

# Novel technique for monitoring of MOVPE processes

P.V. Volkov, A.V. Goryunov, V.M. Daniltsev,  
A.Yu. Luk'yanov, D.A. Pryakhin, A.D. Tertyshnik,  
O.I. Khrykin, and V.I. Shashkin

Institute for Physics of Microstructures RAS,  
Nizhny Novgorod, Russia



ICMOVPE - XIV

14th International Conference of Metalorganic Vapor Phase Epitaxy



Metz (France), June 2008

# Outline

Motivation

Methodology and experimental setup

Calibration

Measurement of temperature

Thickness measurement

Substrate bowing

Summary



IPM RAS

# Motivation

*In-situ* monitoring of

- growth parameters in MOVPE, MBE and PECVD reactors;
- microfabrication: laser ablation or dry etching in RIE reactor and ICP plasma.

Parameters:

- true temperature of substrate in different points;
- thickness of semiconductor layer;
- substrate bowing.

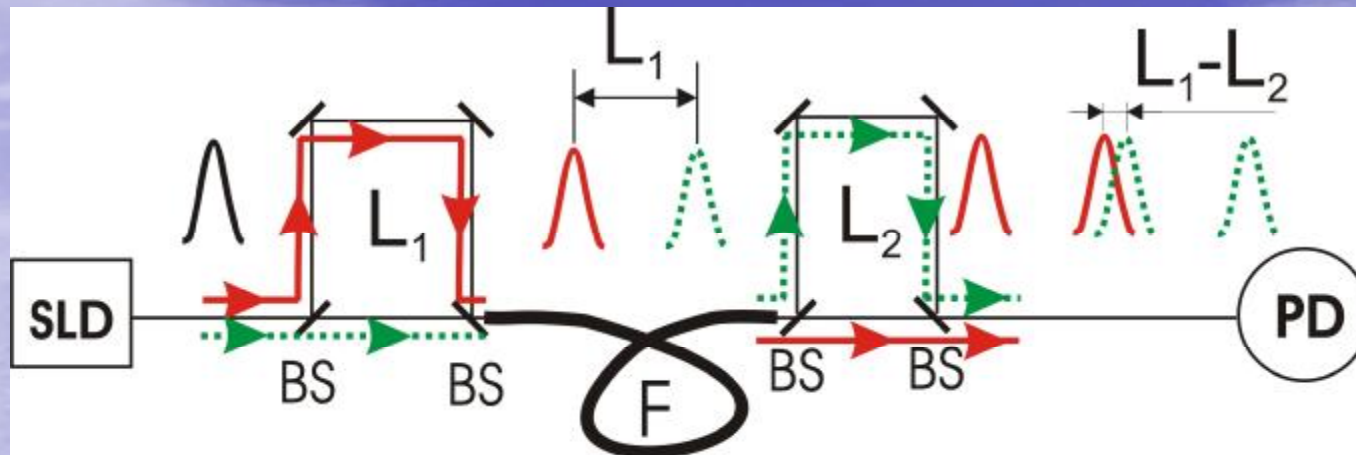


# Methodology

- Low-coherent tandem-type interferometry
- Measurands: total optical thickness and everything convertible into it (temperature, real thickness, strain, pressure, etc.)
- Robustness and noise immunity, reliability in real conditions
- Multiple measurement channels



# Experimental setup



SLD – superluminescent diode

F – fiber

BS – beam splitter

PD - photodiode

$L_{1,2}$  – optical path length in delay lines 1 and 2

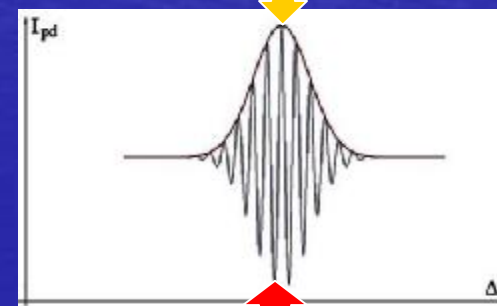
1 – reference delay line with swiped length

2 – delay line in substrate

Interference will occur if difference

$|L_1 - L_2| < L_{\text{coh}}$  (coherence length)

The optical thickness is registered as position of the envelope maximum.

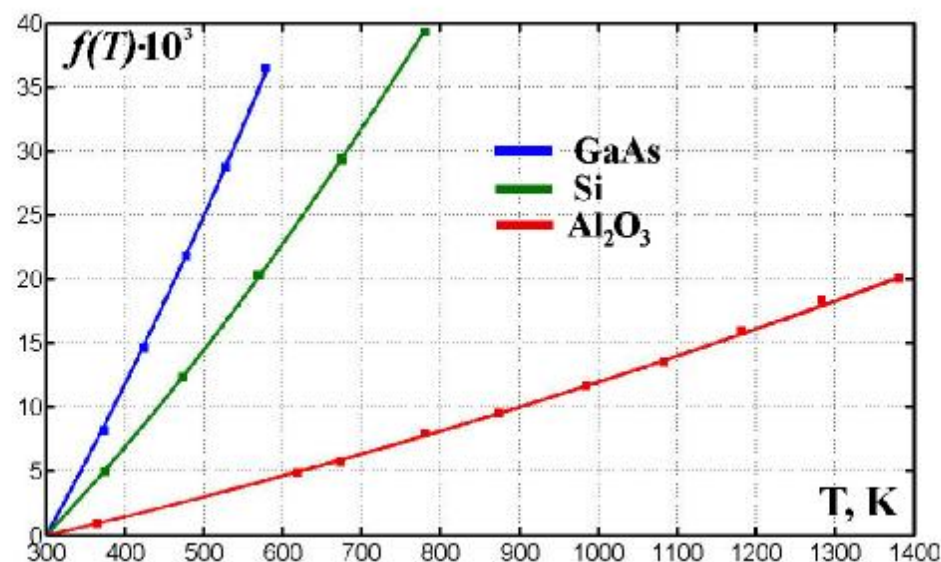


Tiny changes in the optical thickness can be registered as a phase shift of interference fringes.

# Calibration for measurements of temperature (along the envelope)

$$D(T) = n(T)d(T) = D_0(1 + f(T)),$$

$D$  – optical thickness,  
 $n$  – index of refraction,  
 $d$  – thickness of substrate  
 $D = D(T_0)$



$$f_{\text{GaAs}}(T) = 6.369 \cdot 10^{-8} \cdot T^2 + 7.407 \cdot 10^{-5} \cdot T - 2.795 \cdot 10^{-2}$$

$$T_0 = 300 \text{ K}, l = 1.3 \text{ mm}$$

$$f_{\text{Si}}(T) = 3.486 \cdot 10^{-8} \cdot T^2 + 4.455 \cdot 10^{-5} \cdot T - 1.65 \cdot 10^{-2}$$

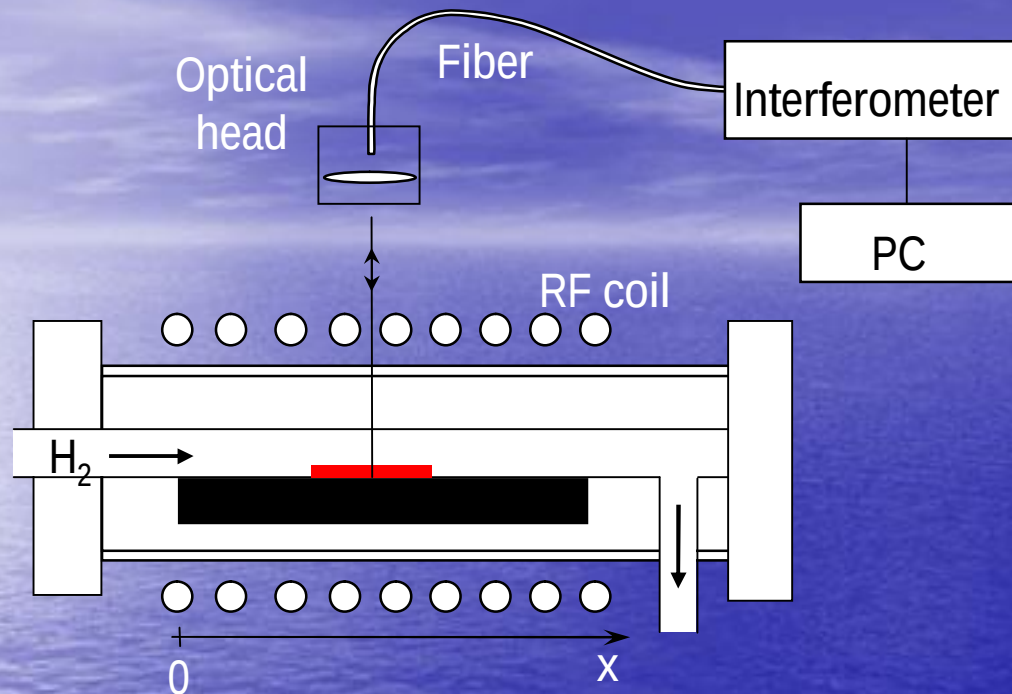
$$T_0 = 300 \text{ K}, l = 1.55 \text{ mm}$$

$$f_{\text{Al}_2\text{O}_3}(T) = 4.08 \cdot 10^{-9} \cdot T^2 + 1.178 \cdot 10^{-5} \cdot T - 3.903 \cdot 10^{-3}$$

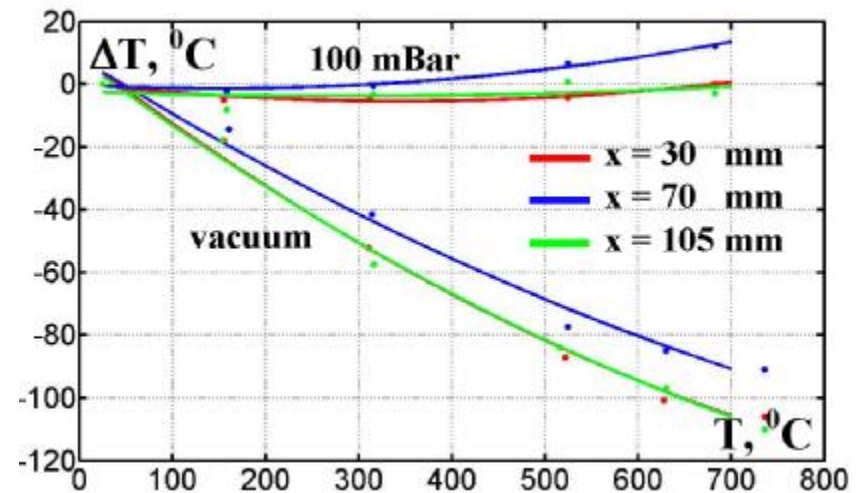
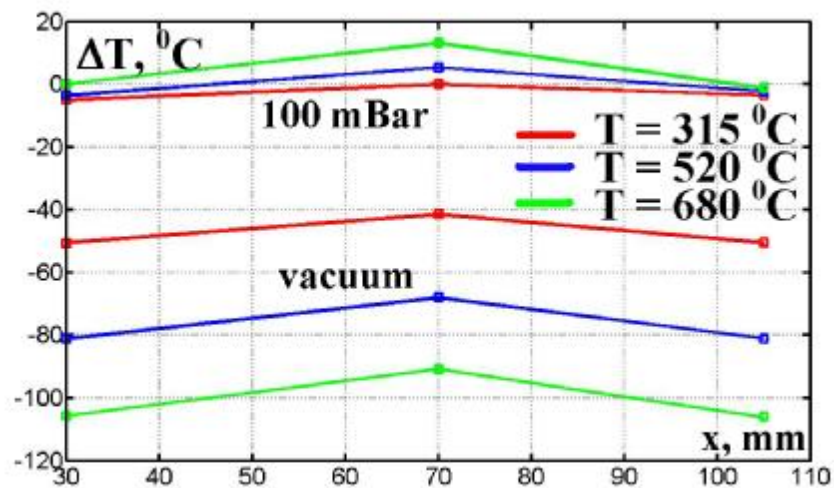
$$T_0 = 300 \text{ K}, l = 1.55 \text{ mm}$$

Calibration accuracy in thermostatic oven  $\pm 1^\circ\text{C}$

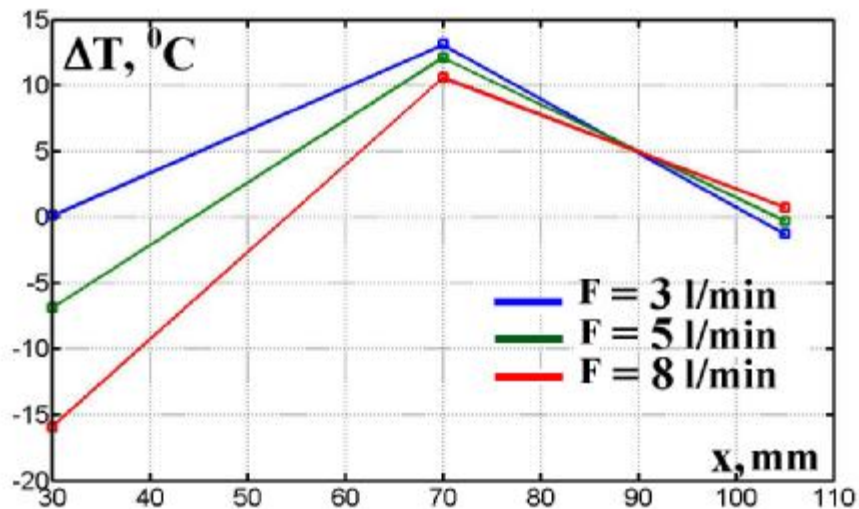
# Horizontal reactor MOVPE



$$\Delta T = T_{\text{optic}} - T_{\text{thermocouple}}$$

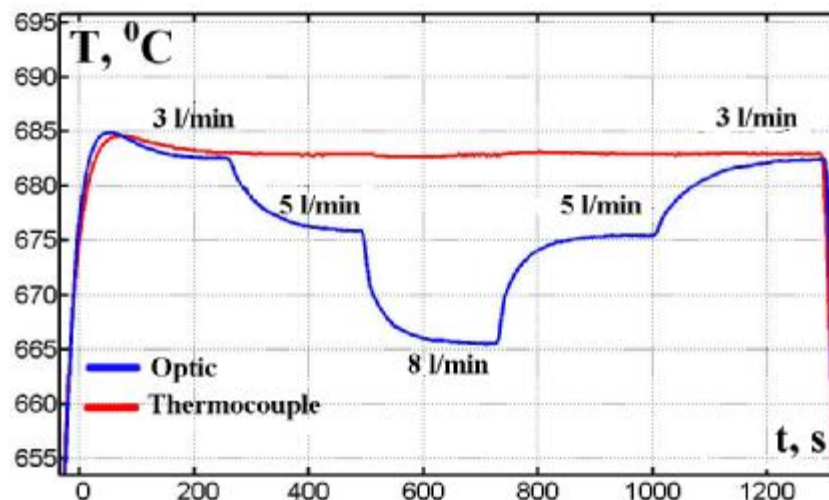


# Effect of hydrogen flow



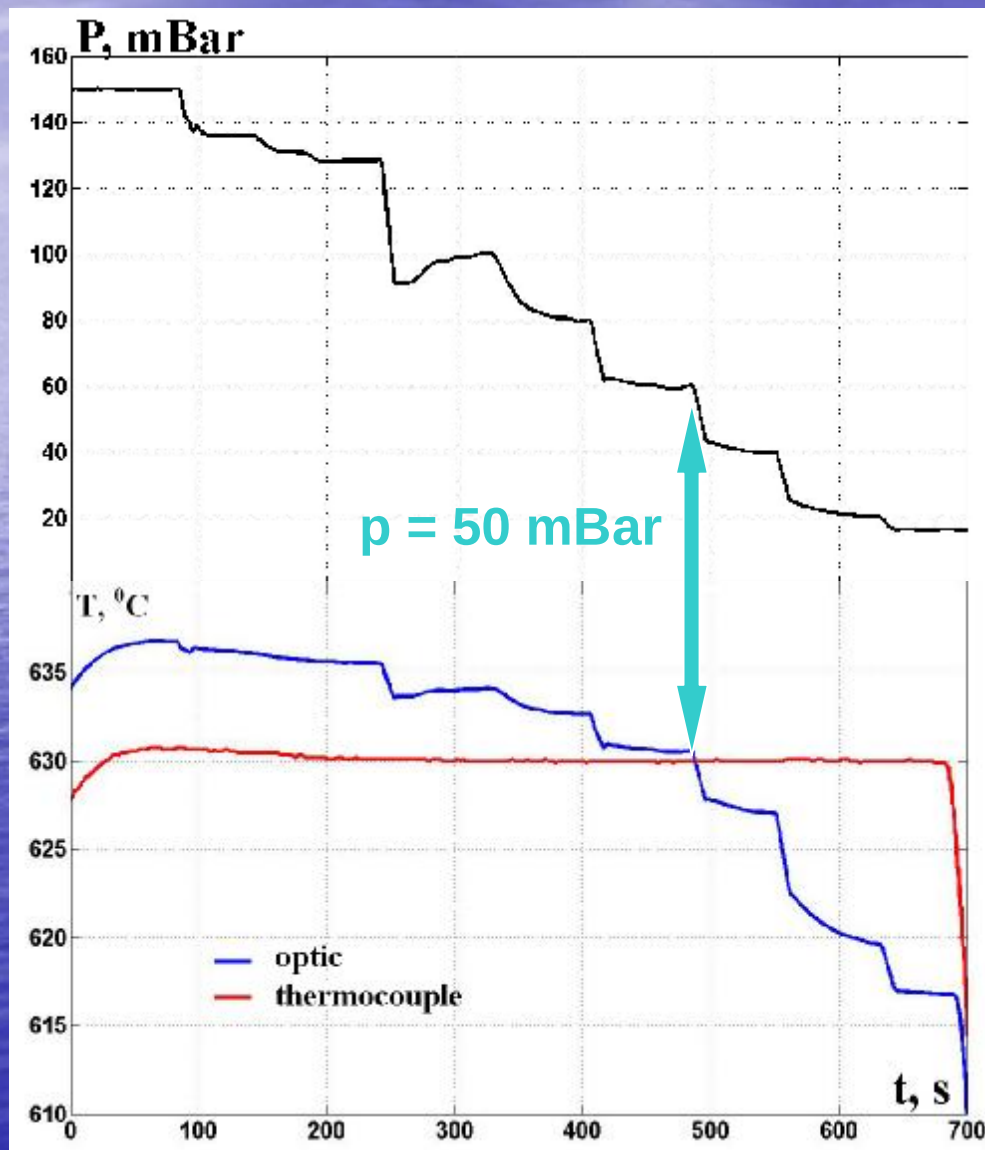
$$\Delta T = T_{\text{optic}} - T_{\text{thermocouple}}$$

$p = 100 \text{ mBar}$ ,  
 $T = 680^{\circ}\text{C}$



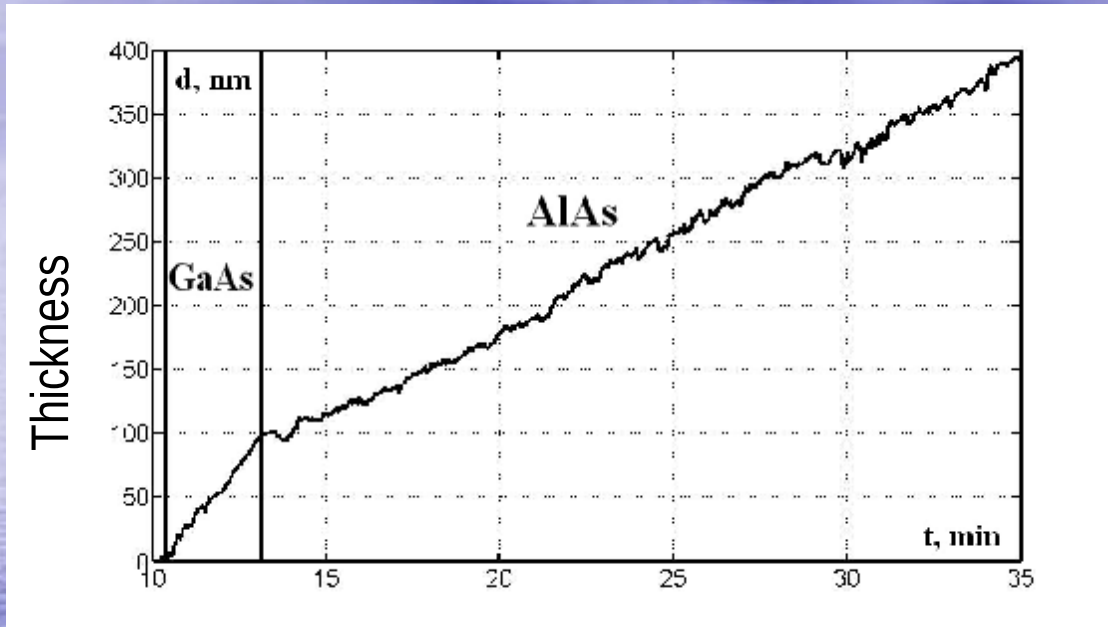
$F = 3, 5, 8 \text{ l/min}$ ,  
 $p = 100 \text{ mBar}$ ,  
 $x = 30 \text{ mm}$

# Dependence on pressure

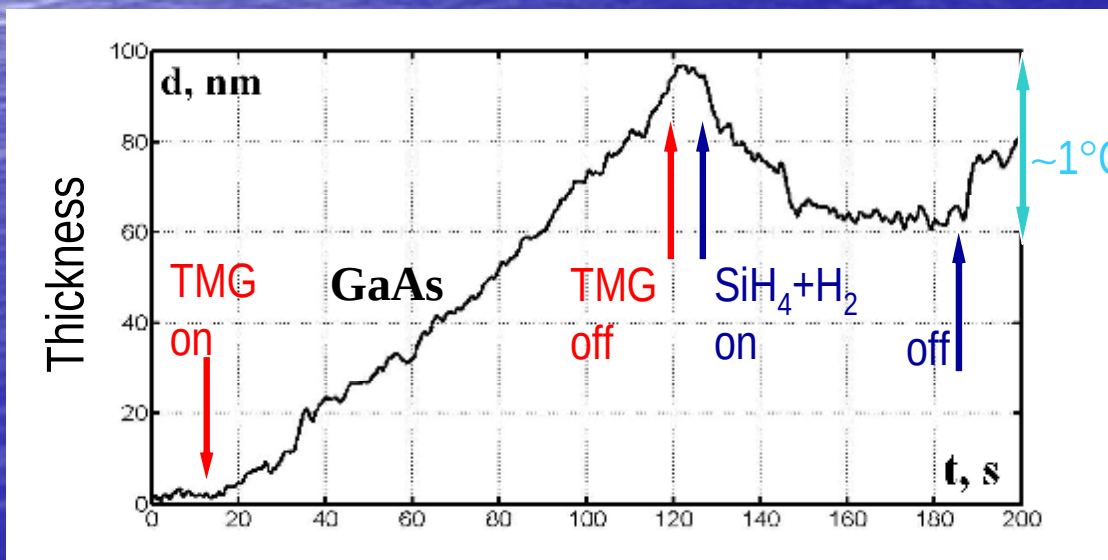


$F = 3 \text{ l/min,}$   
 $x = 40 \text{ mm,}$   
 $P_{\text{RF}} = 1150 \text{ W (PID - off)}$

# Monitoring of thickness (along the phase)



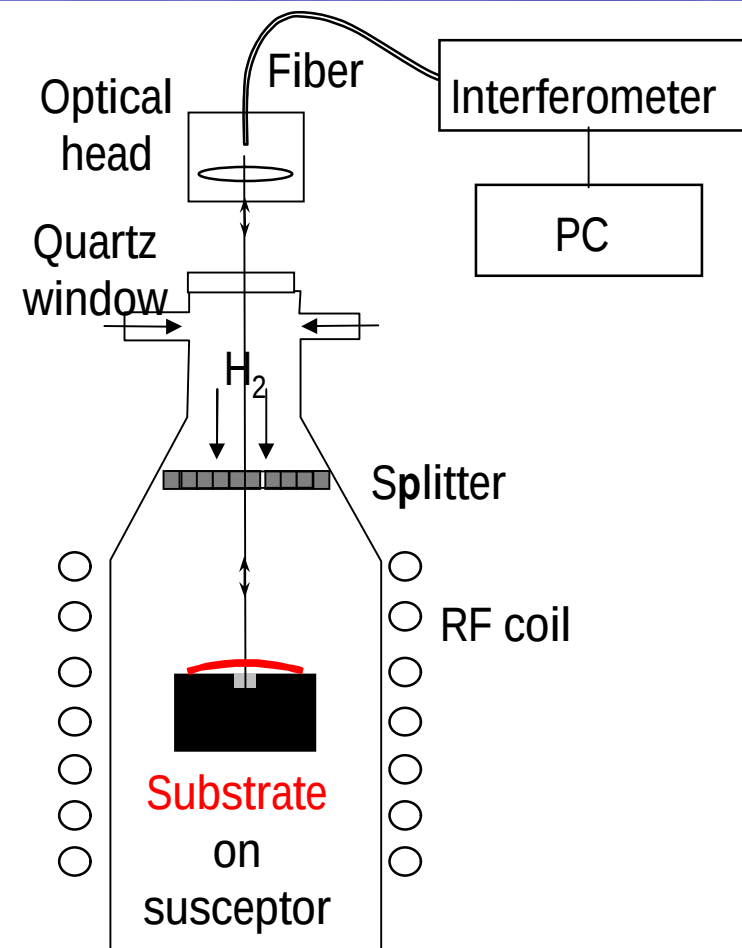
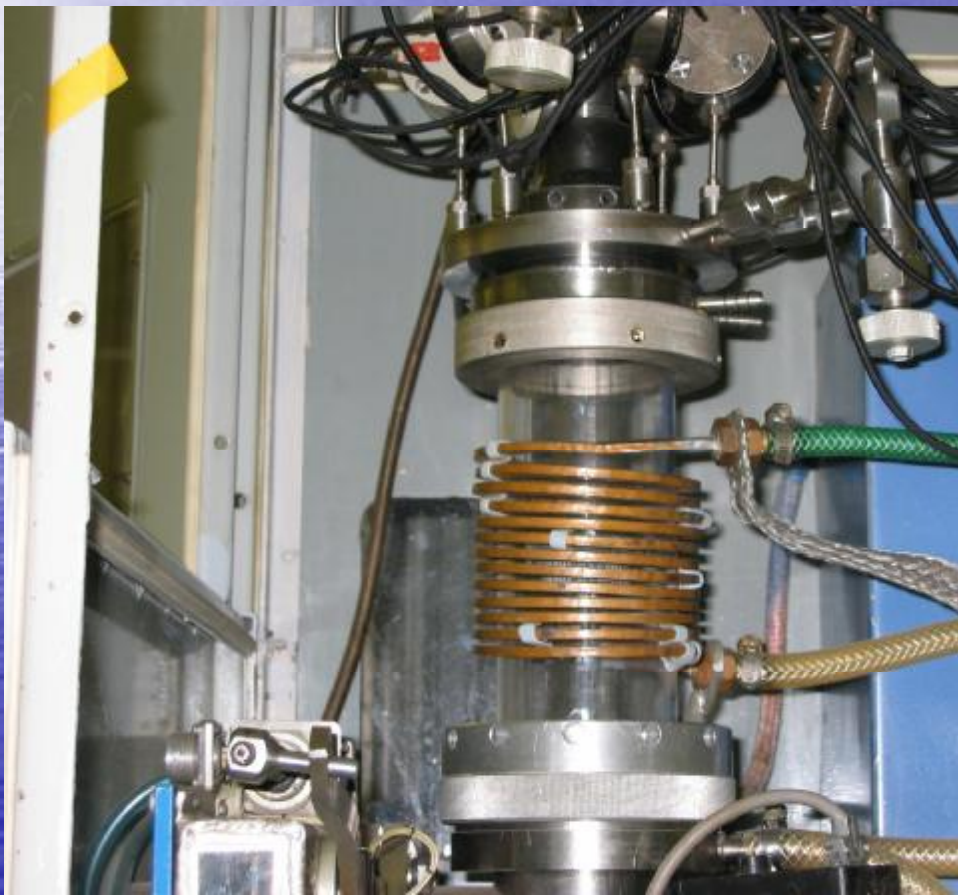
GaAs/AlAs  
heterostructures



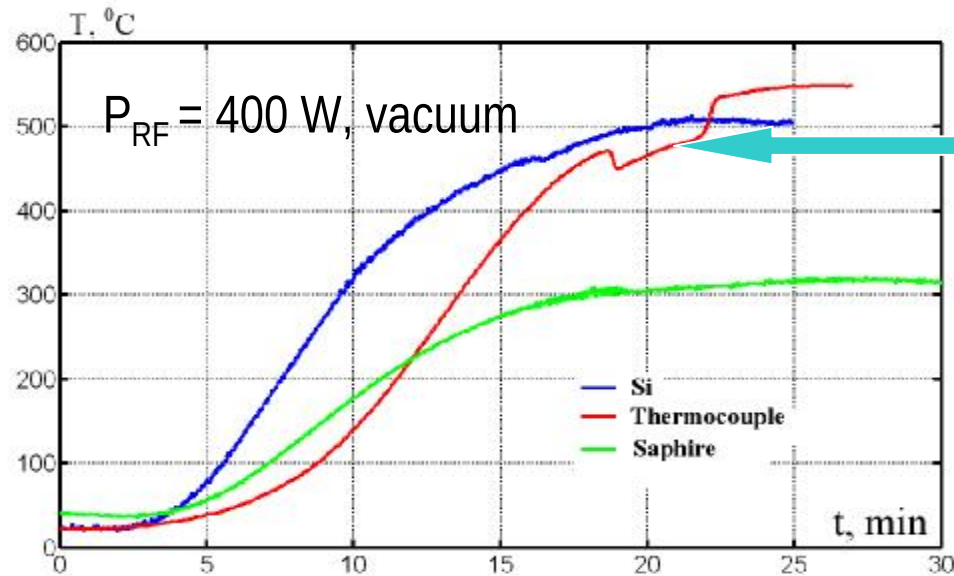
GaAs-d(Si)-GaAs  
structures

The accuracy is  
equal to  $\pm 2$  nm

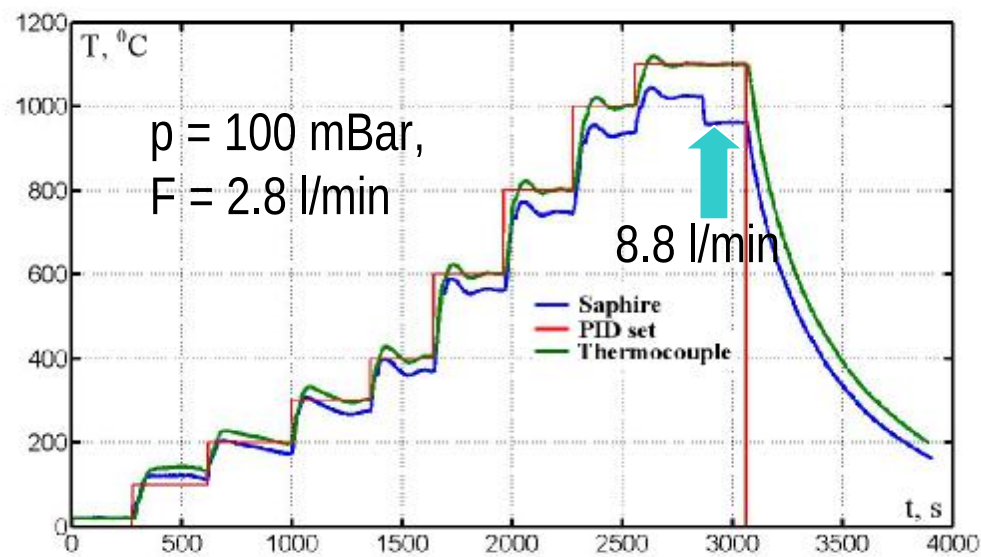
# Vertical reactor MOVPE



# Heating of sapphire substrates

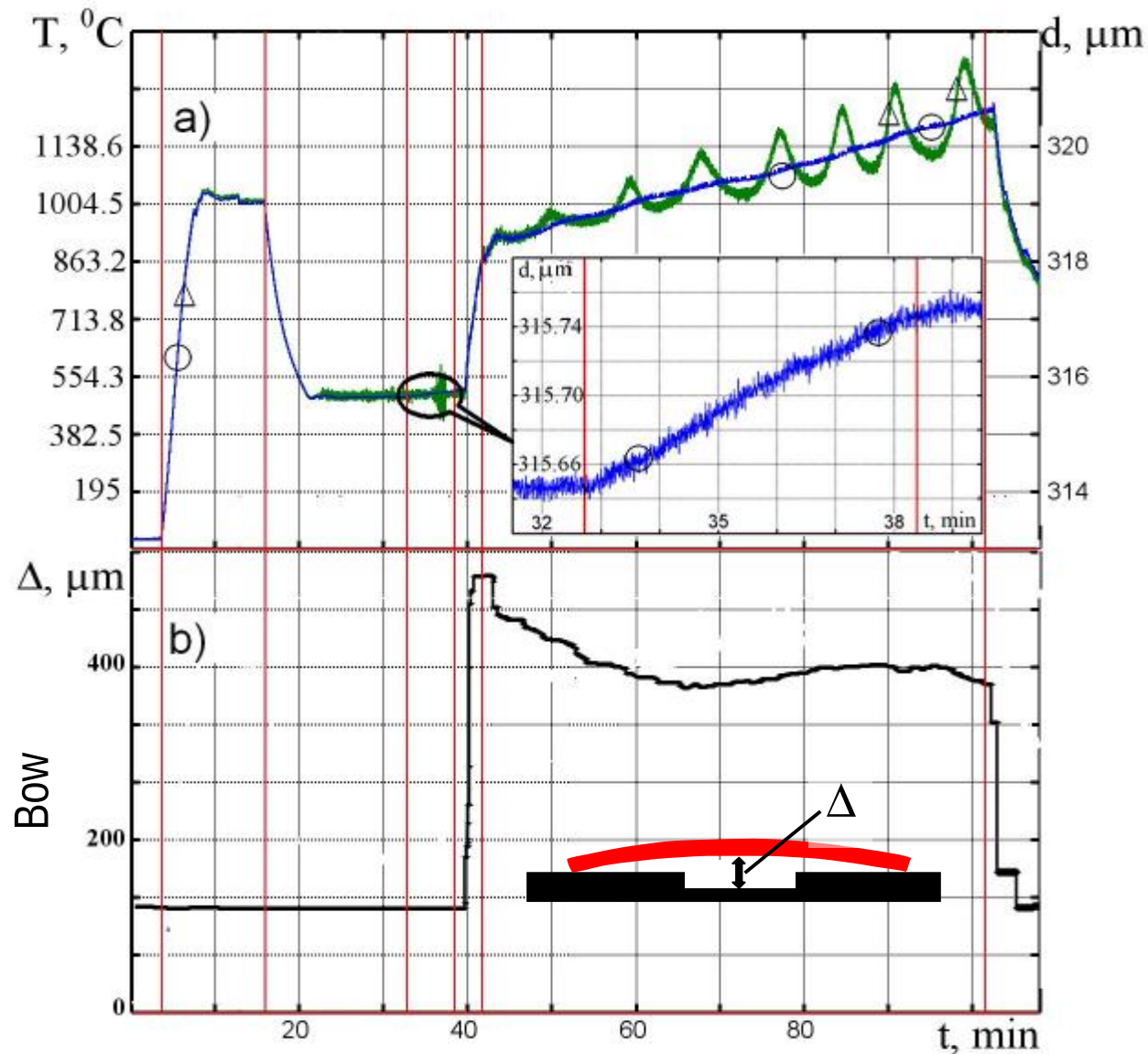


Unstable  
thermocouple  
reading



**Absolute  
precision of  
temperature  
measurements  
reaches  $\pm 1^{\circ}\text{C}$**

# Monitoring of the GaN growth



Along the phase  
Along the envelope

Accuracy:  
temperature -  $\pm 1^{\circ}\text{C}$ ;  
thickness -  $\pm 2 \text{ nm}$ ;  
bow -  $\pm 3 \text{ mm}$

# Summary

- Novel technique for monitoring of MOVPE processes is developed
- High-accuracy measurements of substrate temperature ( $\pm 1^\circ\text{C}$ ), thickness ( $\pm 2\text{ nm}$ ), as well as the bow ( $\pm 3\text{ }\mu\text{m}$ ) are performed
- Monitoring system is available at TEOS:

[www.teos-npp.com](http://www.teos-npp.com)

[teos-npp@mail.ru](mailto:teos-npp@mail.ru)



IPM RAS

# View of monitoring system



Thank you for attention !