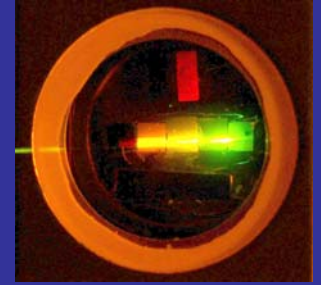


# Determination of Al-content in AlGaInP by in-situ reflection measurements

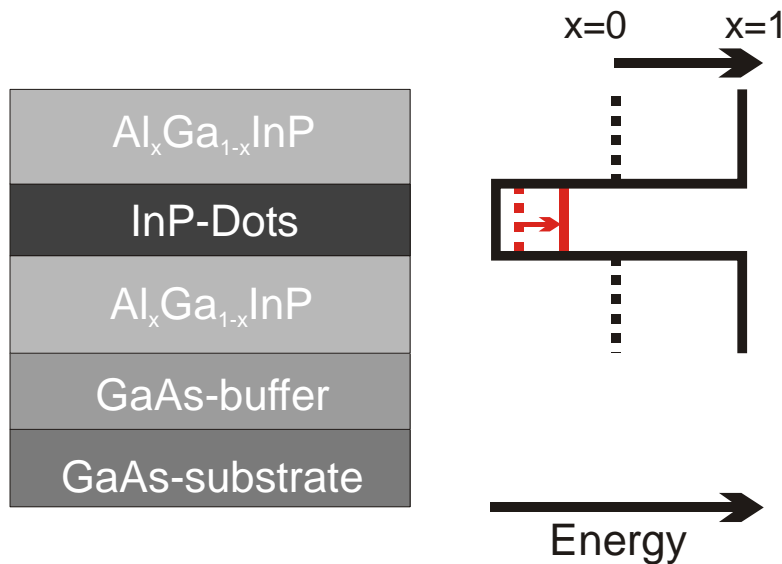
R. Roßbach, M. Jetter, and P. Michler  
5<sup>th</sup> Physics Institute, University Stuttgart



## Motivation

### InP-Quantum Dots

in different Al-containing  $(\text{Al}_x\text{Ga}_{1-x})\text{InP}$



→ Higher confinement

### Ex-situ:

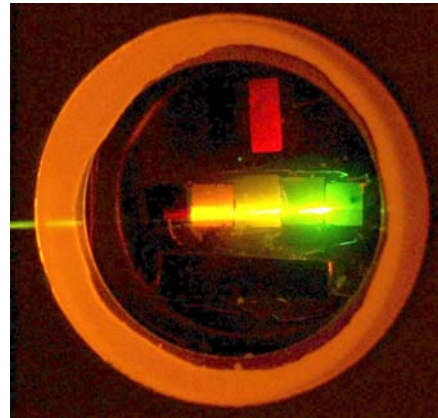
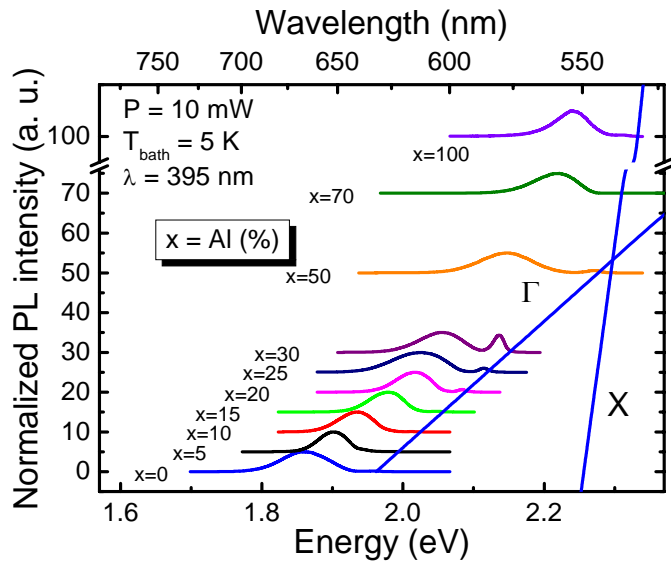
X-ray diffraction measurements  
cannot differ Al and Ga in AlGaInP

Barrier photoluminescence  
determines Al-content

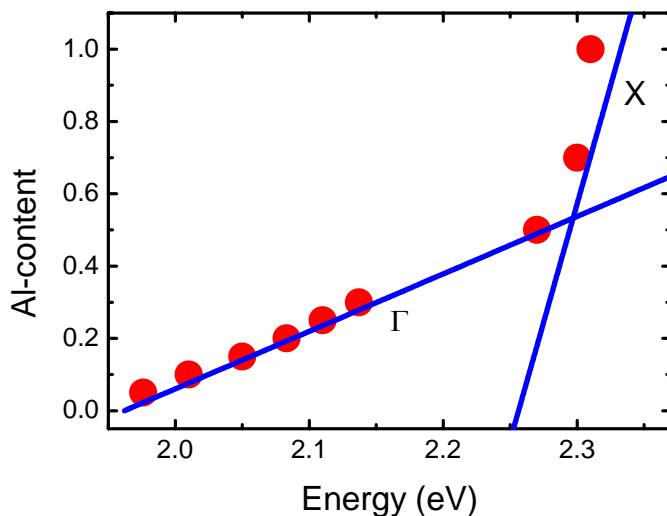
### In-situ:

Determination of Al-content  $x$   
in  $(\text{Al}_x\text{Ga}_{1-x})\text{InP}$   
by in-situ reflection  
measurements?

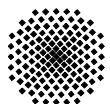
# Photoluminescence (PL) measurements



PL of QD-samples with Al-content  $x=0, 0.3, 0.5, 0.7, 1$



- PL measurements determines the Al-content for following in-situ measurements
- Measured barrier energy follows nicely the theoretical band gap energy



# Growth

## MOVPE & *EpiR* - M

Growth conditions:

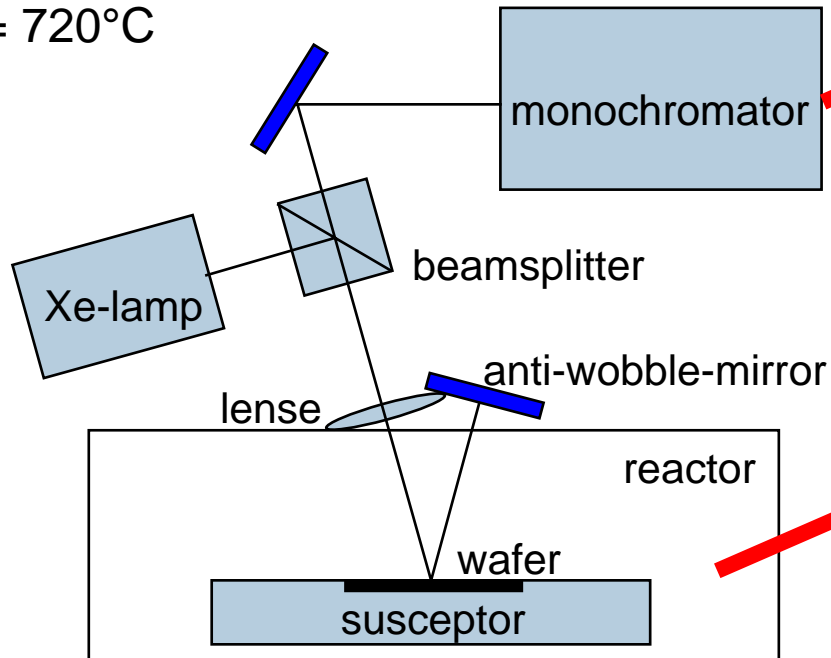
AIX – 200

Materials:

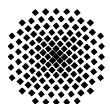
TMGa, TMAI, TMIIn, AsH<sub>3</sub>, PH<sub>3</sub>

horizontal reactor at 100 mbar

T<sub>G</sub> = 720°C



AIX – 200



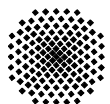
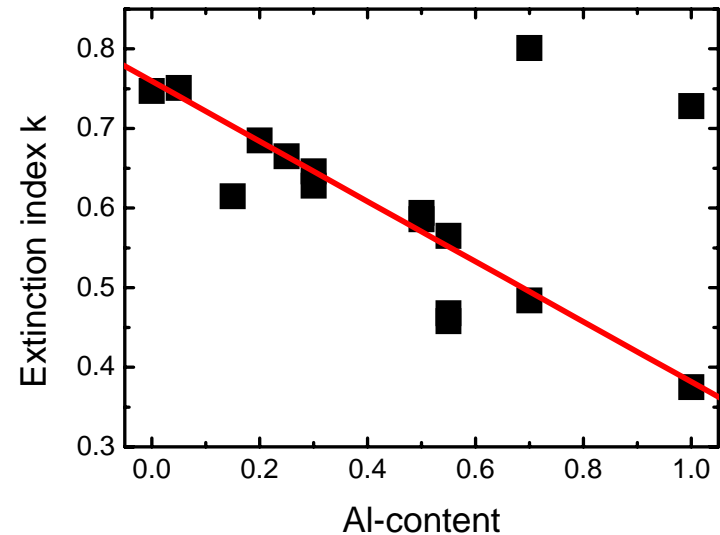
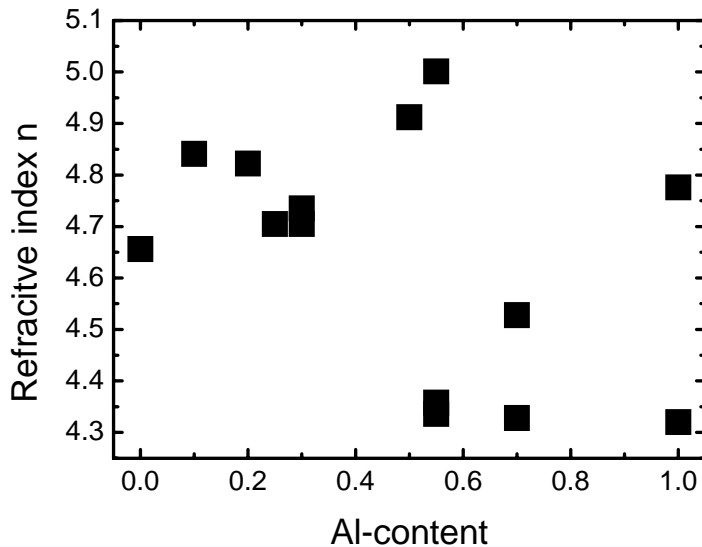
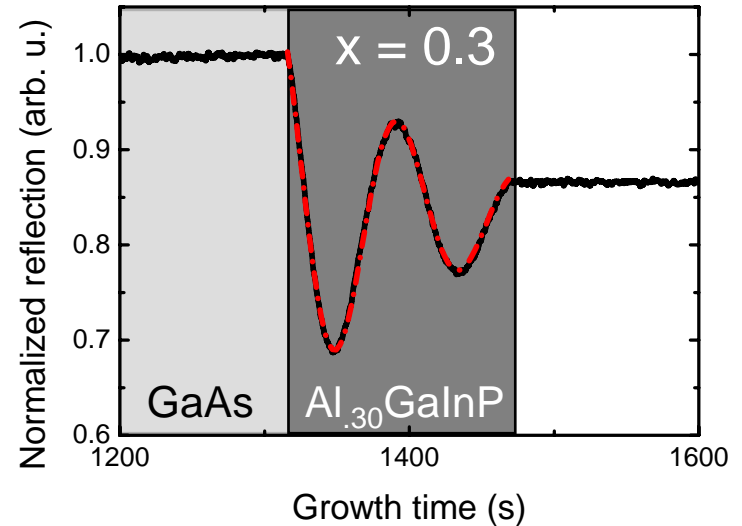
# Time-resolved measurements

## EpiSENSE

~ 20 samples with different Al-content

Fit of Fabry-Perot-oscillations:

- Growth rate: error < 1 %
- Refractive index (Al-content)
- Extinction index (Al-content)

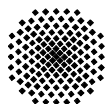
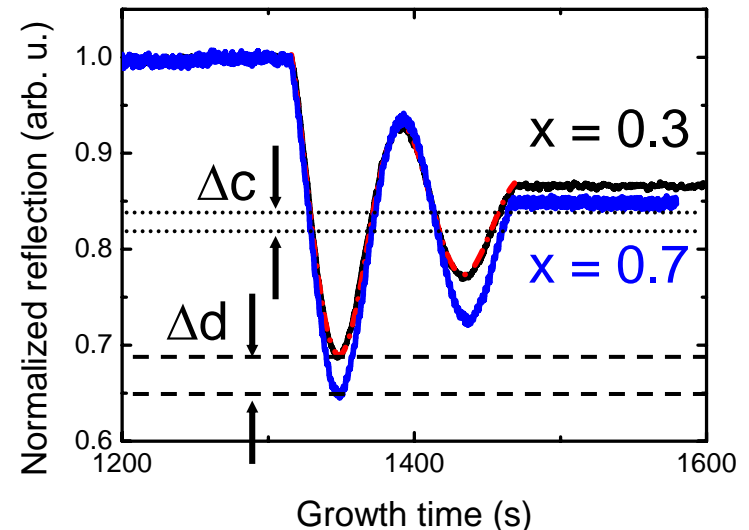
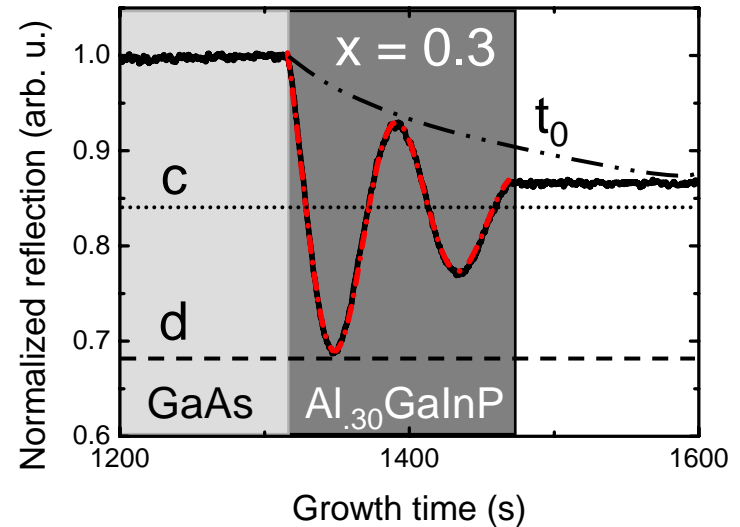


# Analysis of Fabry-Perot-oscillations

## Fabry-Perot-oscillations

$$R_N = A \cdot \exp\left(-\frac{t}{t_0}\right) \cdot \sin(\omega(t - t_c)) + c$$

- A      amplitude
- t      growth time
- t<sub>0</sub>    damping constant
- ω      frequency
- t<sub>c</sub>    phase
- c      equilibrium point
- d      oscillation depth



# Equilibrium point c

## Equilibrium point c

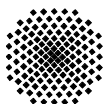
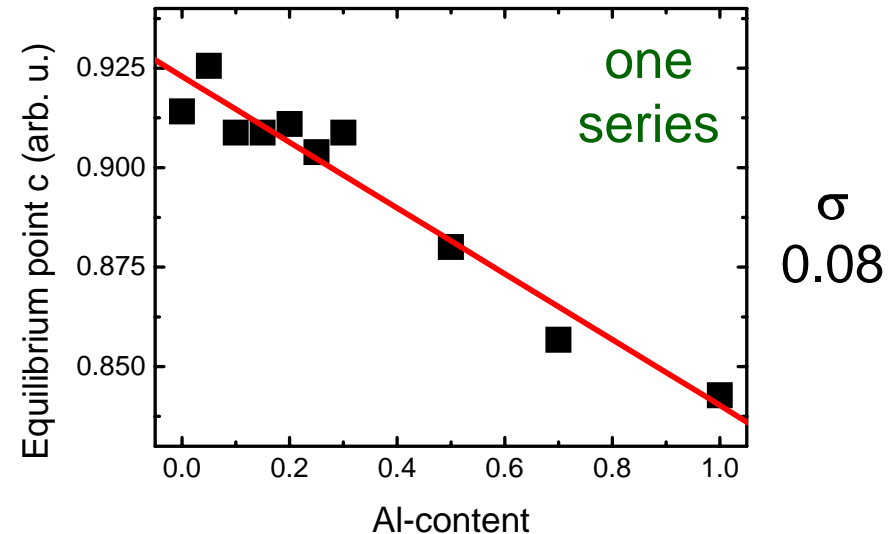
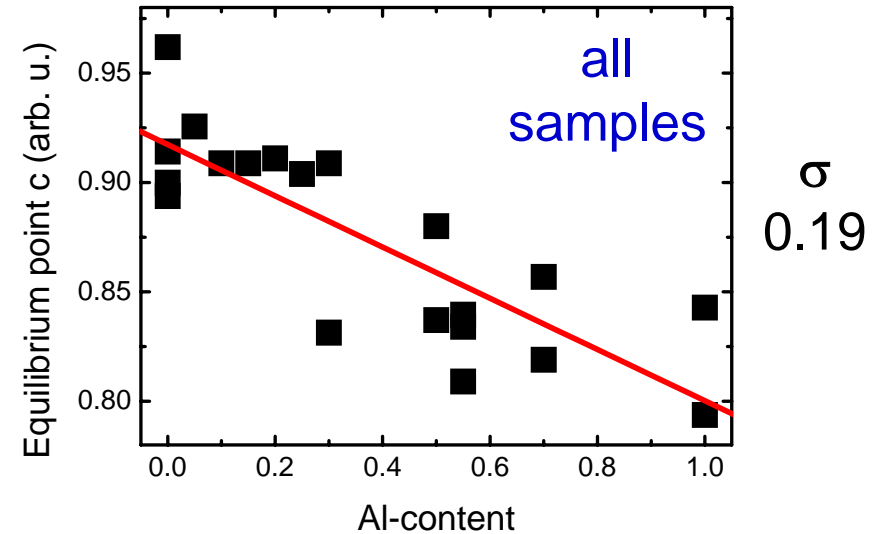
depends on refractive index n

for **all samples**:

c vs. Al-content shows a trend  
but no determination  
of Al-content possible within  
an error of  $\sim 20\%$

for **one series**:

c vs. Al-content shows  
nice dependence on Al-content  
Determination of Al-content  
with an error of  $\sim 8\%$



# Oscillation depth $d$

## Oscillation depth $d$

depends on extinction index  $k$

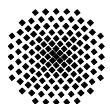
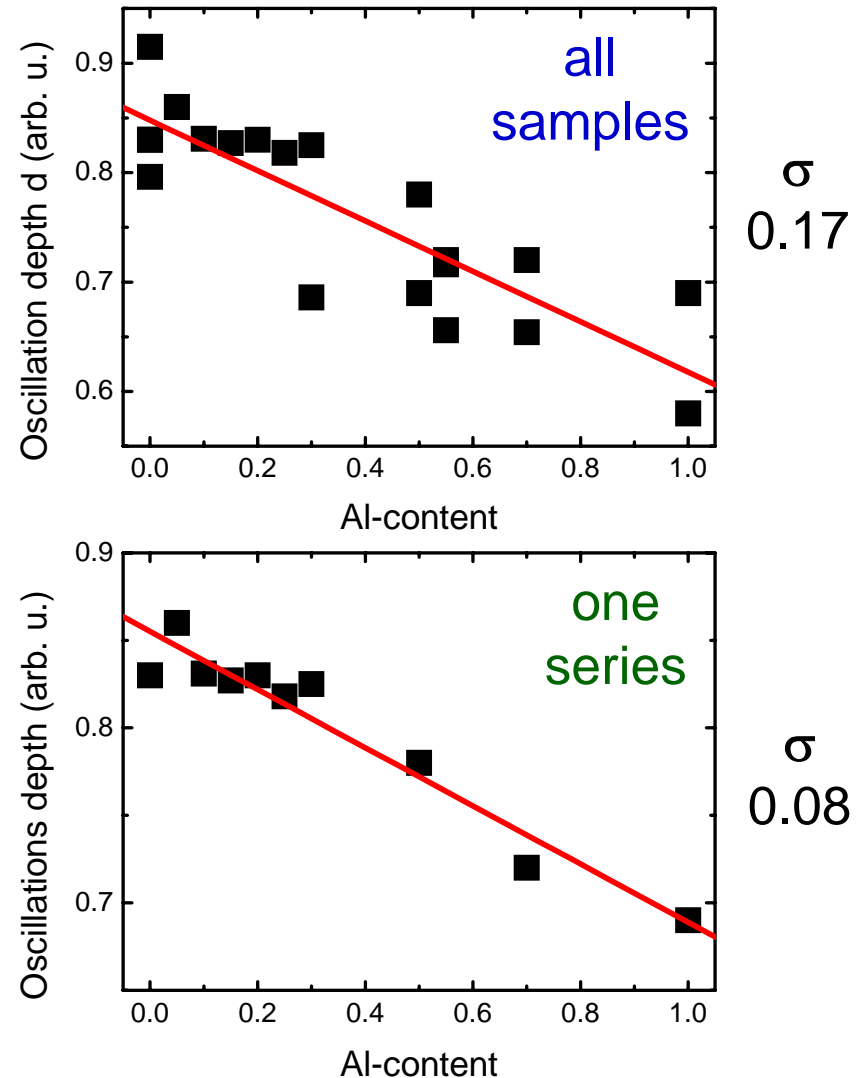
for **all samples**:

$c$  vs. Al-content shows also a trend  
but no precise determination  
of Al-content possible (error  $\sim 17\%$ )

for **one series**:

$c$  vs. Al-content shows nice dependence  
on Al-content (error  $\sim 8\%$ )  
but just for samples grown in a row

no absolute measurement!



# Damping constant $t_0$

**Damping constant  $t_0$**   
depends on extinction index  $k$

for **all samples**:

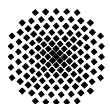
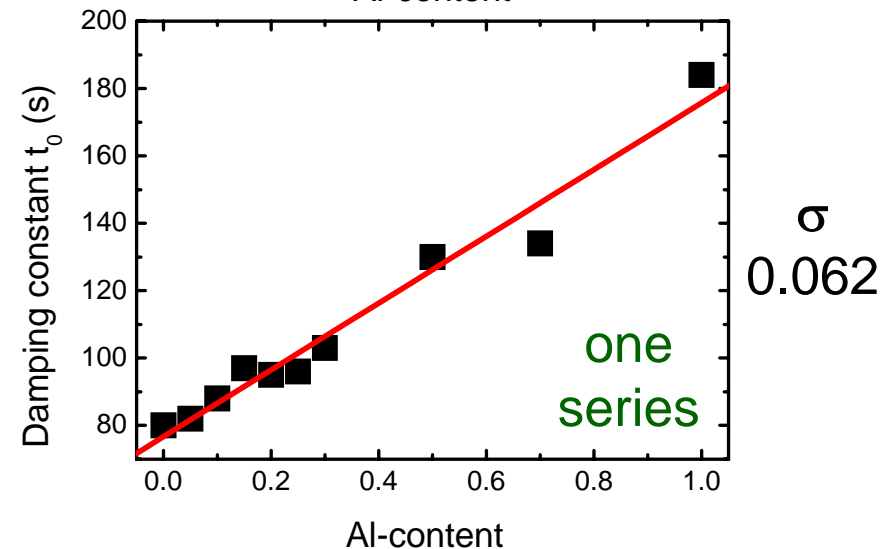
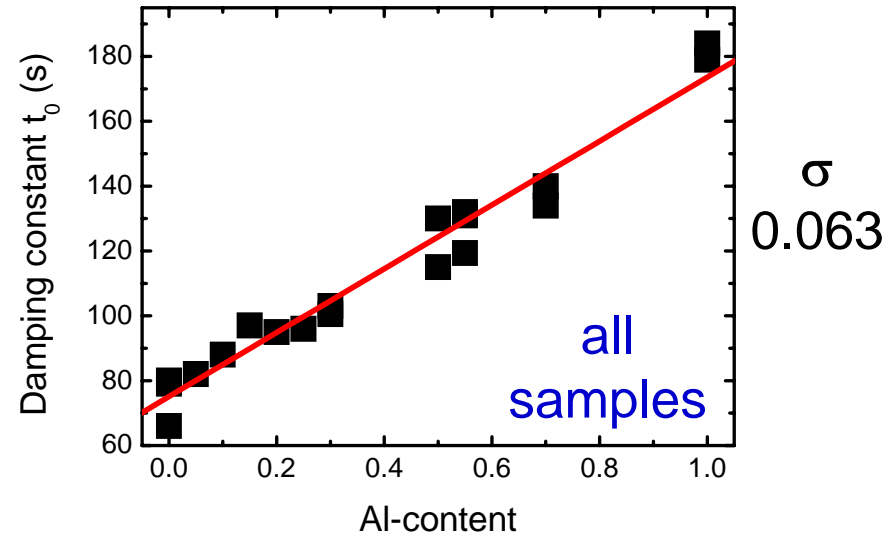
By fitting the measured reflection curves a determination of the Al-content is possible (error < 7 %)

for **one series**:

$c$  vs. Al-content shows as expected above a nice linear behavior.

**Error < 7 %**

**Damping constant** seems to indicate the Al-content for **all samples!**



# Summary

## Ex-situ:

- Determination of Al-content of quaternary  $(\text{Al}_x\text{Ga}_{1-x})\text{InP}$  alloys impossible with XRD measurements
- PL measurements allows to fix Al-content

## In-situ:

- Refractive index  $n$  and extinction index  $k$  by fitting the Fabry-Perot oscillations with EpiSENSE are not significant for the Al-content with our setup.
- Determination of equilibrium point  $c$  and oscillation depth  $d$  only useable for samples grown in a row
- **Damping constant  $t_0$**  is useful for a calibration of  $x$  in  $(\text{Al}_x\text{Ga}_{1-x})\text{InP}$  within an error of  $< 7 \%$

## Acknowledgement:

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- **DFG Forschergruppe FOR 730**

