Monolithically integrated 850-nm VCSEL / Electro-Absorption Modulator structures grown by MBE
Lucas Laplanche, Alexandre Arnoult, Quentin Gravelier, Stéphane Calvez, Christophe Viallon, Guilhem Almuneau

To cite this version:
Lucas Laplanche, Alexandre Arnoult, Quentin Gravelier, Stéphane Calvez, Christophe Viallon, et al.. Monolithically integrated 850-nm VCSEL / Electro-Absorption Modulator structures grown by MBE. 22nd International Conference on Molecular Beam Epitaxy (ICMBE 2022), Sep 2022, Sheffield, United Kingdom. 2022. hal-03727282

HAL Id: hal-03727282
https://hal.laas.fr/hal-03727282
Submitted on 30 Aug 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
**High-speed VCSEL applications:***
- Short-reach optical links in Datacenters, supercomputers,..
- LDAR (3D imaging), mobiles >>> 940 nm-arrays
- Optical cables (USB, video)
- Wireless optical links (OWC)
- System on Chip (SoC)
- Quantum computing (Cryogenic readout circuit)

**Double microcavity resonant system:**
Frequency modulation response, is correlated to the optical coupling between VCSEL and EAM cavities (K. Panajotov et al. doi.org/10.3390/app10176128)

- **Strong coupling** disrupts the VCSEL CW emission
- **Moderate coupling** gives maximized frequency bandwidth
- **Weak coupling** results in small modulation contrast

**In-situ measurement methods implemented:**
- Wafer curvature by EZ-CURVE (LAAS patent)
- Optical reflectometry 700-1100 nm range
- Real-time reflectometry full spectrum allows to:
  - Check the DBR central wavelength,
  - Track the VCSEL FP resonance,
  - Adjust and the middle and top DBR wavelength
  - Track and adjust the EAM FP detuning
  - Fab yield increase

**MBE growth**
Growth on RIBER 412 MBE reactor on 4” GaAs wafer

**State-of-the-art**

**Modelisation & Design**
Refractive index profile of the EAM-VCSEL
Field distribution in the case of:
- **Strong coupling** (red)
- **Moderate coupling** (blue)

**Optical results**
Room temperature post-growth FTIR reflectivity measurement of the grown EAM-VCSEL structure (black)
Numerical calculation of the reflectivity in the case of:
- **Strong coupling** (red)
- **Moderate coupling** (blue, EAM cavity deviation of ~3nm)
- **Overcoupling** (orange, deviation of +7.5nm)
The grown structure exhibits a case of strong coupling

**Achievements**
- **Vertically integrated VCSEL / Electro-absorber modulator (EAM):** Original and efficient approach for overpass the limits of directly-modulated VCSELs
- **Design/modeling** of electro-optical behavior of the EAM-VCSEL
- **MBE growth with in-situ monitoring:** reflectometry + wafer curvature
- **EAM-VCSEL growth requires high precision:** Best performances (moderate coupling) requires an error of less than +/-0.5% on the EAM cavity thickness

**Acknowledgments:** RENATECH (French Network of Technology Platforms) at LAAS-CNRS
Project ANR-19-CE24-0018

Contact : almuneau@laas.fr