CHALMERS
UNIVERSITY OF TECHNOLOGY

Laser and System Technologies for Access and Datacom

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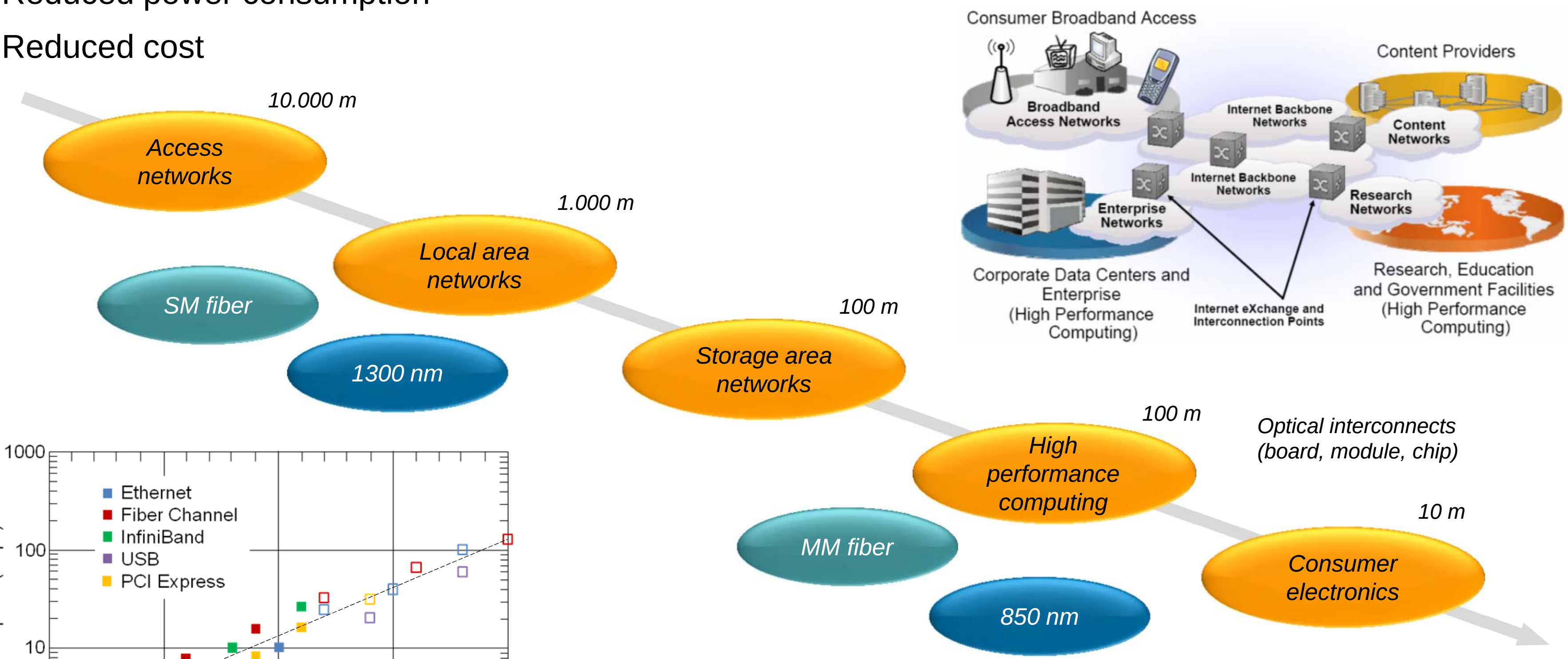
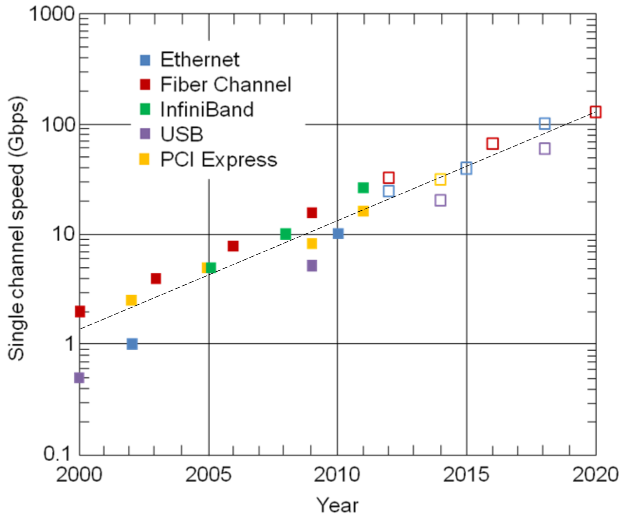
Outline

- 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
- Reduced cost





10 Gbps (2009) 25 Gbps (2012) 40 Gbps (2015) 100 Gbps (2020)

Objectives and goals

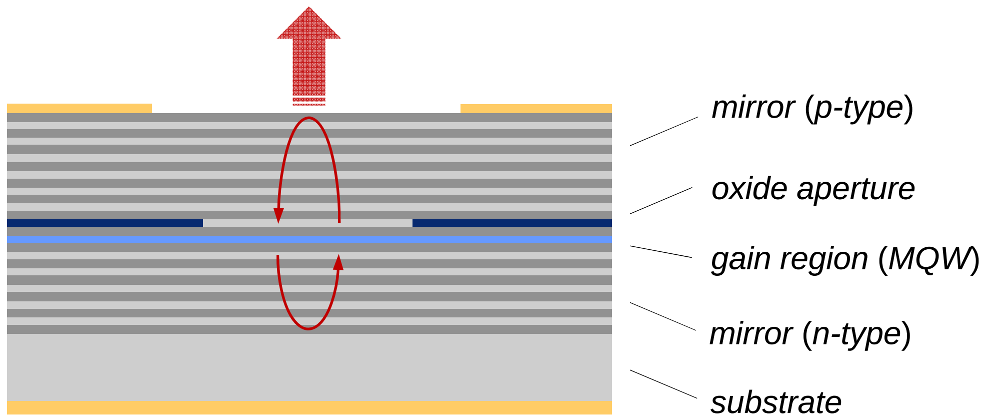
Objectives

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

Vertical Cavity Surface Emitting Laser (VCSEL)



- *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)

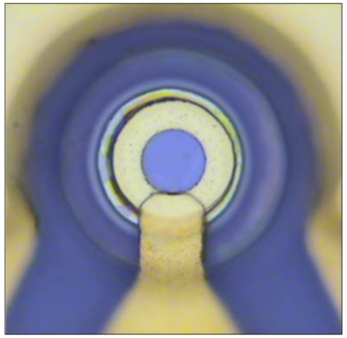
Short wavelength (850 nm) MM-VCSELs (1)

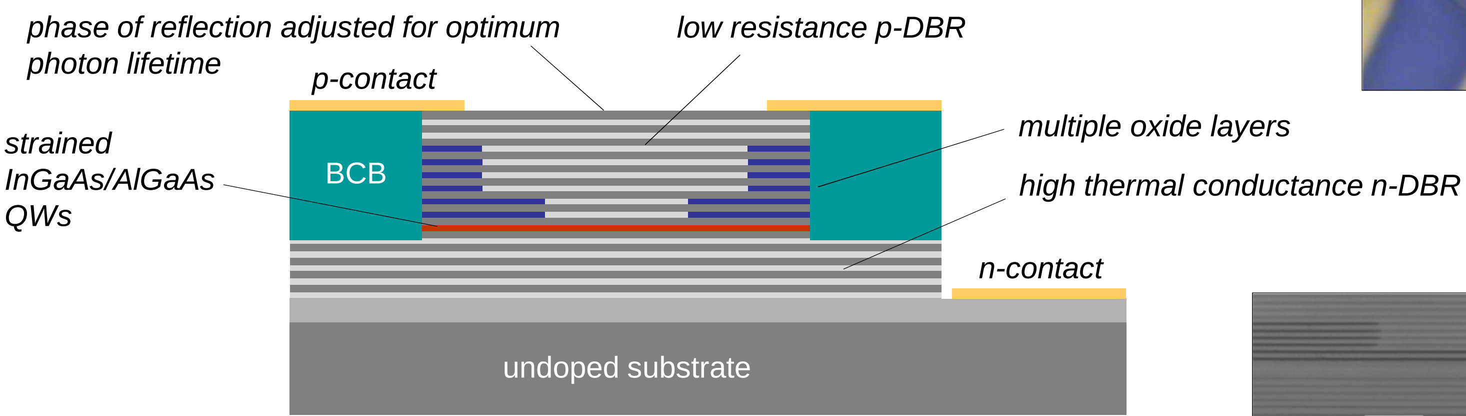
Target performance

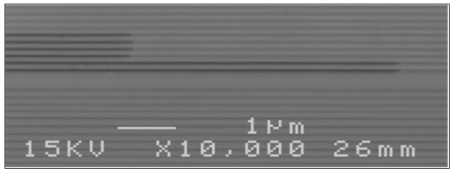
- Emission wavelength 840 – 860 nm (high speed MMF)
- Modulation speed 25 Gbps (year 2), 40 Gbps (year 5)
- Operating temperature 85°C

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 (AlAs) in bottom mirror (low thermal impedance)



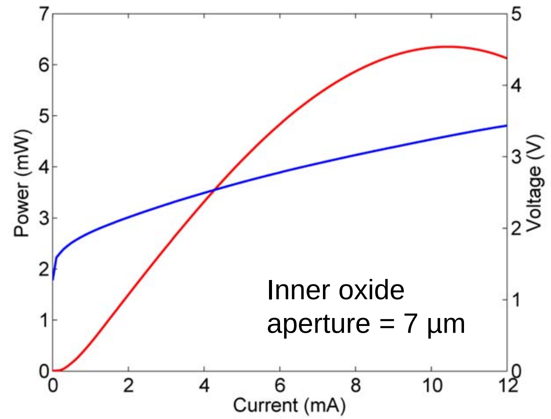


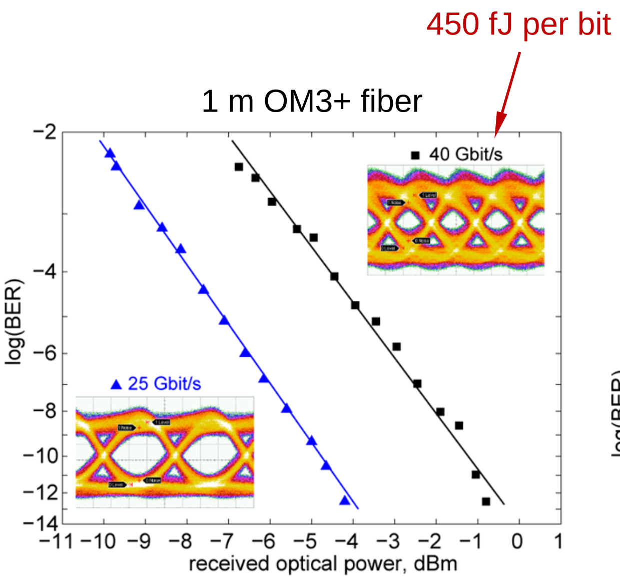


Short wavelength (850 nm) MM-VCSELs (2)

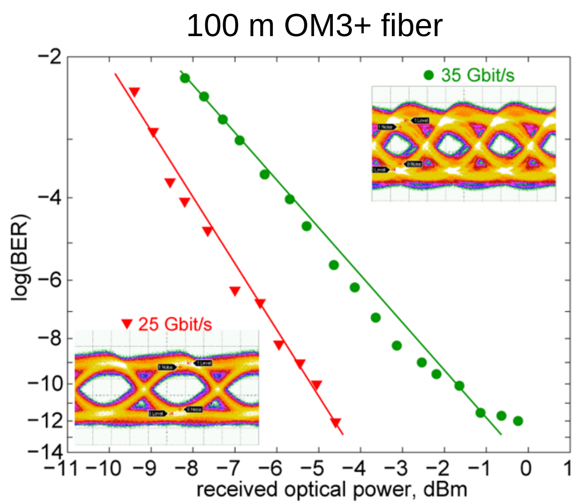
Performance

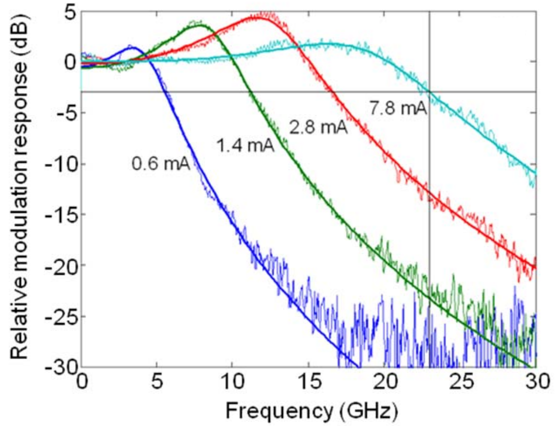
- Low threshold current (0.4 mA)
- High differential efficiency (1.0 W/A)
- 23 GHz modulation bandwidth
- 40 Gbps transmission over 1 m MMF@ 25°C
- 35 Gbps transmission over 100 m MMF@ 25°C
- 25 Gbps transmission over 100 m MMF @ 85°C





First datacom VCSEL to transmit at 40 Gbps





Record modulation bandwidth (23 GHz)

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

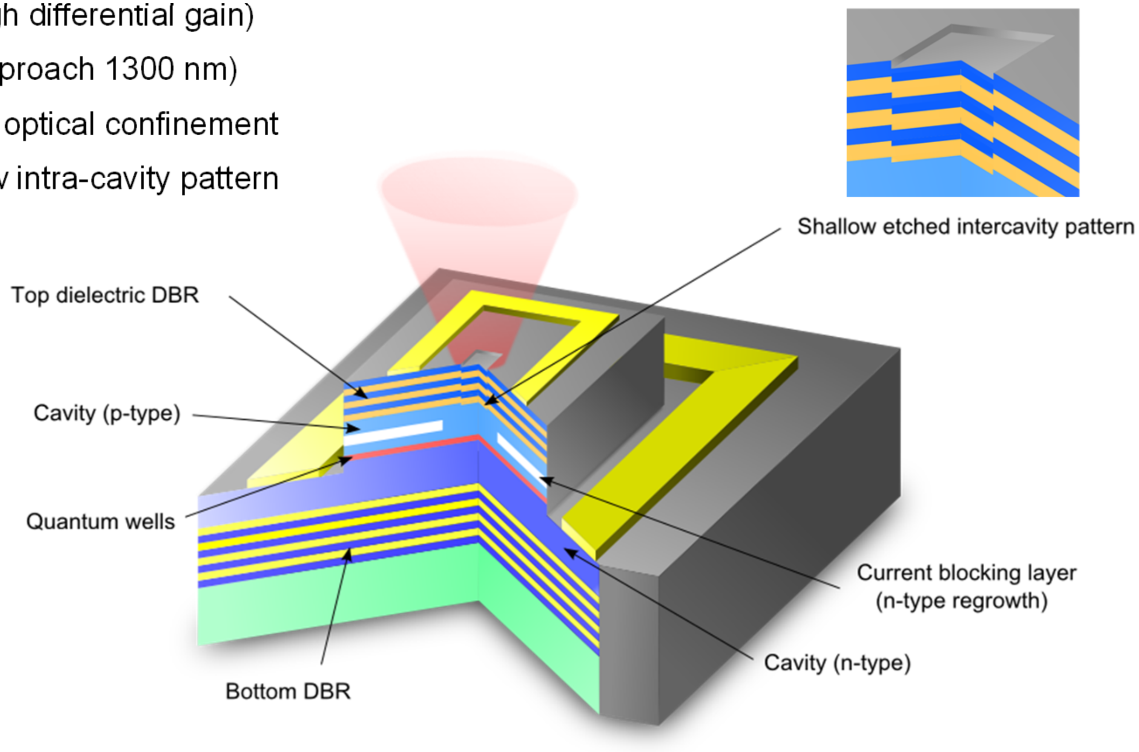
Target performance

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

New concept for electrical and optical confinement

Design for long wavelength single-mode emission and high speed

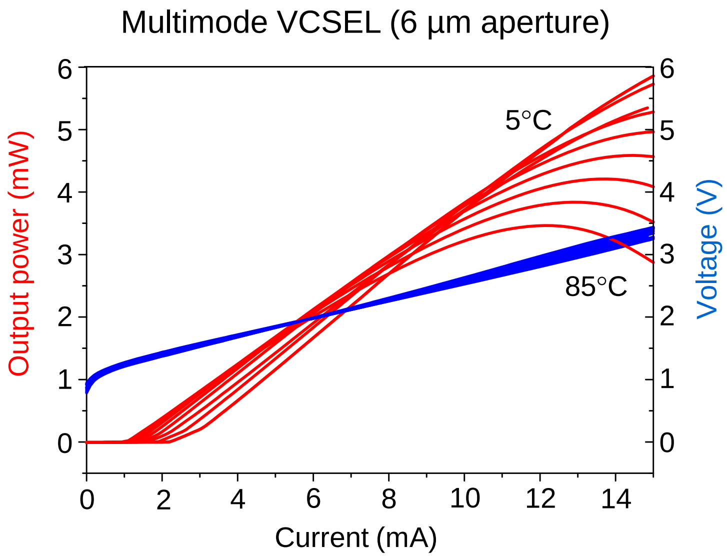
- Strained InGaAs/GaAs quantum wells (high differential gain)
- Large negative gain-cavity detuning (to approach 1300 nm)
- Epitaxial regrowth process for current and optical confinement
- Single-mode emission enforced by shallow intra-cavity pattern

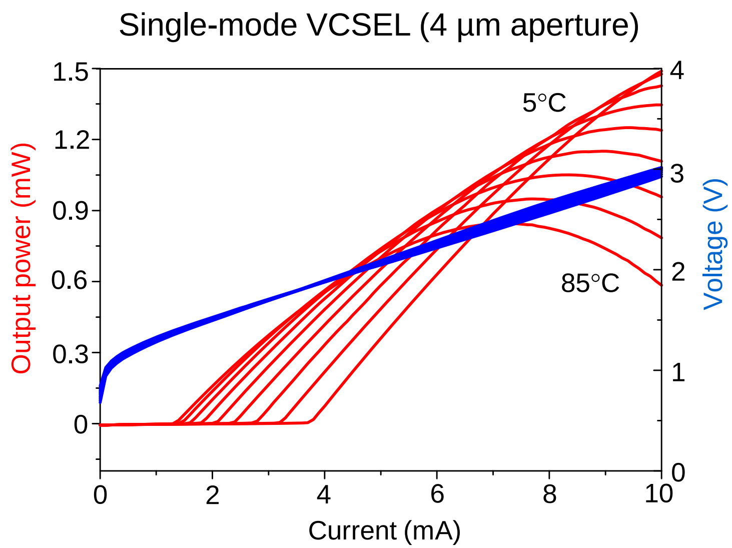


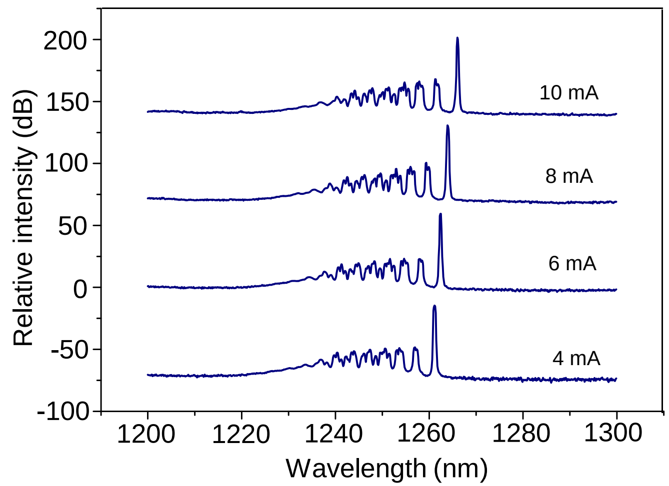
Long wavelength (1300 nm) SM-VCSELs (2)

Performance

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







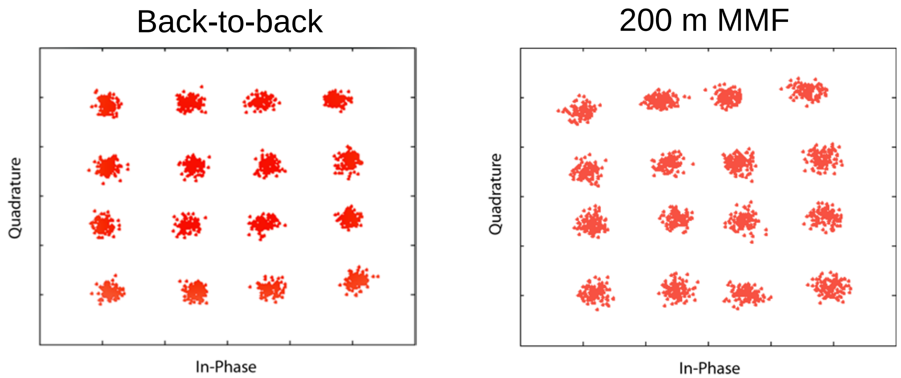
Advanced modulation formats (1)

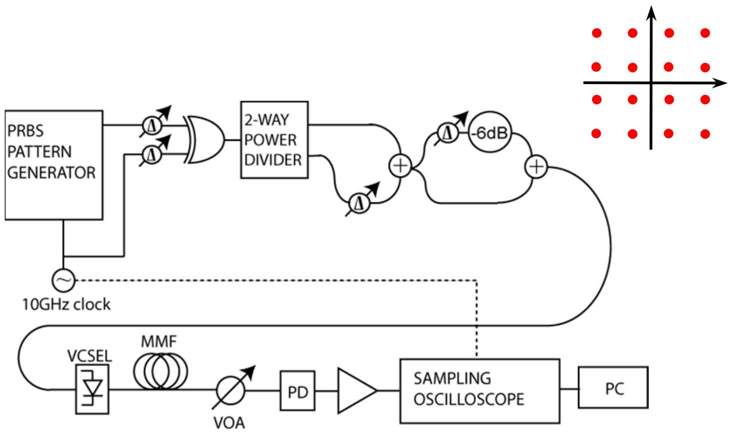
Multilevel modulation formats for improved capacity and reach of intensity modulation/direct detection (IM/DD) links

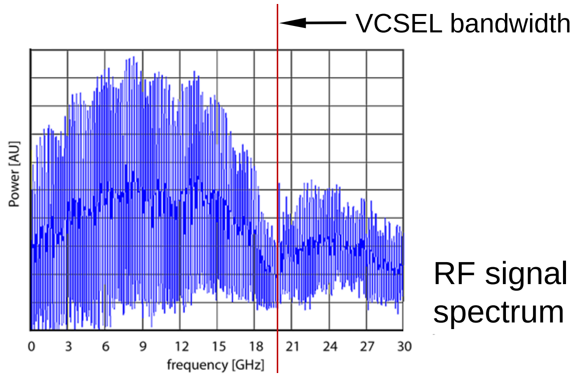
- Improved spectral efficiency
- Increased requirements on laser linearity and noise
- Trade-off between capacity/reach and complexity/power consumption

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)







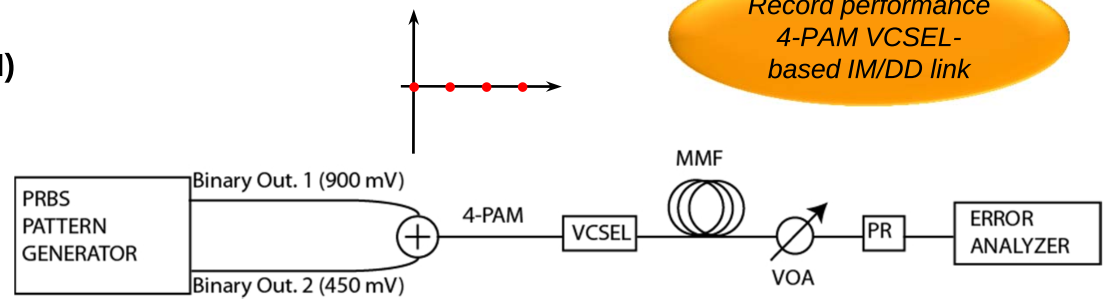
- Extended reach compared to OOK-NRZ modulation

Advanced modulation formats (2)

Record performance 4-PAM VCSEL-based IM/DD link

4-level pulse amplitude modulation (4-PAM)

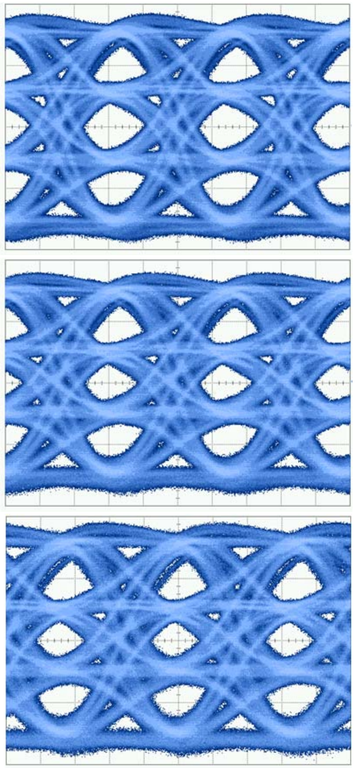
- 4 levels, 2 bits per symbol
- 15 Gbaud
- 30 Gbps transmission
- 16 GHz bandwidth 850 nm MM-VCSEL
- 200 m OM3+ fiber (23 GHz bandwidth)

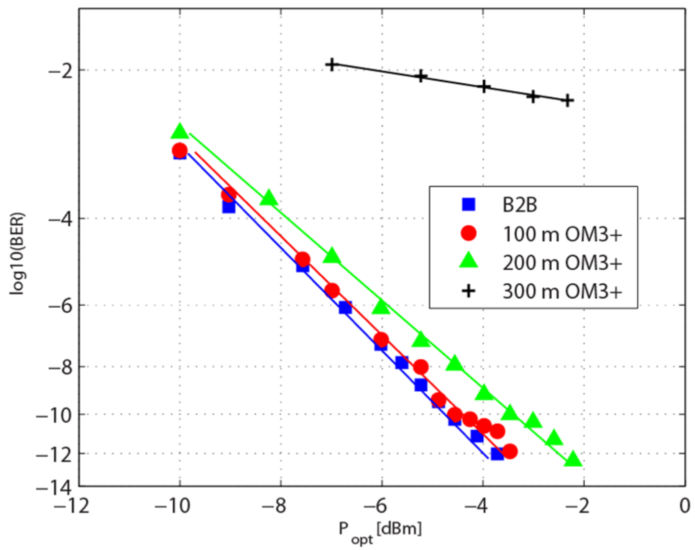


Back-to-back

100 m MMF

200 m MMF

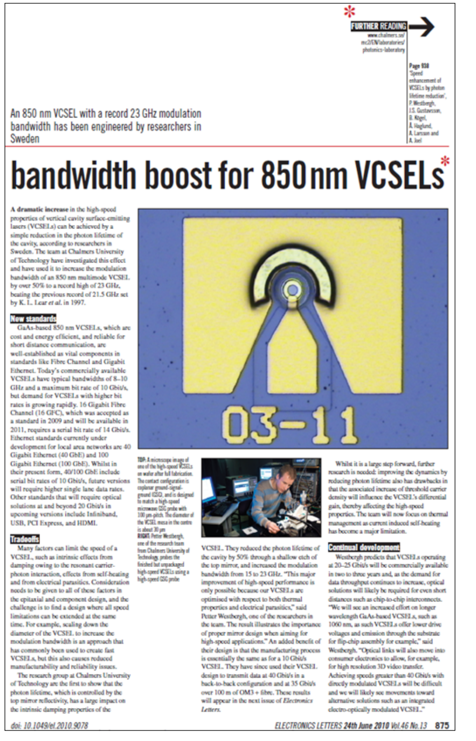


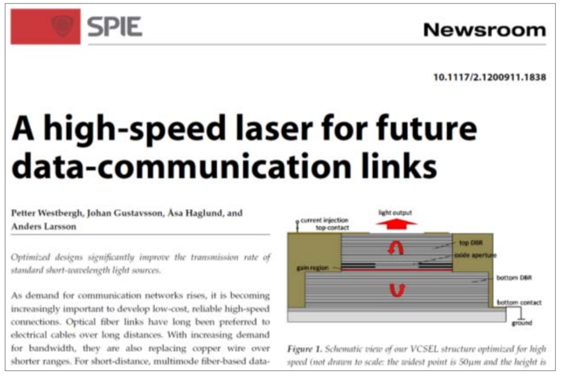


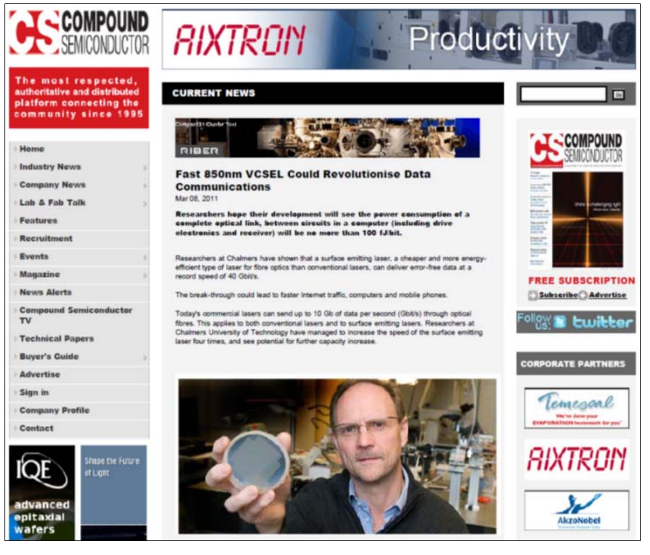
- Extended reach compared to OOK-NRZ modulation
- Low system complexity (low cost, low power consumption)

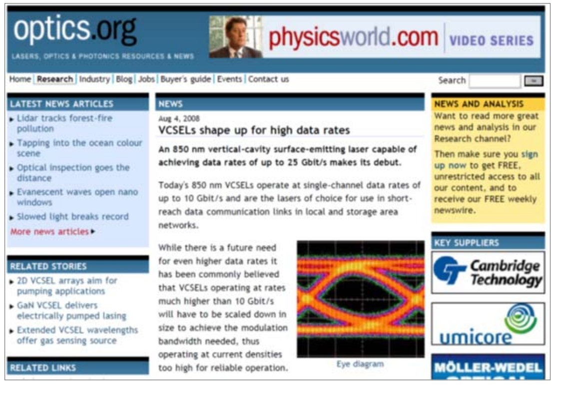
Publications, presentations and patents

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









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