

Laser and System Technologies for Access and Datacom

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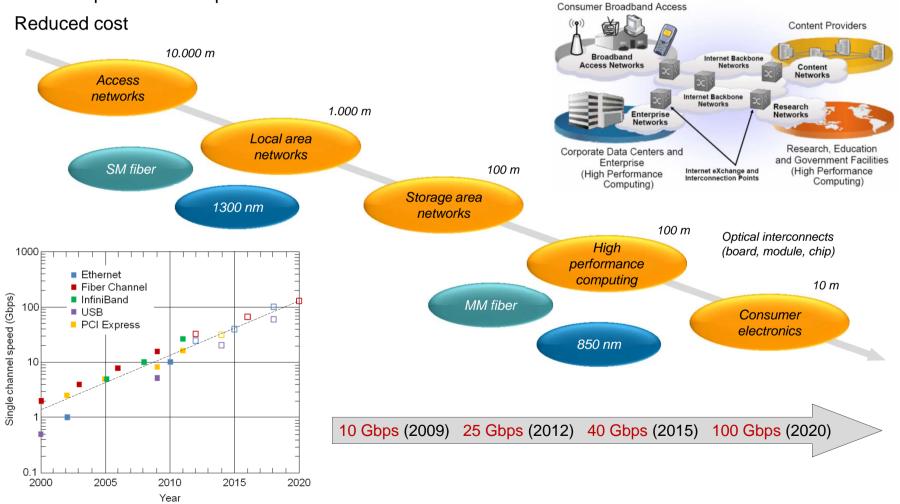
Outline

- Background and motivation
- Objectives and goals
- Partners, organization and tasks
- Results and achievements
- Industrial collaboration and exploitation



Background and motivation

- Need for much higher communication and interconnect capacity at the lower levels of the network
- Reduced power consumption





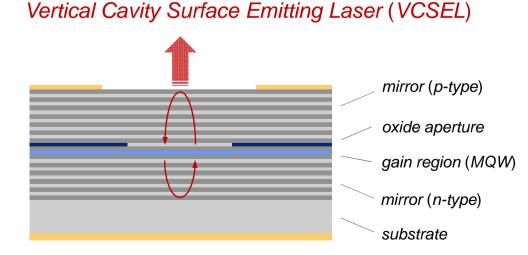
Objectives and goals

Objectives

To develop new laser and system technologies for a significantly increased data throughput and efficiency of short to medium distance optical links

Goals

- GaAs-based 850 nm multimode VCSELs for direct binary (OOK) modulation at 40 Gbps
- GaAs-based 1300 nm single-mode VCSELs for direct binary (OOK) modulation at 25 Gbps
- New modulation formats for extending the link reach and capacity towards 100 Gbps



- Low drive current (a few mA)
- Low output power (a few mW)
- High efficiency (up to 60%)
- Low divergence, circular beam
- High speed modulation at low currents
- Low manufacturing cost (on-wafer testing)
- Array integration (1D and 2D)



Partners, organization and tasks

Partners

- Optoelectronics Group, Chalmers University of Technology (Anders Larsson)
- Semiconductor Materials Group, Royal Institute of Technology (Mattias Hammar)
- Optical Communications Group, Chalmers University of Technology (Peter Andrekson)
- TE Connectivity (Olof Sahlén)
- Ericsson (Arne Alping)

Work packages

- Short wavelength (850 nm) MM-VCSELs (Anders Larsson)
- Long wavelength (1300 nm) SM-VCSELs (Mattias Hammar)
- Modulation formats, electronic compensation and system evaluation (Peter Andrekson)

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Short wavelength (850 nm) MM-VCSELs (1)

Target performance

- Emission wavelength
 840 860 nm (high speed MMF)
- Modulation speed
 25 Gbps (year 2), 40 Gbps (year 5)

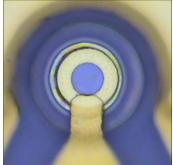
85°C

Operating temperature

Design for high speed and high efficiency

- Strained InGaAs/AlGaAs quantum wells (high differential gain)
- SCH for fast carrier capture (low gain compression)
- Reduced photon lifetime (low damping)
- Graded interfaces and modulation doping in mirrors (low resistance)
- Multiple oxide layers, undoped substrate, BCB under bond pad (low capacitance)
- Binary compound (AIAs) in bottom mirror (low thermal impedance)





26mm



Short wavelength (850 nm) MM-VCSELs (2)

450 fJ per bit

0 -1

1

log(BER)

-8

40 Gbit/s

First datacom

at 40 Gbps

25 Gbit/s

Performance

-4 log(BER) 9-

-8

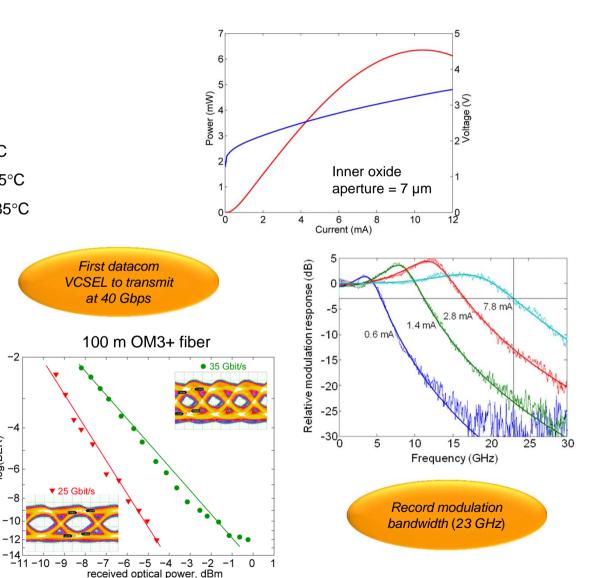
▲ 25 Gbit/s

-14 -11-10-9-8-7-6-5-4-3-2

received optical power, dBm

- Low threshold current (0.4 mA)
- High differential efficiency (1.0 W/A)
- 23 GHz modulation bandwidth
- 40 Gbps transmission over 1 m MMF@ 25°C
- 35 Gbps transmission over 100 m MMF@ 25°C
- 25 Gbps transmission over 100 m MMF @ 85°C

1 m OM3+ fiber





Long wavelength (1300 nm) SM-VCSELs (1)

Target performance

- Emission wavelength 1260 1350 nm
- Output power
- Modulation speed
- Operating temperature
- 12.5 Gbps (year 2), 25 Gbps (year 5) 85°C

Top dielectric DBR

Cavity (p-type)

Quantum wells

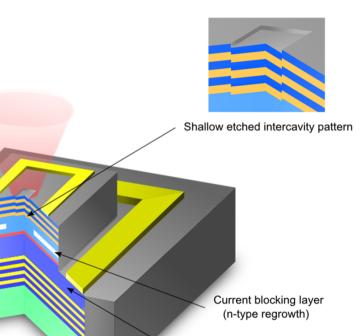
Bottom DBR

New concept for electrical and optical confinement

Design for long wavelength single-mode emission and high speed

2 mW

- Strained InGaAs/GaAs quantum wells (high differential gain)
- Large negative gain-cavity detuning (to approach 1300 nm)
- Epitaxial regrowth process for current and optical confinement
- Single-mode emission enforced by shallow intra-cavity pattern



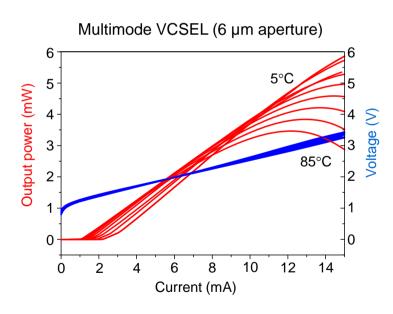
Cavity (n-type)

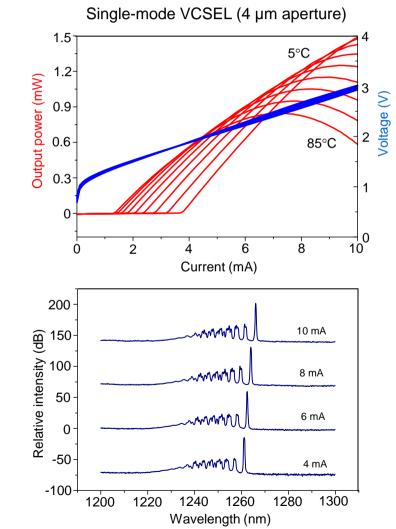


Long wavelength (1300 nm) SM-VCSELs (2)

Performance

- 8 mW multimode power
- 1 mW single mode power
- 10 Gbps transmission over 5 km SMF @ 25°C







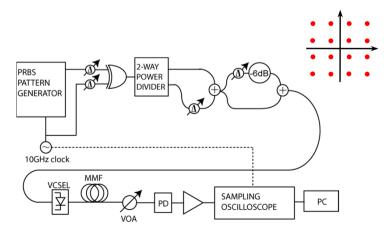
Advanced modulation formats (1)

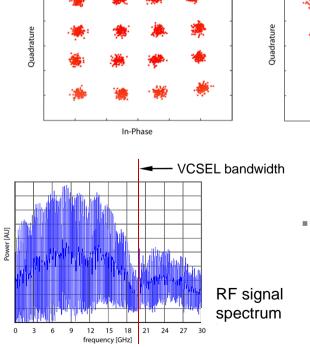
Multilevel modulation formats for improved capacity and reach of intensity modulation/direct detection (IM/DD) links

- Improved spectral efficiency
- Increased requirements on laser linearity and noise
- Trade-off between capacity/reach and complexity/power consumption

Single – cycle subcarrier modulation (SCM)

- 16-QAM, 4 bits per symbol
- 10 Gbaud = subcarrier frequency (10 GHz)
- 40 Gbps transmission
- 20 GHz bandwidth 850 nm MM-VCSEL
- 200 m OM3+ fiber (23 GHz bandwidth)





Back-to-back

 Extended reach compared to OOK-NRZ modulation

200 m MMF

In-Phase

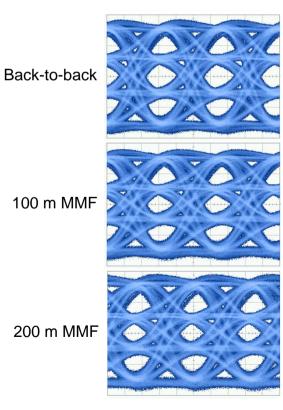


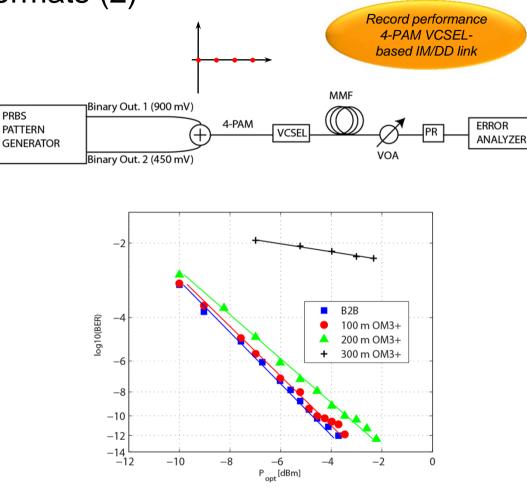
Advanced modulation formats (2)

PRBS

4-level pulse amplitude modulation (4-PAM)

- 4 levels, 2 bits per symbol
- 15 Gbaud
- 30 Gbps transmission
- 16 GHz bandwidth 850 nm MM-VCSEL
- 200 m OM3+ fiber (23 GHz bandwidth)





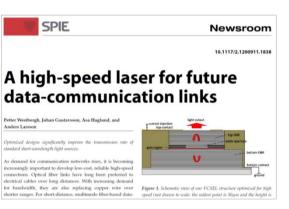
- Extended reach compared to OOK-NRZ modulation
- Low system complexity (low cost, low power consumption)

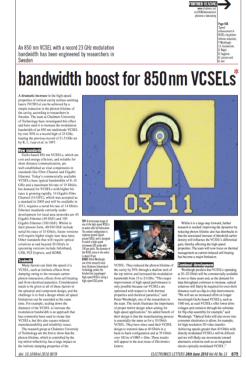


Publications, presentations and patents

- 13 journal papers (4 invited)
- 15 conference presentations (6 invited)
- 1 licentiate thesis (Petter Westbergh)
- 2 patent applications







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electrically pumped lasing Extended VCSEL wavelengths offer gas sensing source RELATED LINKS	will have to be scaled down in size to achieve the modulation bandwidth needed, thus operating at current densities too high for reliable operation. Eye diagram	



Acknowledgment

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