SIXTH FRAMEWORK PROGRAMME
PRIORITY 2
IST

SPECIFIC TARGETED RESEARCH OR INNOVATION PROJECT

Project Summary

Project acronym: MOSEL
Project full title: Monomode Surface Emitting Lasers
Contract no.: 035183
Start date of contract: *01/06/2006*

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1 Project summary

Vertical cavity surface emitting lasers (VCSELs) have several particular advantages over the edge emitting lasers (EEL) for replacing them in optical communications applications, as the possibility of wafer-level testing during the fabrication process as well as facilitated optical coupling and overall module packaging. Nevertheless, major improvements should be brought to the existing VCSELs before they become widely used in high speed optical datacom links. Among existing limitations, a limited power delivered by high speed (10 Gbit/s and up) transversely monomode VCSELs. This limitation may be issue for the introduction of VCSELs in FTTx devices, especially in Passive Optical Networks where the power launched into the fiber must be rather high.

Hence, mode size and polarization control are the key issues in design of high performance VCSELs. Introducing elements of photonic crystal is an efficient way to increase the mode size while maintaining or even improving operating characteristics

In the present project, we aim to achieve an overall improvement of the VCSELs performances using micro and nanoscale patterning. The novel cavity configurations explored will allow:

- to increase the size (and thus the power) of the fundamental transverse mode of the VCSEL
- to keep the laser transversely monomode at much larger current ranges
- through the latter, to improve the modulation speed of the lasers
- to control the polarisation of the emitted beam in temperature range and under modulation

Two general geometrical configurations, patterning of the mirrors and patterning of the cavity close to the active layer will be explored.

The objective of the project is to demonstrate a configuration of the vertical cavity that would allow a 10-fold improvement in the monomode powers over the conventional VCSEL structures operating at 850, 1310 and 1550 nm. This improvement should be obtained while keeping appreciable modulation speed (10 Gbit/s) and a single polarisation.
The final target of the MOSEL project is to demonstrate two kinds of sources emitting at a wavelength above 1260nm:

- a fiber-coupled VCSEL with an output power of 1 mW at 2.5 Gb/s.
- a fiber-coupled VCSEL with an output power of 0.5 mW at 10 Gb/s.

2 Project Objective(s)

Electrical interconnects (from inter-board to local networks) are currently reaching their limits in terms of the bandwidth. To replace the copper wires, the optical solutions should be affordable and should be compatible with mass production. On the transmission side, the vertical cavity surface emitting lasers (VCSELs) fulfil these two requirements. The VCSELs have two particular advantages over the edge emitting lasers. The possibility of wafer-level testing during the fabrication process radically decreases the production costs of the laser components. The mode size of the VCSELs is close to that of monomode optical fibers, that facilitates the optical coupling and the overall module packaging. Nevertheless, several major improvements should be brought to the existing VCSELs before they become widely used in high speed optical datacom links. Among existing limitations, a limited power delivered by high speed (10 Gbit/s and up) transversely monomode VCSELs. The power limitation may be an issue for the introduction of VCSELs in FTTx devices, especially in Passive Optical Networks where the power launched into the fiber must be rather high.
Hence, mode size and polarization control are the key issues in design of high performance VCSELs. As state of the art VCSEL already are operating at current densities of tens of kA/cm2, the way to further increase output power is to increase current aperture size, i.e. area. Increasing diameter from 7 to 9 micron provides active area increasing 2 times, with the same injection current density one can have twice as much power, but with existing VCSEL technology is not possible to maintain single mode regime Introducing elements of photonic crystal is an efficient way to increase the mode size of the VCSEL while maintaining or even improving operating characteristics
For high speed datacommunications where VCSELs could eventually replace the existing EEL, another limitation is the modulation bandwidth, as well as the control of the polarisation of the emitted beam. Yet additional limitation concerns relative difficulty in achieving the 1.5 µm wavelength bandwidth.

In the present project, we aim to achieve an overall improvement of the VCSELs performances using micro and nanoscale patterning. The novel cavity configurations explored will allow:

- to increase the size (and thus the power) of the fundamental transverse mode of the vertical cavity surface emitting lasers
- to keep the laser transversely monomode at much larger current ranges
- through the latter, to improve the modulation speed of the vertical lasers
- to control the polarisation of the emitted beam in temperature range and under modulation

The essence of the project is to introduce in VCSEL architecture elements of photonic crystal in order to benefit from it in VCSEL technology in the same way as optical fiber technology have benefited. In other words, we have to modify essential parts of the VCSEL: DBRs, QWs, optical aperture, current injection scheme following the logic of photonic crystal. It is clear that one can introduce these elements in top DBR, bottom DBR, in active region or at the interfaces between them. It is the goal of the project to find the optimal position, size and configuration of photonic crystal elements for VCSELs dedicated to chosen application.

We can loosely group all the physical possibilities we are to explore (through numerical modelling, fabrication and tests) into two general geometrical configurations:

- patterning of the mirrors
- patterning of the cavity close to the active layer

Both of these two main approaches are currently considered as very promising, with continuous significant improvements in obtained performances. The first one is expected to have a shorter time to the market, since it is closer to the commonly used VCSELs fabrication processes. The second one is more prospective but could potentially be more advantageous. Some of the principles of both architectures, as well as the numerical simulations necessary for the device development, are very similar. The architectures explored share many common physical principles, as well as the numerical simulations that are necessary for the device development.

The **first phase** of the project will last for two years, when both the architectures (with two to three particular configurations tested in each architecture) will be explored. Then an important milestone and **decision point** will occur at the end of the second year, where one or two most promising cavity configurations will be identified:

- One will be chosen with respect of the maximal monomode output power provided in low speed modulations (<2.5 Gbit/s)
- another one should provide maximal monomode power at high modulation speeds (>10 Gbit/s).

Ideally, the same cavity concept would suit both classes of applications, but this issue is not guaranteed.

Then in the **second phase** the development will focus on the selected VCSEL configurations in order to practically demonstrate a radical improvement in terms of performances over all the existing long wavelength vertical cavity lasers. Particularly, the application of the VCSELs in high speed short reach data links will be aimed.

During the first year of the phase 1, the work will focus on structures emitting in the 850 nm range. The VCSELs at 850 nm is a well established technology. This choice of a high gain material will allow rapid prototyping of the proposed novel cavity configurations. But this wavelength band is of high interest for multiple applications[1].

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[1] Due to the readily available materials technology at 850 nm a rapid start on the device work can be ensured. In this phase of the project materials from commercial foundries will be used to ensure a good basis for comparison across the different device strategies. The 850 nm technology is well established in the data communication sector where a transition to 10 Gb/s is expected to take place within the next few years. However, some indication from the market seems to indicate reliability issues with the 10 Gb/s VCSELs and argue that this is related to the very small oxide apertures necessary to increase the photon density for these multimode devices to reach 10 Gb/s operation. More ideally one would use single mode devices since all photons will be in one mode to reach high speed. However, traditional

The objective of the project is to demonstrate a configuration of the vertical cavity that would allow a 10-fold improvement in the monomode power over the conventional VCSEL structures operating at 850, 1310 and 1550 nm. Two goals will be followed corresponding to two different application fields:

- **The first goal is to achieve high power while keeping appreciable modulation speed (< 2.5Gb/s). Applications as PON networks for FTTx or high performance printing are targeted.**
- **The second goal is to achieve high modulation speed (> 10 Gb/s) while obtaining high average power**

These improvements should be obtained while keeping a single polarisation.

The final target of the MOSEL project is to demonstrate two kinds of VCSELs emitting at a wavelength above 1260nm with the following performances:

- **an output power of 2 mW at 2.5 Gb/s, leading to an output power of 1 mW after launching in a single mode fiber.**
- **an output power of 1 mW at 10 Gb/s, leading to an output power of 0.5 mW after launching in a single mode fiber.**

The different deliverables of the project will include:

- The demonstration of generic building blocks including:
  - VCSEL mode confinement by different methods
  - VCSEL polarisation control
  - PC mirror demonstration
- Demonstration of high-power and /or high bandwidth VCSEL coupled into a SMF

The VCSELs that will be demonstrated in this project are expected to be fully compatible with advanced packaging techniques such as flip-chip. Some of the partners of MOSEL are already using flip-chip for assembling and alignment of VCSELs with respect to optical fiber. Attention will be paid during the project to the compatibility of the laser sources with flip-chip assembly. In order to reduce the overall cost of the project, the coupling of the VCSEL in a SMF will be made on a laboratory workbench rather than using flip-chip on a microbench.

3 Participants list

Partic. Role	**Partic. No.**	**Participant name**	**Participant short name**	**Country**	**Date enter project**	**Date exit project**
CO	1	CEA-LETI	CEA	F	Month 1	Month 36
CR	2	Alight	AL	DK	Month 1	Month 36
CR	3	BeamExpress	BX	CH	Month 1	Month 36
CR	4	EPFL	EPL	CH	Month 1	Month 36
CR	5	INTEXYS	ITX	F	Month 1	Month 36
CR	6	KTH	KTH	S	Month 1	Month 36
CR	7	COM/Technical University of Denmark	COM	DK	Month 1	Month 36

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single mode devices at 850 nm have suffered from even smaller oxide apertures with bad reliability and high differential resistance as a result. Large aperture single mode devices have advantages for both high speed operation and good reliability due to the larger oxide apertures. High power at 850 nm in it self is not required for the high speed devices since these are for short distances which are set by the fiber dispersion and the need for eye-safe operation. However, in the low speed segment of the market a number of emerging applications is waiting for a cheap high-power single-mode laser that’s naturally arrayable. Amongst these is high-performance printing where power levels of 10 mW are needed.