Semiconductor lasers at Turin Technology Center of Avago Technologies

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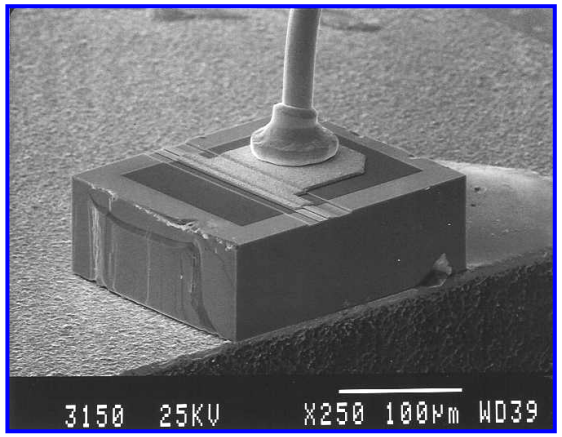
AVAGO TECHNOLOGIES

Outline

- **Company overview**

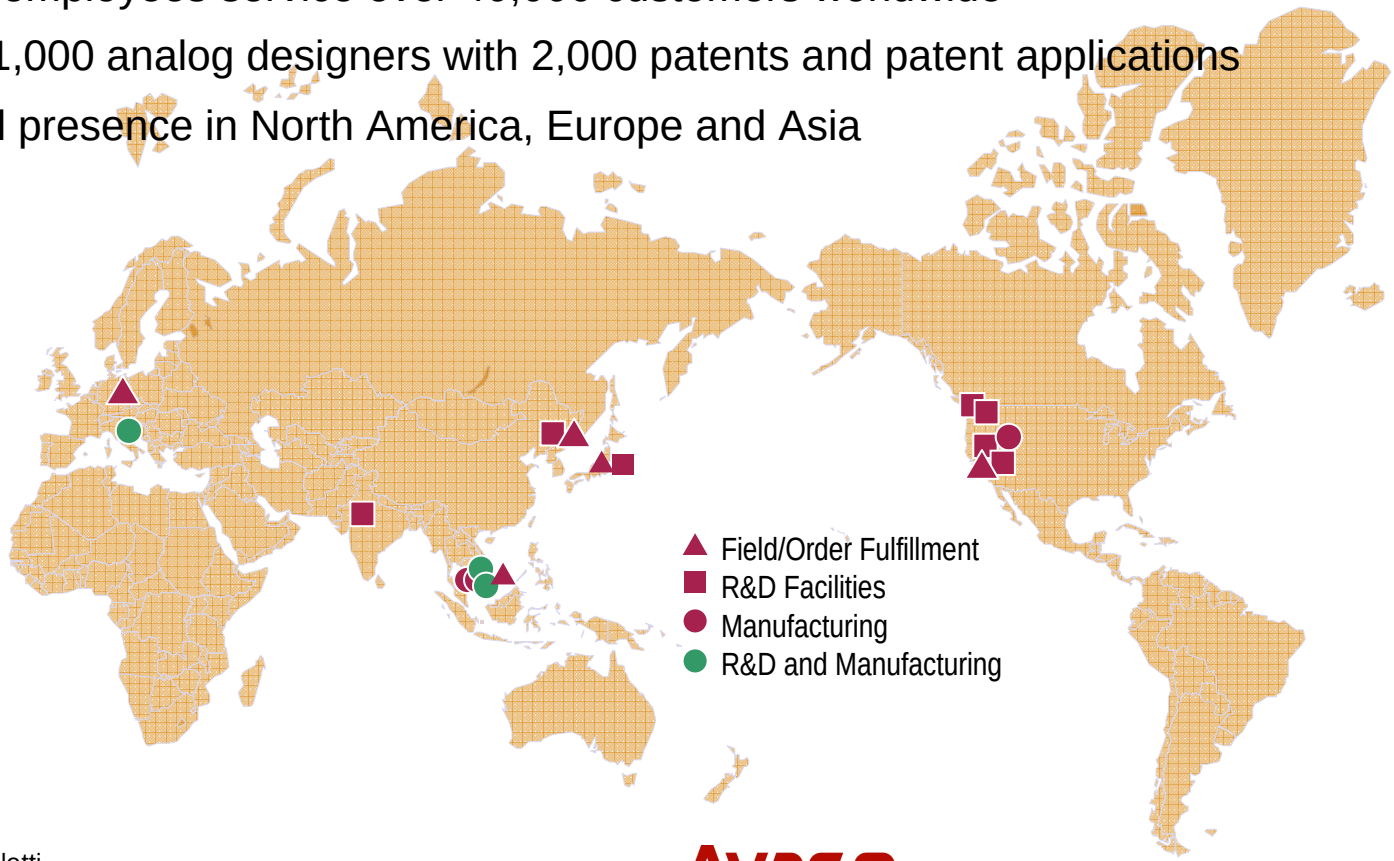
- **Laser sources for pluggable transceiver world**



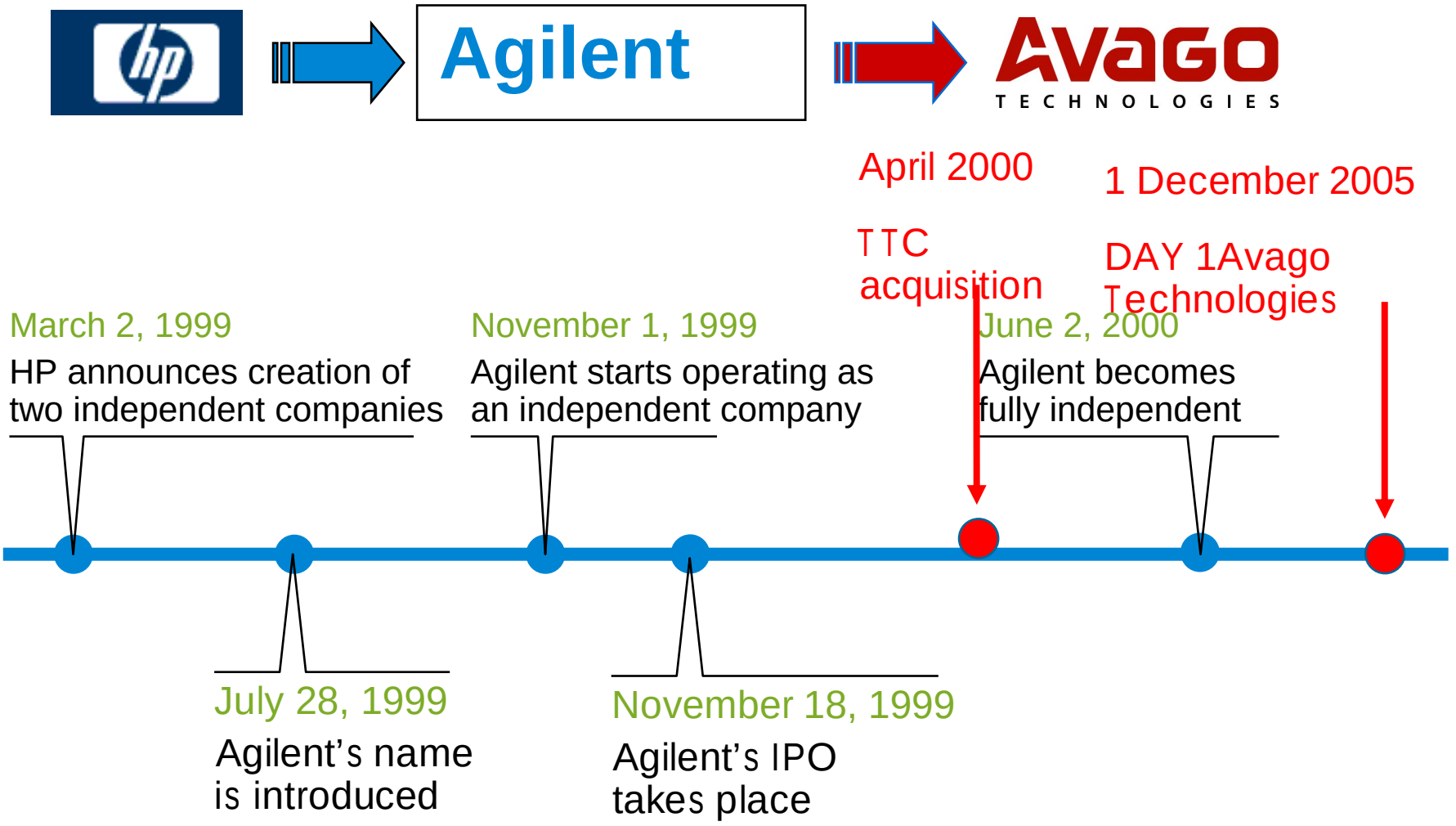
- **TTC: R&D and LVM of III-V photonic devices**

Company Overview

- Leading global manufacturer of analog, mixed signal and optoelectronics components
- Headquarters: San Jose, California and Singapore
- 2005 revenue of $1.8B
- 6,500 employees service over 40,000 customers worldwide
- Over 1,000 analog designers with 2,000 patents and patent applications
- Global presence in North America, Europe and Asia

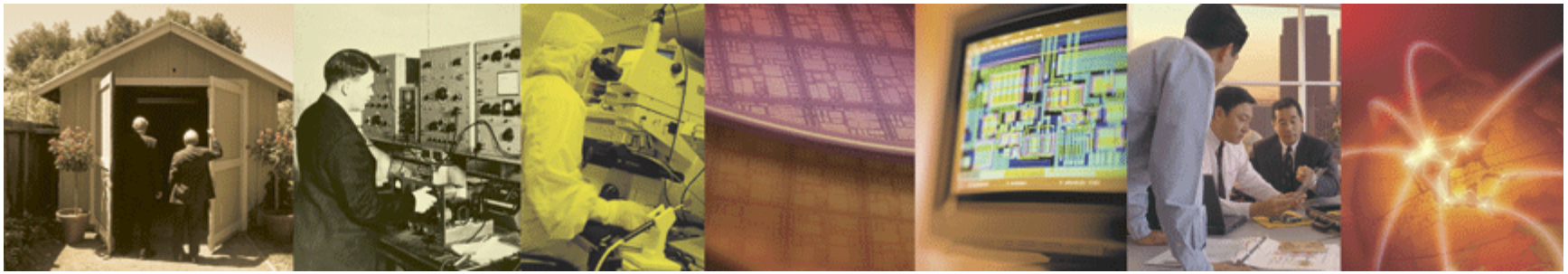


Recent story from HP to Agilent..+ TTC acquisition



Company's History

- Avago Technologies dates back to the earliest days of Hewlett-Packard, the component group in HP that developed technically differentiated components needed by HP's systems
- In 1999, the group spun off from HP as the second largest business group of Agilent Technologies – named Semiconductor Products Group (SPG)
- In 2005, was acquired by Kohlberg Kravis Roberts & Co. (KKR) and Silver Lake Partners to become the world's largest private owned semiconductor company
- Avago Technologies has a rich heritage in RF, mixed signal and optoelectronics innovation, and is the leader in many of its serviced markets



Serviced Markets

Mobile

Wireless handsets

Wireless infrastructure

Wireless networking

Digital Consumer

Printers and imaging

Laser and optical mice

Digital TVs:

-LCD TVs

-Plasma TV's

Storage, Computing & Networking

Data storage

Servers

Storage arrays

Switches and routers

Service provider networking

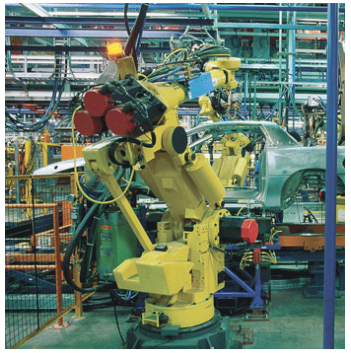
Automotive

Safety

In-car infotainment

Navigation

Lighting



Industrial

Factory automation

Motor controls

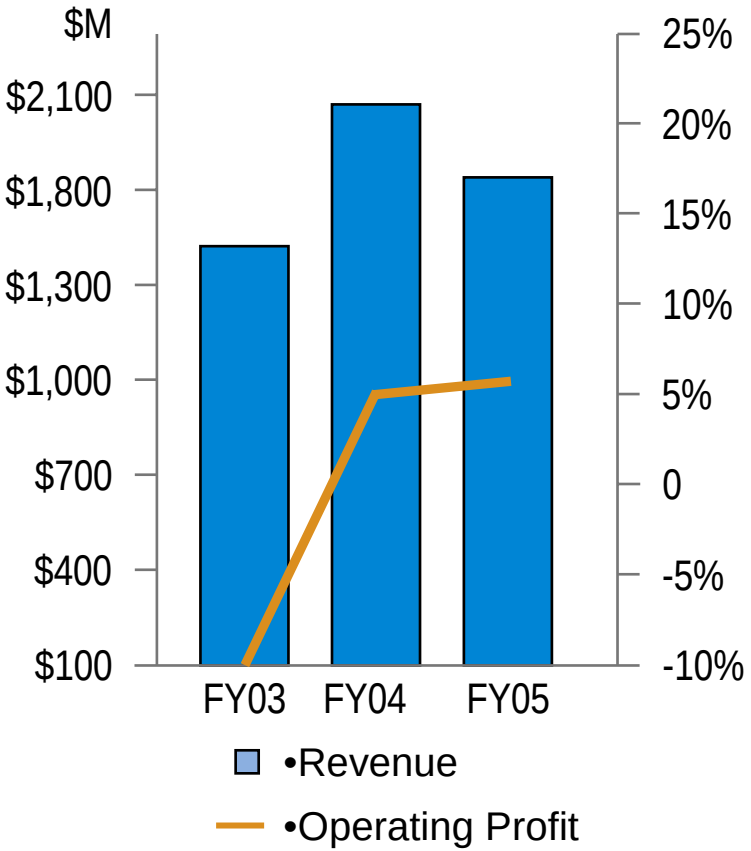
Power generation

Product Leadership in Targeted Markets

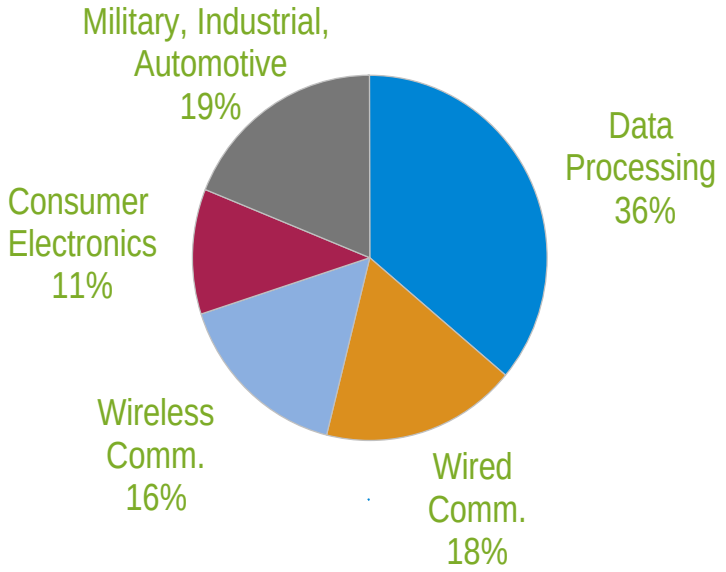
		2005 TAM	Market Position
Optoelectronics and RF	•Optical Navigation	• $0.8B	▪ #1 in optical mouse sensors
	•Isolation	• $1.0B	▪ #1 in photo-IC optocouplers
	•Motion Control	• $0.8B	▪ #1 in office automation encoders
	•Infrared	• $0.9B	▪ #1 in infrared transceivers
	•LEDs and Displays	• $3.1B	▪ #3 in LEDs
	•Wireless	• $9.8B	▪ #1 in semiconductor-based filters
Enterprise Solutions			
	•Fiber Optics	• $2.7B	▪ #2 in Fiber Optic Components
	•Imaging	• $3.3B	▪ #2 in printer ASICs
	•Enterprise ASICs	• $11.8B	▪ Leading supplier to Cisco and HP

Sources: WSTS, RHK, iSuppli and Avago Technologies' internal estimates

Solid Performance with Well-diversified End Markets



FY2005 Revenue By End-Markets



Note: The organization divested its camera module business in Q1 05

Solutions for Mobile Handsets

CMOS Image Sensors
Improved picture quality

Position Sensors
Lens focus control

Front-End Modules
Size advantage and higher integration

E-pHEMT Power Modules
Extend battery life

FBAR Filters
Size & performance advantage

Color Chip LEDs
Improved aesthetics

LED Flash
Higher quality pictures

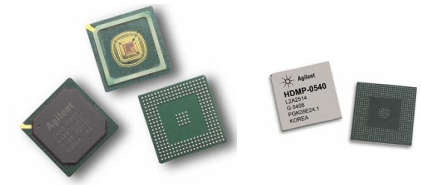
IrDA + Remote Control, IRFM
Size advantage plus increased functionality

Proximity Sensor
Automates speaker phone

Ambient Light Photo Sensors
Extend battery life

Navigation
Improved user interface

Solutions for Storage, Computing and Networking



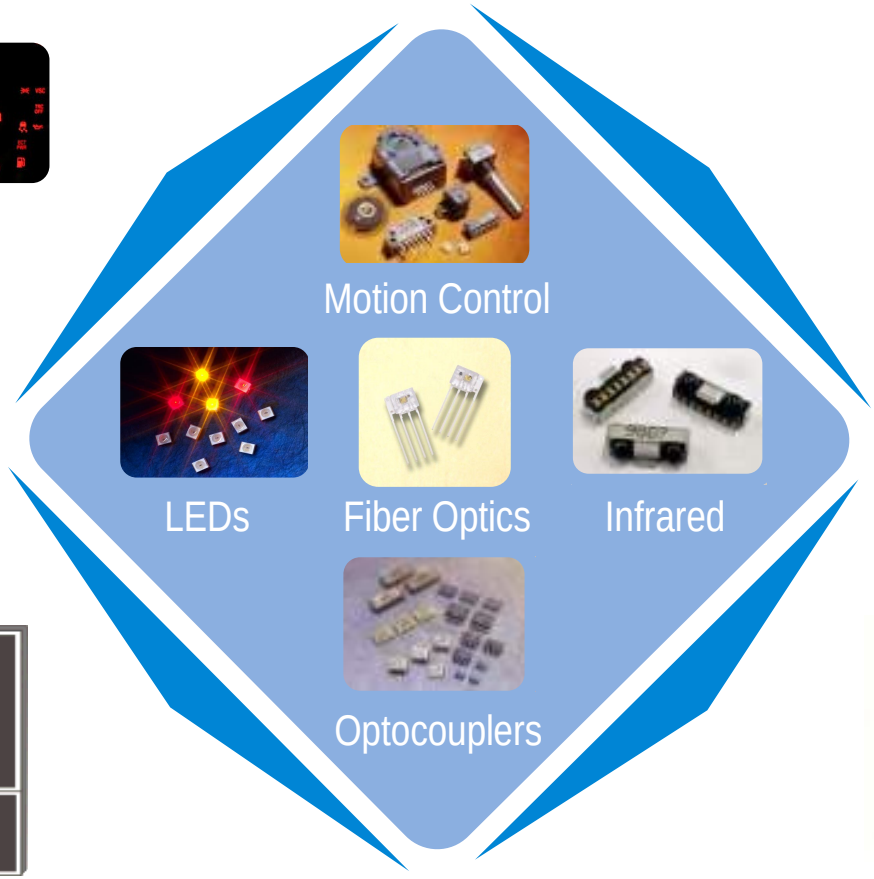
Networking ASICs

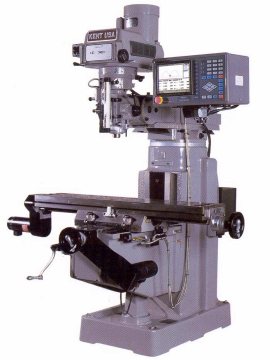
Printer ASICs, SOCs, Motion Control, Infrared, Optical Navigation

Fiber Optics

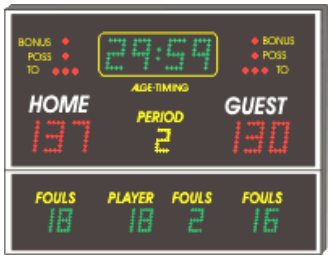
Solutions for Consumer, Industrial and Automotive

Automotive





Industrial



Electronic Signs and Signals

Consumer Appliances

Leading in Technology Innovation

- 40-years heritage of innovation and technology leadership
- Over 2,000 patent and patent applications
- Over 1,000 analog design engineers

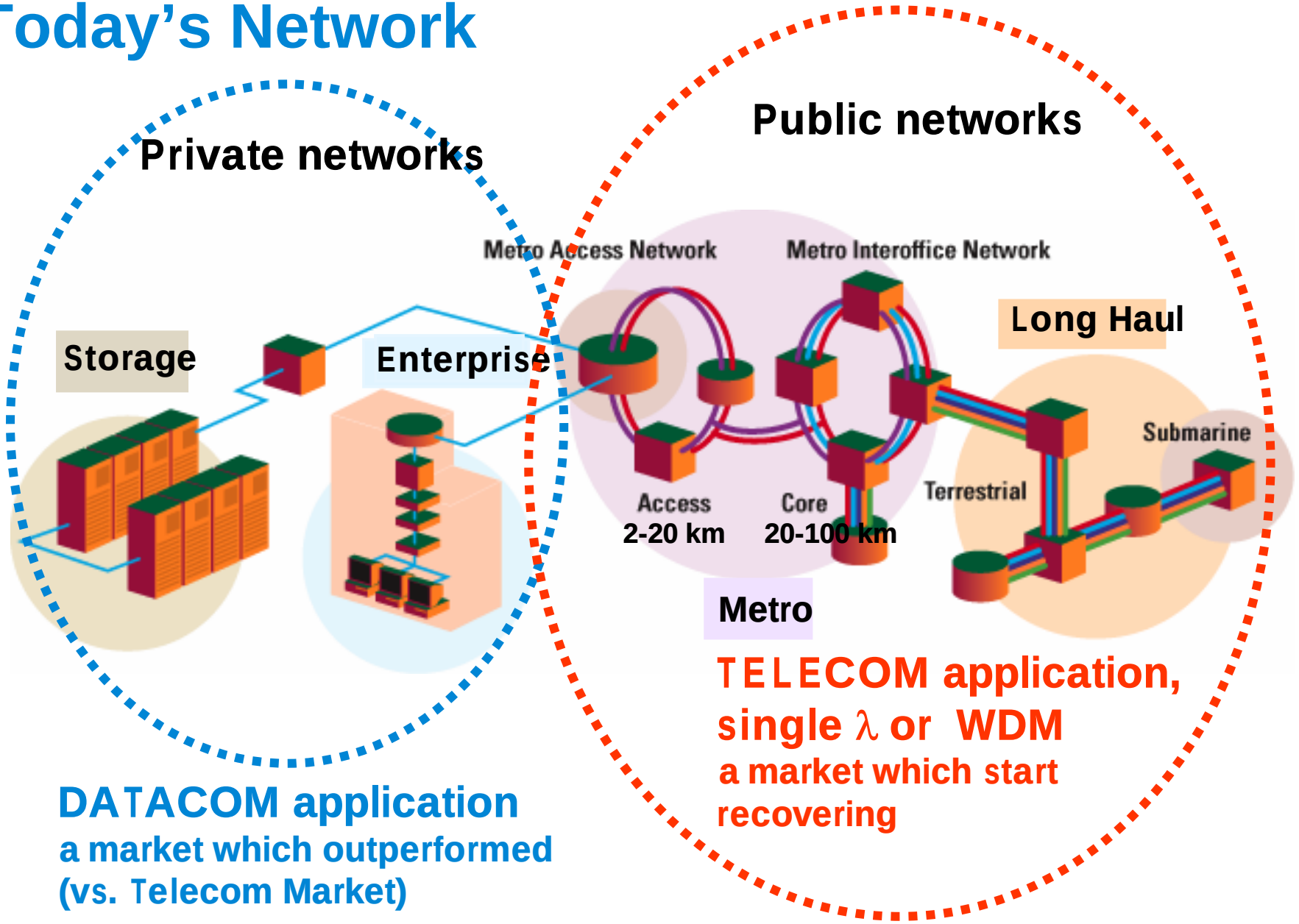
Laser Sources for Plug and Play Transceivers for Datacom and Telecom Applications

AVAGO TECHNOLOGIES

Outline

- Introduction
  - Market downturn and recovering
  - Pluggable solutions
- 10 Gb platforms and segmentation within the network
- 10 Gb devices and technologies for pluggable transceivers
  - Key design elements for high performances laser sources
  - Direct modulation of uncooled laser sources
  - Advanced laser sources for pluggable transceivers

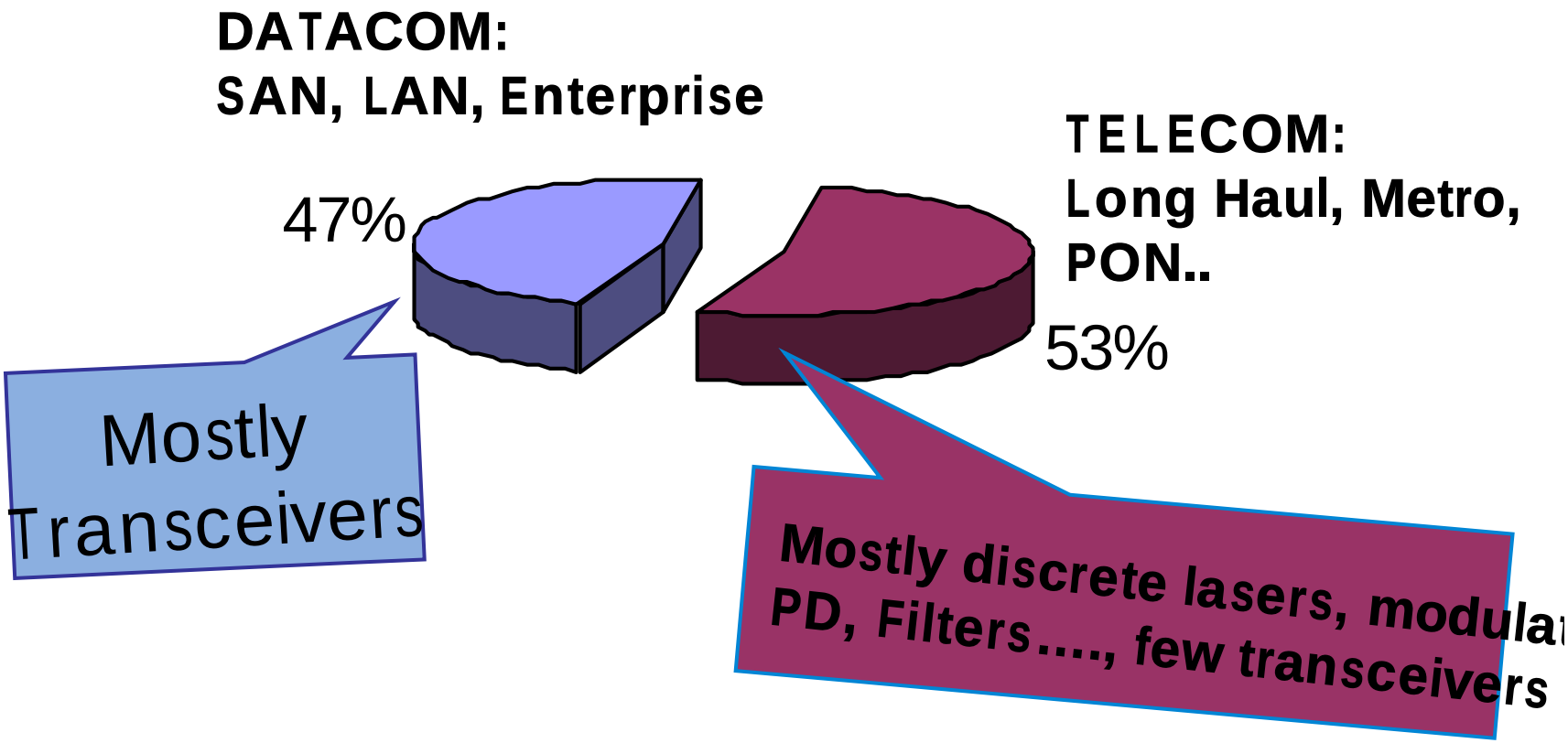
Today's Network



DATACOM application
a market which outperformed (vs. Telecom Market)

TELECOM application, single λ or WDM
a market which start recovering

Size of the optical component market for datacom and telecom

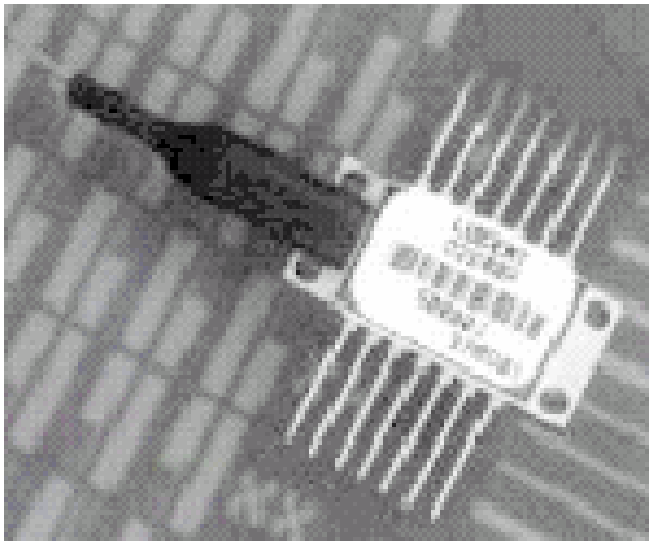


DATACOM and TELECOM trend: from discrete components to subsystems

Market is driving pluggable module solution

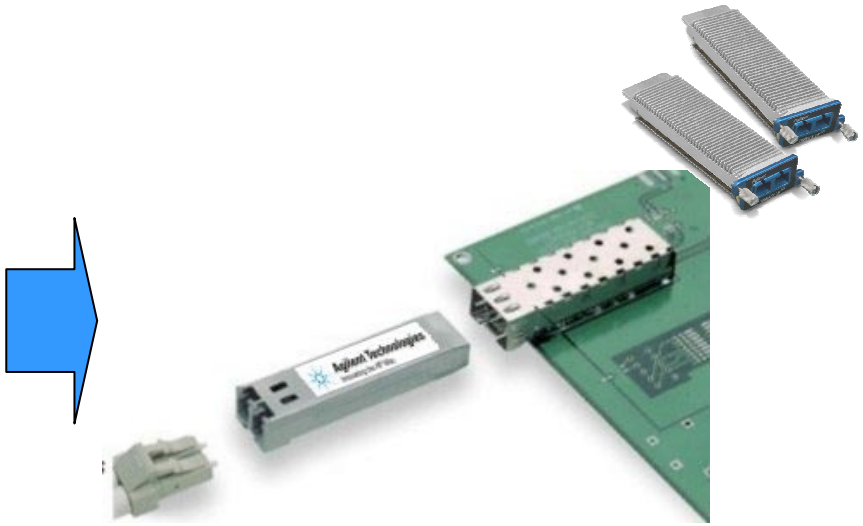
Traditional components

- One bulky, pigtailed, module per equipment circuit card
- Hand soldered assembly



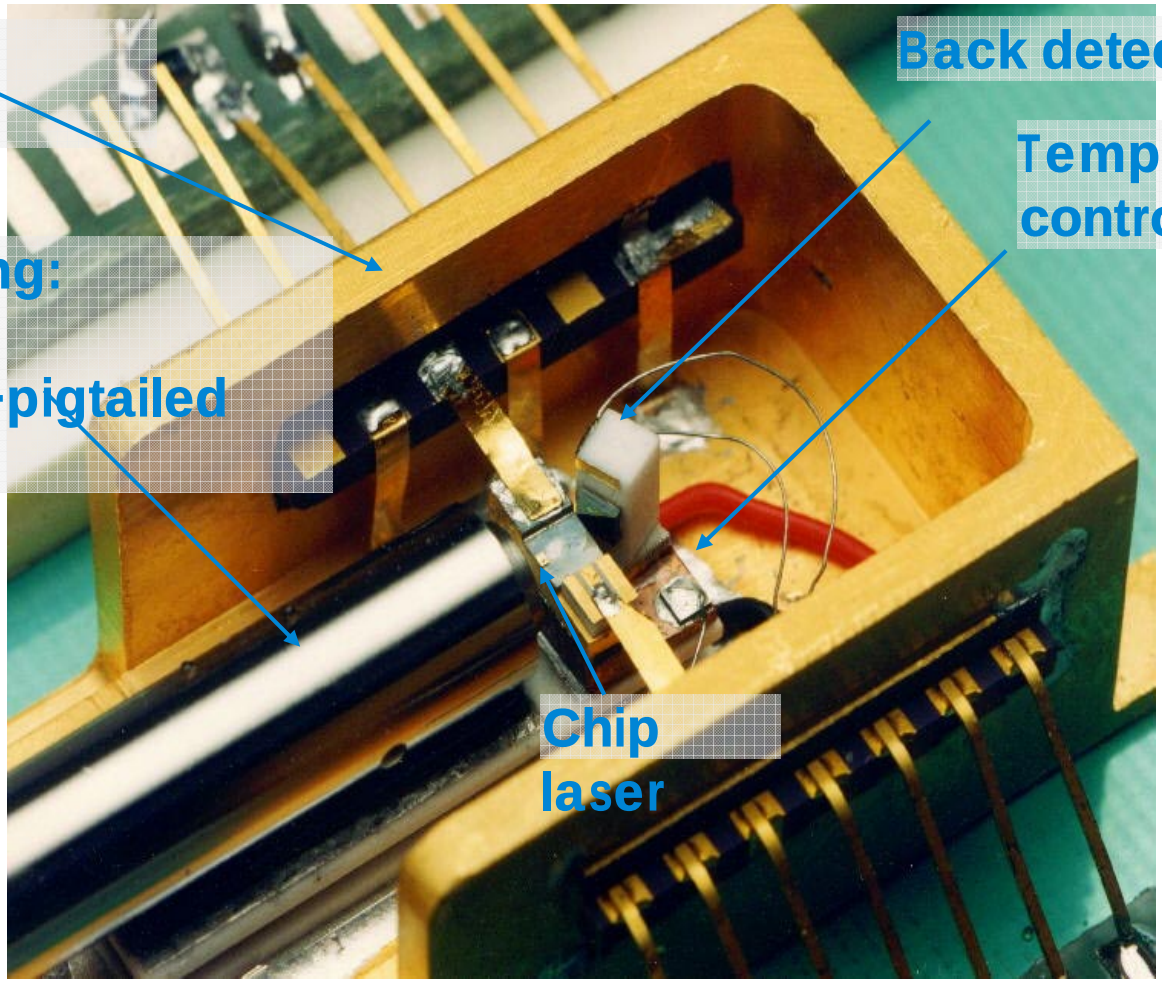
Pluggable transceiver approach

- Multiple compact modules per circuit card
- Pluggability: pay as you go



DATACOM and TELECOM trend: from discrete components to subsystems

Butterfly Laser Module



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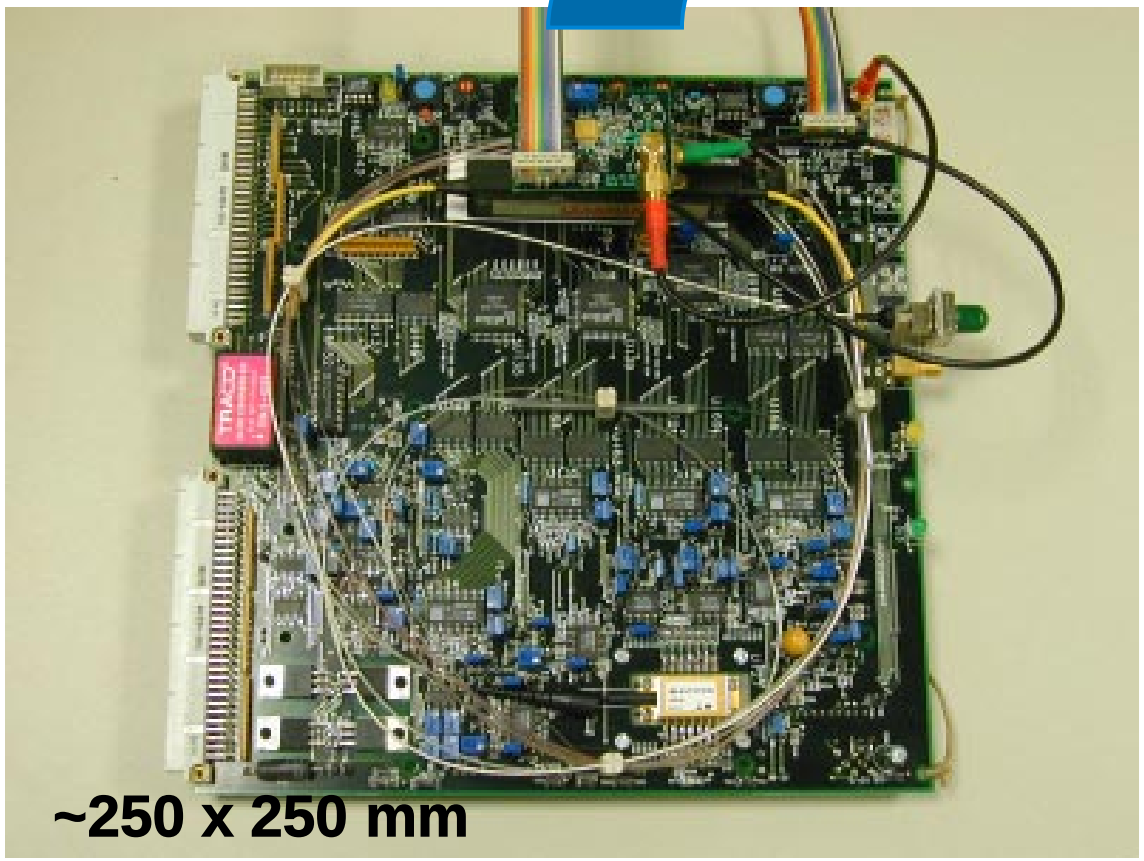


~103 x 51 mr

LAMBDAPACK

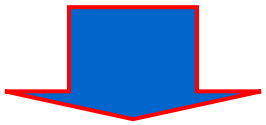
-2.5 DWDM Pluggable Transceiver

- Integrated heatsink

- Up to 8 modules side by side

Cost reduction route for optical components

PLUGGABILITY



LASER SOURCES
working @
HIGH OPERATING TEMPERATURE
LOW POWER CONSUMPTION
but
NO COMPROMISES FOR PERFORMANCES

Stable and reliable technological processes
High Yield, high repeatability run-to-run

a technology ready for high volume/low cost production

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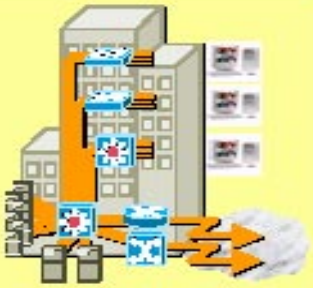
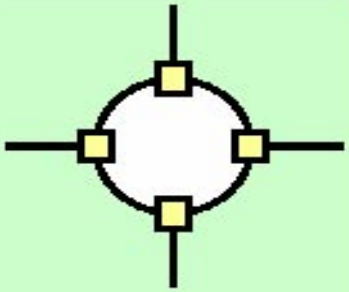
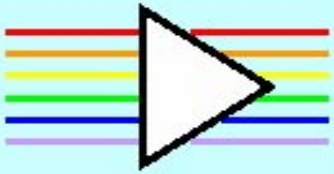
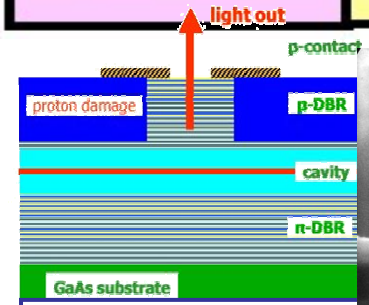
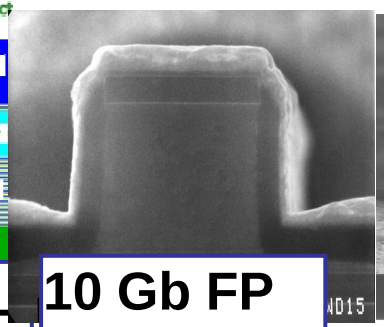
  - **Direct modulation of uncooled laser sources**
  - **Advanced laser access for pluggable**

10G Segmentation Within the Network

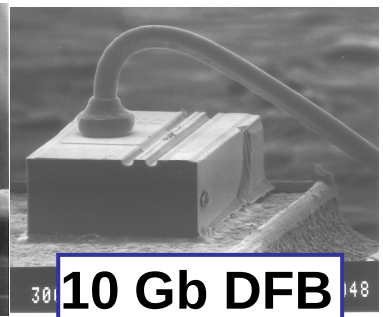
Equipment room ~50m	Enterprise ~300m	Access 2-15km	Metro 15-80km	Long Haul 10-1000's km
	 IP for LANs Fiber Channel for SANs	 ADSL  POTs  ATM  FRAME RELAY IP SONET		
850nm VCSEL Copper	Serial FP +EDC Parallel LX4	1310nm DFB	1550nm EA DFB	cooled DWDM Tech
10GBASE-SR Proprietary	10GBASE-LRM 10GBASE-LX4	10GBASE-LR SONET SR-1 SONET IR-1	10GBASE-ER SONET IR-2/LR-2 DWDM	Proprietary
Xenpak, X2, XFP	Xenpak, X2, XFP	Xenpak, X2, XFP 300 PIN	Xenpak, X2, XFP 300 PIN	300 PIN Discretes



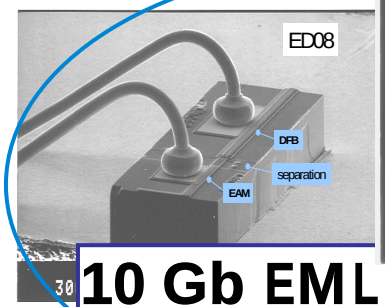
10 Gb VCSEL @ 850nm



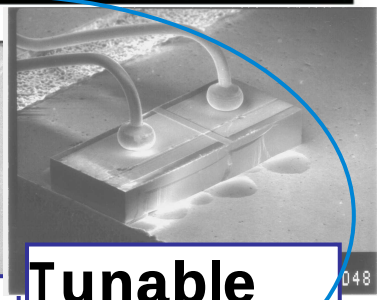
10 Gb FP @ 1300 nm



10 Gb DFB @ 1300 nm

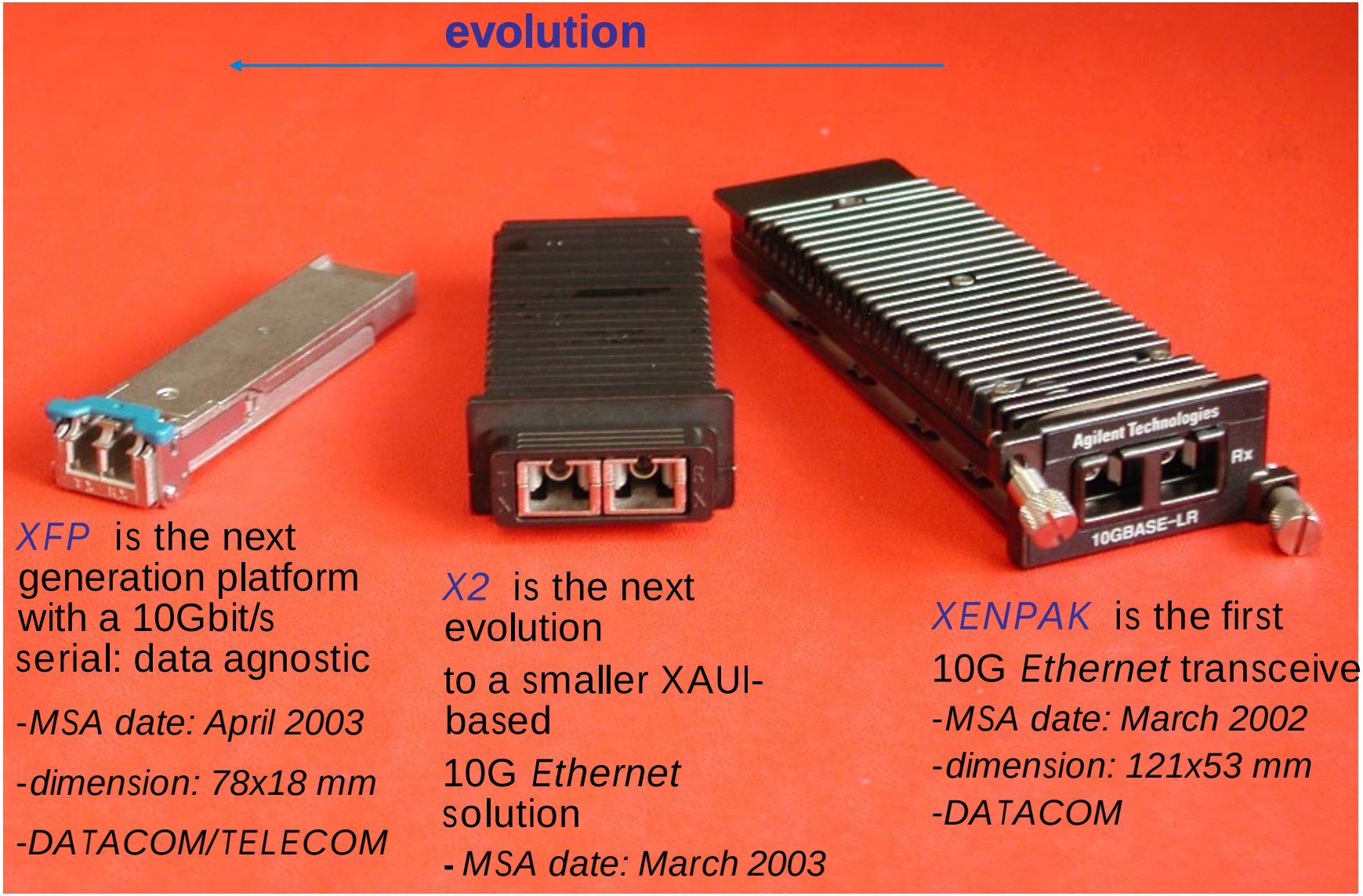


10 Gb EML @ 1550 nm



Tunable @ 1550 nm

10Gb platforms



XFP is the next generation platform with a 10Gbit/s serial: data agnostic

-MSA date: April 2003

-dimension: 78x18 mm

-DATACOM/TELECOM

X2 is the next evolution

to a smaller XAUI-based

10G *Ethernet* solution

- MSA date: March 2003

-dimension: 68x53 mm

-DATACOM

XENPAK is the first

10G *Ethernet* transceiver

-MSA date: March 2002

-dimension: 121x53 mm

-DATACOM

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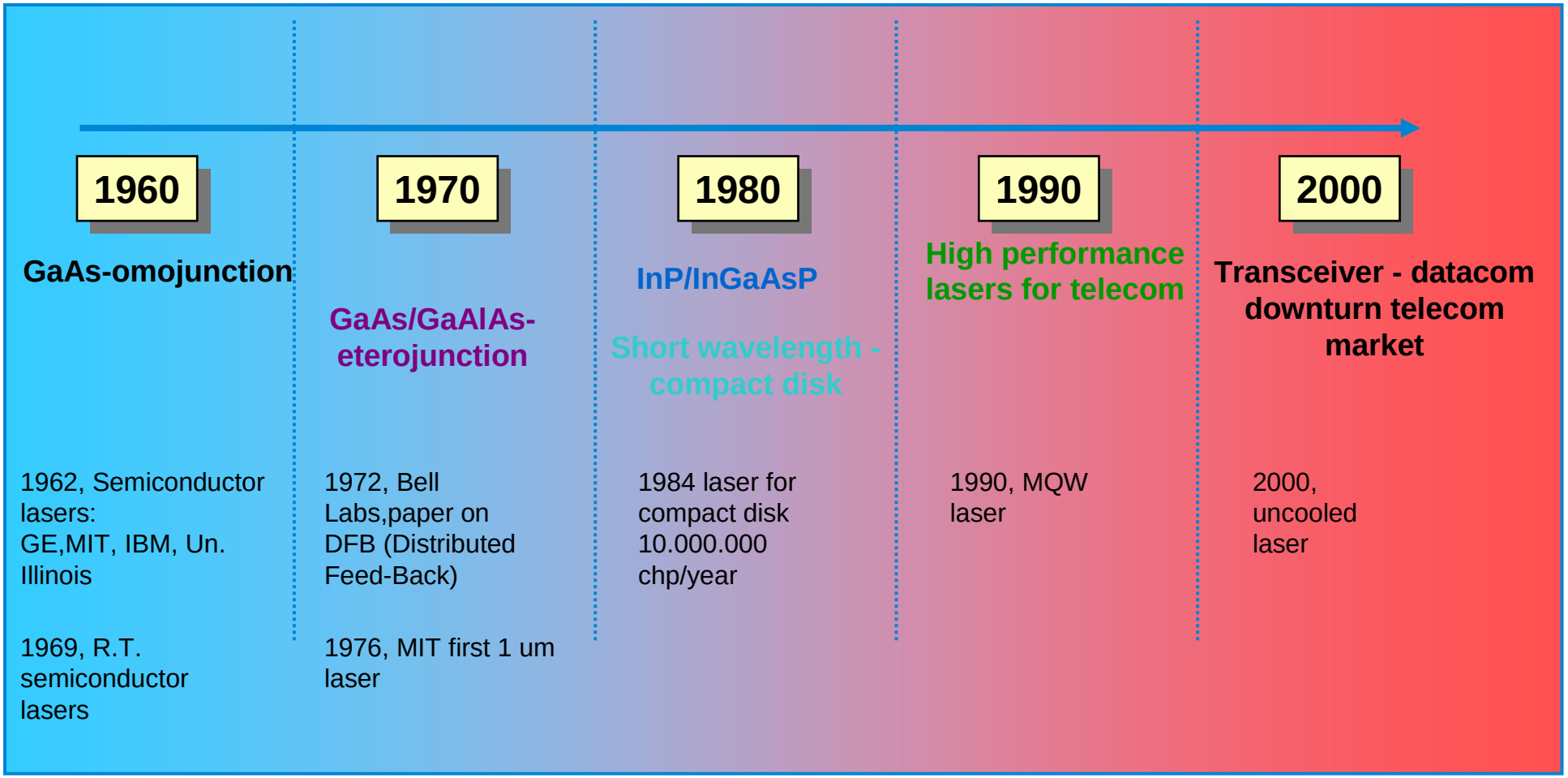
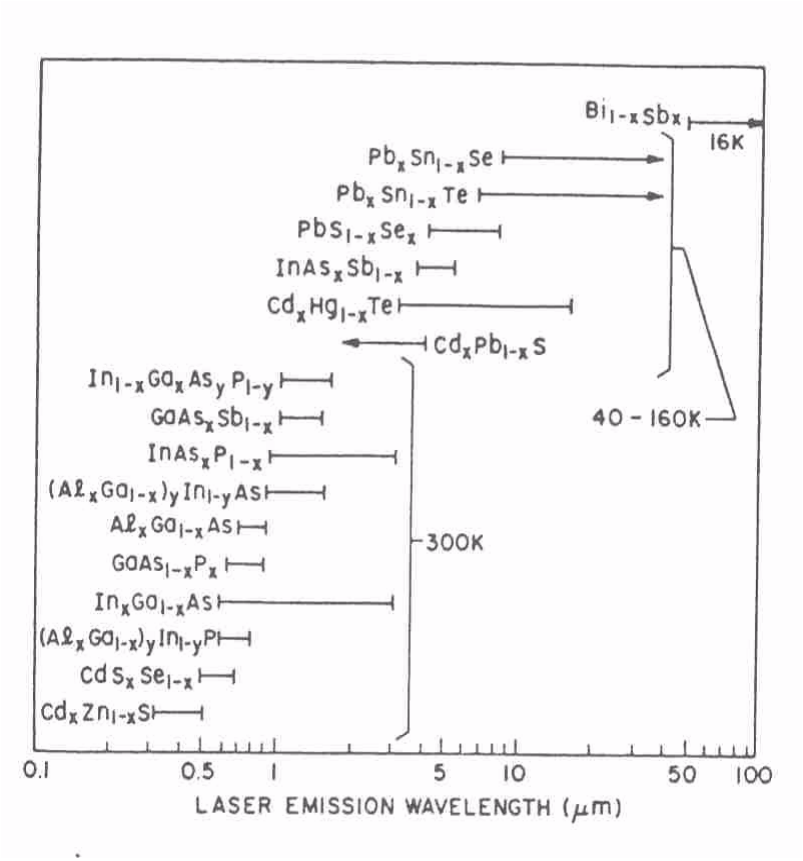
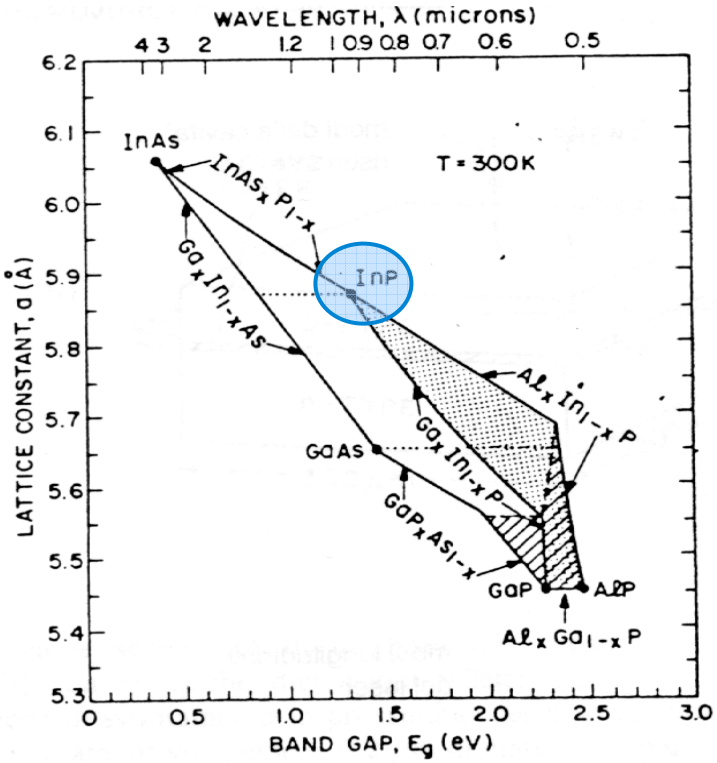
Semiconductor Lasers



Material systems for semiconductor lasers





AVAGO TECHNOLOGIES

Semiconductor Laser is:

Active material → **Semiconductor layer with optical gain**

Carrier population generation → ***Electrical injection***

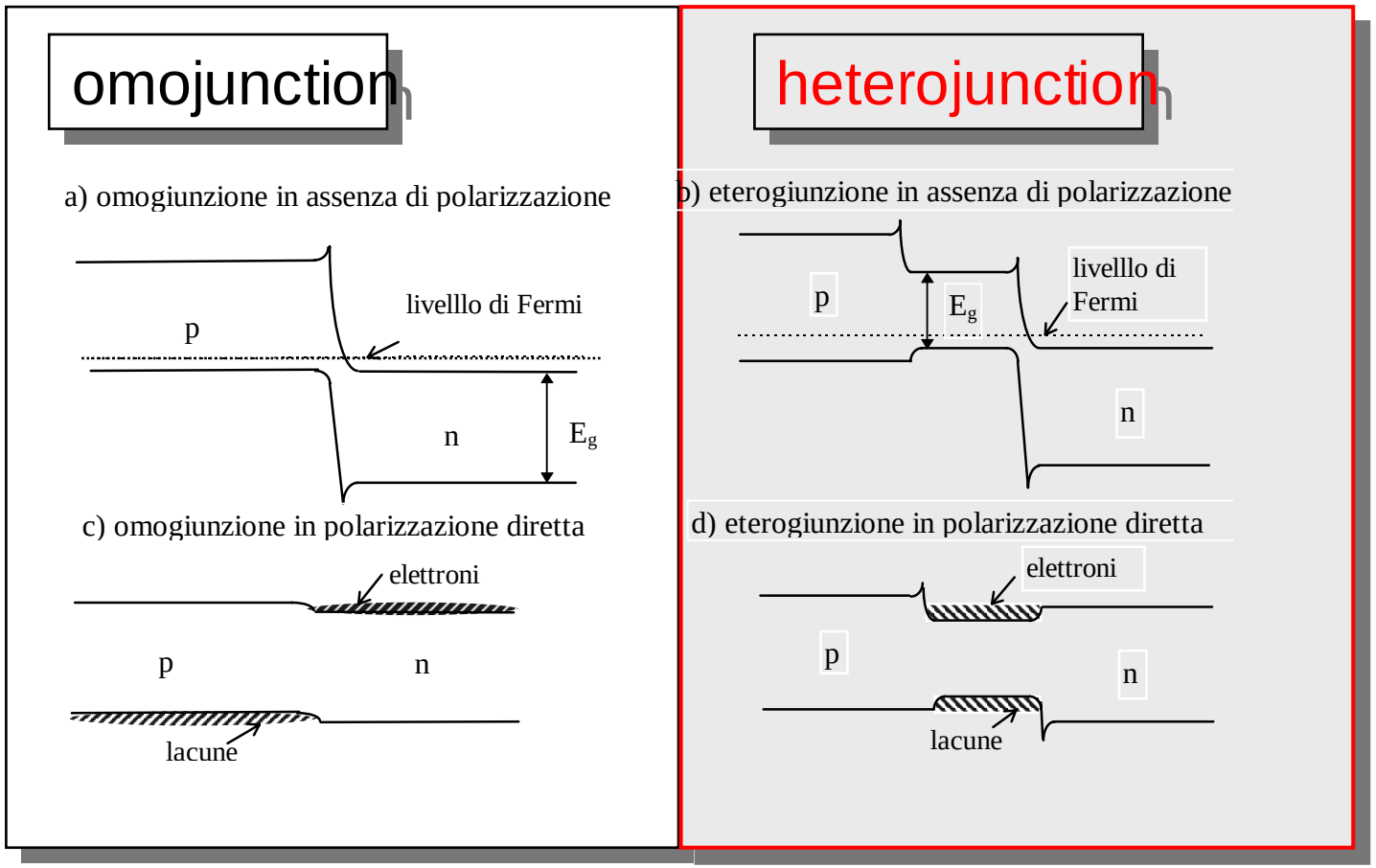
Cavity → ***Crystal Mirrors*** **(FP)**
or ***Grating*** **(DFB – DBR)**

Confinements:

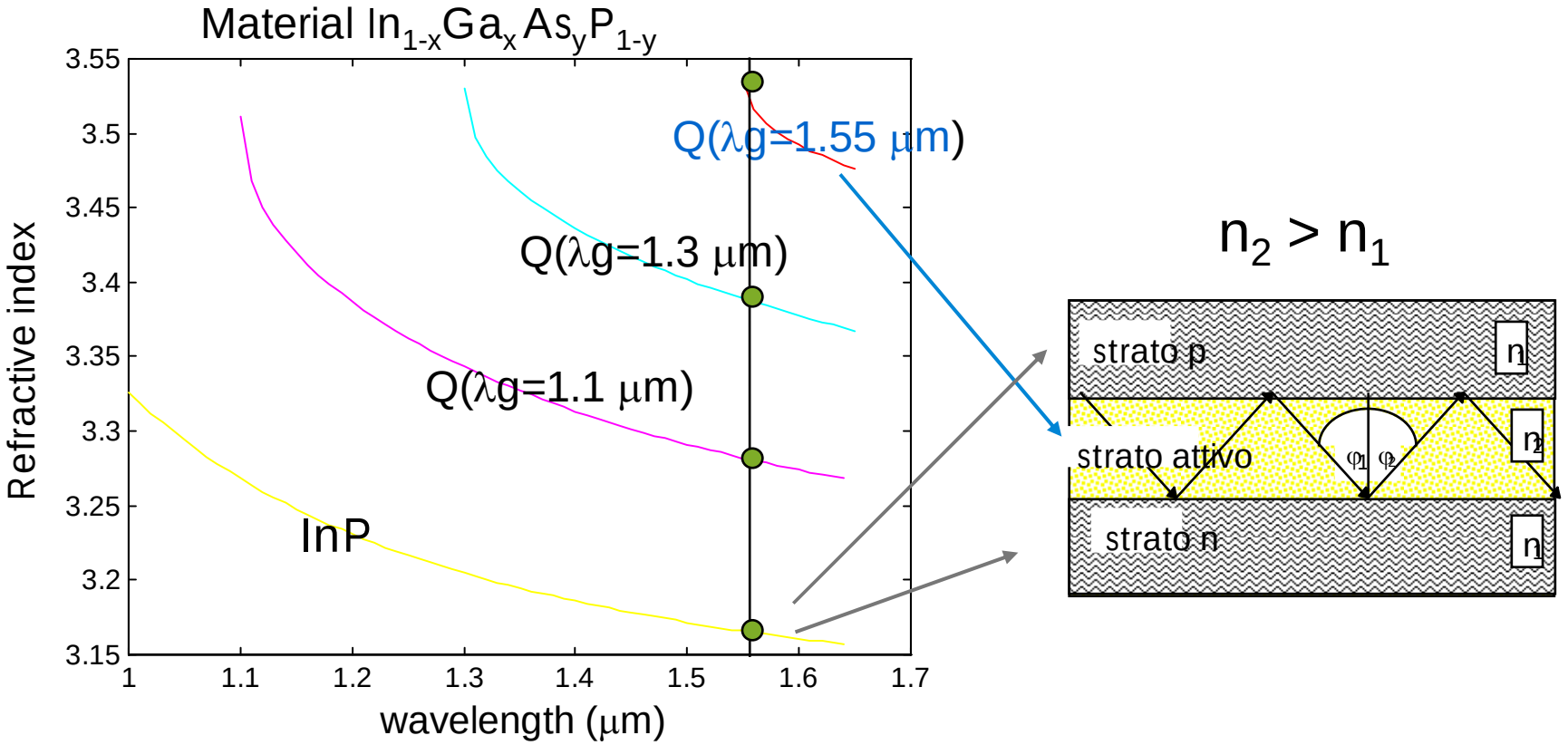
electrical → **Heterojunction**

optical → **Optical waveguide**

Electrical confinement

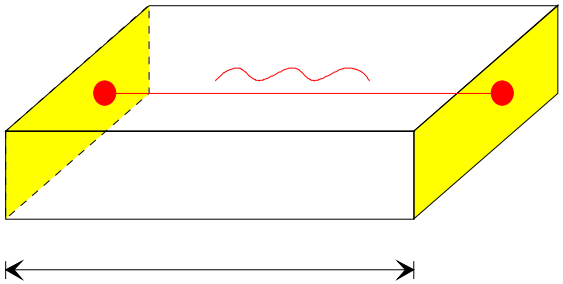


Optical confinement



AVAGO TECHNOLOGIES

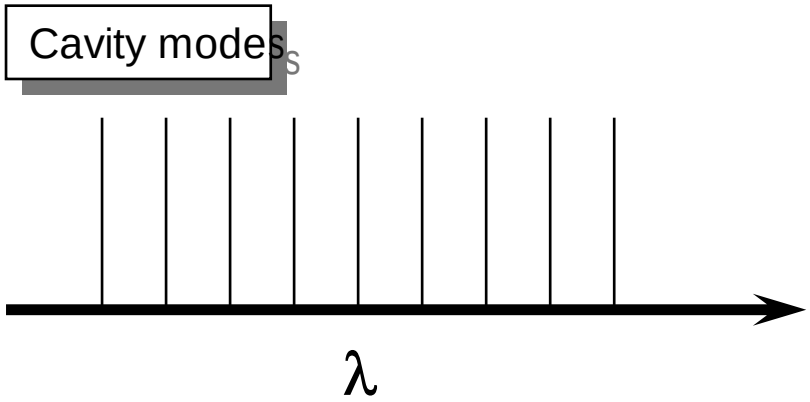
Fabry-Perot resonator

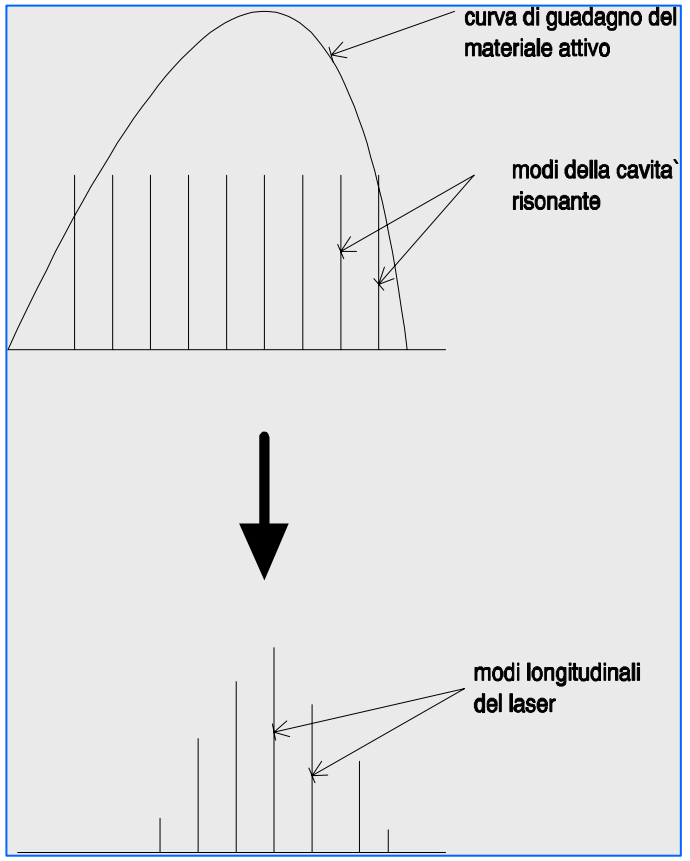


L

$$L = N\frac{\lambda}{2n}$$

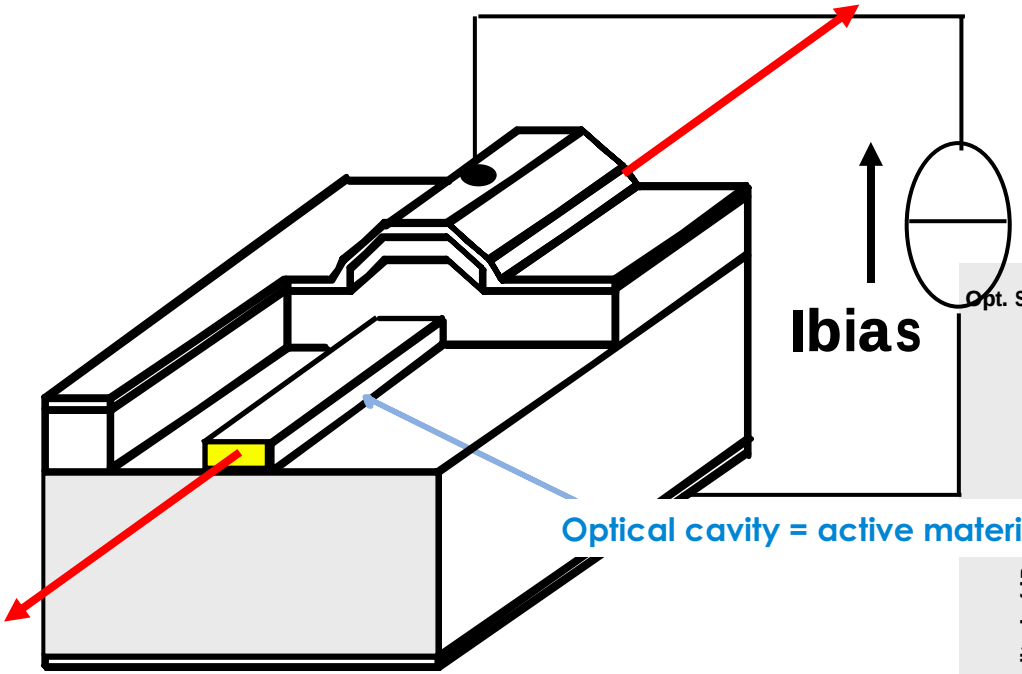
N= integer
n=refractive index
λ = wavelength

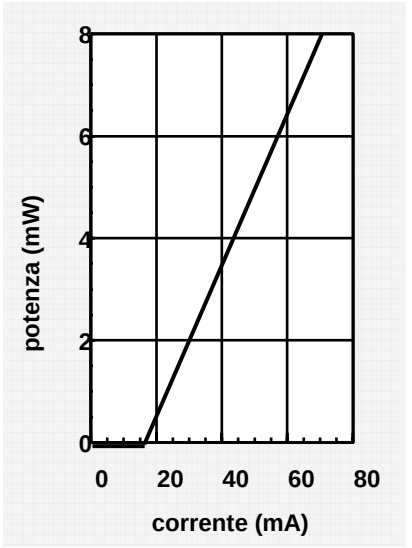


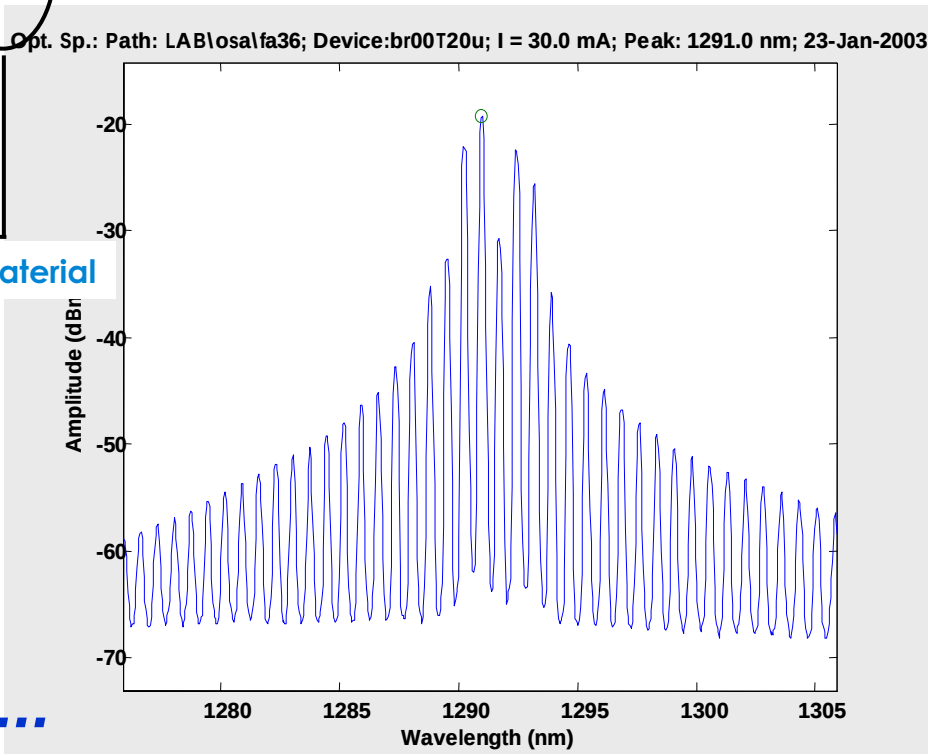


AVAGO TECHNOLOGIES

Fabry-Perot Laser





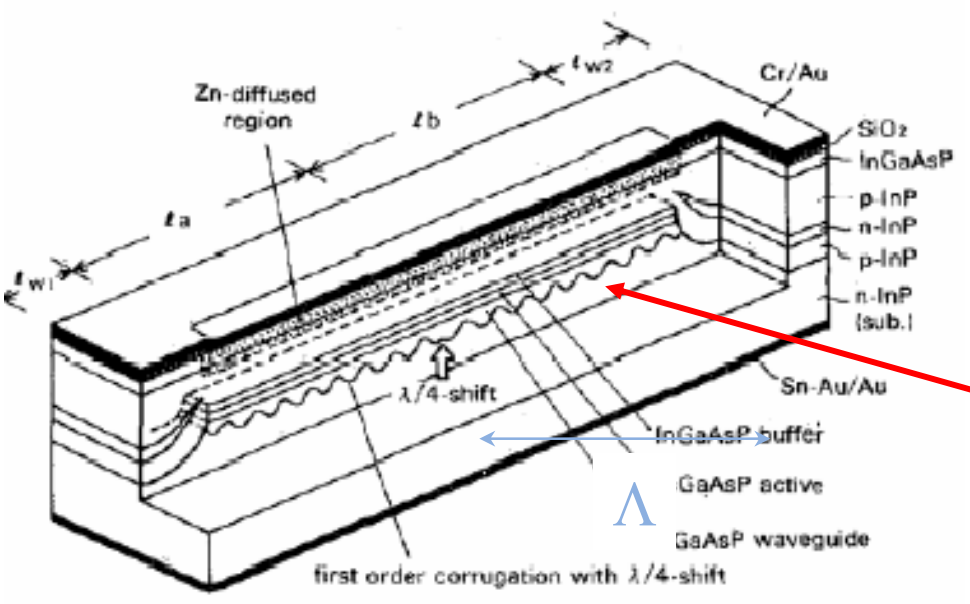


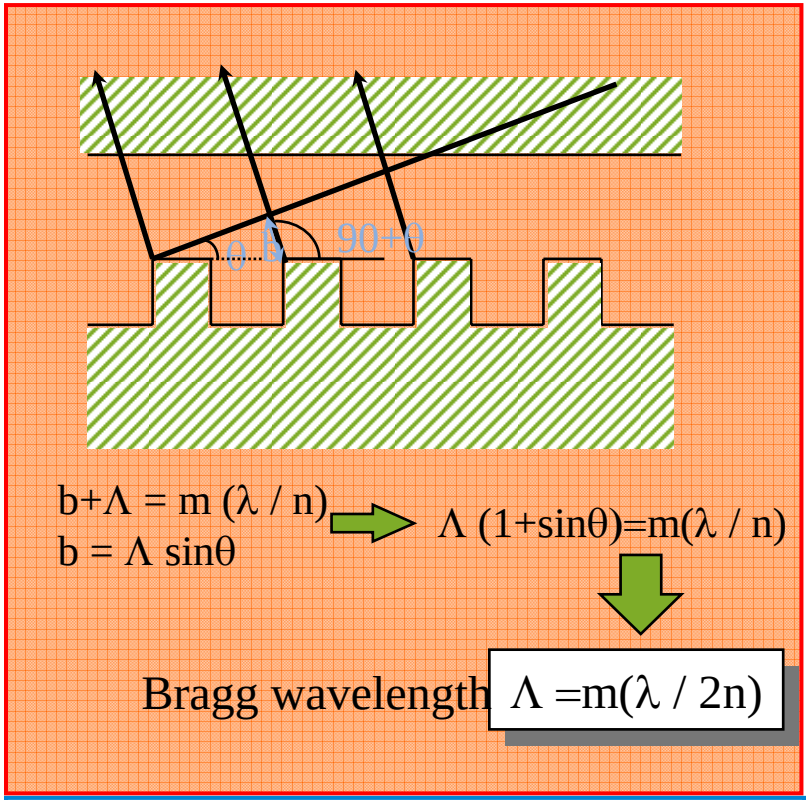
Multimodal emission

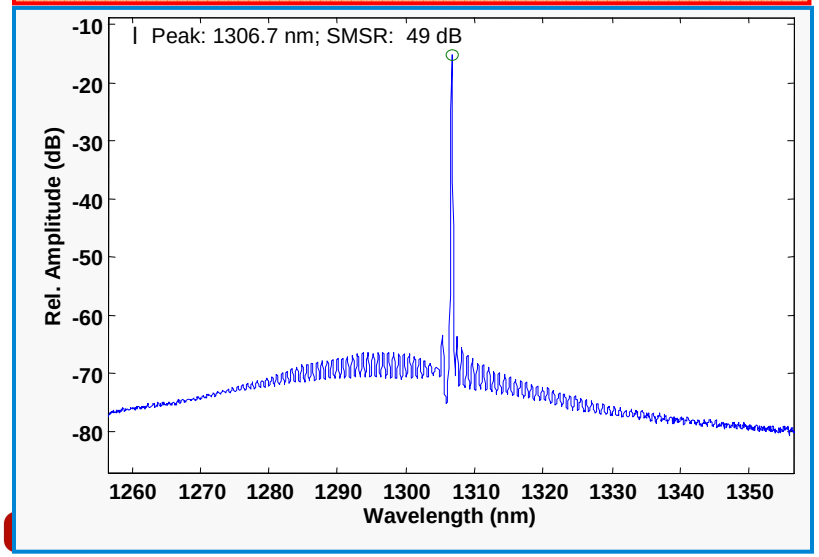
Short haul – *not necessarily true…*

DFB Laser

Grating







- Phase shifted grating allows to get 100% single mode yield, for ideal AR/AR coatings on <u>both facets</u>

Roberto Paoletti
24 November, 2006

Ava TECHNOLOGIES

Key design elements: ridge structure

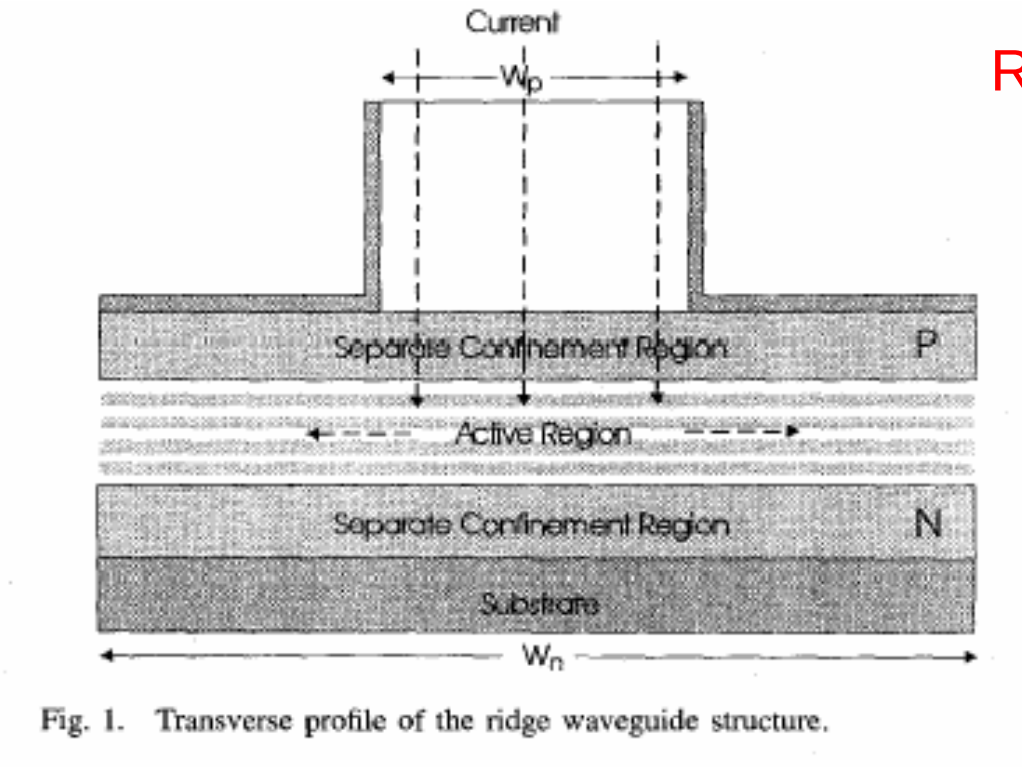


Fig. 1. Transverse profile of the ridge waveguide structure.

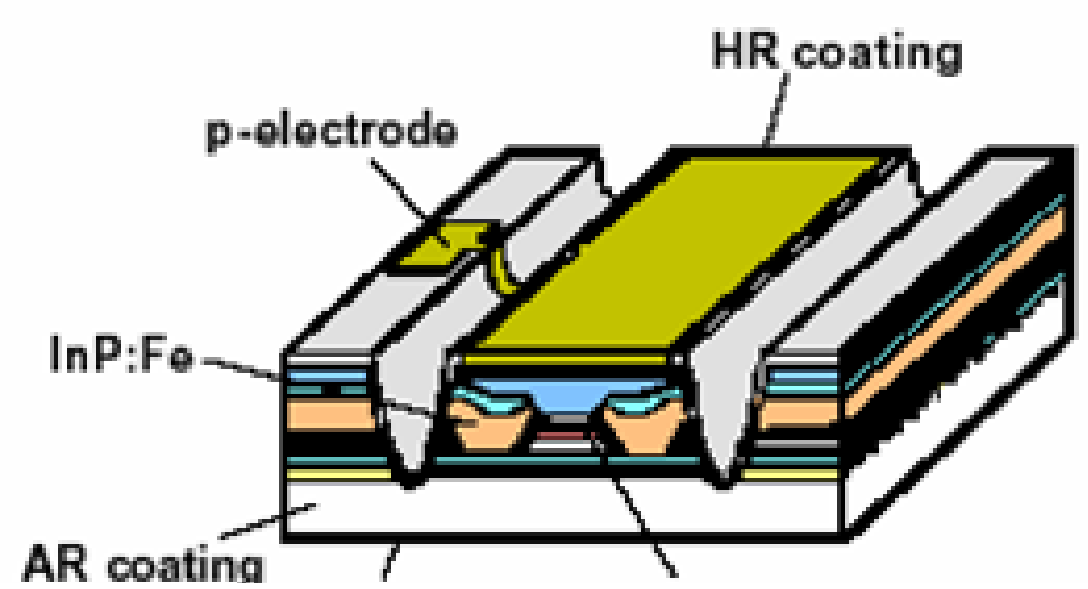
Ridge structure

- No lateral blocking layers
- Very simple technological process (one-step epi-growth)
- Suitable for Al-based lasers and low cost devices

…but….

- Low optical confinement, high threshold
- Trade-off between carriers confinement and mono modal behavior
- Difficult control of series resistance

Key design element: *PBH* buried structure



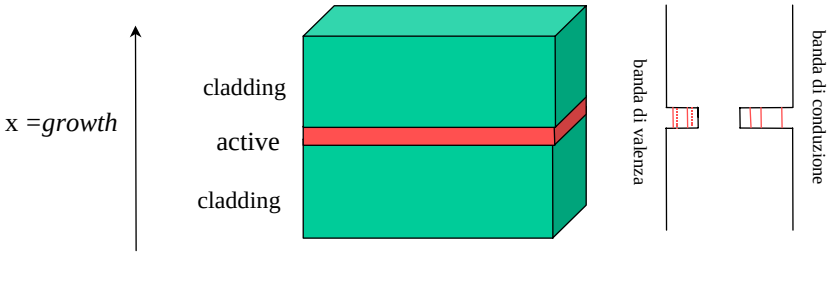
Buried structure

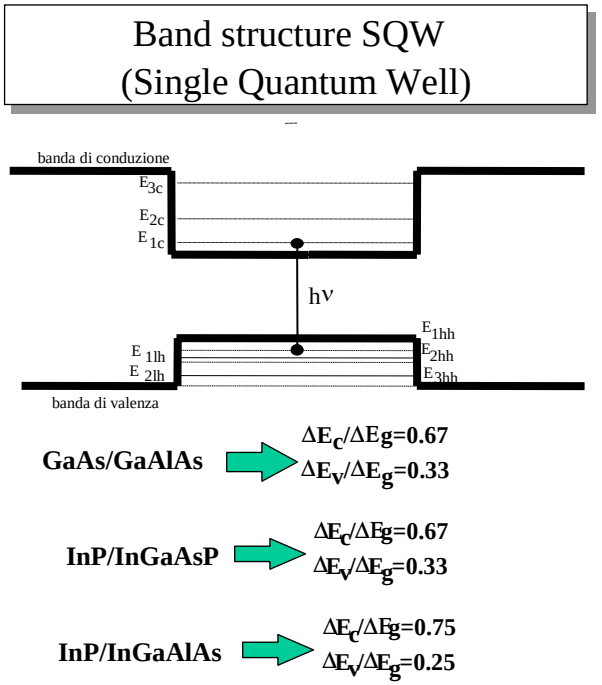
- Good optical confinement
- High carriers confinement with possibility to choose different solutions (multi-junction or semi-insulating layers)
- Low threshold devices

…but….

- Multi step epi-growth, multi step technological process
- Not suitable for low cost devices
- Not mature technology for Al-based lasers

Key design element: MQW active material





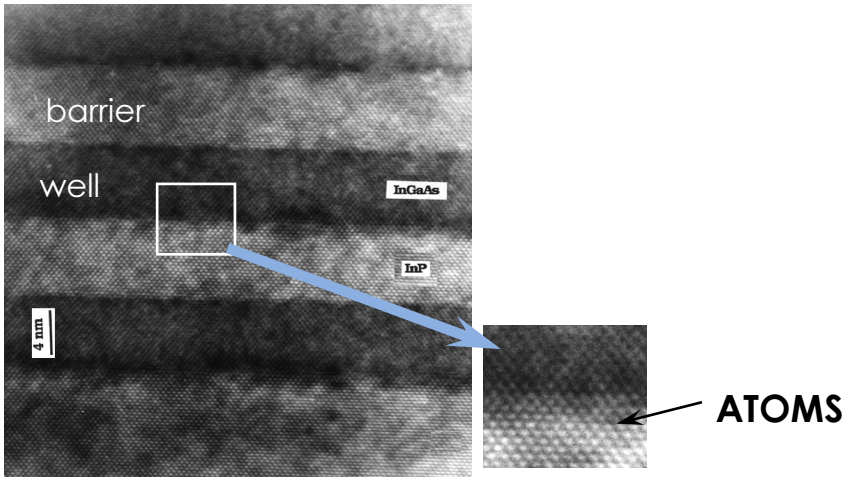
Bulk laser: Active layer $L_x = 0.1 - 0.3\ \mu m$

QW (Quantum Well) laser :
Active layer $L_x < 0.01\ \mu m$

GaAs/GaAlAs → $\Delta E_c/\Delta Eg=0.67$, $\Delta E_v/\Delta E_g=0.33$

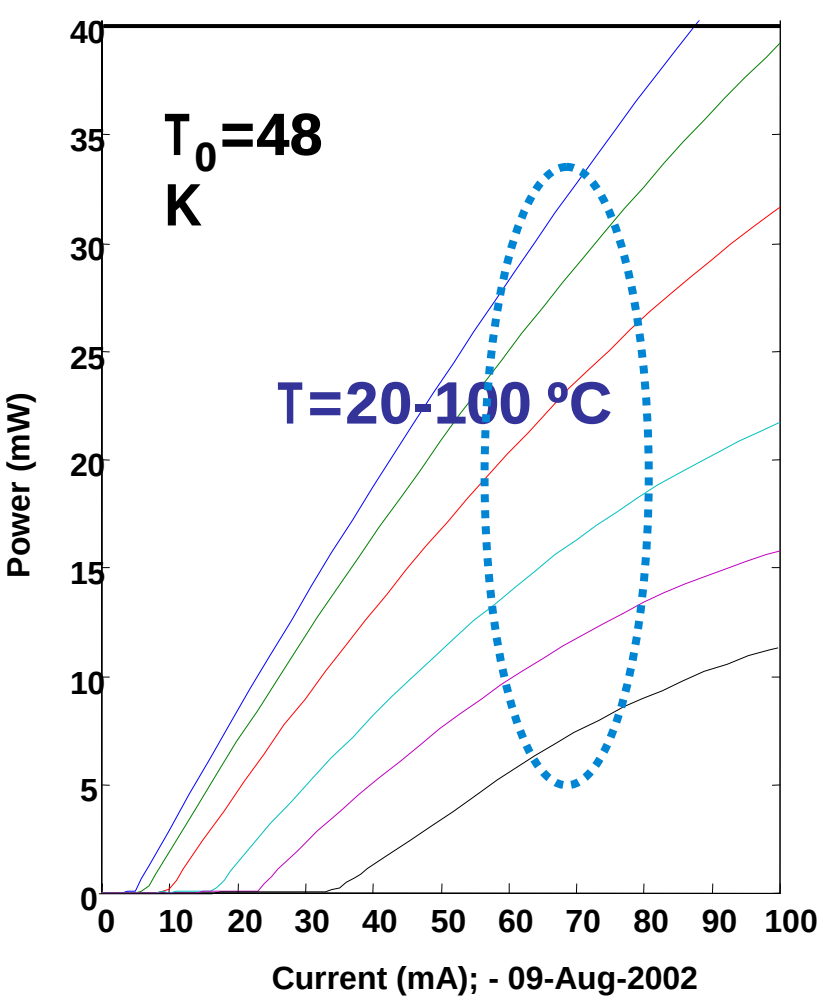
InP/InGaAsP → $\Delta E_c/\Delta Eg=0.67$, $\Delta E_v/\Delta E_g=0.33$

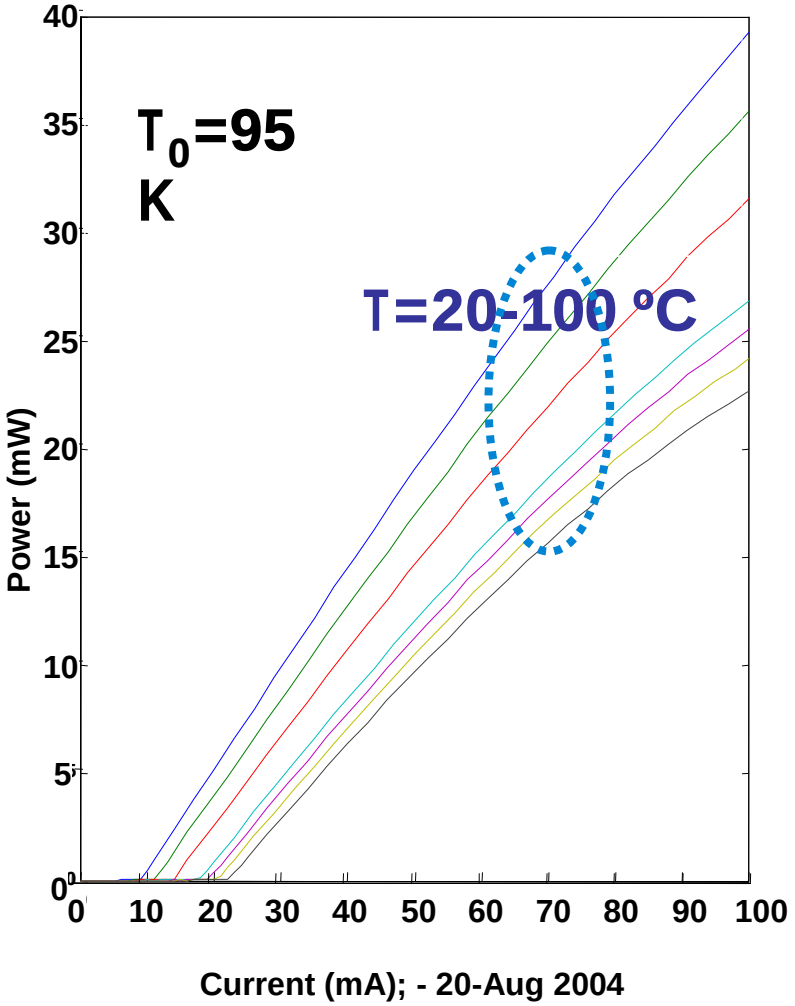
InP/InGaAlAs → $\Delta E_c/\Delta Eg=0.75$, $\Delta E_v/\Delta E_g=0.25$



MQW key features:
- ***gain***
- ***speed***
- ***temperature***

MQW active material optimization

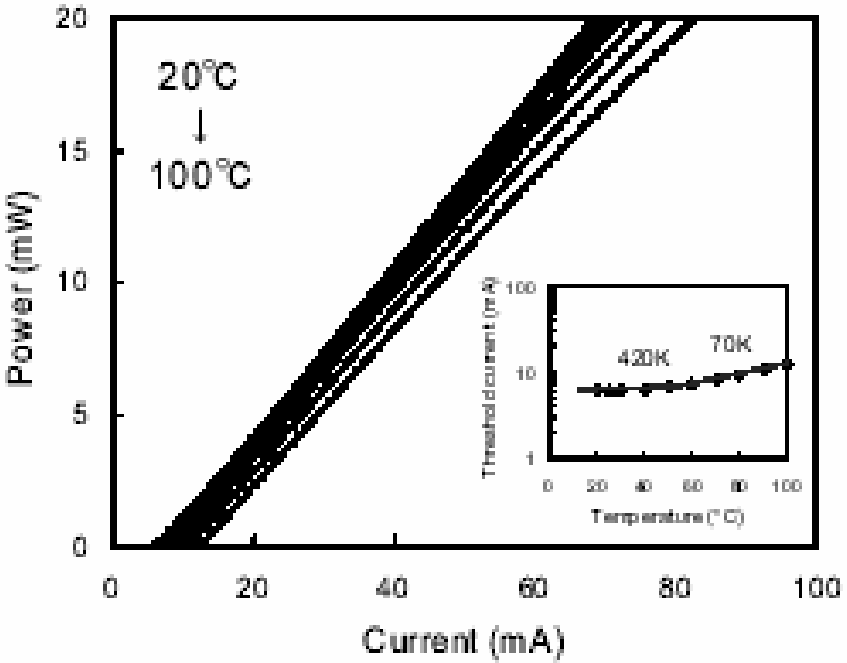




InGaAsP-based MQW

InGaAsAl-based MQW

TREND: is QD active layer the next technological step?



InAs QD/GaAs
10 Gb DM laser (up to 70 C)
T0= 420 K T=20-50 C
T0=70 K T=50-100 C
By Fujitzu and Univ Tokio
PD presented at ECOC 2004
Stockholm, Sweden, September 04

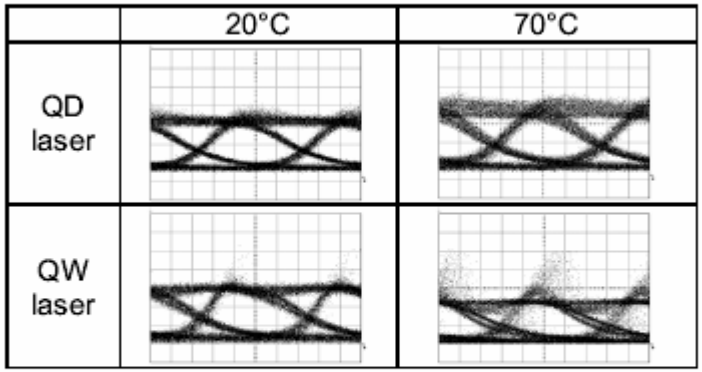


Fig. 4 Eye diagrams at 20°C and 70°C without filters under 10 Gb/s direct modulation without current adjustment. (upper row) the QD laser. (lower row) the QW laser.

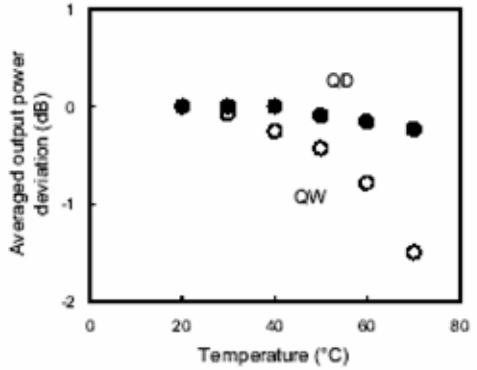


Fig. 5 Deviation of averaged output power from the averaged output power at 20°C under 10 Gb/s modulation against operating temperature.

Outline

- Introduction
  - Market downturn and recovering
  - Pluggable solutions
- 10 Gb platforms and segmentation within the network
- 10 Gb devices and technologies for pluggable transceivers
  - Key design elements for high performances laser sources
  - Direct modulation of uncooled laser sources
  - Advanced laser sources for pluggable transceivers

Modulation of lasers sources

***Transmit information*:**

⇒ **Frequency Modulation of laser source** ☹

⇒ **Intensity modulation of laser source** ☺☺

- **Intensity modulation by:**
  - **External modulator:** ⇒ **expensive** ☹☹

    (long haul only)
  - **Direct modulation:** ⇒ **cheap/simple** ☺☺

    ⇒ **short haul** 😐

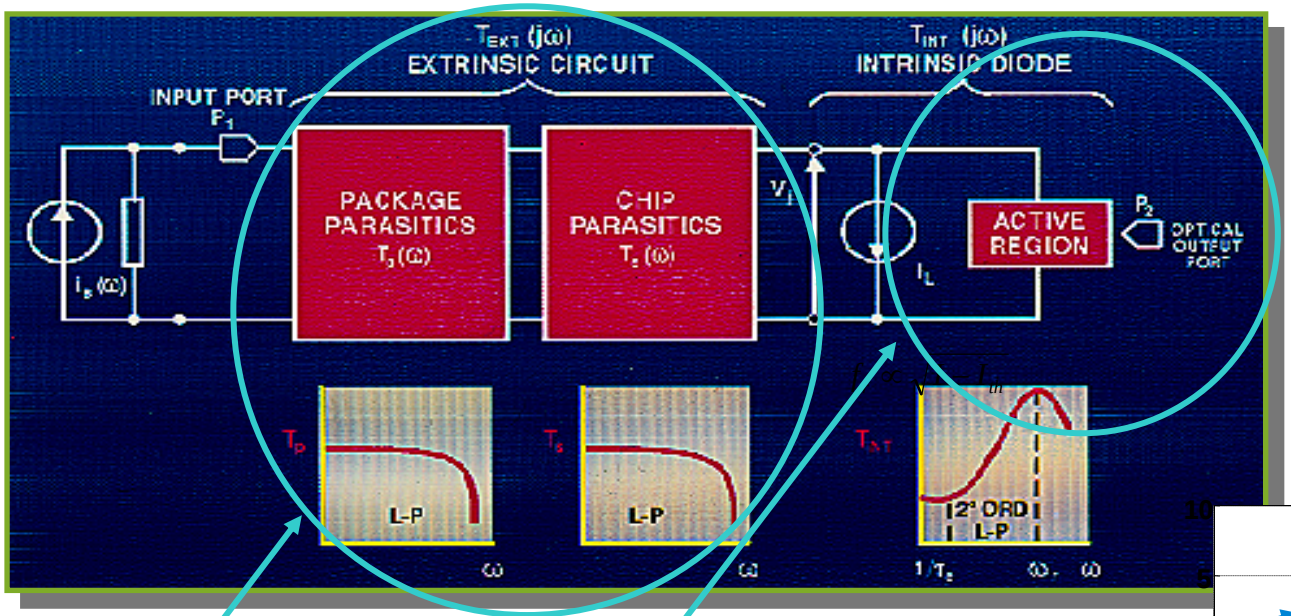
    (<200 km @ 2.5 Gb, 30 km @ 10Gb)

    ⇒ ***need high frequency devices*** ☹

So we want uncooled, low cost laser … and fast!!!

Intensity modulation of laser sources

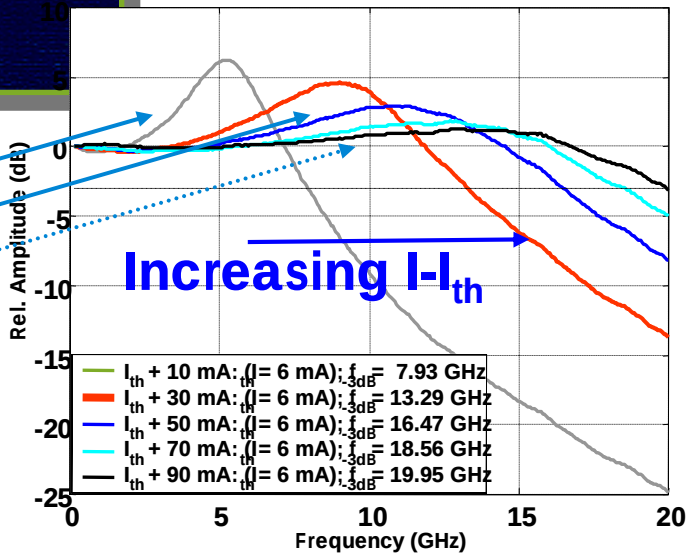
- **Laser chip equivalent circuit**



Parasitics

Active material

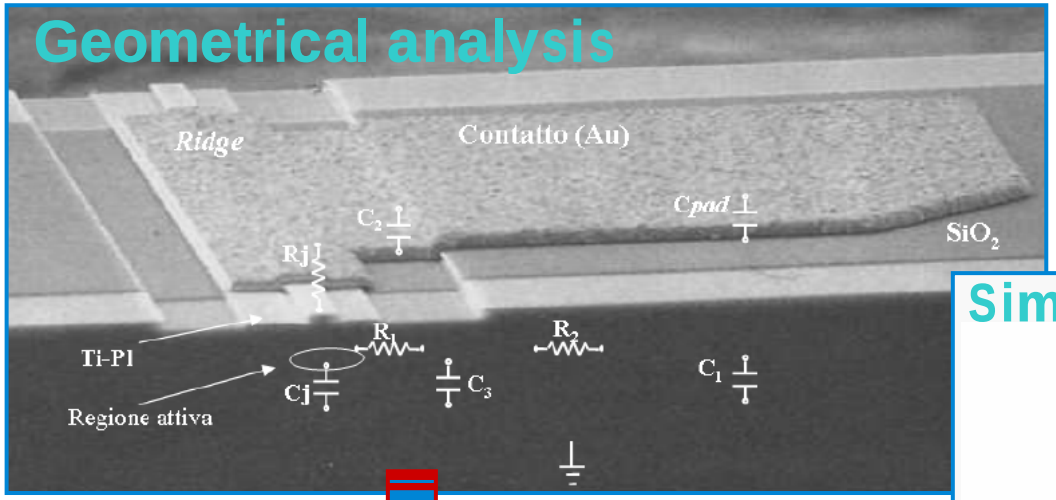
$$f_r \propto \sqrt{I - I_{th}}$$



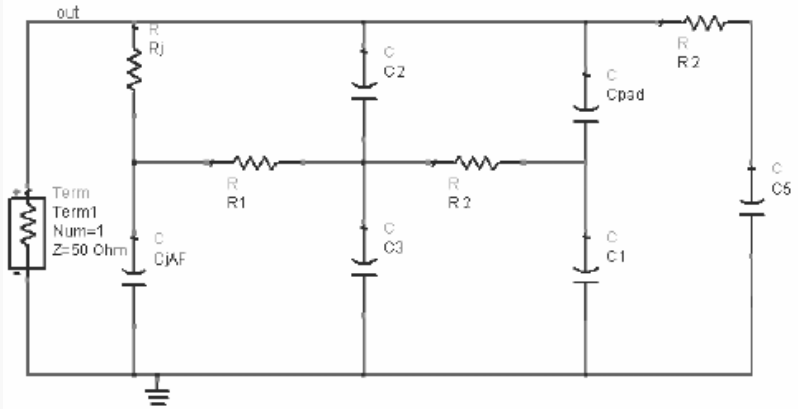
AVAGO TECHNOLOGIES

Intensity modulation of laser sources: chip parasitics

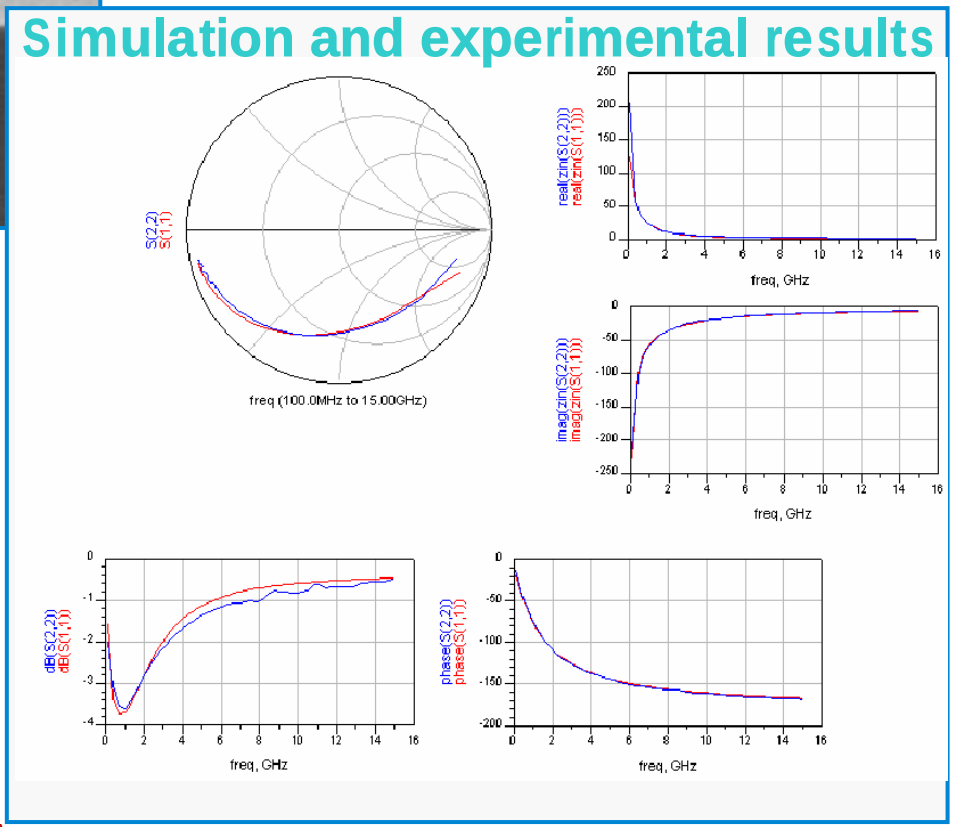
Geometrical analysis



Equivalent circuit



Simulation and experimental results



Intensity modulation of laser sources: active material transfer function

Rate Equations

Linearization at bias conditions

Transfer function

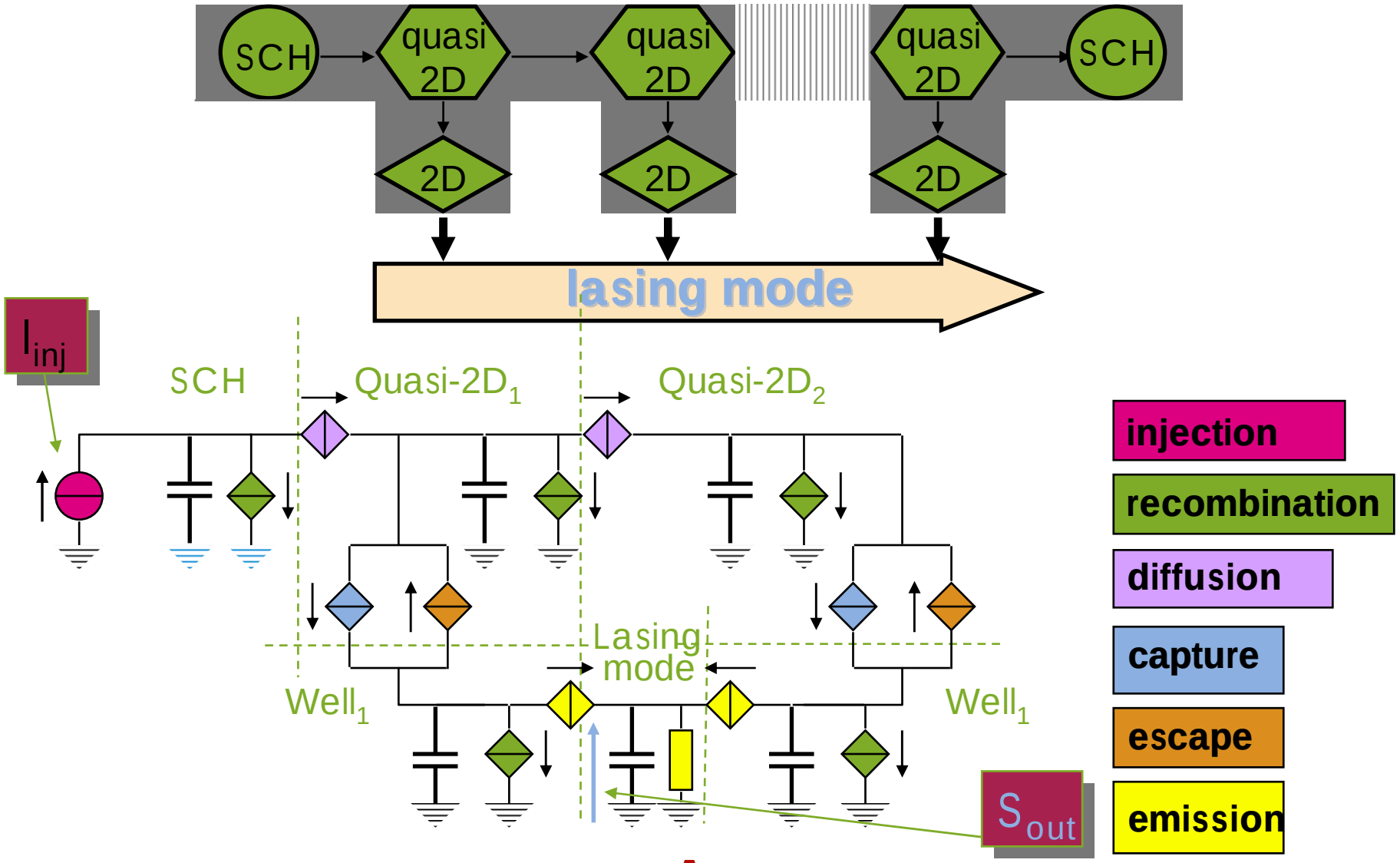
$$\left|\frac{\Delta S(\omega)}{\Delta I(\omega)}\right| = \left(\frac{q}{V}\right)\frac{1}{\left(\frac{j\omega}{\omega_r}\right)^2 + \frac{j\omega}{\omega_d} + 1} = \left(\frac{q}{V}\right)H(j\omega)$$

Bulk (2° order)

$$\left|\frac{\Delta S(\omega)}{\Delta I(\omega)}\right| = \left(\frac{q}{V}\right)\frac{1}{1+j\omega\tau}\frac{1}{\left(\frac{j\omega}{\omega_r}\right)^2 + \frac{j\omega}{\omega_d} + 1} = \left(\frac{q}{V}\right)H(j\omega)$$

Q.W. (3° order)

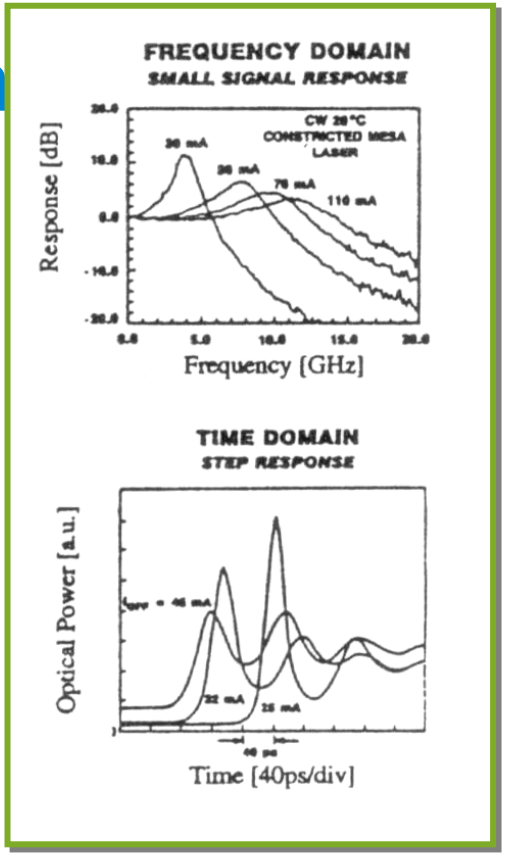
MQW active layer: *SPICE modeling*

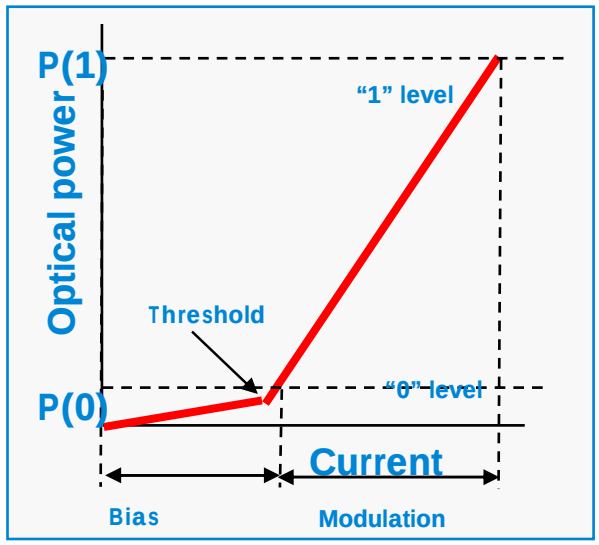


Circuito equivalente del chip laser

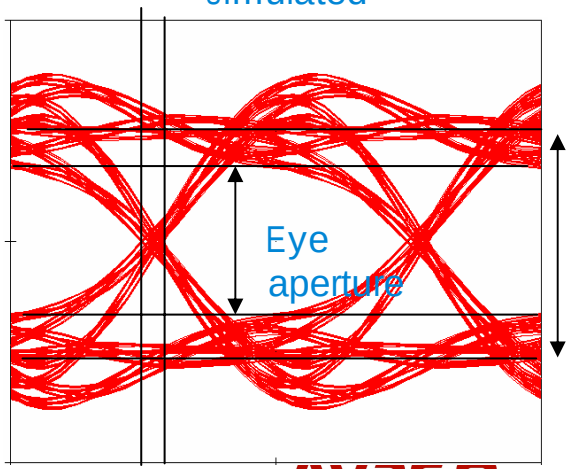
Key features for direct modulation

- **Wide bandwidth**
- **High modulation efficiency**
- **Low Noise (RIN)**
- **High temperature range (*uncooled*)**
- **Low back reflection sensitivity**
- **Low chirp**

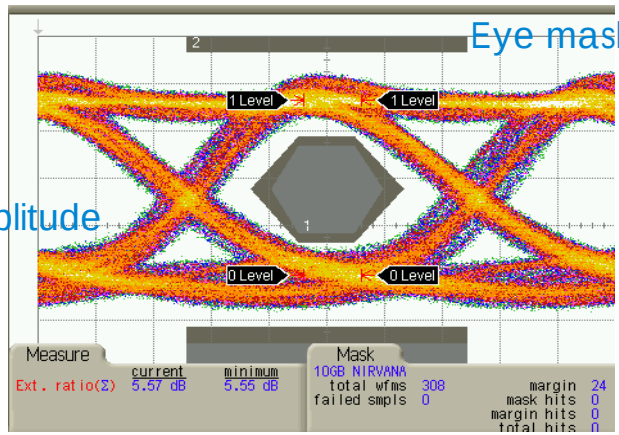




simulated

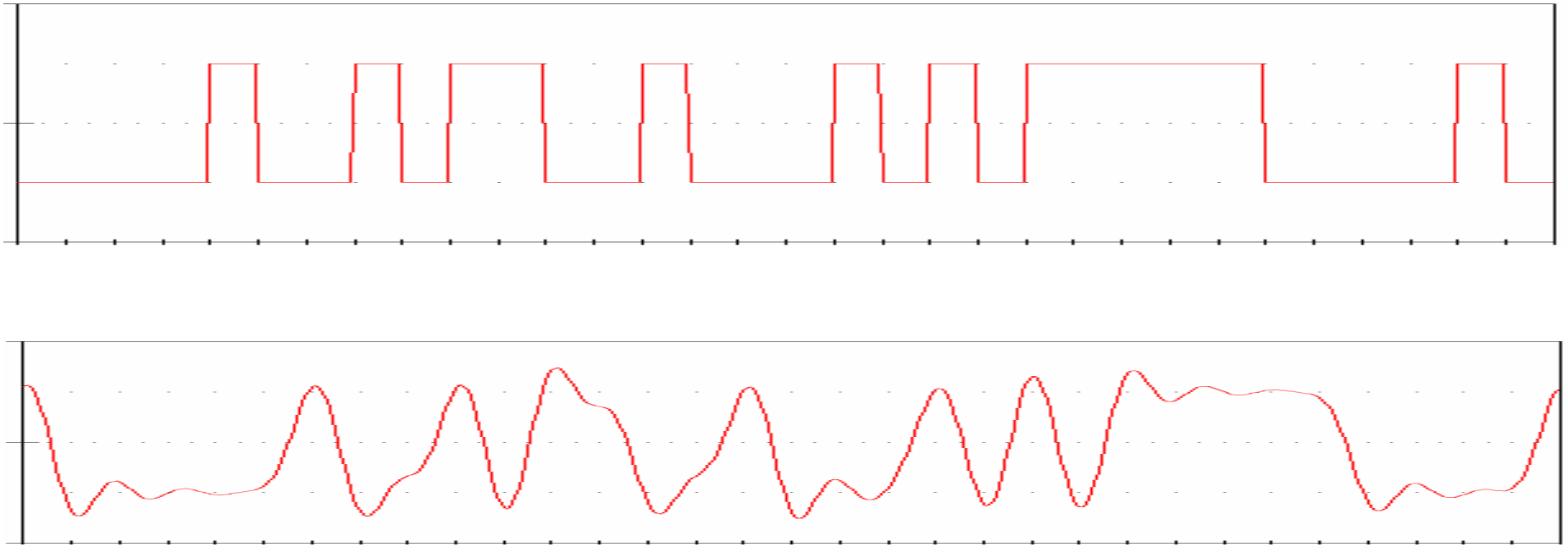


experimental



Recalls of digital communications

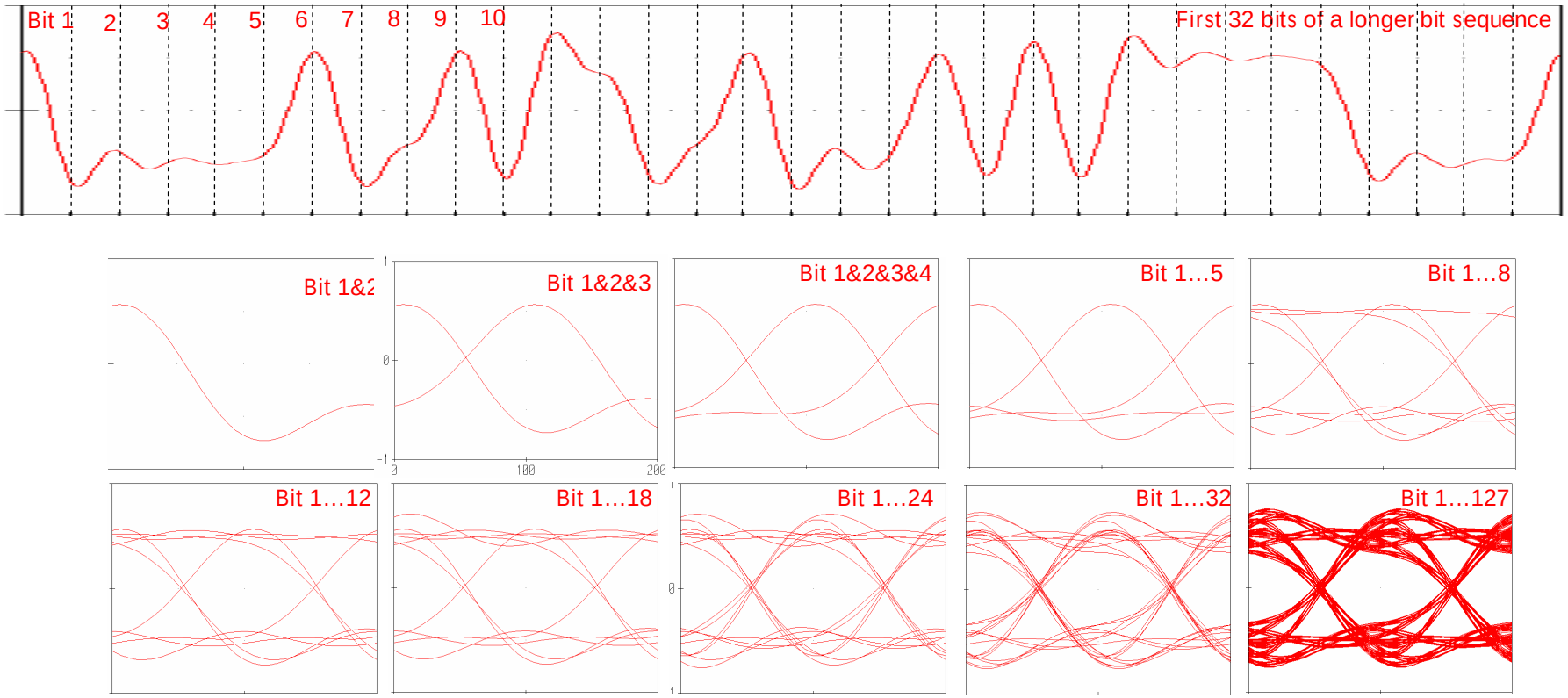
A bit stream like this



can be heavily distorted passing through a non ideal channel;
bit shape can be broadened and spread out of its time slot, overlapping
on its neighbours : this is called “InterSymbol Interference (ISI)”

Recalls of digital communications (2)

A picture like this gives little information on signal distortion

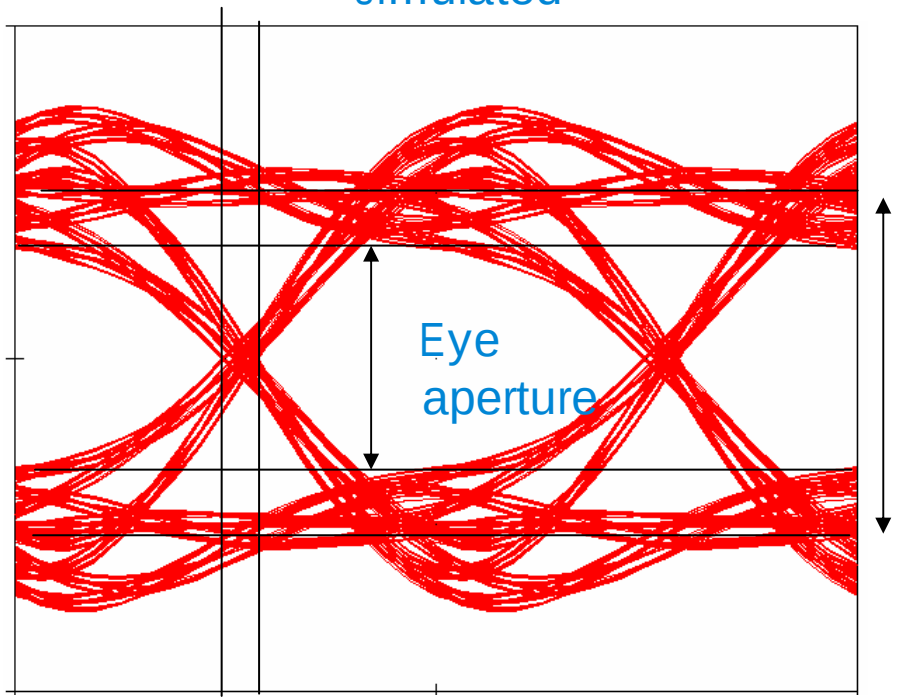


To better evaluate signal distortion an "Eye Diagram" is built

The eye diagram is obtained by slicing the bit sequence in one (or more) b time slots and overlapping them.

Main parameters of an eye diagram

simulated

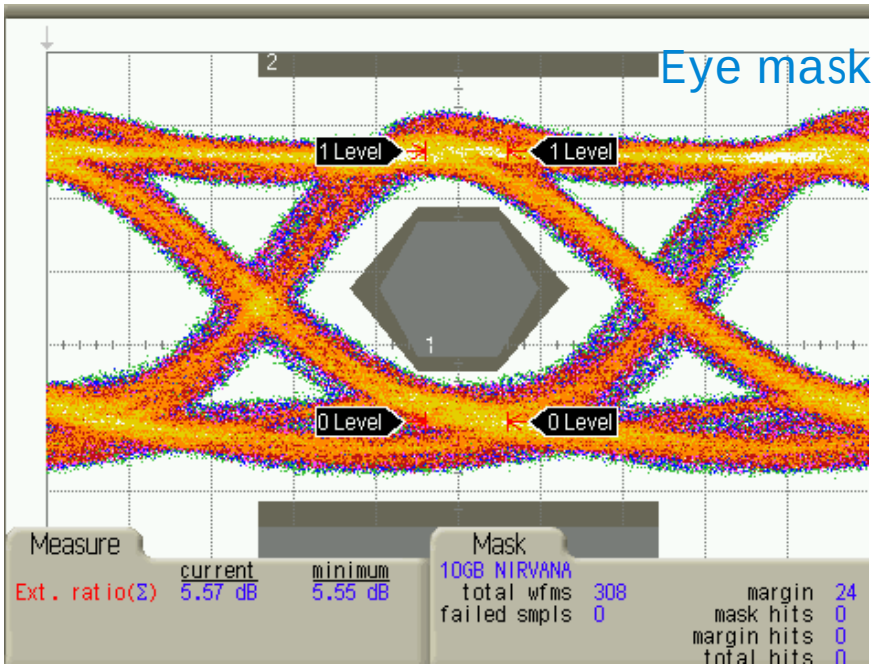


Jitter :

DJ deterministic or pattern dependent jitter

RJ random jitter

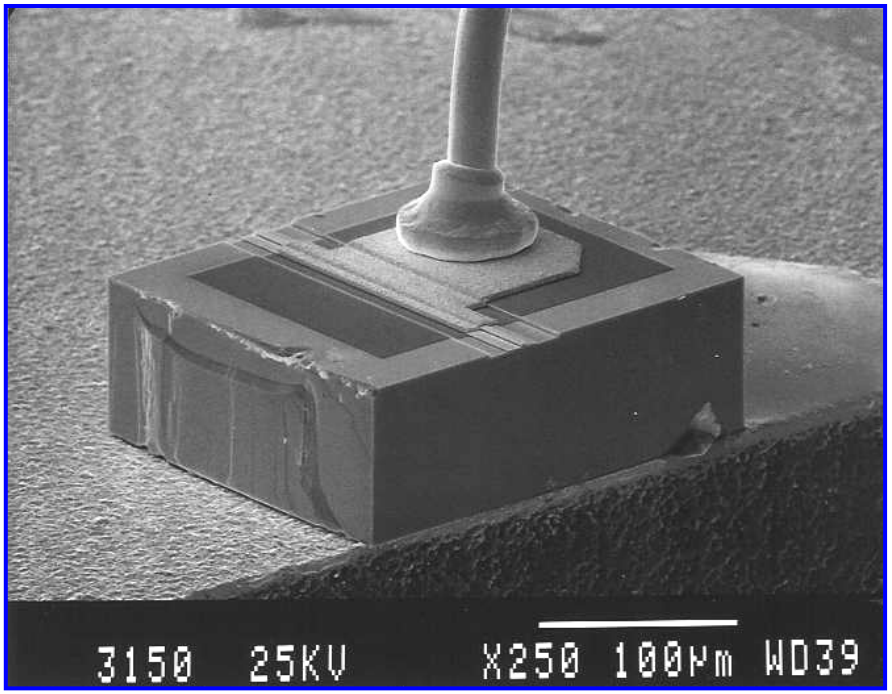
experimental



Agilent uncooled InGaAlAs ridge FP laser for 10GBASE-LRM product (300 m MMF)

Device design:

- Active layer: Al based material
  Designed to enhance T_0
  - 9 InGaAlAs 55Å wells; strain +0.8%
  - 8 InGaAlAs100Å barriers; strain –0.4%
  - 2xSCH$_1$: InGaAlAs 350Å
  - 2xSCH$_2$: InAlAs 500Å
- Device technology:
  High yield/low cost/Al compatible
  - Reversed mesa ridge
  - Auto-aligned mesa
- Optical cavity:
  Very fast chip at high T operation
  - Narrow cavity volume
  - Hr coating optimised versus both Temperature and speed



200 µm long x
250 µm wide device

Post Deadline Paper at OFC 2005

Device results - *stat*

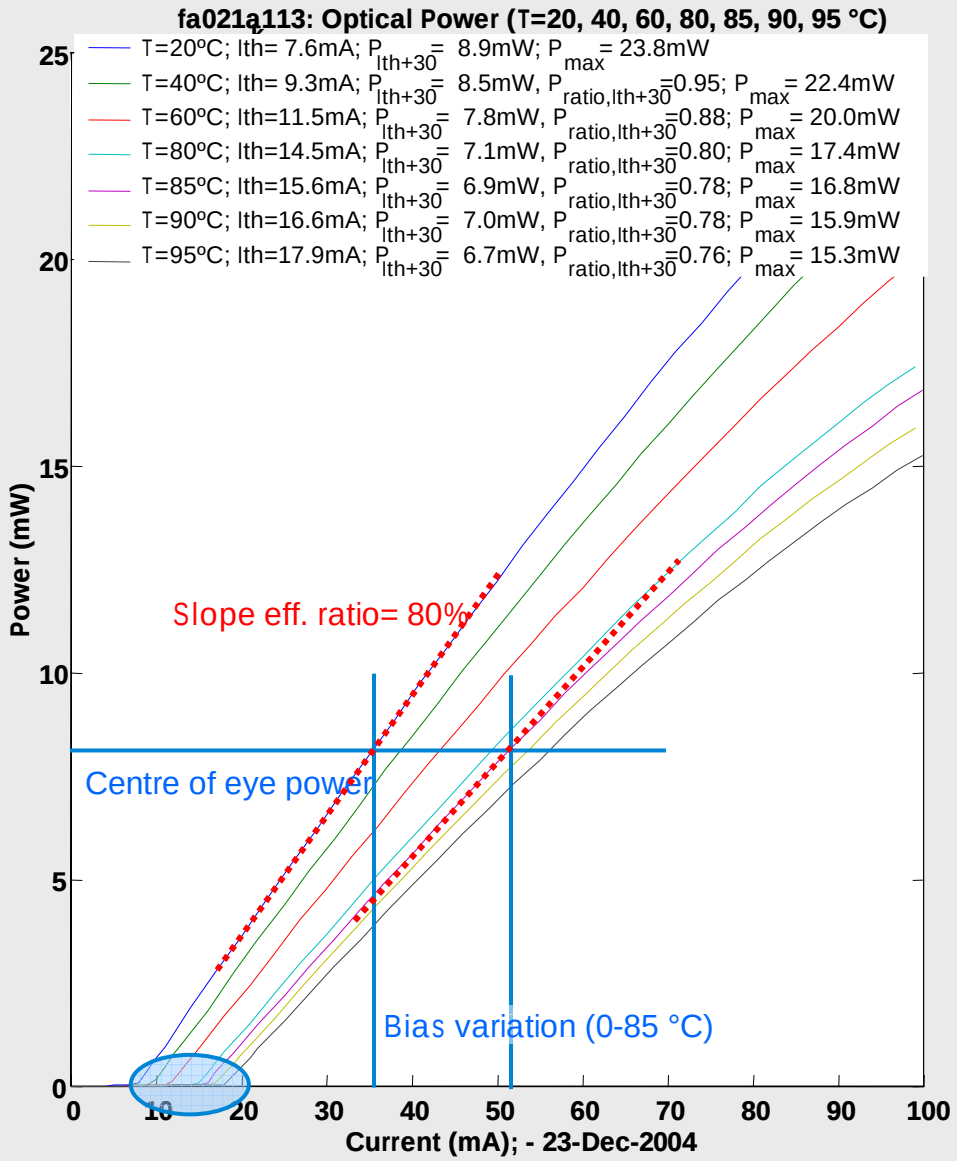
20 °C base chip temperature:
- Threshold 7.6 mA
- High power 23 mW

85 °C base chip temperature:
- threshold 15.6 mA
- power 16.8 mW

95 °C base chip temperature:
- threshold as low as 18 mA
- Still more than 15 mW

Key points:
- High optical power enable high coupling loss
- Small threshold increasing up to 95 C since high T_0
- Small bias variation over T
- *Small efficiency degradation over T*

⇒ ***Constant eye quality with constant modulation current!***



Measured on chip on carrier

Device results - *dynamic (eye diagrams)*

10 Gb eye diagrams, 35 mA modulation current swing constant over T (20-110 °C)

20 °C base chip temperature:

- 5 dB e.r. @ 35 mA bias C.O.E. ✓
- GbE mask: 57% mask margin ✓

85 °C base chip temperature:

- 5 dB e.r. @ 52 mA bias C.O.E. ✓
- GbE mask: 31% mask margin ✓

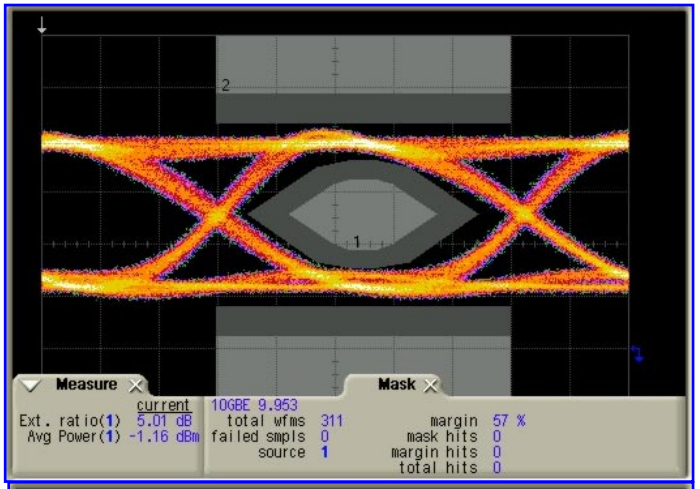
110 °C base chip temperature:

- 4.5 dB e.r. @ 60 mA bias C.O.E. ✓
- GbE mask: 22% mask margin ✓

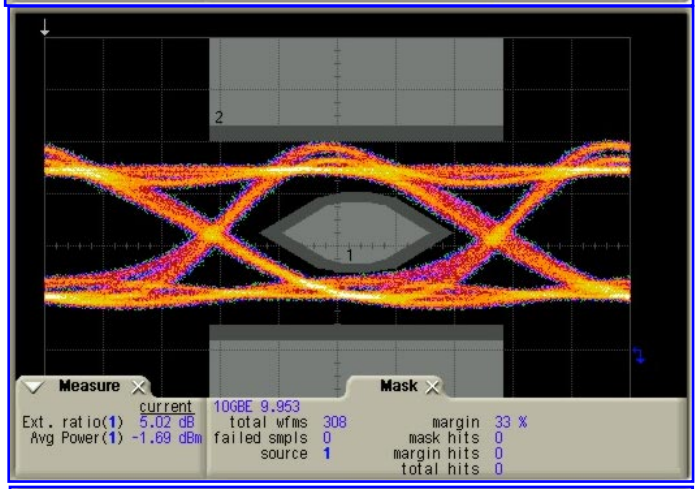
Eyes show no degradation up to –8 dB B.R. (Fiber)

Measured probing directly the chip by 40 GHz 50 Ohm-series matched RF probe

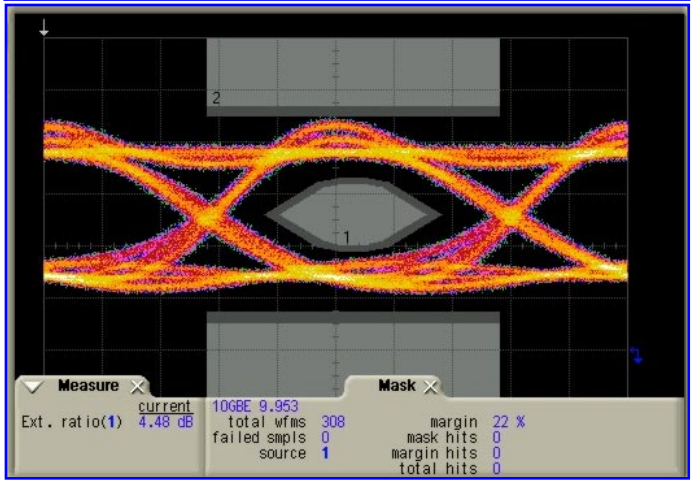
20 °C



85 °C

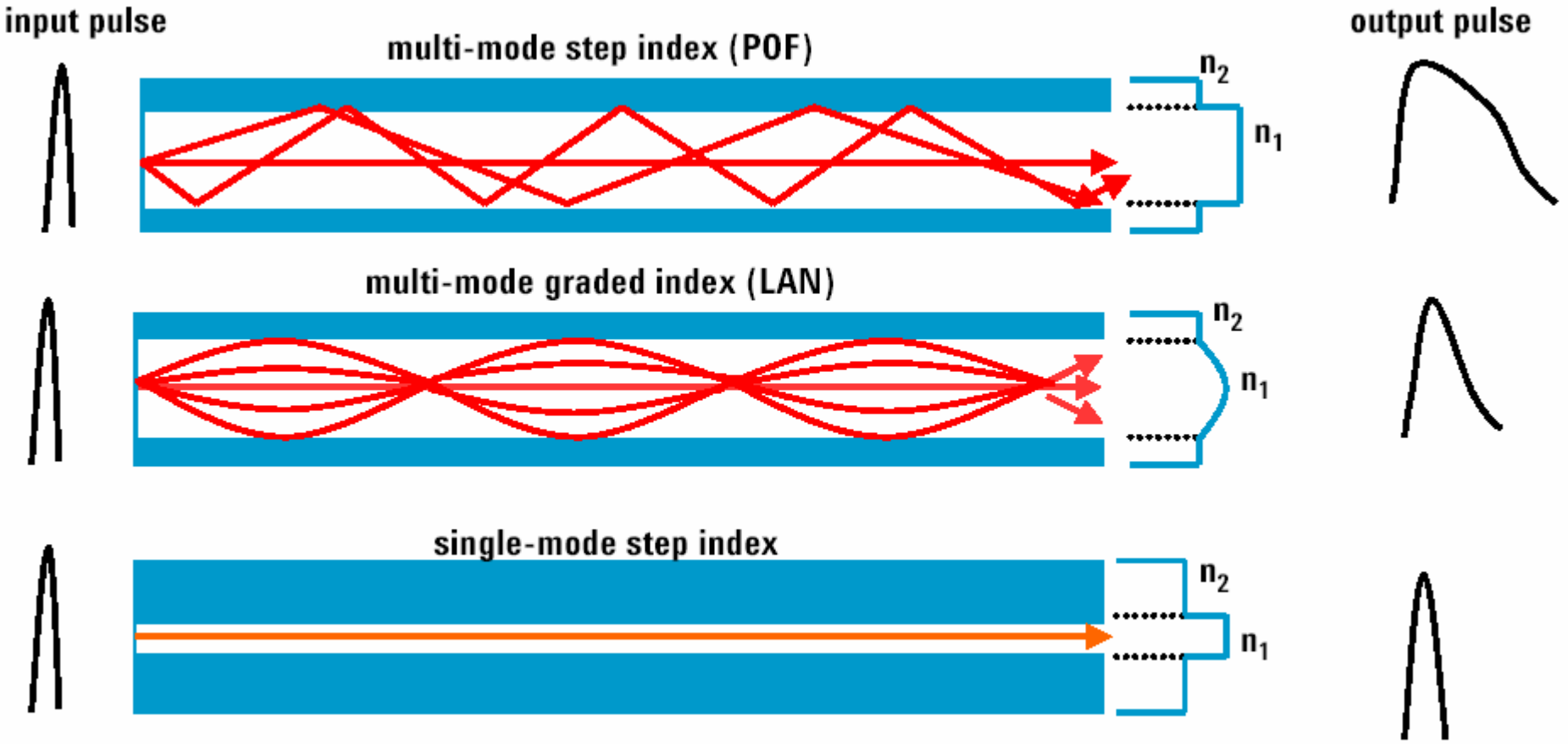


110 °C



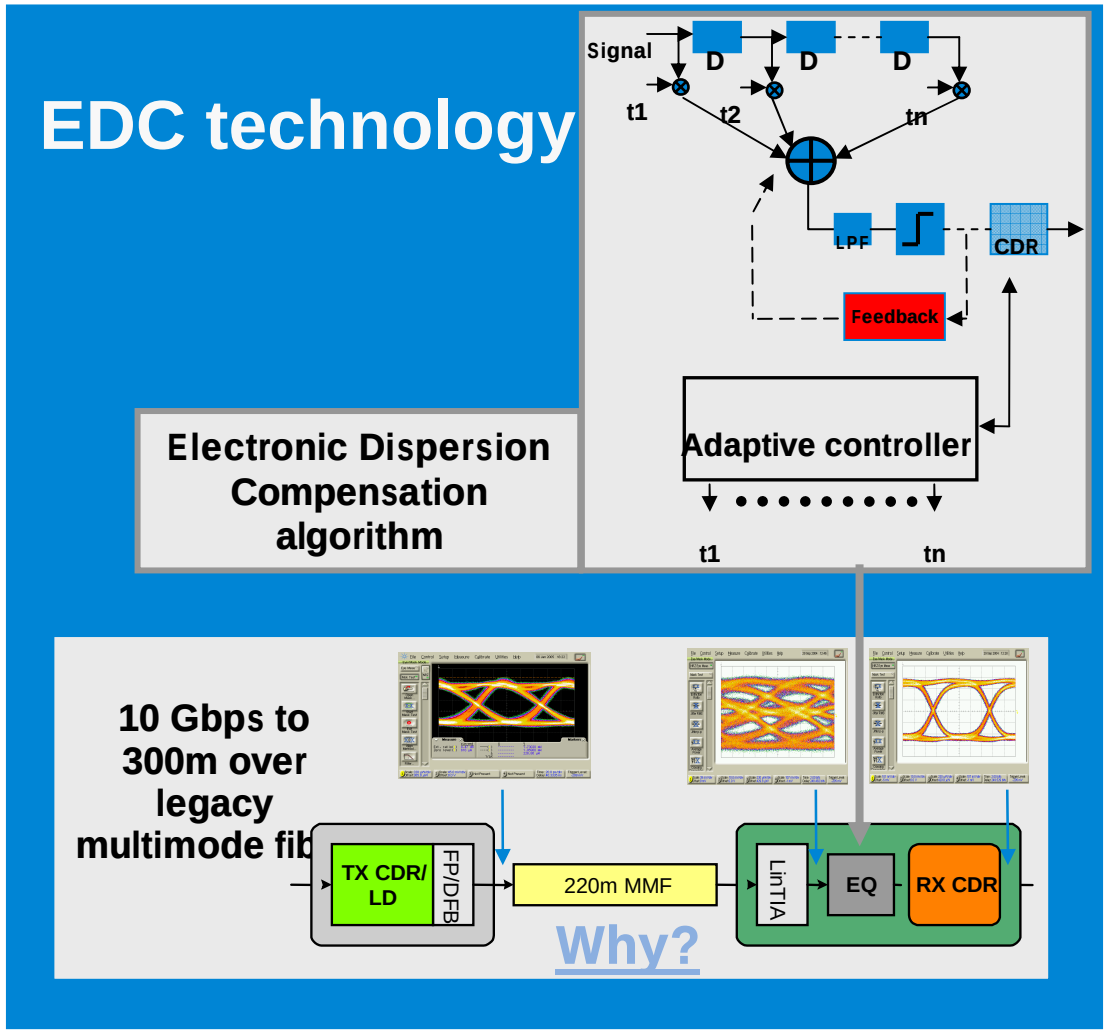
AVAGO TECHNOLOGIES

Modal dispersion in MM fibers



back

Technologies for LRM application: EDC (Electronic Dispersion Compensation)



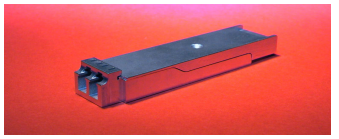
•EDC uses adaptive electrical filtering techniques to compensate for limitations incurred during fiber propagation:

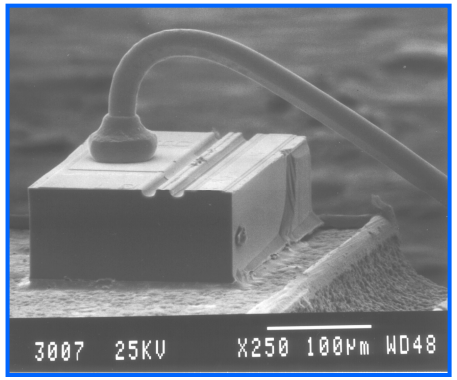
- modal dispersion
- chromatic dispersion
- polarization modal dispersion

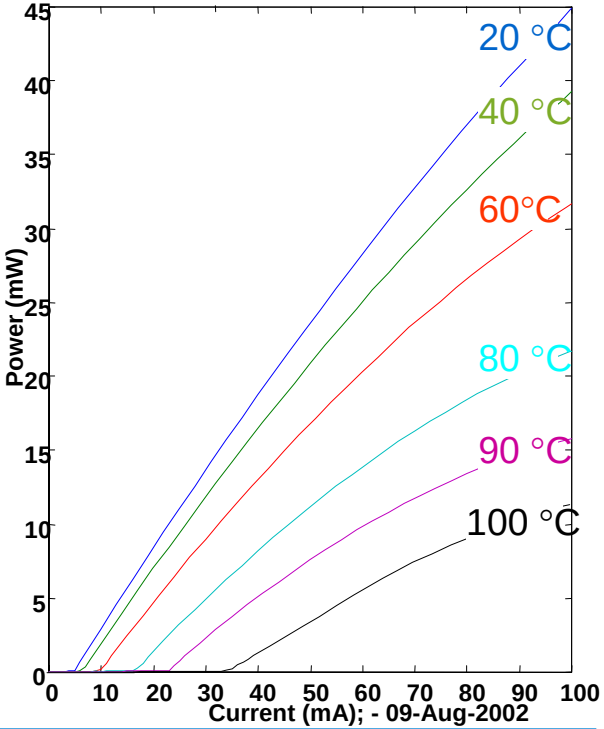
•EDC can be realized in an integrated circuit.

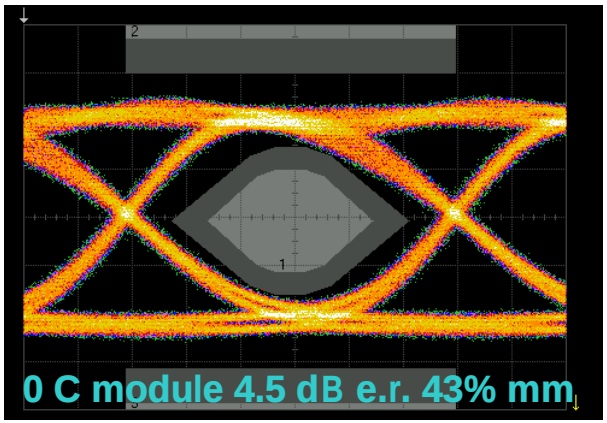
•EDC can enhance the performance of existing transceivers and enabling new applications.

Agilent uncooled InGaAsP BH 10 Gb DFB for 10GBASE-LR product: 2001 results

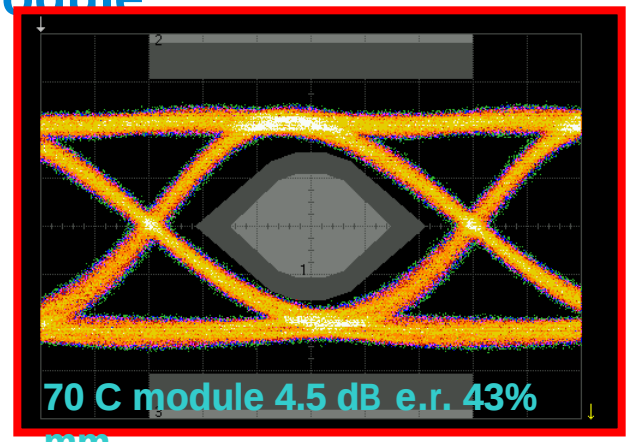


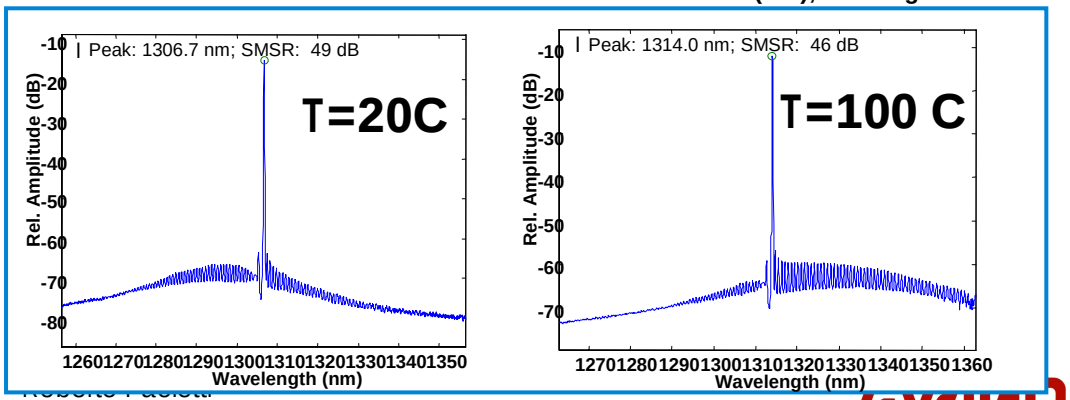






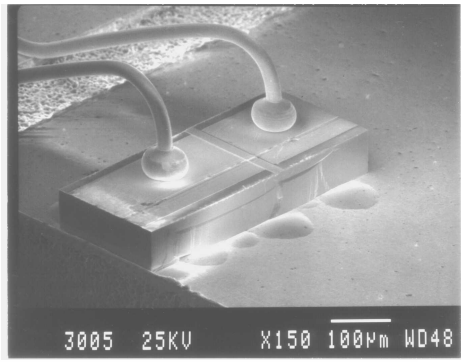
Eye diagram in the XFP module

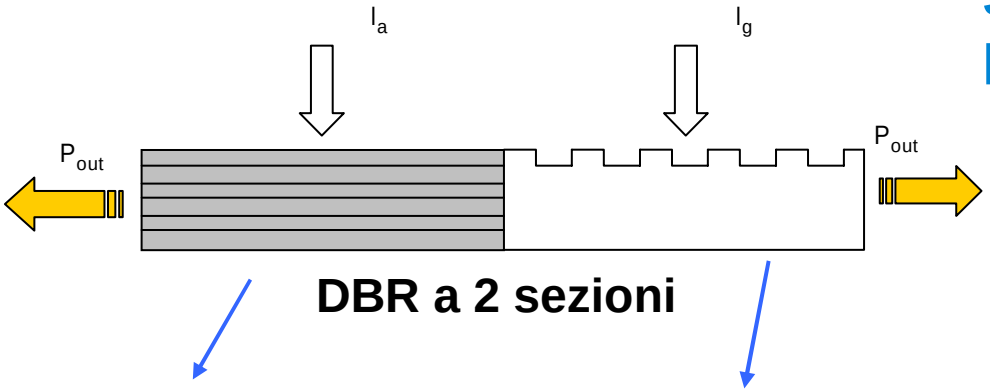


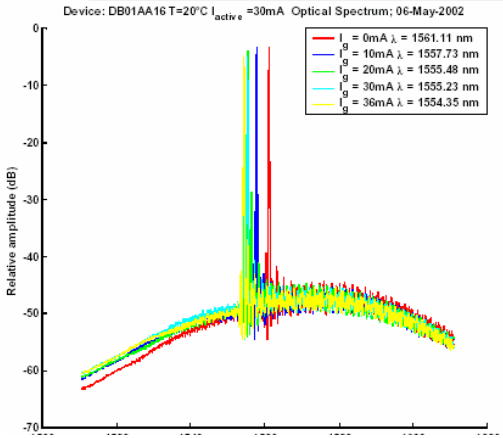


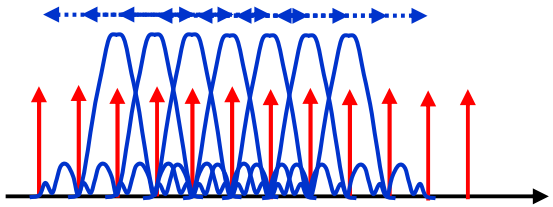
Tunable devices: Distributed Bragg Reflector *DBR*

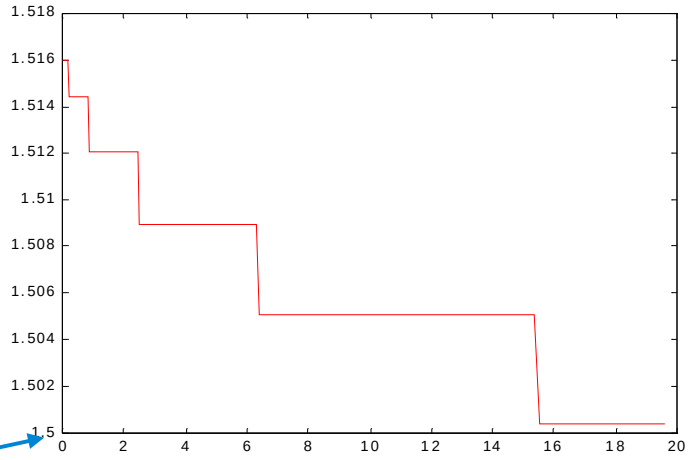
2-sections DBR





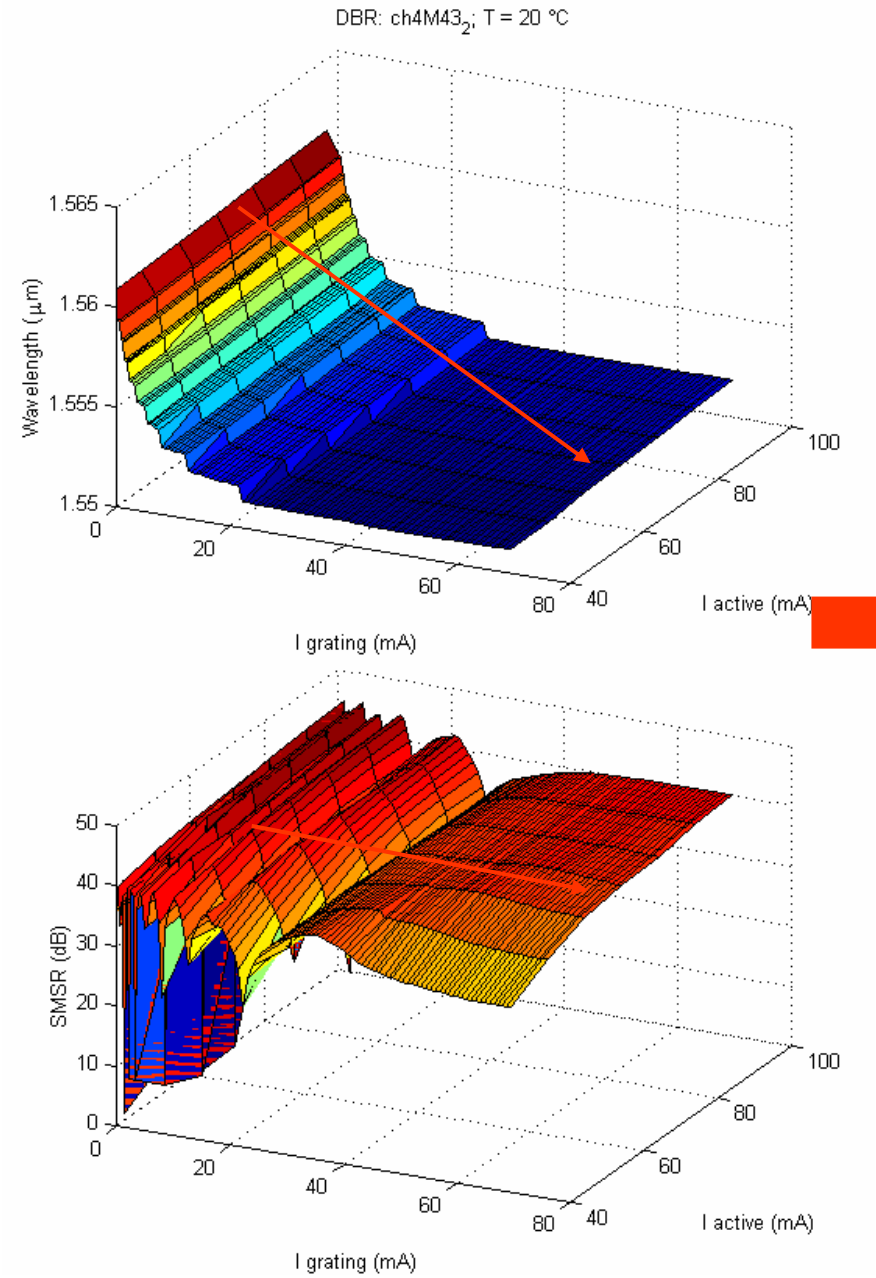




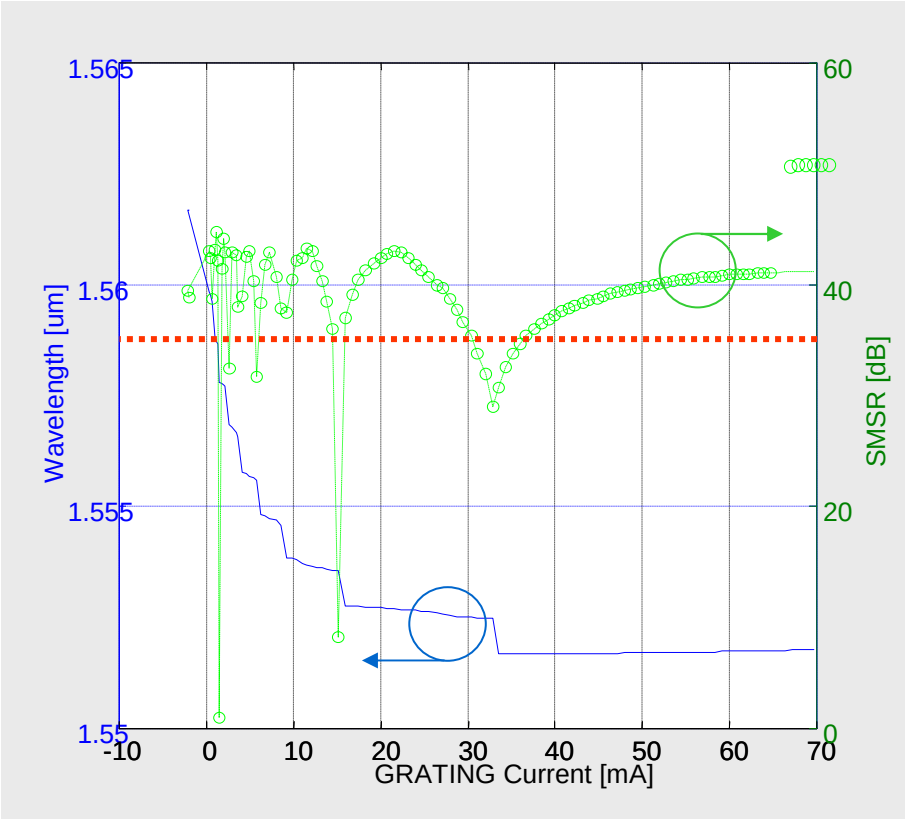


Simulazione e misura della lunghezza d'onda di emissione verso la corrente nel grating

Device results: tuning maps

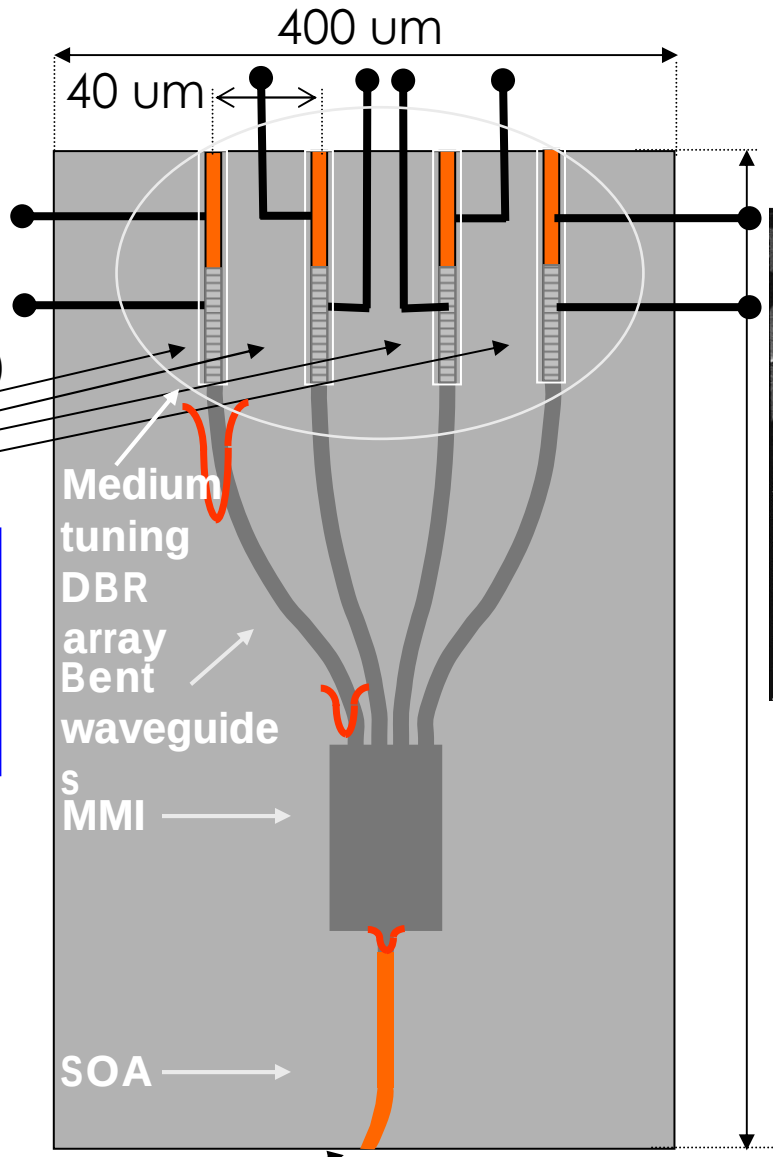


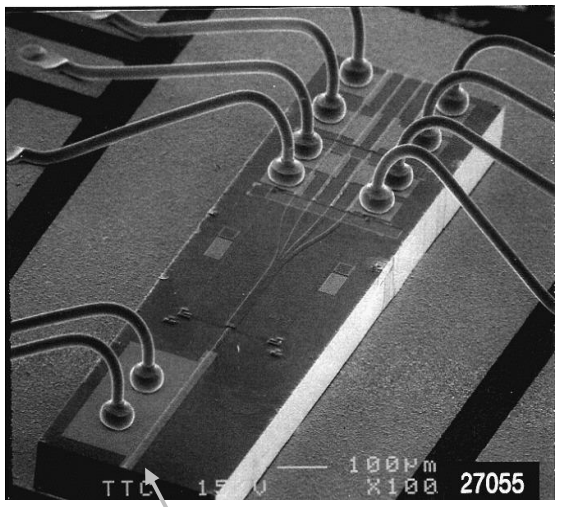
Emitted wavelength and SMSR versus grating current



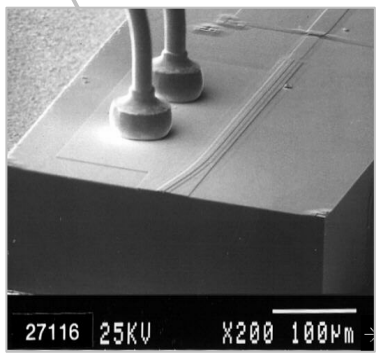
> 10 nm tuning
> 40 dB SMSR @ I active > 40 mA

Wide tunable laser: DBR Array





1670 um



InP Monolithically integrated DBR Array + PIC

Passive and tuning waveguides

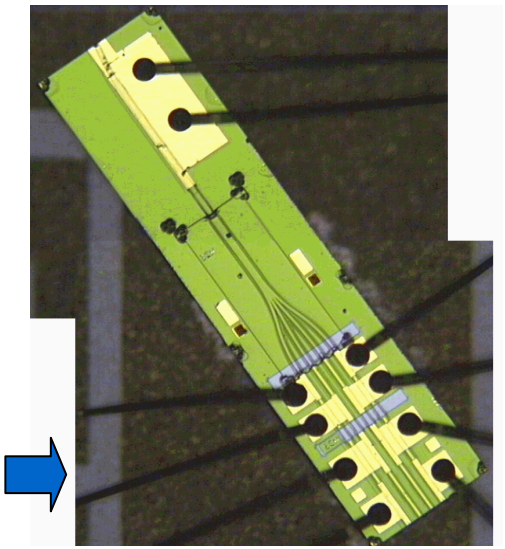
DBR and SOA active waveguide

Paoletti et al. ECOC 2003

Agilent tunable laser: Key features

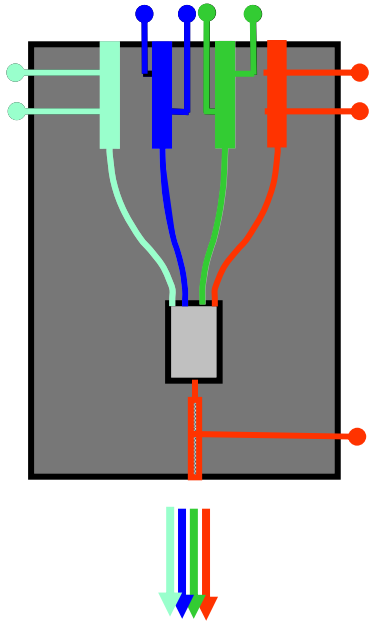
- **Small (0.67 mm^2 ,1670um x 400um) chip size**
- **40 nm tuning range**
  - **4 x 10 nm tuning (each DBR)**
  - **easy tuning control**
- **+ 13 dBm output power ex facet**
  - **at only 50 mA DBR active, various grating curr., 100 mA SOA**
- **Low (<250 mW) power consumption**
- ***Blanking (>40dB)* and *VOA (>10dB)* features**
- **Bent SOA with "relaxed specs" Anti Reflection Coating *(10^{-3})***

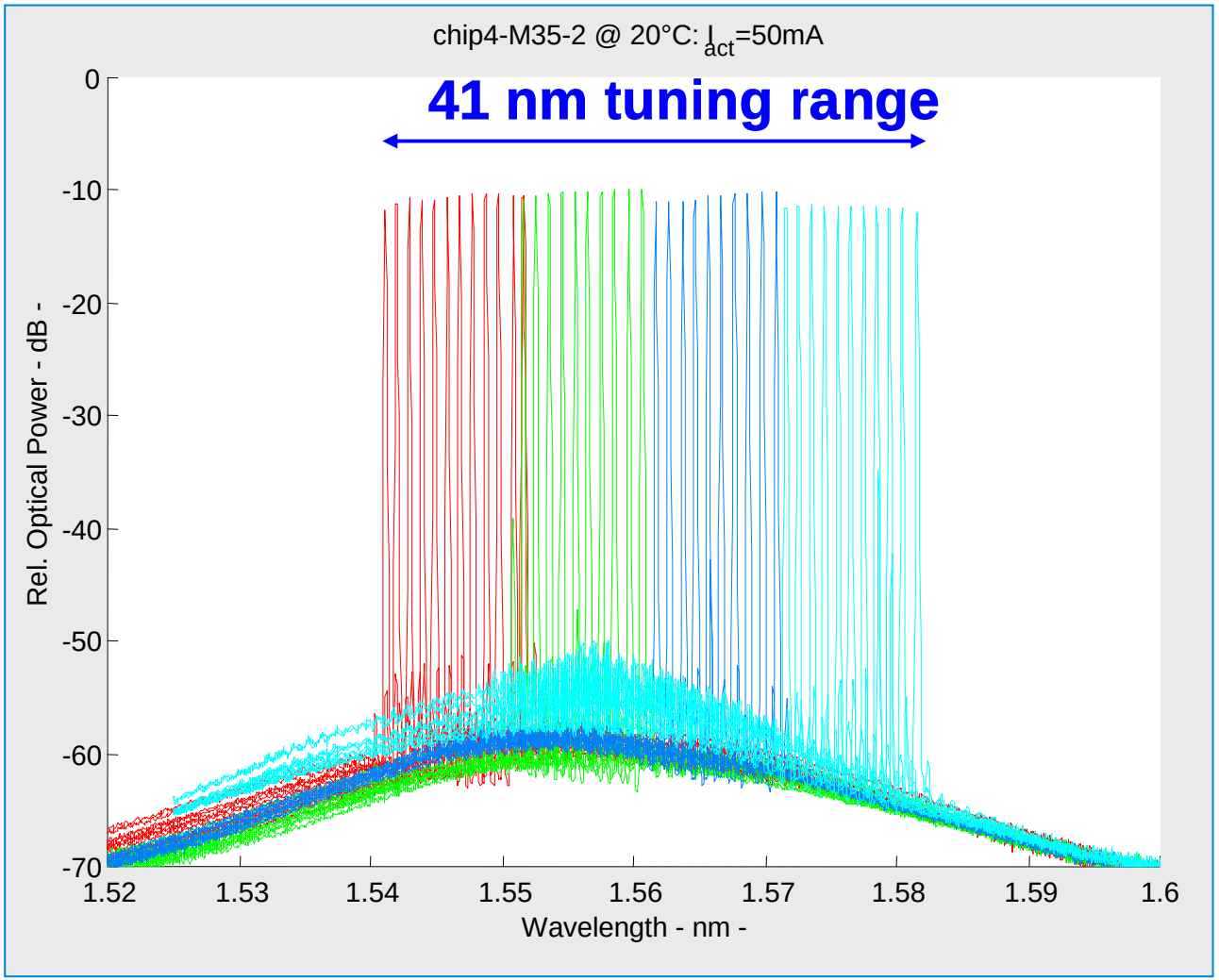
R. Paoletti et al, ECOC 2003



By a monolithic InP based chip

Device results: emitted spectrum





Paoletti et al. ECOC 2003

The Turin Technology Centre (TTC)

Via Reiss Romoli, 274
10148 Torino
Italy

Acquisition by Agilent Technologies 19 April 2000

Activity: R&D (Semiconductor Product Group)

- **Short term Development projects (transceivers @ 2.5 Gbit/s and @10 Gbit/s)**
- **Medium-long term Research projects for active and passive devices**

People: 70 (Mainly R&D Engineers), III-V and Product teams

Expertise: optoelectronic and photonic technologies

- **New devices and components conception and design**
- **Semiconductors**
- **Device design, prototyping and characterisation**
- **Components packaging and characterisation**

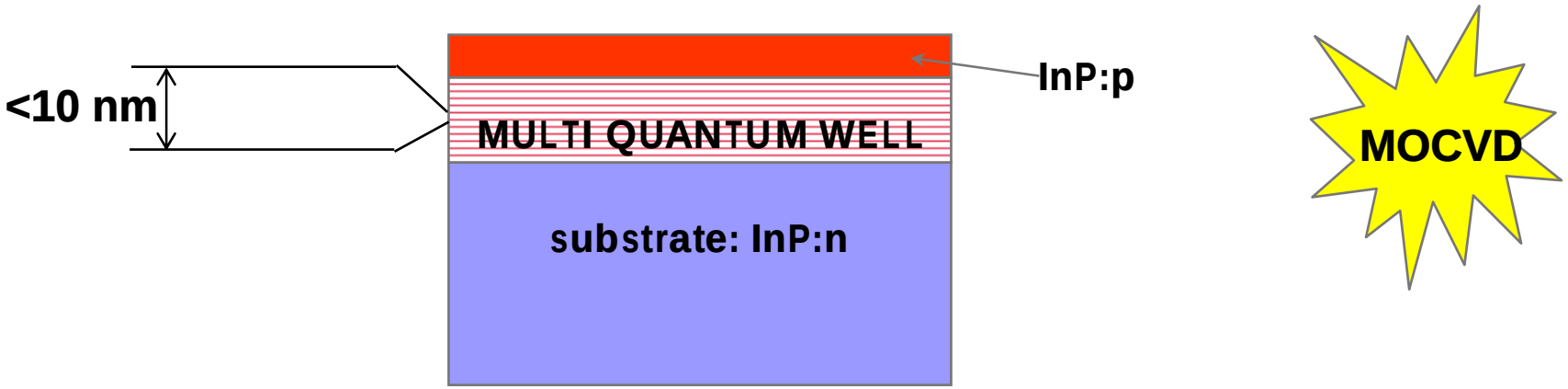
R&D of III-V photonic devices

Sept 16th 1962 GEC

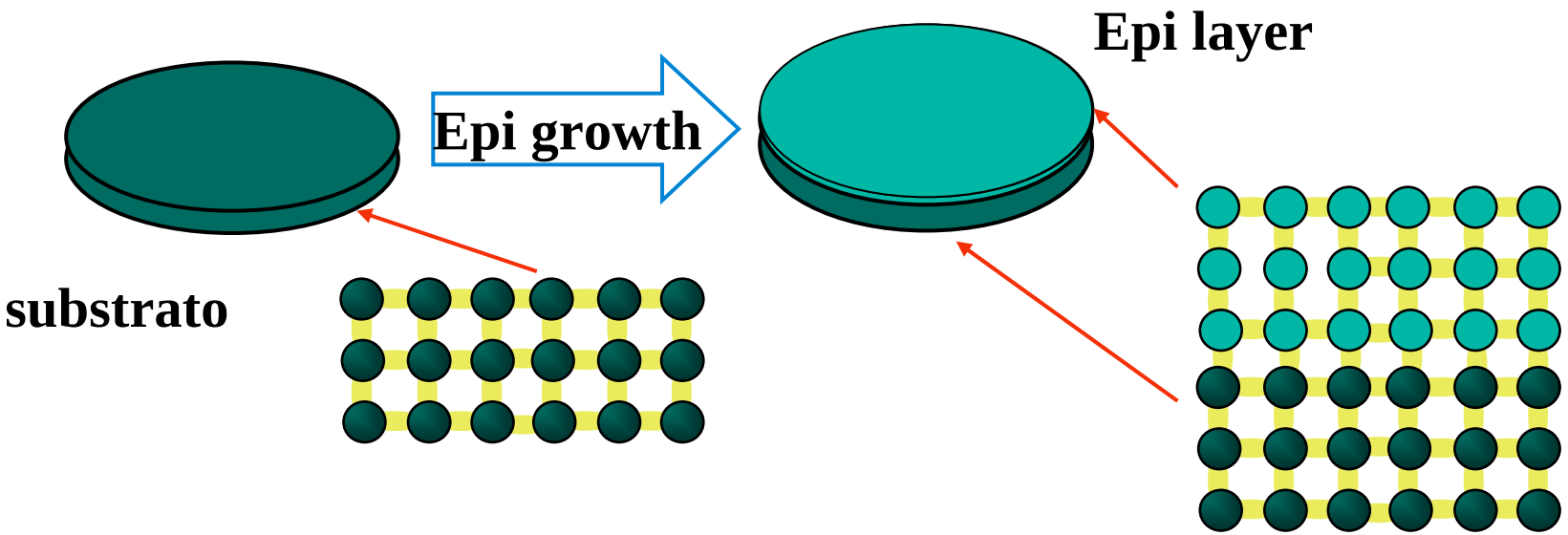
TTC, Turin

http://www.torinoscienza.it/lab-vr/agilent/index.htm

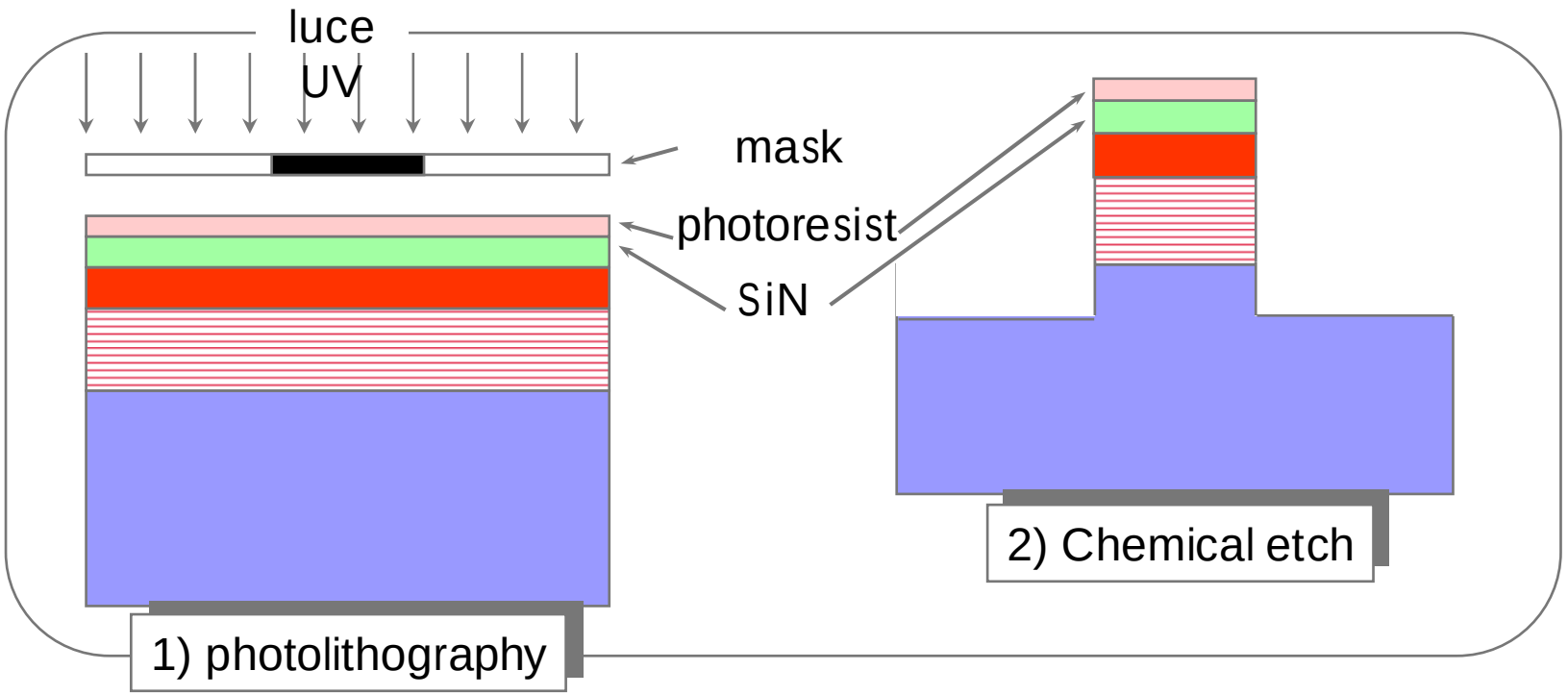
Epitaxial growth



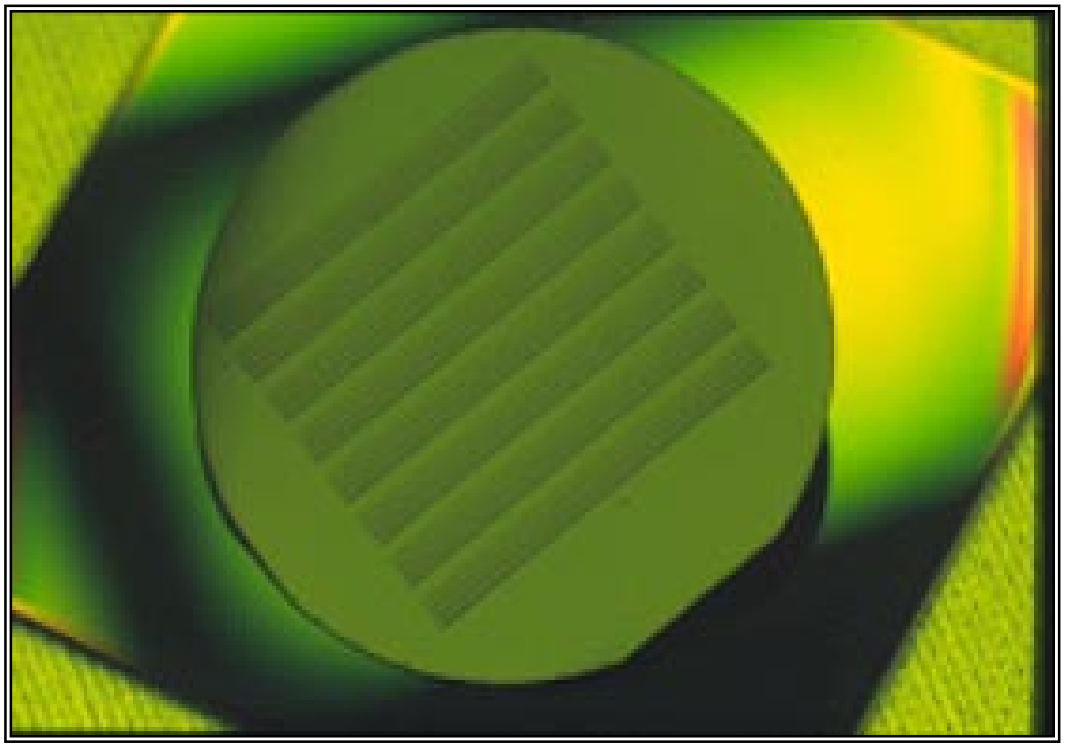
1) Epitaxial growth



Processing


luce
UV
mask
photoresist
SiN
1) photolithography
2) Chemical etch

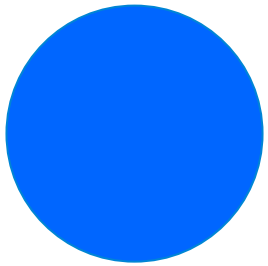
Wafer cleaved in bars

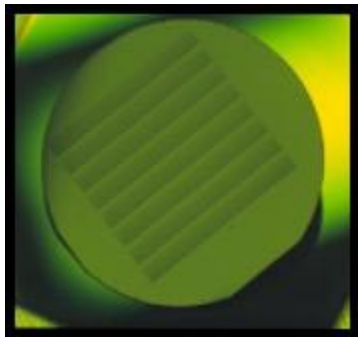


From 2” wafer: up to 20.000 lasers

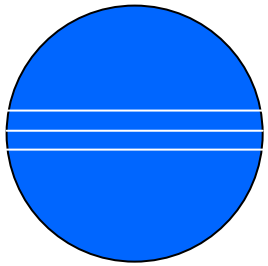
Scribing: from wafer to chip

Wafer



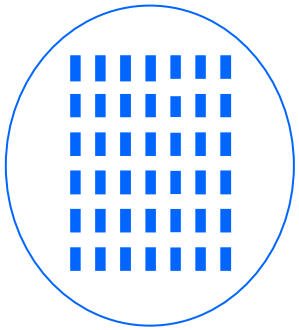


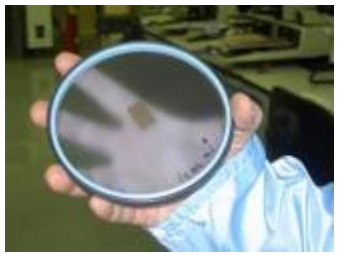
bars



Coating /cleave

Chips

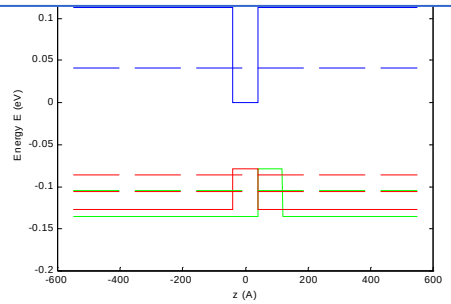




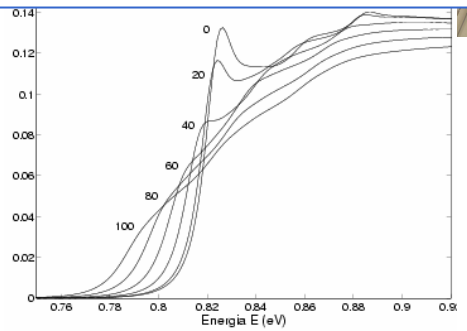
Design/Modeling ⇒

1. Material properties (Q.M.)

MQW band profile and levels

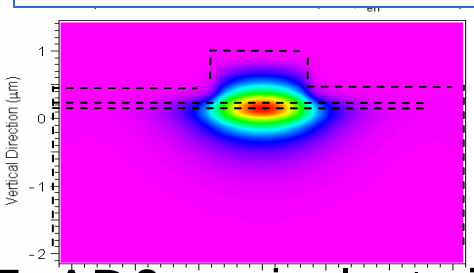


Optical properties: n+ik (I, F, T)

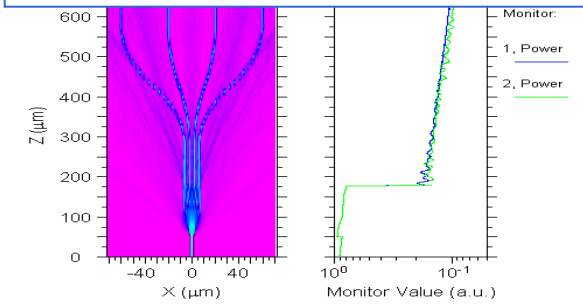


2. E.M.

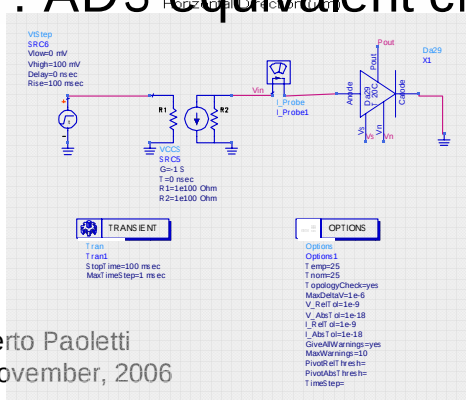
Waveguiding properties

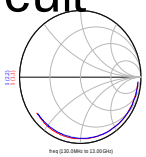


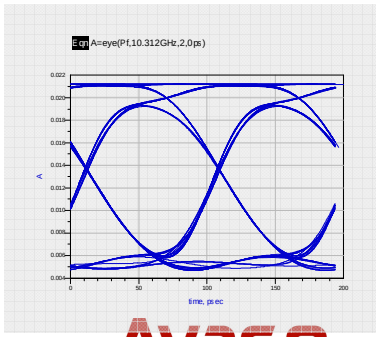
Beam Propagation Method

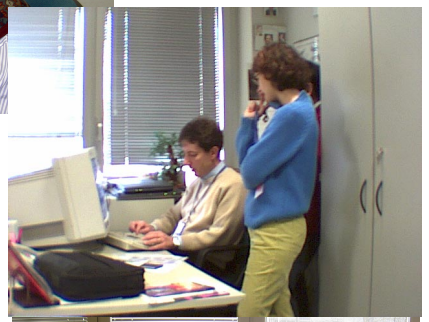


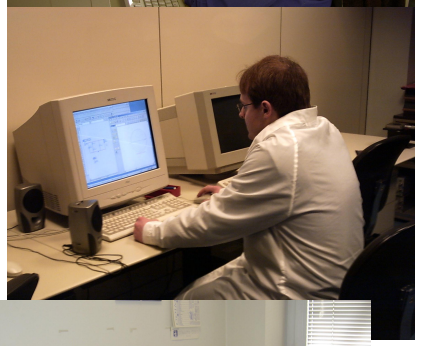
3. HF: ADS equivalent circuit







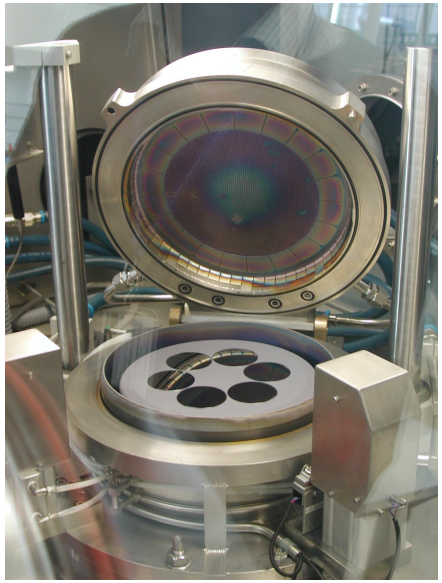


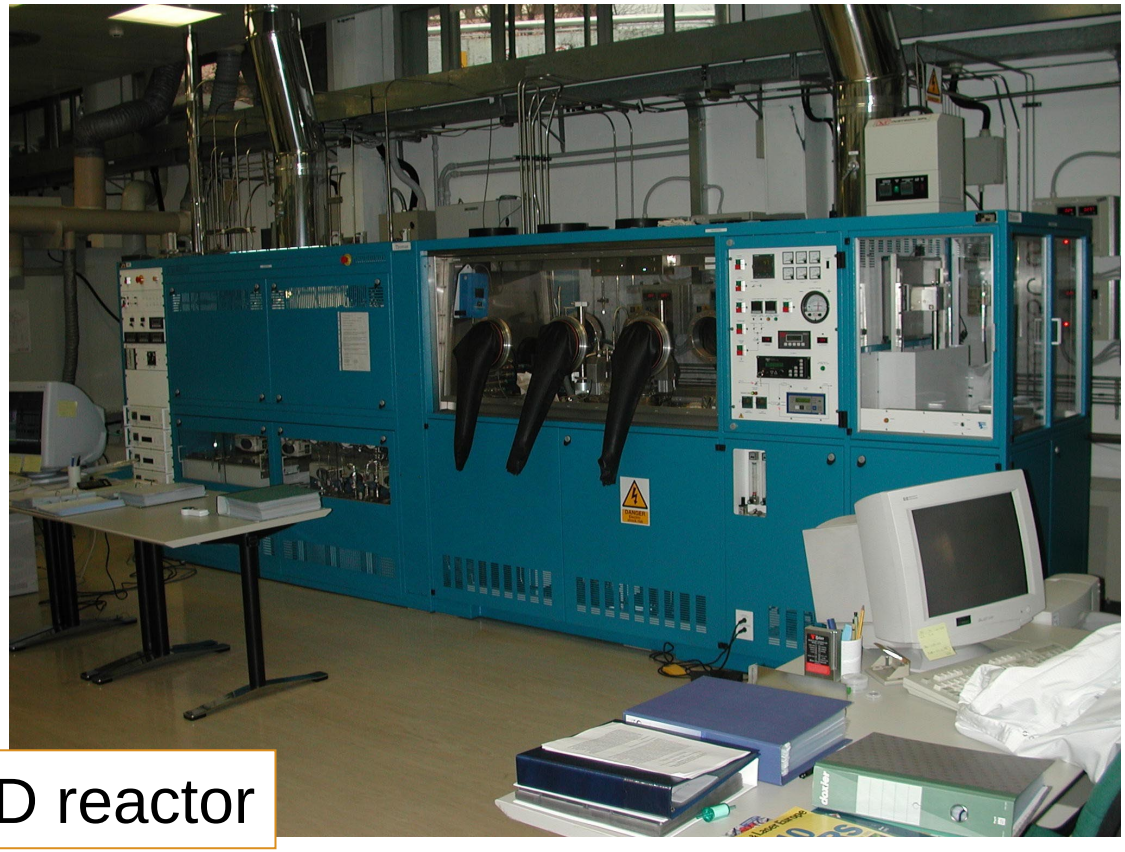


AVAGO TECHNOLOGIES

(1) From ideas to design

⇒ Epitaxy ⇒

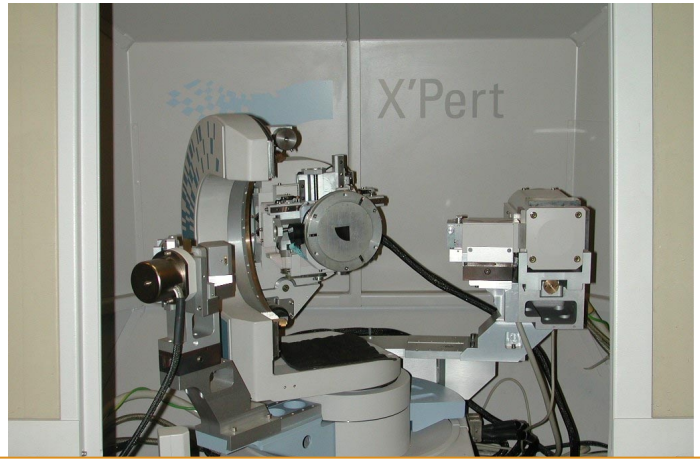




MOCVD reactor

(2) From design to planar structures

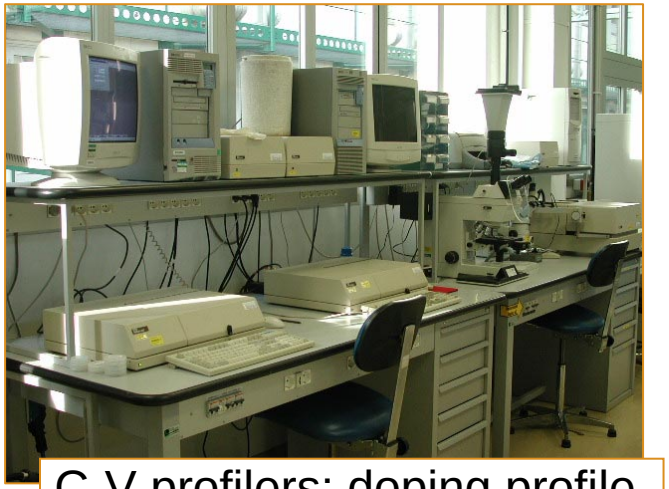
⇒ Material characterization ⇒



X-Ray diffraction: crystal quality +composition

Photoluminescence: alloy composition

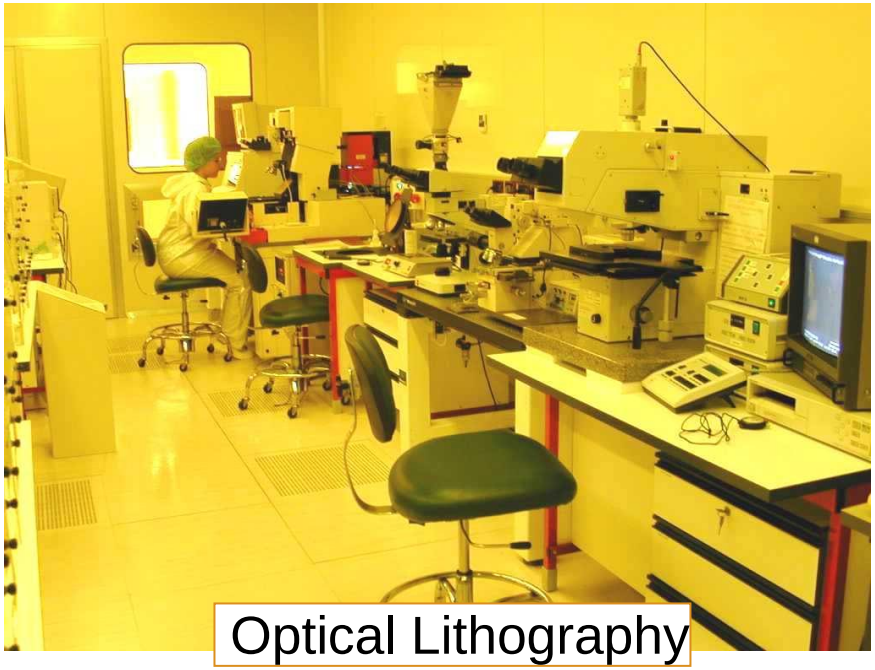
Scanning Electron Microscope (SEM)



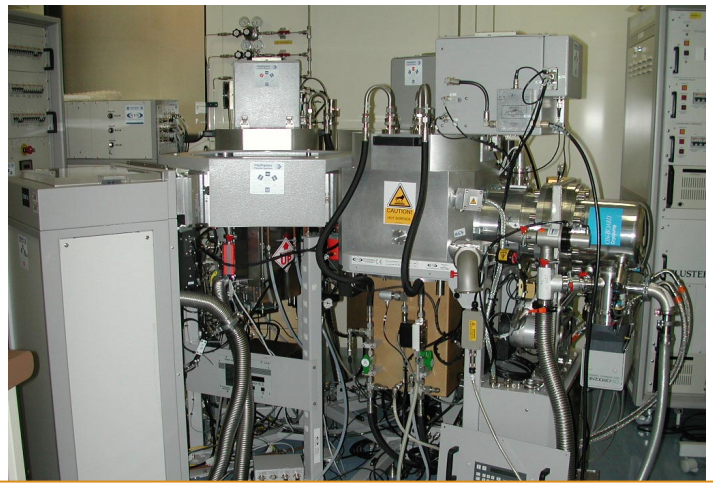
C-V profilers: doping profile

(3) Analysis of planar structures: back to design(BTD)/forward to …

⇒ Processing ⇒



Optical Lithography

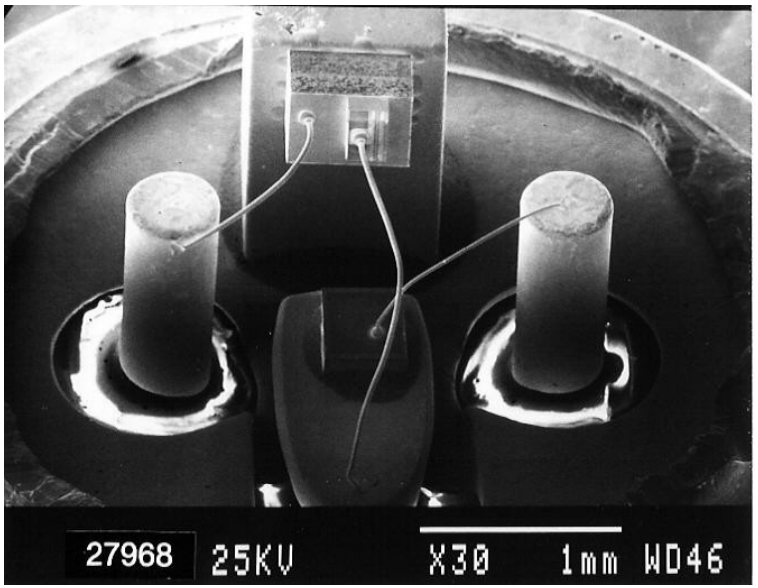


Electron Beam Lithography

(4) From planar structures to wafer fabrication (clean room)

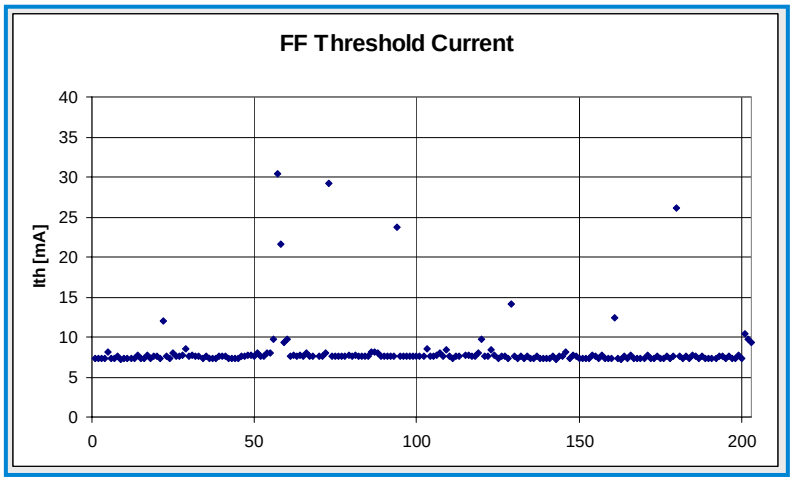
Sputtering: metal layer deposition (Ti, Au, Pt)

⇒ Dicing/Mounting ⇒

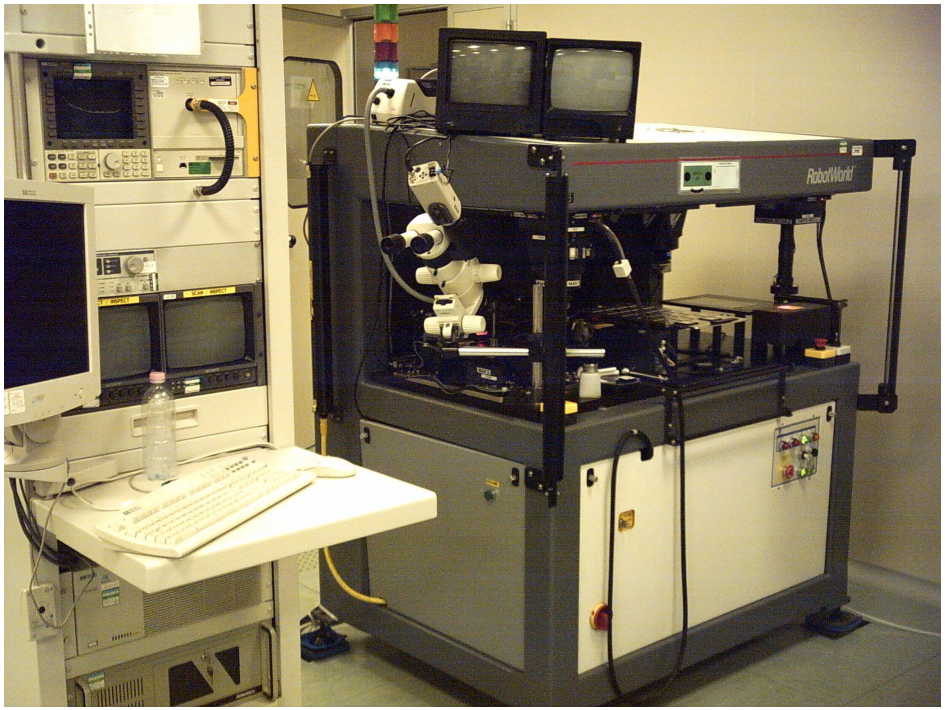


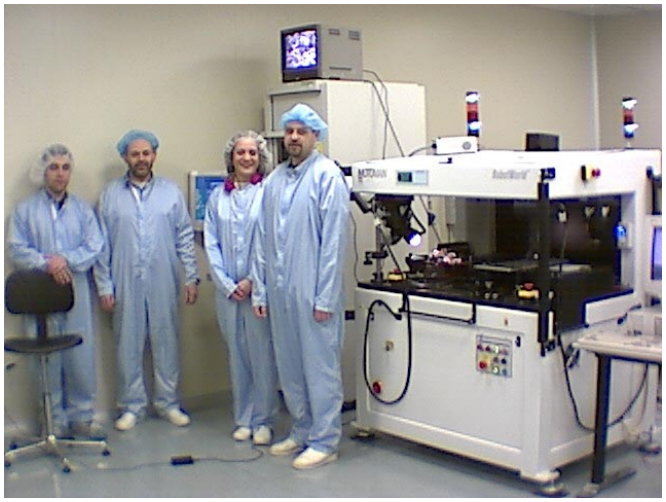
(5) From wafers to chips

⇒Testing/screening ⇒



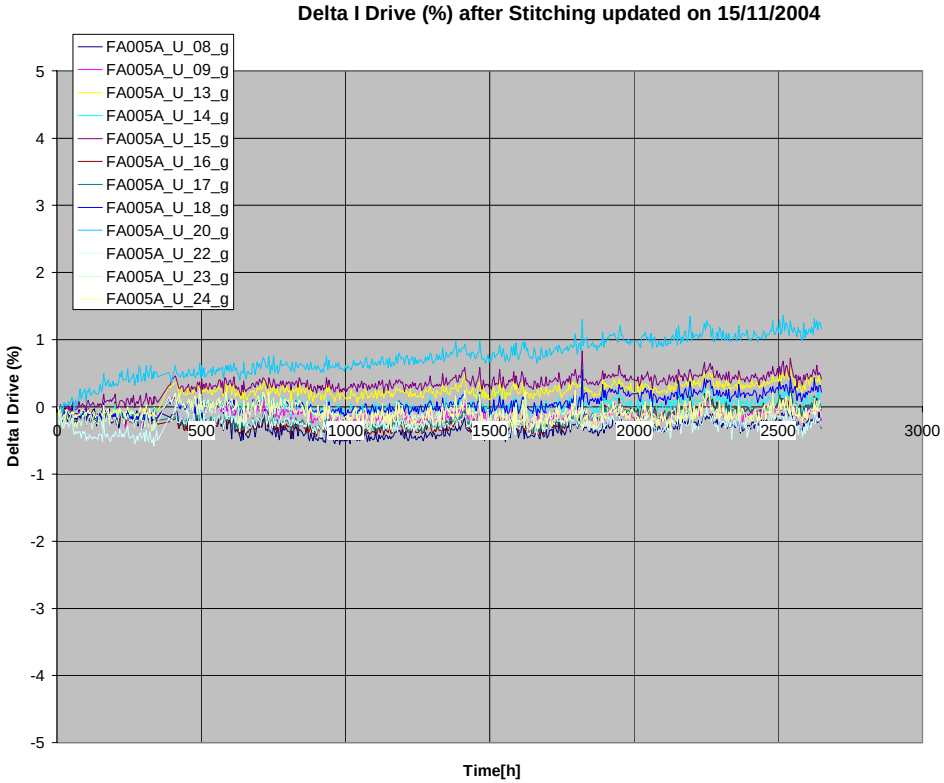
Statistics of main parameters





(6) Automatic selection of chips…

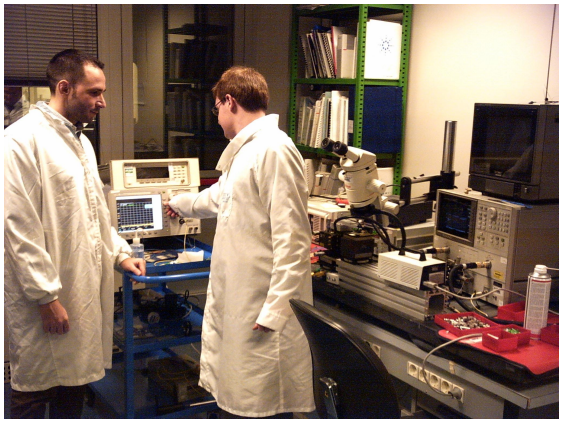
⇒ Reliability ⇒

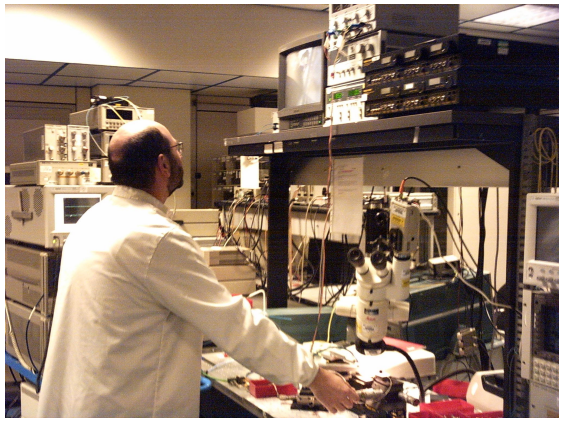


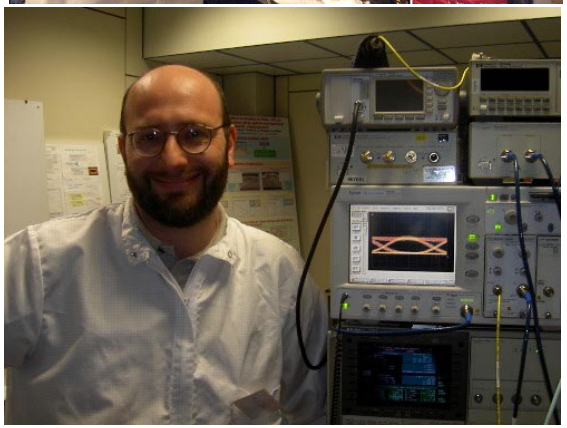
Monitoring of chip parameters in accelerated tests (high T)

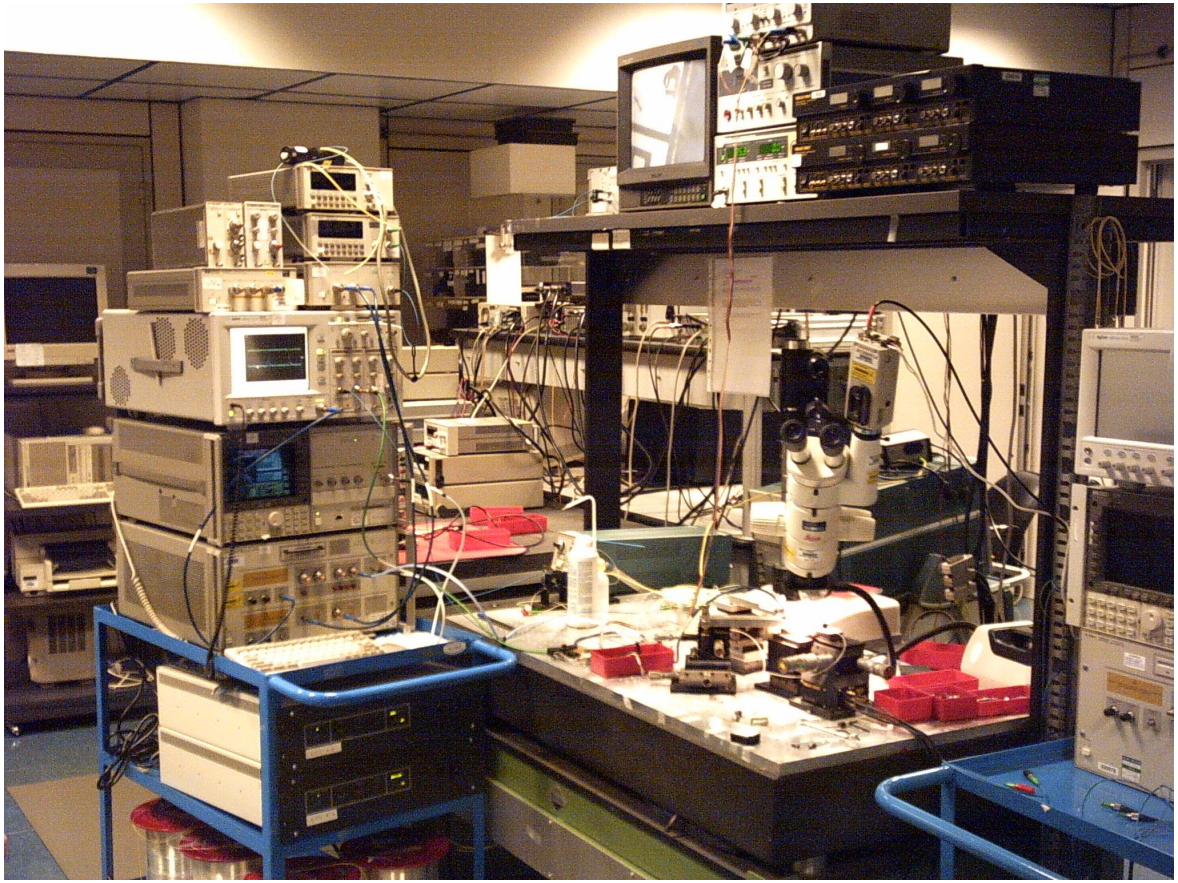
(7) Life Time evaluation of chips…

⇒ Characterization ⇒



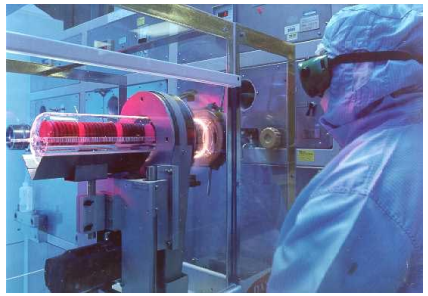






(8) Measurements of static and dynamic characteristics…

⇒ Release to Manufacturing



Singapore Avago Manufacturing Site

- Volume
- Cost
- Return Of Invested Capital
- Link with R&D

The end!

- **Books**
  - G. Guekos, *Photonic Devices*, Springer, 1999, ISBN 3-540-64318-4
  - L. A. Coldren, S. W. Corzine, "*Diode lasers and photonic integrated circuits*", John Wiley and sons, inc.,
  - P. Vasil'ev, "U*ltrafast diode laser*", Artec House Boston-London
  - K. Petermann, "Laser Diode Modulation" and Noise, Dordrecht, The Netherlands: Kluwer Academic Publishers
- **Related published paper**
  - F. Delpiano, R. Paoletti, P. Audagnotto and R. Puleo, "High Frequency Modelling and Characterisation of High Performance DFB Laser Modules", *IEEE Transaction on Components, Hybrids, and Manufacturing Technology,* Part B, Vol. 17, No 3, pp. 412-417, august 1994.
  - R. Paoletti, D. Bertone, A. Bricconi, R. Fang, L. Greborio, G. Magnetti, M. Meliga, "Comparison of Optical and Electrical Modulation Bandwidths in three different 1.55 μm InGaAsP Buried Laser Structures", *SPIE'S International Symposia - Photonics West '96*, pp. 296-305, 30 Jan. - 1 Febr. 1996, S. Josè, CA, USA.
  - R. Paoletti, M. Meliga, I. Montrosset, "Optical Modulation Technique for Carrier Lifetime Measurement in Semiconductor Lasers", *IEEE Photonics Technology Letters*, Vol. 8, No. 11, pp. 1447-1449, November 1996.
  - R. Paoletti, M. Meliga, G. Oliveti, M. Puleo, G. Rossi, L. Senepa, "10 Gbit/S Ultra-Low Chirp 1.55μM Directly Modulated Hybrid Fiber Grating - Semiconductor Laser Source", *23rd European Conference on Optical Communication ECOC '97*, Mo 3B. 22-25 September 1997, Edimburgh (UK).
  - R. Y. Fang, D. Bertone, M. Meliga, Montrosset*, S. Murgia, G. Morello, G. Magnetti, G. Oliveti, R. Paoletti, "A simple structure 1.55 μm InGaAsP/InP Spot Size Converted (SSC) laser", *IEEE Photonics Technology Letters*, Vol. 10, No. 6, pp. 775-777, June 1998.
  - G. Rossi, R. Paoletti, M. Meliga, "SPICE simulation for analysis and design of fast 1.55 μm MQW laser diodes", *IEEE Journal of Lightwave Technology*, Vol. 16, No. 7, July 1998.
  - R. Paoletti, M. Agresti, G. Burns, G. Berry, D. Bertone. P. Charles, P. Crump, A. Davies, R.Y. Fang, R. Ghin, P. Gotta, M. Holm, C. Kompocholis, G. Magnetti, J. Massa, G. Meneghini, G. Rossi, P. Ryder, A. Taylor, P. Valenti and M. Meliga, "100 °C, 10 Gb/s directly modulated InGaAsP DFB lasers for uncooled Ethernet applications", post-deadline at *European Conference on Optical Communication ECOC '2001,* October 2001,Amstedam (NL).
  - R. Paoletti, M. Meliga, "Uncooled, high speed DFB lasers for Gigabit Ethernet applications", invited paper at *SPIE'S International Symposia - Photonics West Optoelectronics 20021*, 19 - 25 Jan. 2002, S. Josè, CA, USA.
  - R. Paoletti, C. Coriasso, M. Agresti, P. Gotta, G. Magnetti, A. Moro, D. Sarocchi, D. Soderstrom, C. Cacciatore, L. Fratta, M. Vallone, A. Stano, E. Liotti, P. Valenti, G. Roggero, G. Fornuto, G. Burns, R.Harrell, P. Charles, D. Clark, G. Berry and M. Meliga, "Small chip size, low power consumption, fully electronic controlled tunable laser source with 40 nm tuning range and 20 mW output power for WDM applications", ECOC 2003, 21 - 25 Sept. 2003, Rimini, Italy
  - R. Paoletti, M. Agresti, D. Bertone, L. Bianco, C. Bruschi, A. Buccieri, R. Campi, C.Dorigoni, P. Gotta, M. Liotti, G. Magnetti, P. Montangero, G. Morello, C. Rigo, E. Riva, D. Soderstrom, S. Stano, P. Valenti, M. Vallone, M. Meliga" Highly reliable and high yield 1300 nm InGaAlAs directly modulated ridge Fabry-Perot lasers, operating at 10 Gb/s, up to 110 ºC, with constant current swing ", Post deadline at Optical Fiber Conference OFC 2005, Anaheim (CA)