

## Contents

# High efficiency GaN-based LEDs: light extraction by photonic crystals

A. David

<b>Table of symbols</b>	<b>3</b>
<b>1 Light-emitting diodes</b>	<b>5</b>
1. Basics on light-emitting diodes	5
2. Solid-state lighting	8
3. Light extraction from an LED	13
4. A few words on GaN LEDs	18
5. Conclusion	23
<b>2 Photonic crystals and light extraction</b>	<b>25</b>
1. Basics of light extraction by periodic structures	25
2. A few theoretical trends	43
3. Photonic crystals in GaN: photoluminescence experiments	52
<b>3 Photonic crystal LEDs</b>	<b>63</b>
1. Tailoring of guided modes distribution	63

2. Crystal lattice, Archimedean tilings	81
3. Laser lift-off PhCLEDs	99
4. Lateral epitaxial overgrowth PhC-LEDs	113
5. PhC-LEDs with patterned emitting region	119
6. Photonic crystal LEDs: conclusions	139
<hr/>	
<b>4 2D simulation of photonic structures</b>	<b>141</b>
1. Aims of photonic crystal modeling	141
2. Plane wave expansion	143
3. Fourier rules for fast convergence	147
4. Generalization to off-plane propagation	155
5. Conclusion	159
<hr/>	
<b>5 3D simulation of photonic structures</b>	<b>161</b>
1. Photonic calculation methods: a quick overview	161
2. Hybrid plane wave / Finite differences method	173
3. Implementation of a Fourier modal method	182
<hr/>	
<b>Conclusion</b>	<b>205</b>
<hr/>	
<b>A Power flow of a Bloch mode</b>	<b>207</b>
<hr/>	
<b>B Wurtzite and zinc-blende Hamiltonians</b>	<b>213</b>
1. Band structure and optical properties: basic discussion	213
2. Zinc-blende structure	215
3. Wurtzite structure	219

Contents	vii
<b>C Carriers localization and source terms in Maxwell's equations</b>	<b>227</b>
1. Quantum well	227
2. Quantum dot	228
<b>References</b>	<b>229</b>