Design and realization of high-power DFB lasers based on Al-free MQW for new generation of transceivers PICS

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Photonics Days

Berlin Brandenburg

innovationconference

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Almæ Technologies

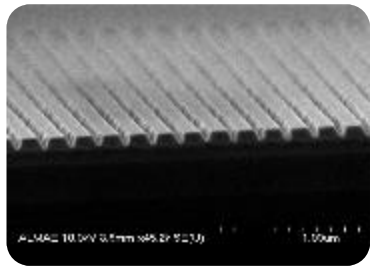
October 6th 2020

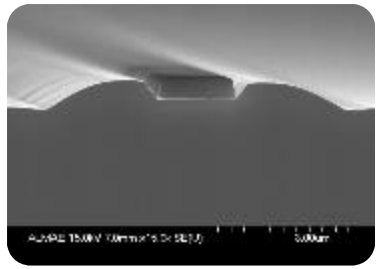
MASSTART

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

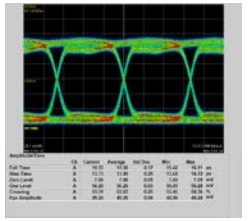
Product development

➢ 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

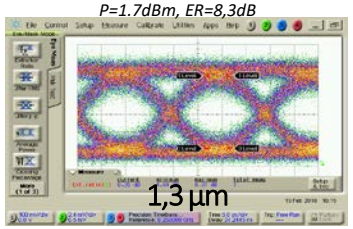
➢ EML process flow: building blocks

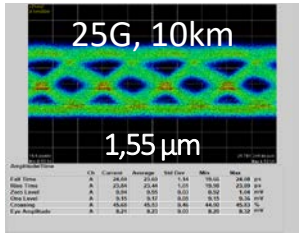
- 10G EML @1.55µm based on SI-BH technology platform
  - High power: +6dBm modulated power in fiber
  - Transmission at low modulation voltage (typ. 0V / -2V) with high extinction ratio ER (10Gb/s transmission over 80km, ER=10dB)



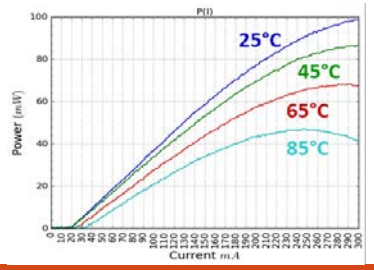
- 25G EML @1.3µm@1,55µm based on SI-BH technology platform
  - Design with reduced modulator capacitance for higher speed at 1.3µm (O-band)
    New developments for higher speed (50Gb/s modulation)
  - Low capacitance, high modulation bandwidth High DER even for 25G modulation (8dB) (C-band)
    25Gb/s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

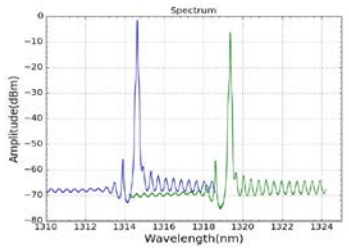
@ 50Gb/s
P=1.7dBm, ER=8,3dB





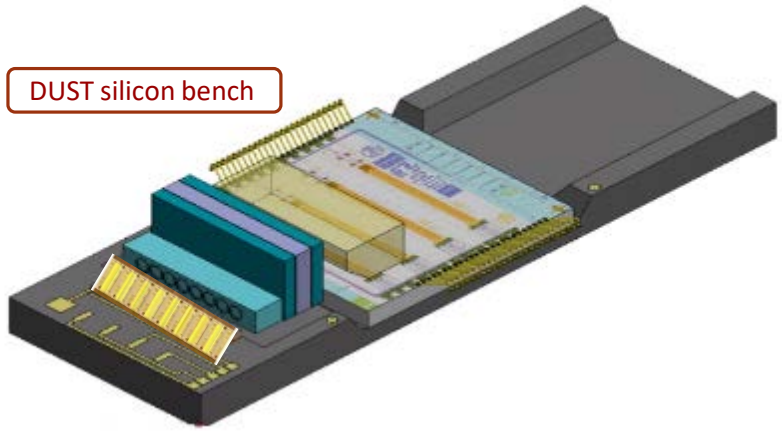
- High-power uncooled 1,3µm laser (RWG technology)
  - 0°C / 85°C uncooled laser at 1.3µm with more than 40mW facet power)





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,

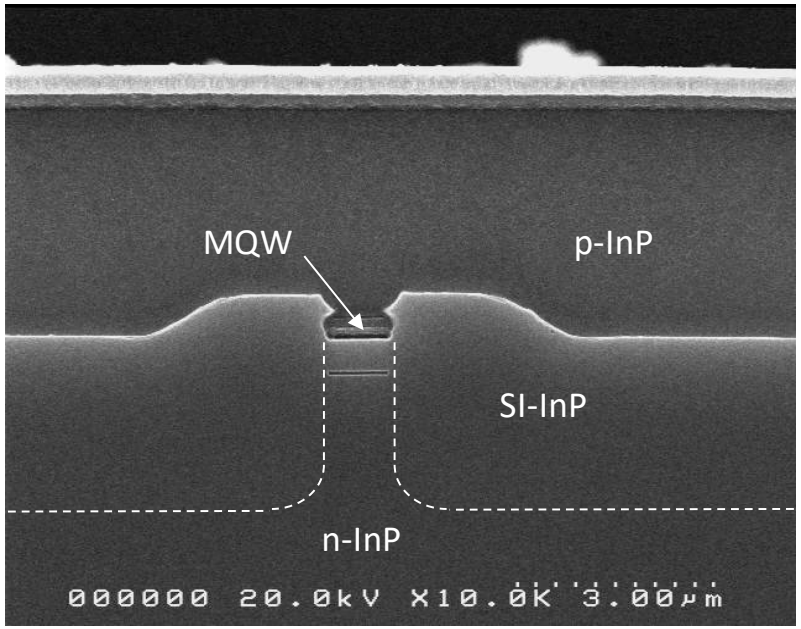
Challenge

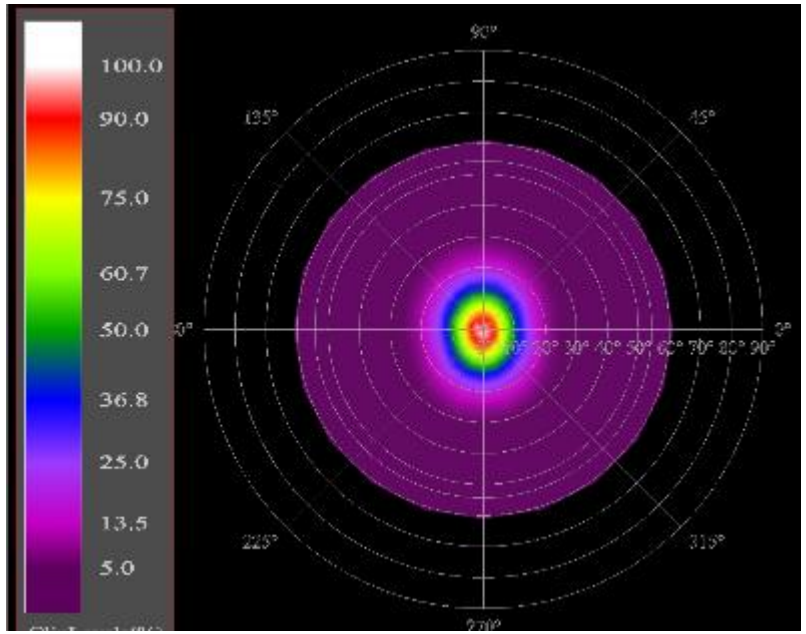
- **Spherical mode and spot size converter for high coupling efficiency**
- **EBL writing for high yield production line in 3"**
- **Find components emitting relatively high powers to compensate the losses**

Photonic integration expertise

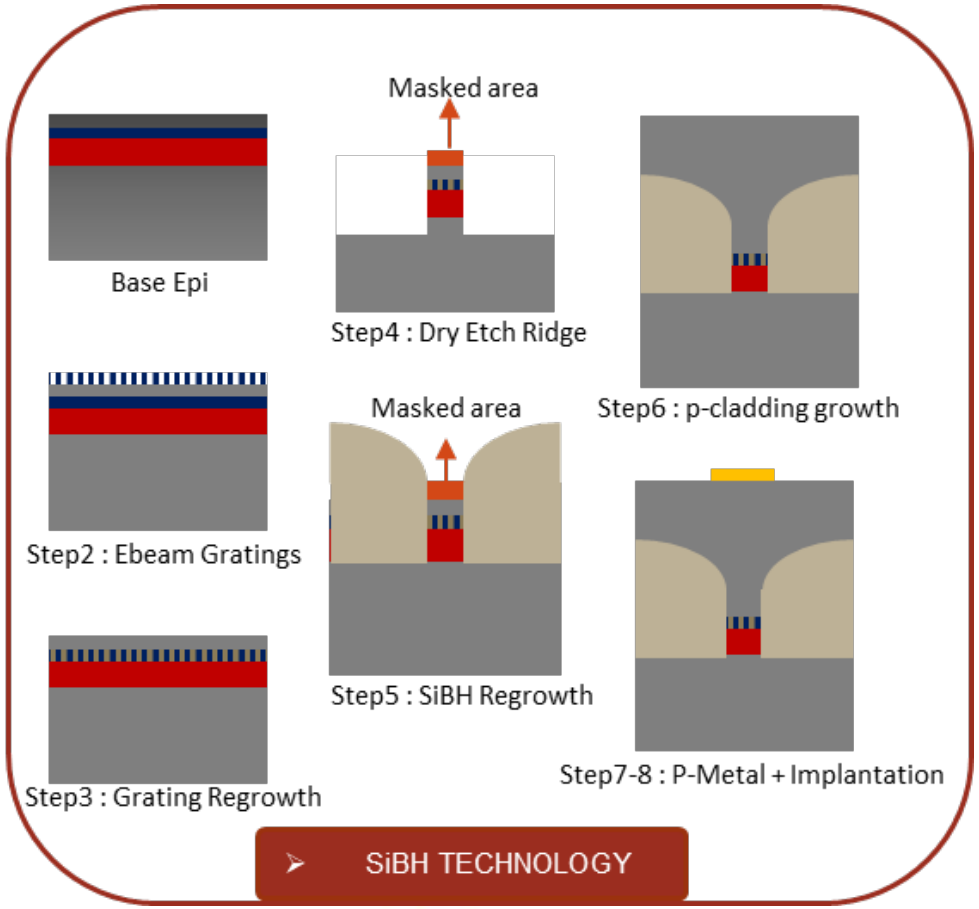
SIBH waveguide technology:

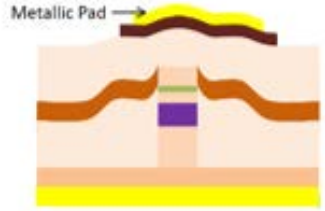
- **Low capacitance** => high modulation bandwidth
- **Spot size converter** => for high coupling efficiency , Spherical far field figure
- **Low consumption** => Efficient heating dissipation and low voltage operation



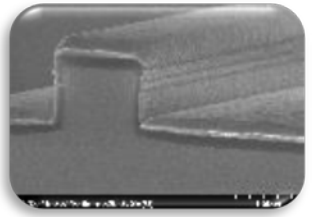


Technology fabrication of lasers





The SiBH technology will be promoted for high coupling efficiency

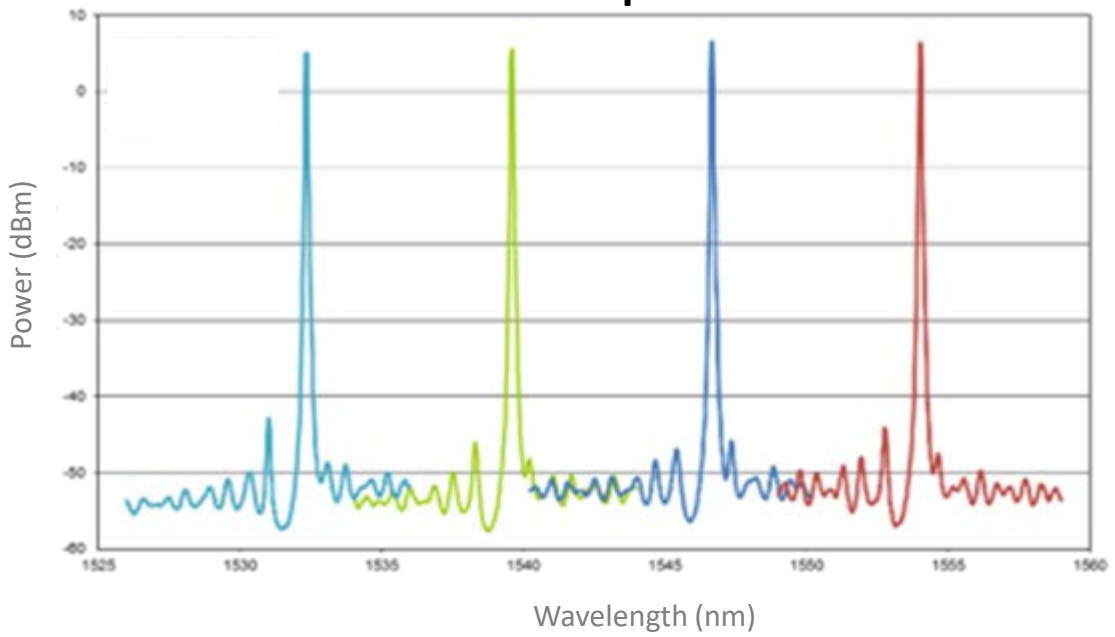


Photonic integration expertise

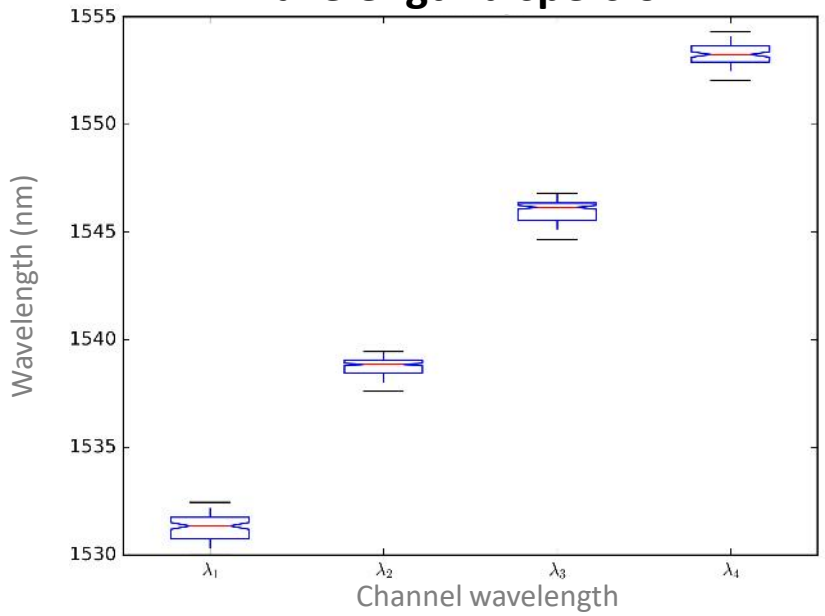
e-beam grating fabrication process:

- **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)

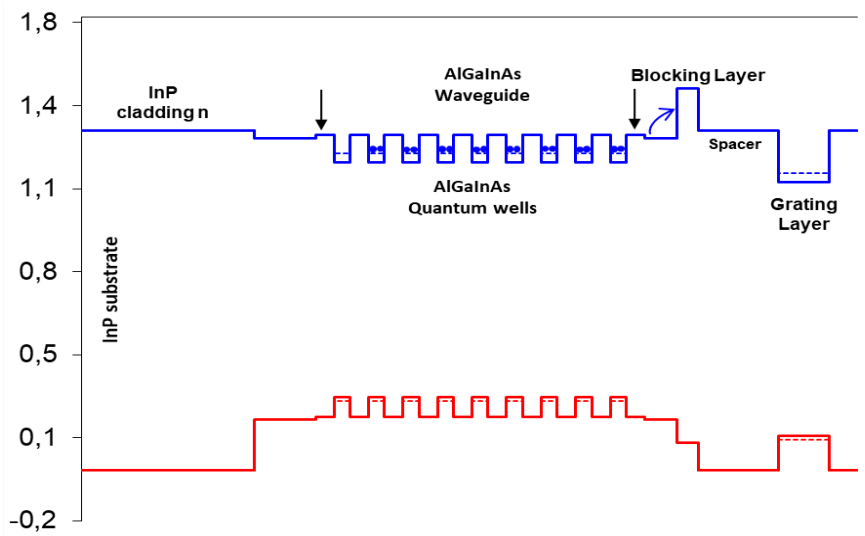
Lasers spectra

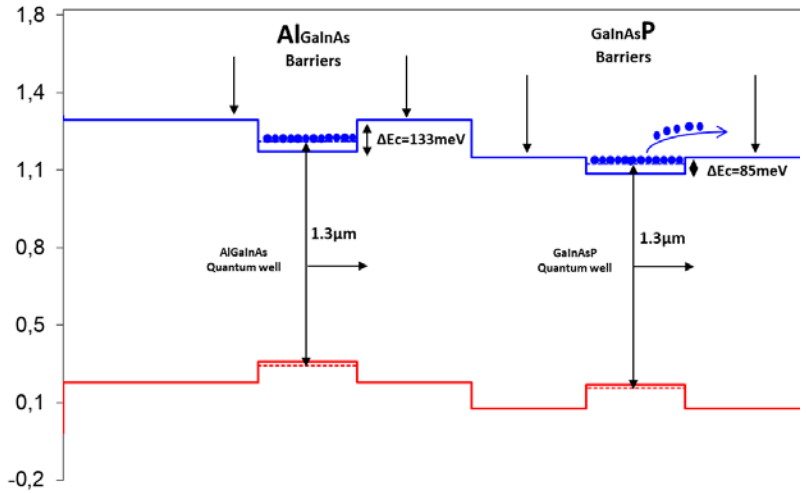


Wavelength dispersion



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



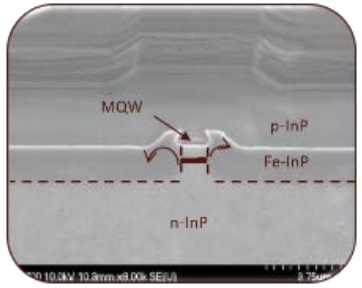


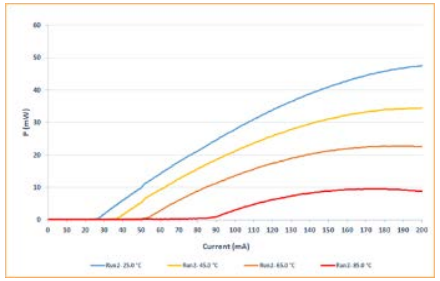
InGaAlAs - based QW

- 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)

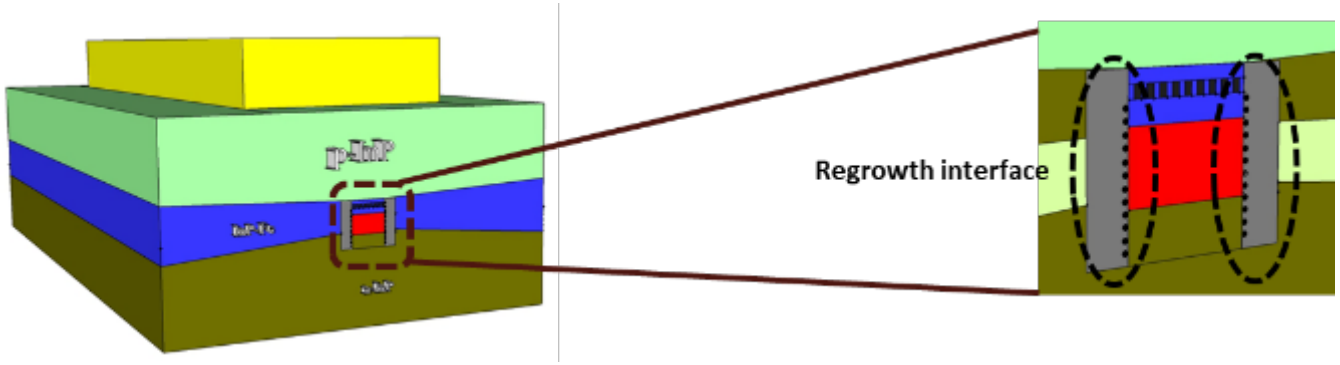
⇨ The use of AlGaInAs based material should be enough to give high output power over a large temperature range.

Al-based SiBH Improvements

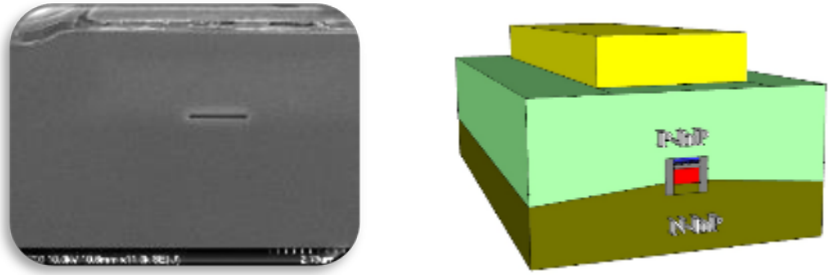




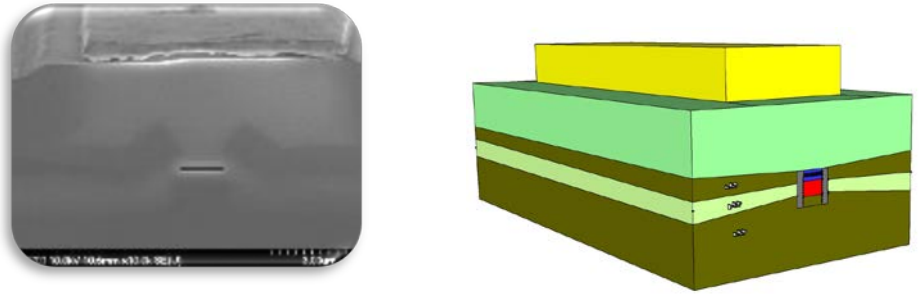
Fe- and Ru-InP current blocking layers were grown



- 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)

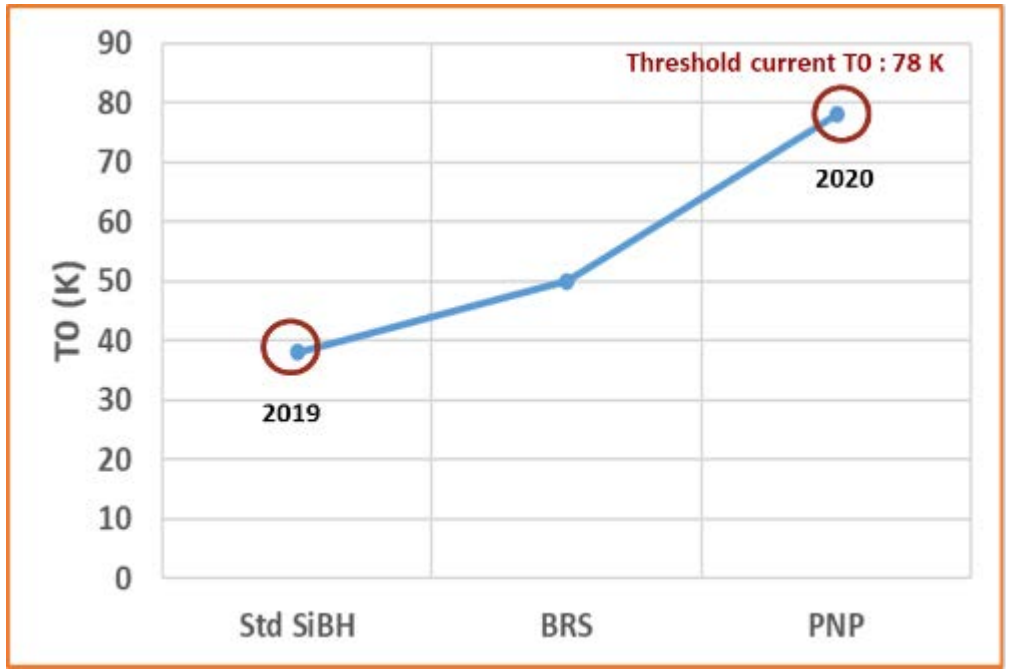


P- and n-InP current blocking layers were grown

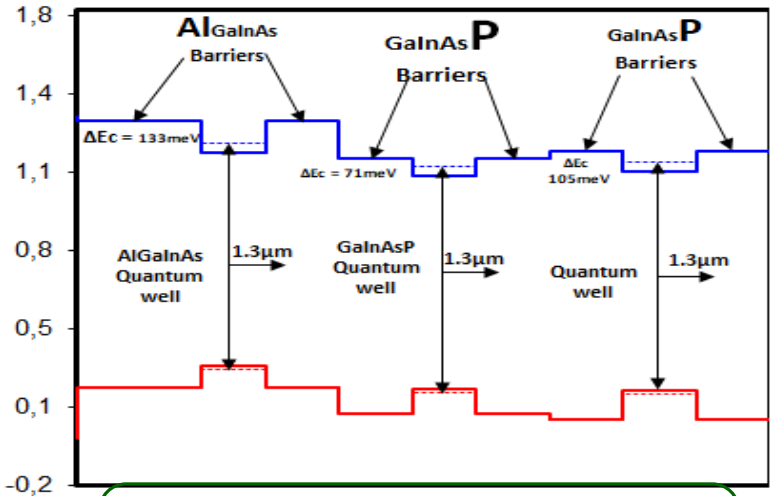
⇨ A new Blocking layers were regrown on Al-based MQWs design

1.3µm AlGaInAs Buried-Heterostructure Lasers

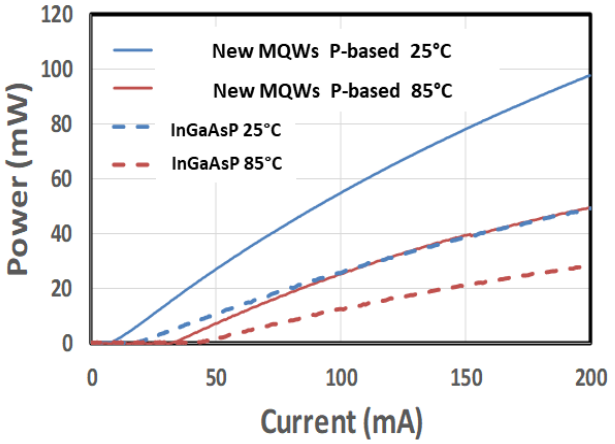
- **Uncooled operation of** *1.3-µm AlGaInAs strain-compensated MQW BH* **with more than 40mW facet power,** which is about 100% higher than that of the conventional SiBH laser.
- The characteristic temperature of the threshold current was measured to be **78 K**
- BH lasers of AlGaInAs MQW are good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

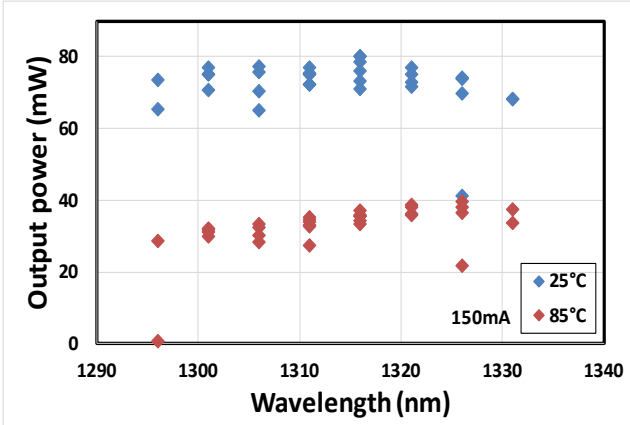


Al- free based MQWs design : LI characterizations

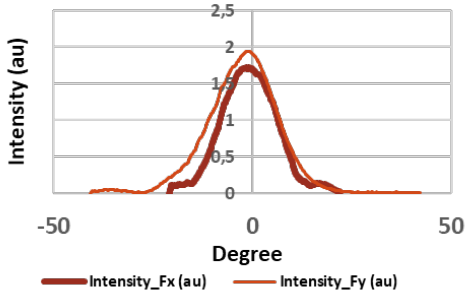


- ✓ Allow to reach the same offset of conduction band for electrons than the AlGaInAs material system (>100meV)
- ✓ More compatible with SIBH technology

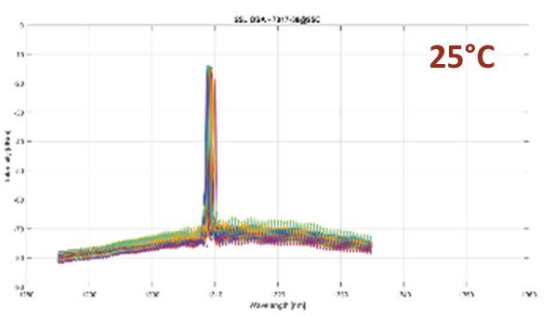


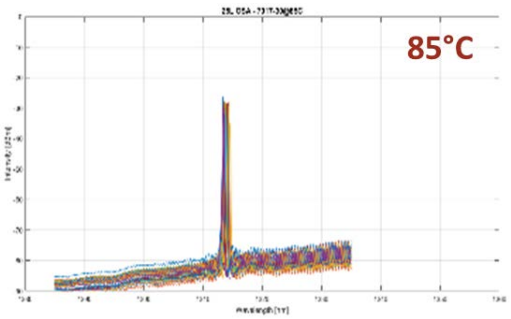


- ➢ Uncooled DFB with low Ith and high Pout
- ➢ Phosphore based, compatible with SiBH technology
- ➢ Phosphore based MQWs design will be used for Demo 1 and 2



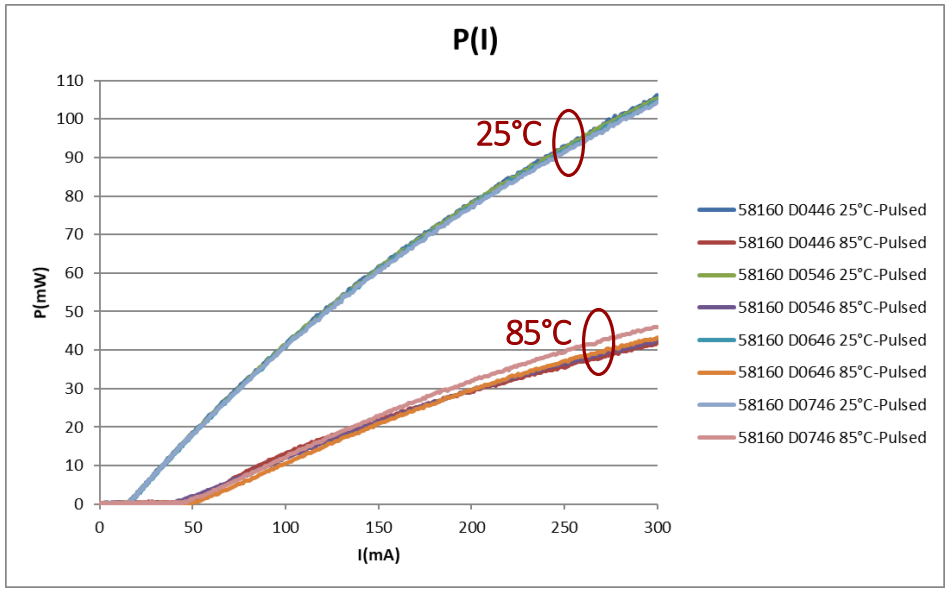
Fx: 16.3 deg. Gaussian approximation Dx ~ 5.9um
Fy: 19.2 deg. Dy ~ 4.9um





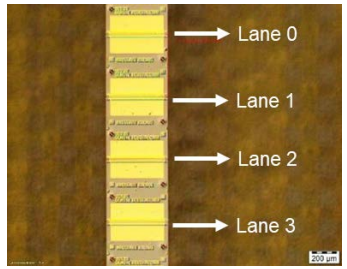
Demo1:400GBASE-DR4 transceiver
LIV, Spectrum Characteristics

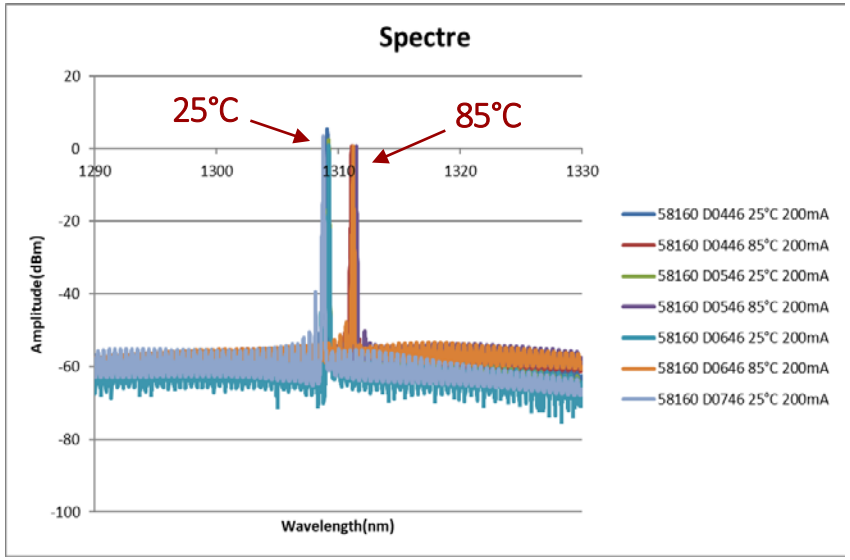
# channels	4
multiplexing type	PSM
wavelength	1304.5 to 1317.5 nm
SMSR	>30 dB
Output Power	16dBm
Temperature operation (Uncooled)	[20°C-85°C]



Bars tested : AR/HR facet coated

- Threshold current : 50 mA at 85ºC
- Output power at 300 mA : 40 mW at 85ºC
- Laser voltage at 200 mA : less than 1.6 V
- SMSR : more than 40 dB

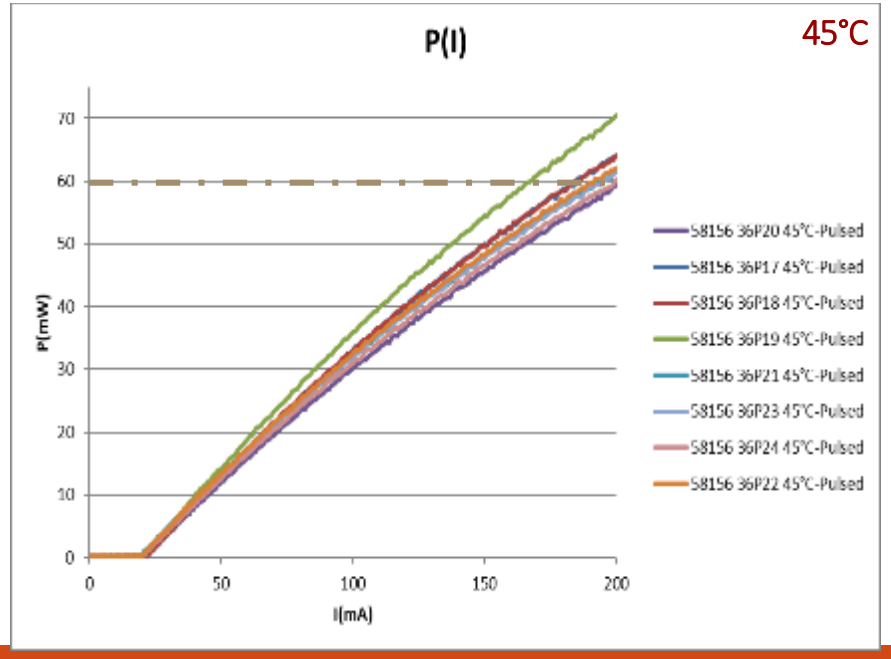




Demo2:800G 8-lane transceiver
LIV, Spectrum Characteristics

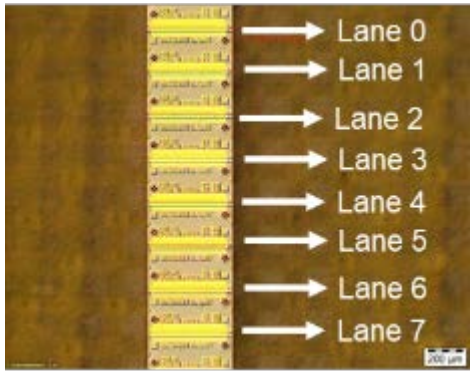
# channels	8
multiplexing type	WDM
wavelength	1273.54 to 1309.14 nm
SMSR	>30 dB
Output Power	18dBm
Temperature operation (semi-Cooled)	45°C

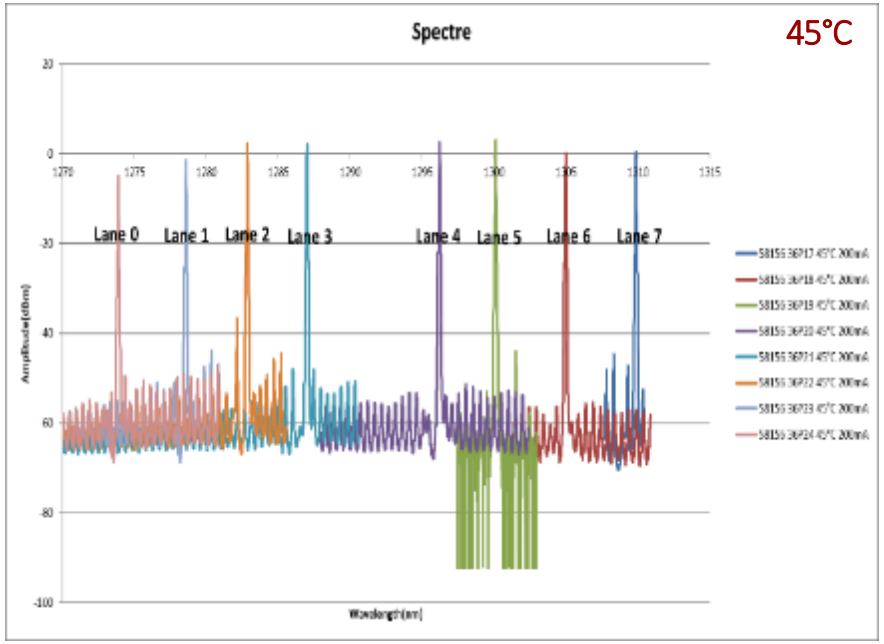
Lane	Center frequency	Center wavelength	Wavelength range
L_0	235.4 THz	1273.54 nm	1272.55 to 1274.54 nm
L_1	234.6 THz	1277.89 nm	1276.89 to 1278.89 nm
L_2	233.8 THz	1282.26 nm	1281.25 to 1283.27 nm
L_3	233 THz	1286.66 nm	1285.65 to 1287.68 nm
L_4	231.4 THz	1295.56 nm	1294.53 to 1296.59 nm
L_5	230.6 THz	1300.05 nm	1299.02 to 1301.09 nm
L_6	229.8 THz	1304.58 nm	1303.54 to 1305.63 nm
L_7	229 THz	1309.14 nm	1308.09 to 1310.19 nm



Bars tested : AR/HR facet coated

- Threshold current : 20 mA at 45ºC
- Output power at 200 mA : 60 mW at 45ºC
- Laser voltage at 200 mA : less than 1.6 V
- SMSR : more than 40 dB





Conclusions

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

  ✓EBL writing for high yield production line in 3 and 4”
  ✓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

- 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)

Acknowledgement

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