October 4th – 7th | 2021

PHOTONICS DAYS Berlin Brandenburg innovationconference

III-V optical sources for high bit rate fiber transmission

October 5th 2021

Almæ Technologies

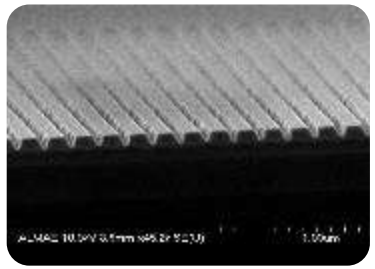
S. Belahsene

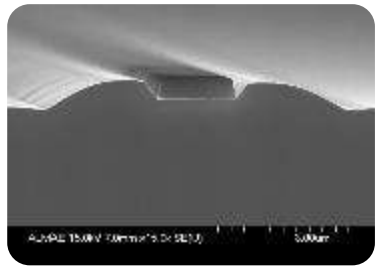
MASSTART

Almae Technologies general presentation

- Almae Technologies SAS is in operation since Feb 2016. It is a spin-off from III-V Lab, a joint laboratory between Nokia Bell Labs, Thales R&T and CEA-Leti.
- Located in Marcoussis in the Paris-Saclay high tech hub, host of French Optics Valley.

Facilities and portfolio





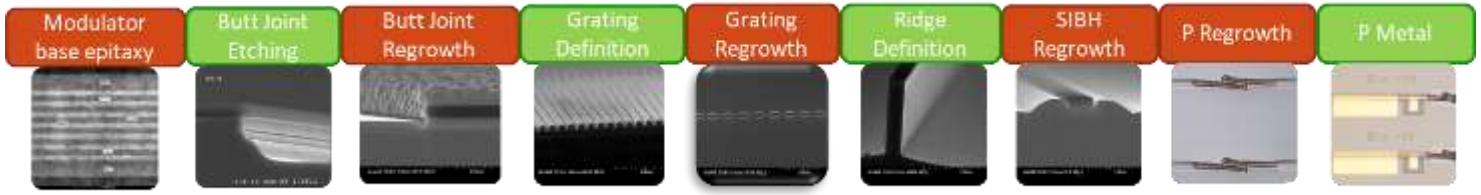
- State of the art facility, two clean rooms for epitaxy and wafer processing (2x 850 m^2)
  - ✓ Modern end-to-end chip fabrication platform
  - ✓ Large capacity increase in epitaxy and e-beam grating fabrication
- Epitaxy for Al based or Al free MQW structures (QD's available)
  - ✓ 4 AIXTRON MOCVD reactors
  - ✓ 2 RIBER/Veeco MBE reactors, one additional RIBER MBE in Q2 2018
- Photonic integration building blocks
  - ✓ Proven butt-joint regrowth technology for active-active or active-passive integration
  - ✓ Precise E-beam grating fabrication process, capacity available for quick turnaround
  - ✓ High performance SI-BH regrowth technology for improved performances and lowest power consumption

Product development

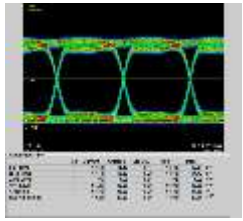
➢ Design, testing and module integration

High speed (10/25/50G) laser and EA modulator design, wavelength fixed or tunable, uncooled wide temperature range, high temperature ‘heat only’ low power solution

➢ EML process flow: building blocks

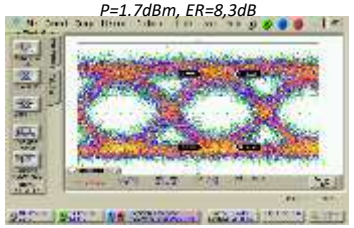


- 10G EML @1.55µm based on SI-BH technology platform
  - High power: +6dBm modulated power in fiber
  - Transmission at low modulation voltage (typ. 0V / -2V) with high extinction ratio ER (10Gb/s transmission over 80km, ER=10dB)

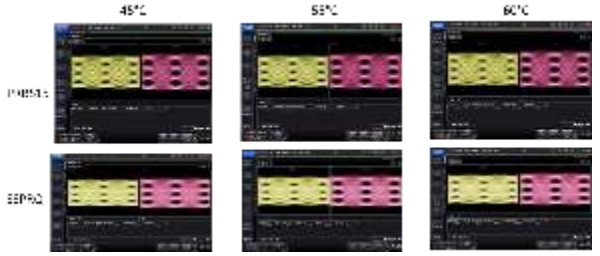


- 25G EML @1.3µm@1,55µm based on SI-BH technology platform
  - Design with reduced modulator capacitance for higher speed at 1.3µm (O-band)
    New developments for higher speed (50Gb/s modulation)
  - Low capacitance, high modulation bandwidth High DER even for 25G modulation (8dB) (C-band)
    25Gb/s transmission over 10km, ER=8dB

@ 50Gb/s
P=1.7dBm, ER=8,3dB

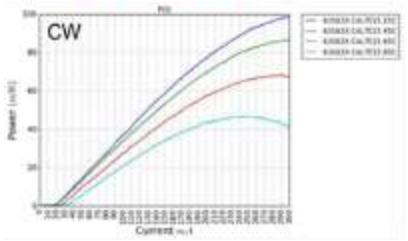


1,3 µm

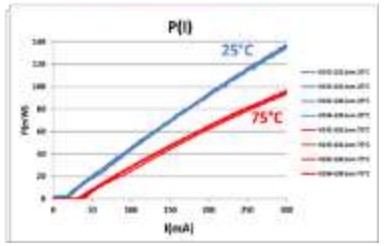


- High-power uncooled 1,3µm laser (RWG technology)
  - 0°C / 85°C uncooled laser at 1.3µm with more than 40mW facet power (Al-based)
- High-power uncooled 1,3µm laser (SiBH technology)
  - 0°C / 75°C uncooled laser at 1.3µm with more than 70mW facet power (P-based)

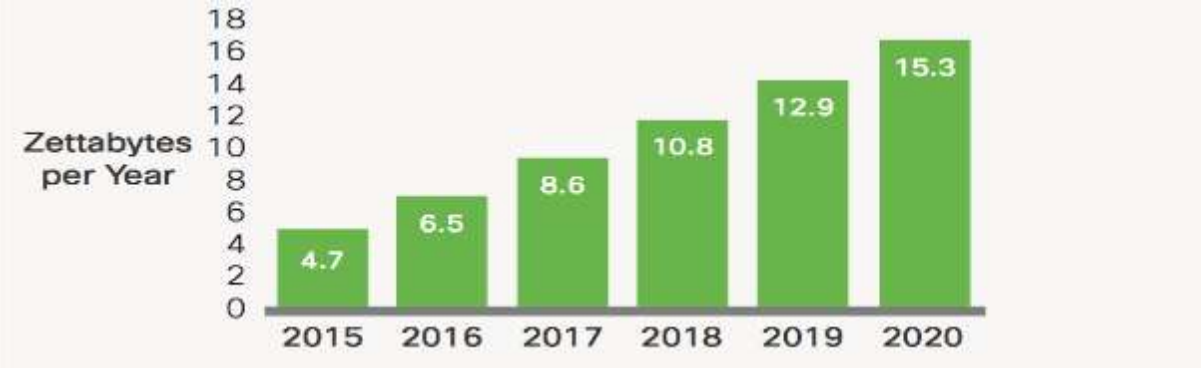
RWG technology



SiBH technology

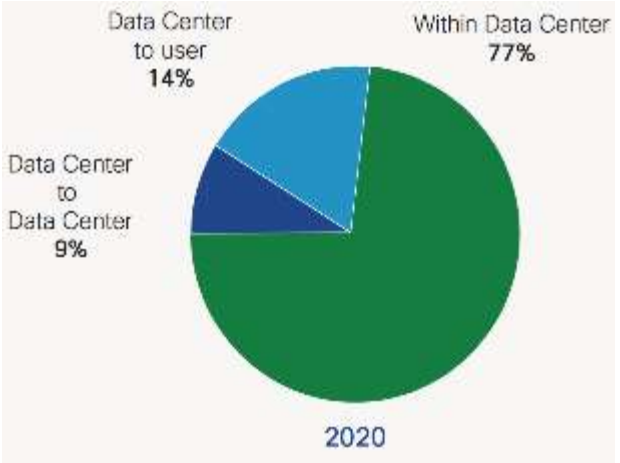


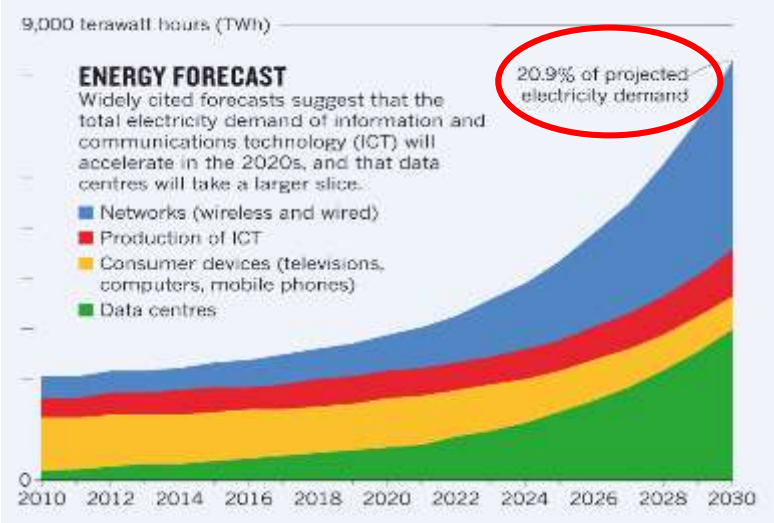
IP Traffic Handling. Source: Cisco Global Cloud Index, 2013–2020



Growth of annual IP traffic from 2015-2020

1 Zettabyte= ~10^{10} Terabyte



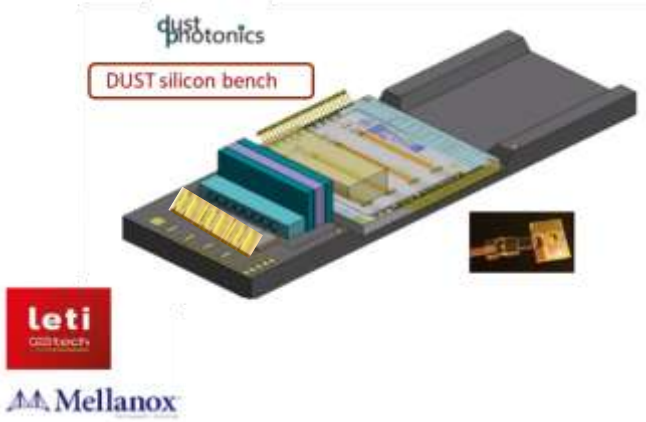


Optical sources:

- Photonic integration: High speed modules
- EML25/50G and DML25G

Masstart Objectives

- Address the next generation of transceivers, targeting 800G and >1Tb/s aggregate data rates, expected to massively use Silicon Photonics based PICs
- Demonstration of new concepts for passive laser chip assembly
- **New laser chip design for low power consumption and ease of optical assembly using Almae's BH technology platform**
- Evaluation of automated assembly and test for future volume production
- **Long term reliability demonstration of new laser chip for high power – high temperature operation**
- Integration of the new solution in a prototype product



- 4-channel PSM4 module in QSFP-DD format with 400G aggregate bit rate,
- 8-channel WDM module in a QSFP-DD format with 800G aggregate bit rate,
- 16-channel WDM on-board module delivering 1.6Tb/s aggregate line rate,

Demonstrators

- Inter Data Center (QAM)
- Intra Data Center (PAM4)
- On board

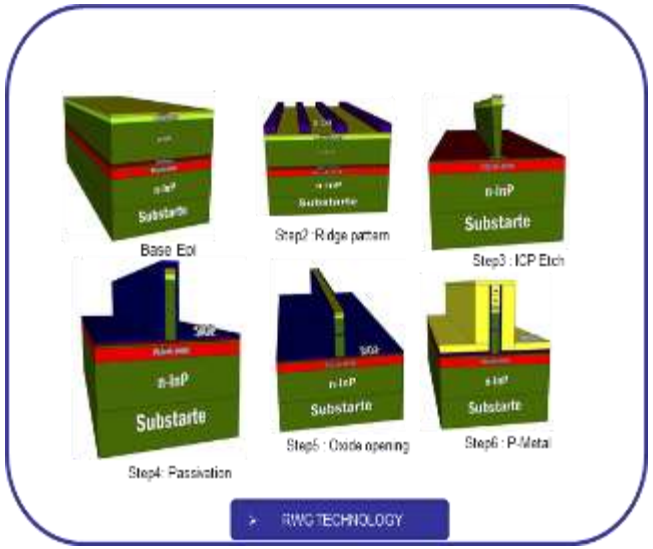
Challenge

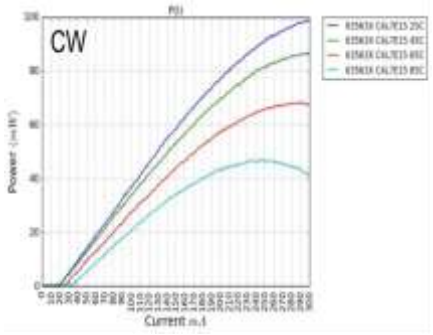
- Spherical mode and spot size converter for high coupling efficiency
- EBL writing for high yield production line in 3"
- Find components emitting relatively high powers to compensate the losses

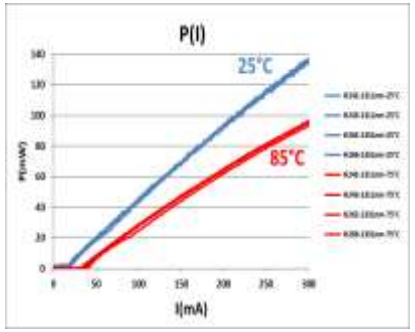
High-power DFB integration

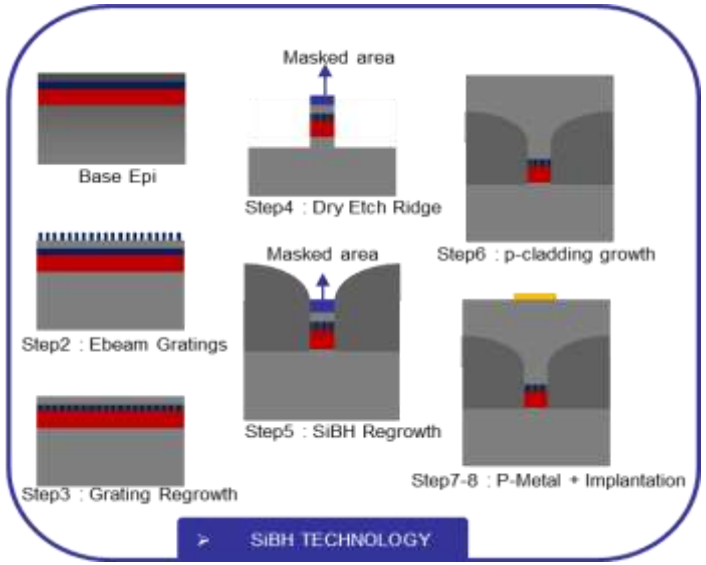
Silicon Photonics platform is an excellent platform for passive components, however, is not so mature for the active components (coupling losses). To overcome this:

- ✓ Components emitting relatively high powers to compensate the losses.
- ✓ Reduce the coupling losses using innovative coupling techniques.

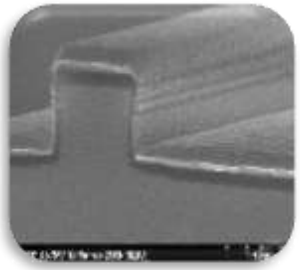


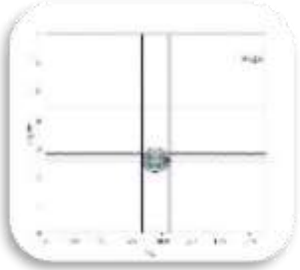




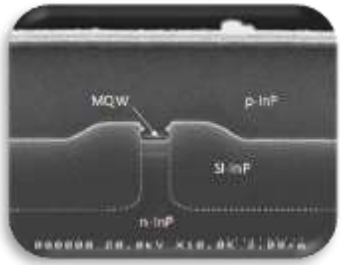


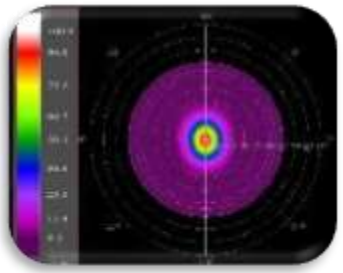
High performance Si-BH regrowth technology





- ➢ Low capacitance => high modulation bandwidth
- ➢ Spot size converter => for high coupling efficiency , Spherical far field figure
- ➢ Low consumption => Efficient heating dissipation and low voltage operation





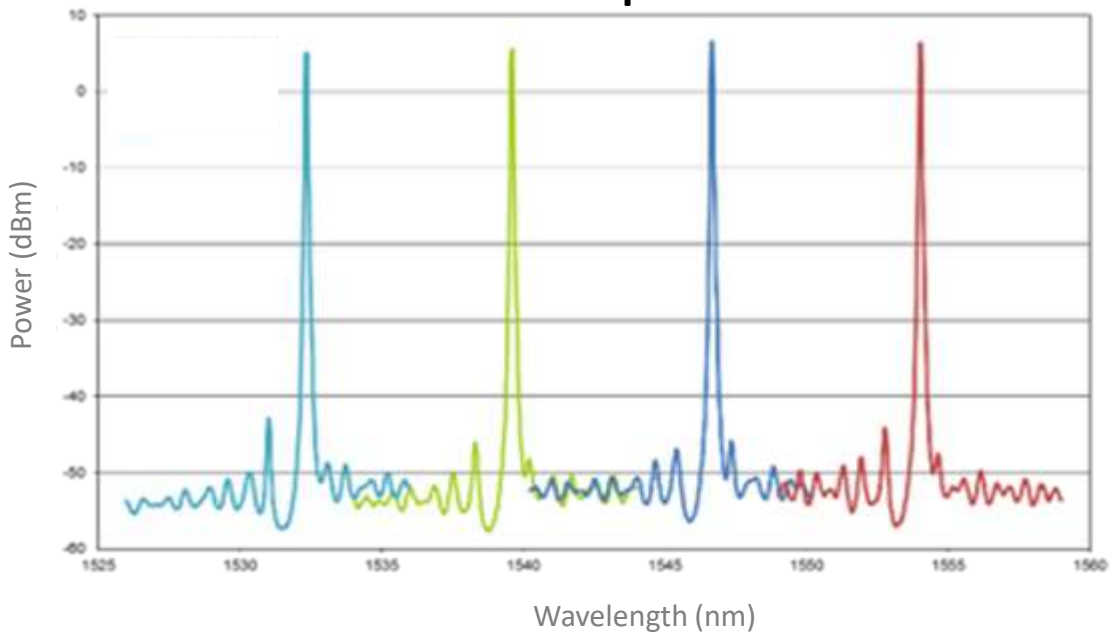
The SiBH technology will be promoted for high coupling efficiency

Photonic integration expertise

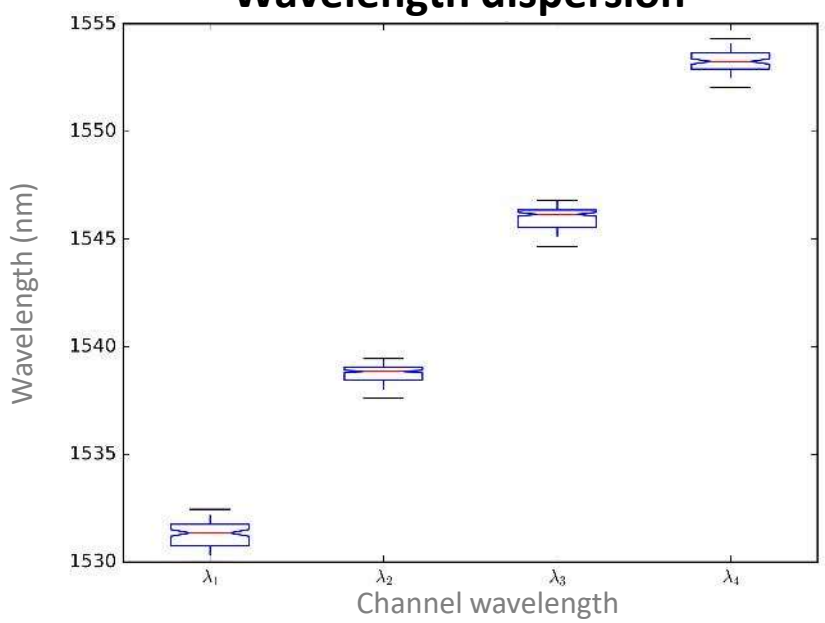
e-beam grating fabrication process:

- **Extreme uniformity** over 3 and 4-in wafers => High yield on lasers (SMSR>50dB)
- **Accurate wavelength control** for multi-wavelength coverage (< ±1nm error over wafer)

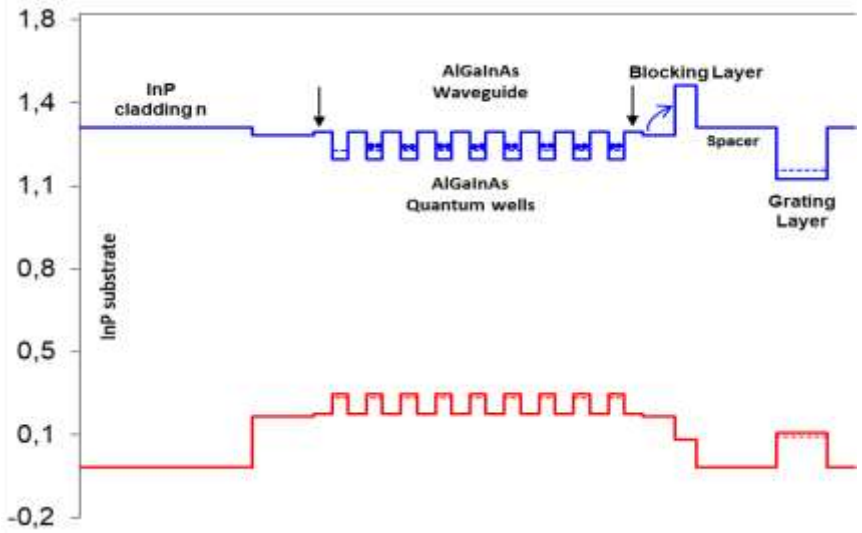
Lasers spectra

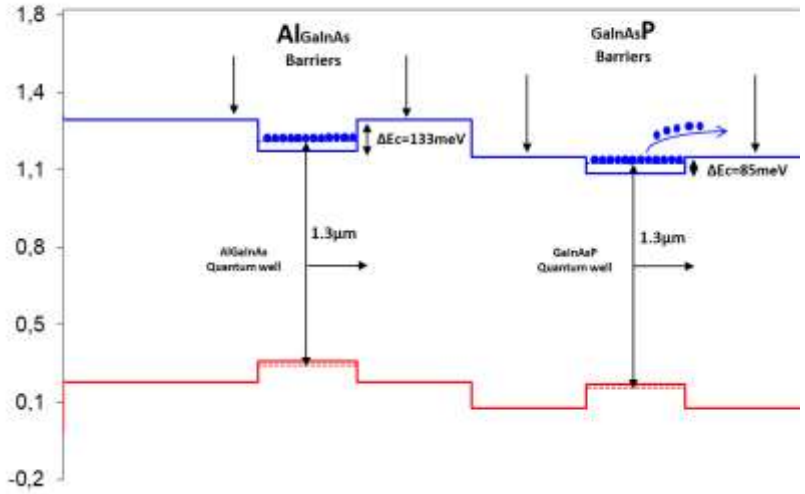


Wavelength dispersion



The conventional InGaAsP material vs AlGaInAs for uncooled lasers emitting at 1.3µm



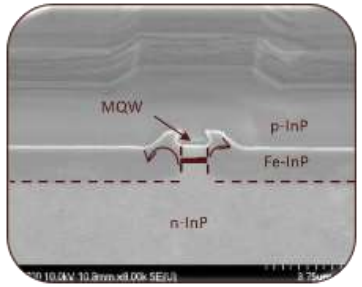


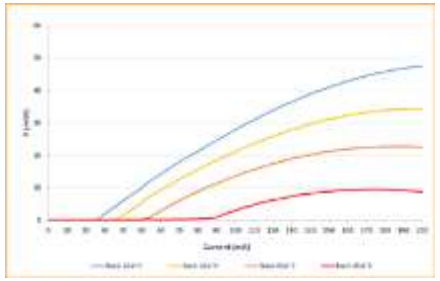
InGaAlAs - based QW

- Reduces the carrier leakage from the Qw compared to the conventional InGaAsP material system under high temperature operation.
- The reduced carrier leakage results from AlGaInAs having a larger conduction band offset (ΔEc= 0.72 ΔEg) compared to the smaller conduction band offset of GaInAsP (ΔEc= 0.4 ΔEg)

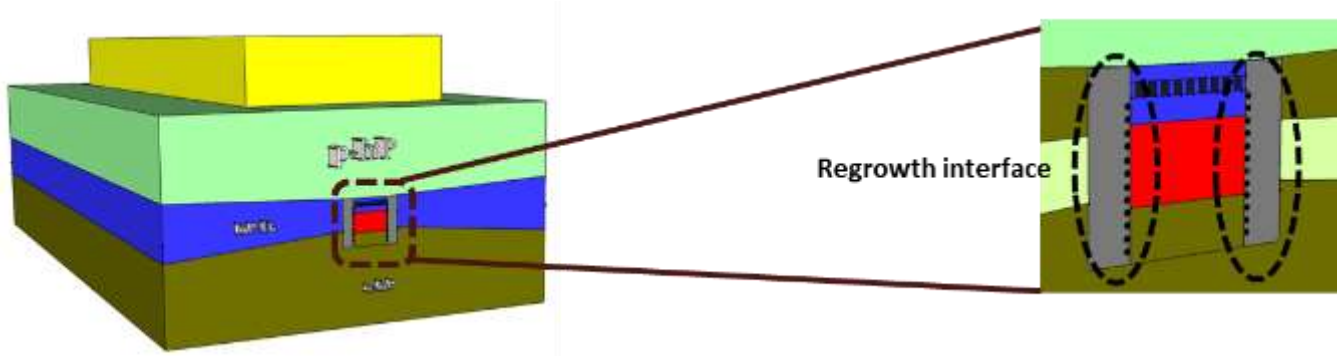
The use of AlGaInAs based material should be enough to give high output power over a large temperature range.

Al-based SiBH Improvements

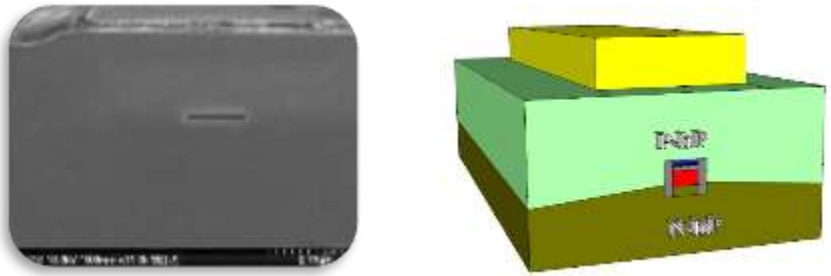




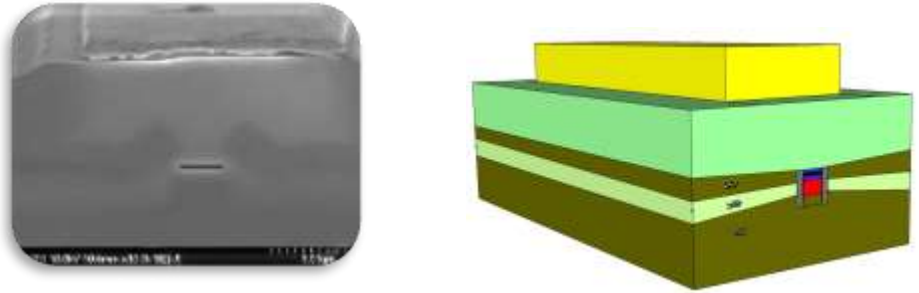
Fe- and Ru-InP current blocking layers were grown



- Damage and contamination is often caused by the etching process for ridge formation
- The Al containing system, is generally more sensitive to contamination and oxidation
- Reduce the leakage current in BH



Just a P- layer was grown (BRS-Buried-Heterostructure)



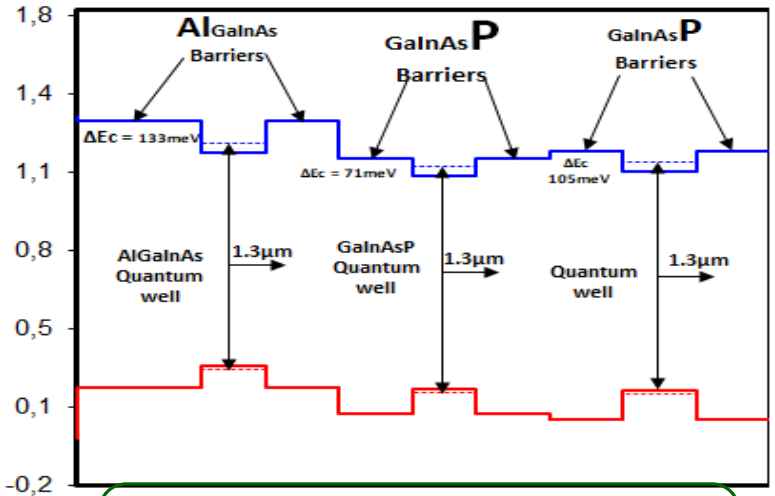
P- and n-InP current blocking layers were grown

⇨ A new Blocking layers were regrown on Al-based MQWs design

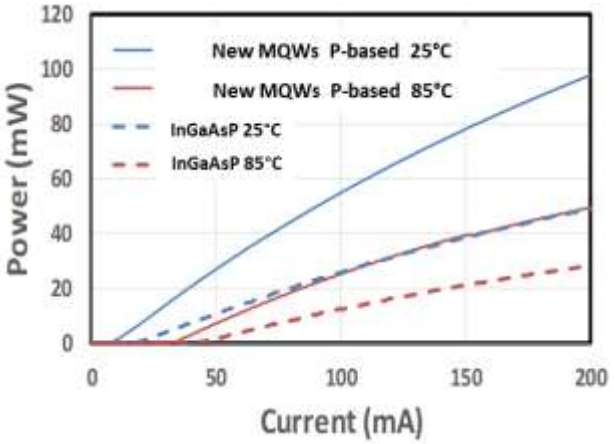
1.3µm AlGaInAs Buried-Heterostructure Lasers

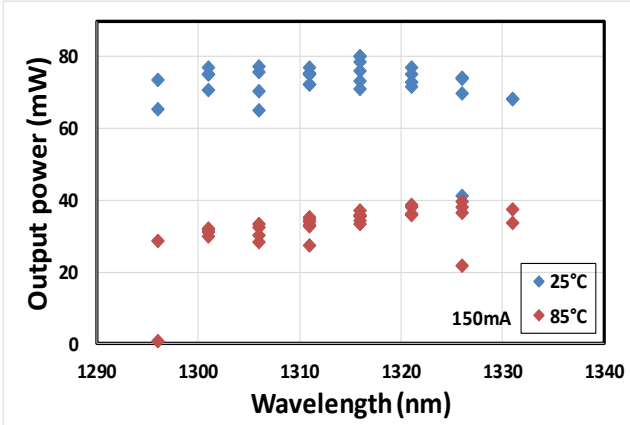
- **Uncooled operation of** *1.3-µm AlGaInAs strain-compensated MQW BH* **with more than 40mW facet power,** which is about 100% higher than that of the conventional SiBH laser.
- The characteristic temperature of the threshold current was measured to be **78 K**
- BH lasers of AlGaInAs MQW are good candidates for uncooled applications

Al- free design : LI based MQWs characterizations

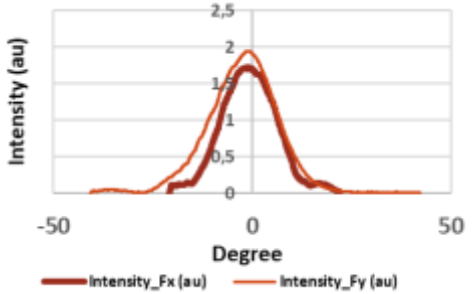


- ✓ Allow to reach the same offset of conduction band for electrons than the AlGaInAs material system (>100meV)
- ✓ More compatible with SIBH technology

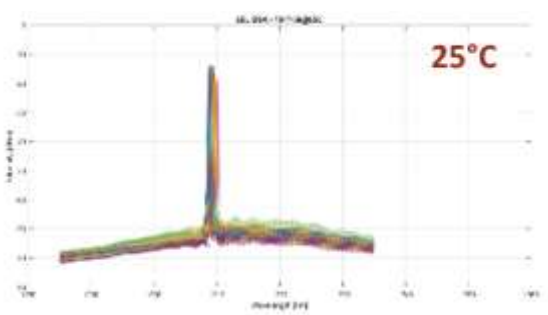


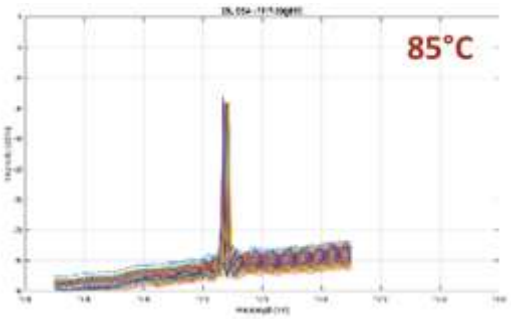


- ➢ Uncooled DFB with low Ith and high Pout
- ➢ Phosphore based, compatible with SiBH technology
- ➢ Phosphore based MQWs design will be used for Demo 1 and 2



Fx: 16.3 deg. Gaussian approximation Dx ~ 5.9um
Fy: 19.2 deg. Dy ~ 4.9um

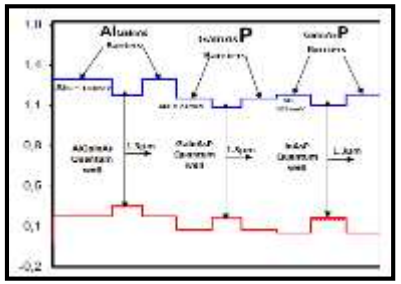


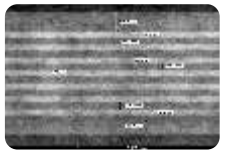


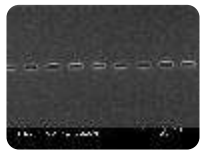
High-power DFB lasers based on Al-free MQW for new generation of transceivers PICS

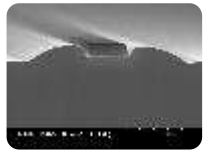
HPDFB-SiBH process flow: building blocks:

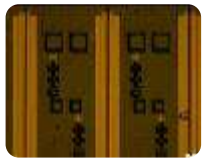
Band gap engineering/optical waveguides	Laser base epitaxy	Grating Definition	Grating Regrowth	Ridge Definition	SIBH Regrowth	P Regrowth	P Metal



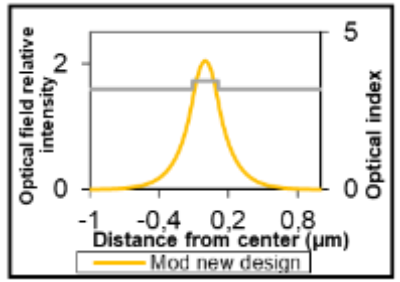


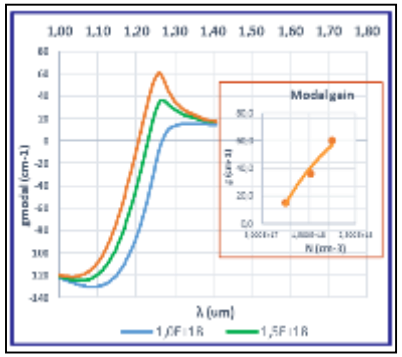


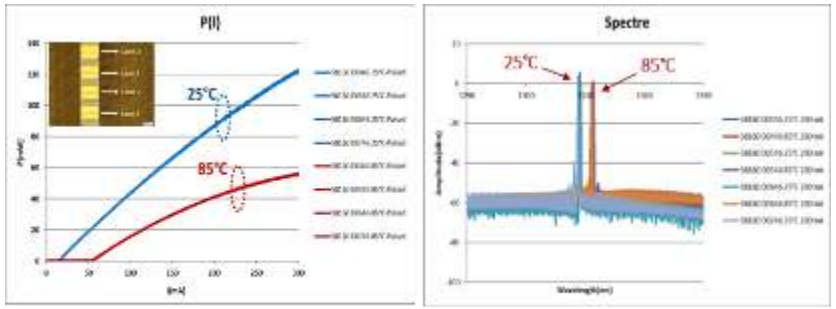




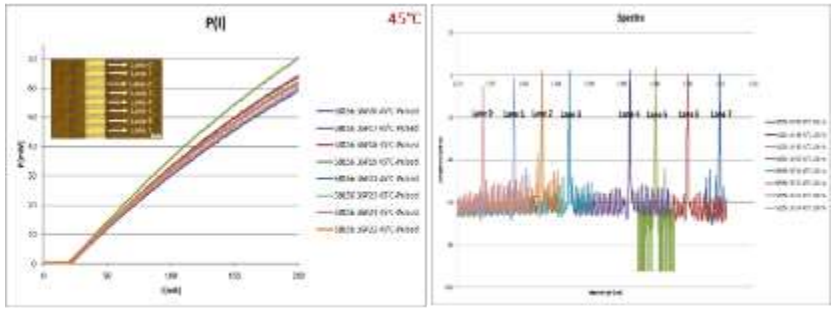
- Fully mastered in ALMAE (from conception to characterization)





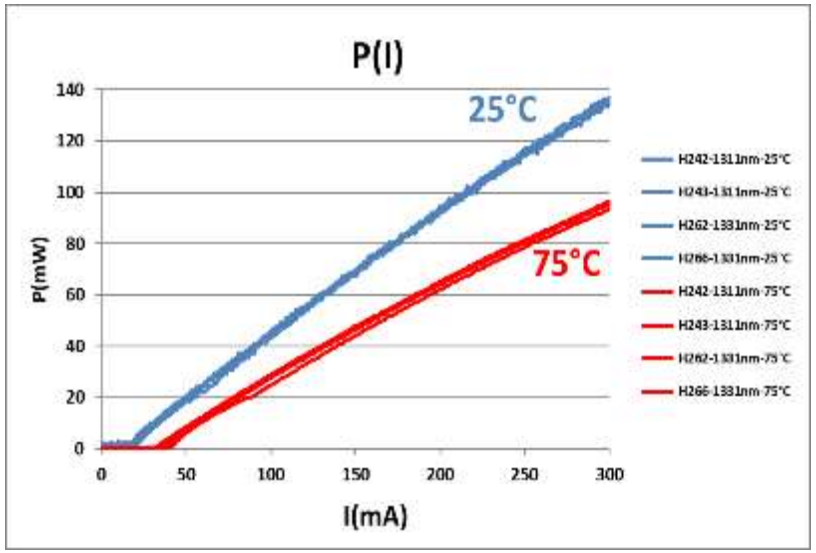


Demo 1 – 400GBASE-DR4



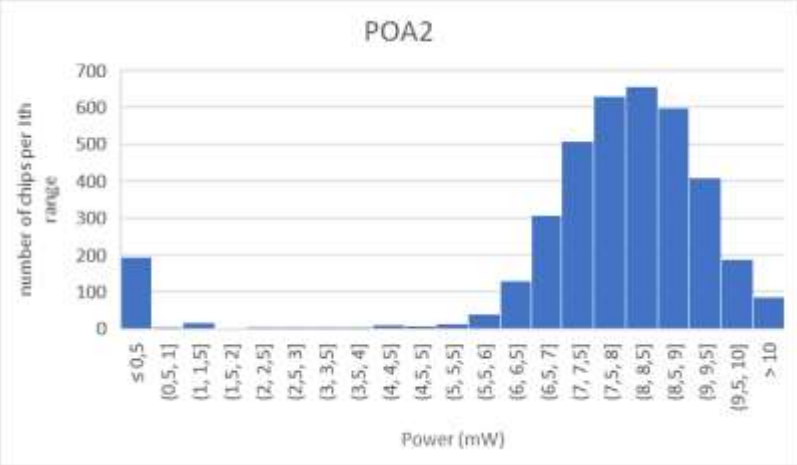
Demo 2 – 800G – 8 lambdas

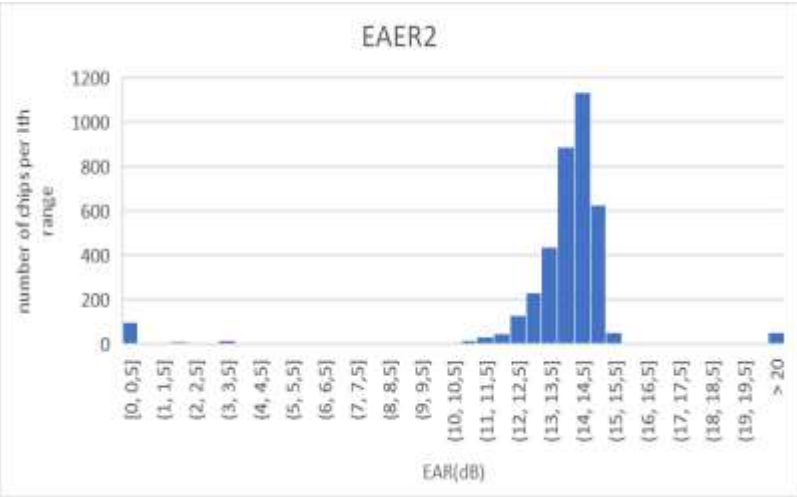
New generation of HPDFB



The output power is improved by 25% at high temperature operation

High power 1577-EML for PON



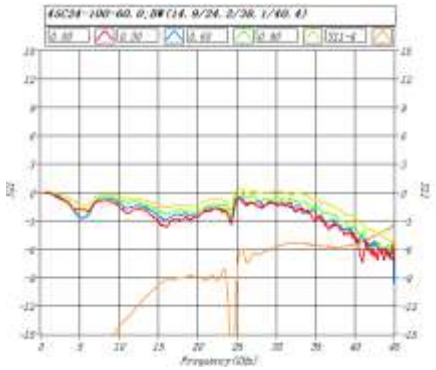


chip SN	N° device	Pf (mw) @109mA 43° TO	CE	P (mw) @109mA 43°	dBm	N° Module	Module test
65K30	0003	12.23	59%	6.9	8.4	XG_011	5.7
54M20	0004	11.5	69%	7.76	8.9	XG_012	6.4
64I31	0005	12.12	61%	7.2	8.6	XG_013	5.9
64M21	0006	11.86	45%	5.33	7.3	XG_014	5.2
54M24	0007	12.23	48%	5.72	7.6	XG_015	6.0

- ✓ High power keeping a high ER
- ✓ On-going Telcordia qualification (>3000h aging)
- ✓ EPON/XGSPON2 using 70mA injected current
- ✓ First COMBO with 110mA injected current

EML performances PAM4 112Gb/s

BW>35GHz



Accelink packaging in DR4 modules

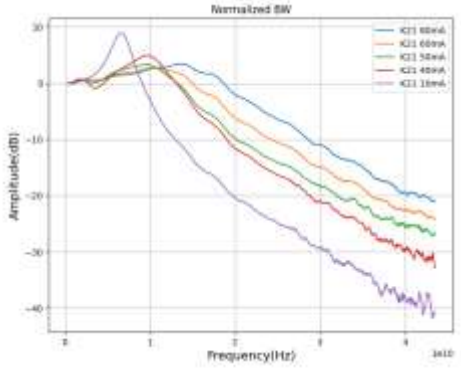
T (° C)	Vbias (V)	Ilaser (mA)	TDECQ PRBS15 (dB)	TDECQ SSPRQ (dB)	OMA (dBm)	ER (dB)	AP (dBm)
45	-1.59	73	2.87	3.13	0.86	4.2	1.26
55	-1.47	84	2.87	3.08	0.46	4.15	0.89
60	-1.34	91	3.04	3.18	-0.15	4.26	0.2

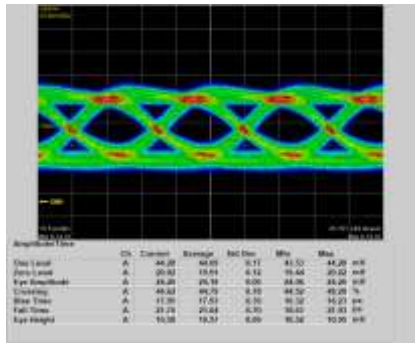
45°C 55°C 60°C

PRBS15

SSPRQ

Directly modulated laser 25G





Conclusions

- Almae Semi-Isolating Buried Head platform is a proven technology

  High-power DFB integration

  ✓Spherical mode and spot size converter for high coupling efficiency

  ✓Efficient heating dissipation and low voltage operation for high temperature and low consumption performances

  ✓Design rules for semi-cooled and uncooled operation in O-band

  High speed laser (III/V)

  ✓ High power 1577-EML for PON (10G)

  ✓ EML performances PAM4 112Gb/s (50G)

- Masstart results

  ✓ All specification of demo 1 are fulfilled (25°C / 85°C uncooled laser at 1.31µm with more than 40mW facet power)

  ✓ All specification of demo 2 are fulfilled (45°C operation laser covering a wide (36 nm- 8 channels)

  ✓ New generation will be tested