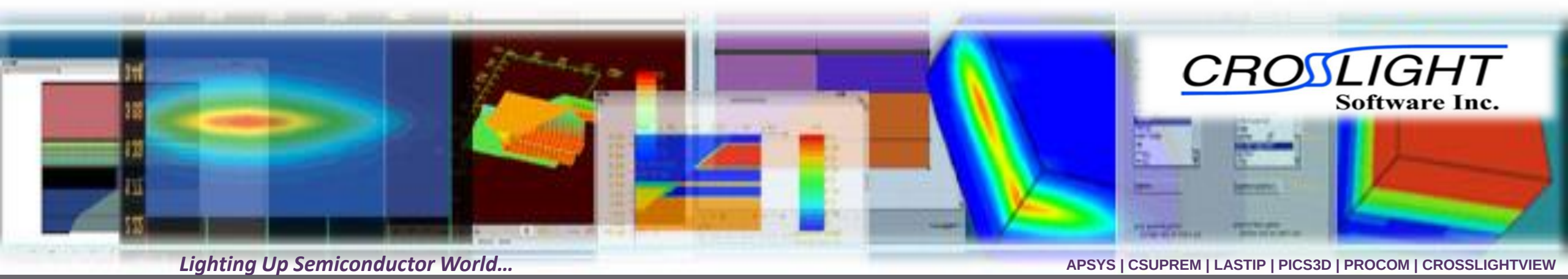

Crosslight Simulation of Tunable MEMS VCSEL with Optical Pumping

CROSSLIGHT
Software Inc.

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Contents

- Structure
- Model
- Results
- Summary

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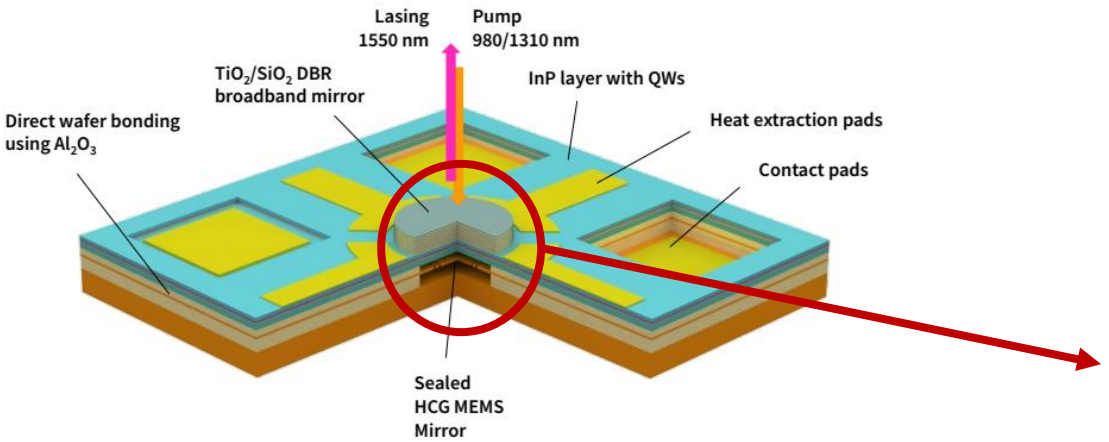
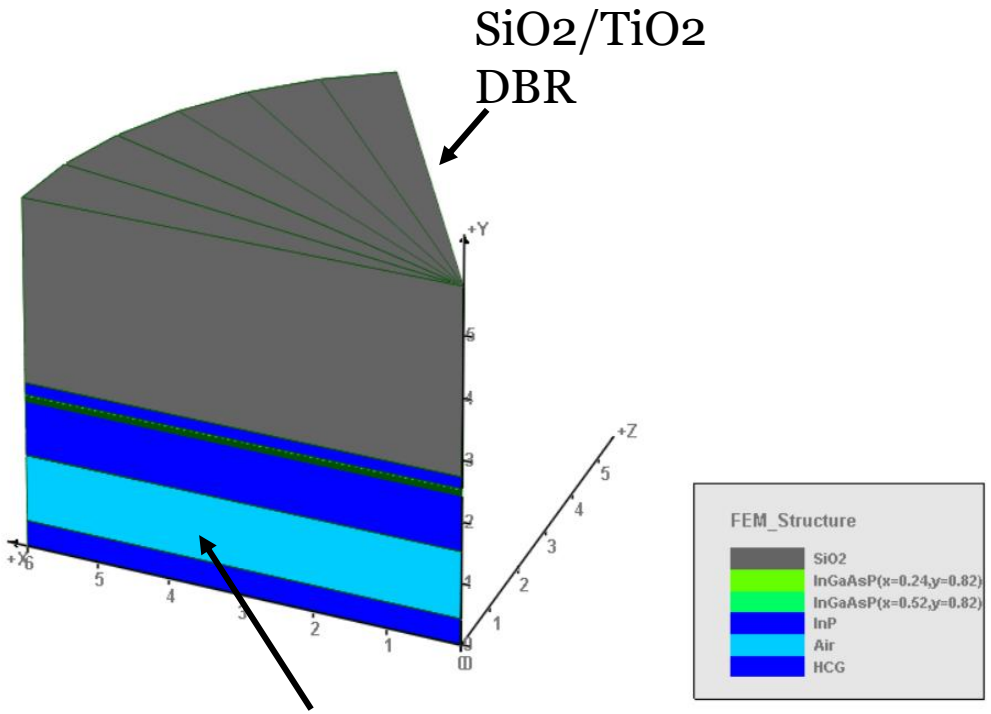
MEMS/VCSEL Structure





Tunable MEMS VCSEL on Silicon substrate

Hitesh Kumar Sahoo, Thor Ansbæk, Luisa Ottaviano, Elizaveta Semenova, Fyodor Zubov, Ole Hansen, Kresten Yvind

https://arxiv.org/abs/1903.08691v1

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Contents

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Crosslight Models

- K.p theory based MQW model.
- Efficient multiple band valley model (HH,LH) with effective mass fit to k.p theory.
- Optionally, manybody gain/spontaneous theory for quantum wells or dots.
- Accurate spectrum model with inhomogeneous broadening using bandgap tail states.
- Flexible electrical and optical pumping system based on bandgap interaction with photons.
- Setting of air gap thickness as scan variable so that DC and transient simulation can be performed.

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Input commands for the MEMS/VCSEL

Optical pump at 0.98um

```
$
$ vcsel stuff
vcsel_model index_core=3.2 index_cladding=1.0 &&
  core_radius =6.  bessel_order=0

light_power light_dir=top incident_power=2.0e9 wavelength=0.98
$multimode mode_num=2
$
init_wave backg_loss=500 init_wavel=1.56 wavel_range=(1.5, 1.6)
cylindrical axis=y
$
```


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Input commands for the MEMS/VCSEL

```
$
scan var=light value_to=1.0 solve_rtg=yes &&
 init_step=1.e-4 min_step=1.e-8 max_step=0.1

scan var=change_layer_thickness value_to=-0.2 solve_rtg=yes &&
 init_step=1.e-5 min_step=1.e-9 max_step=0.001 &&
var2=time value2_to=1.e-3

$lateral_mode3d sort_modes=no mode_num=2
longitudinal ref_wavel = 1.56E-6  &&
     layer_exit_model=reflectivity &&
     left_f_refl=0.999 right_f_refl=0.3
set_scan_layer  tag=n-air
```

Optical pumping until lasing

Define change_layer_thickness vs time here

Setting HCG reflectivity as 0.999

Define the air gap as a variable to be scanned.

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Contents

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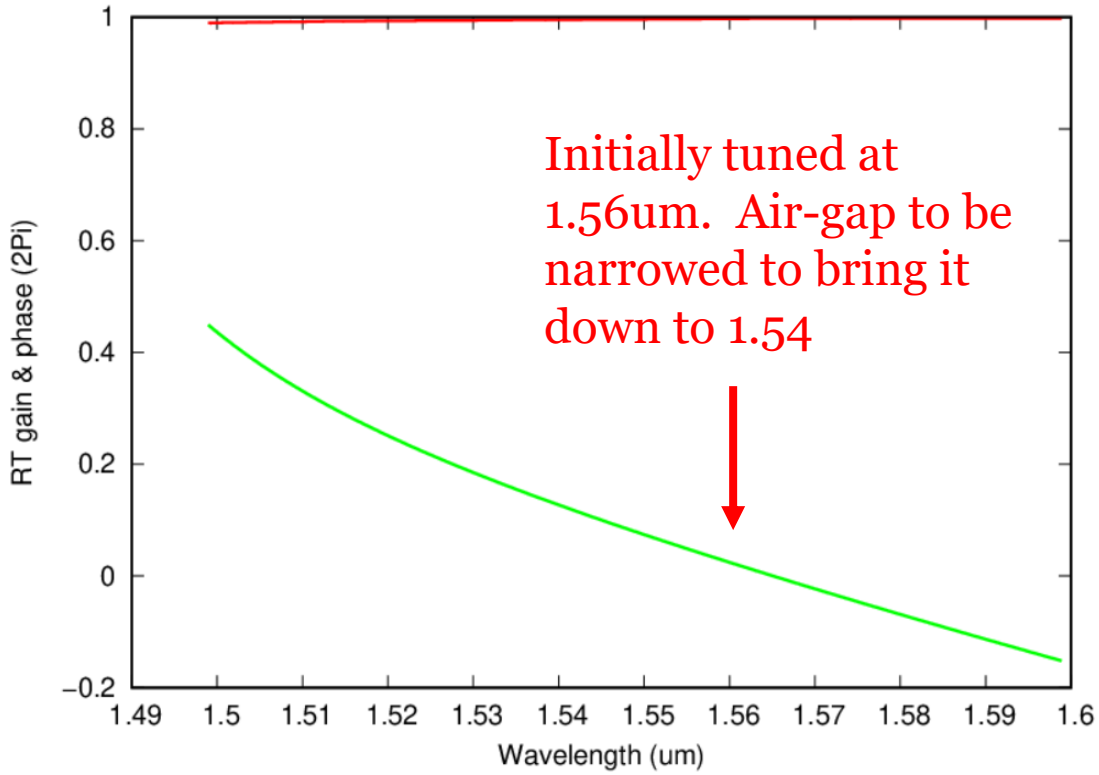
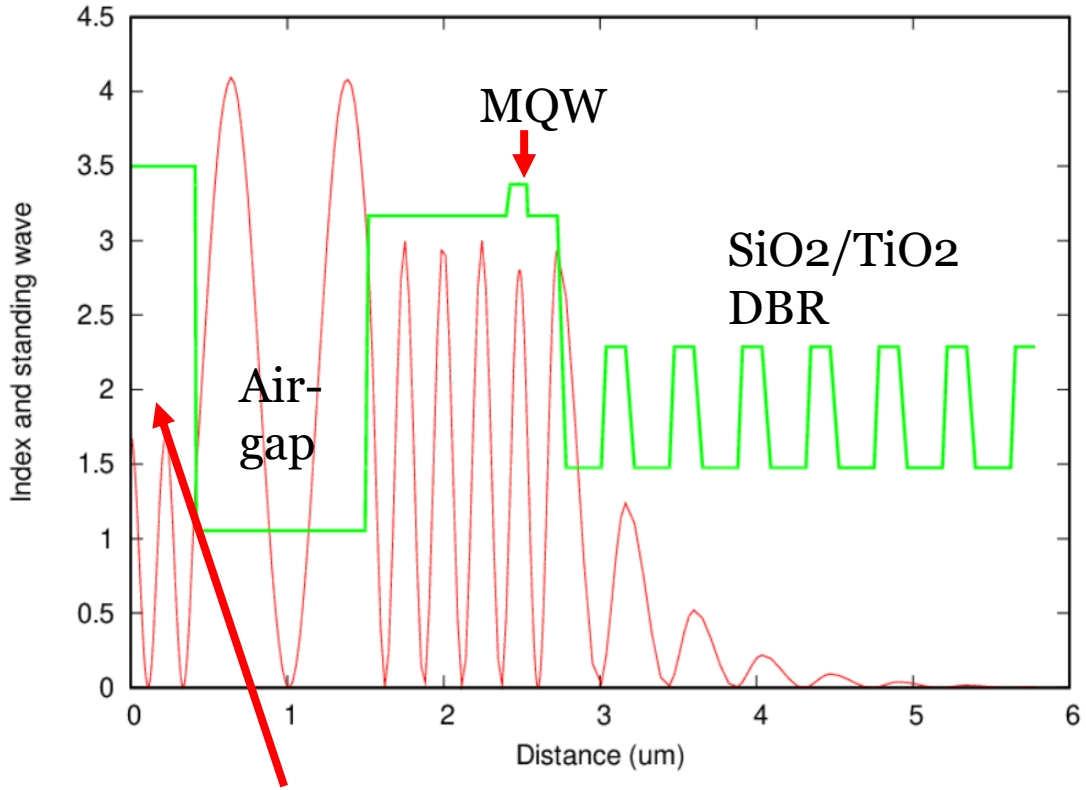
Transfer matrix calculation





High-contrast-grating (HCG) region approximated by high index material with AR (R=0.999) back surface

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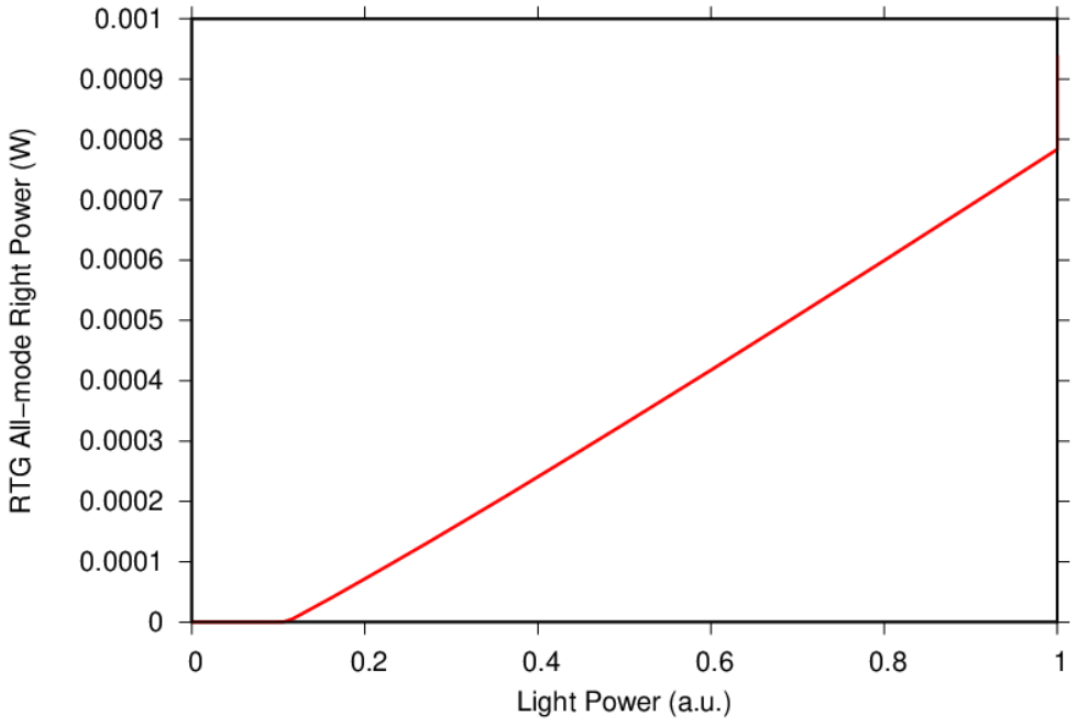
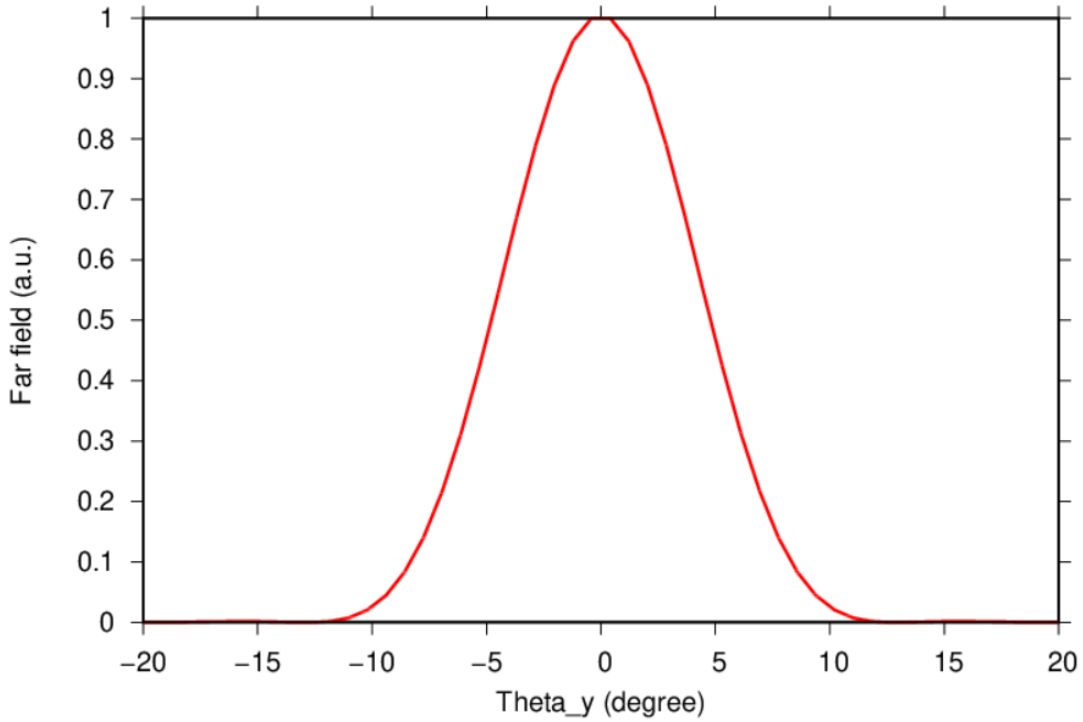
Lasing characteristics





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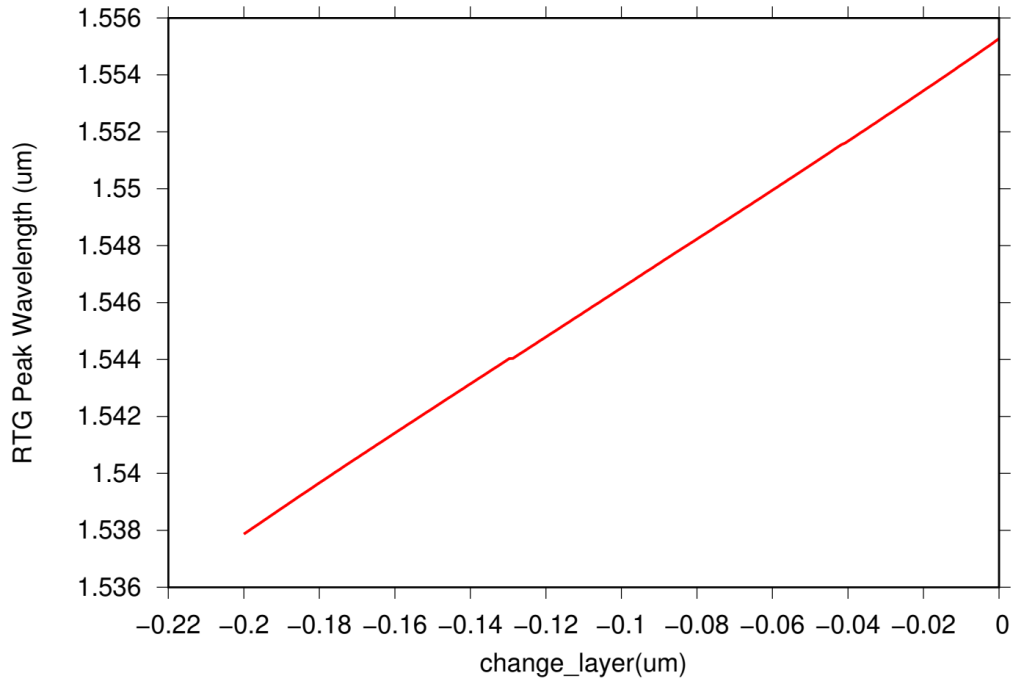
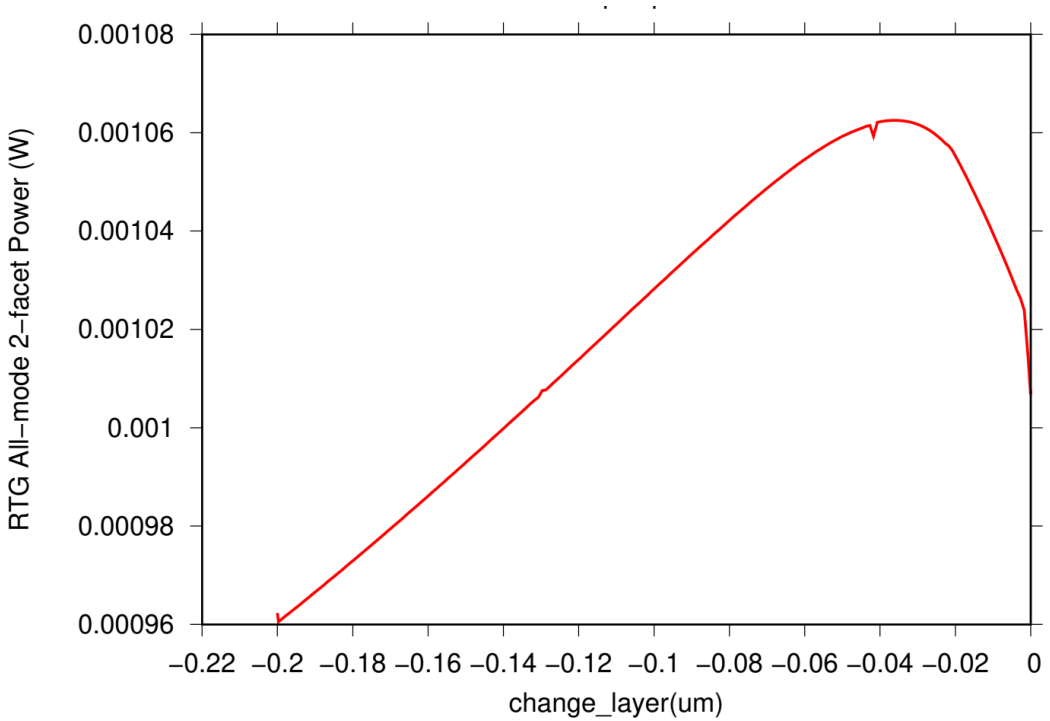
Mechanical tuning characteristics





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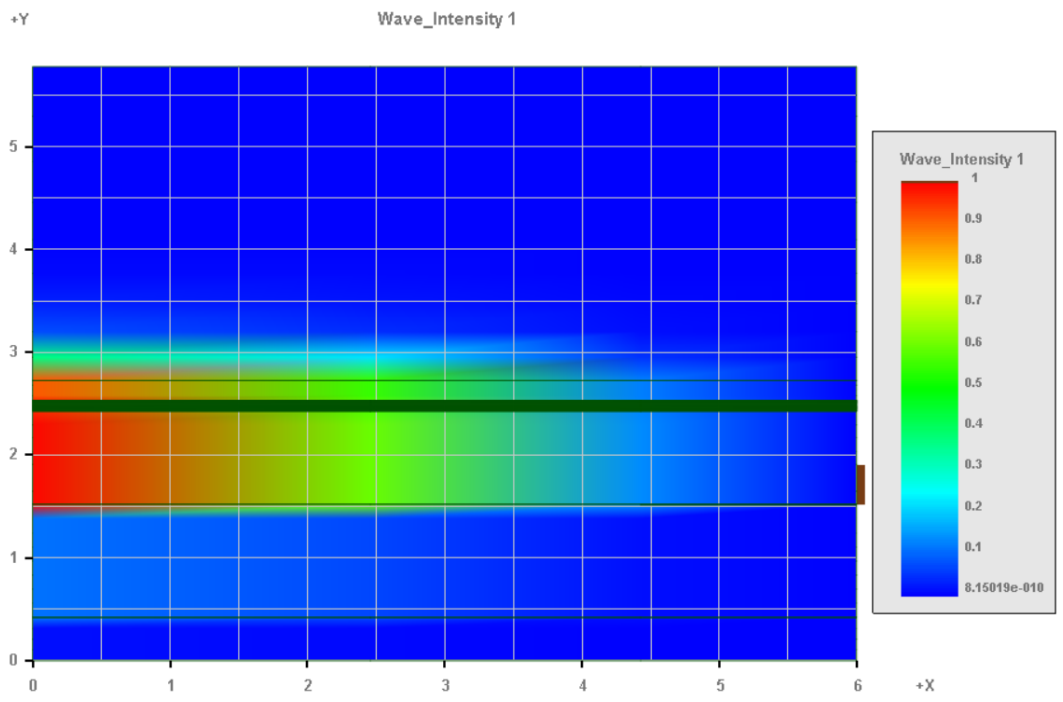
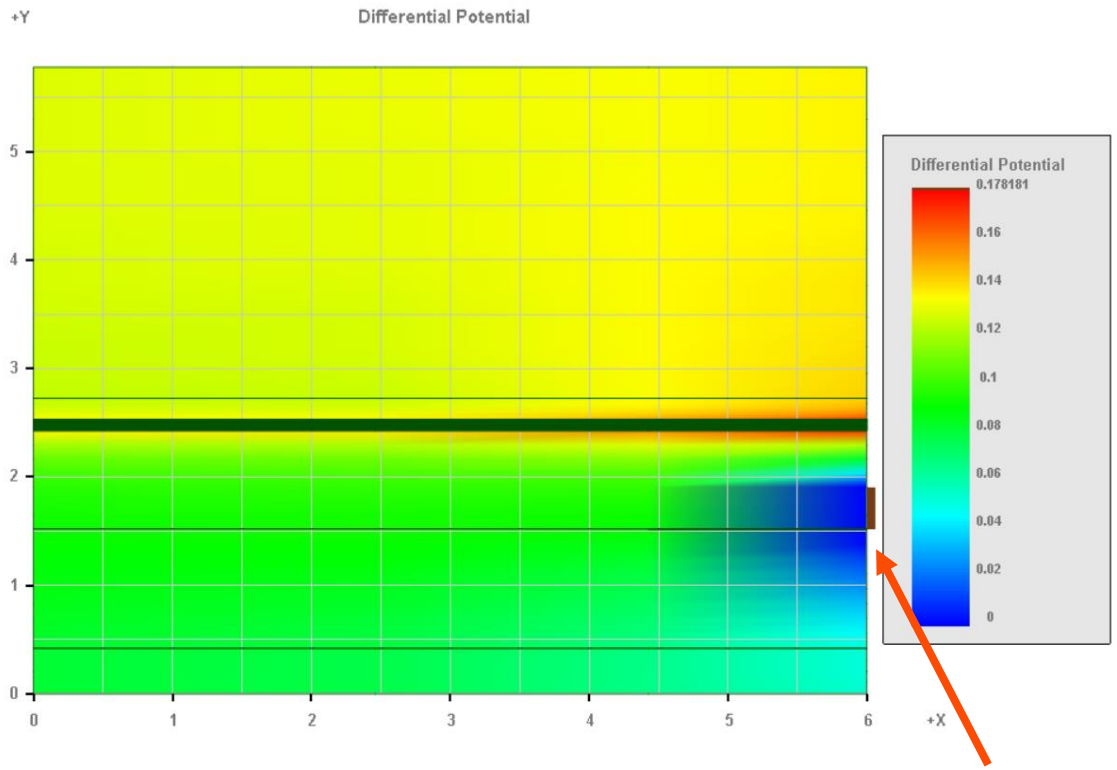
Fine details





A side electrical contact is used to provide a reference potential for the whole device which is optically pumped.

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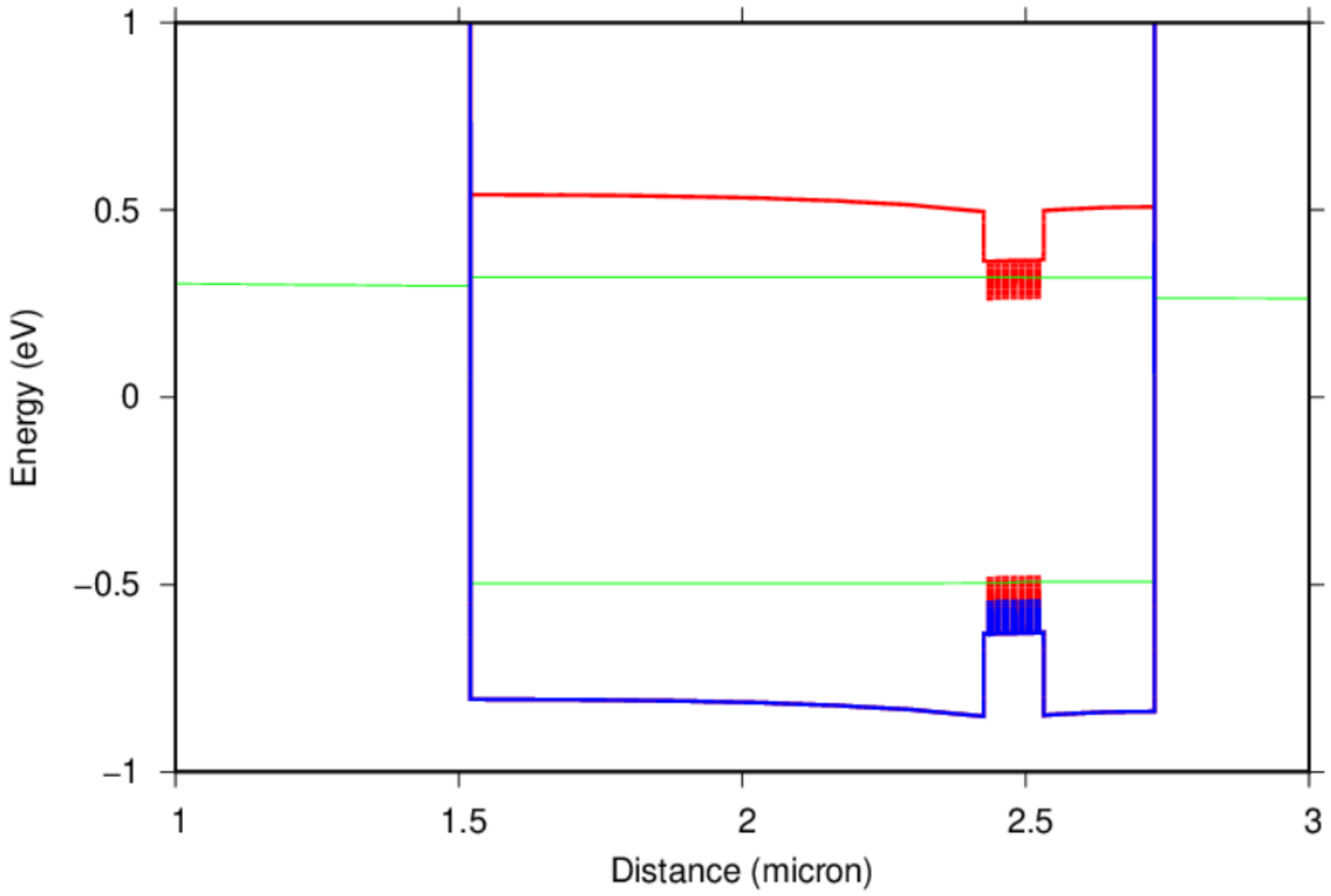
Fine details



Observation:

Band diagram does not show the usual p-n junction potential but only a split of Fermi level due to optical pumping which provides the population inversion needed for lasing action

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Summary of Key Points

- Optical pumping
- Capability to scan the air gap thickness due to MEMS action
- Treatment of high-contrast-grating (HCG)

Further developments

- Use of EIM to model lateral optical confinement
- Use of FDFD to model lens effect
- Use of Csuprem to compute stress and bending of the MEMS structure as related to the optical part

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Thanks for your attention!

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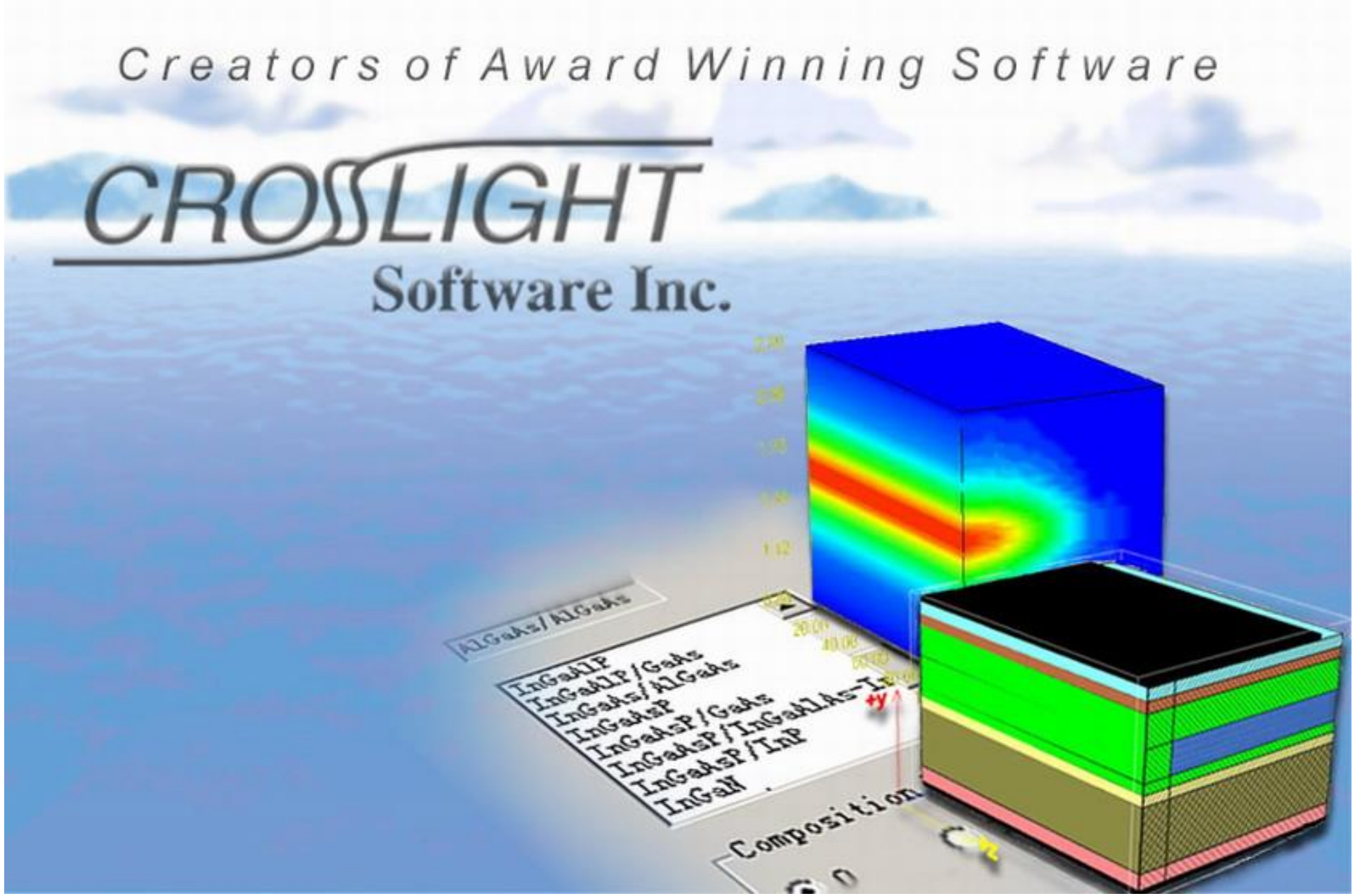

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