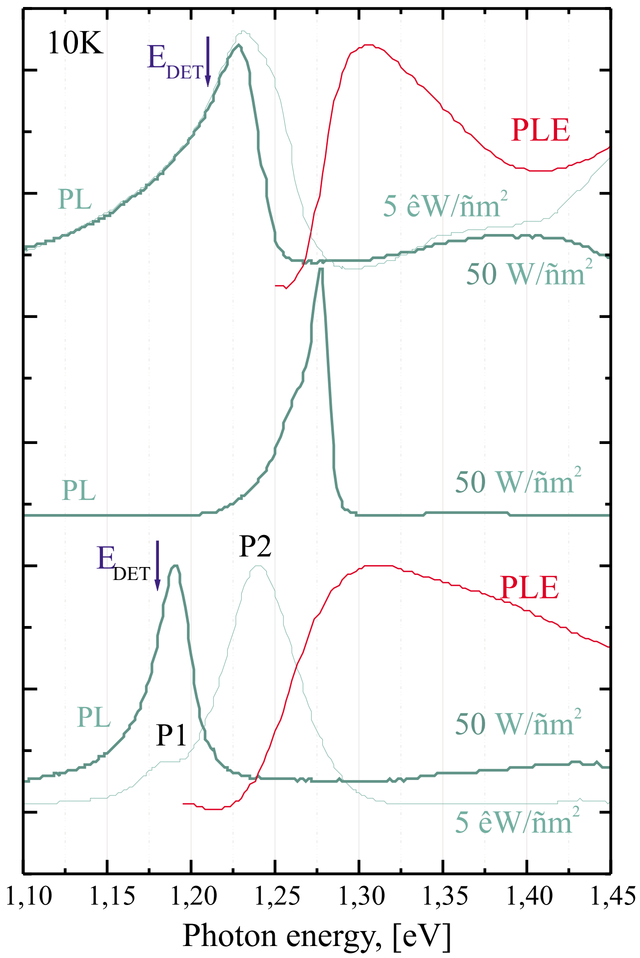


Increasing of N-rich areas size or N content along the growth direction

Band alignment in GaNAs/InGaAs heterostructures

The band alignment scheme
of the heterostructures studied.

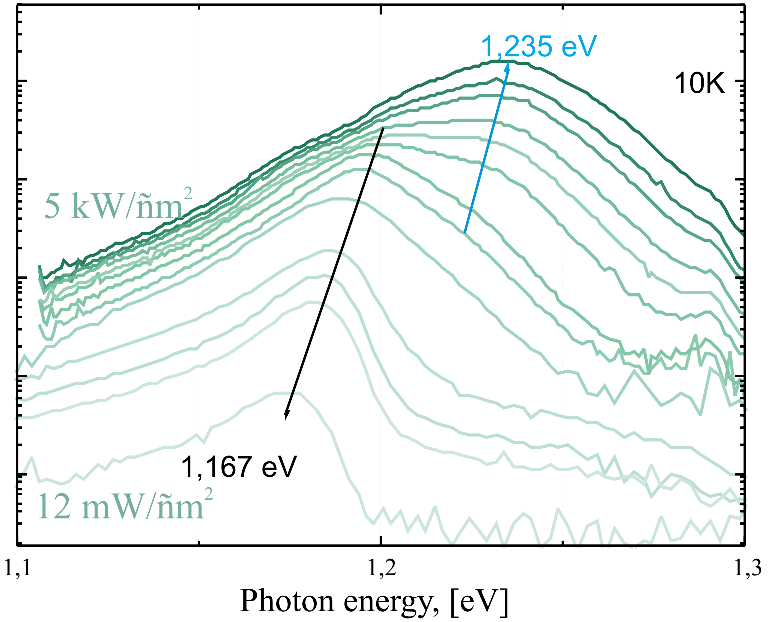




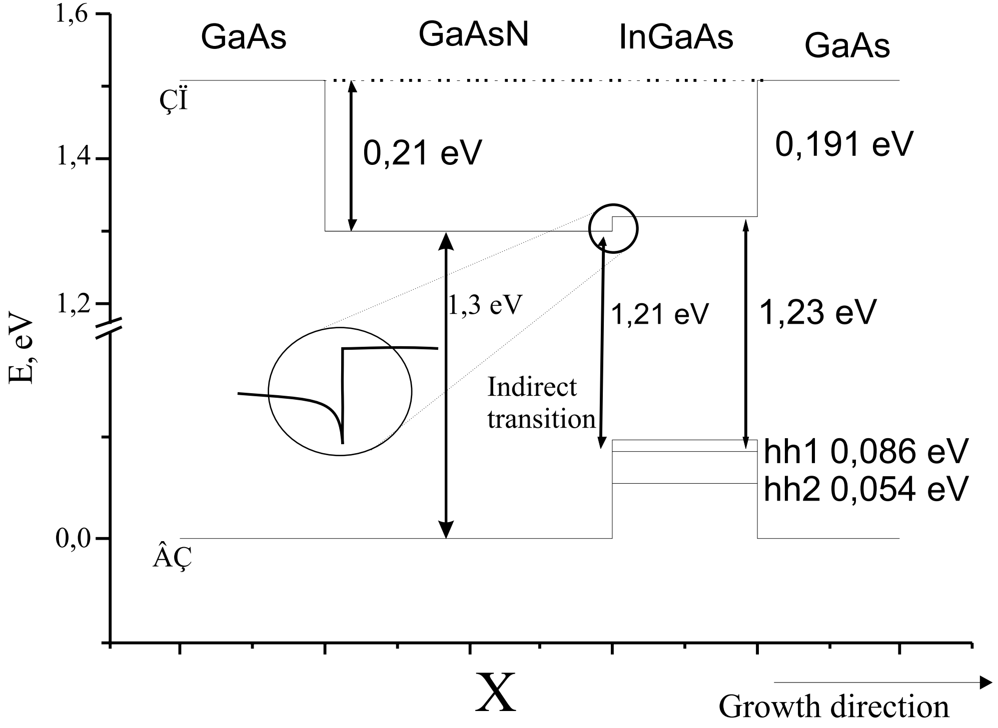
GaAsN/GaAs heterostructure has type I alignment
(with a large conduction band offset and a small valence band discontinuity)

Band alignment in GaNAs/InGaAs heterostructures

With rising excitation density, the PL maximum shifts towards higher energies



Offset of investigated heterostructure at 10K



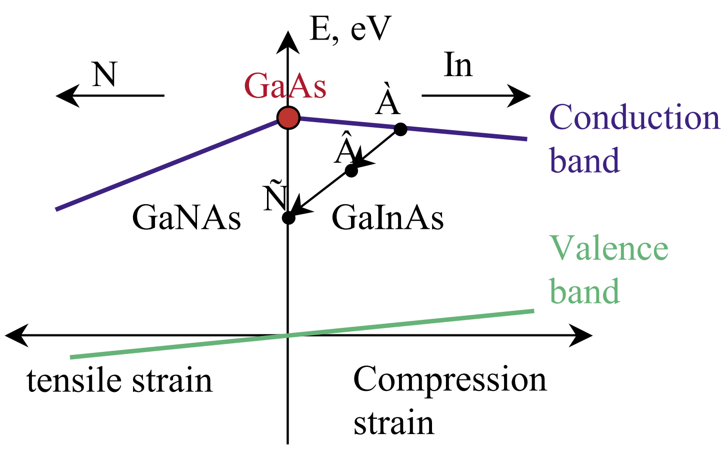
Line-up in the $In_xGa_{x-1}As/GaAsN_y$ heterojunctions dependences on *x* and can be both type I or II.

Basic properties of InGaAsN compounds

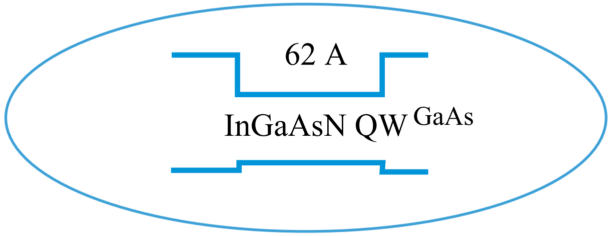
Incorporation of N atoms into InGaAs leads to:

- Decreasing of band gap
- Partial compencation of strains in layers
- Forcing of phase separation effects

Strain and band gap energy diagram
for GaAsN è InGaAs compounds



Structural and optical properties of GaInNAs/GaAs quantum well

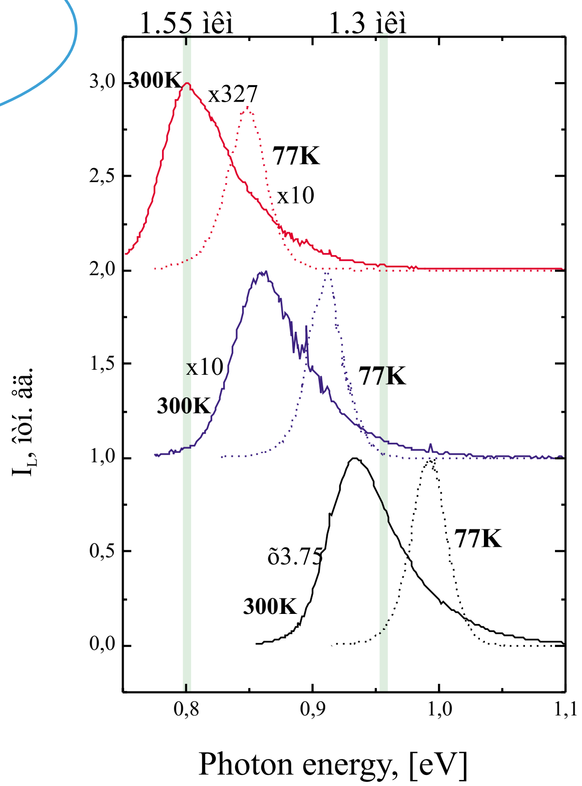


$In_{0.41}GaAsN_{0.05}$

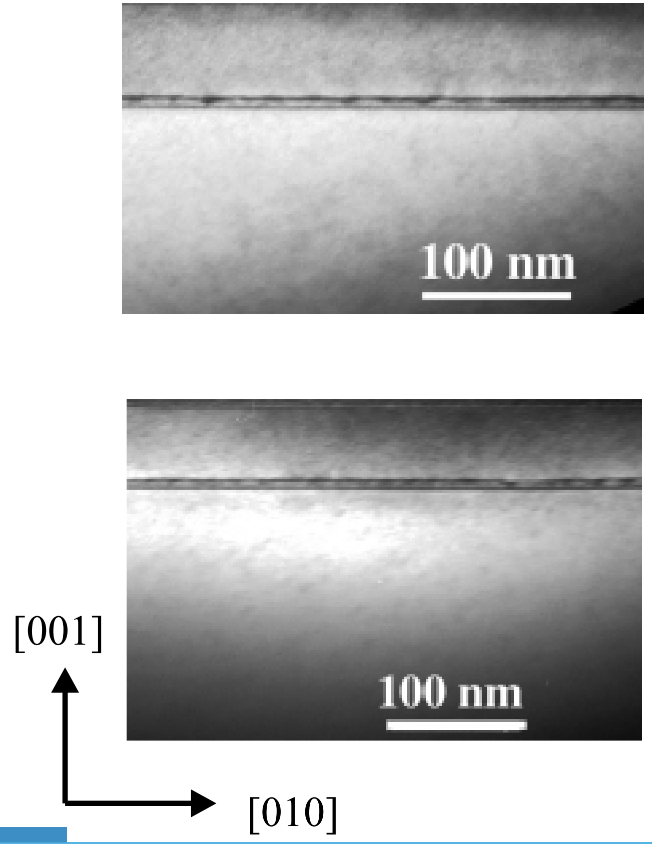
$In_{0.38}GaAsN_{0.035}$

$In_{0.38}GaAsN_{0.024}$

PL data



BF cross sectional TEM micrographs of structures with InGaAsN quantum well



Emission at 1,3 and 1,5 at room temperature was obtained.

Conclusions

✓ Optical properties of thick GaAsN layers grown in GaAs matrix were investigated

✓ Use of short-period superlattice *GaAsN/GaAs* allows to increase emission wavelength as compared with thick GaAsN layer thus to obtain 1.3 mkm.

✓ Line-up in the $In_xGa_{x-1}As/GaAsN_y$ heterojunctions was investigated and estimation band diagram was carried out.

Acknowledgements

A.R. Kovsh, A.G. Gladishev, A.Yu.Egorov, V.A.Odnoludov,
A.F. Tsatsul'nikov[1], J.Y. Chi[2], J.S. Wang[2], L. Wei[2], N.N.Ledentsov[1], V.M. Ustinov[1].

References

[1]. *Н.В. Крыжановская, Б.В. Воловик, Д.С. Сизов, А.Р. Ковш, А.Ф. Цацульников, J.Y. Chi, J.S. Wang, L. Wei, В.М. Устинов*
Оптические свойства гетероструктур $GaAsN$, выращенных методом молекулярно-пучковой эпитаксии
Материалы третьей всероссийской молодежной конференции по физике полупроводников и полупроводниковой опто- и наноэлектронике, С-Пб, 5-8 декабря 2001г., Тезисы докладов, стр.56;

[2]. *Б.В. Воловик, Н.В. Крыжановская, Д.С. Сизов, А.Р. Ковш, А.Ф. Цацульников, J.Y. Chi, J.S. Wang, L. Wei, В.М. Устинов*
Влияние локализации носителей на оптические свойства гетероструктур $GaAsN/GaAs$, выращенных методом молекулярно-пучковой эпитаксии
ФТП, 2002, том 36, выпуск 9.

[3]. *Н.В. Крыжановская, А.Р. Ковш, А.Г. Гладышев, А.Ф. Цацульников, В.М. Устинов, Н.Н. Леденцов, J.Y. Chi, J.S. Wang, L. Wei*
Структурные и оптические свойства сверхтонких $GaAsN$ внедрений в $GaAs$ матрицу
Материалы четвертой всероссийской молодежной конференции по физике полупроводников и полупроводниковой опто- и наноэлектронике, С-Пб, 1-3 декабря 2002г., Тезисы докладов

[4]. *Н.В. Крыжановская, А.Г. Гладышев, А.Р. Ковш, И.П. Сошников, А.Ф. Цацульников, В.М. Устинов, J.Y. Chi, J.S. Wang, L. Wei*
Структурные и оптические свойства сверхрешоток $GaAsN$ /$GaAs$ выращенным методом молекулярно-пучковой эпитаксии
Материалы 2-ой Всероссийской конференции “Нитриды галлия, индия и алюминия:структуры и приборы” Физико-технический институт им. Иоффе РАН, С-Пб, 3-4 февраля 2003 г.