

# Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
1.1	Introduction	1
1.2	Optics in Telecom and Datacom and the role of VCSELs	2
1.3	Moore's Law in Datacom	7
1.4	Recent Progress on High Speed VCSELs	9
1.4.1	State-of-the-art of 850 nm VCSELs	10
1.4.2	State-of-the-art of 980 nm VCSELs	11
1.4.3	State-of-the-art of 1100 nm VCSELs	12
1.5	Dissertation Contribution and Overview	13
	References	14
<b>2</b>	<b>Physical Processes in Lasers and VCSEL Design</b>	<b>19</b>
2.1	Optical Properties	20
2.1.1	Transfer Matrix Method and 1D Simulations	21
2.1.2	Eigenmode Expansion Technique for 3D VCSEL Modeling	28
2.1.3	Mode Structure of Oxide-Confined VCSELs	33
2.1.4	Calculation of the Lasing Mode Parameters	35
2.2	Electrical Properties	41
2.2.1	Carrier Dynamic in Semiconductor Lasers	41
2.2.2	Electrical Design of the DBR Mirrors	44
2.2.3	Design of the Active Region	48
2.2.4	Equivalent Circuit and Electrical Parasitics of a VCSEL	53
2.2.5	Design of Impedance Matched High Frequency Contact Pads	56
2.3	Thermal Properties	59
2.3.1	Heat Generation and Thermal Resistance of Oxide-Confined VCSELs	59
2.3.2	Temperature Dependence of the Basic Laser Parameters	64

2.4	The Rate Equations . . . . .	67
2.4.1	Rate Equation Model and Steady-State Solutions . . . . .	67
2.4.2	Small-Signal Frequency Response. . . . .	74
	References . . . . .	82
<b>3</b>	<b>VCSEL Growth and Fabrication . . . . .</b>	<b>85</b>
3.1	Growth of the VCSEL Epitaxial Structure . . . . .	85
3.2	VCSEL Fabrication Technology . . . . .	88
	References . . . . .	93
<b>4</b>	<b>High Temperature Stable 980 nm VCSEL Results . . . . .</b>	<b>95</b>
4.1	VCSELs with the SML Active Region. . . . .	95
4.1.1	Device Structure . . . . .	95
4.1.2	Static Characteristics . . . . .	96
4.1.3	Small Signal Modulation Analysis . . . . .	101
4.1.4	Large Signal Modulation Characteristics . . . . .	107
4.1.5	Summary of the 980 nm SML-VCSEL Results. . . . .	109
4.2	VCSELs with the QW Active Region . . . . .	111
4.2.1	Device Structure . . . . .	111
4.2.2	Static Characteristics . . . . .	112
4.2.3	Small Signal Modulation Analysis . . . . .	117
4.2.4	Large Signal Modulation Characteristics . . . . .	127
4.2.5	Summary of the 980 nm QW-VCSEL Results . . . . .	130
	References . . . . .	132
<b>5</b>	<b>High Speed 850 nm VCSEL Results . . . . .</b>	<b>133</b>
5.1	Device Structure . . . . .	134
5.2	Static Characteristics . . . . .	135
5.3	Small Signal Modulation Analysis. . . . .	138
5.4	Large Signal Modulation Characteristics . . . . .	144
5.5	Summary of the 850 nm QW-VCSEL Results. . . . .	149
	References . . . . .	150
<b>6</b>	<b>Conclusions and Outlook . . . . .</b>	<b>151</b>
6.1	Summary . . . . .	151
6.2	Future Works . . . . .	153
	References . . . . .	156
	<b>Appendix . . . . .</b>	<b>159</b>
	<b>Curriculum Vitae . . . . .</b>	<b>163</b>
	<b>List of Publications and Conference Presentations . . . . .</b>	<b>165</b>



<http://www.springer.com/978-3-642-16569-6>

High Speed VCSELs for Optical Interconnects

Mutig, A.

2011, XIV, 169 p., Hardcover

ISBN: 978-3-642-16569-6