LayTec's Gen3 in-situ metrology for MOCVD: Latest progress in software, hardware and new reactor adaptations

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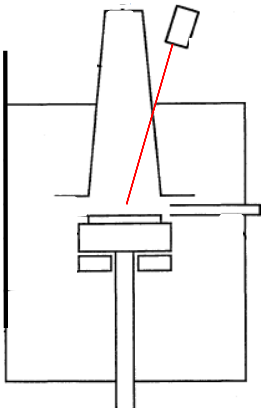
LAYTEC
Knowledge is key

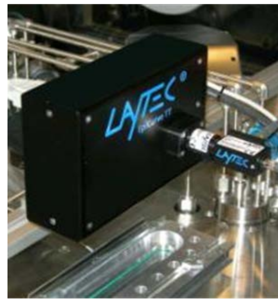
Outline

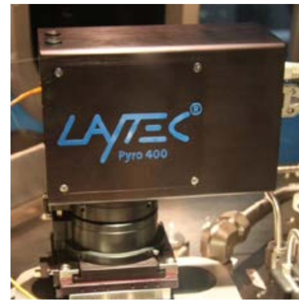
- From Gen1 to Gen2 to Gen3 – rising requirements in semiconductor R&D and production
- What‘s new in 2016 – Gen3
  - New modularity - new connectivity - new accuracy
- New modularity
  - EpiTT Gen3 - EpiCurve® TT Gen3 – Pyro 400 Gen3
- New connectivity
  - SECS/GEM
- New accuracy
  - New database accuracy for III-Vs
  - New curvature resolution
- Only good news?

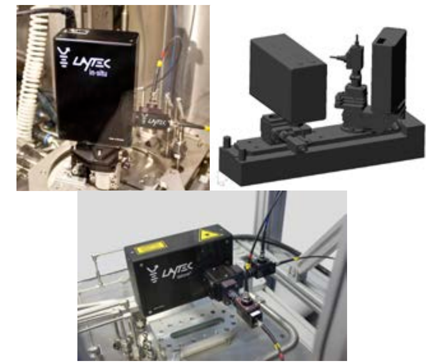
Rising requirements in semicoductor R&D and production

1991	2001	2005	2009	2012	2016
Nakamura	EpiTT	EpiCurve® TT	Pyro 400	EpiNet 2	Gen3 / EpiNet 2016









Gen1: powerful R&D tools

Gen2: GaN industry proven solutions

Gen3: modular high-performance at ALL MOCVD

Main driving force: cost efficient production of blue LEDs

Nobel prize invention → mature industry → what‘s new in 2016?

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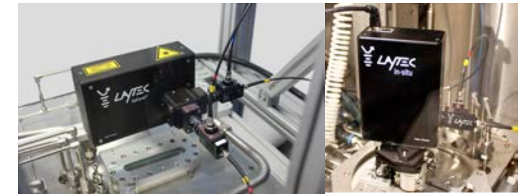
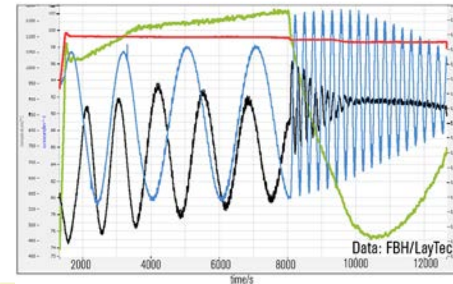
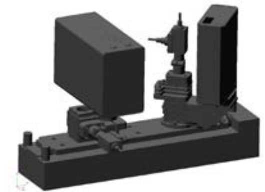
What‘s new in 2016 – Gen3

- New modularity: reactor specific optimizations instead of „one fits all“!
    - Hardware: application specific hardware solutions (rotation speed, T-range, multiple curvature heads…)
    - Software: application specific analysis modules



- New connectivity
    - Compound semiconductor manufacturing adopts silicon industry quality control
    - SECS/GEM and other interfaces to fab-wide MES systems
    - Tight statistical process control
- New accuracy
    - Avoid time and cost intensive ex-situ control
    - In-situ precision equivalent to XRD and bow





LayTec‘s Gen3 in-situ metrology – tunable for maximum performance at all MOCVD (AIXTRON, TNSC, Veeco, …) and all materials (GaN, GaAs, InP, Oxides, 2D, …)

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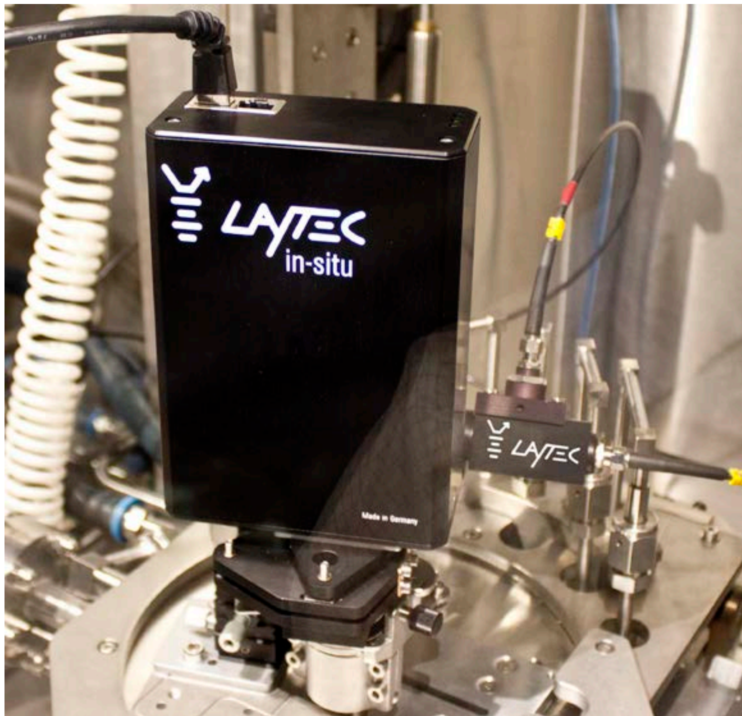
EpiTT Gen3

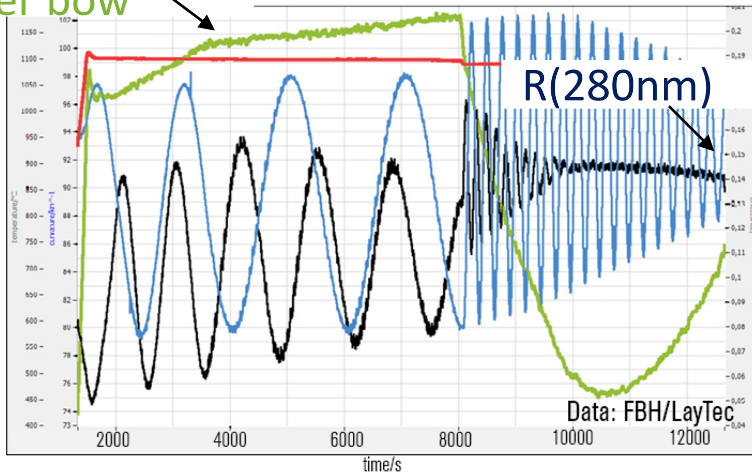


- Extended T-range: 1500°C (UV-LEDs) and 1700°C (SiC)
- Laser-based systems (for MOCVD systems with susceptor z-shift)
- New 280 nm reflectance wavelength for UV-C LED surface morphology inspection
- Additional spectral reflectance module (R-VCSEL) for complex structures (DBRs, VCSELs, …)

New add-on modules to meet specific customer requirements

Epi(Curve®)TT Gen3 – modules for 280 nm-reflectance and high-resolution wafer bow sensing

High-resolution wafer bow



- Additional **280 nm reflectance** (separate fiber optical head)
- Absorbed in AlGaN layers up to 65% Al-content
- Suitable for surface morphology monitoring

At AIXTRON CCS and Emcore/Veeco: **high-resolution wafer bow (0.3 km^{-1})** for in-situ 50 ppm lattice matching of ternary and quaternary layers.

R280 nm-module: essential for UV-LED processes

High-resolution wafer bow: a must for devices on GaAs and InP

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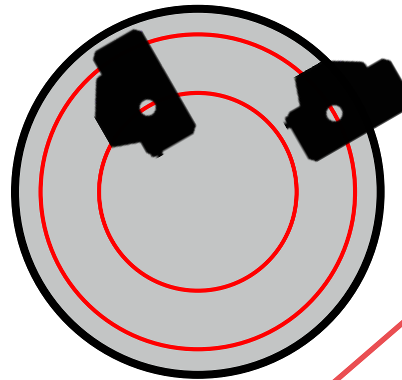
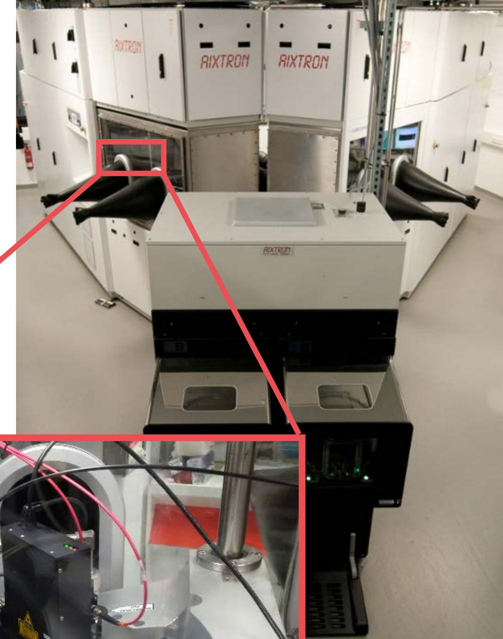
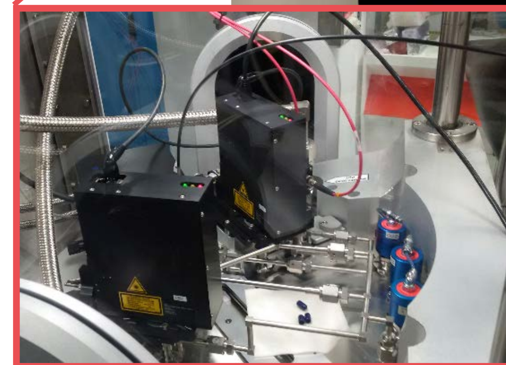
EpiCurve® TT Gen3

- Multihead curvature for single wafer (large diameter) reactors
- Here: AIXTRON's Crius II-XL reactor with single 300 mm wafer (2 measurement heads)
- Up to 5 heads possible – dependent on viewport configuration







Wafer bow and wafer flipping of 300 mm wafers taken under tight control

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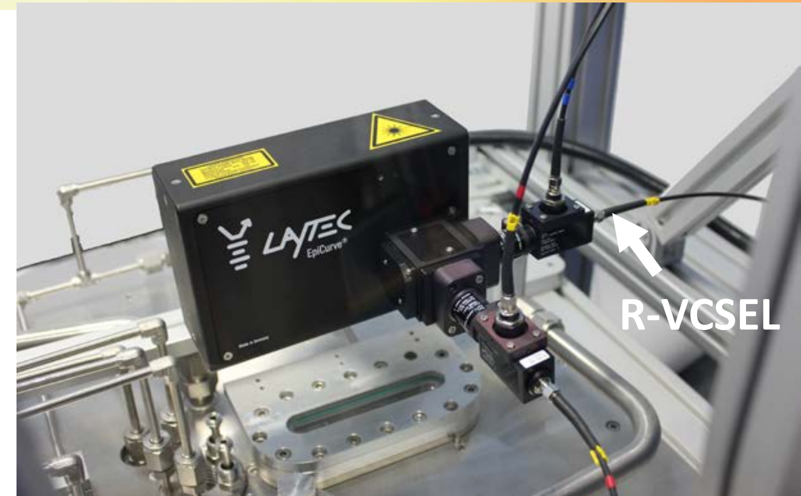
EpiTT / EpiCurve® TT VCSEL

- Proven work-horses – enhanced with spectral analysis
- 4in1 metrology system (TT, curvature, 3λ-reflectance, spectral reflectance)
- Epi(Curve®)TT systems can be upgraded with additional spectral reflectance module (R-VCSEL)
- Spectral monitoring of DBR-growth, stop-band and cavity-dip position



EpiCurve® TT VCSEL at the view-port of an AIXTRON G3 Planetary Reactor®

Full EpiTT or EpiCurve® TT performance + spectral analysis at one viewport

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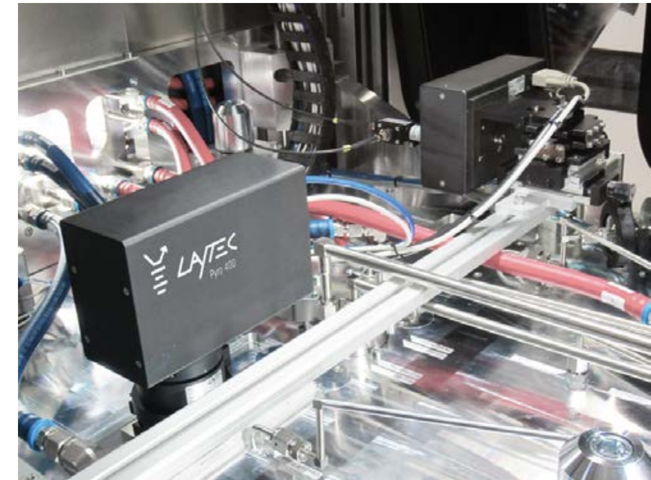
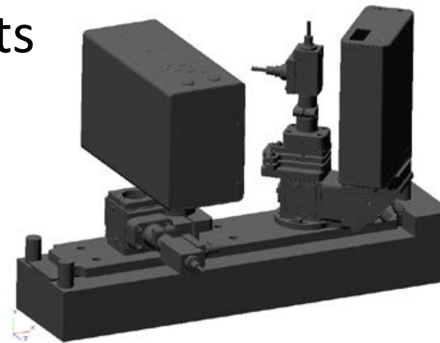
Pyro 400 Gen3

- **New:** embedded Beckhoff CX enables 24/7 performance
- **New:** emissivity correction
- For AIXTRON Planetary Reactor® series with 2 viewports
- For Veeco K700 and other systems with suitable viewports
- AbsoluT400 calibration
- No Fabry-Perot oscillations in surface temperature sensing





Precise wafer suface temperature measurement for blue LEDs and GaN-on-Si structures

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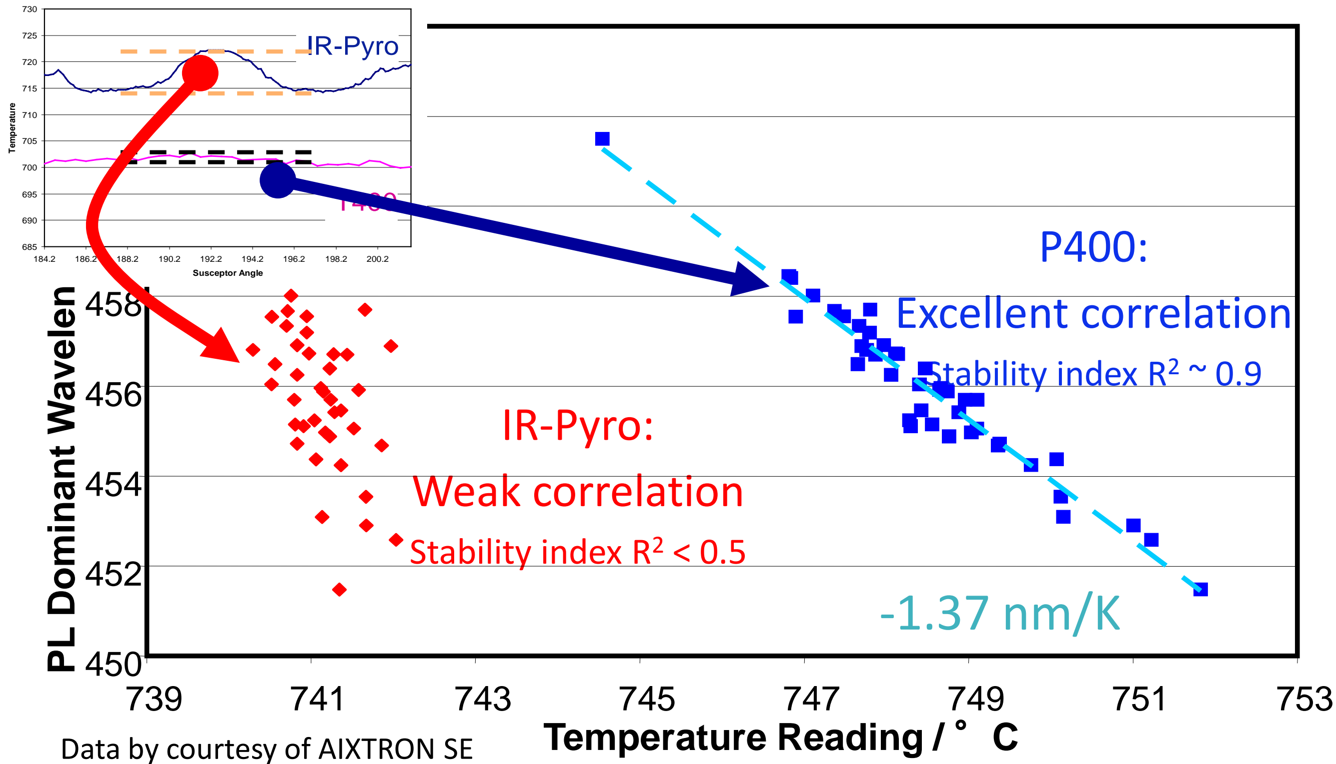
Pyro 400 Gen3



Exellent correlation with RT-PL both at AIXTRON Planetary Reactor® and at Veeco K700 reactors. New ECP feature for latest, high-output LED stacks.

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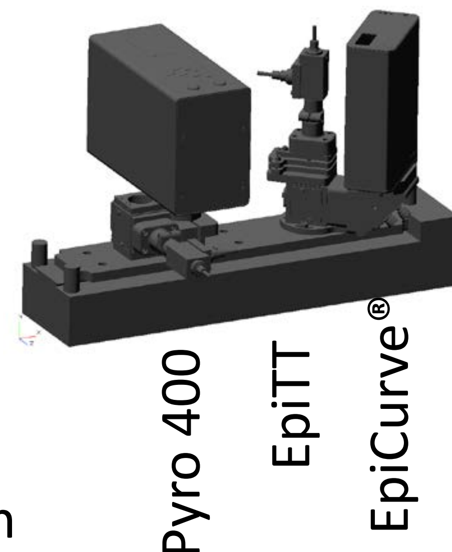
Gen3 products for high speed rotation reactors:

- Pyro 400 ECP (on recent models, e.g., Veeco K700)
- For reactors of Veeco, Emcore, SMI, Agnitron, and Asian vendors:
    - EpiTT series
    - EpiCurve® TT
    - EpiGuard® PC (analyzing DRT data for SPC)
- Several EpiTT/EpiCurve® TT successfully installed on D125/D180 Veeco/Emcore RnD Systems
- Software interfaces to growth system software (Agnitron, SMI)



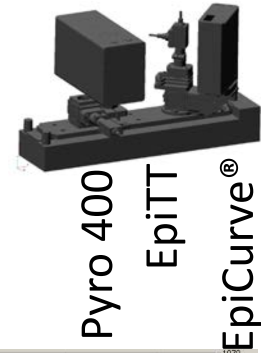
Whatever type of reactor you are using – LayTec in-situ metrology is a must for cutting edge R&D and highest productivity!

Pyro 400 Gen3 at Veeco K700

±1K GaN (AbsoluT!) surface temperature

MQWs

LED Run



GaN surface temperature

- at MQW temp.: noise < ±0.5K
- ECP removing FPO artifacts
- calibrated to AbsoluT scale
- Data output via SECS/GEM to MES

In addition: EpiGuard® PC analyses your DRT reflectance and bow data based on Pyro 400 GaN temperature + forward through SECS/GEM to MES!

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EpiNet 2016

- Based on industry qualified EpiNet 2.2
- EpiNet 2016 OEM
  - Via AIXTRON (similar features to EpiNet 1.10) + Multipocket analysis, e.g., G4-TM (15x4“)
- EpiNet 2016 Premium
  - All OEM features + Pocket guardian, SPC analysis + many (optional) Add-Ons
- Add-Ons (examples):
  - Special analysis packages: e.g., III-V high precision analysis package
  - SECS/GEM and other industry standard interfaces
  - Data import from non-LayTec systems (DRT) and OEM metrology heads for analysis
  - High resolution wafer bow modules (CCS/ARs, Planetary/AR, TNSC/HR)

Select your specific moduls - pay only what you use!

Example: Routine AlGaAs composition calibration by in-situ reflectance (by courtesy of Jenoptik/Germany)

Run F	Target		ex-situ XRD		in-situ	in-situ	in-situ	in-situ
Layer	d (nm)	x	r (nm/s)	x	r(nm/s)	x	Δr/r	Δx
GaAs	750	0,000	0,5971	0,000	0,602	0,002	0,8%	0,2%
Al(0,4)GaAs	450	0,400	0,5531	0,402	0,564	0,402	2,0%	0,0%
GaAs	750	0,000	0,5964	0,000	0,602	0,000	0,9%	0,0%
Al(0,6)GaAs	450	0,600	0,5659	0,601	0,558	0,607	-1,4%	0,6%
GaAs	750	0,000	0,5959	0,000	0,600	0,000	0,7%	0,0%
Al(0,7)GaAs	450	0,700	0,5828	0,695	0,577	0,690	-1,0%	-0,5%
GaAs	750	0,000	0,5967	0,000	0,599	0,000	0,4%	0,0%
AlAs	450	1,000	0,5890	1,000	0,598	1,000	1,5%	0,0%
GaAs-Sub.		0,000						

Single wavelength (633 nm) in-situ reflectance analysis gives:

- AlGaAs composition with accuracy of ±0.5%

- Growth rates with ±1% variation from XRD

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Always everything good?

- NO!
  - The way from EpiNet 2.0 to EpiNet 2016 – Longer than expected, more bumpy…
  - Hardware (especially PC) – 2015 – component optimization (e.g., SSD for better database performance)

- Thank you to all of you – for your patience (sometimes necessary), input and support

Keep on pushing us to improve our products and services!

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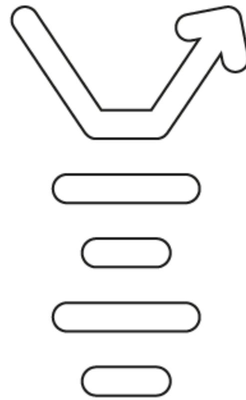

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