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Trends in cavity designs for vertical cavity lasers – and simulation of their consequences

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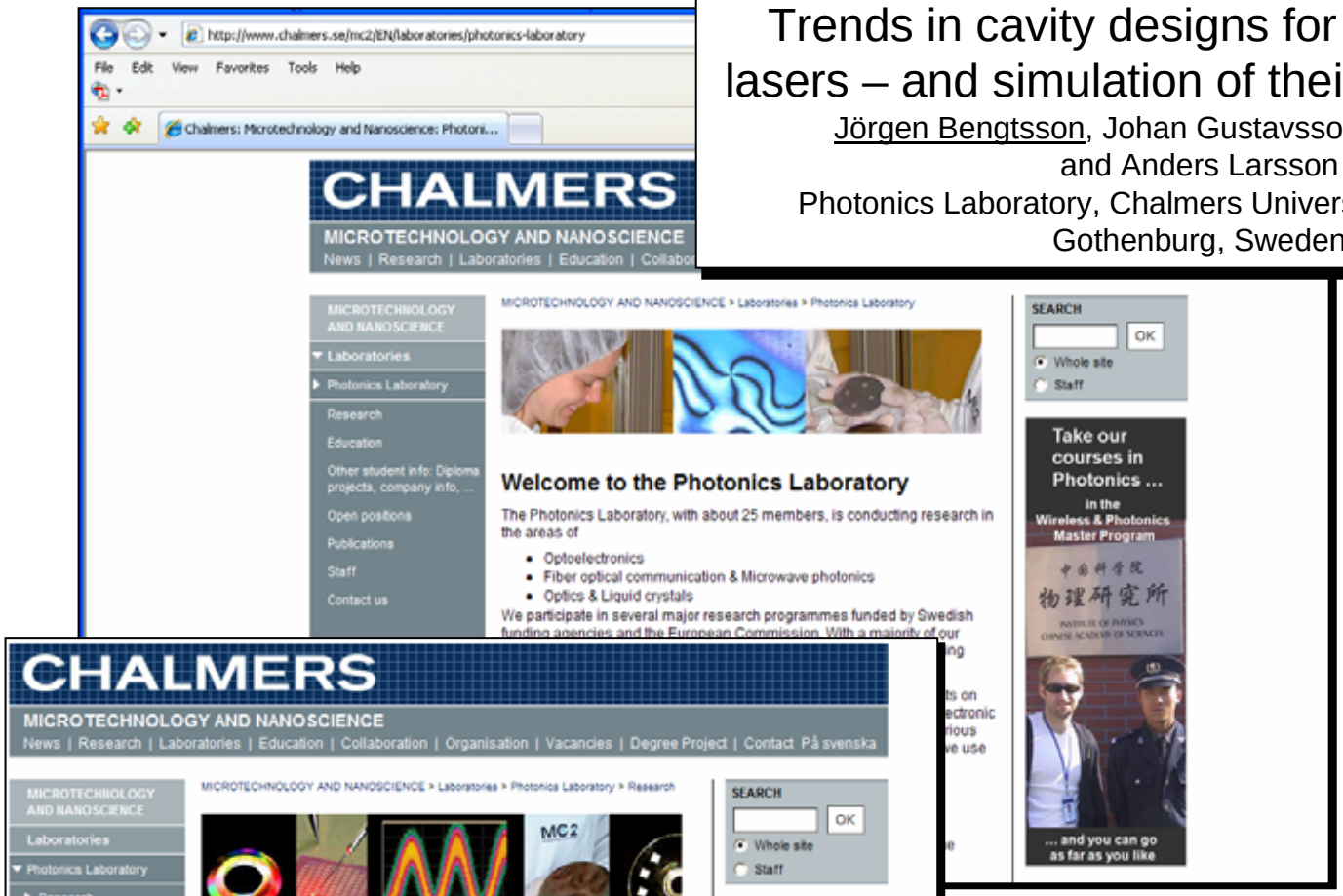
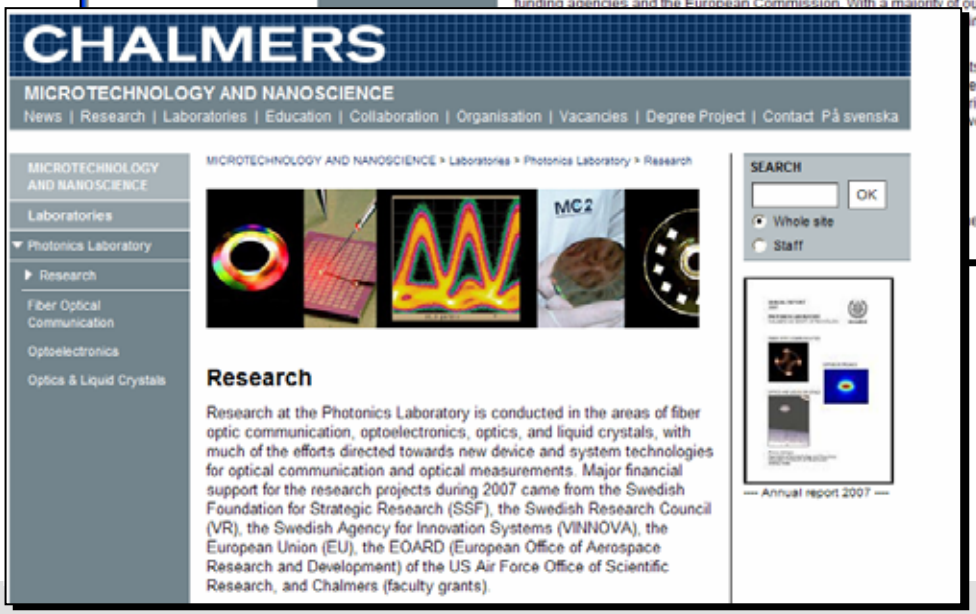
Gothenburg, Sweden





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Two things that never to go out of fashion:

- high-Q music …

…&

- high-Q optical cavities

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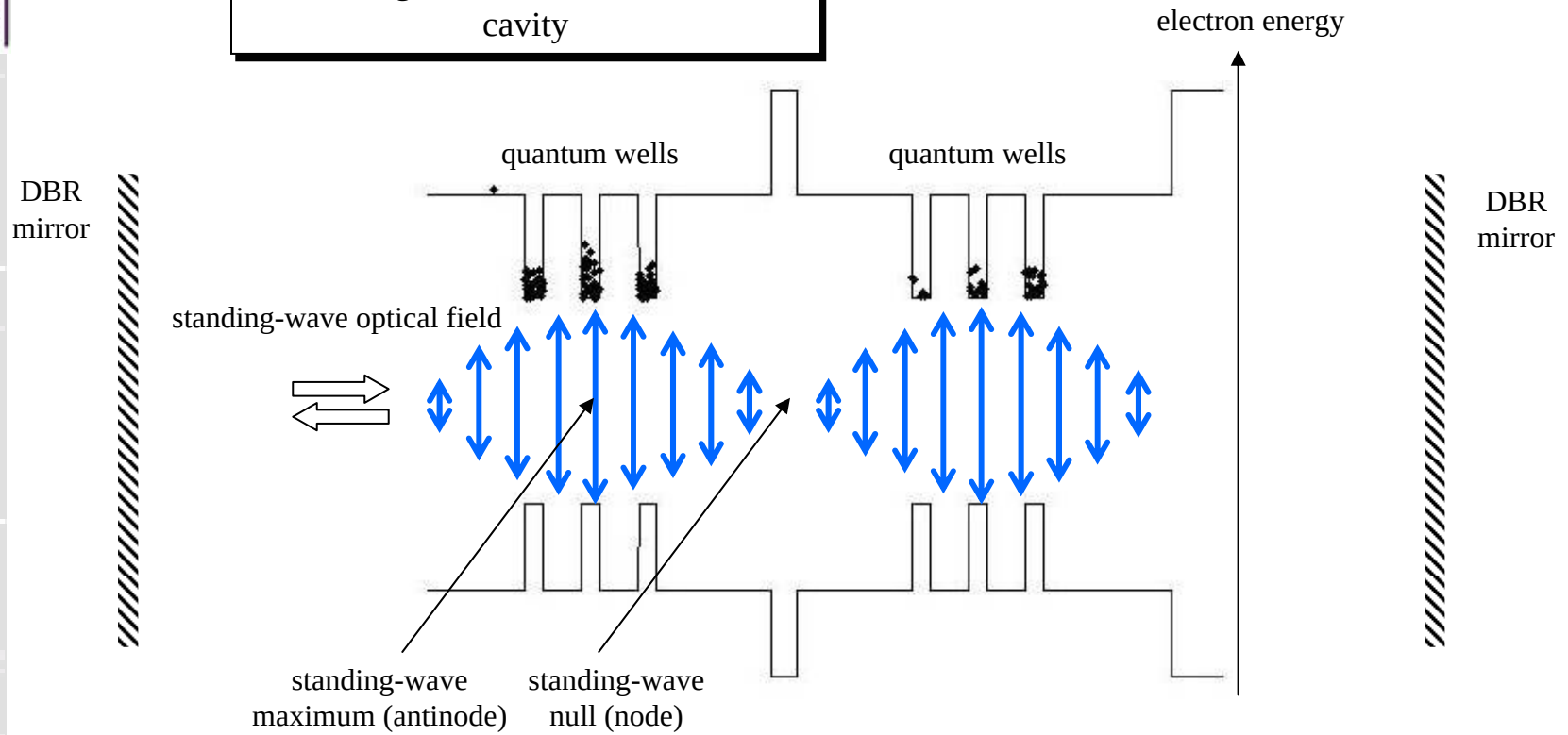
Optical cavities can still fool anyone!

Active region of semiconductor laser cavity



Observation & theory:
QW at standing wave null has no effect!

The “null field explanation”:
The field is zero in some positions;
obviously there the QW cannot have any effect!

A very simple and very dangerous(?) explanation!

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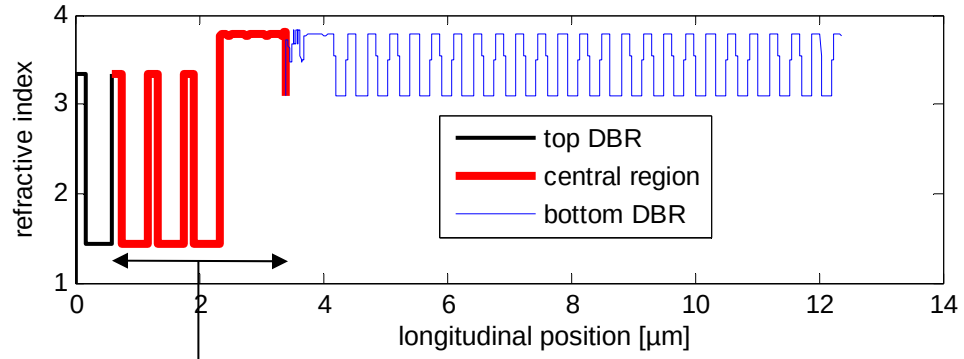
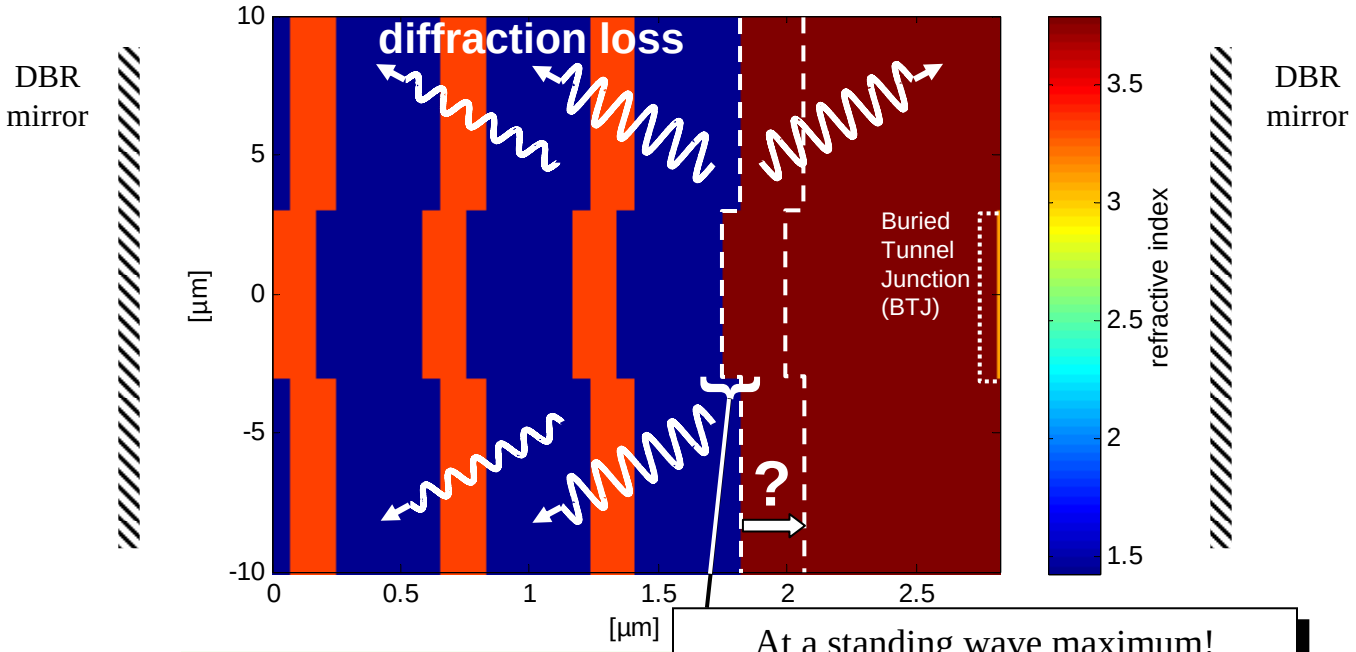
Exam in cavity optics (give your answer at the end of this presentation!)





At a standing wave maximum!
Q: Would the diffraction loss be smaller at a null?

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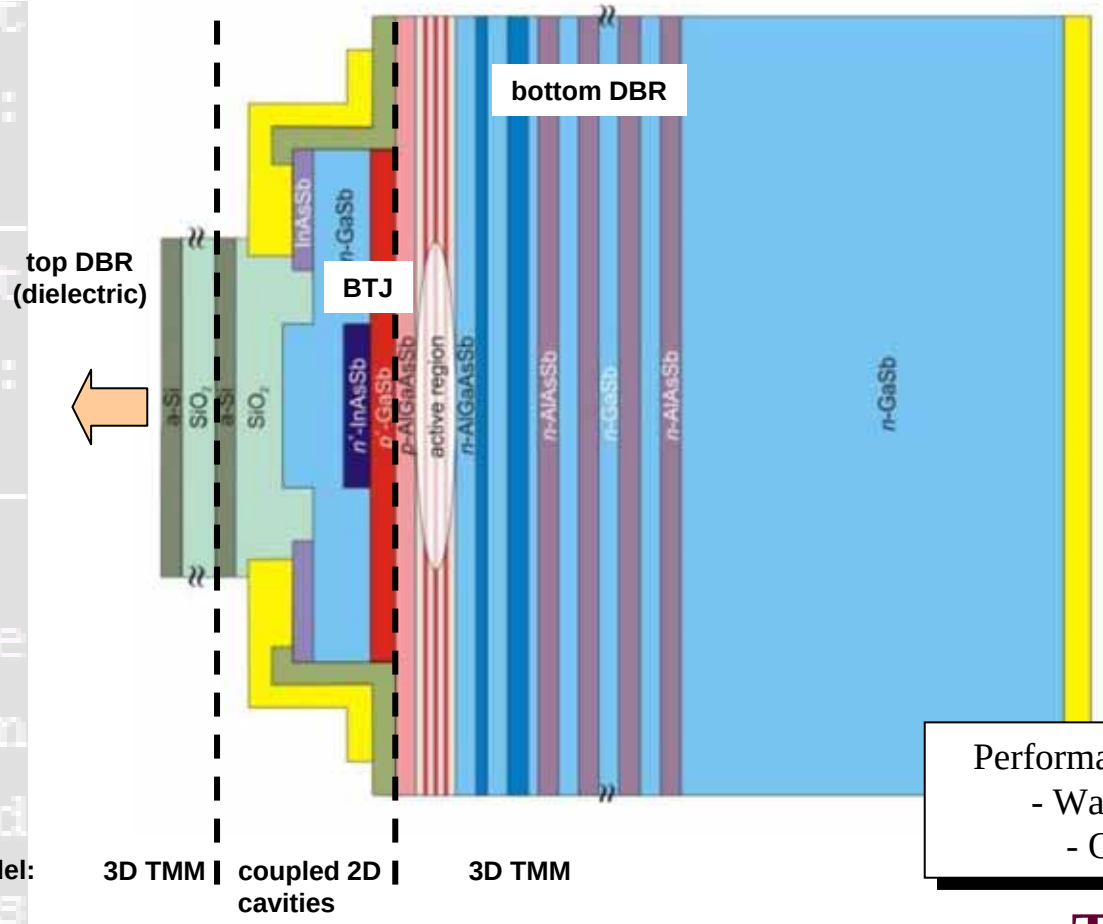
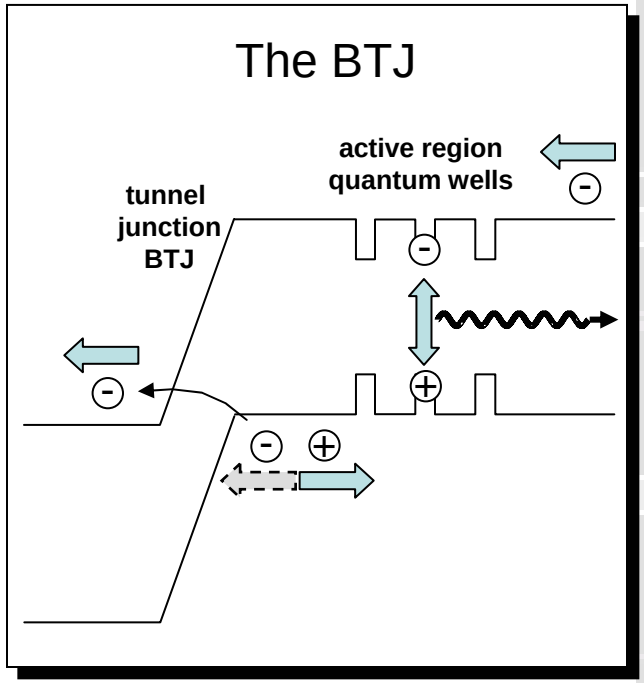
The GaSb-based VCSEL for 2.3 µm emission





Performance of fabricated VCSEL:
- Wall-plug efficiency ~1%
- Output power 87 µW

That´s bad!

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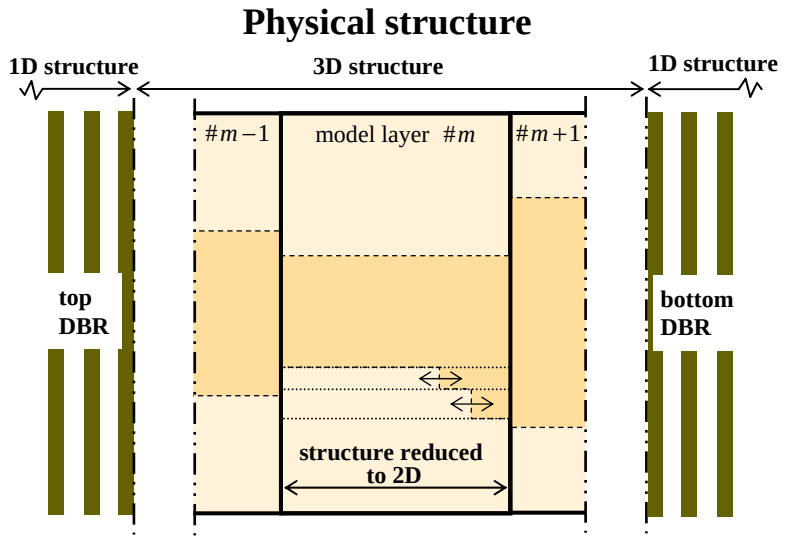
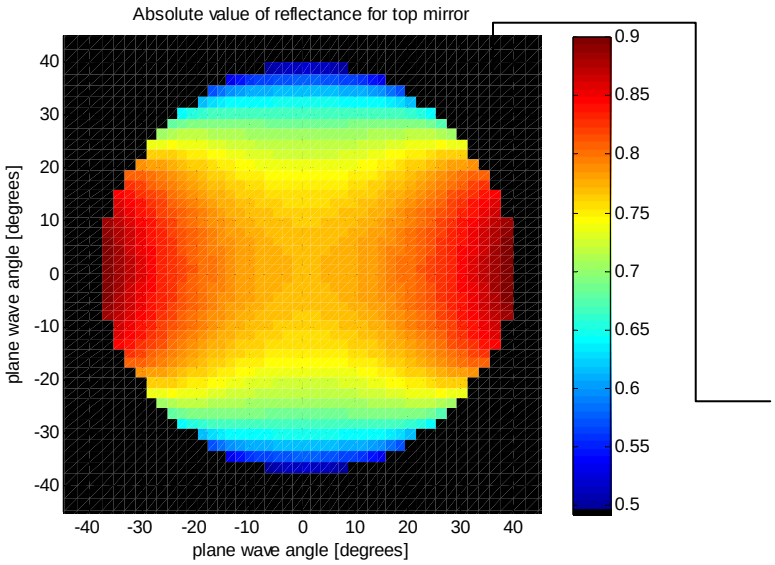
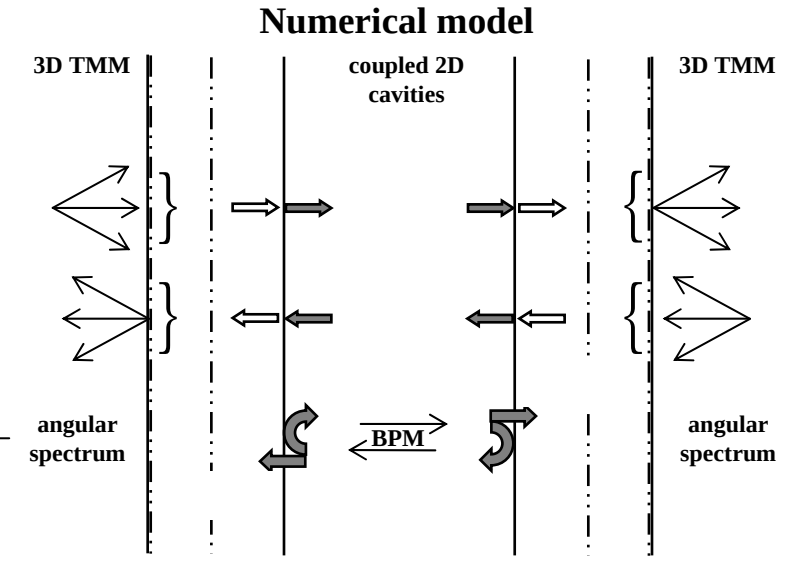
A hybrid model for the cavity







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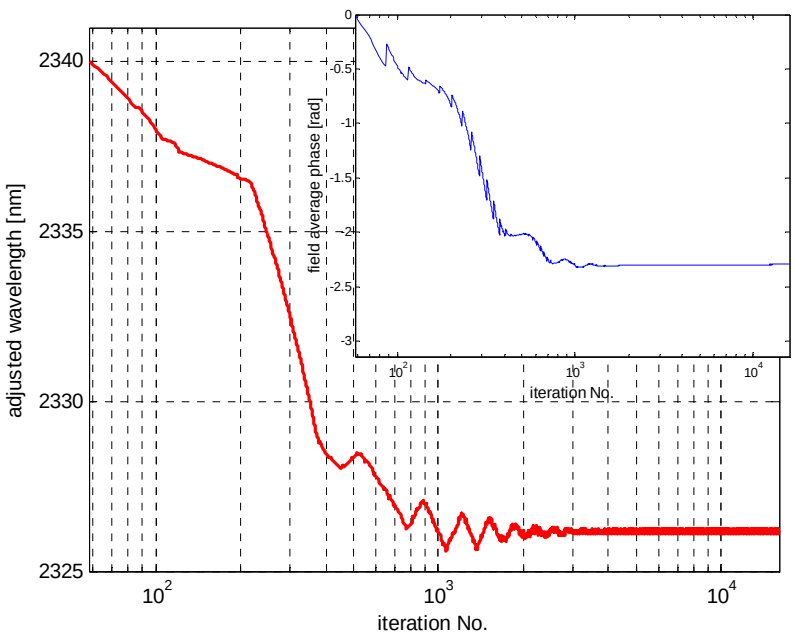
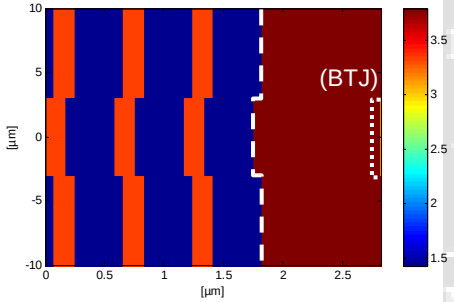
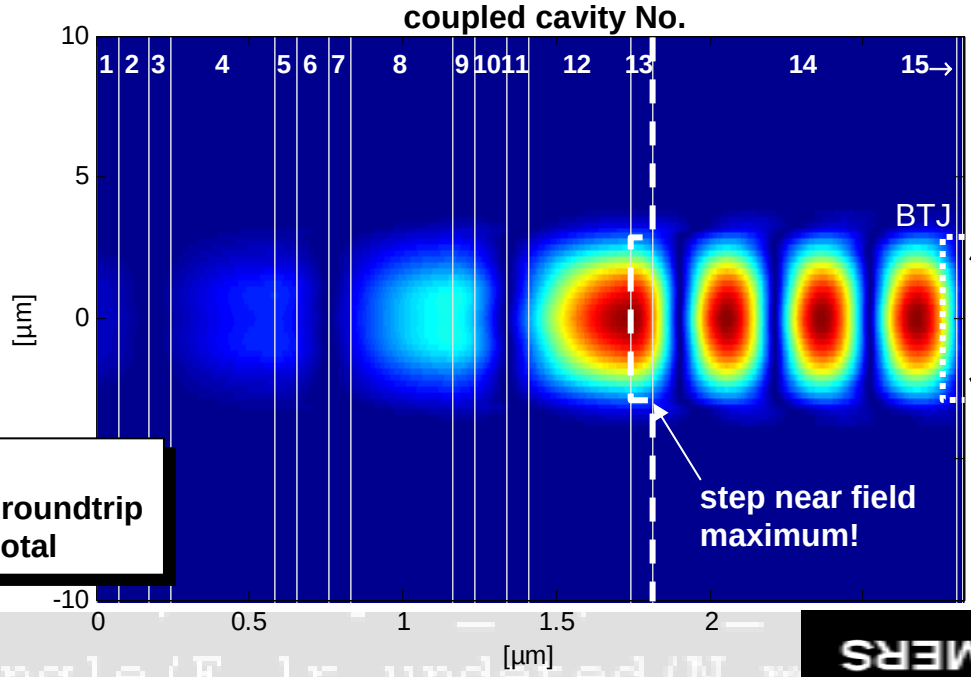
Obtaining the intracavity field





iterative propagation
(incl wavelength adjustment)…

… and final result
(absolute value of standing wave field)



This example (BTJ diameter 6 µm):

- **Resonance wavelength: 2327.3 nm**
- **Absolute diffraction loss: 0.33% per roundtrip**
- **Relative to total cavity loss: 46% of total**

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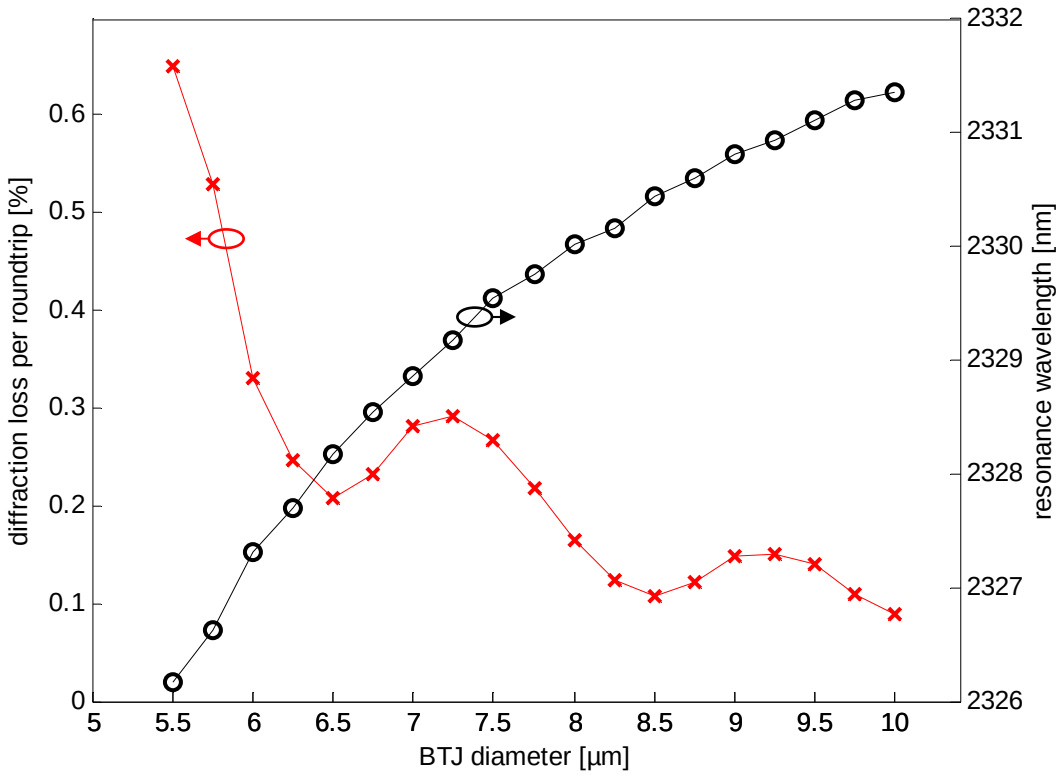
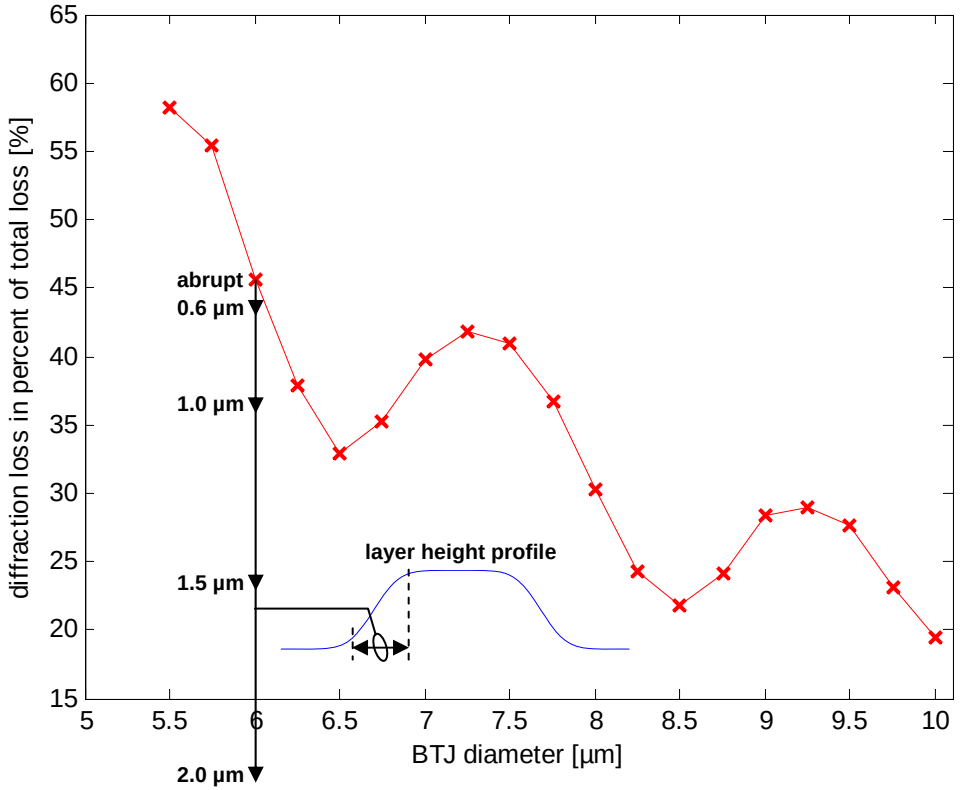
… and for different BTJ diameters (absolute loss)



Each point requires a hard day´s night (for the computer), i.e., < 5 seconds per iteration

… and relative to total loss



- Diffraction loss can be the dominant loss mechanism
- … but it can be reduced!

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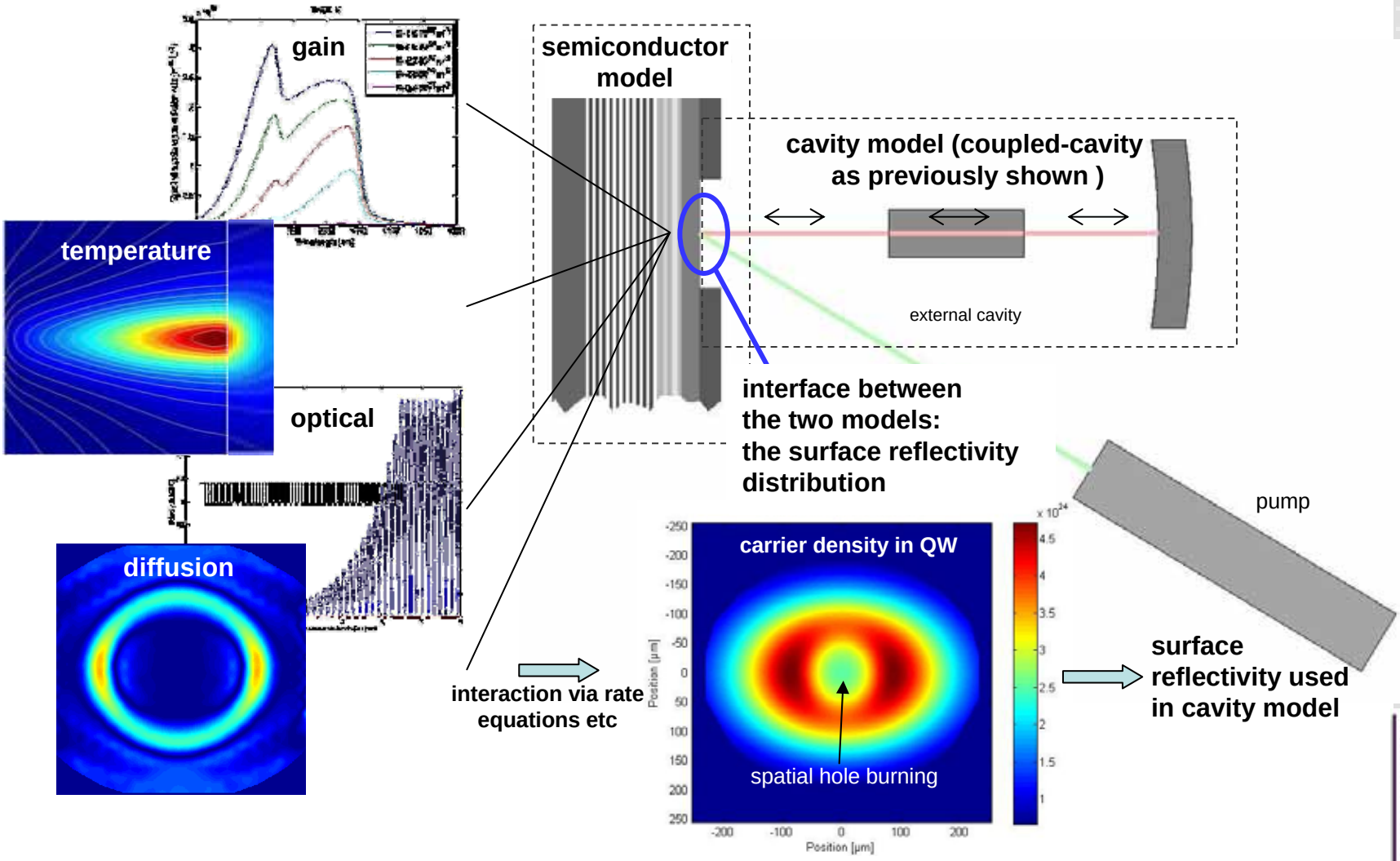
Is µW too little for you?
The external-cavity VECSEL can have several watts cw output.



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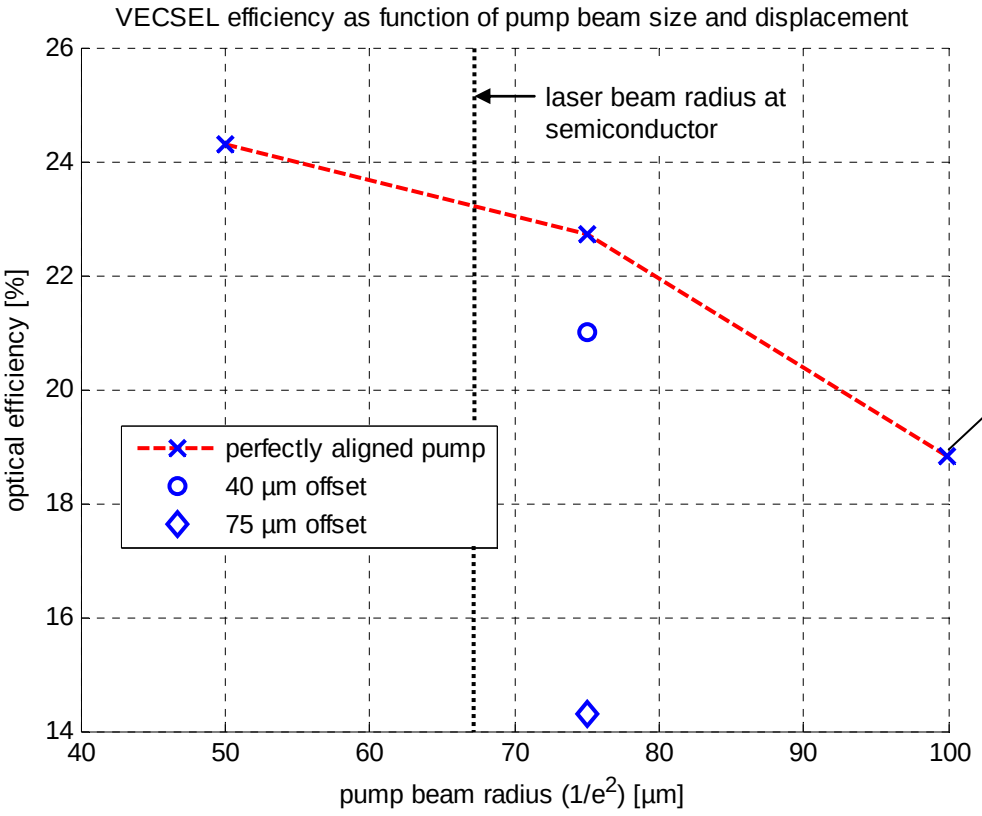
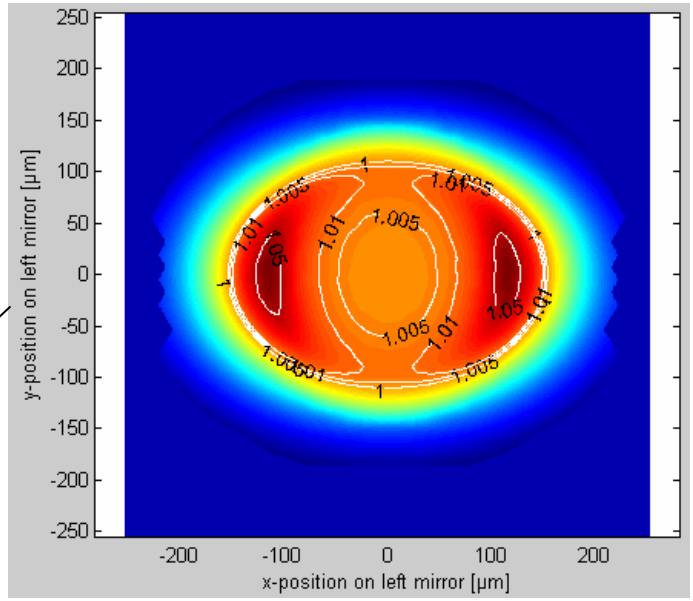
The total VECSEL model: semiconductor & cavity working together…

1. …to assess the pump beam size and alignment tolerance (example given in the proceedings)…



surface reflectivity



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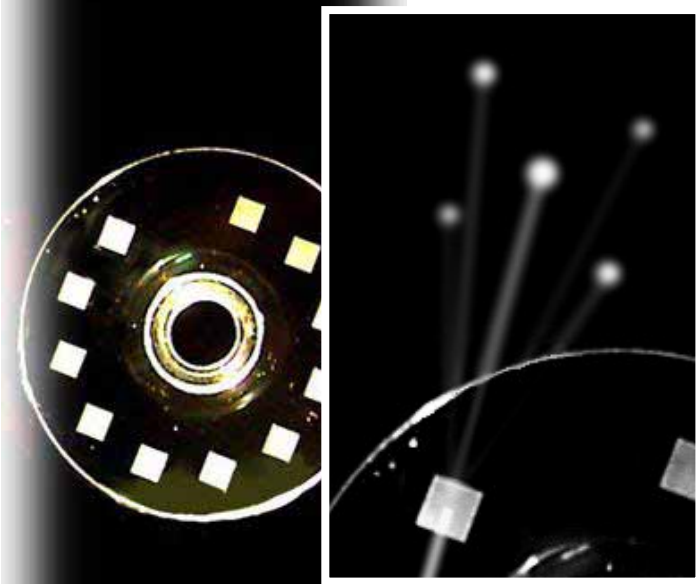
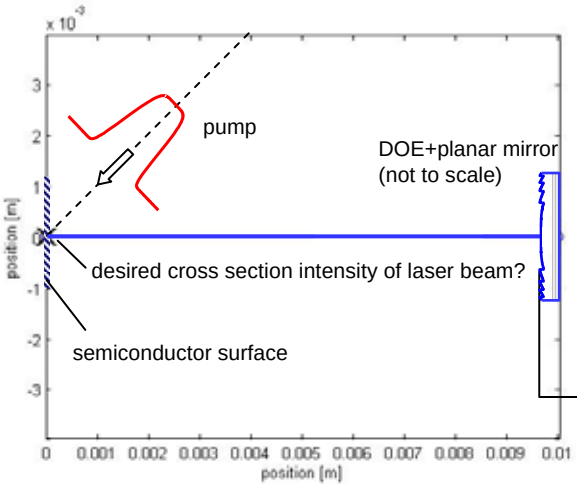
2. … to investigate the effects of an inserted intracavity DOE

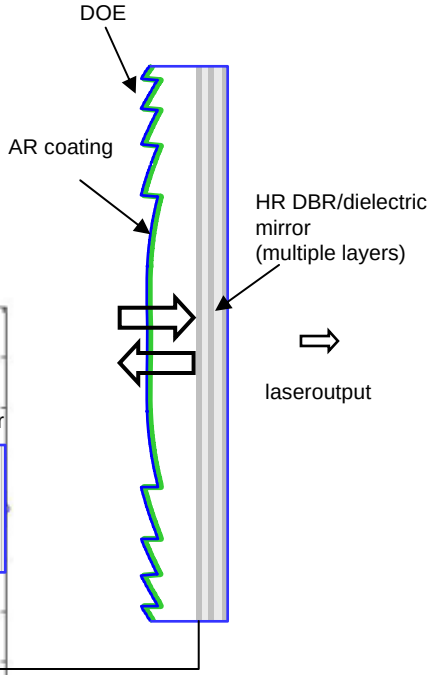
Inserting a DOE for beam shaping (to better overlap pump beam)?
Not yet a trend because no one thinks it will work!

Free-space beam splitting DOE (diffractive optical element)



Intracavity DOE?





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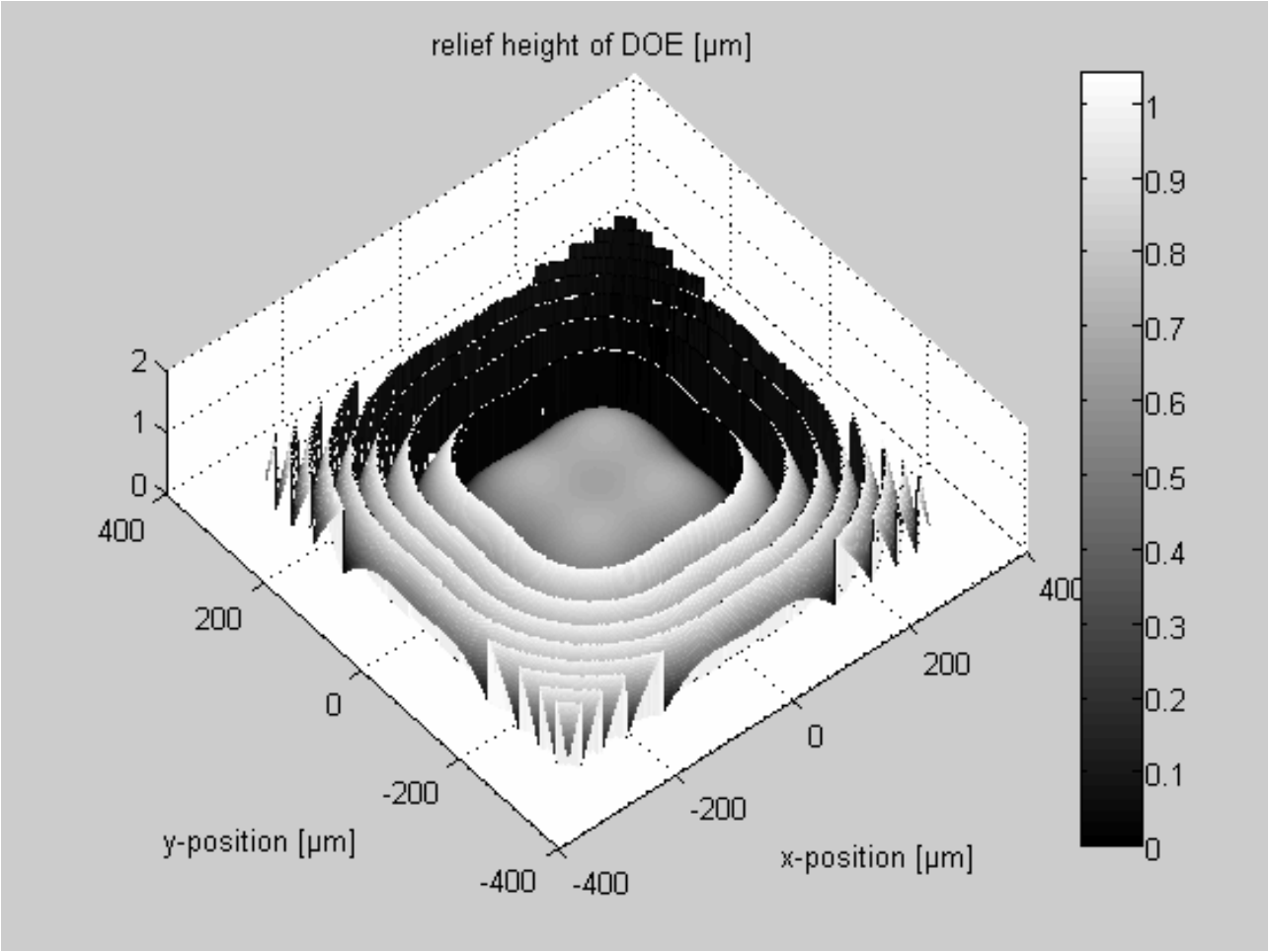
With some tricks, old designs for free-space DOEs, preliminary tests and hope for good luck, we decided to test the following DOE:



Q1: Will it lase at all? (typically even perfect DOEs have efficiencies <90%)

Q2: Will it produce a square tophat at the plane of the semiconductor? (instead of the usual Gaussian)

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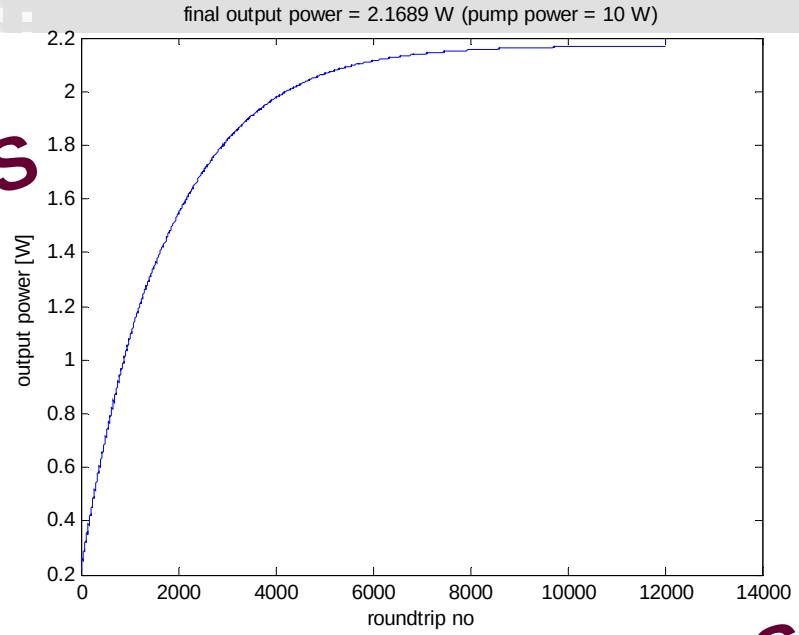
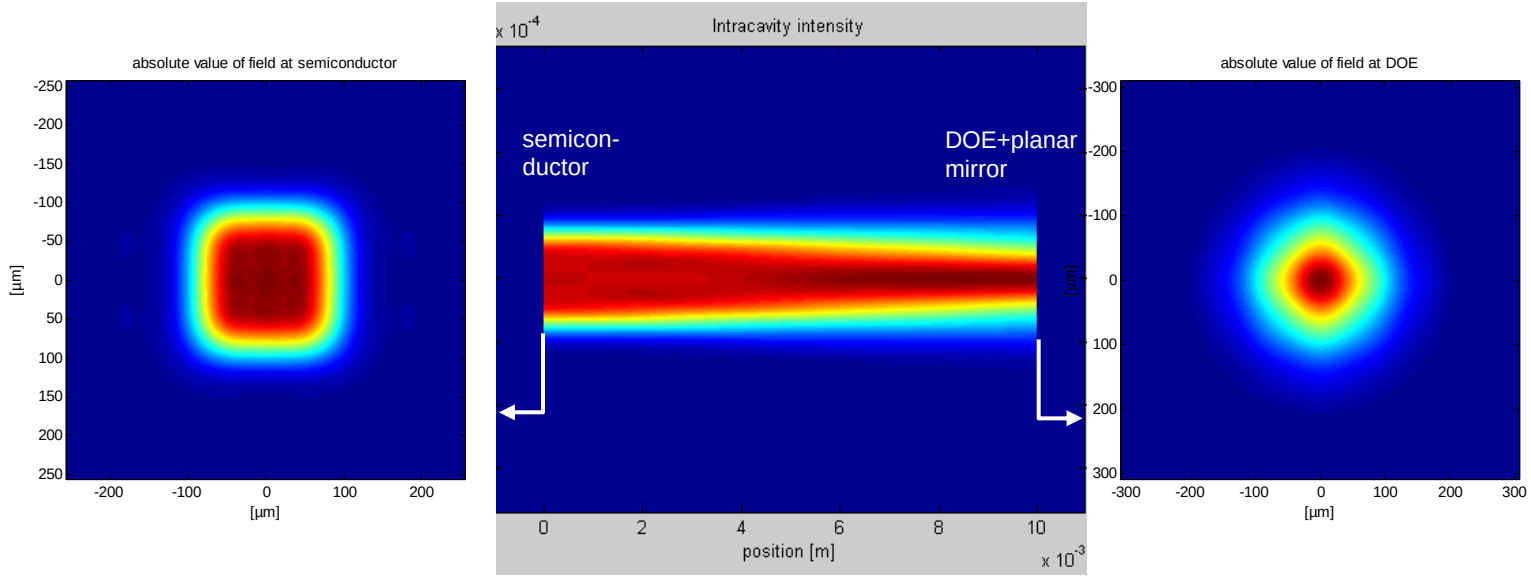
Q1: Will it lase at all? YES



Q2: Will it produce a square tophat at the semiconductor? YES



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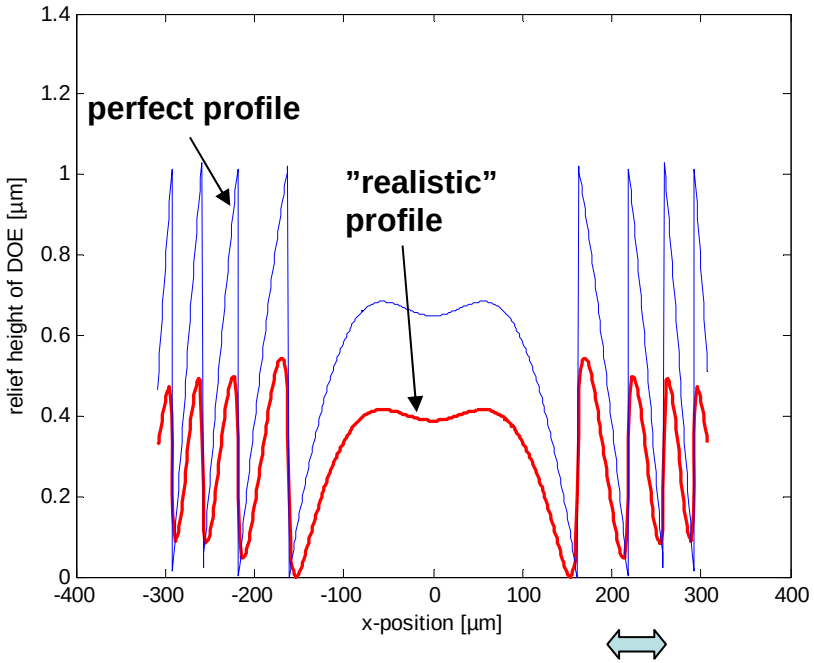
But with a <u>true</u>, fabricated, DOE it won´t lase, right?



height scaling error (development error, -20%)

smearing error (proximity error, 2 µm + 10 µm)

<u>No way</u> this could work (at least I thought so)...

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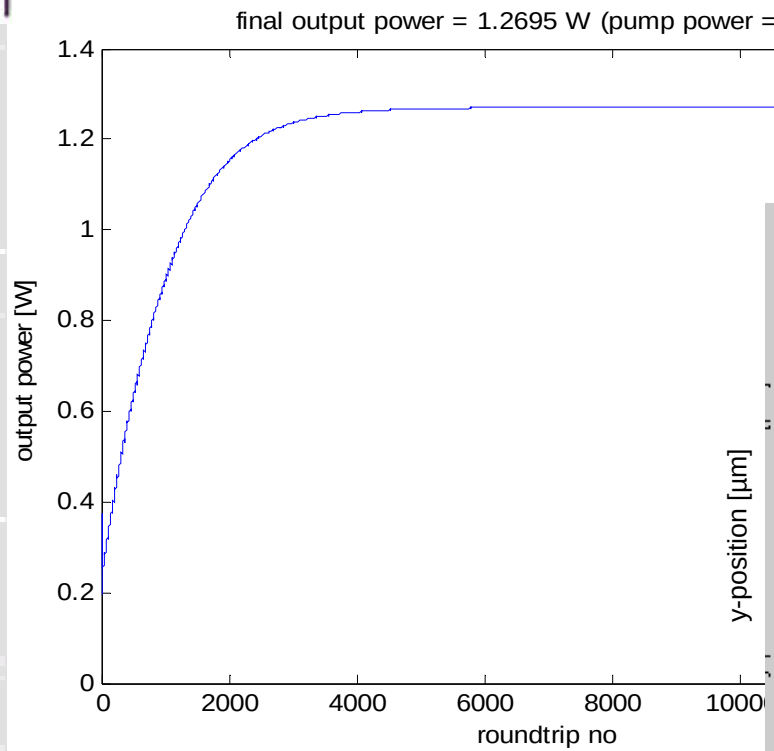
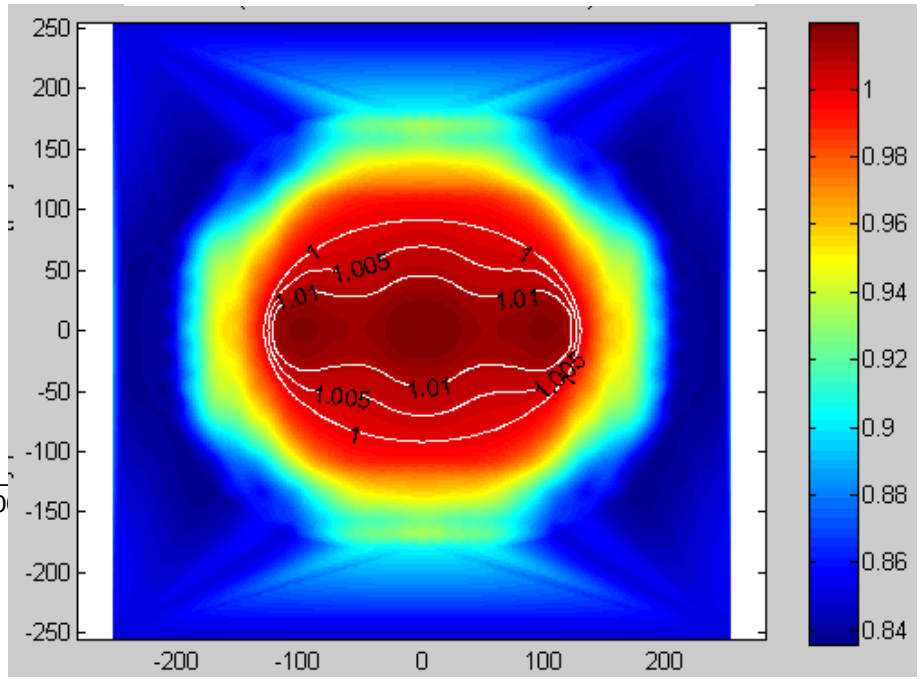
Q1: Will it lase at all? YES !



reflectivity of semiconductor surface



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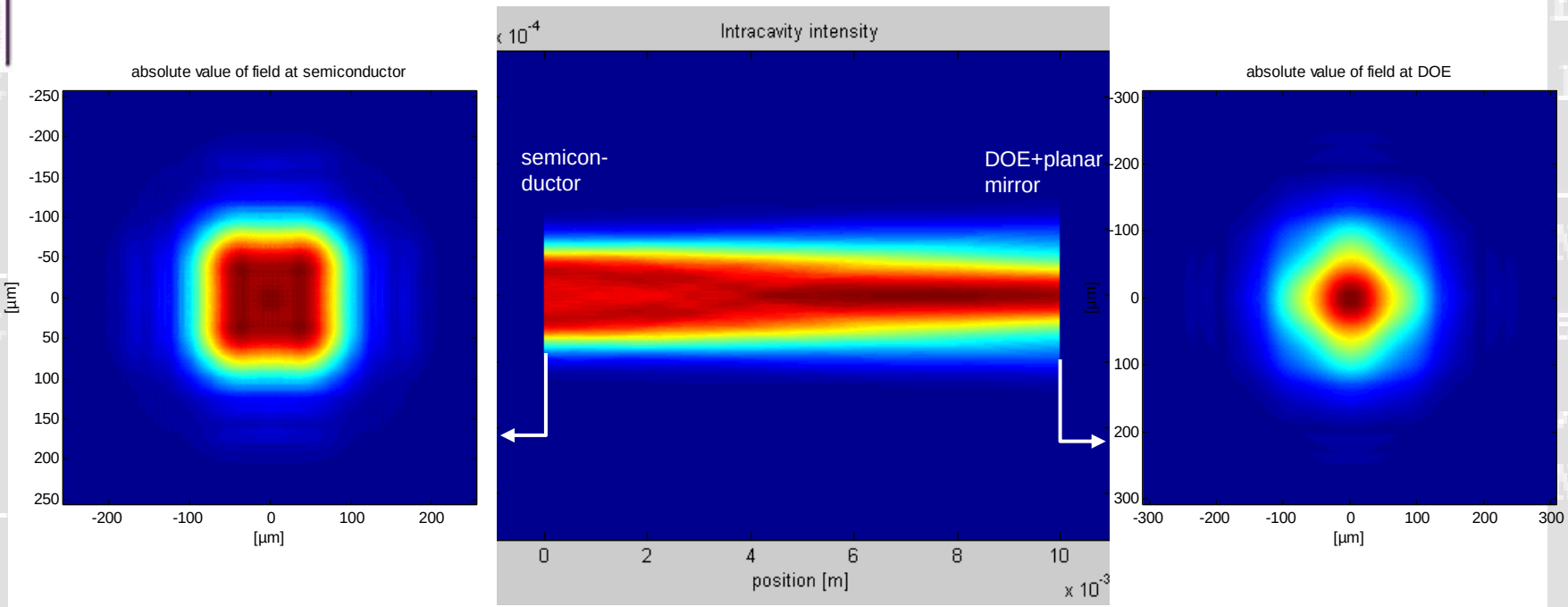
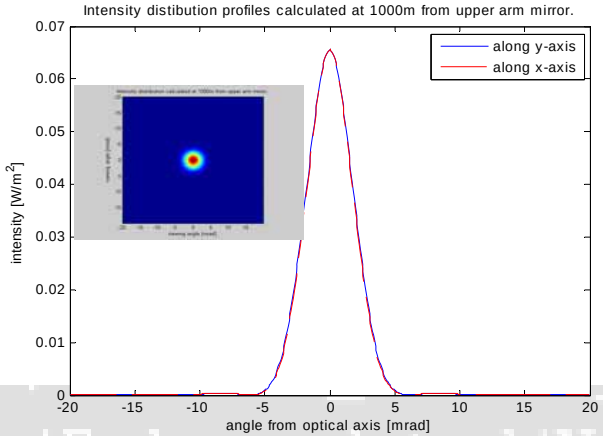
Q2: Will it produce a square tophat at the semiconductor? YES !



and the far-field is still almost Gaussian



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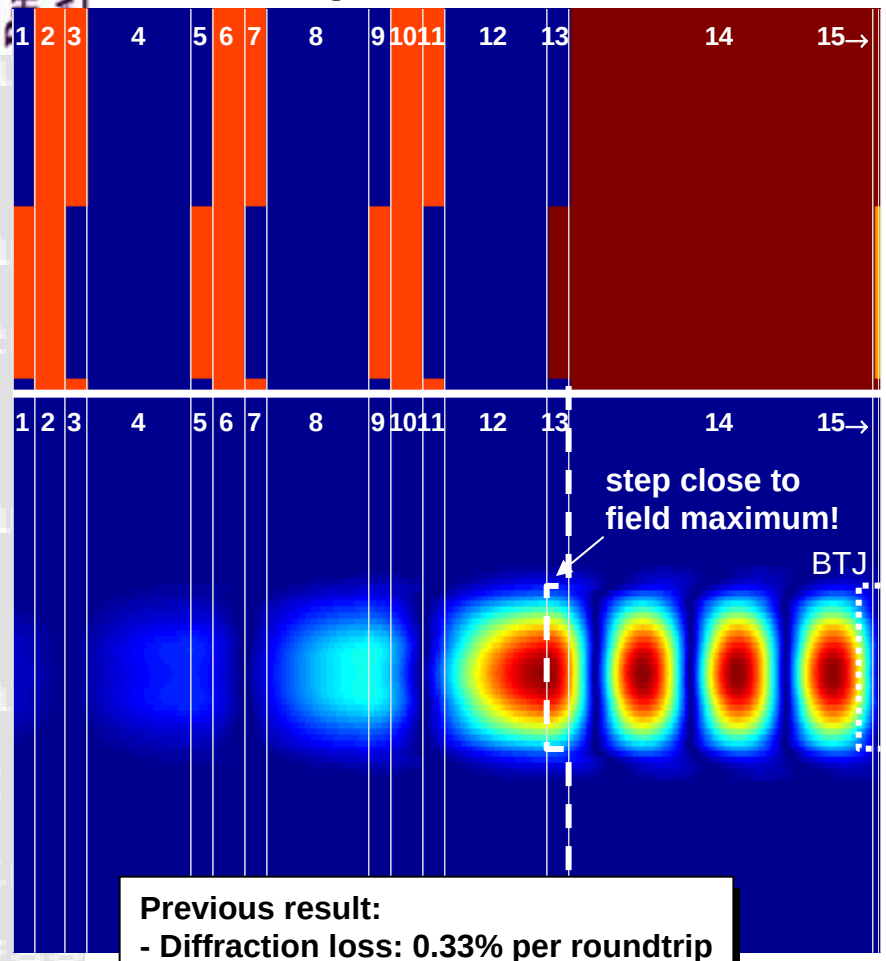
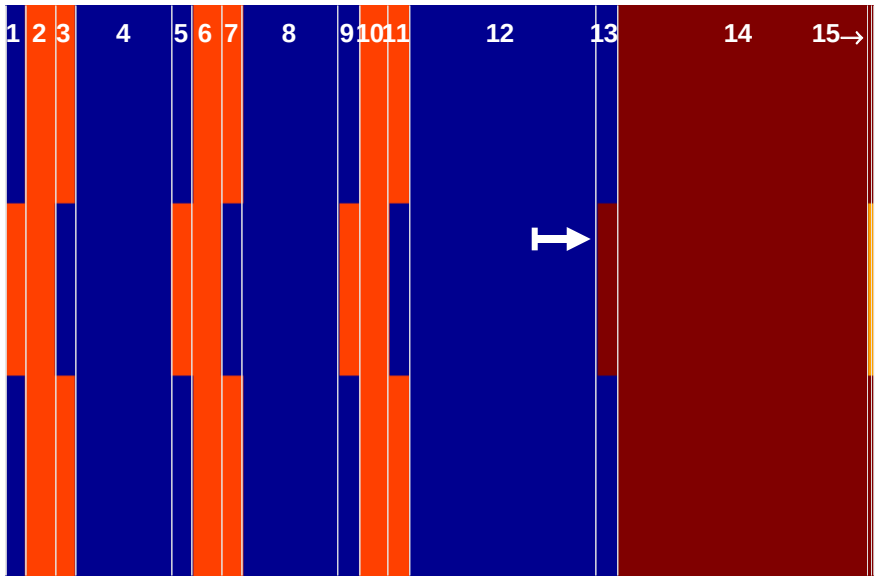
So, exam time! YES !

original structure



Previous result:
- Diffraction loss: 0.33% per roundtrip

surface step moved to null field position



Q: What will be the new value for the diffraction loss?

a) Roughly the same as before (no standing wave effects)!

b) Nearly zero (the null field theory)!

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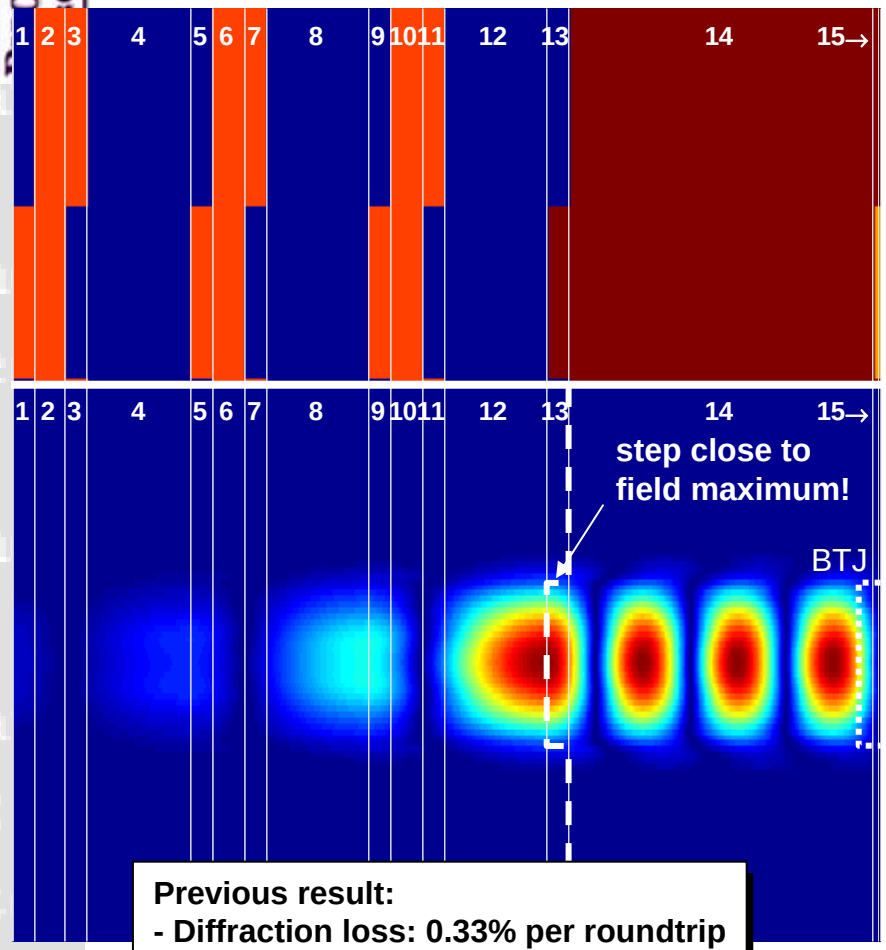
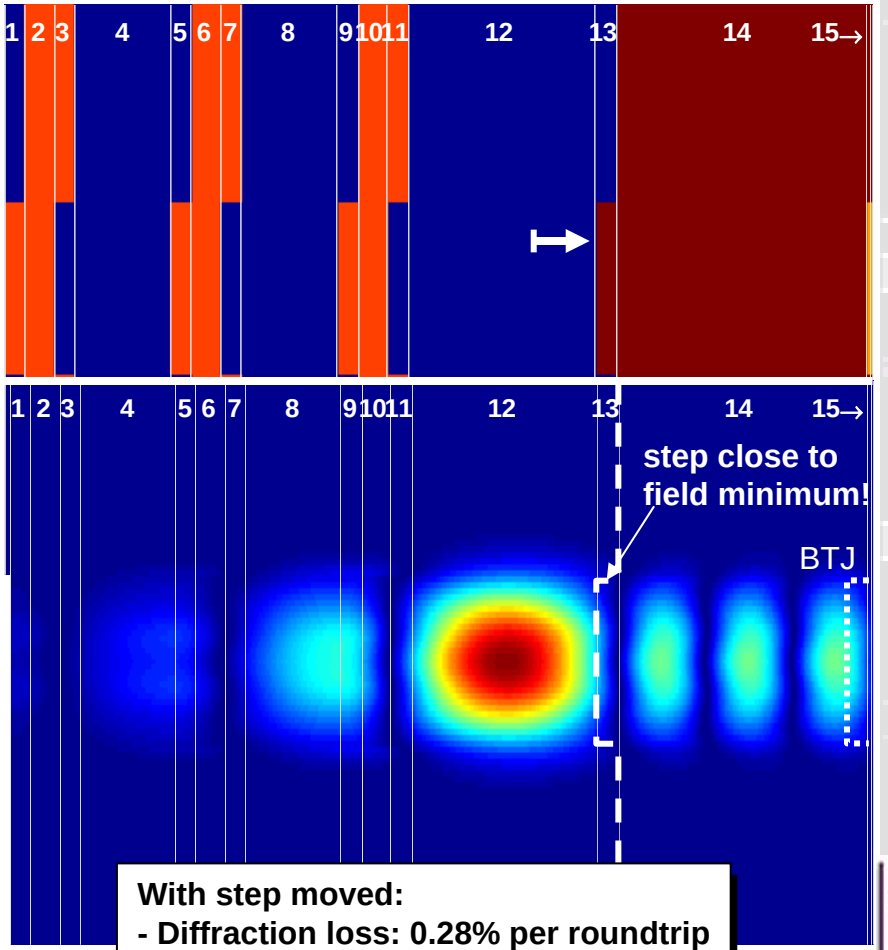
Simulation results

original structure



Previous result:
- Diffraction loss: 0.33% per roundtrip

surface step moved to null field position



With step moved:
- Diffraction loss: 0.28% per roundtrip

Conclusion: No winner can be identified since we have changed the problem!

Actually it is quite difficult to device a simulation that answers the question “is null field theory valid also for diffraction loss”. Maybe I will have a better answer at NUSOD´09!

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… so I say thank you for your attention

- high-Q quadruple vocal cavities

- for giving it to me.

- high-Q double VECSEL cavity

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