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Vertically emitting microdisk lasers

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People involved

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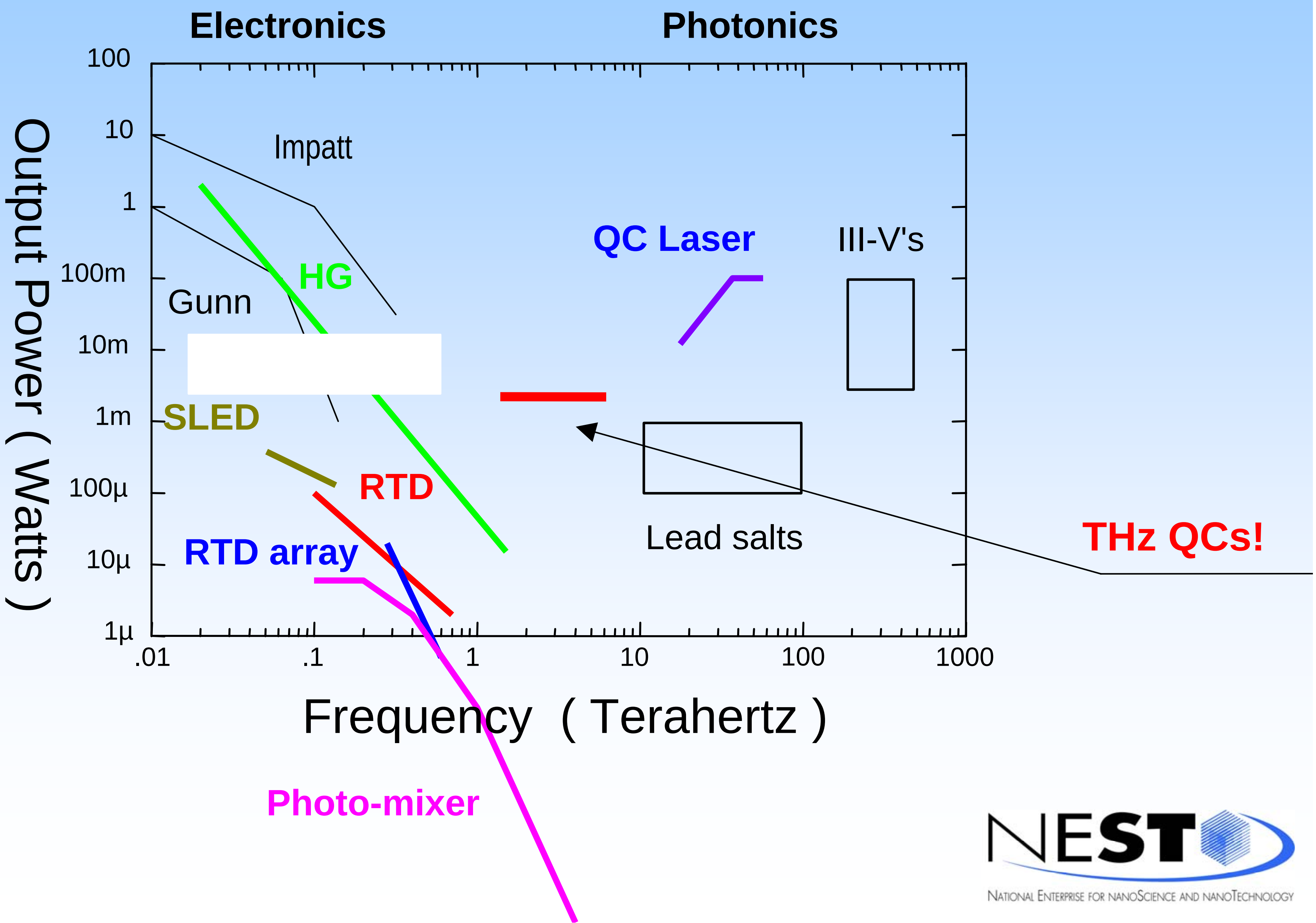
Cavendish Laboratory, University of Cambridge

The THz gap!



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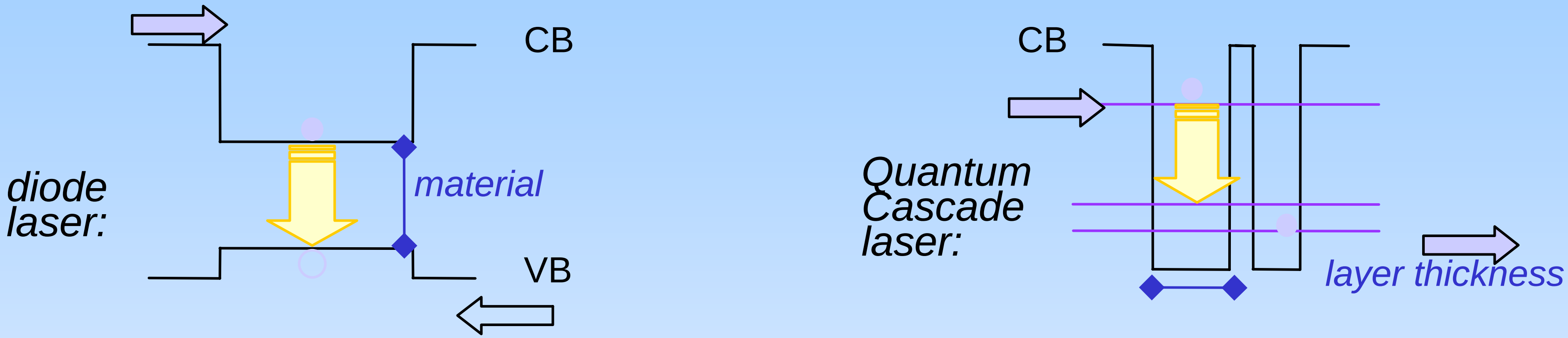
Technology applications

- Information
  - Ultra fast signal processing
  - Massive data transmission
  - Wireless communications
- Space Science
  - Cosmology
  - Planetary, cometary
  - Cosmochemistry
- Environment
  - Atmospheric sensing
- Medicine
  - Imaging of biological tissue
- Security Controls

- Defense
  - Chemical agent detection
  - Digital radar
  - Imaging radar
  - Covert communication
  - Space-space
  - Short range battle field
- Transportation
  - Collision avoidance
- Material processing
  - Tomography

⇒Unknown applications created by new technology

The unipolar semiconductor laser



"materials by design":
band structure engineering and molecular beam epitaxy (MBE)
population inversion, matrix elements, scattering times, and transport are *designed* for optimum performance

- 1971: amplification from intersubband transitions is first postulated by
  R. F. Kazarinov and R. A. Suris *Sov. Phys. Semicond.* **5,** 207 *(Ioffe)*
- 1994: QC-laser is first experimentally demonstrated by
  J. Faist et al. *Science* **264,** 553 *(Bell Labs)*
- 2002: THz QC-lasers Nature 417, 156 *(INFM Pisa-Cavendish Lab)*

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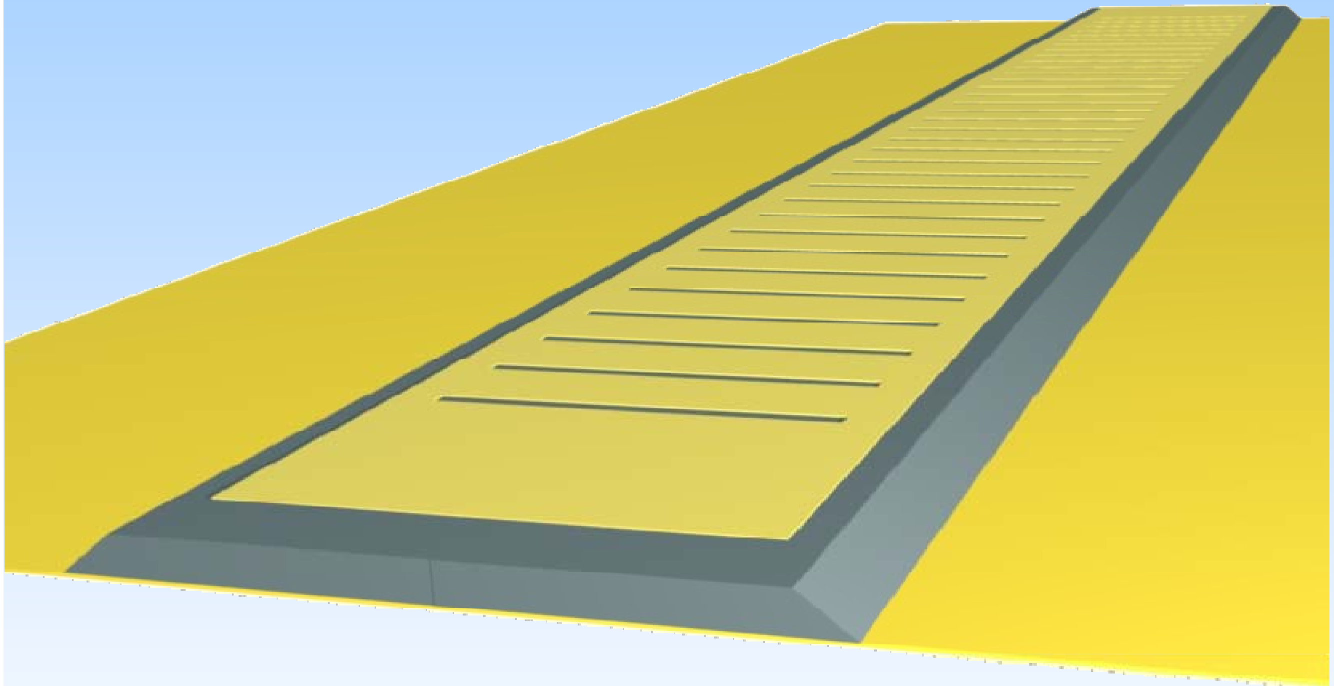
Distributed feedback resonator for THz QCL



- Double metal waveguide
- Periodic slits in the top metallization

→ Very big coupling constant

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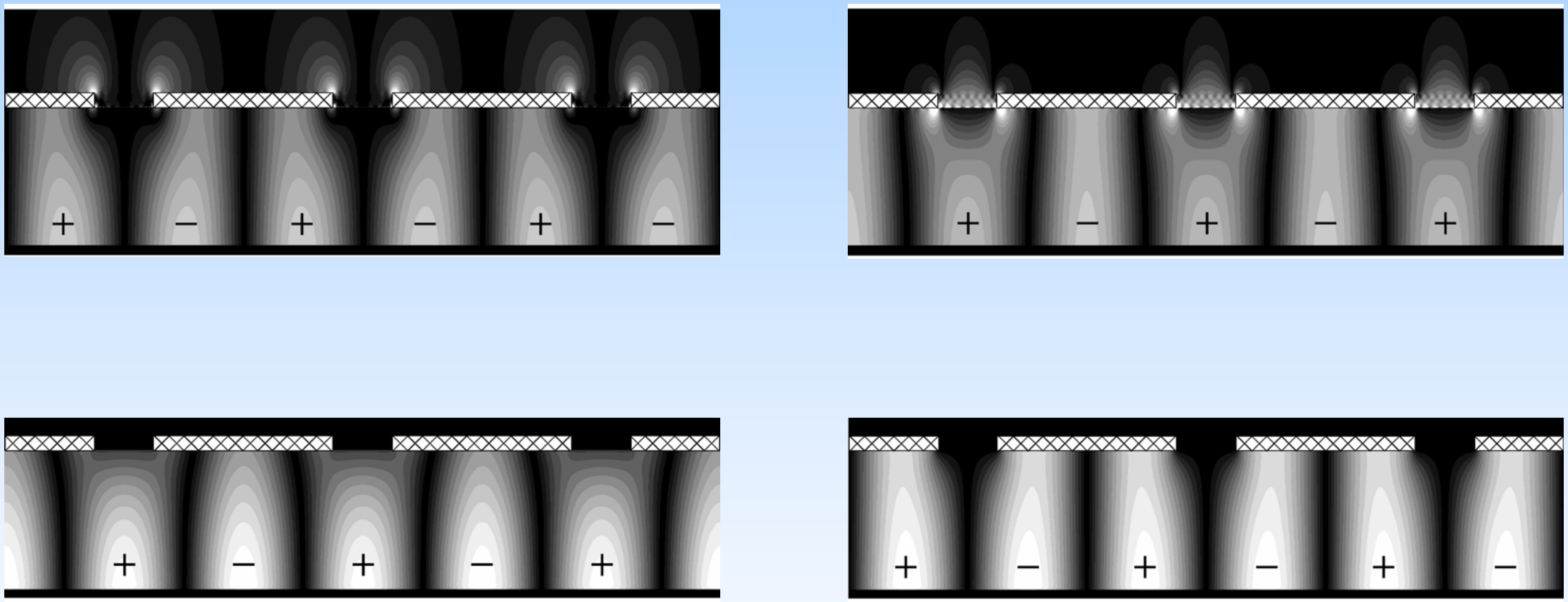
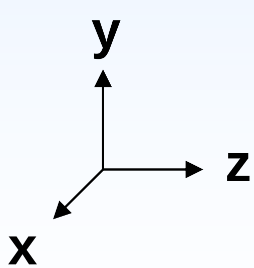
Linear gratings

Radiative mode | Non-radiative mode

E_y

H_x





M. Schubert *et al.* JQE **42**, 257 (2006)

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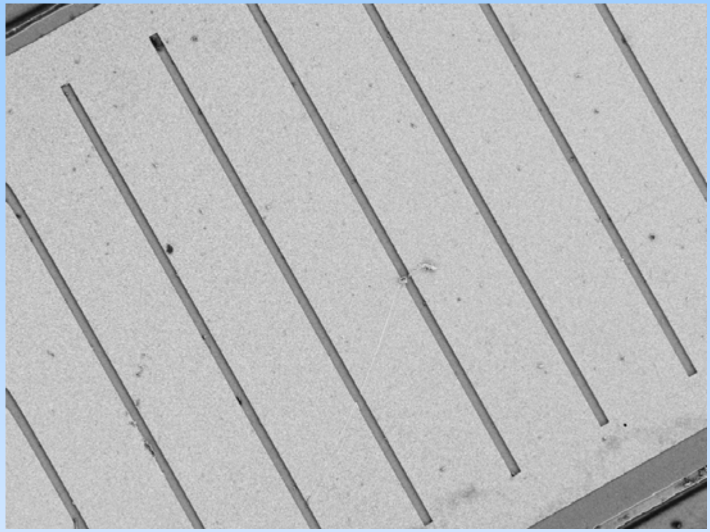
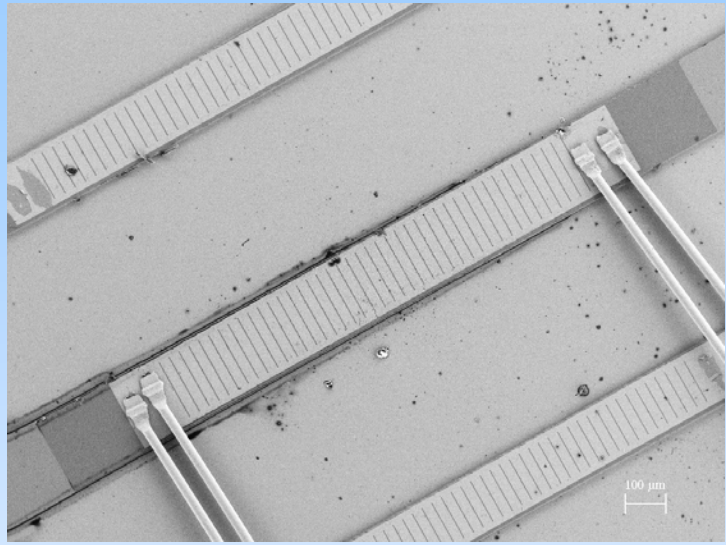
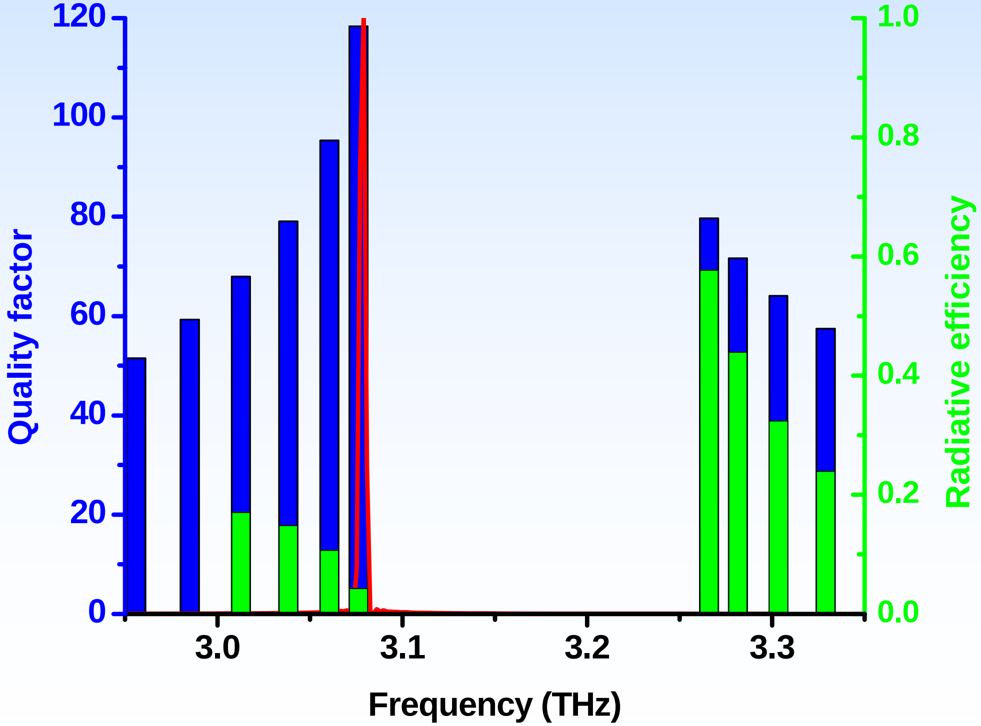
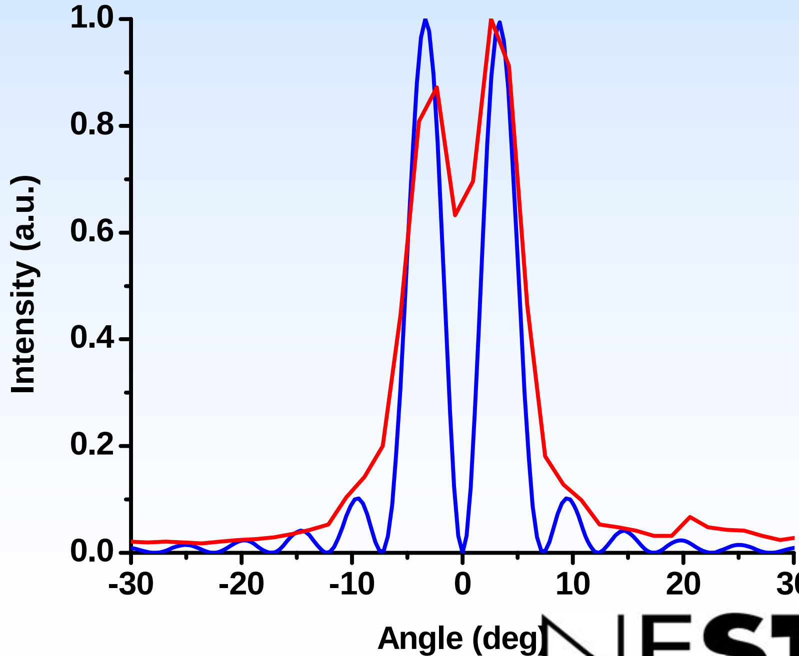
Device









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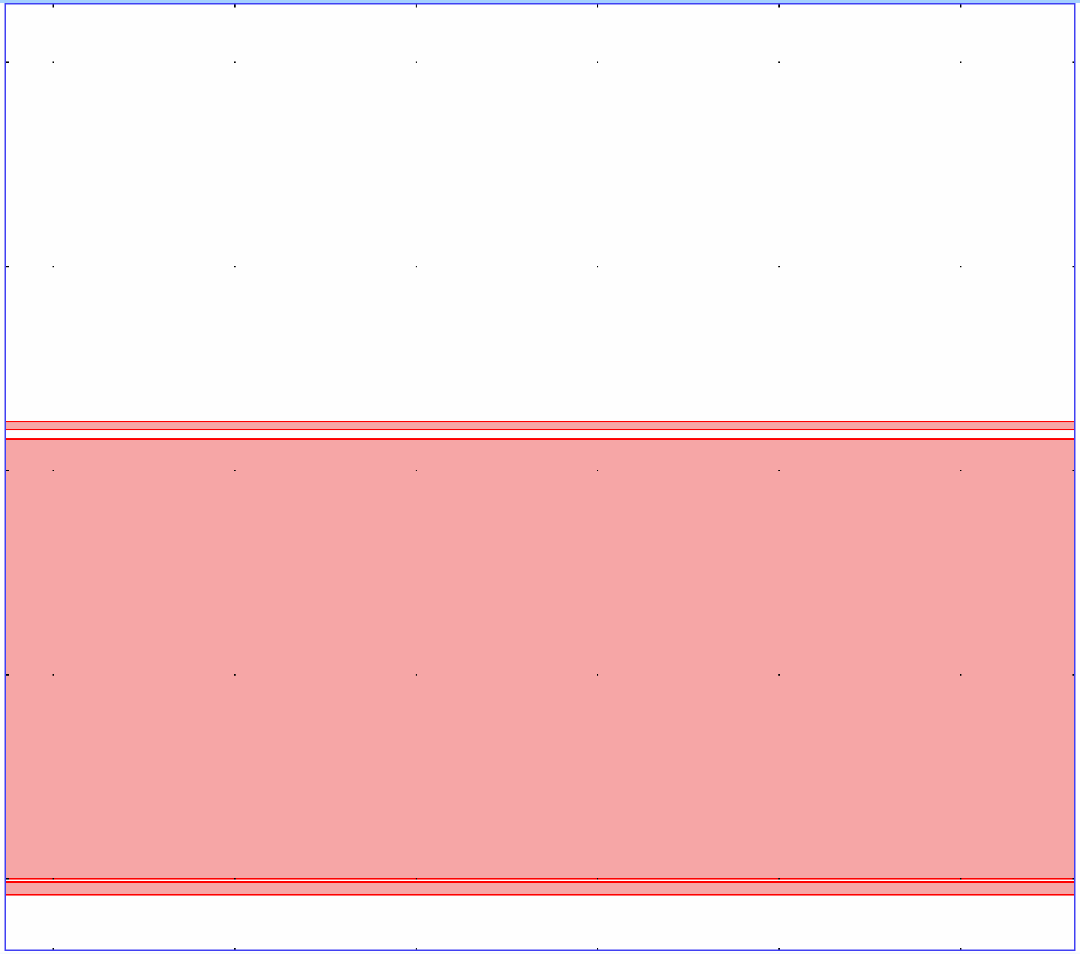
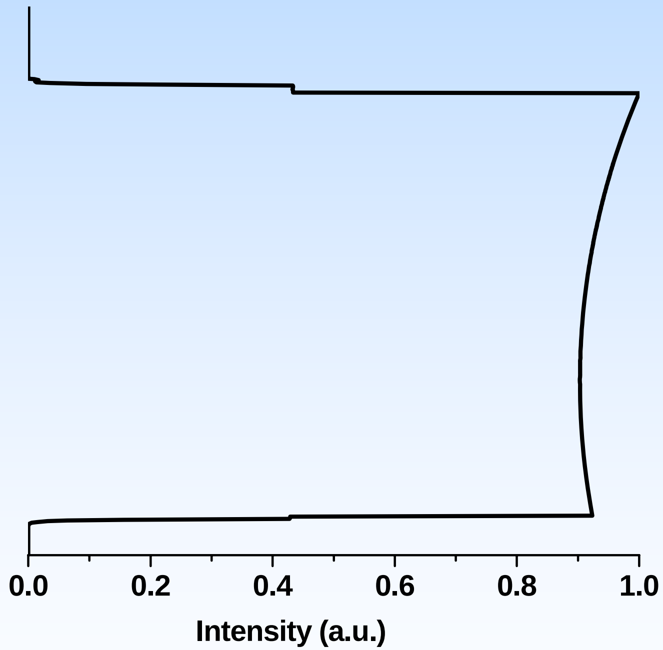
Slab mode analysis





neff = 3.60-0.011i

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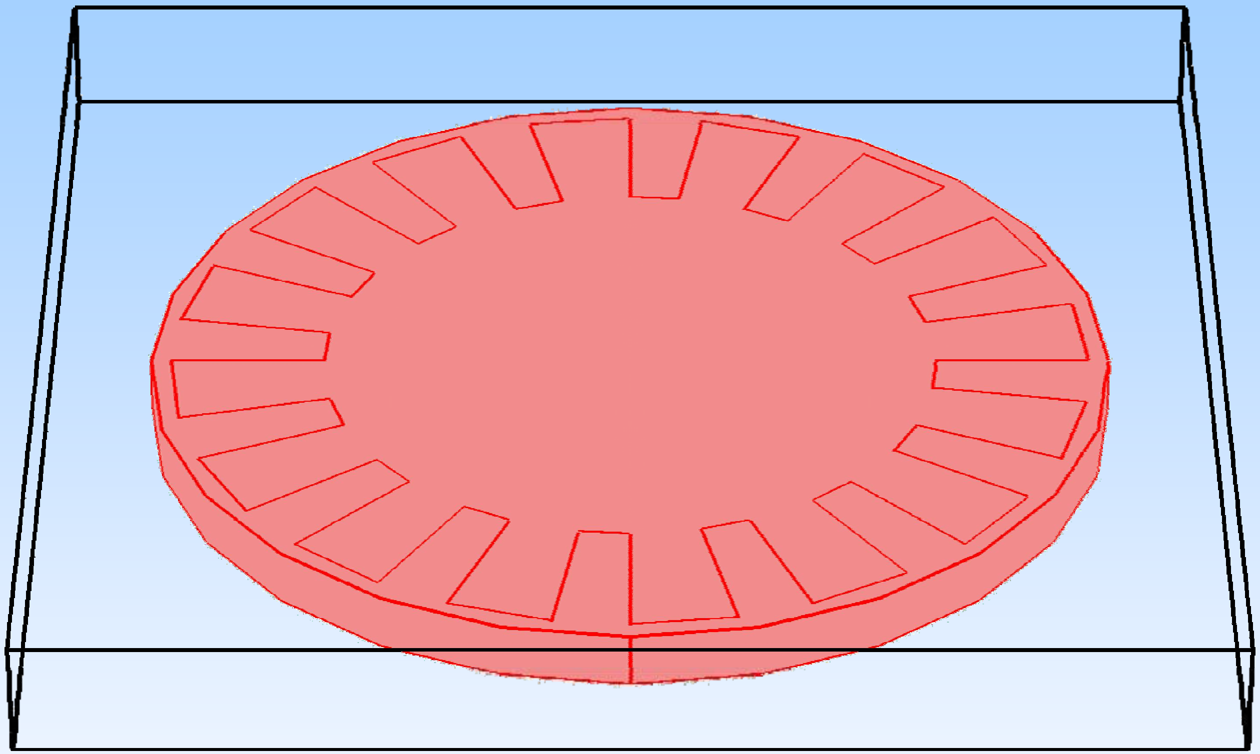
Vertically emitting disks



- Coupling mechanism for whispering galleries
- "infinite" grating

- Full 3D simulation
- Gold layers approximated with perfect electric conductors

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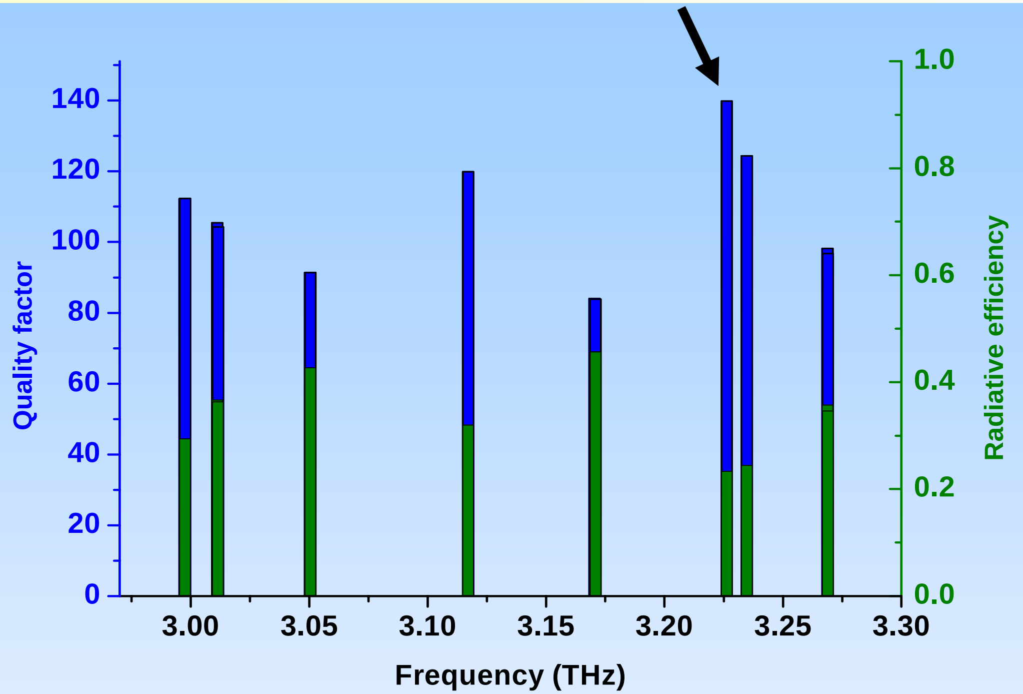
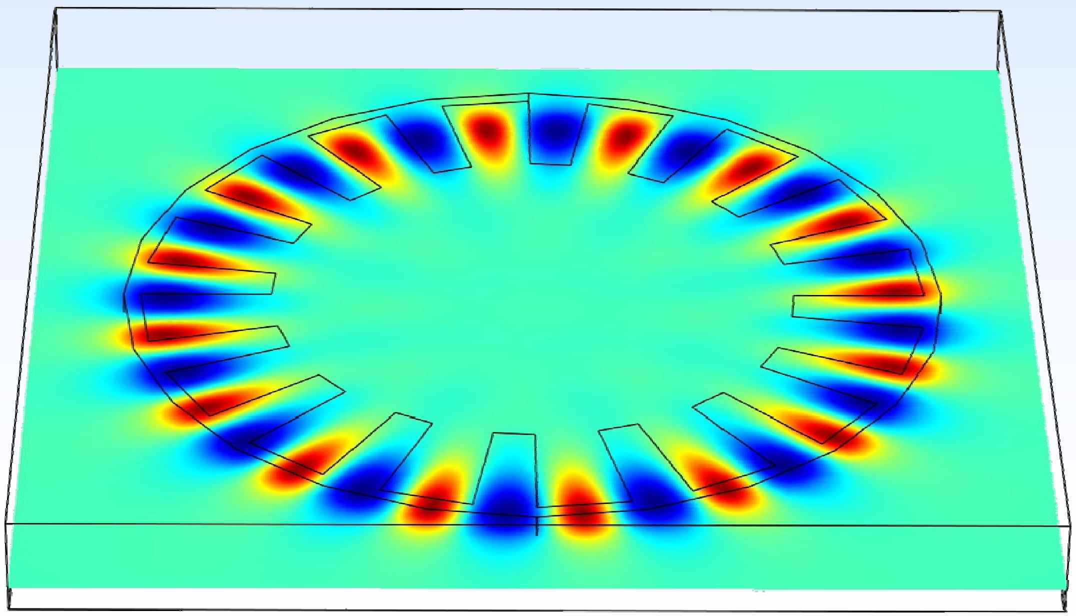
Simulation





- Good quality factor
- Reasonable outcoupling efficiency

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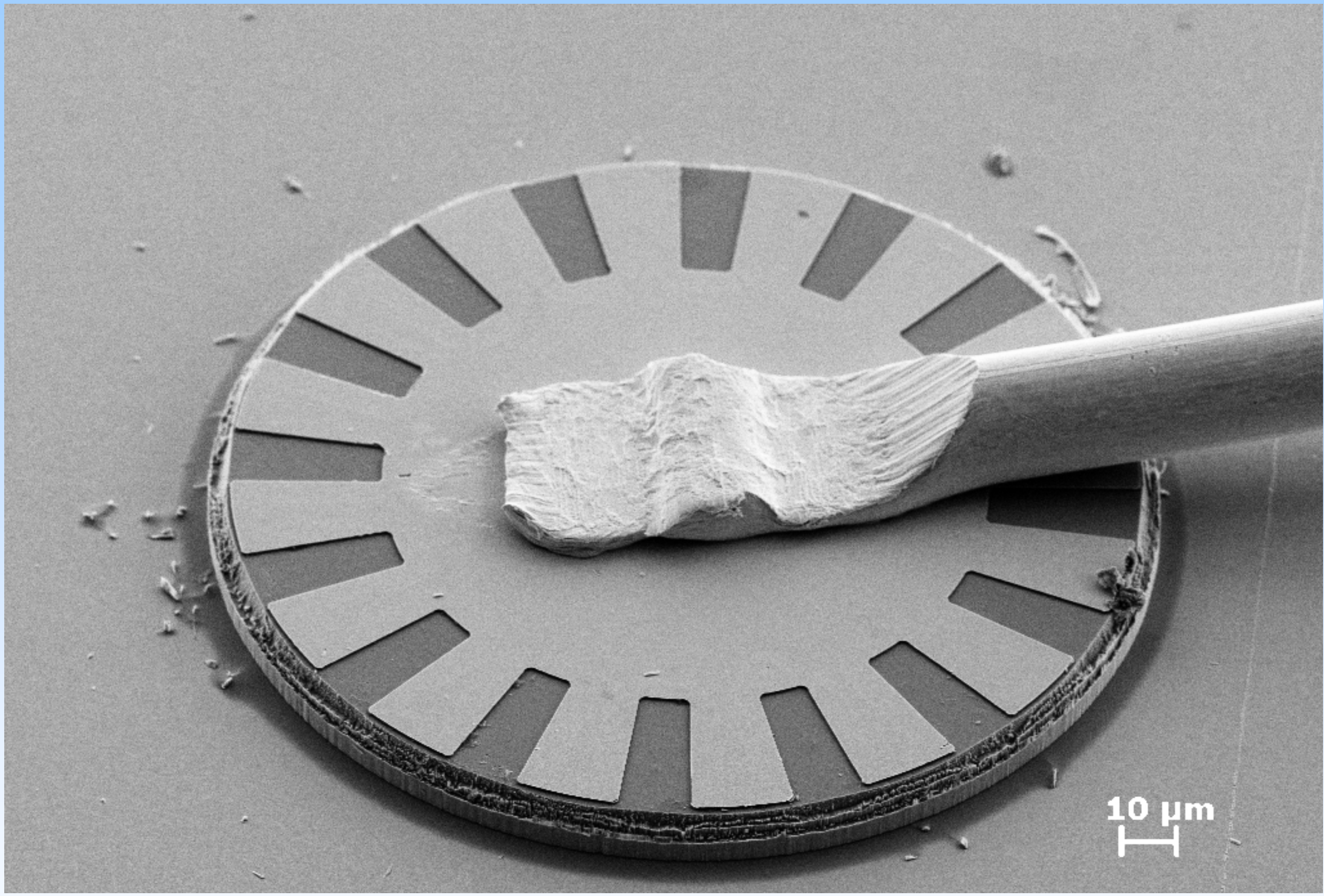
Fabrication



- Etch the top contact layer in the slit region
- Dry etched mesa

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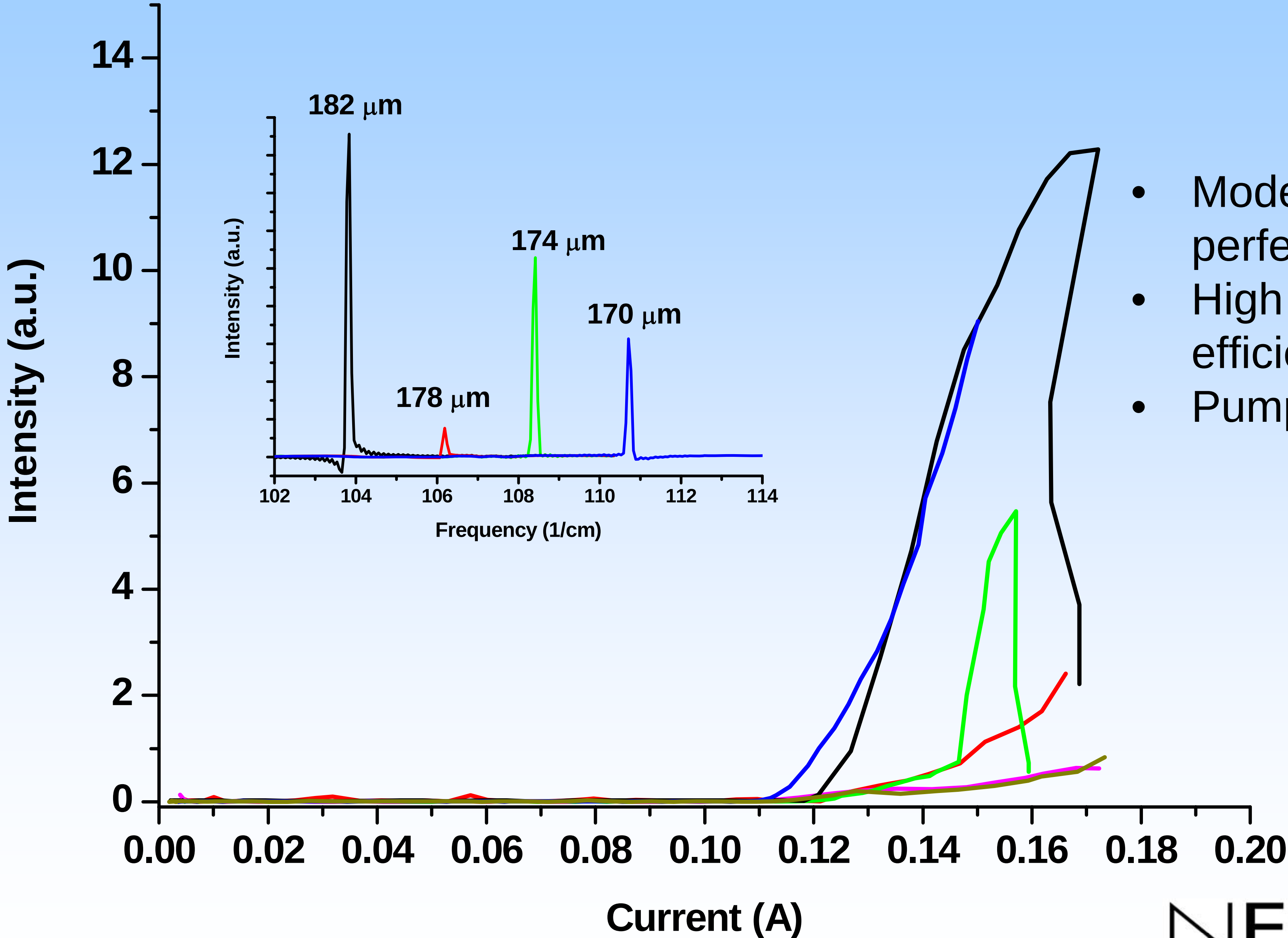
Measurement



- Mode shifts perfectly
- High slope efficiency
- Pumping ok?

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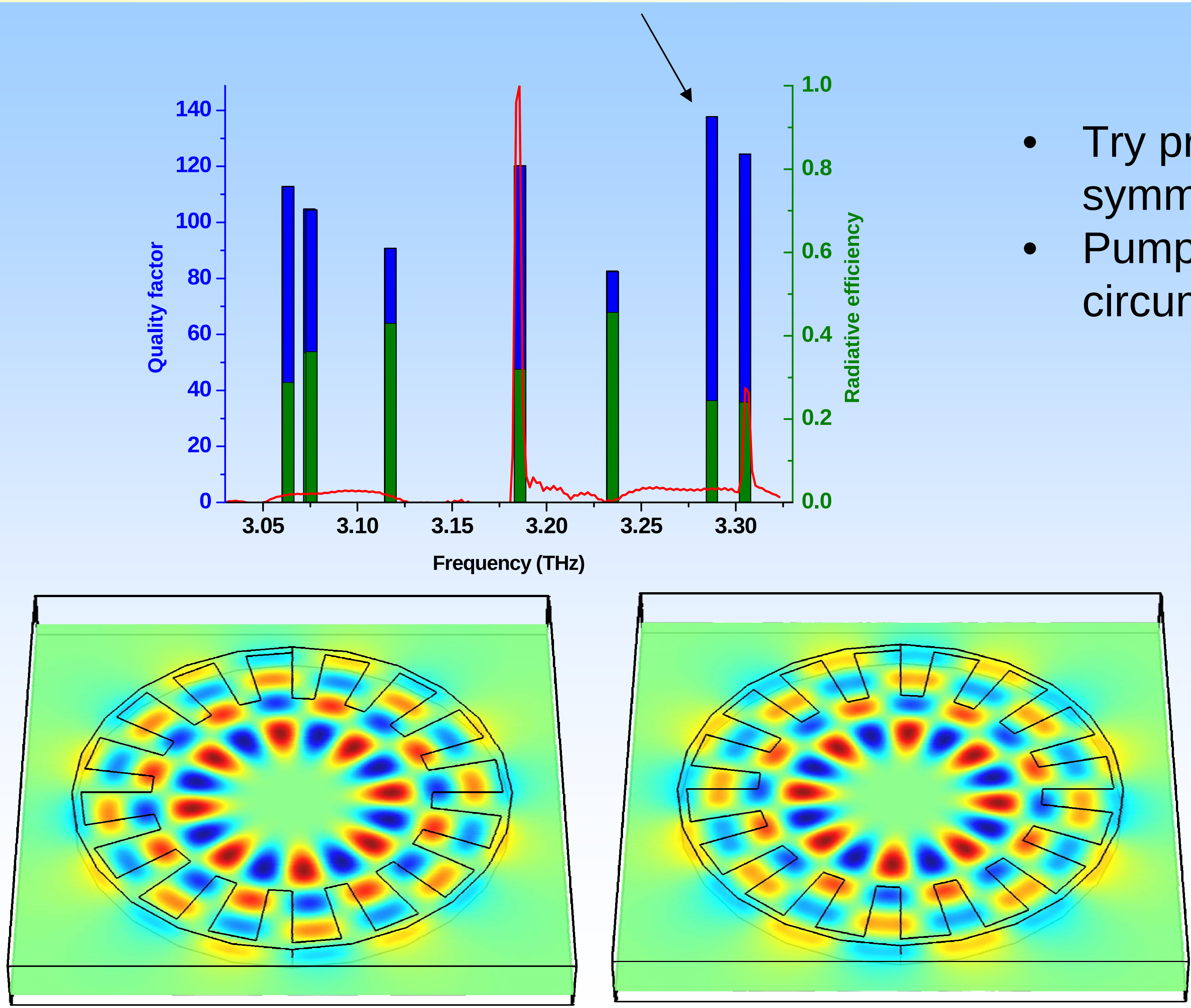
Which modes are lasing?



- Try prime symmetry
- Pump only the circumference

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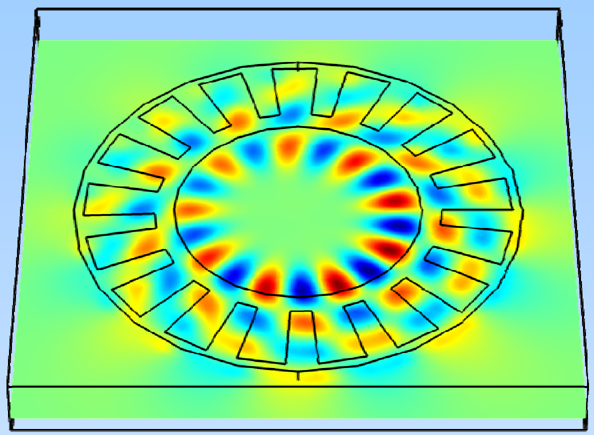
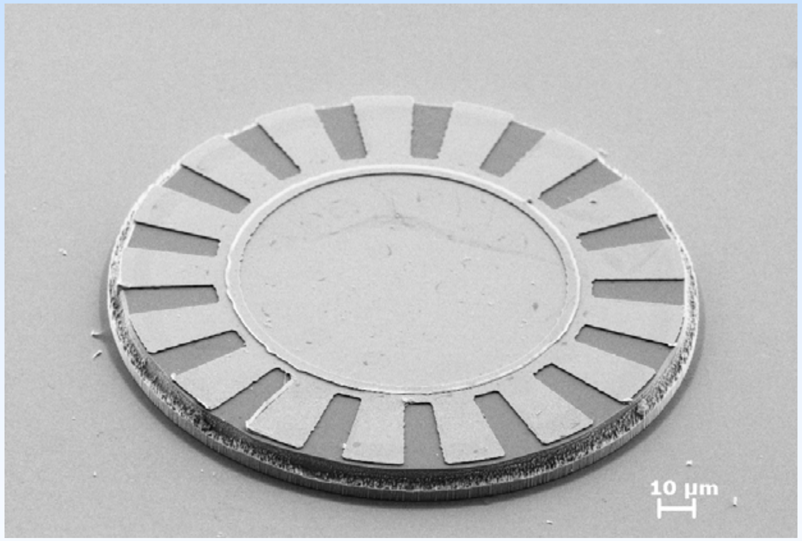
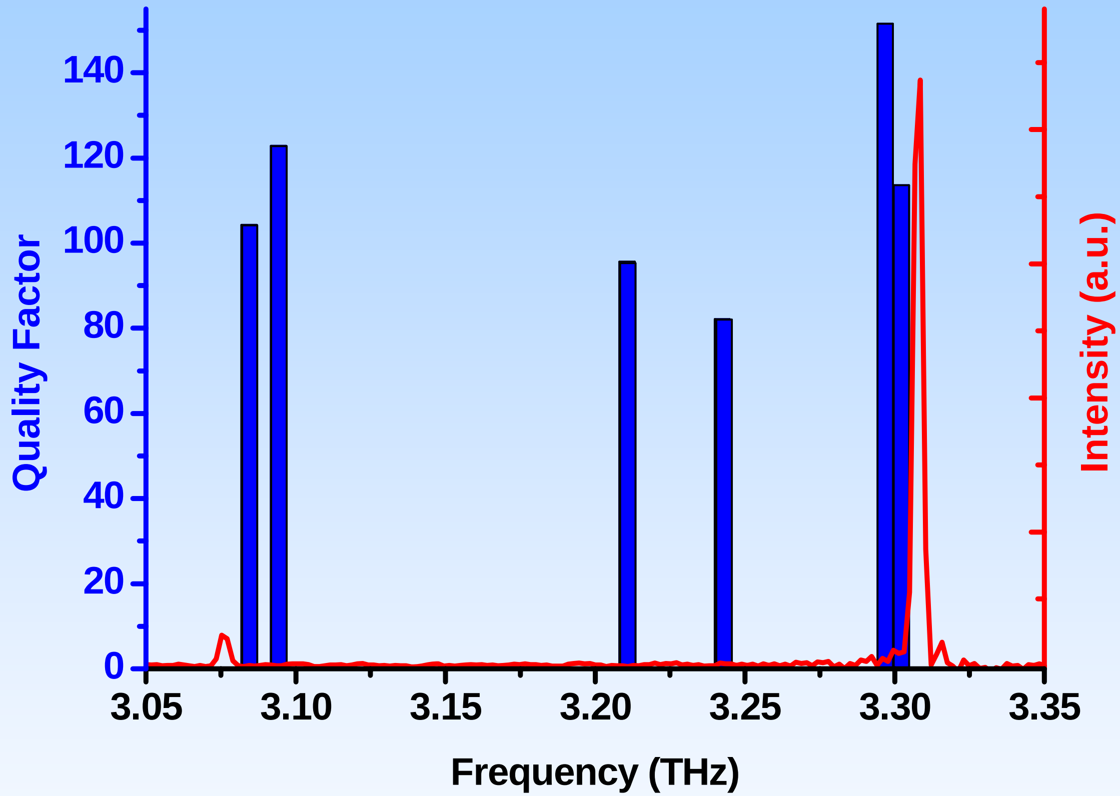
Prime symmetry







- 17 periods on the circumference
- Remove the top contact layer in the center

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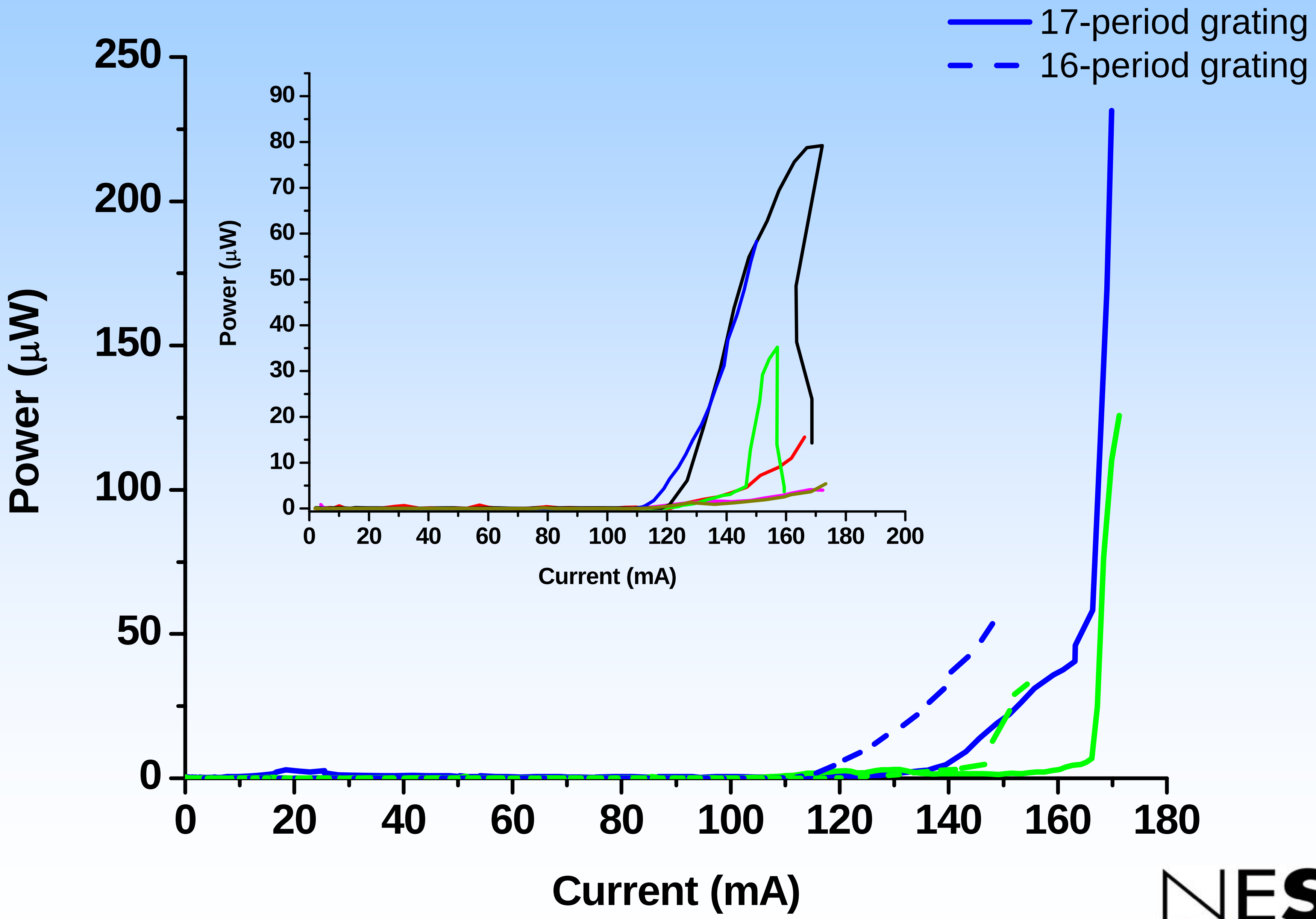
Light-Current



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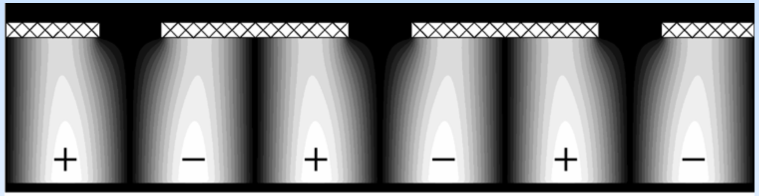
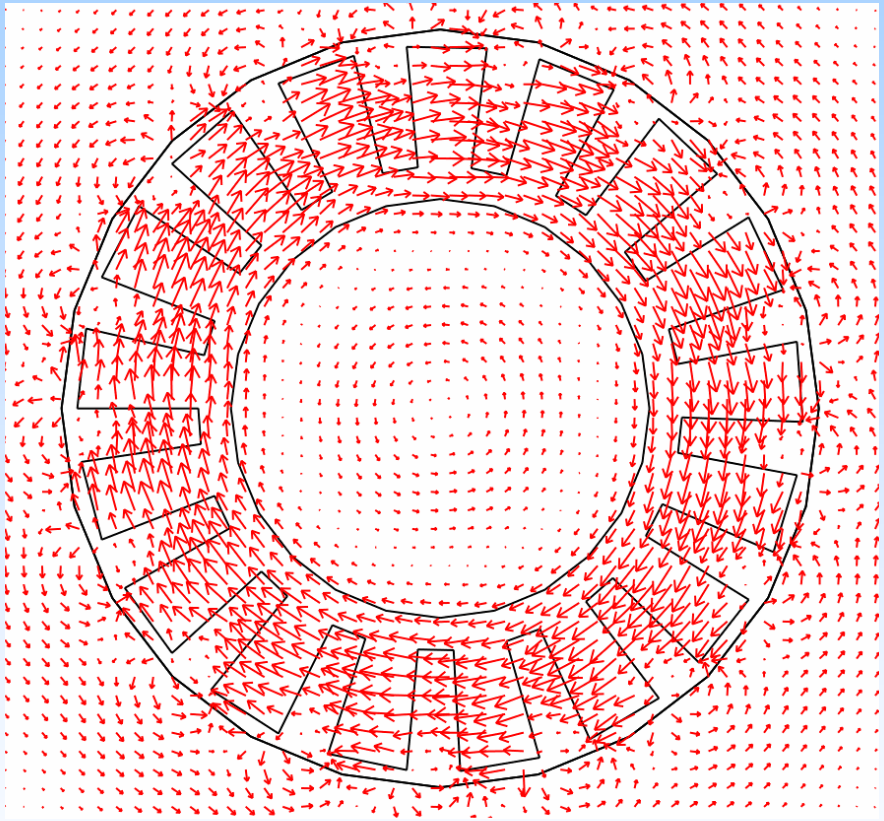
Nearfield

Magnetic field



In the device



Above the device

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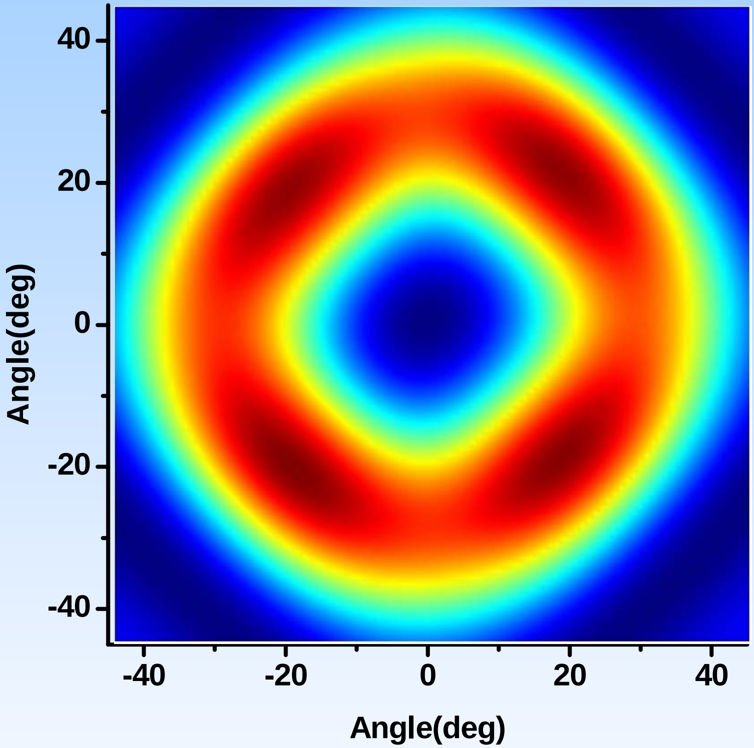
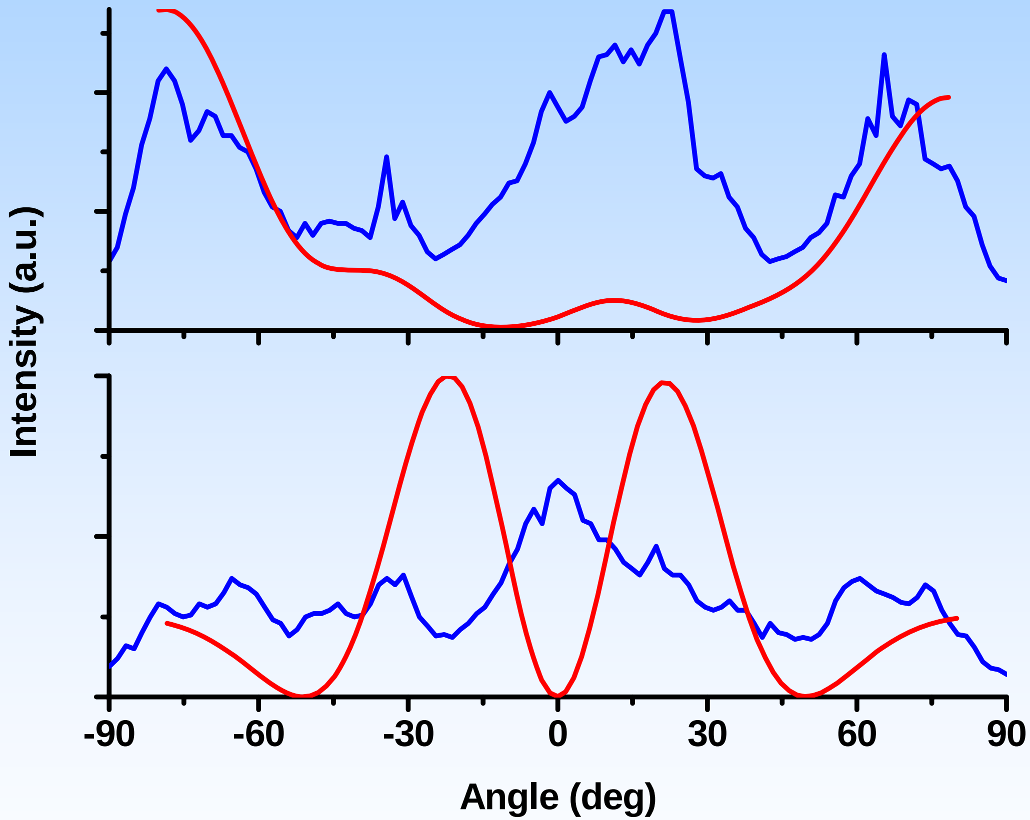
Farfield



Computed farfield of a whispering gallery mode

16-fold symmetry radial mode



17-fold symmetry whispering gallery mode

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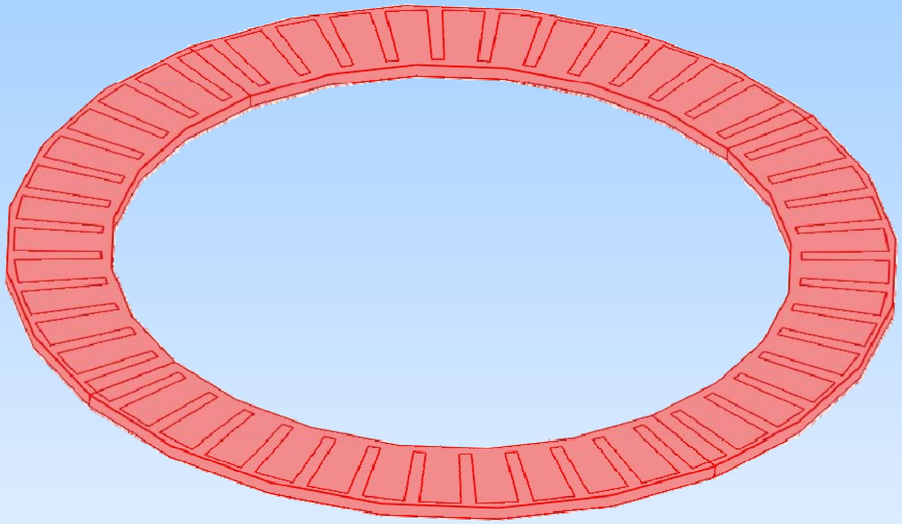
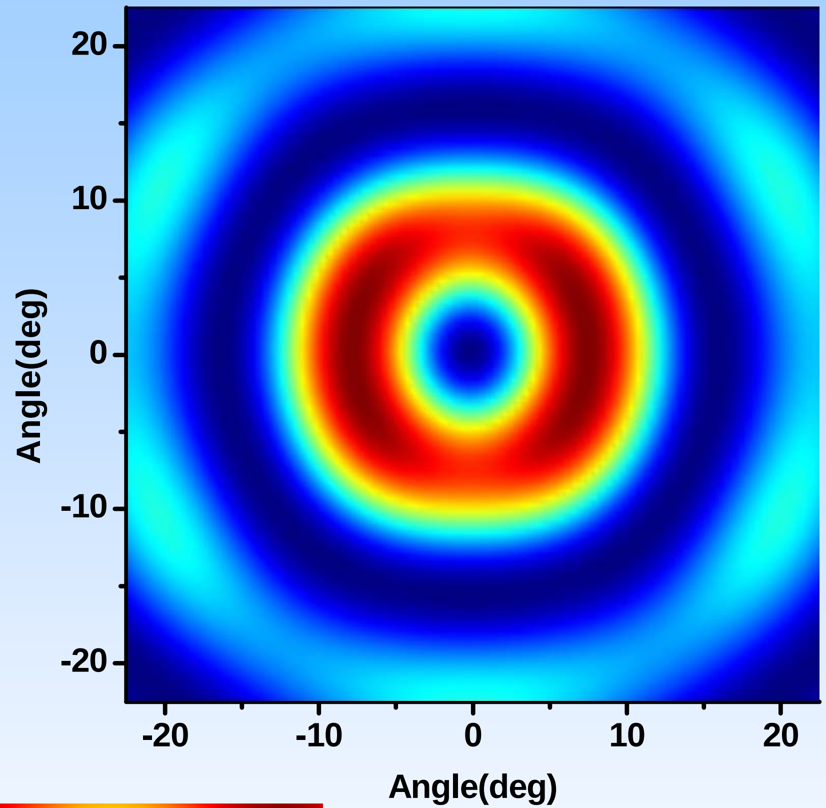
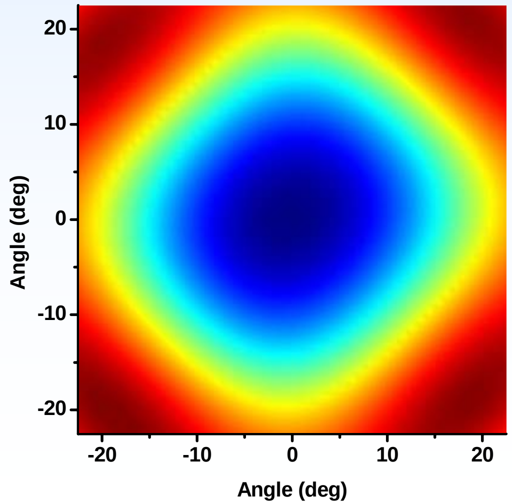
From microdisk to milliring





The farfield is determined by λ/d



1 mm diameter
1.5 THz

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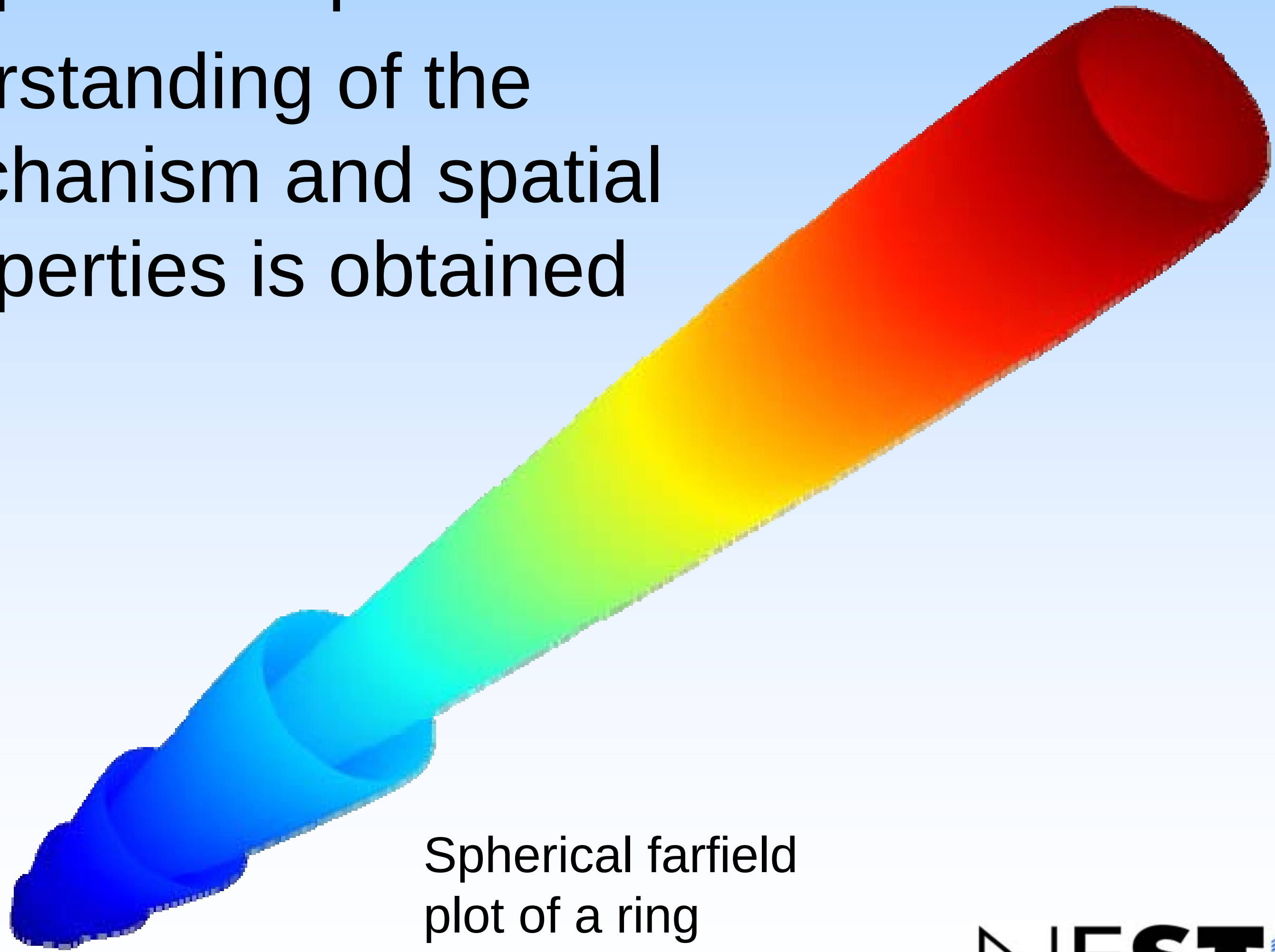
Conclusions

- Accurate prediction of spectral emission properties is possible
- A good understanding of the coupling mechanism and spatial emission properties is obtained



Spherical farfield plot of a ring

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