Dispersion relationships for moderately deep gratings in distributed Bragg reflector lasers

Nai-Hsiang Sun, Zhi-Ming Lin
Department of Electrical Engineering
I-Shou University, Kaohsiung, Taiwan
E-mail: snh@isu.edu.tw

Jerome K. Butler, and Gary A. Evans
Department of Electrical Engineering
Southern Methodist University, Dallas, U.S.A.
E-mail: jkb@smu.edu
Outline

• Introduction
• Numerical methods
• Results
• Conclusion
Introduction

- Gratings are very important structure in DFB and DBR Lasers.
- The grating depth is an important parameter for properties of gratings.
- Grating depths:
  - Shallow gratings: $h < 0.1 \, \mu m$
  - Moderate gratings: $0.1 \sim 0.5 \, \mu m$
  - Very deep gratings: $1.0 \sim 3.0 \, \mu m$
Shallow gratings

- Shallow gratings: typical grating depths
- Grating depths: \( h < 0.1 \, \mu m \)
- Very long grating lengths (>500 \( \mu m \))
- Narrow spectrum (\(~1 \, \AA\))
Schematic diagram of very deep gratings

- Grating depth $\approx 1\text{ to }3\ \mu m$
- Etch completely through active layers.
- Very high reflectivities (>90%)
- Very short grating length (5 ~ 10 $\mu m$)
- Very wide the reflectivity spectrum (50 ~ 100 Å)

Moderate gratings

- Etch through the cladding layer.
- Moderate gratings: 0.1~0.5 μm
Grating-outcoupled surface-emitting lasers

Numerical Methods

• Coupled Mode Theory (CMT)
  simple, easy to calculate. Valid when grating depth < 0.1μm

• Finite-difference time domain (FDTD)
  apply for very deep gratings, need a lot of computing time

• Floquet-Bloch Theory (FBT)
  a complicated method, nearly rigorous solutions, apply to analyze moderate gratings.
Floquet-Bloch theory

\[ F_i(x, z) = \sum_{n=-\infty}^{\infty} \mathbf{f}^{(i)}(x) \cdot e^{-j k z n z} \]

\[ k z n = \beta_n + j \alpha = (\beta + n K) + j \alpha, \quad K = \frac{2\pi}{\Lambda} \]

\[ F_i = E_{yi} \quad \text{for TE mode} \]

\[ F_i = H_{yi} \quad \text{for TM mode} \]
The index profile

<table>
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<tr>
<th>Layer</th>
<th>Thickness (μm)</th>
<th>Refractive Index</th>
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<td>1.000/3.165</td>
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<tr>
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<td>3.165</td>
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Jerome K. Butler, Nai-Hsiang Sun, Gary A. Evans, Lily pang, and Philip Congdon, “Grating-Assisted Coupling of Light Between Semiconductor and Glass Waveguides”
Deep-etched grating height (\( h = 0.4275 \mu m \))

- **Runge-Kutta Method** (space harmonics: \(-8 \sim 3 \), \(-2 \sim 2\))
- **Eigen-Value Technique** (space harmonics: \(-8 \sim 3 \), \(-6 \sim 3\))
ERROR: invalid restore
OFFENDING COMMAND: restore
ERROR: invalid restore
STACK:
- dictionary
- savelevel
- savelevel
- savelevel
STACK: