Ultrafast Narrow-Band Modulation of VCSELs

Cun-Zheng Ning
Center for Nanotechnology
NASA Ames Research Center
MS T27A-1, Moffett Field, CA 94035
Phone (650) 604 3983
Email: cning@mail.arc.nasa.gov
http://www.nas.nasa.gov/~cning

Outline
- Introduction (application and generation)
- Model and Equations
- Coupled VCSELs
- Multi-Transverse Mode Dynamics
- Modulation of Multimode VCSELs
- Extension of Bandwidth
- Conclusion

Introduction: Application
- High-Frequency: \( \Omega >> \omega_0 \)
- Narrow Band: \( \Delta \Omega << \Omega \)
- Microwave, millimeter-wave photonics
- Narrow-band communications
- All-optical clock generation and recovery
- Digital communication, if bandwidth \( \Delta \Omega \) expanded

Model and Equations

\[
\begin{align*}
\frac{\partial N}{\partial t} &= \nabla^2 N - \gamma N + \eta f(x,y) - \frac{\omega}{8\alpha} (P' - P) \\
\frac{\partial P}{\partial t} &= -\Gamma (N) + \delta \delta (N) P - \omega d A_j (N) E \\
(P &= P_0 + P_1 +...) \\
\end{align*}
\]

Common features:
- Generating a second resonance in addition to the RO oscillation either through external cavity, feedback or multimode beating
- Using multi-section DFB or DML lasers or needing external cavity or feedback

Introduction: Generation
- Modulation of mode-locked (-coupled) lasers at 100GHz (theory, Lau 1988, 1990)
- Resonant enhancement by feedback (experiment, Lau and Yariv 1985) or by external cavity (Negrajan et al. 1993)
- Push-pull modulated DFB lasers (theory, Marcuse et al. 1994)
- Detuned DFB lasers (theory, Feste 1998)
- 2-Section DFB lasers (theory and experiment, Kajon et al. 1997, Nather et al. 2000)
- Coupled VCSELs (theory, Ning and Goorjian, 2001)

Coupled VCSELs: 40GHz Modulation

https://ntrs.nasa.gov/search.jsp?R=20020051087 2019-03-30T11:57:54+00:00Z
Averaged Intensity Patterns (Index Guided)

Near-field intensity output: half and full facet

21GHz

Power Spectra

Frequency (GHz)

Intensity (a.u.)

Time (ps)

Multi-Transverse Mode Dynamics
Multimode relaxation oscillations and mode beating

Near-field intensity output: half and full facets

Optical Spectrum

Modulation of Multimode VCSELs

Higher beating frequency with smaller device

Extension of Bandwidth
Conclusion

- Multimode beating greatly enhanced by taking output from part (e.g., half) of output facet
- Simpler sources of microwave, millimeter wave of various frequencies generated by varying VCSEL diameter in a single multimode VCSEL or coupling of a few VCSELs
- Breathing frequency in multi-mode operation affects modulation response and bandwidth
- Optimizing RO frequency and mode beating frequency could potentially expand bandwidth suitable for wide band digital communication