

In-situ monitoring of InGaAsN MQW structures

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LayTec in-situ seminar in Bratislava

June 3rd 2007



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1. MOVPE growth of dilute nitrides
2. In-situ monitoring of thin layer growth
 - Slope method
 - QW composition using matrix method
3. Summary



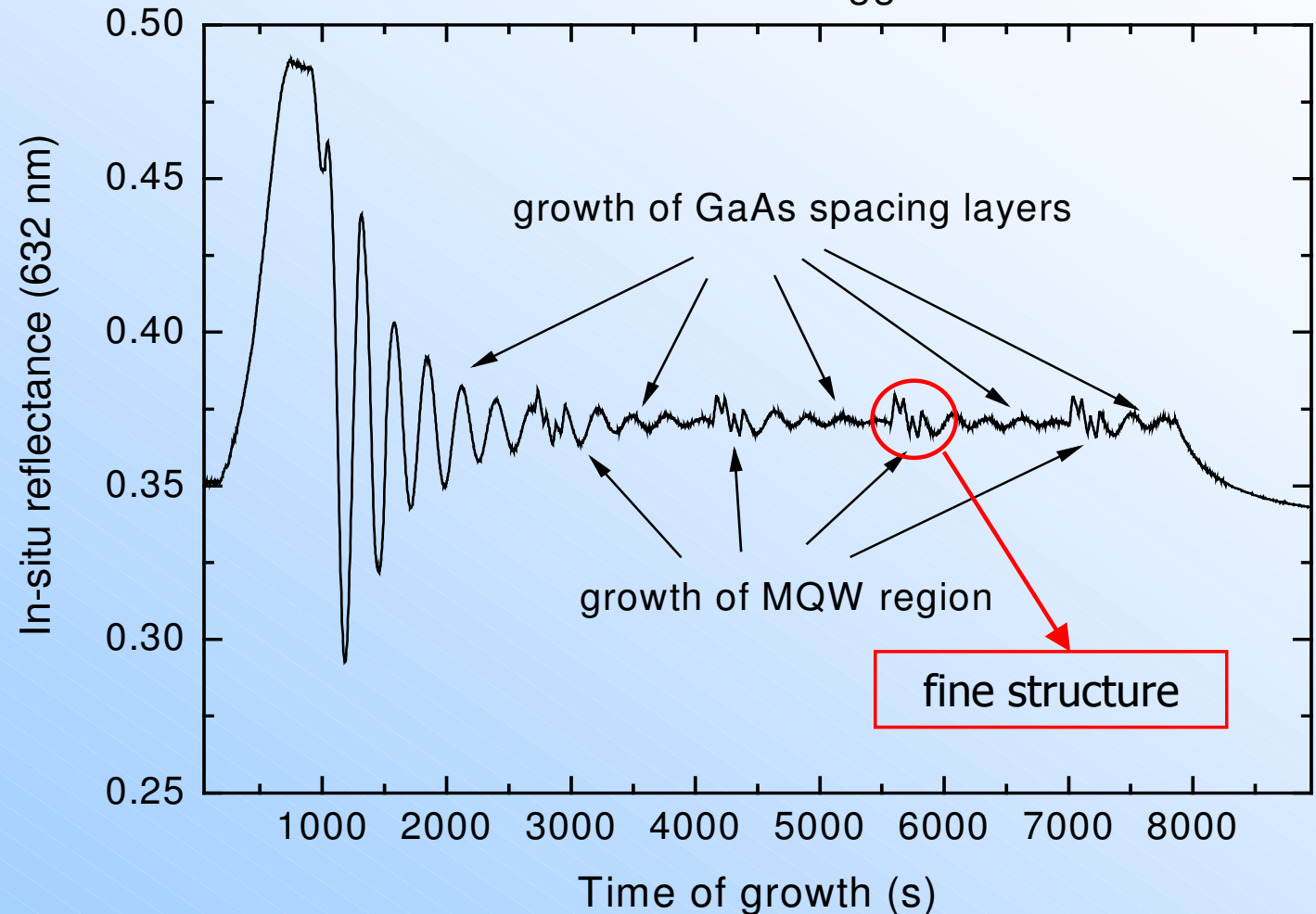
Growth of dilute nitride MQW samples by low pressure Thomas Swan MOVPE system, ex-situ characterization by HR-XRD, PL, AFM...

In-situ monitoring by LayTec's EpiTT at 635 nm.

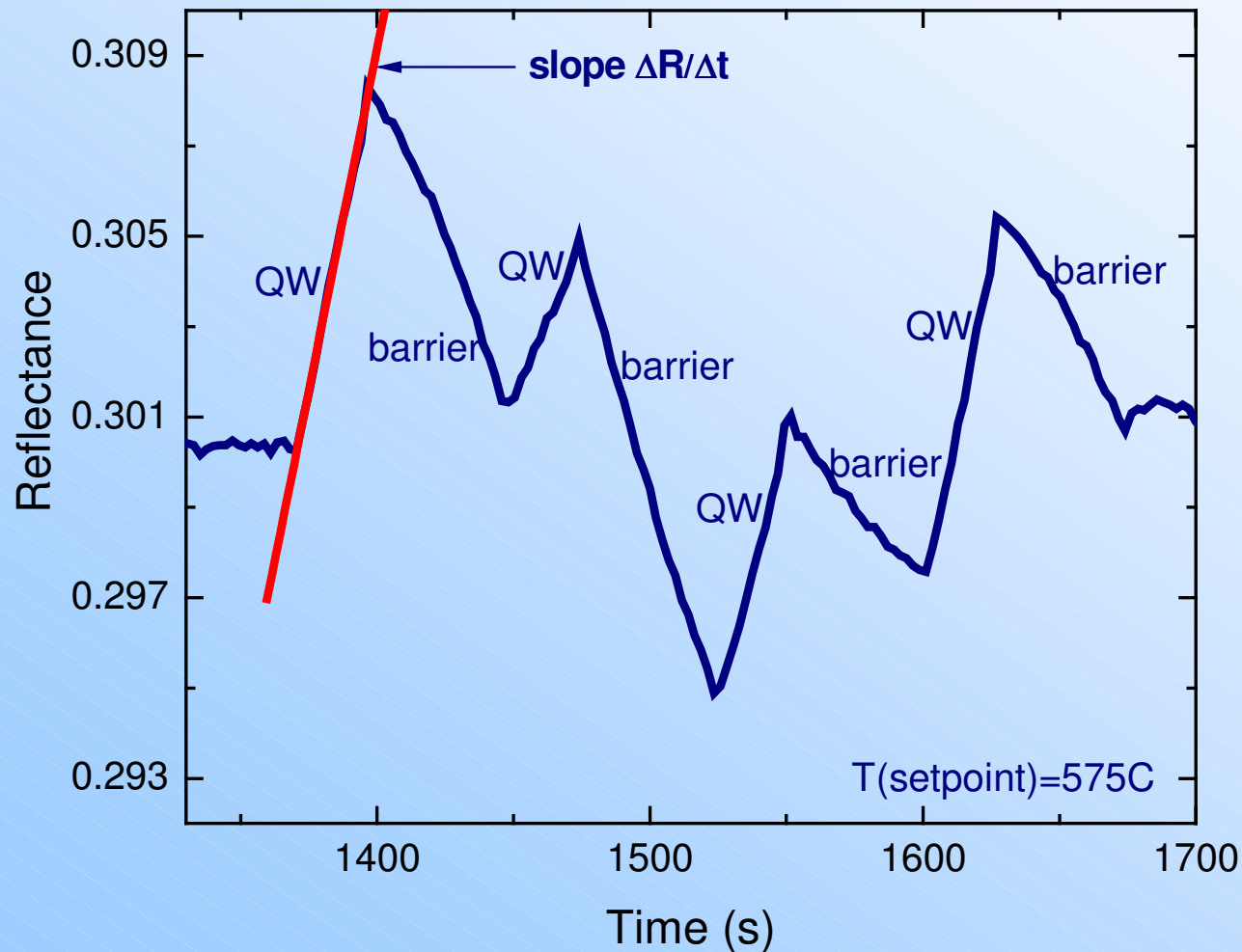
Example, SESAM structure:

Fabry-Perot oscillations are observed during growth of thick layers, fine structure seen for growth of thin InGaAsN QWs (7 nm thick).

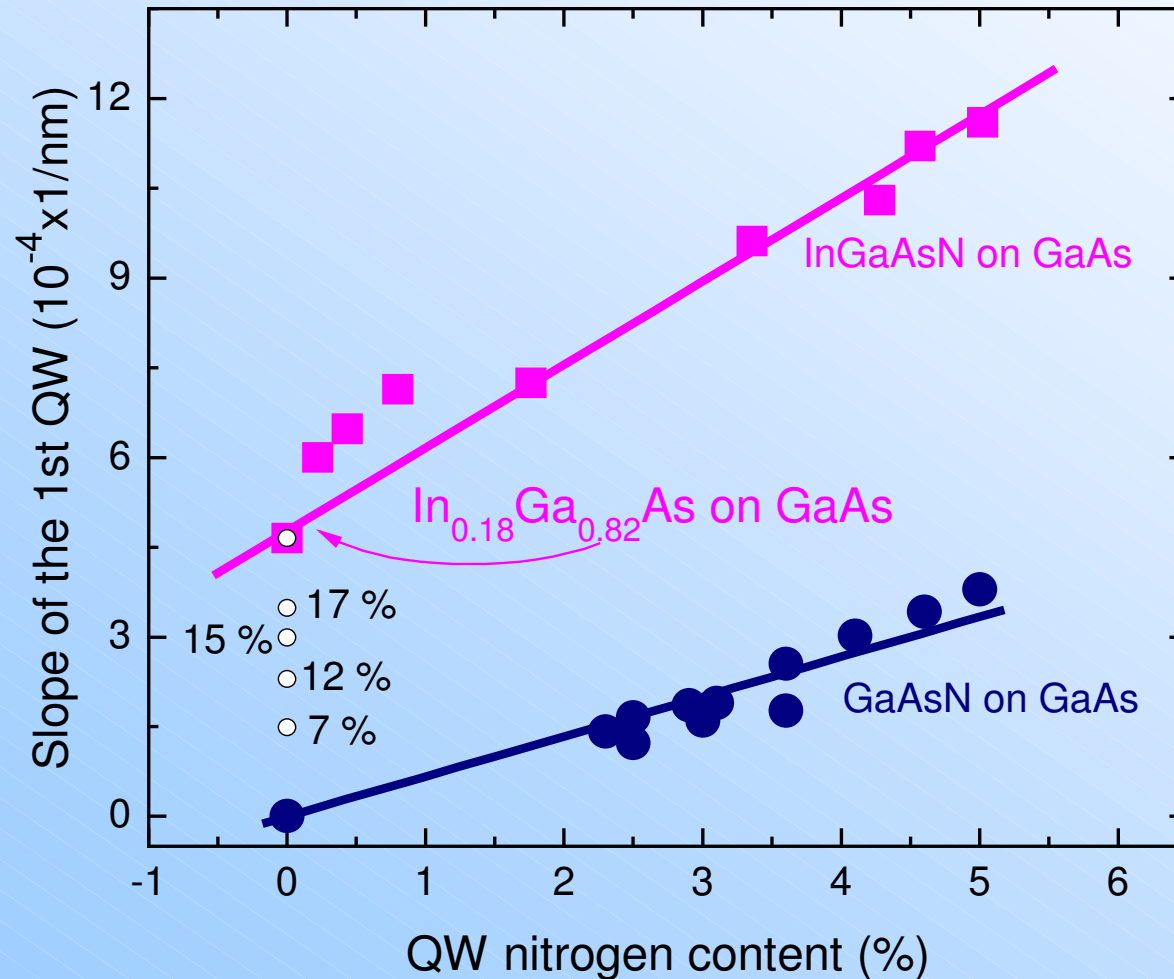
In-situ monitoring of an absorber structure on GaAs/AlAs Bragg mirror



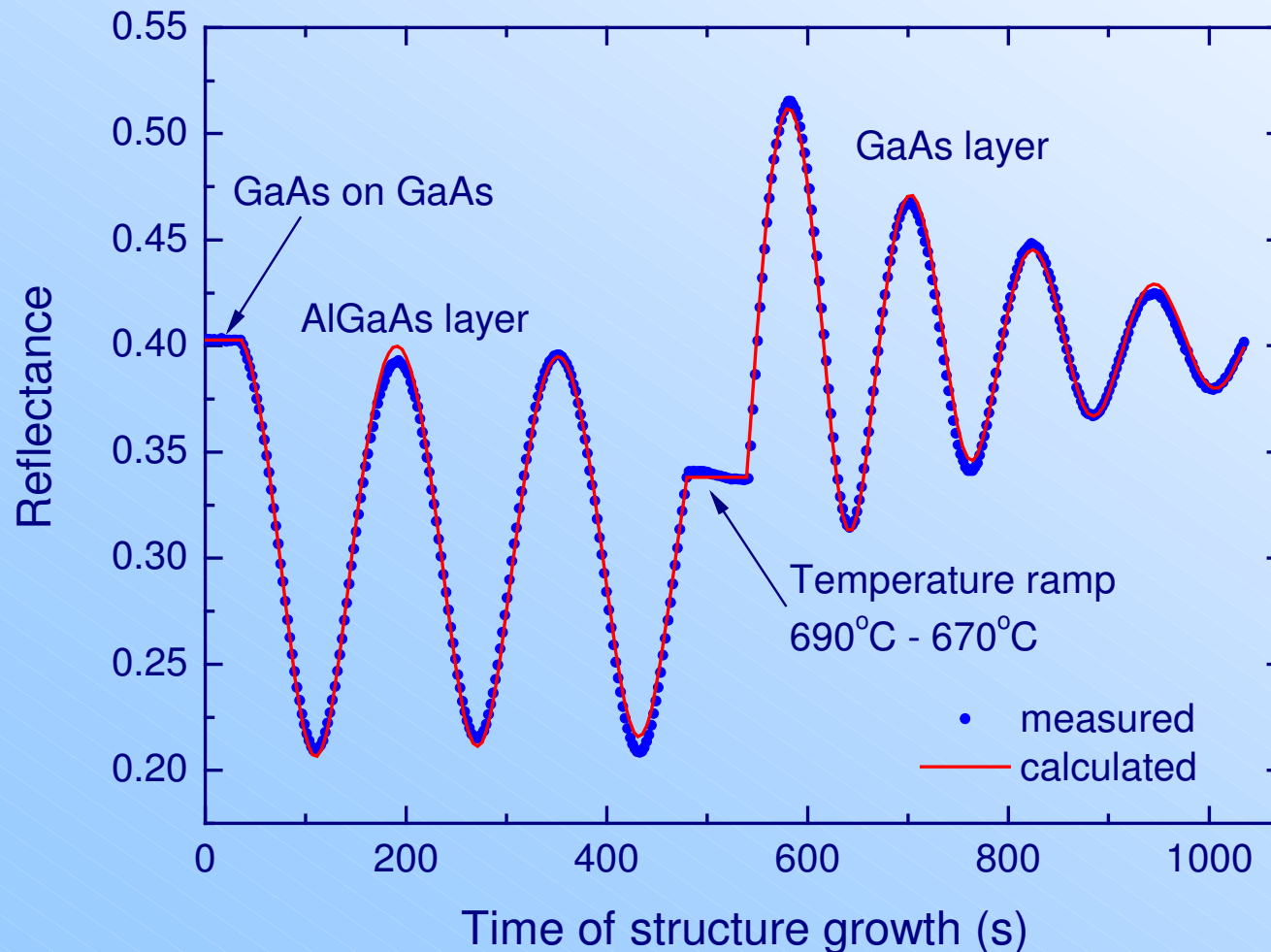
- no complete Fabry-Perot oscillations
- increasing (decreasing) reflectance during QW (barrier) growth



Rough analysis of the QW composition using a slope method:



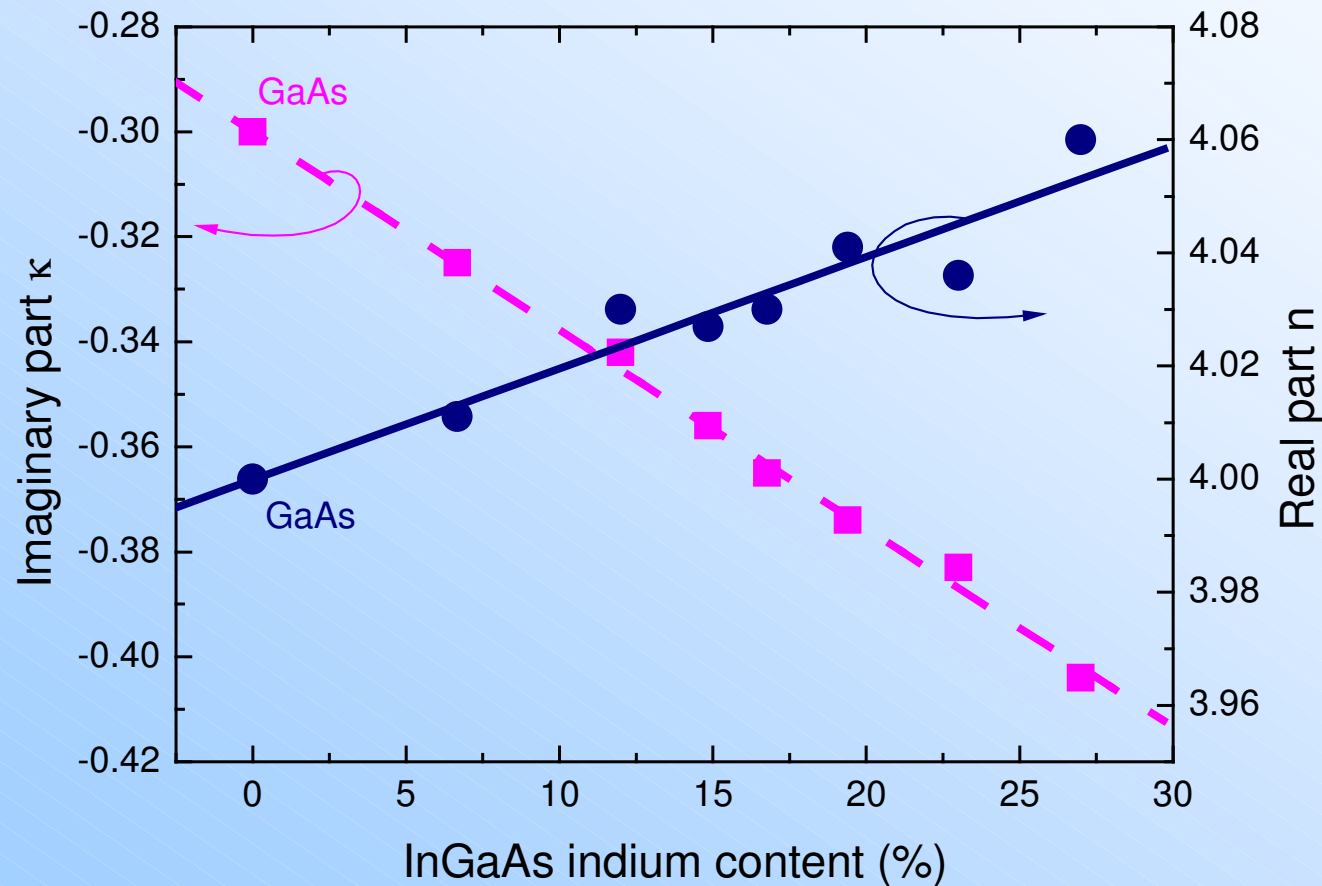
For more sophisticated MQW in-situ analysis:
use of matrix method to calculate theoretical reflectance curves.



From simulation:
GaAs at 670°C
 $n = 4.2 - 0.3i$
AlGaAs at 690°C:
 $n = 3.3 - 0.03i$
(growth rates determined by XRD)

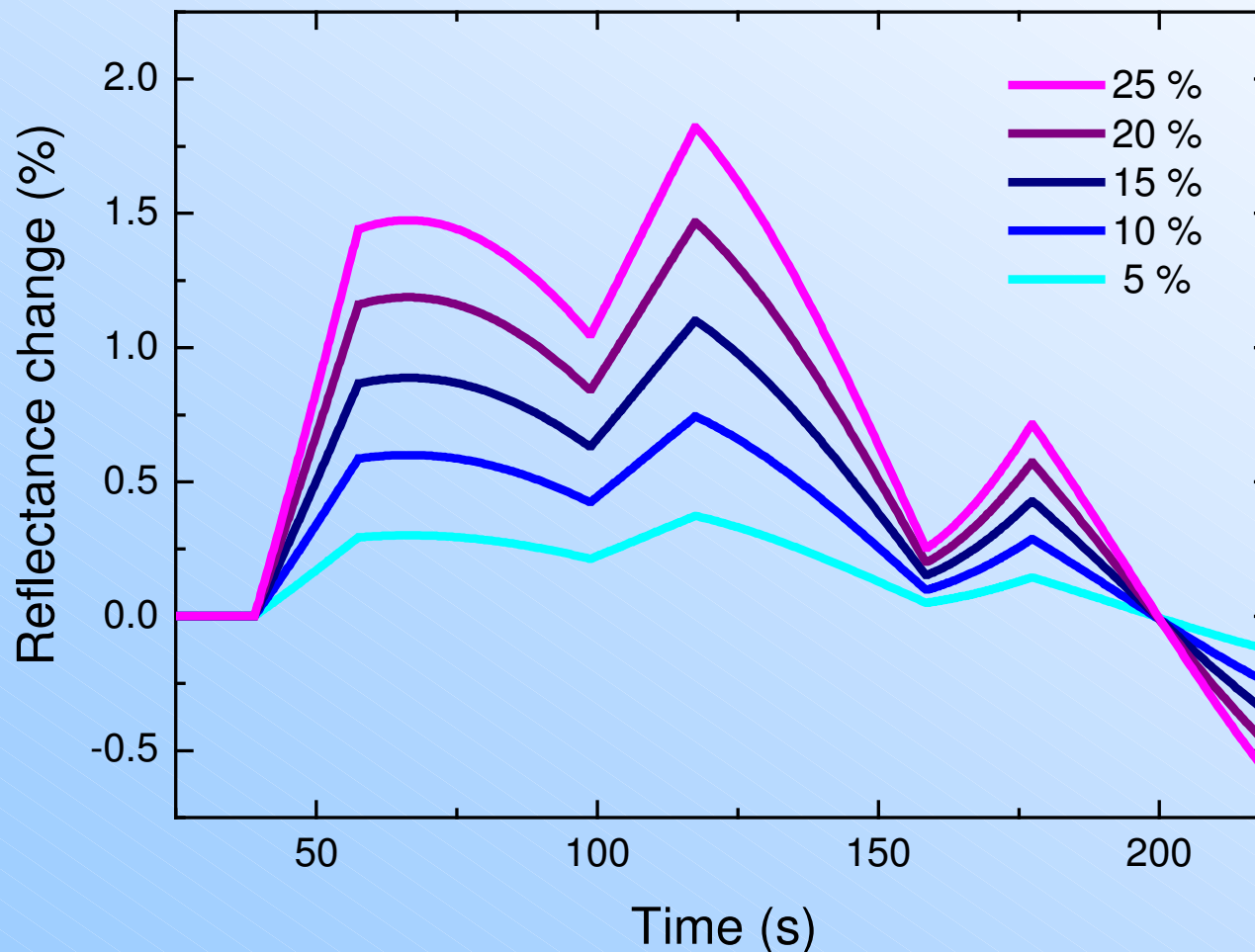
O. Reentilä *et al.*, J. Appl. Phys.
101 033533 (2007)

Measured real and imaginary parts of refractive index of $\text{In}_x\text{Ga}_{1-x}\text{As}$ QW as a function of In content x :



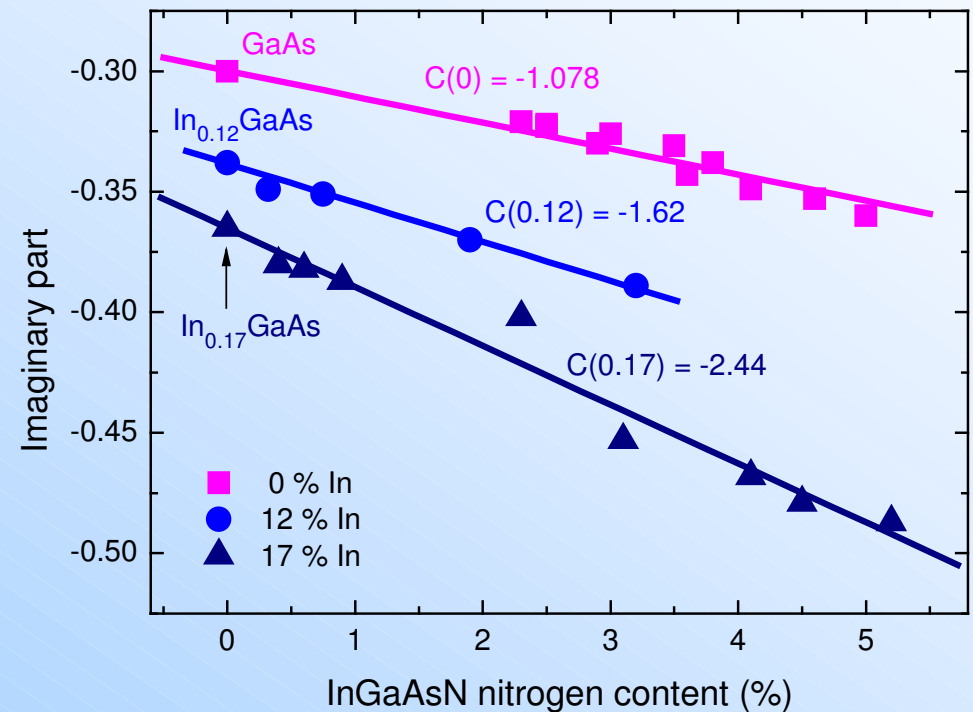
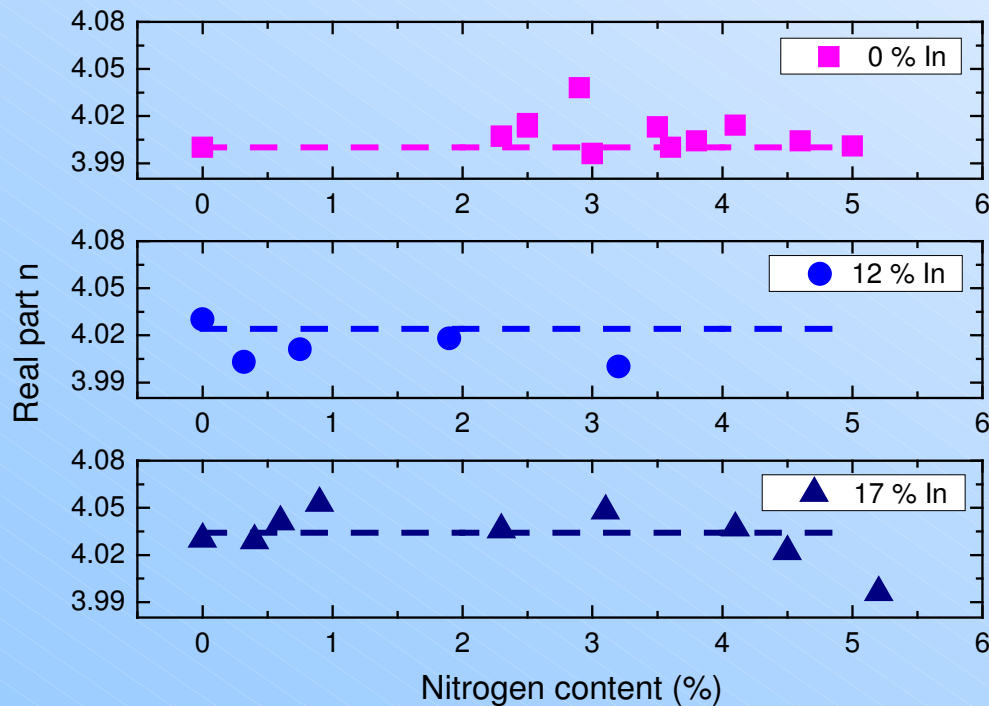
Indium content more accurately from imaginary part (κ).

Calculated curves for InGaAs/GaAs MQW structures (different indium contents) using n and κ obtained by fitting to measured curves.



For (In)GaAsN:

- linear dependency between the imaginary part and [N]
- no dependency was found in the real part when [N] was varied



- Dilute nitride samples fabricated by low-pressure MOVPE system were studied by in-situ reflectometry and several ex-situ measurements
- Growth of MQW structures can be monitored and the layers (at least partially) analysed during growth
- More work is needed to resolve
 - the effect of strain on the refractive index
 - in-situ monitoring of the growth rate AND the refractive index at the same time, i.e., full in-situ characterization of the MQW structures
 - the reason why n is not changing when the nitrogen content is varied

RELATED PUBLICATIONS

- O. Reentilä, M. Mattila, M. Sopanen, H. Lipsanen, *Nitrogen content of GaAsN quantum wells by in-situ monitoring during MOVPE growth*, Journal of Crystal Growth, **290** 345-349 (2006)
- O. Reentilä, M. Mattila, L. Knuuttila, T. Hakkarainen, M. Sopanen, H. Lipsanen, *In situ determination of nitrogen content in InGaAsN quantum wells*, Journal of Applied Physics, **100** 013509 (2006)
- O. Reentilä, M. Mattila, L. Knuuttila, T. Hakkarainen, M. Sopanen, H. Lipsanen, *Comparison of H₂ and N₂ as carrier gas in MOVPE growth of InGaAsN quantum wells*, Journal of Crystal Growth, **298** 536-539 (2007)
- O. Reentilä, M. Mattila, M. Sopanen, H. Lipsanen, *In-situ determination of InGaAs and GaAsN composition in multi-quantum-well structures*, Journal of Applied Physics, **101** 033533 (2007)
- O. Reentilä, M. Mattila, M. Sopanen, H. Lipsanen, *Simultaneous determination of indium and nitrogen contents of InGaAsN quantum wells by optical in-situ monitoring*, Applied Physics Letters, **89** 231919 (2006)

ACKNOWLEDGEMENTS

M. Sc. Marco Mattila
Dr. Teppo Hakkarainen
Dr. Lauri Knuutila
Docent Markku Sopanen
Prof. Harri Lipsanen

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