Dispersion relationships for moderately deep gratings in distributed Bragg reflector lasers

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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 μm
  - Moderate gratings : 0.1~0.5 μm
  - Very deep gratings : 1.0~3.0 μm

Shallow gratings

- Shallow gratings : typical grating depths
- Grating depths : $h < 0.1$ μm
- Very long grating lengths (>500 μm)
- Narrow spectrum (~1 Å)

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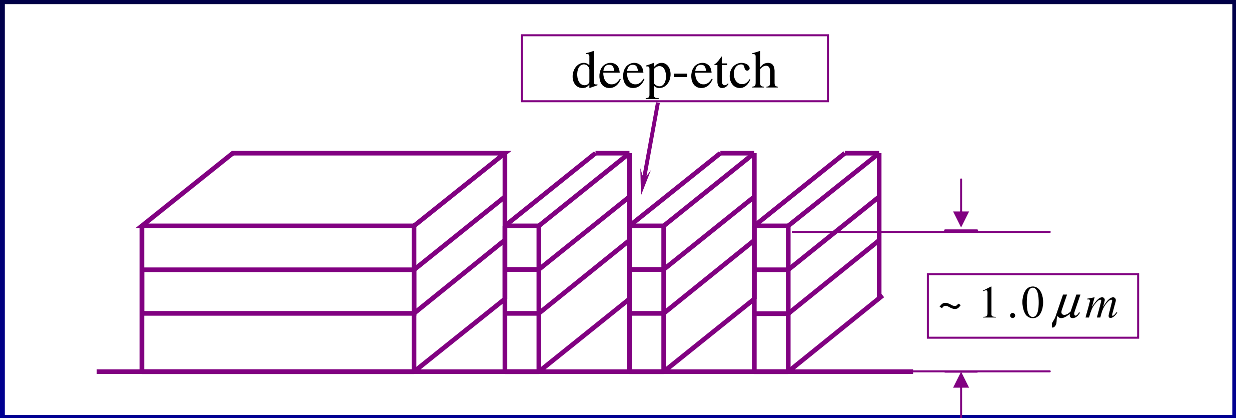
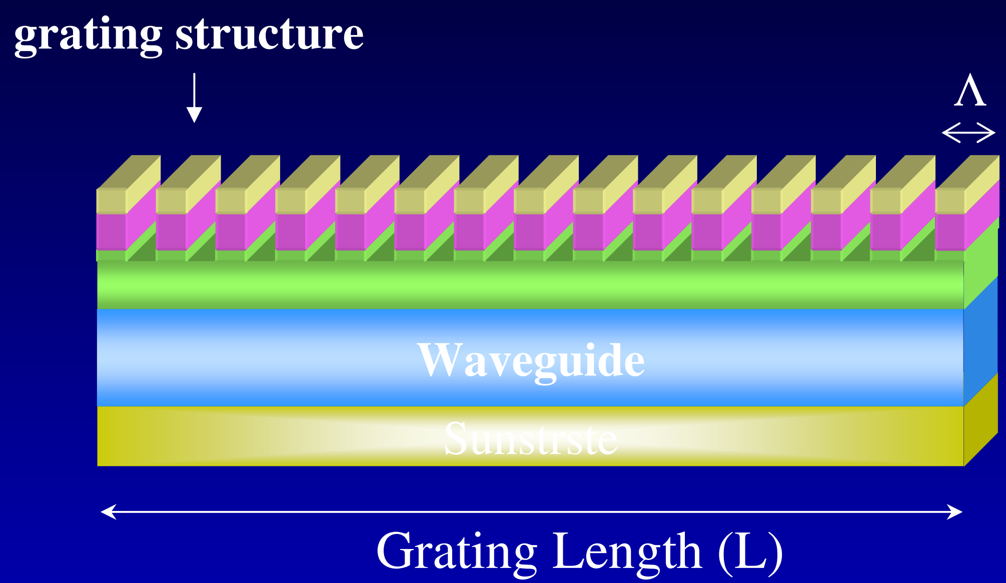
Schematic diagram of very deep gratings



- Grating depth ≅ 1~3 μm
- Etch completely through active layers.
- Very high reflectivities (>90%)
- Very short grating length (5 ~ 10 μm)
- Very wide the reflectivity stpectrum (50 ~ 100 Å)

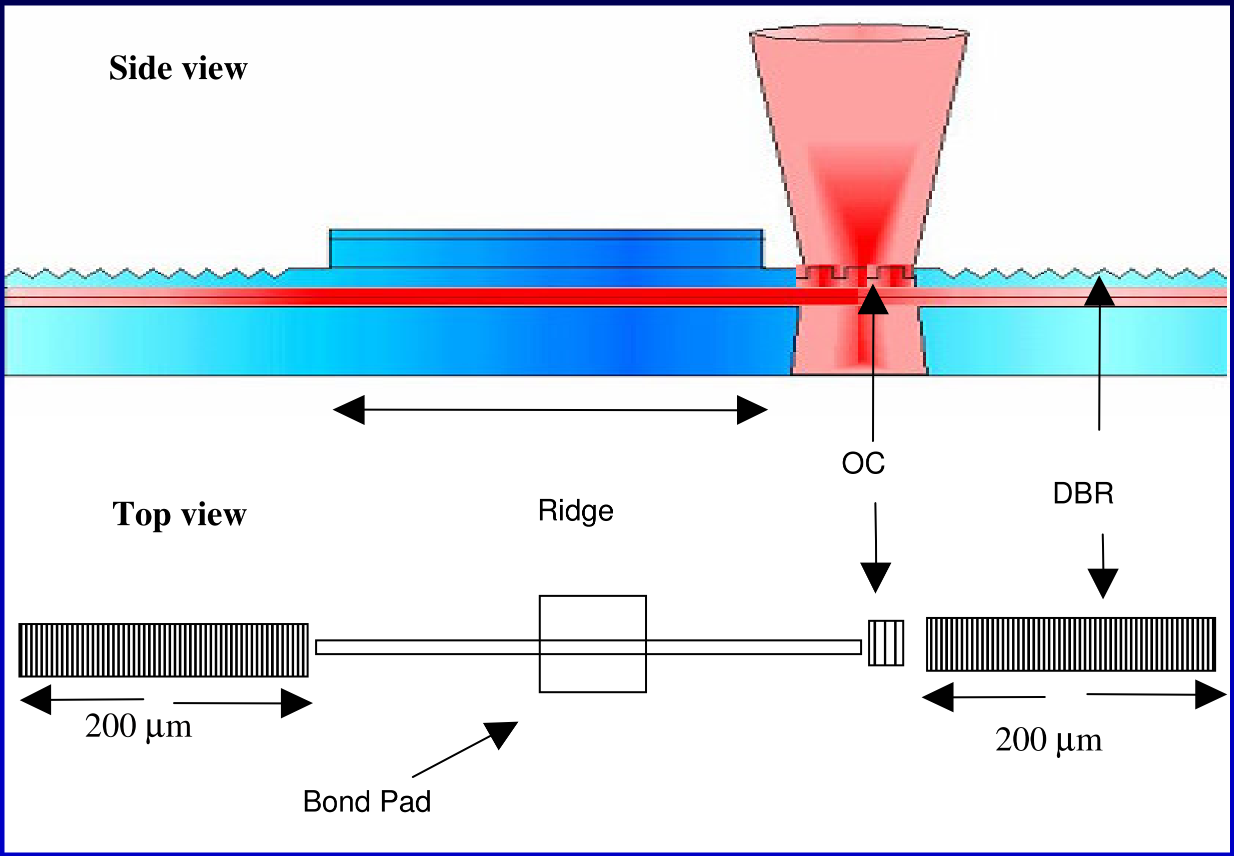
(R. Jambunathan and J. Singh, *IEEE J.Q.E.*,vol. 33, pp. 1180–1189, July 1997.)

Moderate gratings



- Etch through the cladding layer.
- Moderate gratings : 0.1~0.5 μm

Grating-outcoupled surface-emitting lasers



(Taha Massood etc., *IEEE PTL*, vol. 16, pp. 726–728, March 2004.)

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

$$F_i(x,z) = \sum_{n=-\infty}^{\infty} f_n^{(i)}(x) \cdot e^{(-jk_{zn} z)}$$

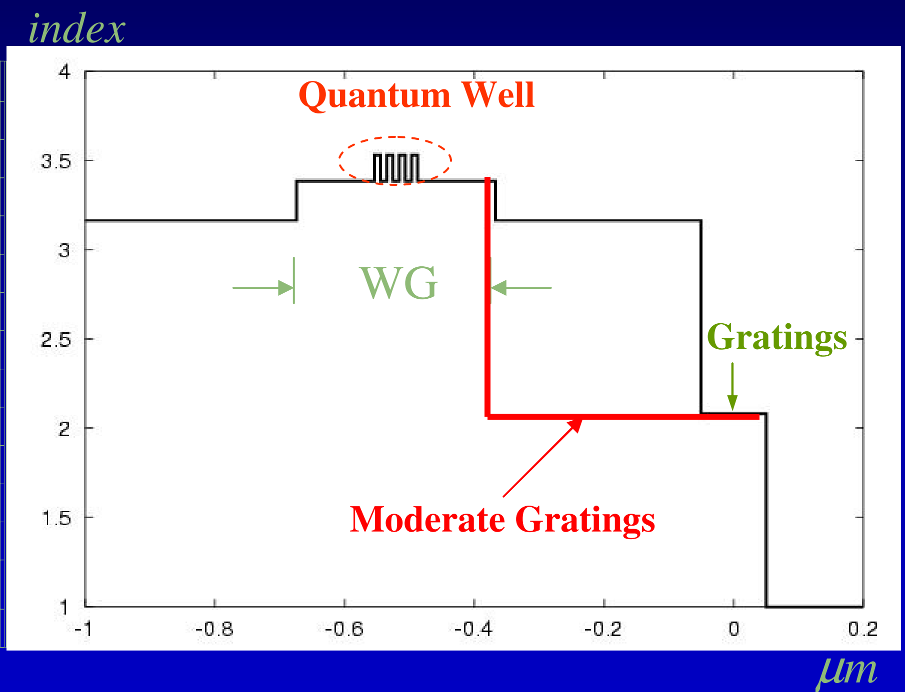
$$k_{zn} = \beta_n + j\alpha = (\beta + nK) + j\alpha, \quad K = \frac{2\pi}{\Lambda}$$

$F_i = E_{yi}$ for TE mode

$F_i = H_{yi}$ for TM mode

The index profile

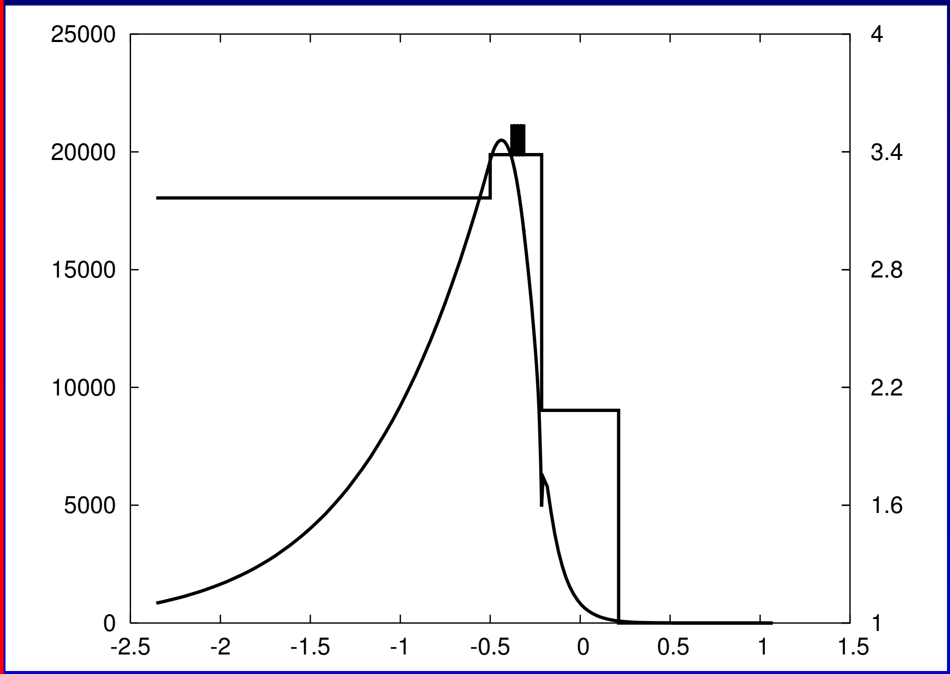
	厚度(μm)	等效折射率
Layer 1 (Air)	∞	1.000
Layer 2 (Grating)	0.100	1.000/3.165
Layer 3 (P-Spacer)	0.3175	3.165
Layer 4 (SCH Layer)	0.120	3.386
Layer 5 **(Quantum Well)**	0.009	3.532
Layer 6 (Barrier)	0.010	3.386
Layer 7 **(Quantum Well)**	0.009	3.532
Layer 8 (Barrier)	0.010	3.386
Layer 9 **(Quantum Well)**	0.009	3.532
Layer 10 (Barrier)	0.010	3.386
Layer 11 **(Quantum Well)**	0.009	3.532
Layer 12 (SCH Layer)	0.120	3.386
Layer 13(Substrate Cladding)	1.000	3.165
Layer 14 (Substrate)	∞	3.165



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 =0.4275μm)

- Runge-Kutta Method (space harmonics: -8 ~3 → -2~2)
- Eigen-Value Technique (space harmonics: -8 ~3 → -6 ~ 3)



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ERROR: invalidrestore
OFFENDING COMMAND: restore

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-savelevel-
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