Intelligent Epitaxy Technology, Inc.

IntelliEPI Status Update
2Q/2015

ISO 9001: 2008
FM 511967

1250 E. Collins Blvd., Richardson, TX 75081, USA

IntelliEPI: The Company

- *A Texas semiconductor manufacturing company located in Richardson, TX, since January 1999.*
- *Founded by Dr. Yung-Chung Kao (TI), Dr. Paul Pinsukanjana (UCSB/JPL), Randy Thomason (TI), and Kevin Vargason (TI), combining experiences in electronics and optoelectronics. In 2001, Dr. J.M. Kuo (Lucent) joined*
- *A venture capital funded company (A-round: 1999; B-round: 2000)*
- *ISO 9001 certified since March 2007 (current ISO9001:2008)*
- *Listed on Taiwan GTSM exchange (Stock # 4971) under holding company registered at Cayman Islands (IPO on July 24, 2013)*

IntelliEPI provides GaAs (up to 6in) and InP (up to 4in) MBE PHEMT and HBT epitaxial wafers to RF MMIC and wireless wafer fabs for communications applications. We also provide optoelectronics products (PIN/APD, IR detectors, lasers) and various III-V based industrial and energy-related products

Intelli*EPI* Business Status Update (05/2015)

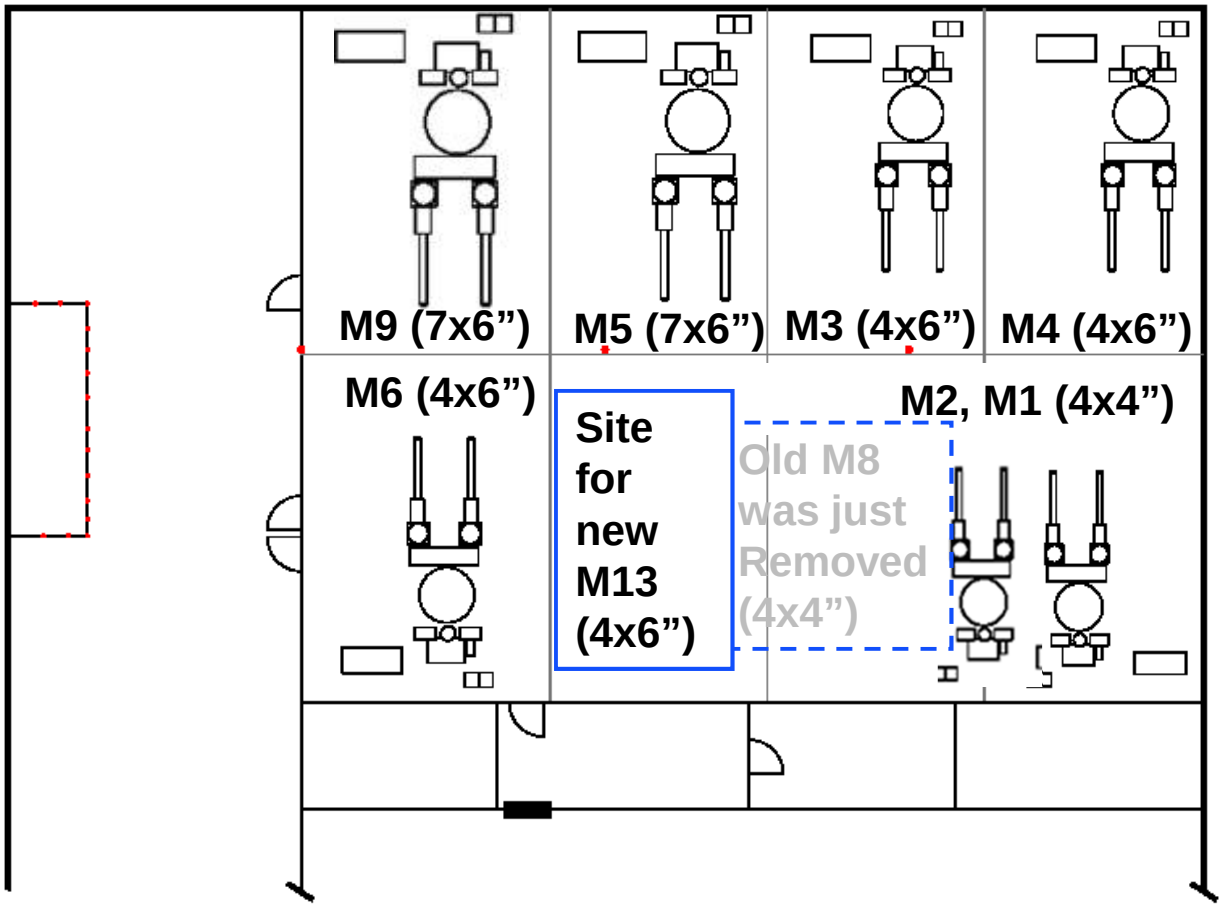
- *Completed 16 years of operation (1999 -); profitable position since 2007*
- *2015 projection: $25-27M, 2014 sales: $21.6M, 2013: $19.5M*
- *2014 product mix:*
  - GaAs: 47%, InP: 31%, Opto (PIN, APD, VCSEL, GaSb IR detector): 22%
  - Top 3 products: GaAs pHEMTs, InP-based HBT/HEMTs, Sb-based IR detectors
- *2015 product mix projection: GaAs (50%); InP (24%); GaSb (26%)*
- *2014 notables:*
  - Acquired Soitec and Skyworks GaAs MBE business & equipment (10 MBEs)
  - Establish Arapaho back-up site for GaAs/InP/GaSb MBE (3 MBEs)
  - Completed issuance of US$10M convertible bond for plant expansion
  - Acquired land in North Texas area for future expansion
- *2015 focus:*
  - Set up a 60K ft2 new site to consolidate current operations at 3 different sites besides back-up site
  - Install 4 MBE systems at Collins and Arapaho sites for GaAs, InP, GaSb growth
  - Develop HB CdZnTe crystal growth and InSb crystal growth
  - Set up 3in to 6in GaAs and InP re-polishing capability at IET/C

Intelli*EPI*: Facility at Richardson, Texas

Current facility since January 2002: 1250 E. Collins, Richardson, TX (Dallas suburb)

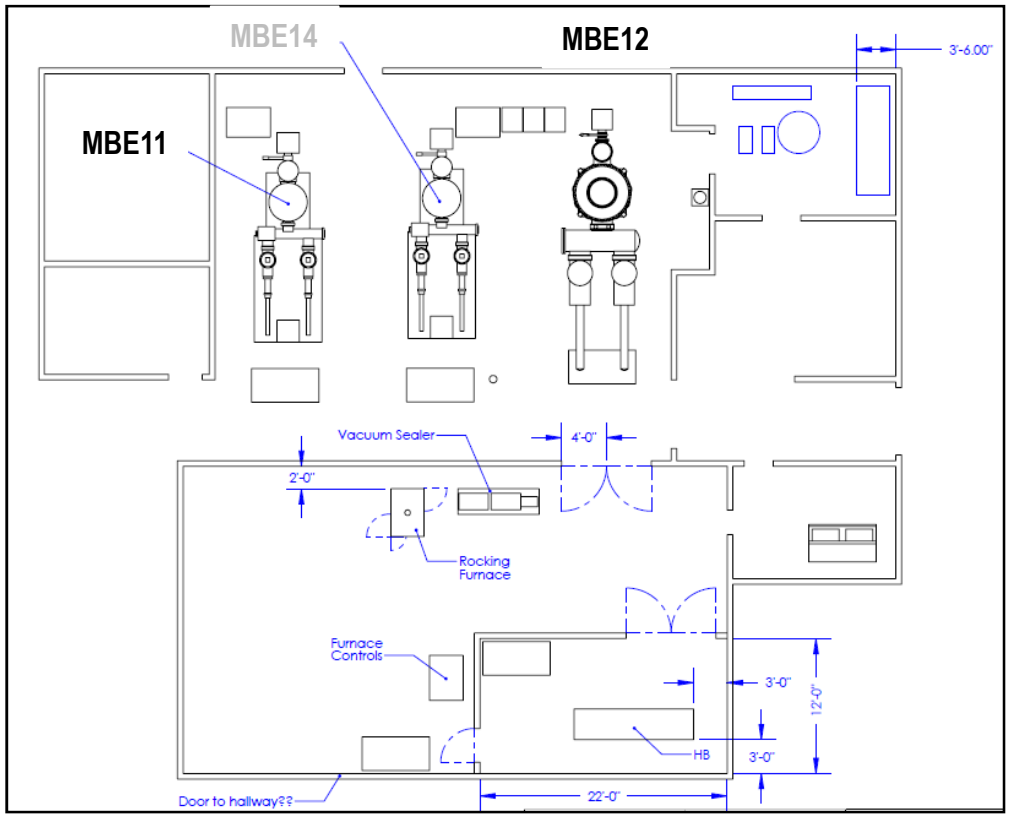
- *23,000 ft2 (production: 13,000 ft2; Office: 10,000 ft2); set up of 8 production MBEs*
- *Clean room for post growth testing and LAD processing*
- *48 full time employees in Texas*
- *2nd site: 8,500 ft2 facility in Allen, TX (10 miles north)*
- *3rd site: 4,000 ft2 Arapaho Rd, Richardson (3 production MBEs installed or in installation)*

IntelliEPI: MBE Manufacturing Area at Richardson, TX Site



- *MBE manufacturing area have 7 multi-wafers MBE systems installed (two 7x6", three 4x6", two 4x4"); each bay has independent AC, exhaust, class100 load/unload, airline, waterline, N2 connections*
- *Plan to install a 4x6" R6000 in 2Q/15*

IntelliEPI: Offsite Back-up MBE at Arapaho Site (2014)



- *IET/Arapaho site ready by 3Q/2014*
- *MBE11 system in operation; MBE12 installations in progress*
- *Plan to convert a MBE49 for GaN pHEMT growth due to customer demands*

IntelliEPI: III-V Compound Semiconductor Product Matrix

	RF and microwave	High Speed Digital	Optoelectronics
Applications	• RF components in handsets • Automotive radar • Defense related	• OC768- 40Gbps network • OC192-10Gbps network	• Fiber optic network light sources and Photo-detectors
Device Structure (Red in Production mode)	• GaAs pHEMT • GaAs mHEMT • InP HEMT • InP HBT	• InP SHBT/DHBT • InP HEMT • GaAs mHEMT • GaAsSb DHBT	• GaAs PIN/APD • InP PIN/APD • QWIP • Diode laser • Type-II SLS • Modulator

IntelliEPI: 6in Capacity Analysis and Expansion (pHEMT)

	Current Capacity 24x7 (18 pHEMT runs/day)	2014 Capacity for pHEMT (24X7, 18 runs)
4X6"MBE3(As,P)	1650 pHEMT/mo	1650 pHEMT/mo
4X6"MBE4(As)	1650 pHEMT/mo	1650 pHEMT/mo
7X6"MBE5(As)	2900 pHEMT/mo	2900 pHEMT/mo
4X6"MBE6(As,P)	1650 pHEMT/mo	1650 pHEMT/mo
7x6"MBE9(As)	2900 pHEMT/mo	2900 pHEMT/mo
4x6" MBE13 (As)*		1650 pHEMT/mo
For pHEMTs	11000 pHEMTs	12500 pHEMTs/mo

- Based on 85% machine uptime, and 90% yield under 24/7 operation
  - Typical production MBE campaign PM turn-around time: 4-6 weeks.
- Currently, 3 MBEs have Sb capability: 4x4" (MBE1, MBE2, MBE11); another 7x5" Riber6000 MBE is in installation (industrial first 5/6in multi-wafer MBE)
- 5 P-containing MBE systems: 4x4" (MBE2, MBE11); 9x4" (MBE3, MBE6, MBE13)
- By 3Q/15, we should have 11 installed MBE system and 30% capacity increase

IntelliEPI: MBE Facility in Collins Blvd., Richardson, Texas

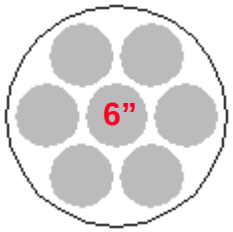
- *8 installed MBE reactors:*
  - 2 Riber 7000 (7x6”, 14x4”)
  - 3 Riber 6000 (4x6”, 9x4”, 15x3”)
  - 2 Riber 49, 1 Riber V100 (4x4”, 6x3”)
- *Mobile partitions allow MBE operation & maintenance at the same time*
- *Dedicated operation and cleaning facilities designed to handle phosphorous for all MBE systems*

Riber 7000

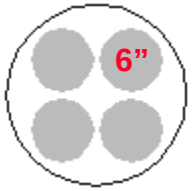
IntelliEPI: Multi-Wafer Production MBE Platen Design

Capacity for production reactors

Riber7000: **7x6”**
14x4”
25x3”



Riber6000: **4x6”**
9x4”
15x3”



Riber 49: **4x4”**
6x3”
11x2”

Riber7000: 7x6” MBE reactor

Experienced with product transition:

- *Development to production on multi-wafer MBE systems*
- *Reactor & substrate size scaling: mainly support from 2” to 6” size substrates (1”, 200mm, and 300mm are also supported)*

Characterization Facility

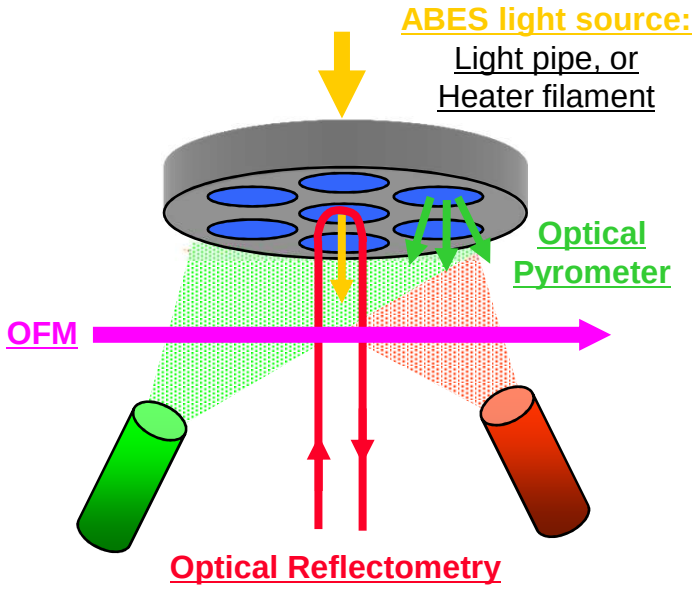
- *Class 100 clean room: (2000 ft^2)*
- *Characterization tools:*
  - X-ray diffraction
  - PL mapping
  - Surface particle scan
  - Hall measurement
  - Contactless resistivity mapping
  - Electro-chemical CV profiling
  - White light reflection spectrometer
  - Electrical CV profiling
  - Mercury probe CV
  - Parameter analyzer
  - 77K FT-IR PL
  - 77K Dark I-V
  - Wire bonder
  - Wafer flatness measurement
  - Variable temperature cryostat

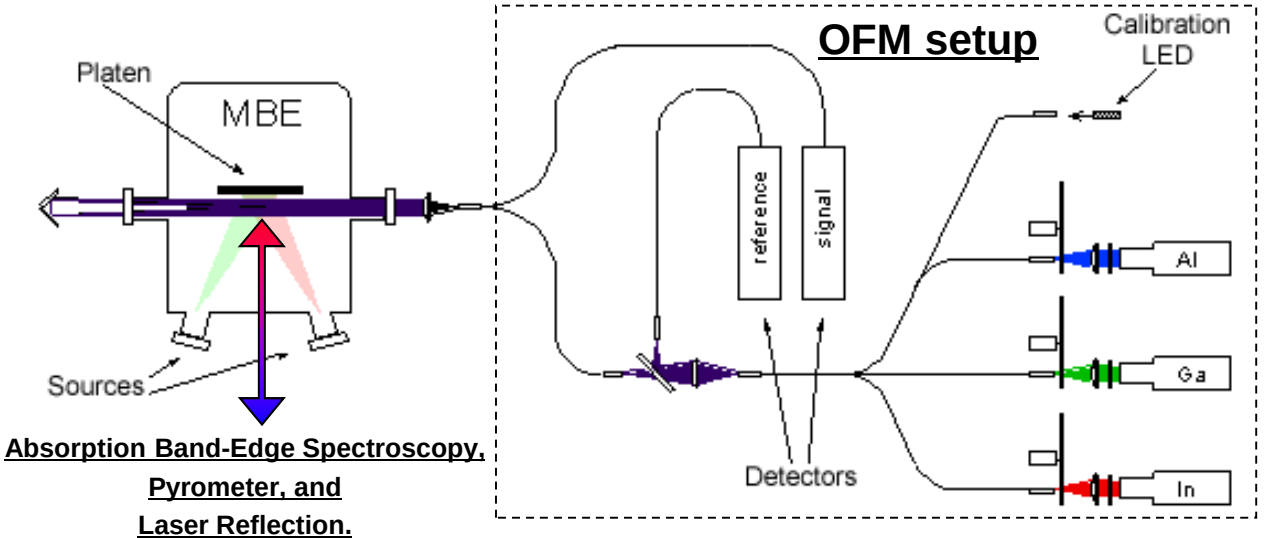
IntelliEPI: Production Real-Time Sensors

- ***Run-to-run reproducibility:***
  - Maintaining critical specification ranges
  - Verification of growth process details (condition and layers)
- ***Limitations of ex-situ characterization:***
  - Slow post-growth feedback
  - Additional wafer handling and cost
  - Limited information about growth condition profile vs. epi-depth
- ***New product development:***
  - Faster development cycle time
  - Improved performance for more demanding specifications
- ***Bad run detection/correction/termination:***
  - Loss of wafers: very expensive for larger systems and for InP
  - Wasted machine time, materials, & operating expenses

IntelliEPI: Overview of in-situ Sensor Technologies

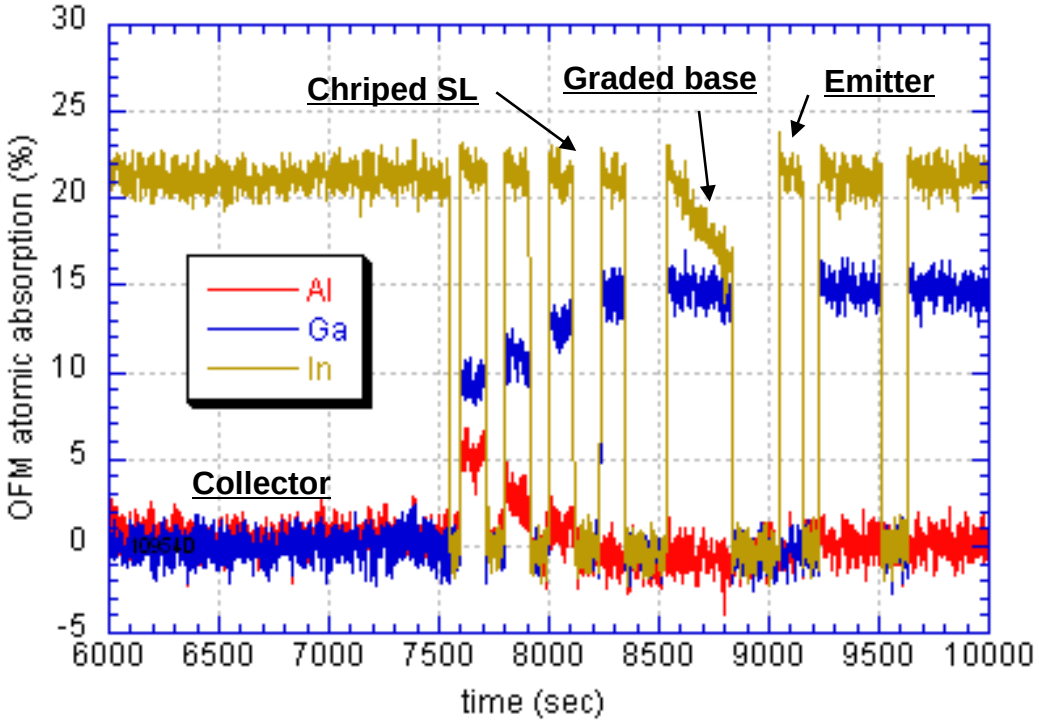
- ***Substrate temperature***
  - Pyrometry
  - Absorption Band-Edge Spectroscopy (ABES): band-gap dependence on temp
- ***Materials composition***
  - Optical-based Flux Monitor (OFM): atomic absorption of group III fluxes
- ***Growth rate***
  - Optical Reflectometry
  - Pyrometric Interferometry

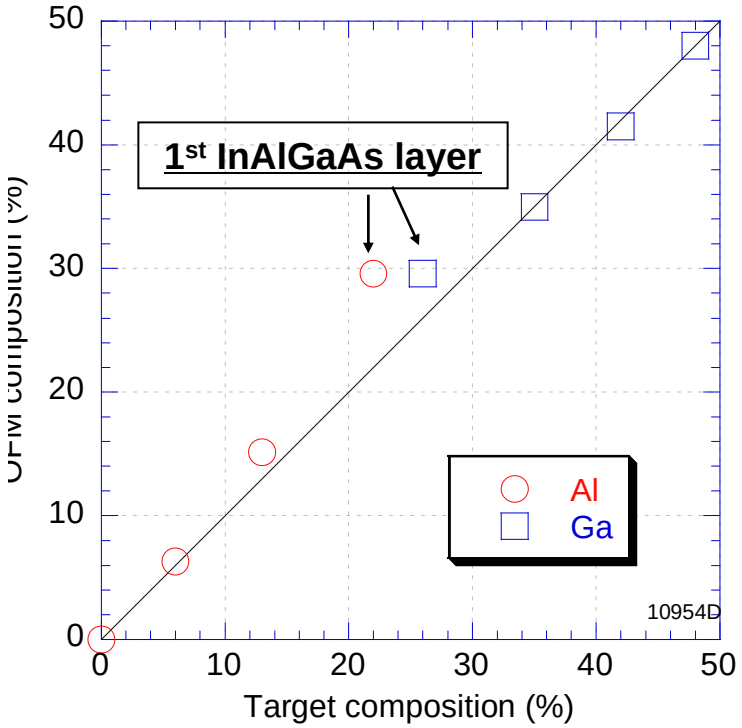




Absorption Band-Edge Spectroscopy, Pyrometer, and Laser Reflection.

IntelliEPI: InAlGaAs In Situ Composition Monitoring

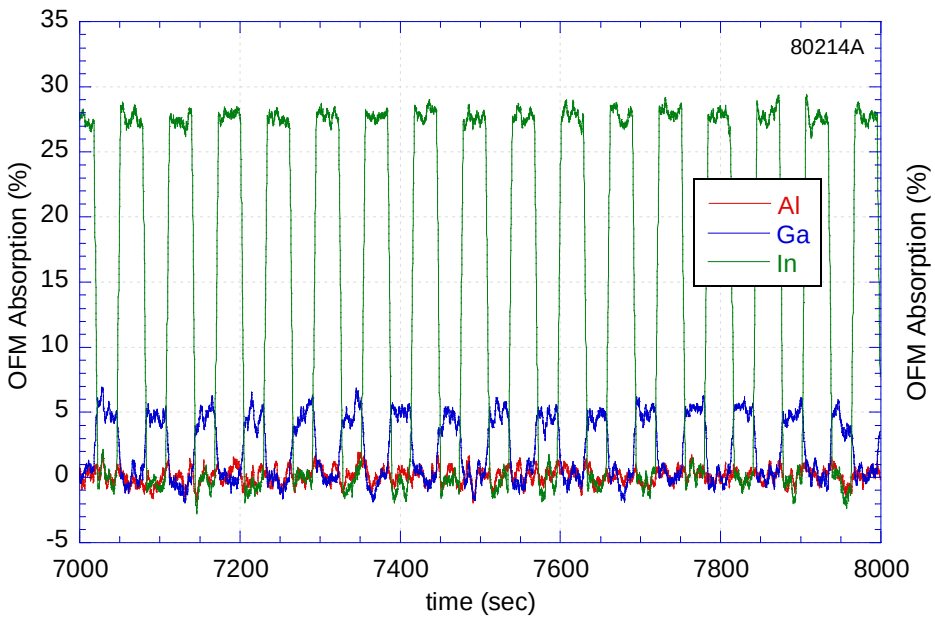




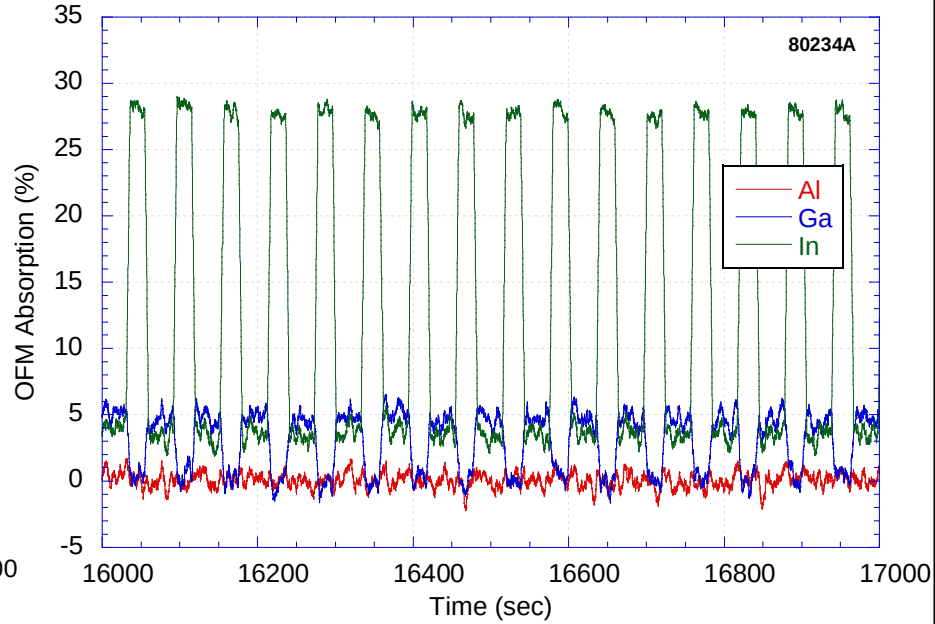
- *Quantitative composition measurement of Al, Ga, and In of each InAlGaAs layer (10nm) of superlattice (SL)*
- *Al and Ga composition slightly higher in the first layer: growth transient*
- *C-doped graded InGaAs base composition change clearly shown by OFM*

Intelli*EPI:* OFM Flux Measurement During SLS Growth

Binary InAs/GaSb



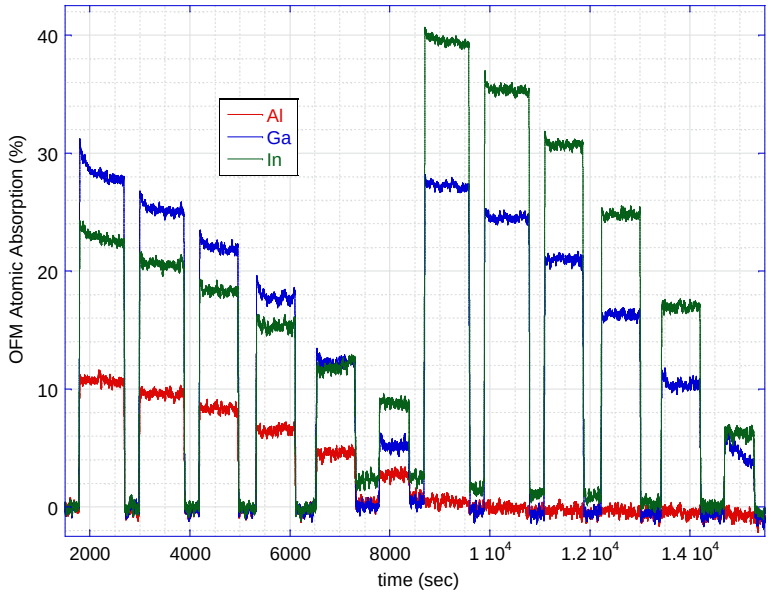
Ternary InAs/InGaSb



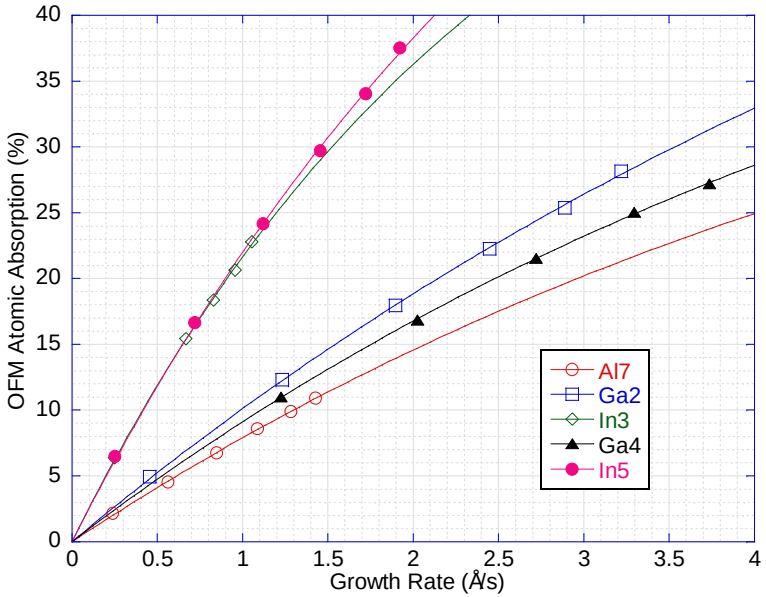
- ***Shutter verification***
- ***Group III composition monitoring***

Intelli*EPI:* OFM Calibration Development

Atomic absorption profile during test run



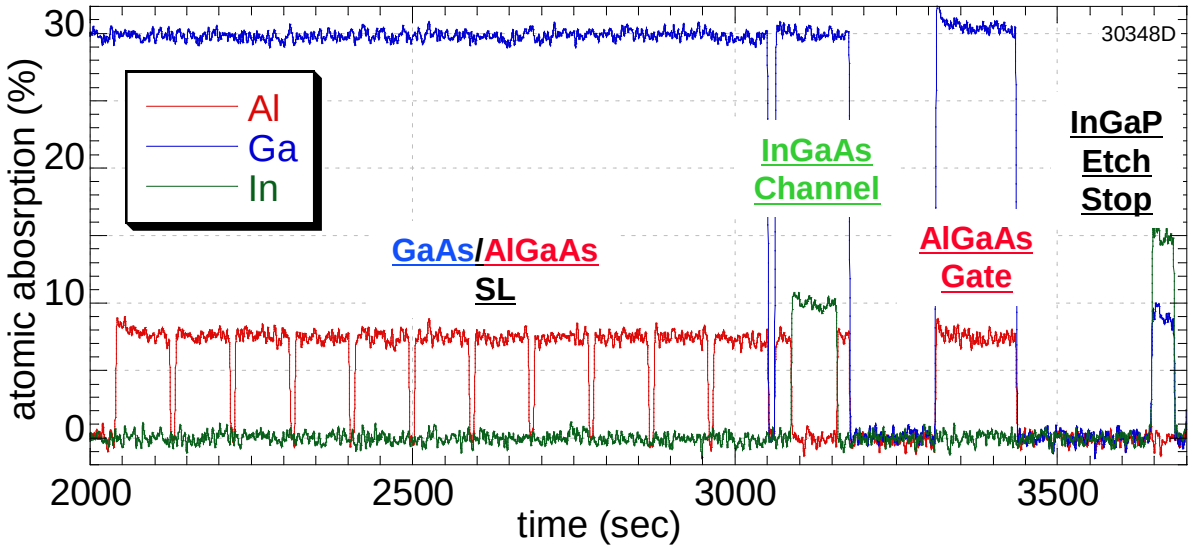
OFM flux calibration model



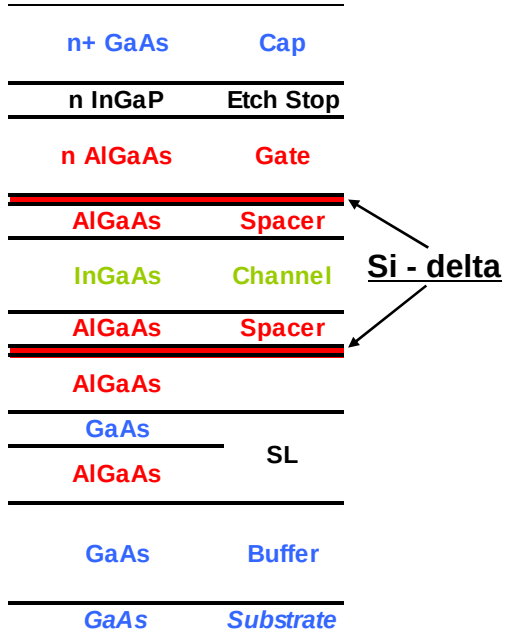
- ***Measure group III flux profile in real-time during growth***
- ***Quantitative measurement of growth rate and composition***

IntelliEPI: PHEMT In-situ Monitoring with OFM

OFM Profile During PHEMT Growth

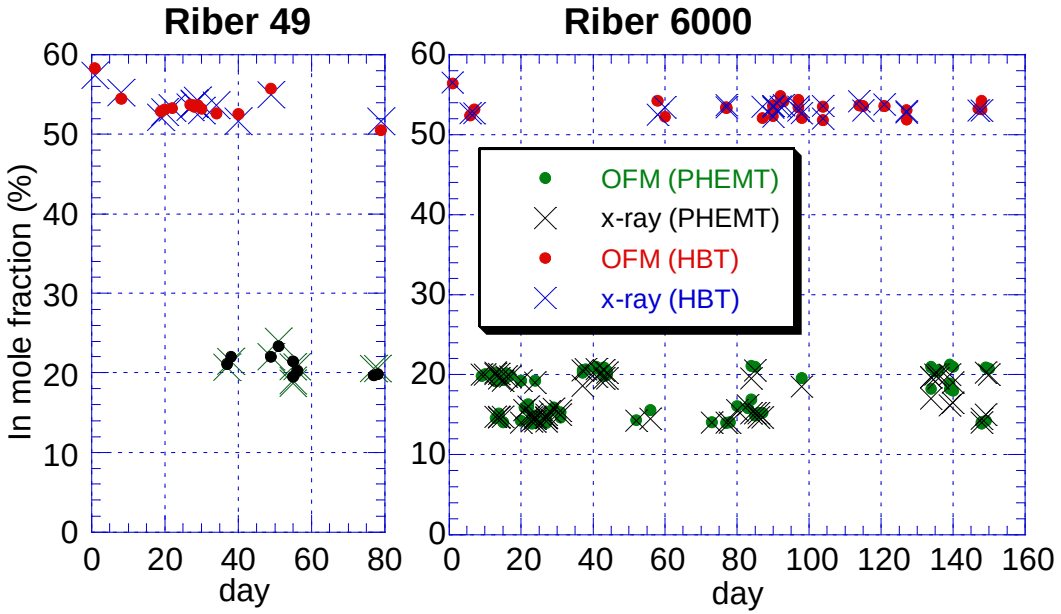


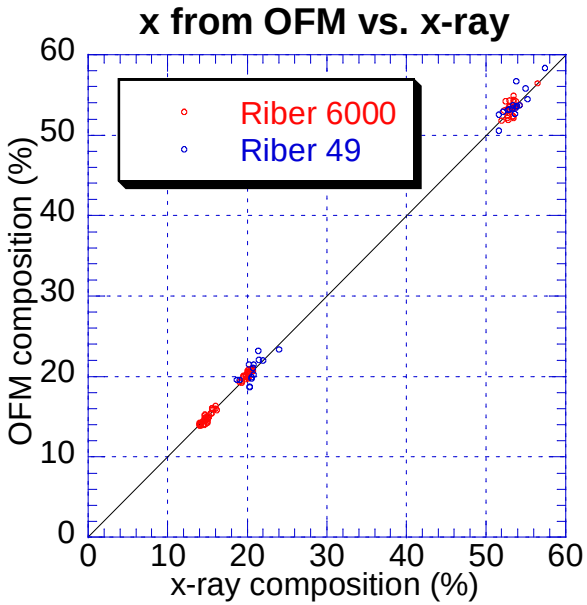
PHEMT Structure



- ***Direct composition monitoring for each critical layer***
- ***In-situ composition monitoring for key layers:***
  - **InGaAs Channel: Accurate x-ray measurement**
  - **AlGaAs Gate: X-ray represents average of SL and Gate**
  - **InGaP Etch Stop: Very thin layer limits x-ray accuracy**

IntelliEPI: Comparison of OFM to x-ray for $In_xGa_{1-x}As$



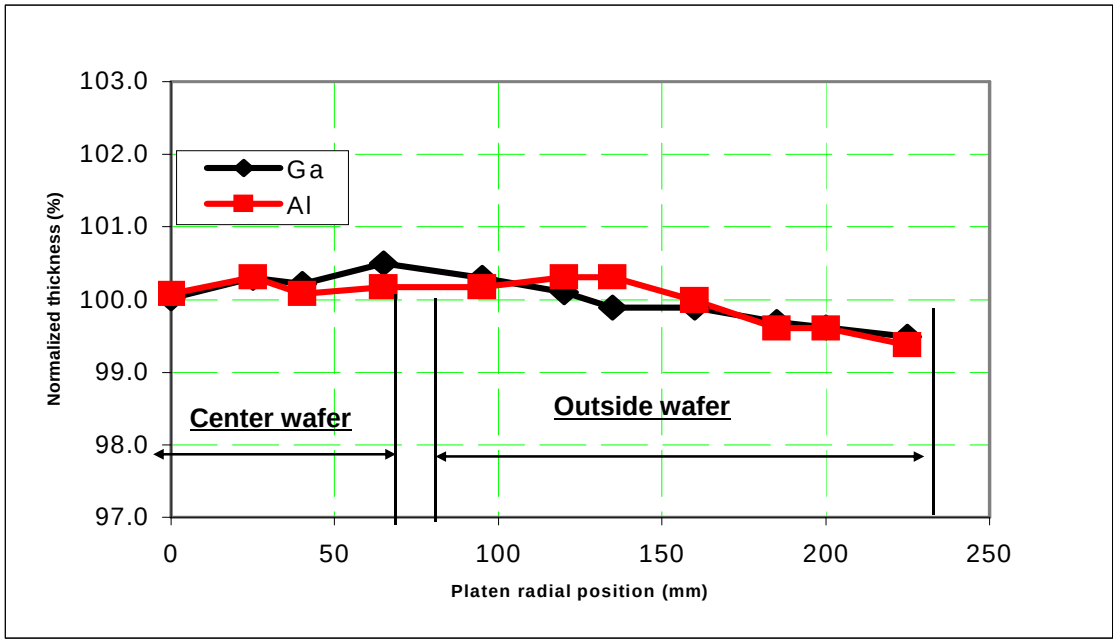


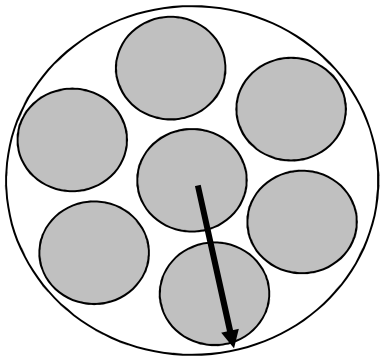
	Standard deviation (σ) of the difference between measured OFM & x-ray compsoition x (%)		
Composition Range	15%	20%	53%
Riber49		±0.7%	±0.7%
Riber6000	±0.3%	±0.3%	±0.7%

- *Relative absorption sensitivity factor for each range of x is kept fixed.*
- *Data up to 5 months span: $\sigma(x_{OFM} - x_{x\text{-}ray})$ is 0.7% or better for all ranges of x, In mole fraction (%).*

IntelliEPI: Thickness Uniformity Across 7x6” Platen

Riber 7000 thickness uniformity measured by white light reflection





7X6” platen

2,500ÅGaAs

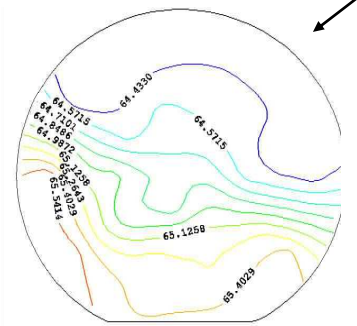
2,000ÅAlAs

GaAs substrate

- ***Thickness variation across platen < 1% (for all MBE systems)***

IntelliEPI: Resistivity Mapping for 7x6” MBE

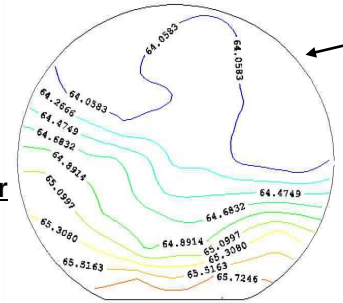
Center wafer



Statistical Summary

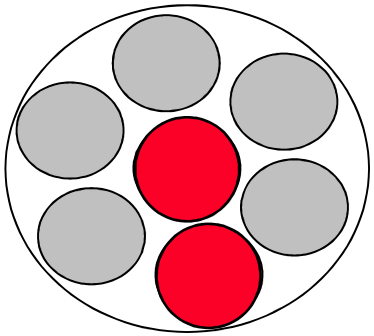
Number of Test Points	36
Average Value	64.8411
Maximum Value	65.6182
Minimum Value	64.3223
Sample Spread (%)	2.01
Std Dev Value	0.4017
Wafer Uniformity Value (%)	0.62

Outside wafer



Statistical Summary

Number of Test Points	36
Average Value	64.4873
Maximum Value	65.8275
Minimum Value	63.862
Sample Spread (%)	3.08
Std Dev Value	0.5295
Wafer Uniformity Value (%)	0.82

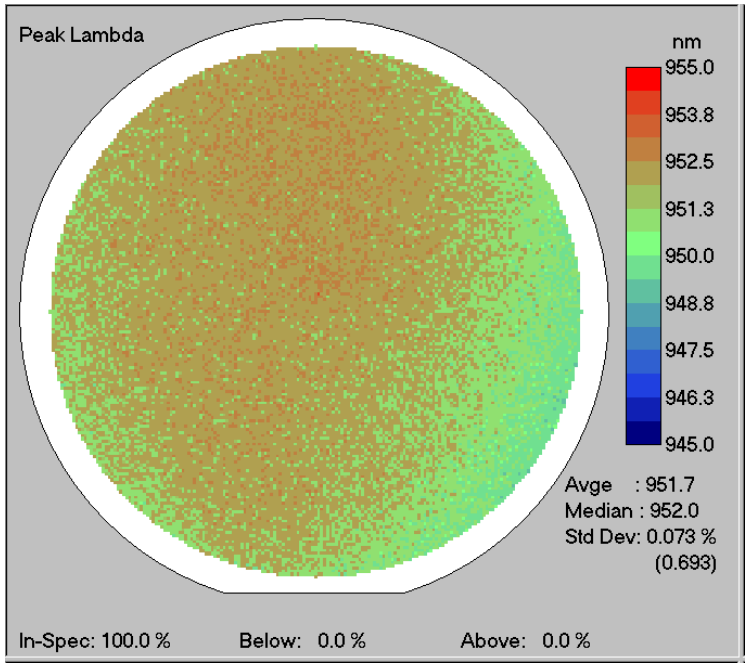


Riber 7000

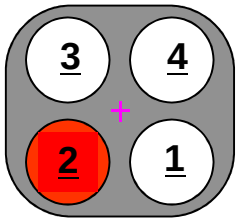
7x6”

- ***Doping variation across platen < 1% (for all MBE systems)***

IntelliEPI: Uniformity Profile of InGaAs Channel for PHEMT



4 X 4”



Wafer in 4x4" platen	wavelength (nm)	Standard deviation (nm)
1	951.5	.761 (0.08%)
2	951.7	.693 (0.073%)
3	951.4	1.166 (0.123%)
4	951.9	1.015 (0.107%)

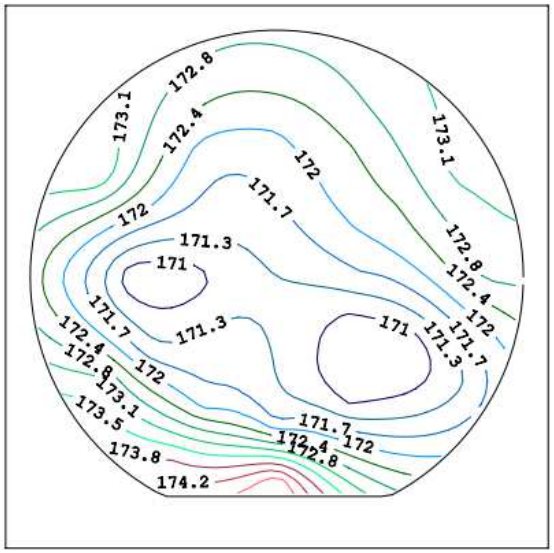
- ***PL mapping of InGaAs QW on 4” GaAs***
- ***PL peak wavelength within +/- 1 nm → Composition variation < 0.1 atomic %***

Intelli*EPI*: Current typical 6” Rs mapping

Test File: 110179D6BF01_C1_W01.tst
Date:5/23/2011 Test Time:9:56:4

Statistical Summary

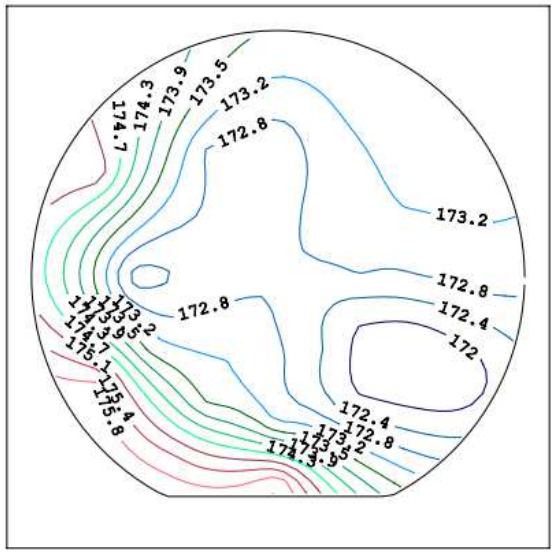
Number of Test Points	37
Average Value	172.0
Maximum Value	175.3
Minimum Value	170.4
Sample Spread(%)	2.81
Std Dev Value	1.0
Wafer Uniformity Value(%)	0.59



Test File: 110179D6BF02_C1_W02.tst
Date:5/23/2011 Test Time:9:58:4

Statistical Summary

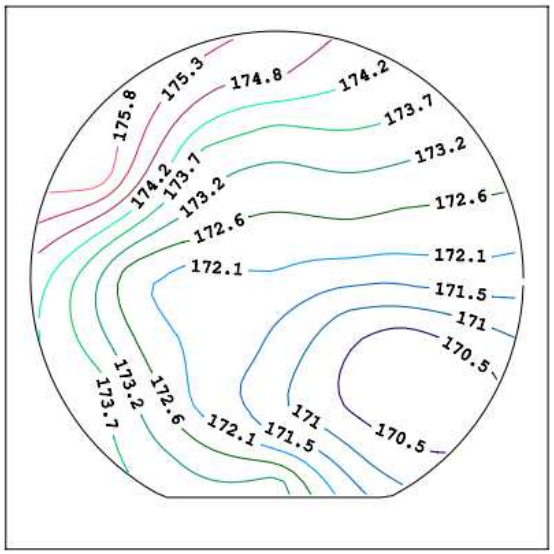
Number of Test Points	37
Average Value	173.2
Maximum Value	176.5
Minimum Value	171.5
Sample Spread(%)	2.88
Std Dev Value	1.1
Wafer Uniformity Value(%)	0.64



Test File: 110179D6BF03_C1_W03.tst
Date:5/23/2011 Test Time:10:00:!

Statistical Summary

Number of Test Points	37
Average Value	172.5
Maximum Value	176.6
Minimum Value	169.8
Sample Spread(%)	3.94
Std Dev Value	1.5
Wafer Uniformity Value(%)	0.85

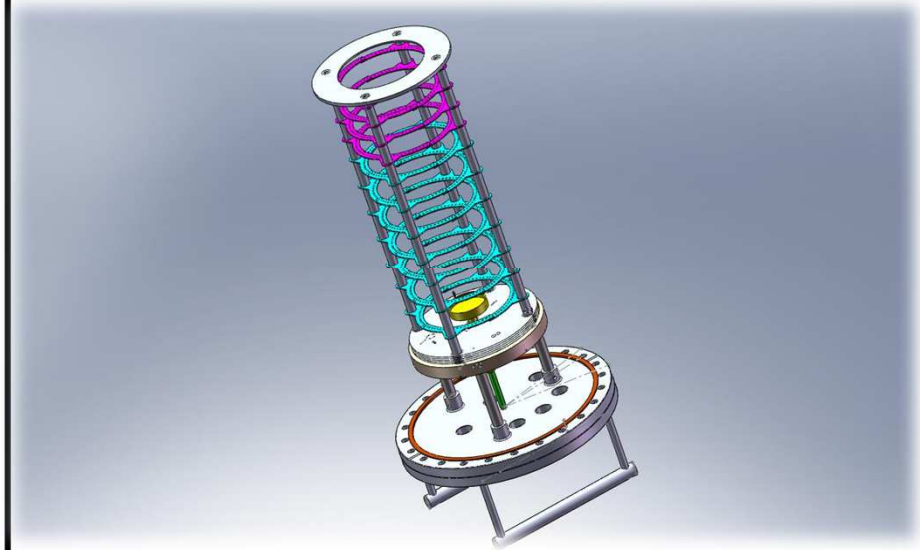


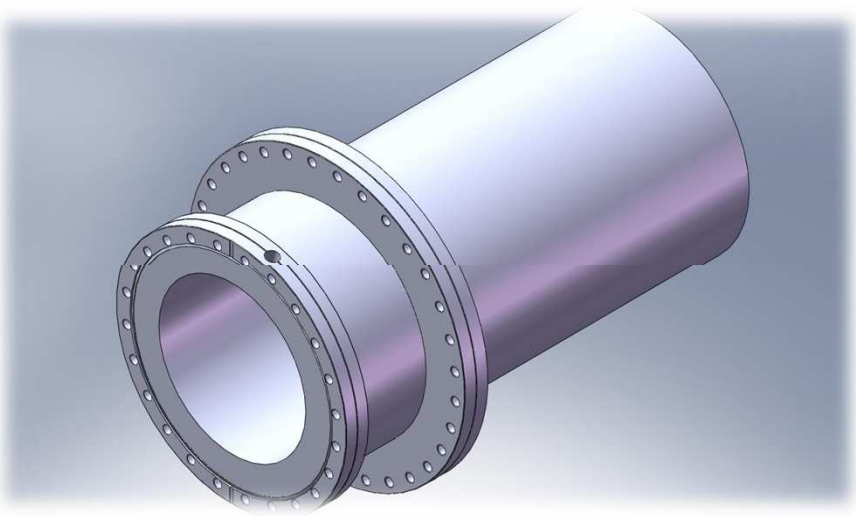
- ***Rs mapping pattern improves significantly due to mainly better heater, platen, and cells design***

IntelliEPI Infrastructure 2: Cell Development

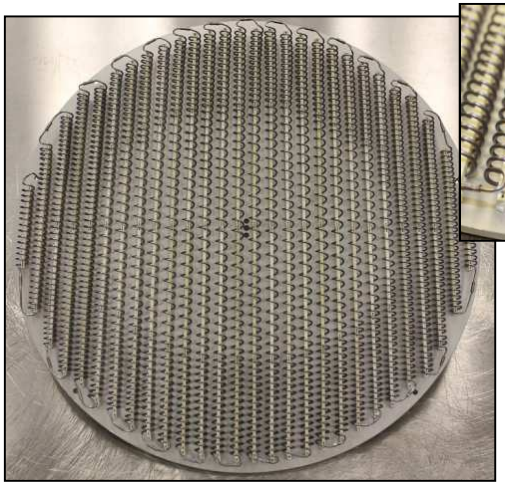
Production MBE system used for high volume operation has to be low cost and highly reliable. R&M replacements of key components are required due to heavy cycling under elevated temperatures.

- *IntelliEPI is 100% hardware independent from MBE vendor for R&M*
- *IntelliEPI has established a self-sufficient K-cell design (50% more capacity than SUMO cells), manufacturing, and overhaul capability since 2008. Currently, all cells have been exclusively constructed and maintained in-house.*

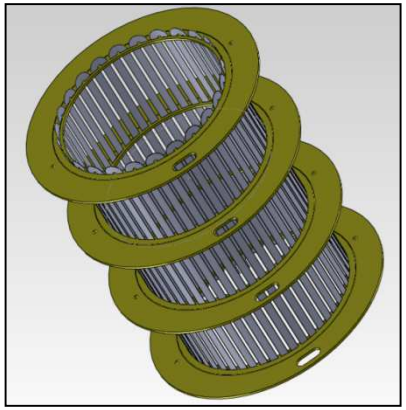


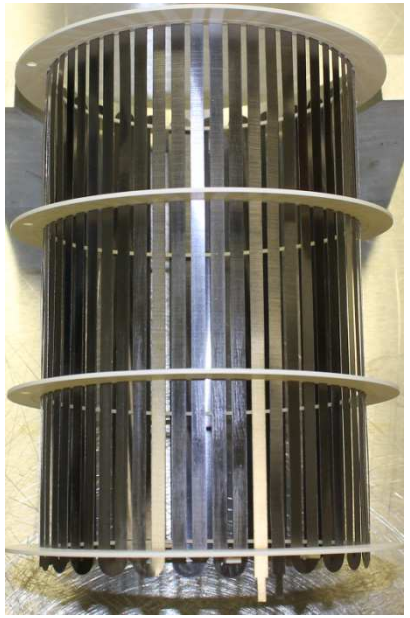


Intelli*EPI*: Infrastructure

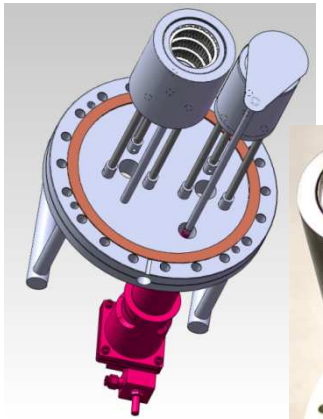


IET built R6000 18" Manipulator Oven

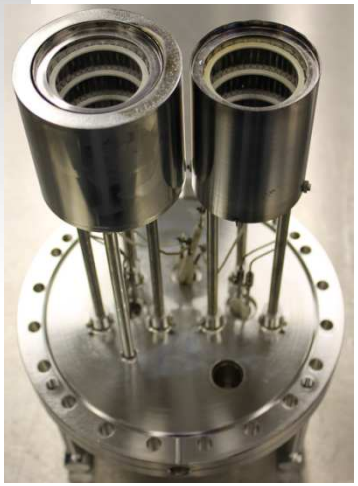




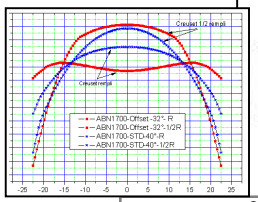
IET designed/built K-cell assembly

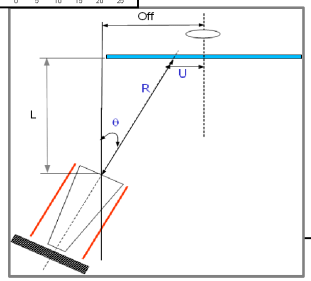


IET built dual cell on one flange

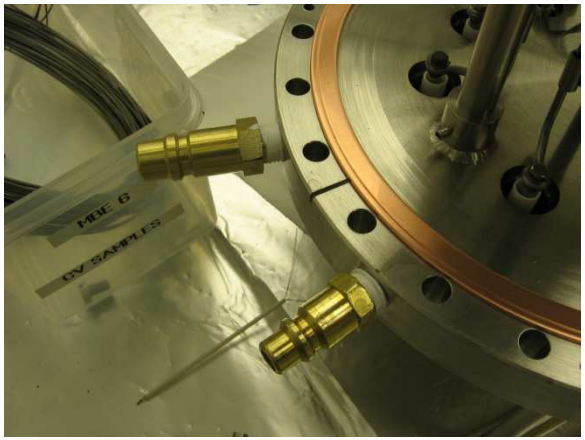


IET: uniformity hardware/simulat.

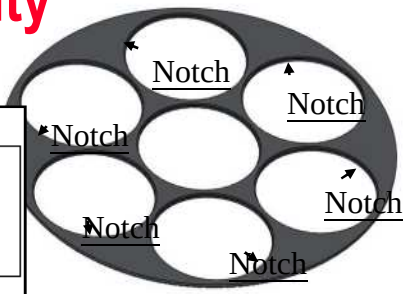


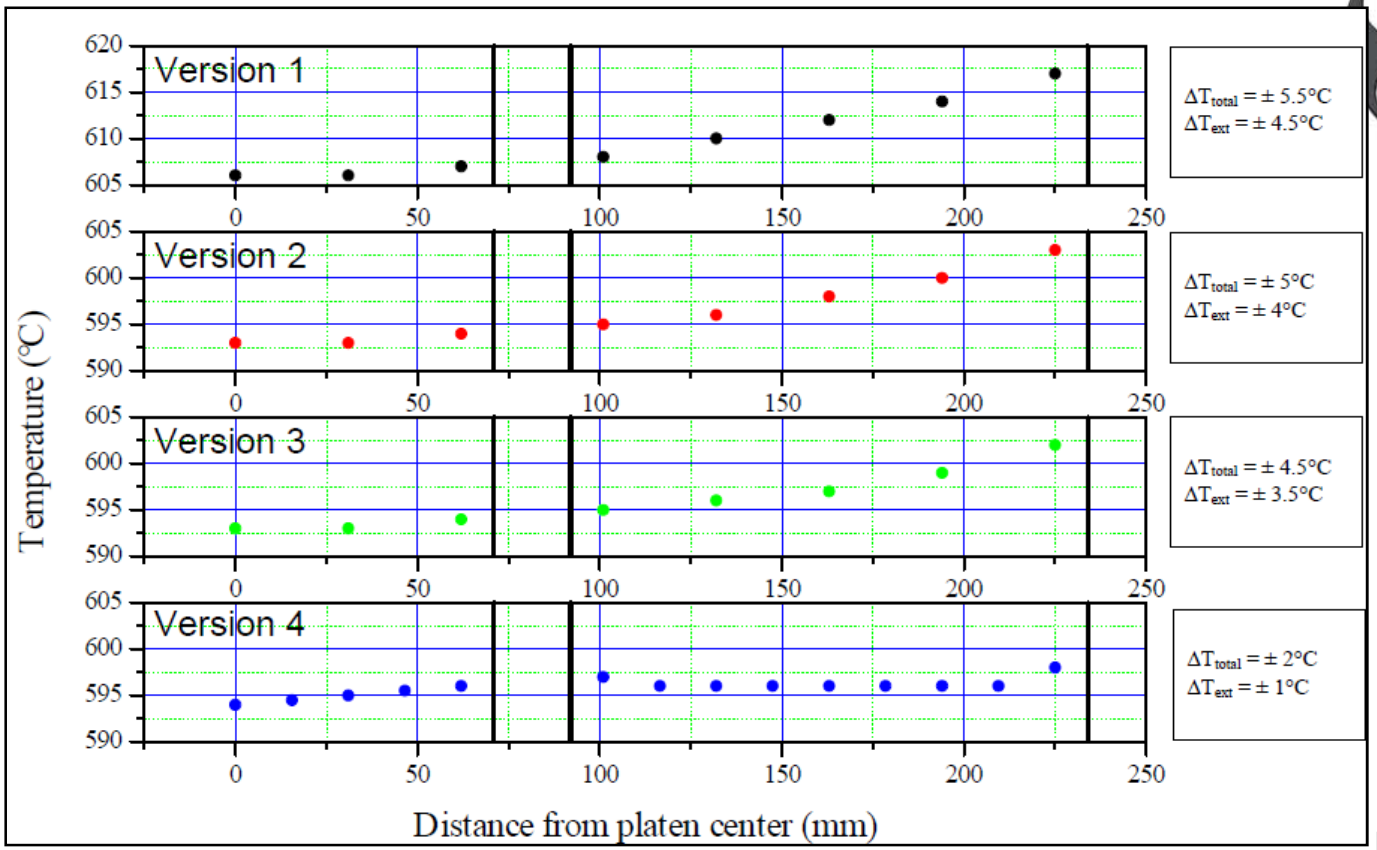


IntelliEPI: Cell Completion



Infrastructrue 3: 2-Zone Heater forTemperature uniformity



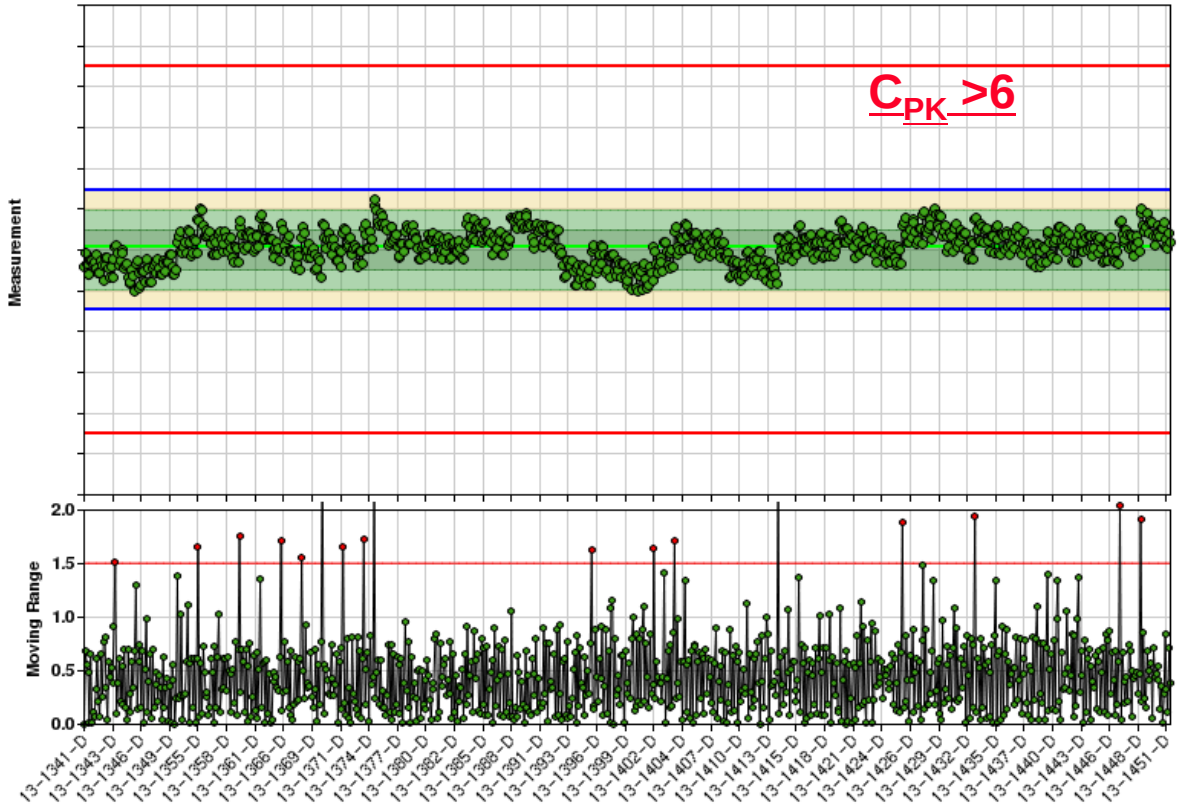


Data courtesy of

RIBER ADDON VG SEMICON

- ***6”GaAs wafer uniformity***
  - **Improved from over ±4.5° C variation on outer (single zone) wafer to ±1° C (dual zone V.4)**
    - » **No data from single zone manipulator available, but admittedly worse than V.1**

IntelliEPI: Quality Management System



SPC chart of contactless sheet resistivity mapping during PHEMT production

- *ISO9001:2000 certified since March 2007*
- *Utilize SPC for volume production tracking/control*

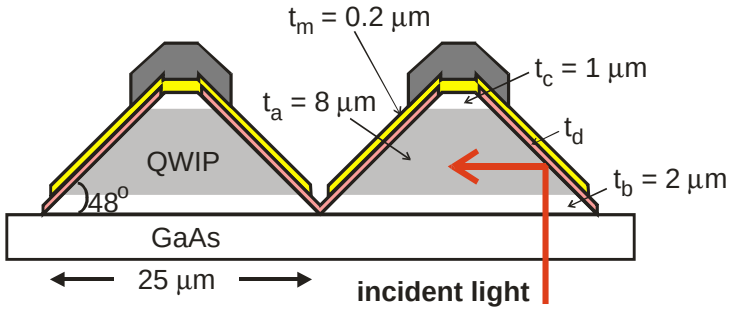
QWIP Activities

1k x 1k Format QWIP FPA

Image
Courtesy of
ARL/L-3

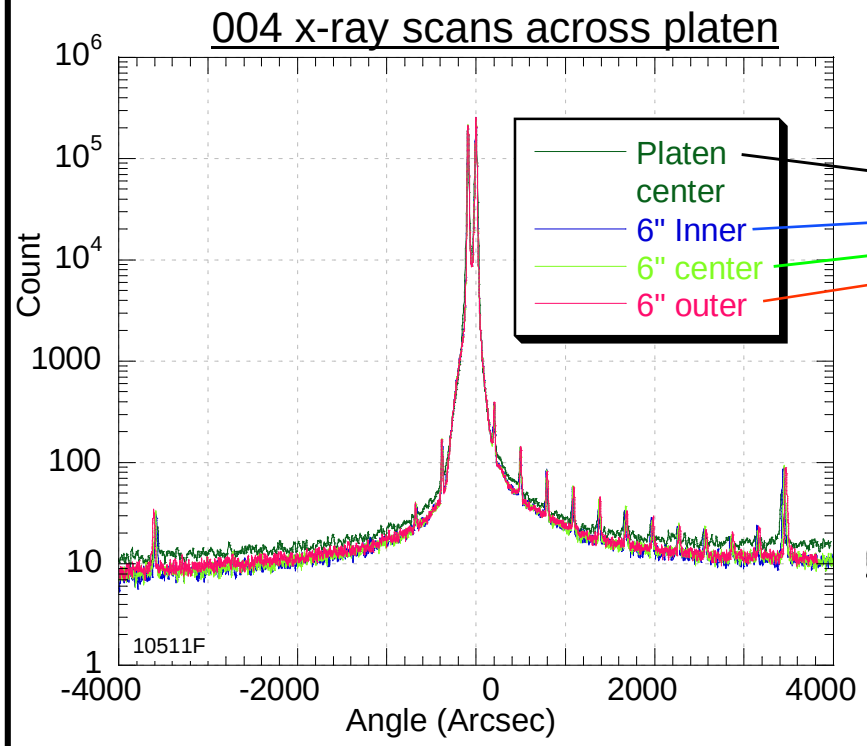
8.6 µm thermal image taken with large format 1024 x 1024 C-QWIP FPA with 25 µm pitch. Epi grown by IntelliEPI.

Corrugated-QWIP
(C-QWIP) Design

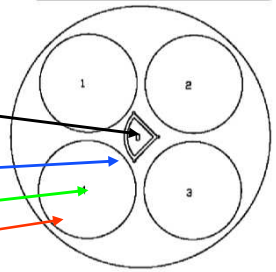


- ***MBE grown epi materials with excellent uniformity***

QWIP Production Experience

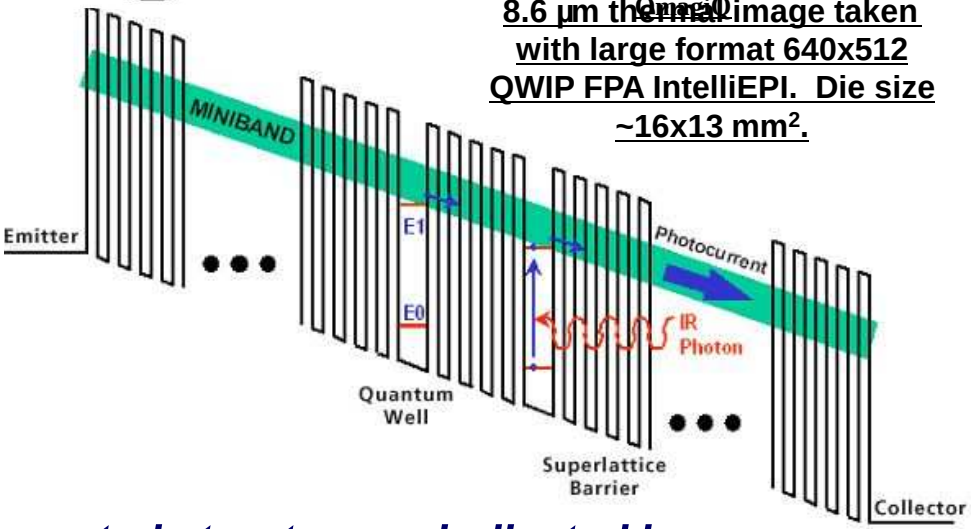


Riber6000
4x6" Platen



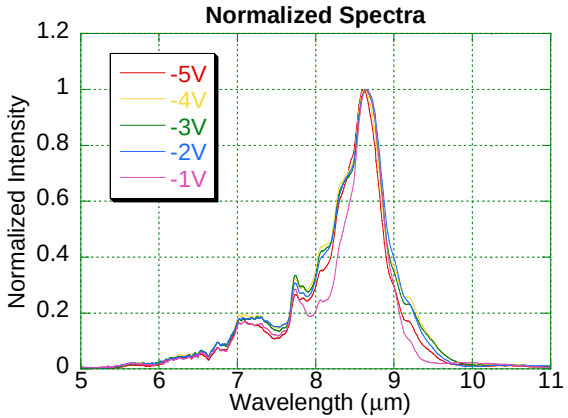
Courtesy of Qmagiq

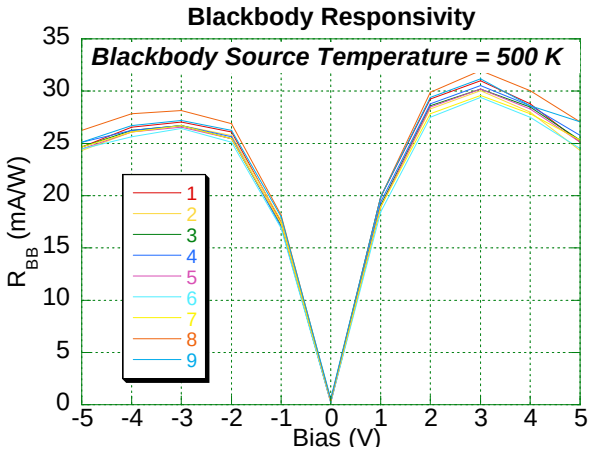
8.6 μm thermal image taken with large format 640x512 QWIP FPA IntelliEPI. Die size ~16x13 mm².

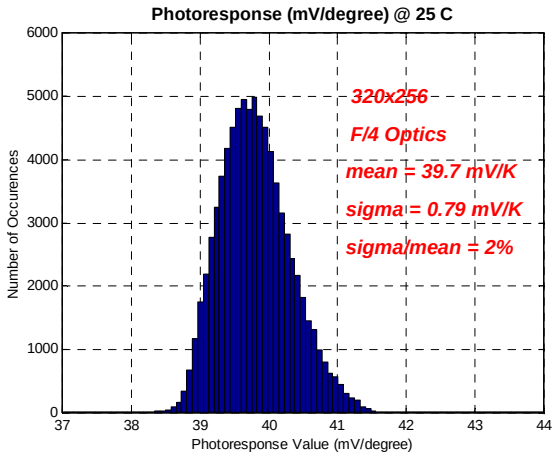


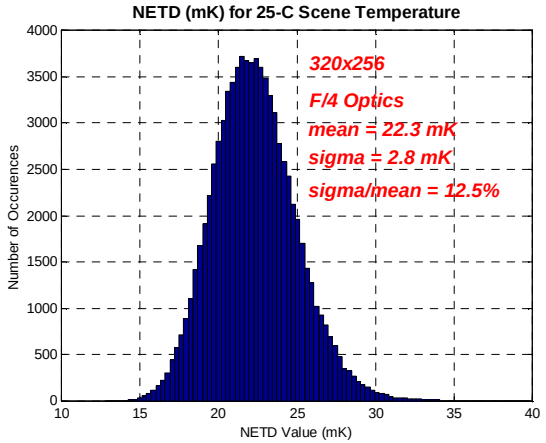
- ***Stability of growth rate during long repeated structure as indicated by narrow x-ray peaks***
- ***Excellent interface and materials quality as indicated by sharp x-ray peaks***
- ***±0.5% thickness uniformity across 6 inch diameter wafer based on x-ray***
- ***Achieved 100% pixel yield with 320x256 format FPA***

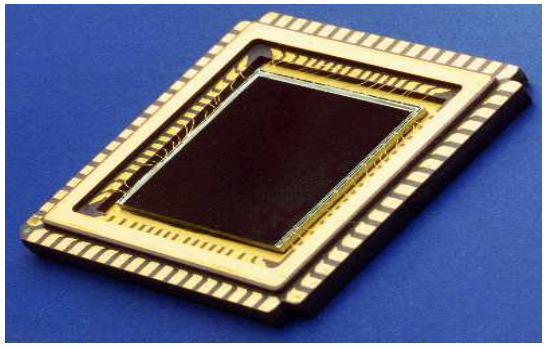
Device Data for QWIP FPA











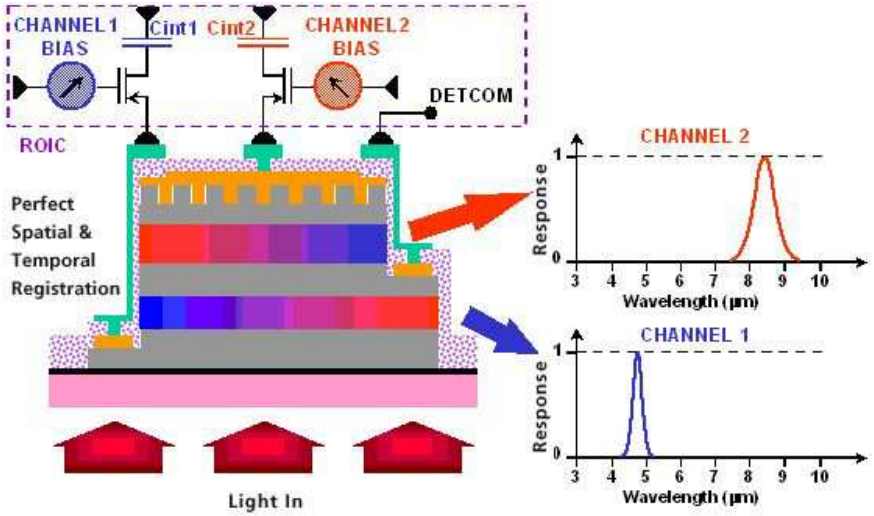
- *320x256 and 640x512 formats*
- *LWIR band, 8.6-mm peak wavelength*
- *Optical response uniformity » 2%*
- *Average NEDT less than 25 mK at F/4*
- *Operability greater than 99.8%*

Data Courtesy of QmagiQ

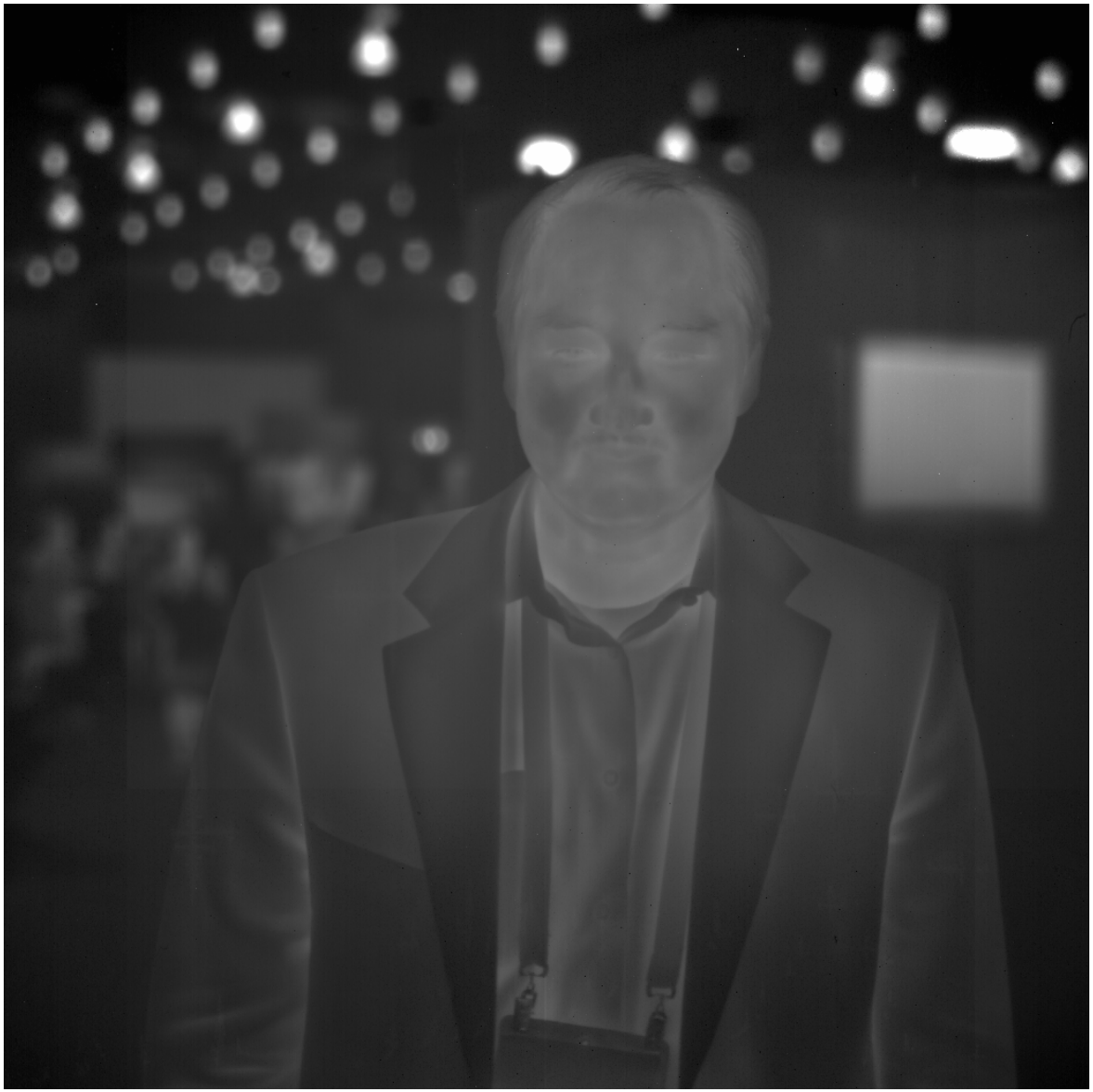
Dual-color QWIP

Data Courtesy of QmagiQ

- *2-color per pixel in 320x256 format*
- *Dual-band for MWIR and LWIR*
- *Epi materials on 6 ” GaAs*

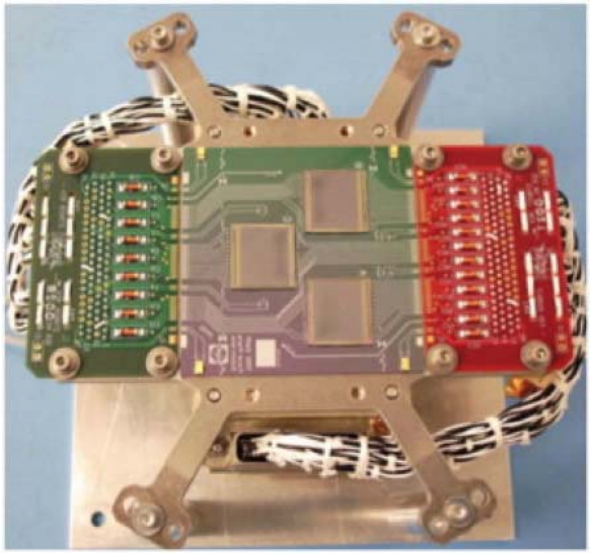


QmagiQ: 1kx1k LWIR QWIP



- *QmagiQ LWIR QWIP Camera demo at SPIE DSS 2010 exhibit*

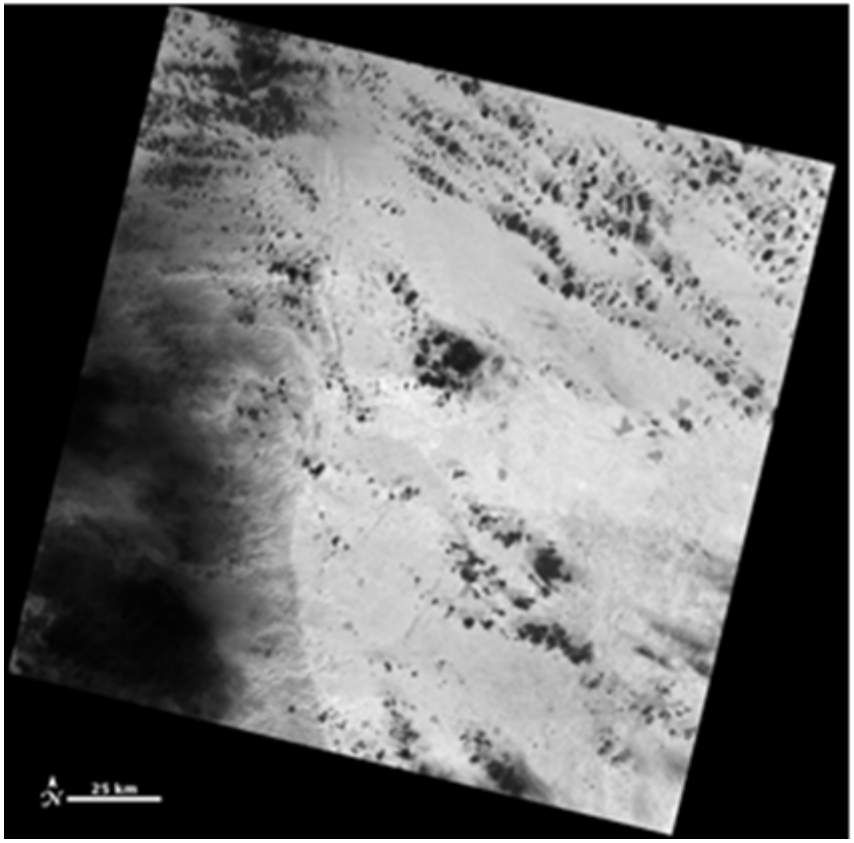
TIRS Instrument on LDCM Satellite Uses IntelliEPI QWIP



Landsat Data Continuity Mission (LDCM) satellite with Thermal Infrared Sensor (TIRS) instrument successfully launched on Monday (2/11/2013). The ITRS instrument uses QWIP epi produced by IntelliEPI as the IR detector materials. This satellite is a continuation of the Landsat satellite series. It will be renamed Landsat 8 once in operation. The TIRS instrument has 3 QWIP FPAs which are staggered in the center of the instrument. The FPAs selected for this mission was fabricated by QmaigQ using our epi. The TIRS instrument covers two spectral bands:

Band 10 TIRS 1 (10.3 - 11.3 µm)

Band 11 TIRS 2 (11.5 - 12.5 µm)



First thermal image taken by TIRS Instrument.

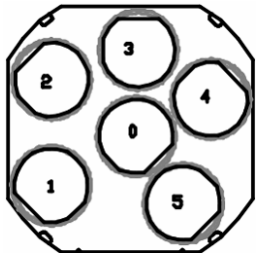
- *IntelliEPI now space qualified*

Sb-capable Production MBE for SLS

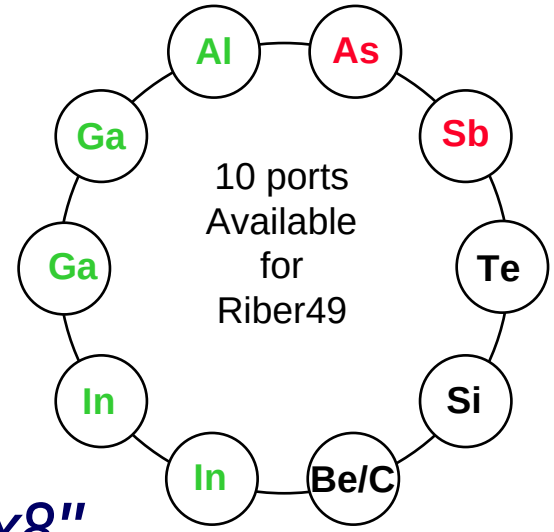
Sb-based Multi-wafer Production MBE Capabilities

MBE-1: Riber 49 multi-wafer MBE

- *Source configuration:*
  - Group III: 2 Ga, 2 In, & 1 Al
  - Group V: As, Sb
  - n-dopant: Si, GaTe
  - p-dopant: Be/CBr4



Cell Configuration

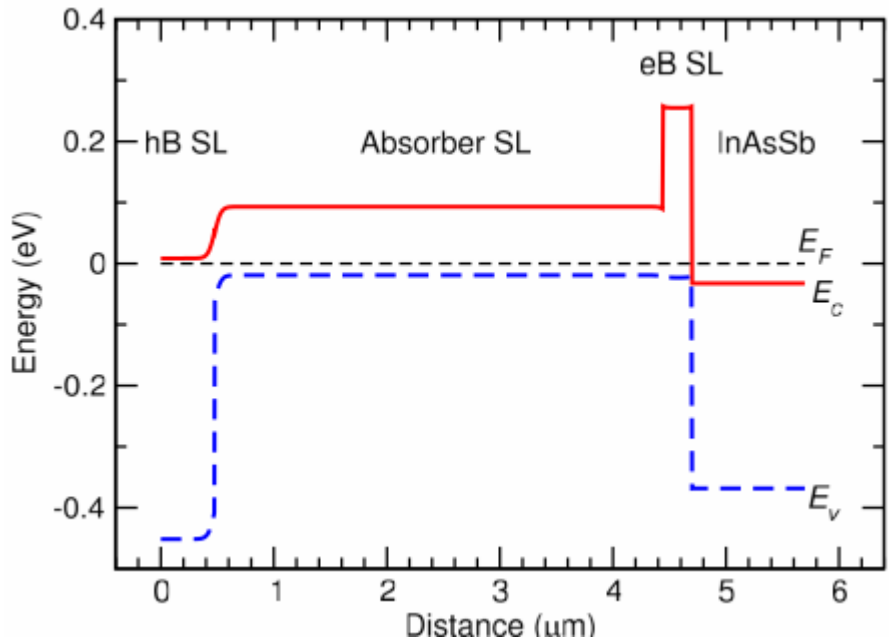


- *Platen: 11x2", 6x3", 4x4", and up to 1x8"*

MBE-8: V100 multi-wafer MBE

- *10 source port: 2 Ga, 2 In, Al, As, Sb, Si, GaTe, & Be*
- *Platen: 7x2", 6x3", 4x4", and up to 1x8”*

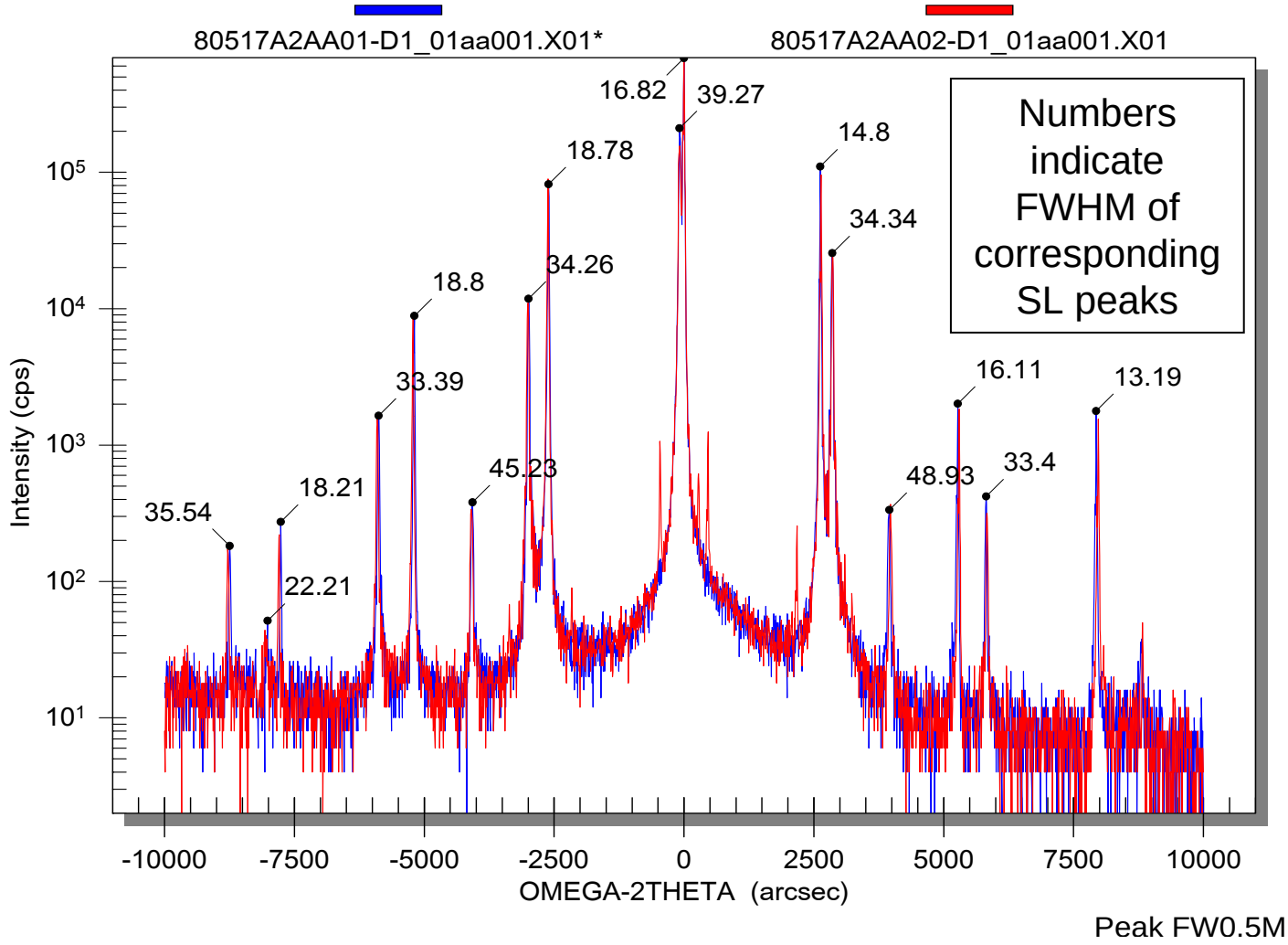
InAs-GaSb SLS CBIRD layer structure



- *Complementary Barrier Infrared Detector (Ting, et al. Appl. Phys. Lett. 95, 023508 2009)*
- *Absorber is clad with selective barriers*

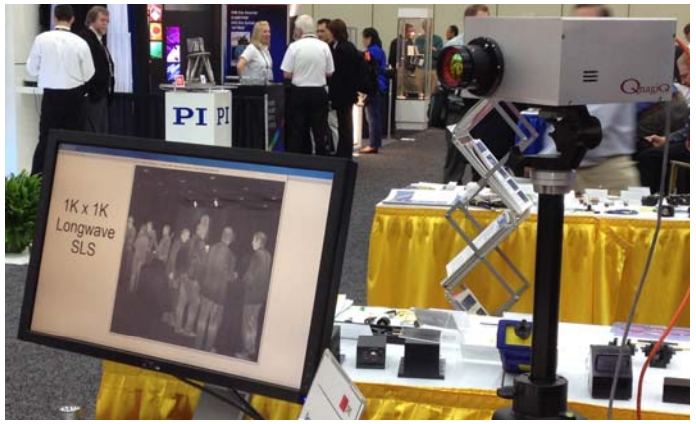
Layer	Comment	Repeat	Material	Thickness (Å)	type
10	cap		GaSb	50	
9	Superlattice 1	80	InAs	46	n
8			AlSb	12	
7	Superlattice 2	300 / 600	InAs	44	p
6			GaSb	21	
5	Superlattice 3	80	InAs	22	p
4			GaSb	21	
3	Bottom Contact		InAs(x)Sb(1-x)	13000	n+
2	Buffer		GaSb	3000	
1	Dry etch stop		Al(x)Ga(1-x)As(y)Sb(1-y)	500	
	SUBSTRATE*		n-GaSb		

JPL 600-period CBIRD: XRD peaks



- *SL0 and subs peaks closely aligned indicate good control of lattaice matching*
- *Narrow absorber SL peaks indicate stable and reproducible of absorber region*

QmagiQ 1K x 1K LW SLS FPA



QmagiQ SLS 1kx1k LW SLS camera.

QE: >40%

Operating at 77K

Λ(cut-off) ~ 9-10 um

Pixel operability: >98%

Thermal image taken at 2012 SPIE DSS Conf. in Baltimore, MD (April 2012).

- *QmagiQ demonstrated high quality FPA utilizing IntelliEPI grown SLS materials*

QmagiQ 2nd Generation 1K x 1K LW SLS FPA

Thermal image taken at 2012 SPIE DSS Conf. in Baltimore, MD (April 2012).

Installed in 1kx1k FLIR's InSb camera

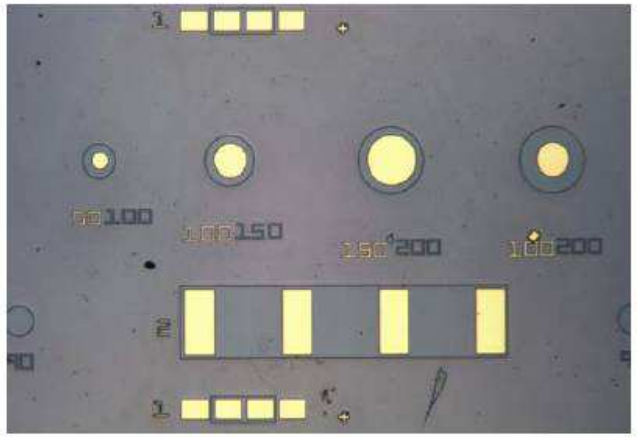
Operating at 77K

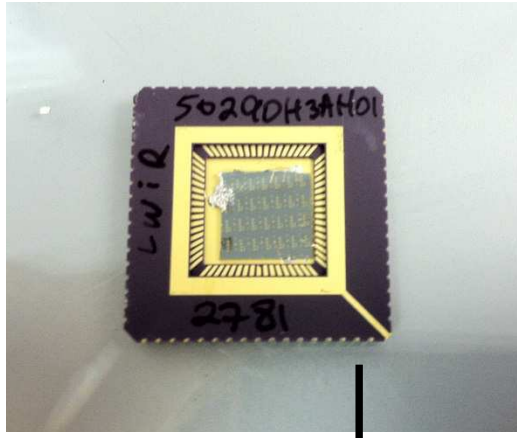
Λ(cut-off) ~ 9-10 um

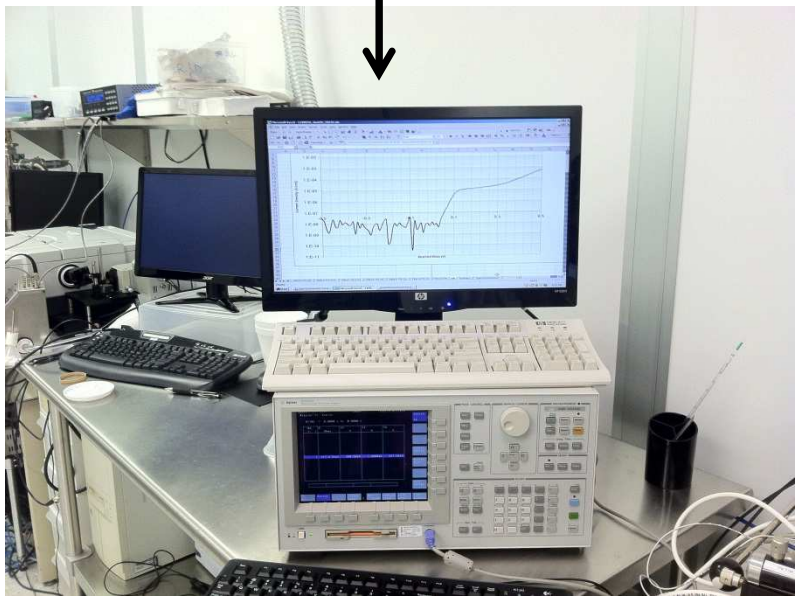
- *This SLS camera was on display by FLIR at 2013 SPIE DSS Conference in Baltimore MD*

Detector Characterization Capabilities

Large Area Device Processing for IR Detector







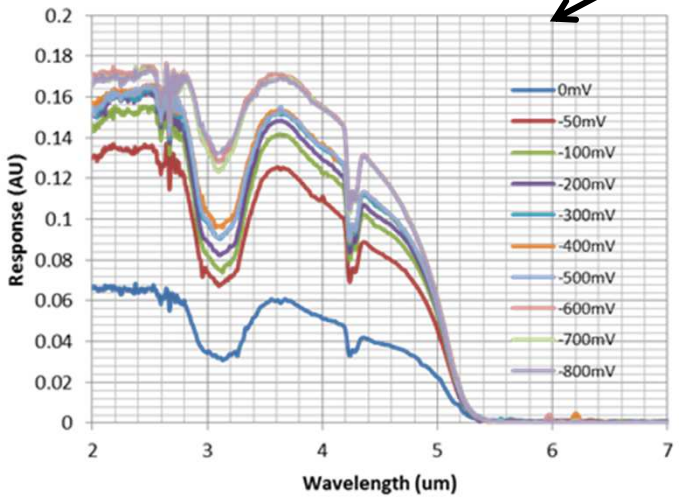
Test device capabilities

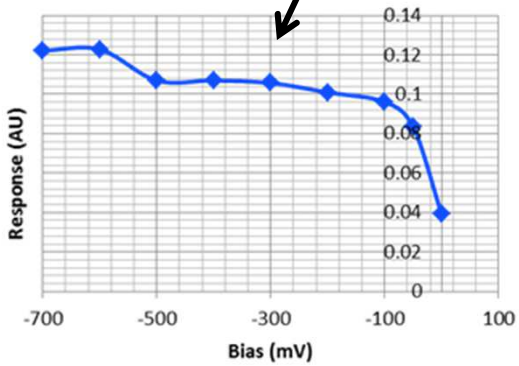
- *Device processing*
- *Device packaging and wire bonding*
- *Dark-IV, spectral response and turn-on bias measurements (77K, room temp, and variable temp)*

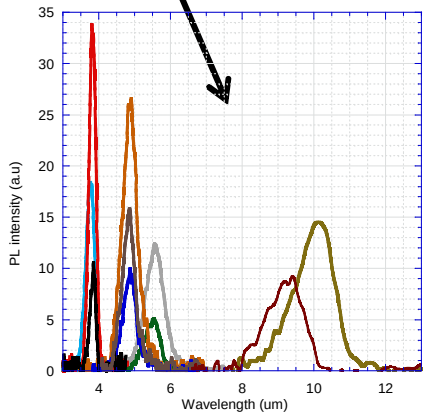
FTIR for IR Detector Characterization

FTIR

- ***Room temp transmission***
- ***Spectral response (77K, room temp, &variable temp)***
- ***Turn-on bias measurements (77K & Room Temp)***
- ***Photoluminescence (77K & Room Temp)***

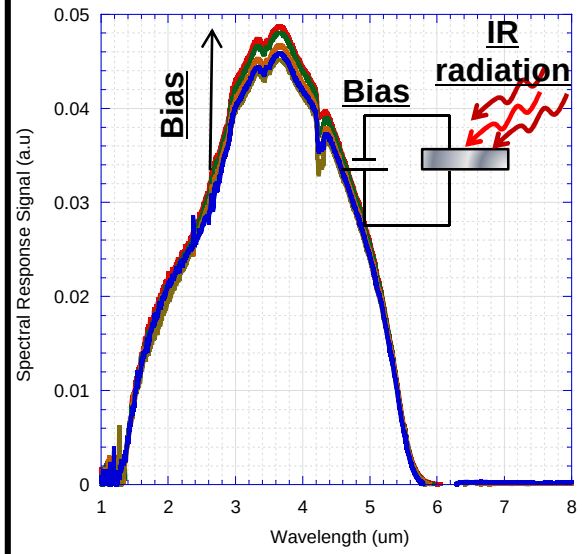






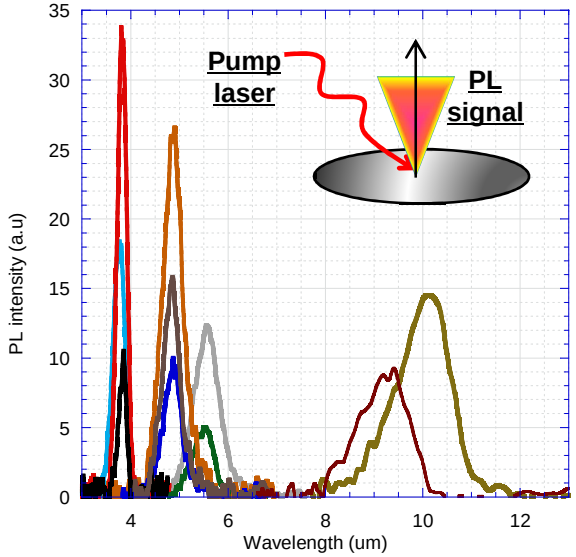
Wafer, Epi, Device Characterization

Spectral response



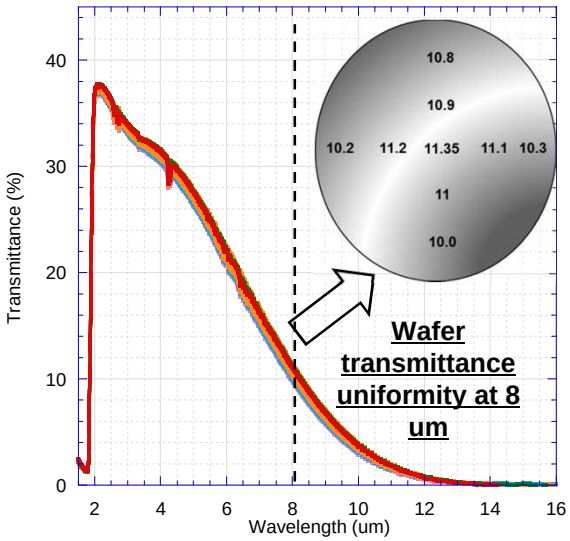
Spectral response vs. Bias

PL



PL optimization

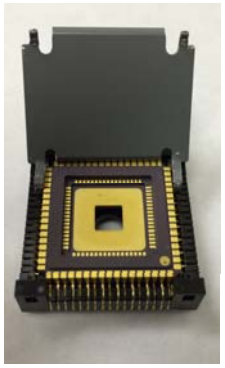
Transmittance



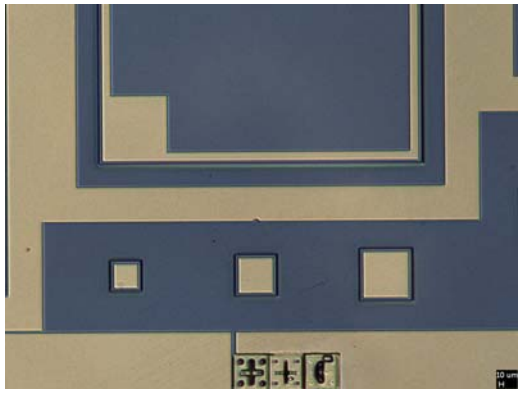
Wafer / epi doping uniformity control

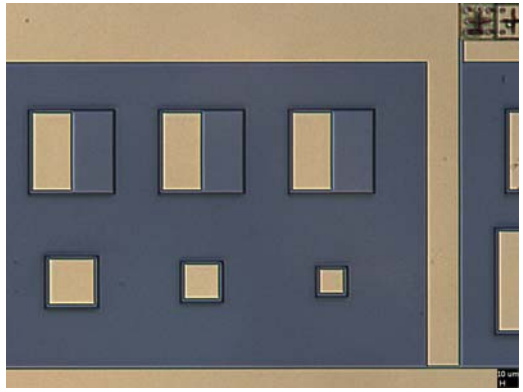
- Device processing
  - Dark IV
  - PL
- Transmittance / Absorbance
  - Spectral Response
  - Electroluminescence

In-house Characterization Capabilities for SLS Detector



Technique	Turn around time
Surface Scan	same day
X-ray	same day
77K FT-IR PL	same day
Nomarski Microscope image	same day
Zygo flatness map	same day
AFM	1 day
Large Area Device (LAD) processing	1-2 days
Wire bonding	same day
77K Dark I-V	same day
77K Spectral response	same day
Variable temperature dark current	1 day



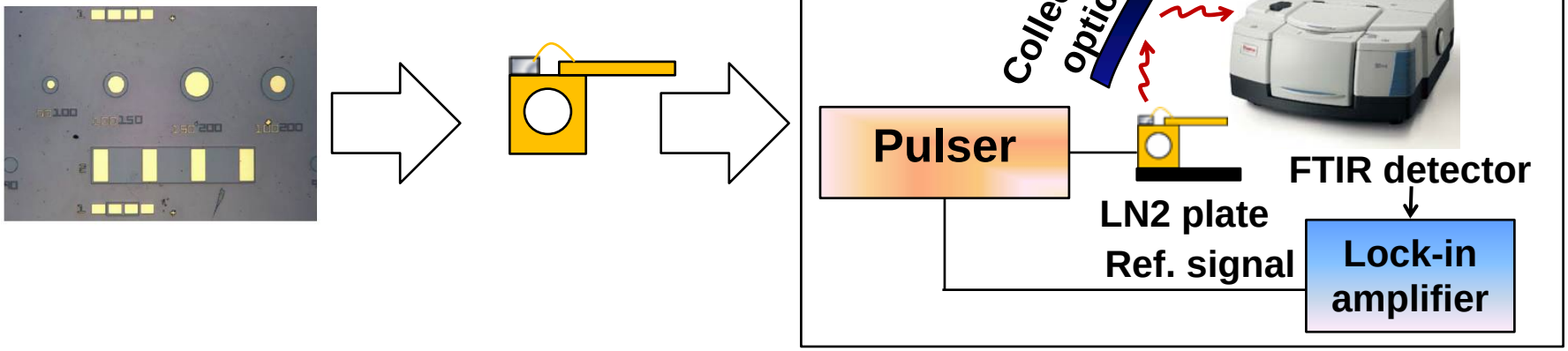


Established in-house quick turn device characterization capabilities

- *Typical turn for device processing < 1 day*
- *Hot lot 1 day quick turn possible through 77K dark I-V and spectral response possible*

Electroluminescence (EL) Measurement Setup (For Laser)

LAD processing **Wire bonding** **EL measurement**

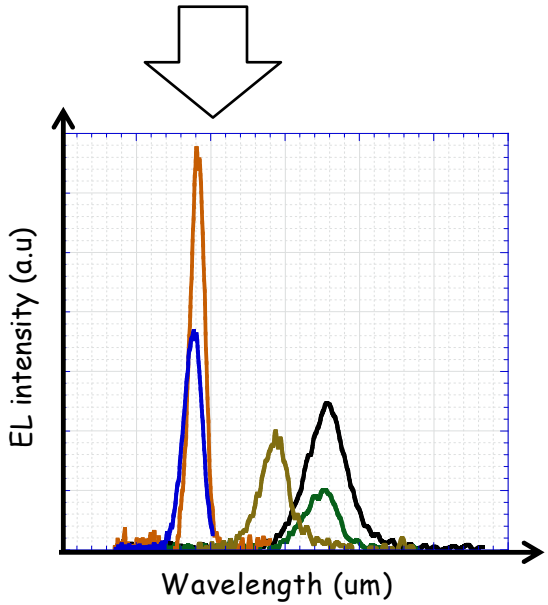


Electroluminescence processing

- *Epi-wafer is processed into Large Area Device (LAD)*
- *LAD is wire-bonded on a c-mount (or other mount)*

Electroluminescence measurements:

- *Device measured under pulse mode*
- *EL spectrum measured with FTIR*
- *Measurement temperature: Room temp or 77K*



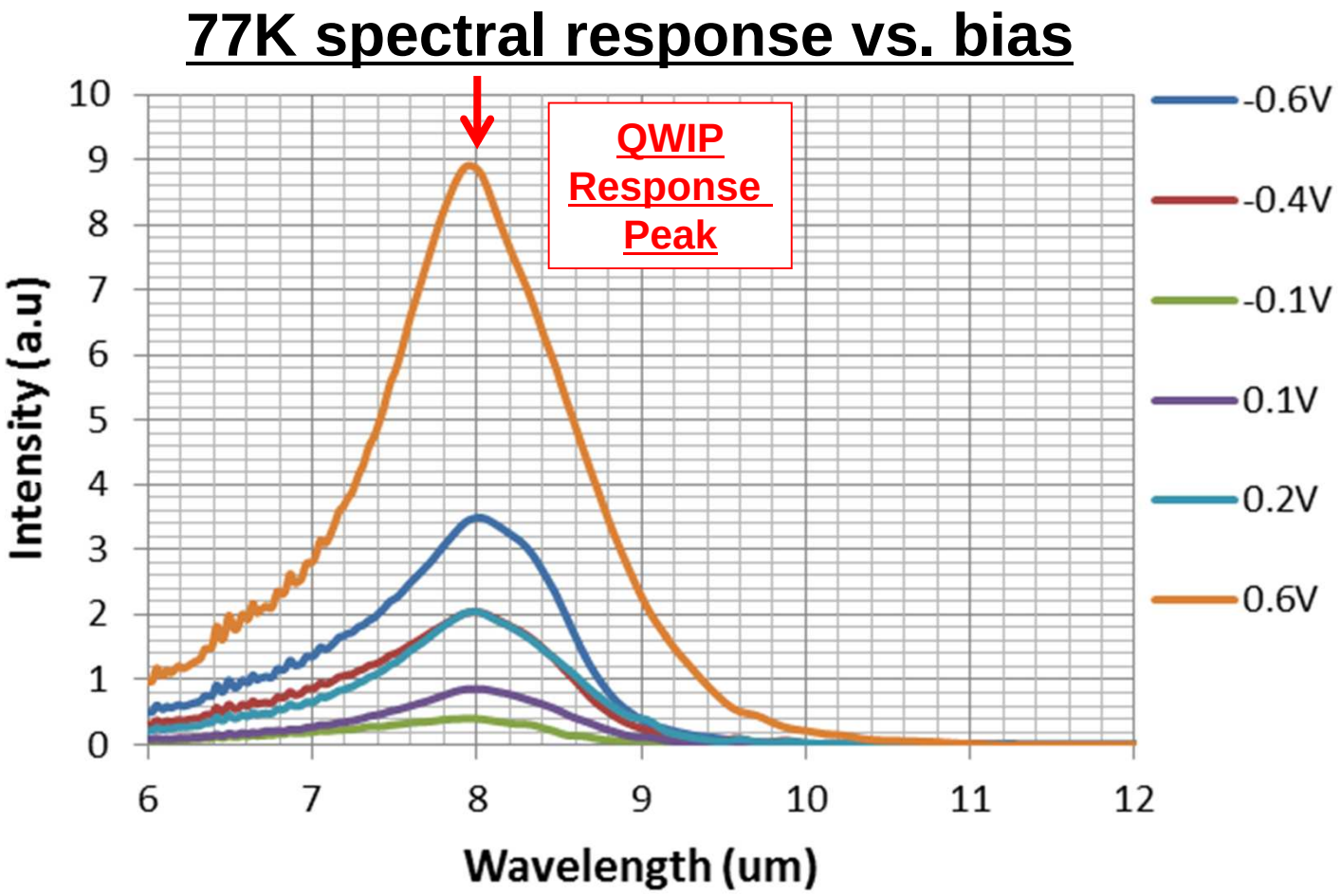
Intelli*EPI*: Infrared Materials Characterization

- ***IntelliEPI 300K characterization***
  - **Wafer level tests**
    - » Surfscan, x-ray, visible to near IR PL
  - **Device level test**
    - » Fabrication (Lithography, etch, metallization

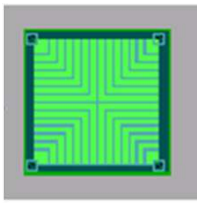
- ***IntelliEPI quick-turn 77K characterization***
  - **PL**
  - **Dark current**
  - **Spectral response**
- ***FTIR Spectrometer***
  - **Measurement range 1 – 15 µm**
- ***Epi Materials can be specified by:***
  - **Structure Design Target**
    - » X-ray model fitting
  - **Wavelength Design Target**
    - » 77K PL target, etc

Recently Developed QWIP Measurement Capability

FTIR Spectral Response for QWIP Device at 77K



Mesa with ohmic grating for optical coupling



- *Use mesa with grating on top to couple electric field into the growth direction*
- *Established spectral response measurement capability for QWIP*

GaSb Wafer Manufacturing Capability

LEC Crystal Puller for Large Diameter GaSb

LEC puller

- *10 inch diameter crucible capable of pulling > 6 inch diameter boule*
- *Installed and operational since 2012*

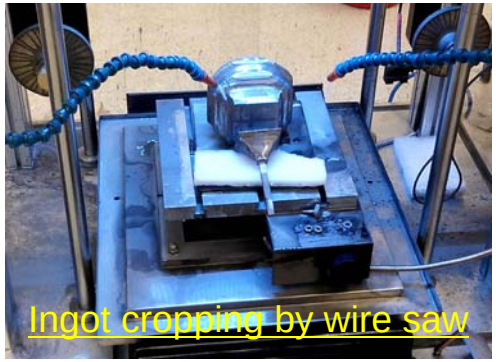
Crystal Puller B at Texas Facility

Crystal Boule Processing Tool for Wafer Slice Manufacturing

Tools for post growth wafer manufacturing

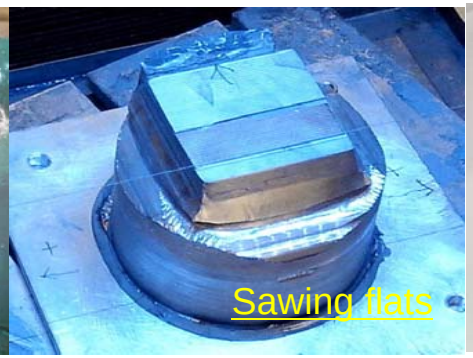
- *Single wire saw: 1) ingot cropping; 2) flat sawing; and 3) wafer slicing*
- *X-ray goniometer: 1) to orient crystals for coring; 2) to zero in mis-cut for wafer slicing; and 3) to determine mis-cut of as sawn wafers*
- *Diameter coring: to produce sections with diameter from 2" to 6"*


IEB025TN

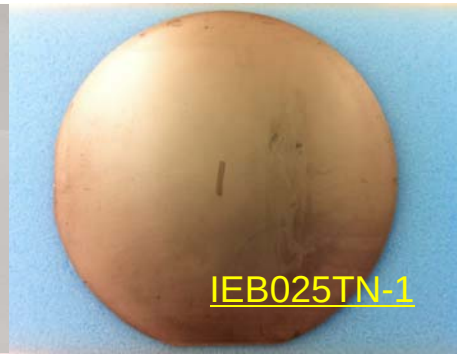

Ingot cropping by wire saw


Orientation by XRD


Diameter coring

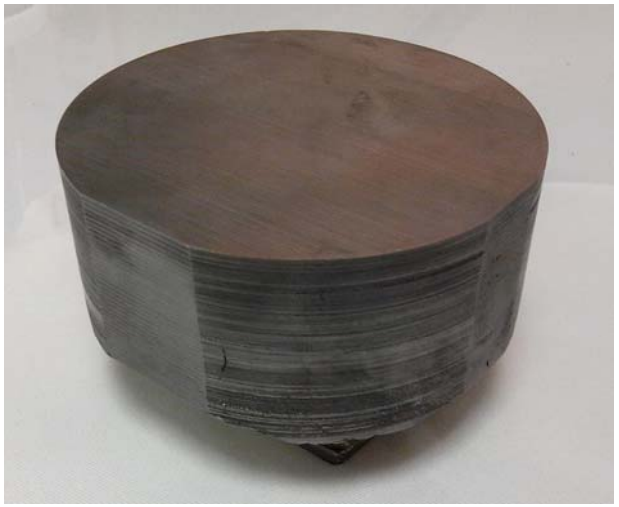

Sawing flats

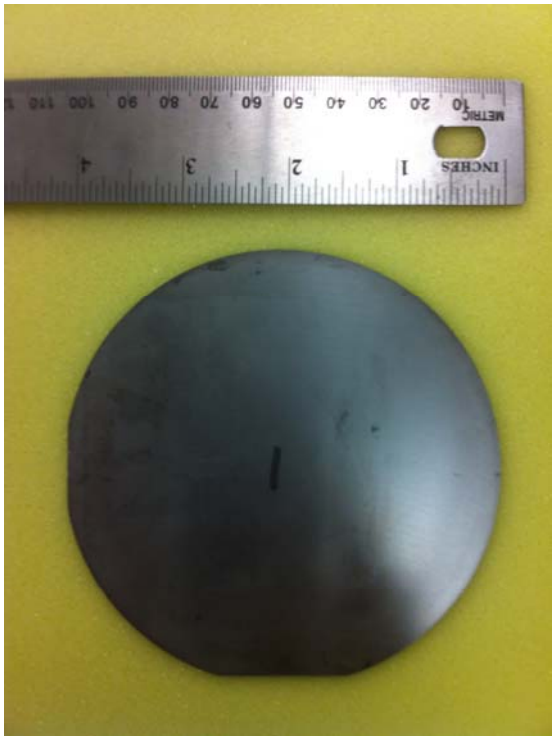

4" ingot section ready for slicing


IEB025TN-1

Ingot Processing at IntelliEPI Allen TX Facility

- *Te doped GaSb boule grown at IntelliEPI Allen TX facility*
- *Boule cored to 4-inch cylinder with major and minor flat saw cuts*
- *Rough cut wafer slices for polishing*



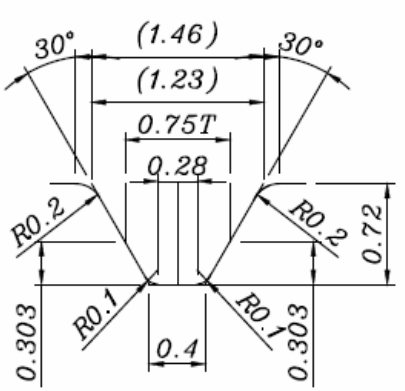


FY12 Task #2.2 Large Diameter Crystal Pulling
Crystal #36 with IET Puller B (IEB036T)

Crystal ID (Date)	Largest Diameter	Shoulder Length	Body Length	Potential # Substrates	Comments
IEB036T (10/4/13)	170 mm 6.7”	20 mm	55 mm	(30) 6” (15) 5”	Repeated IEB034T crystal pulling growth condition. Targeted mid16/cm^3 Te doping. Ingot in queue for post growth downstream processing.

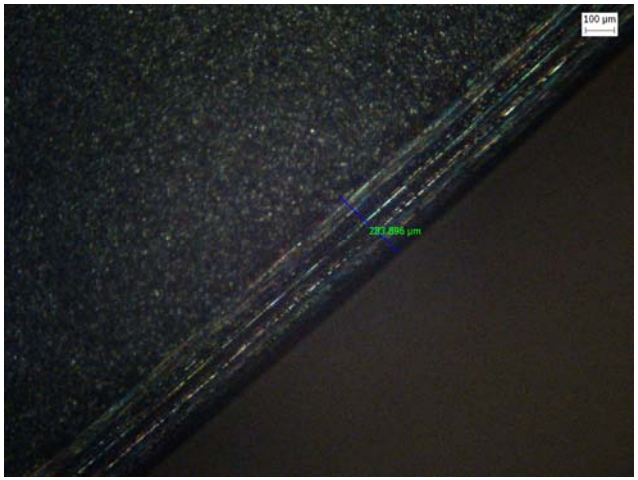
Wafer Edge Grinding Tool

- *Two tools are available: Automatic tool and manual tool*
- *Current diamond wheel is designed to produce edge profile with 30° bevel angle and 400 μm edge thickness*
- *Demonstrated smooth edge on IEB025TN wafers*



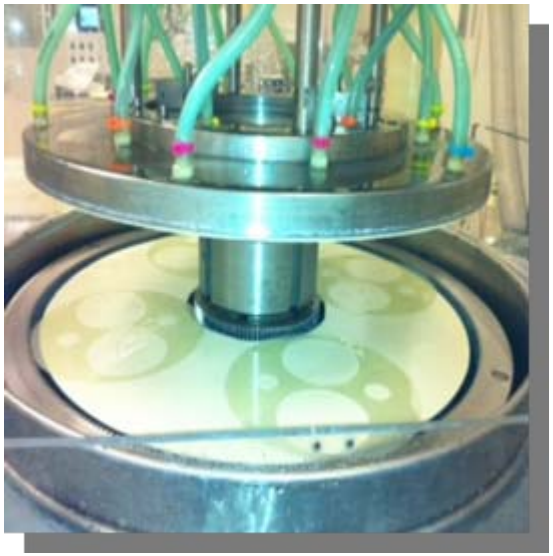

Automatic Edge Grinder


Manual Edge Grinder

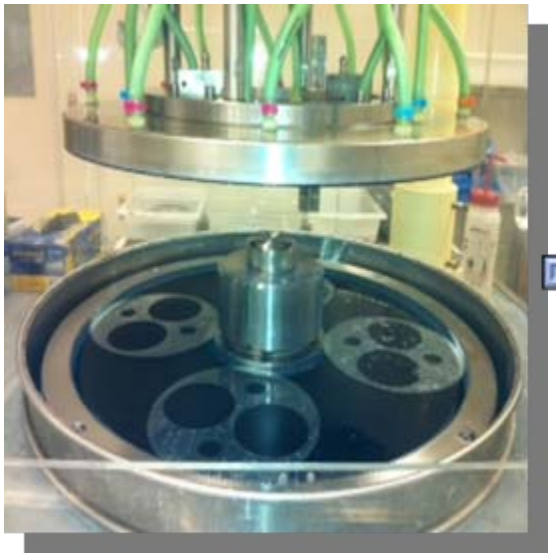


All DSP + Final Touch in SSP

- *All DSP produces excellent flatness, but gives incomplete polish.*
- *SSP allows wider operating range in speed and pressure for surface optimization to reduce roughness.*
- *Re-introduced a final touch step to the existing All DSP process: All DSP + Final Touch in SSP.*



Rough Polish on DSP

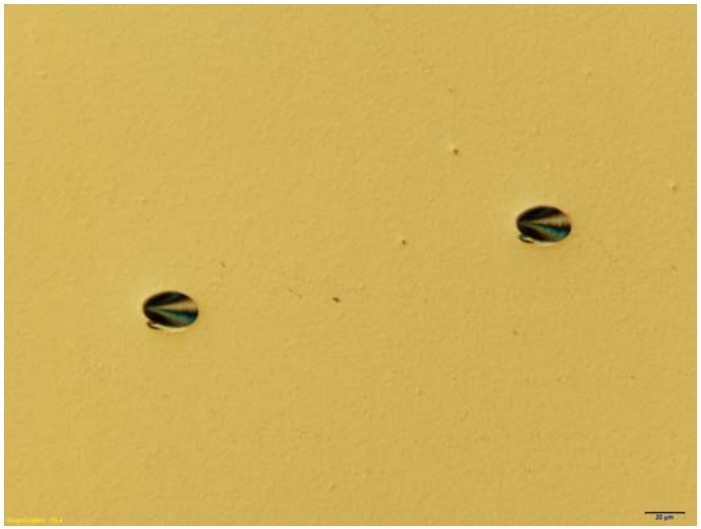


Final Polish on DSP

Final Touch on SSP

IEB025TN Wafer Evaluation: Dislocation Etch Pit Density

- *Lower dislocation EPD is observed on Te doped wafers*
- *Most area has EPD < 1,000 /cm² vs. 3,000-4,000/cm² on the undoped IET grown wafers*



Avg EPD = 754 /cm² over the entire 4" area

4" Wafer: IEB025TN-8
69-Point EPD Map

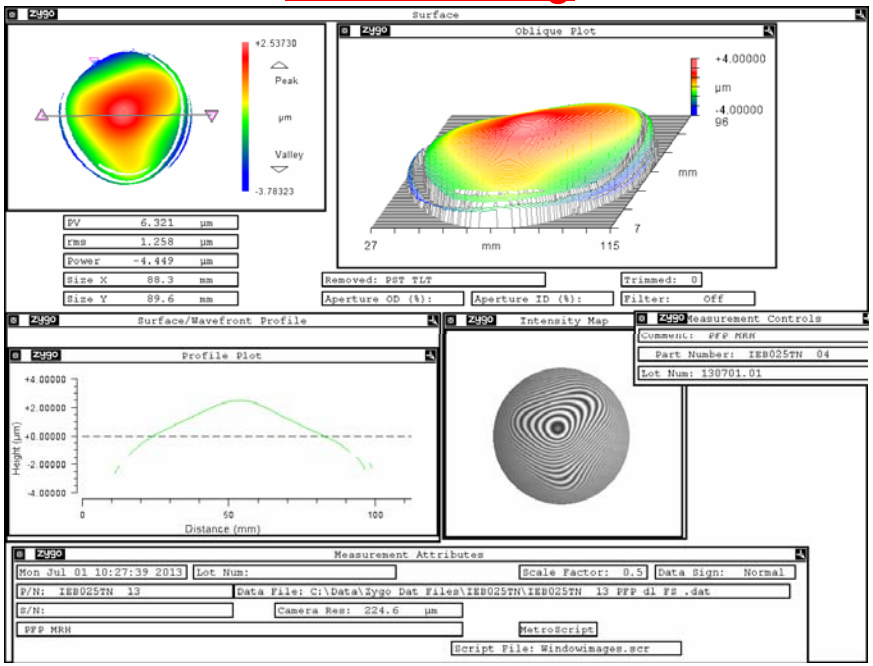
69 point EPD Position								
		1822	607	337	337	810		
	540	540	270	472	405	270	675	
1890	337	270	337	607	675	742	337	540
472	472	270	472	337	742	945	877	810
270	742	540	270	202	1012	472	270	877
472	810	270	405	675	607	1282	742	675
3307	1822	1147	607	742	472	337	810	945
	1890	1012	810	472	337	742	1147	
		472	945	2835	1012	1350		

1000<x<2000
x<500

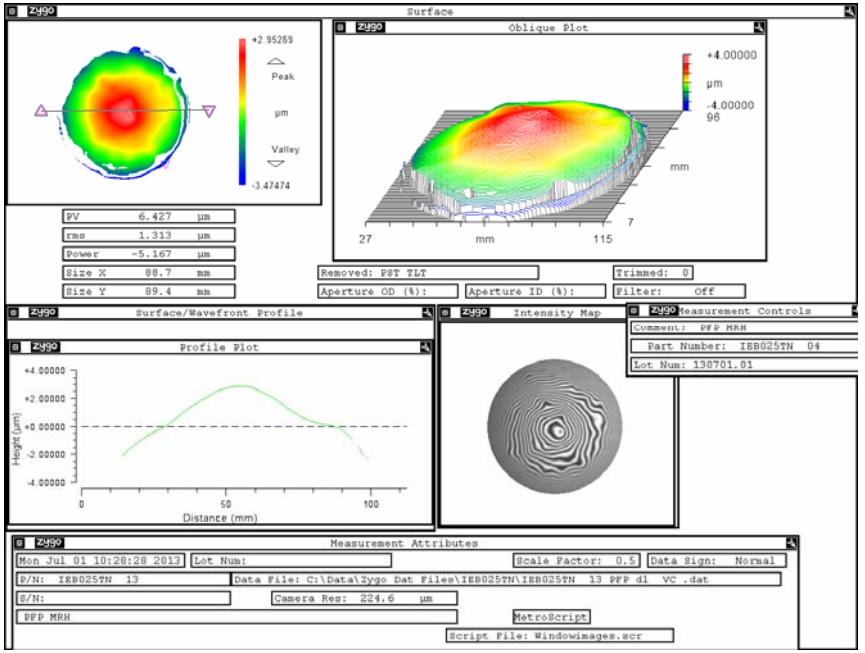
Zygo Flatness Mapping of 4” Epi-ready GaSb Wafer (IEB025TN-13)

- *Convex free standing surface with PV = 6.327 μm, similar to the vacuum clamped surface with PV = 6.421 μm*

Free Standing



Vacuum Clamped

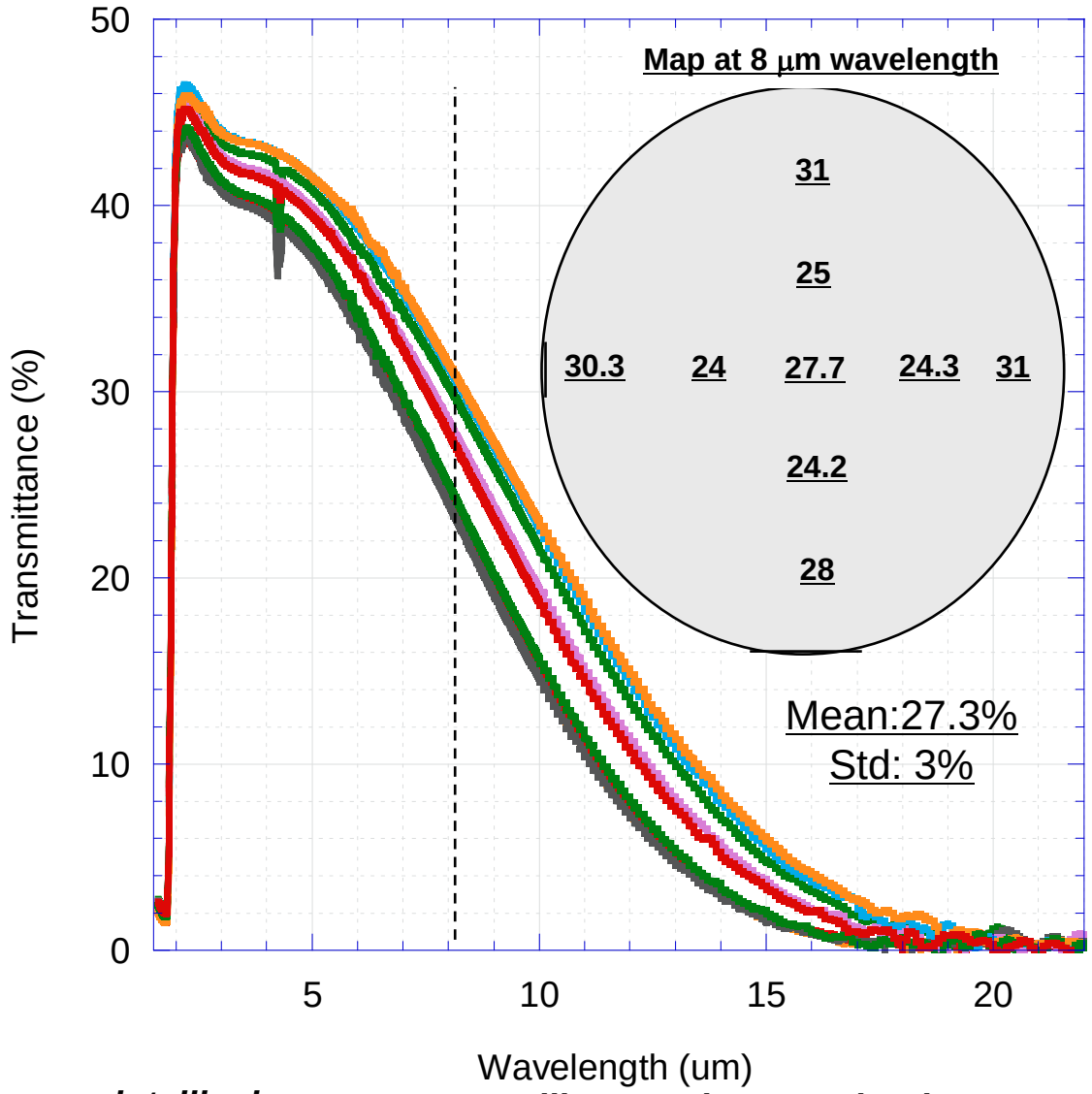


FT-IR Transmission of n-doped 4” GaSb Substrate

- *Demonstrate transparency beyond 10 μm wavelength*
- *Good transmission uniformity*

Wafer ID: IEB027TN-22
Diameter: 4” Thickness: 650 μm

Transmission spectra across wafer at room temp



Summary

- *Space qualified experience: QWIP epi for FPA on NASA-TIRS instrument for LDCM satellite (launched 2/2013)*
- *Significant progress made with SLS epi materials*
  - **Successful FPA prototypes demonstration: LW up to 1kx1k format, and 320x256 MW/LW dual band**
  - **Comprehensive in-house large area device processing and characterization capability for SLS detector**
- *Epi-ready GaSb substrate commercially available for 2”, 3”, and 4” sizes*

IntelliEPI: Supplier Awards

IntelliEPI Win First Supplier Award from Skyworks Solutions * 2/10/2011

Richardson, TX -- IntelliEPI, *the world's leading MBE epi-wafers producer of pseudomorphic high mobility transistor (pHEMT) wafers for smart phones and other mobile devices, announced today that it received 2010 Supplier Award from Skyworks Solutions, Inc. The award was presented to IntelliEPI during Skyworks' Supplier Day Conference, held January 11 in Newport Beach, Ca., for the supply of pHEMT epi-wafers to Skyworks' Woburn, Ma. wafer fab. This is IntelliEPI's first award in this category.*

**** IntelliEPI won Supplier awards from Vitesse Semiconductor from 01 to 04.***

IntelliEPI *2013, 2014* Supplier Award from Agilent technologies, Inc. for excellent supply of Production and R&D Product 11/20/2013, 3/13/2015