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*Publication date:*  
2015

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*Citation (APA):*

Taghizadeh, A., Mørk, J., & Chung, I-S. (2015). Hybrid III-V-on-Si Laser with Ultra-low Energy Consumption. Poster session presented at Danish Opening Ceremony of the International Year of Light, Lyngby, Denmark.

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# Hybrid III-V-on-Si Laser with Ultra-low Energy Consumption

Alireza Taghizadeh\*, Jesper Mørk, Il-Sug Chung

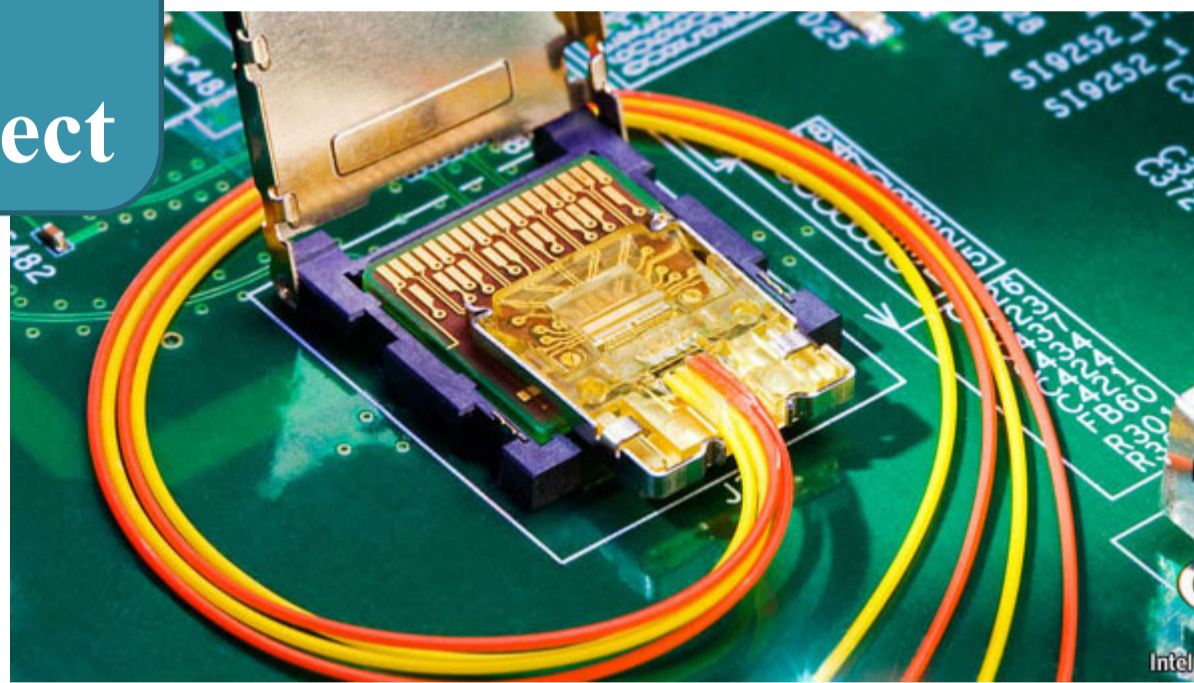
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## Motivation

- Optical Interconnect: low power consumption and high speed modulation for on-chip interconnection technology
- Main goal: Development of a comprehensive laser simulator to investigate different micro-laser structures

Intel Light Peak interconnect



IBM vision for 2020

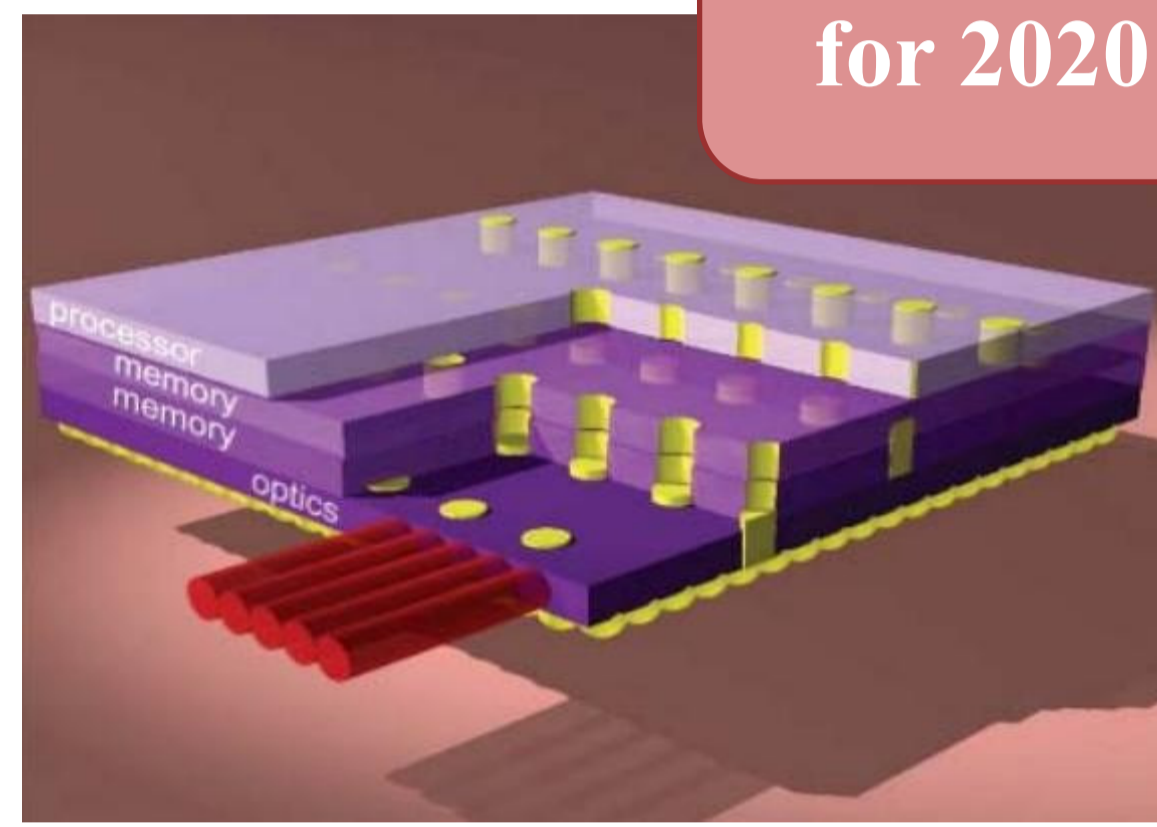


Figure 1. Schematic of the future photonic networks.

## Interesting Device Structures

- 1) Different VCSEL structures with DBR and/or PCM mirrors
- 2) Resonance cavity enhanced photodetectors
- 3) Photonic crystal based waveguides and devices

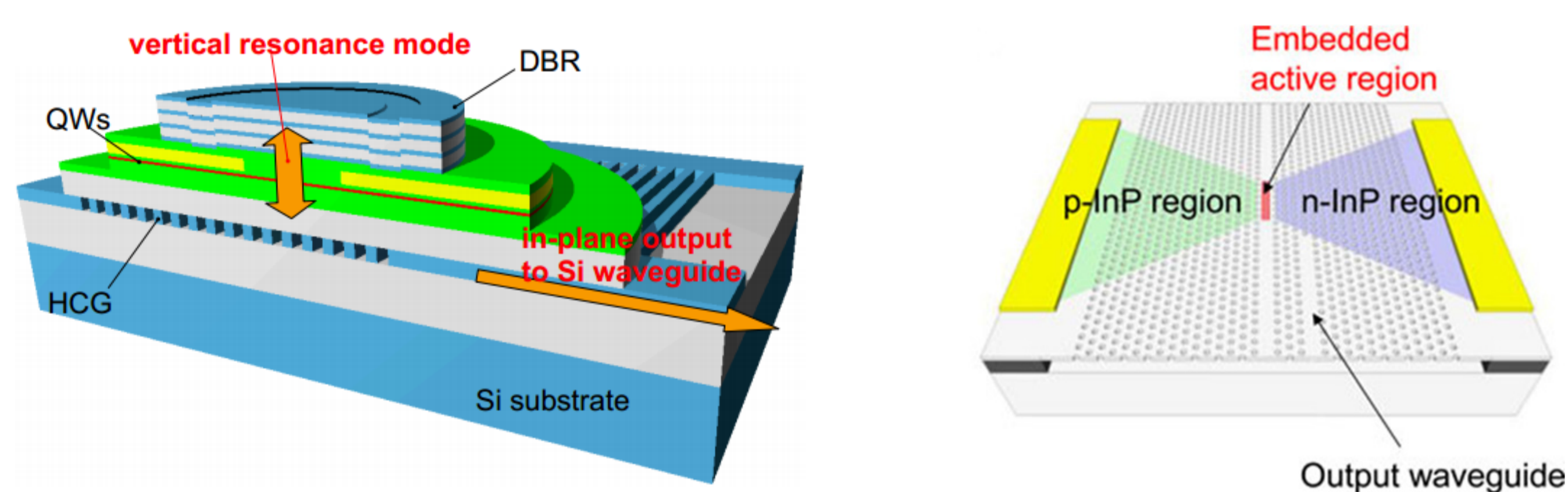
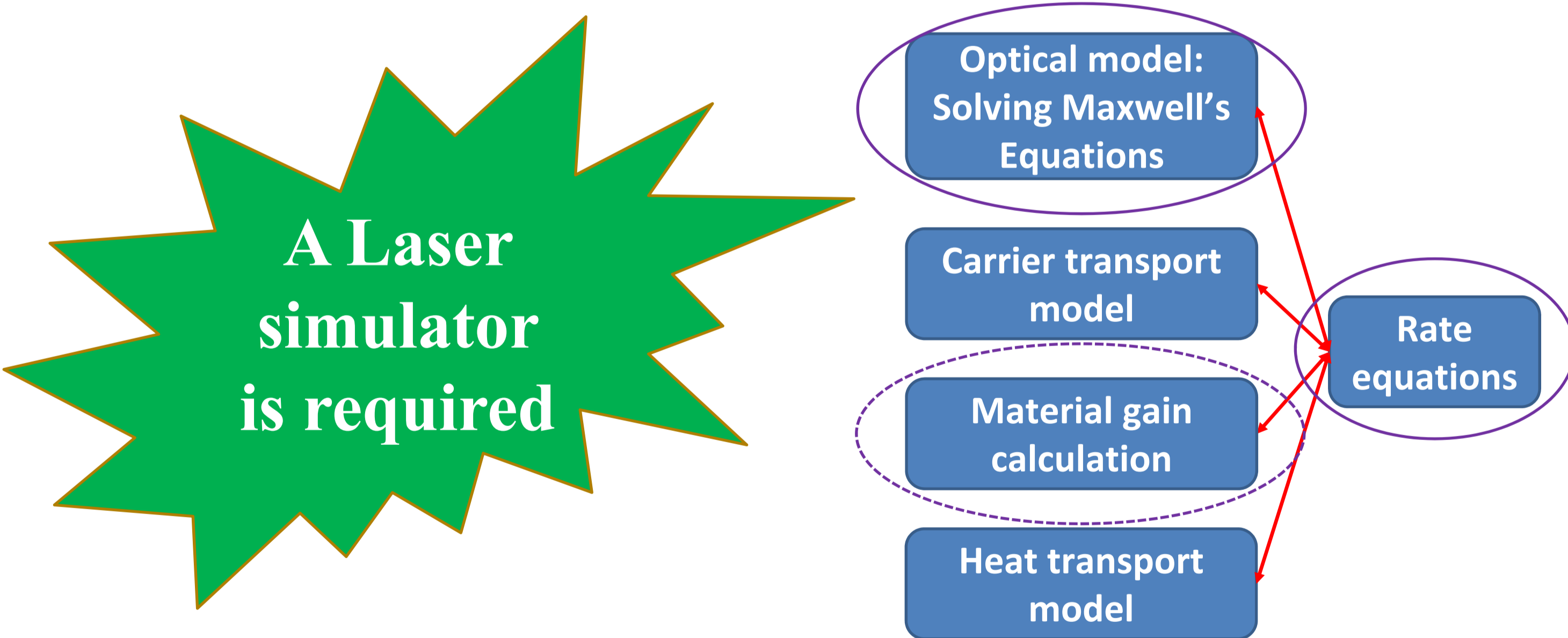


Figure 2. Schematic of various laser structure.



A Laser simulator is required

Figure 3. Laser simulator different part.

## Fourier Modal Method (FMM)

- Spatial frequency domain method (Fourier space)
- Different names: Differential method, RCWA, Plane-wave method, ...
- All electromagnetic quantities are expanded in Fourier series
- Layered discretization, Expansion on modes of layers

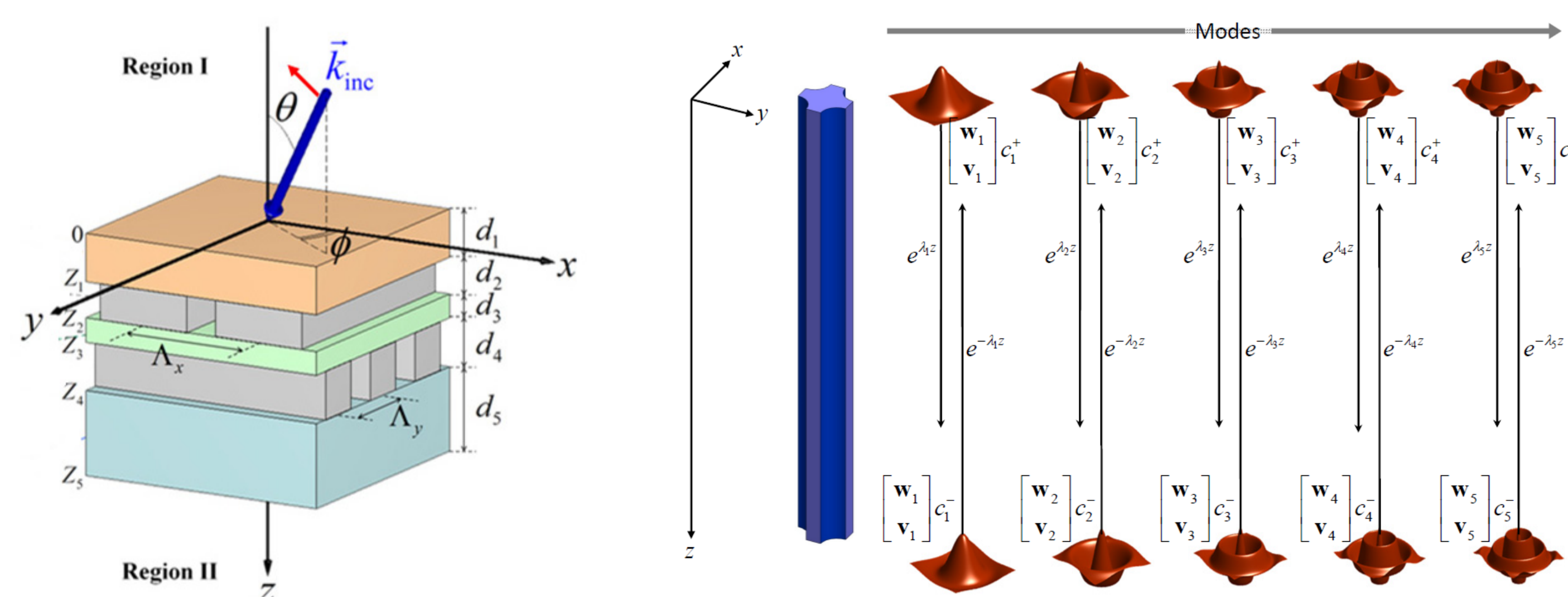


Figure 4. Schematic of a typical device structure and FMM procedure.

## Rate Equation

- Model the electrical and optical performance of a laser
- Calculate carrier and photon density in different modes
- Analyze dynamics of the laser
- We used modal model to solve these equations

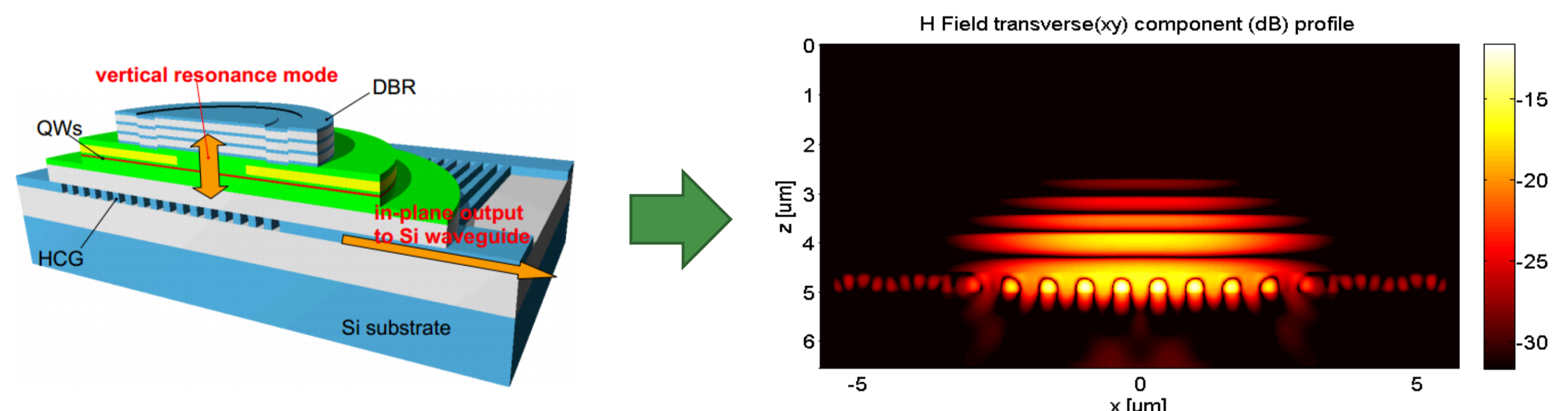
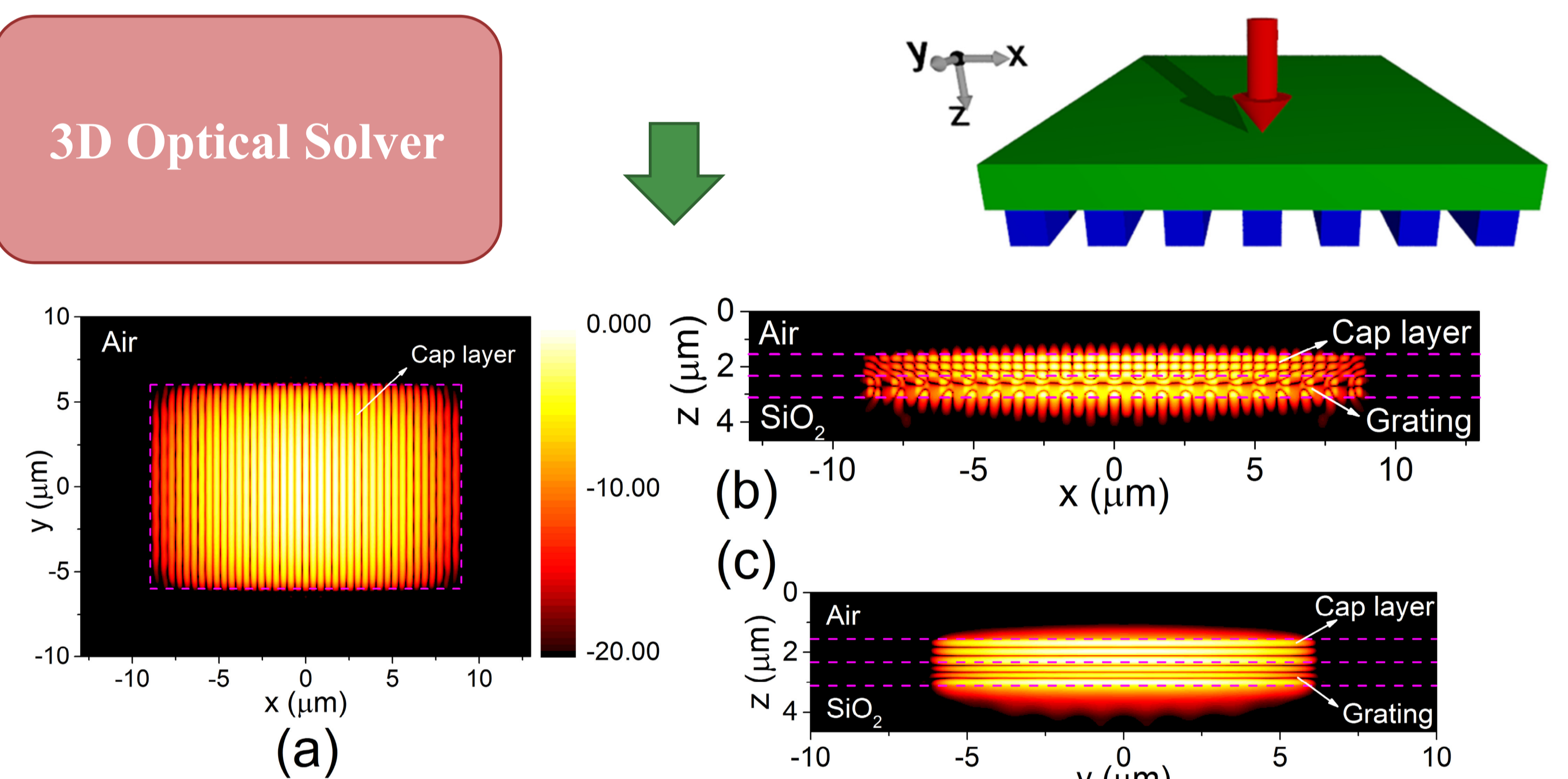
$$\frac{\partial N(x_1, x_2, t)}{\partial t} = \frac{\eta_i I(x_1, x_2, t)}{qV} - \frac{N(x_1, x_2, t)}{\tau_N} + D_N \nabla^2 N(x_1, x_2, t) - \sum_m G_m(x_1, x_2, t) S_m(t)$$

$$\frac{\partial S_m(t)}{\partial t} = -\frac{S_m(t)}{\tau_{sm}} + \frac{\beta_m \Gamma_m}{\tau_N A_m} \iint N(x_1, x_2, t) dA + \frac{\Gamma_m}{A_m} S_m(t) \iint G_m(x_1, x_2, t) dA$$

## Simulation Examples

- A compact Hybrid grating resonator
- VCSEL with PCM mirror
- Conventional VCSEL with rectangular current aperture

### 3D Optical Solver



### Rate Equation Solver

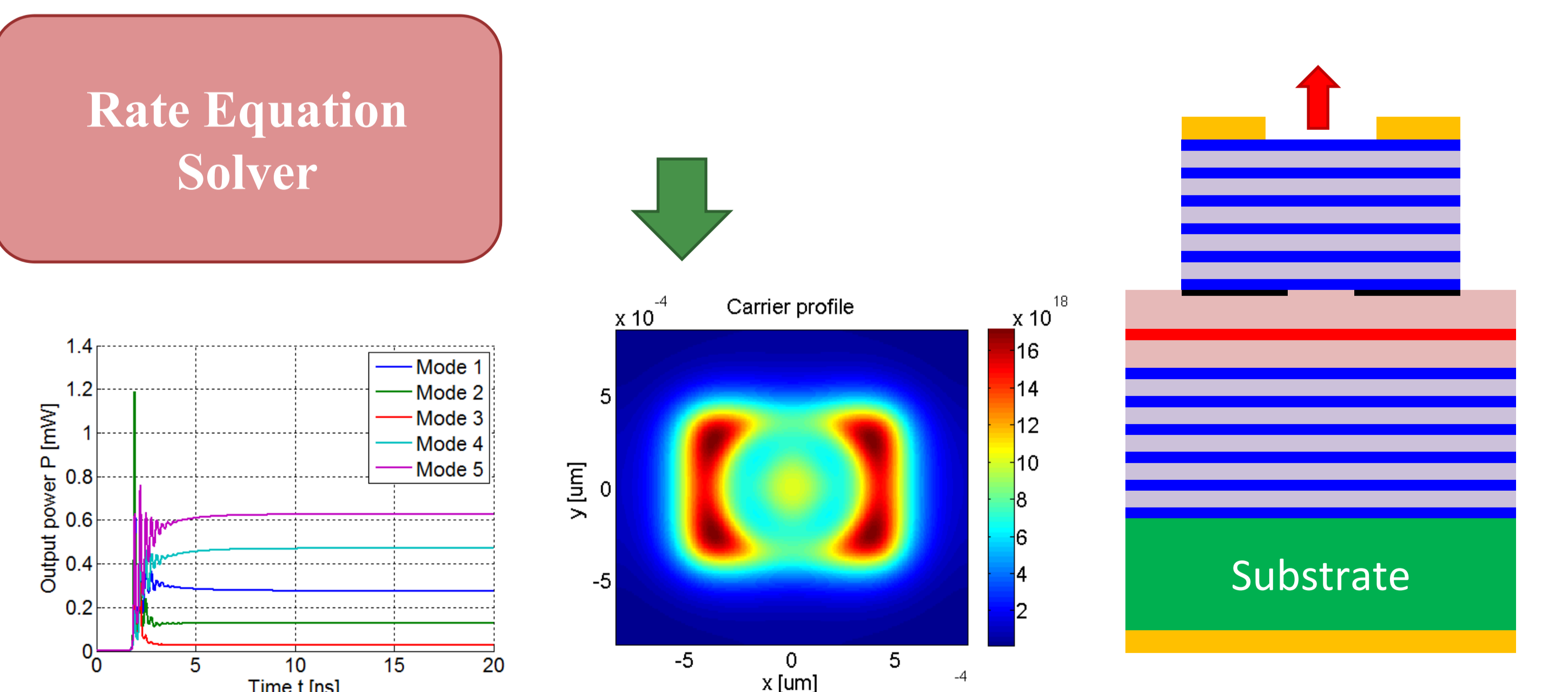


Figure 5. Several simulated structure and their results.

## References

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