STERN: Superradiant THz Radiation Generation at XFEL

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HELMHOLTZ

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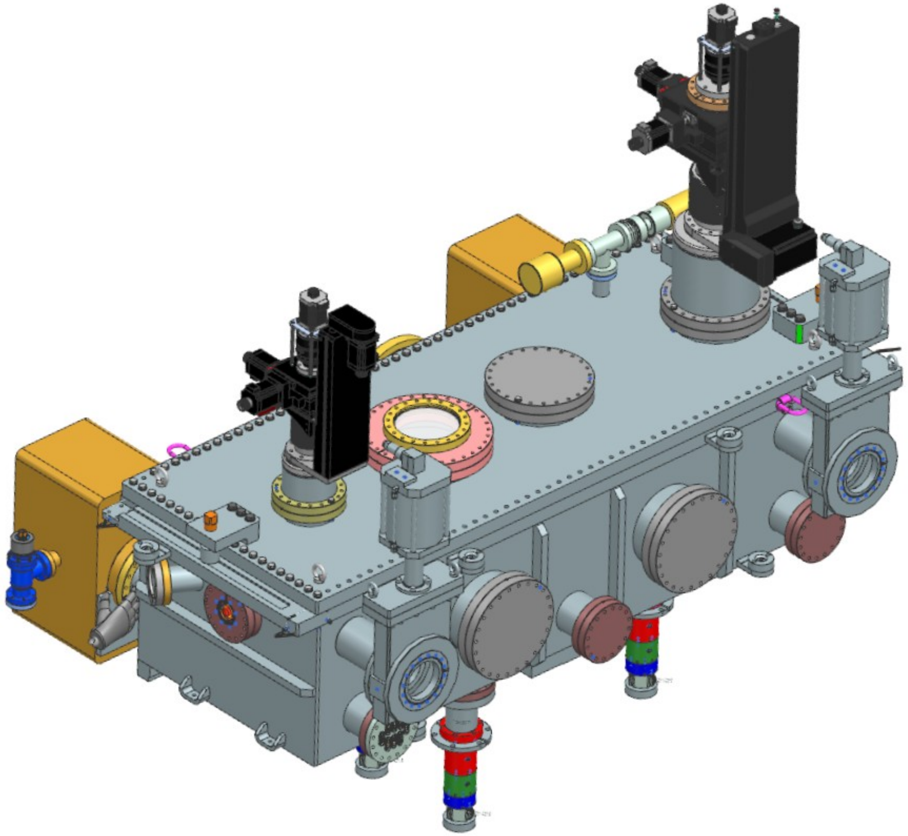
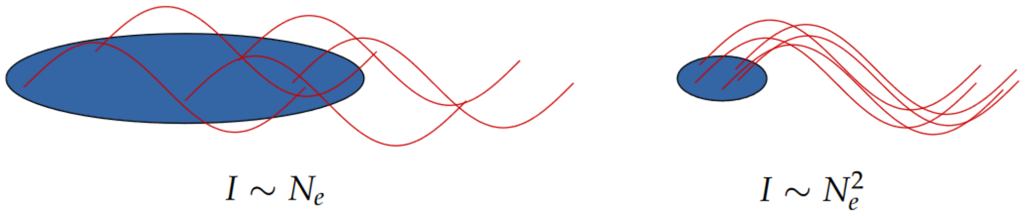
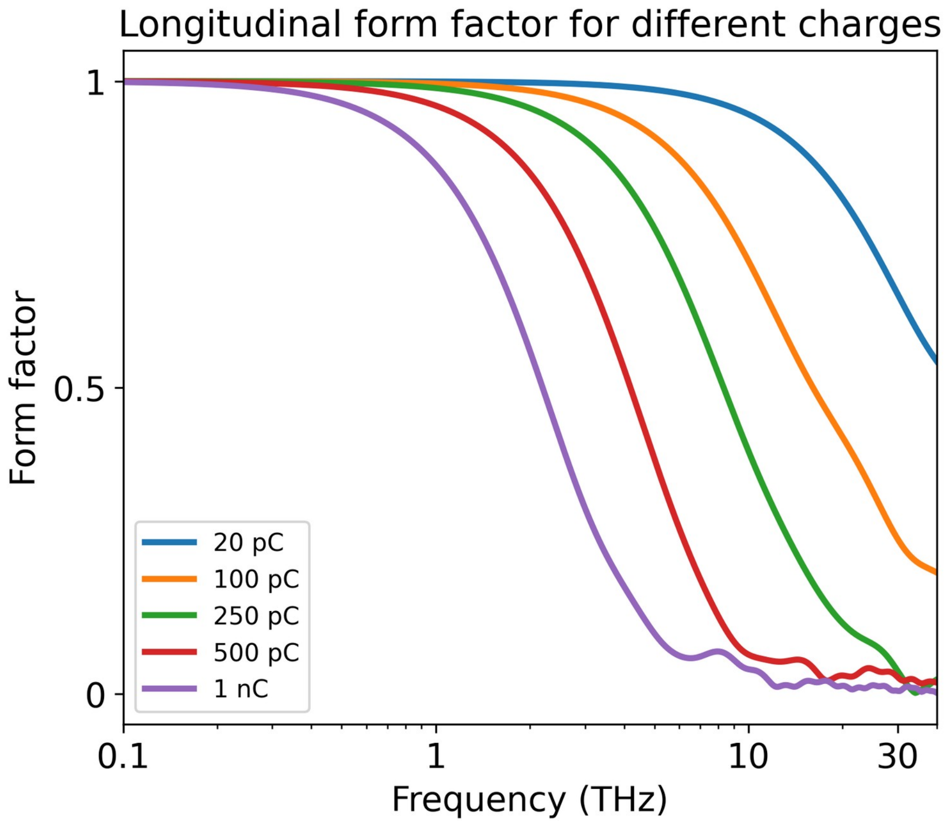


Beam-based THz radiation generation

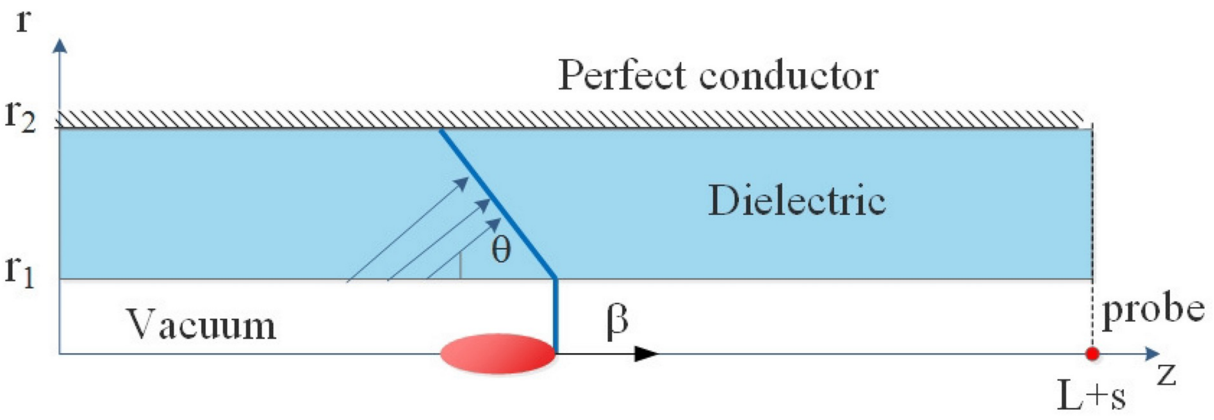
N. Lockmann, Dissertation (2021)



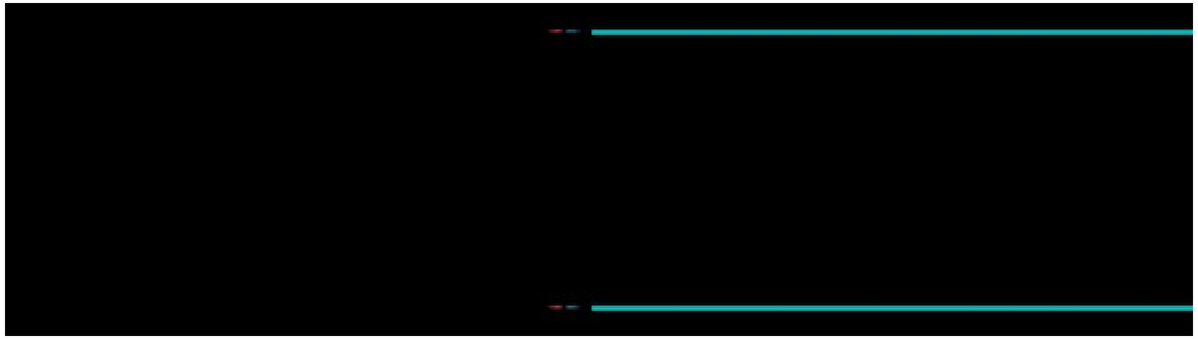
- THz automatically synced to machine/X-ray repetition rate
- High-energy beam → **high energy/power THz**
- Form factor covers THz spectrum → **coherent emission**



Dielectric loaded waveguides



S. Jiang et al., MDPI (2018)

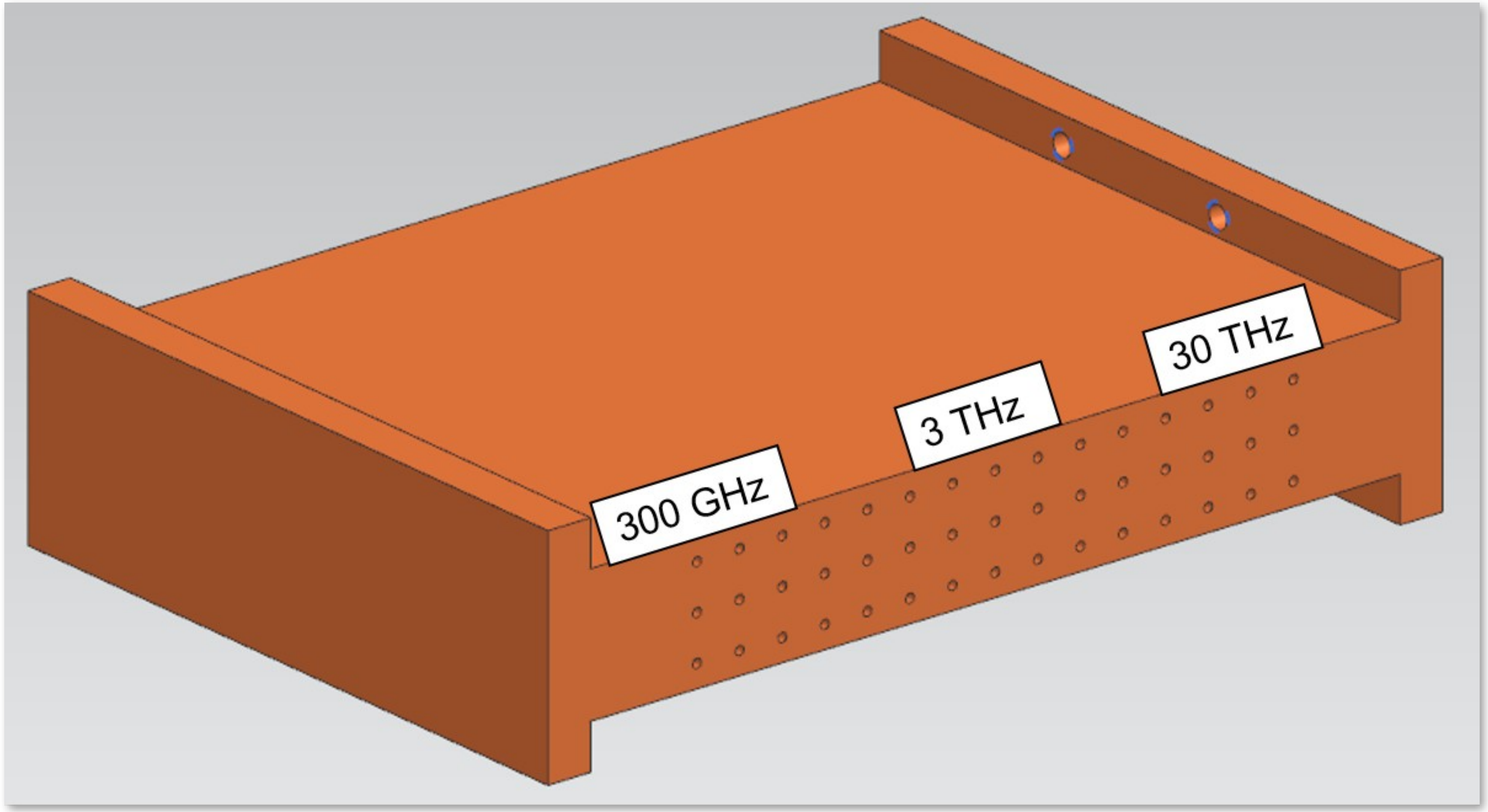


ECHO2D simulation by J. Richards (2023)

- Electron beam travels at
- Interface dielectric boundary: inside light travels slower
- The light experiences Cherenkov effect, coherent wavefront forms
- Electron beam is stripped of its electric field, loses energy in form of light

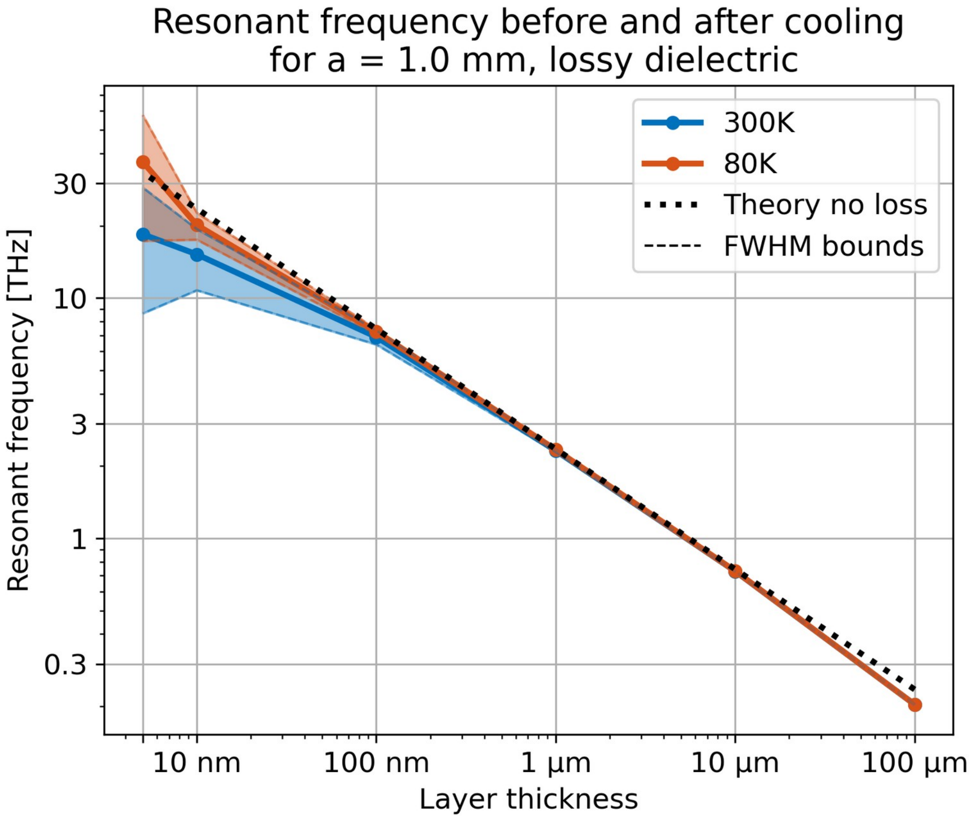
Dielectric loaded waveguides

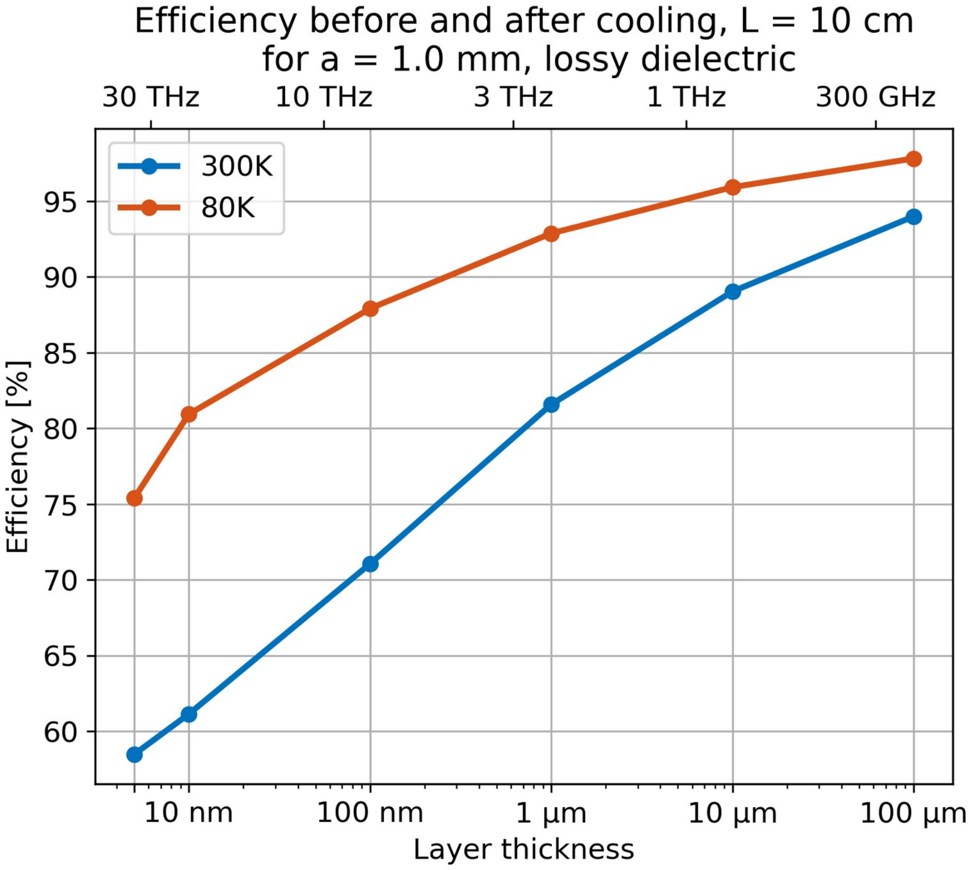
- Array of DLWs to cover freq. spectrum, held together in copper block



Dielectric loaded waveguides

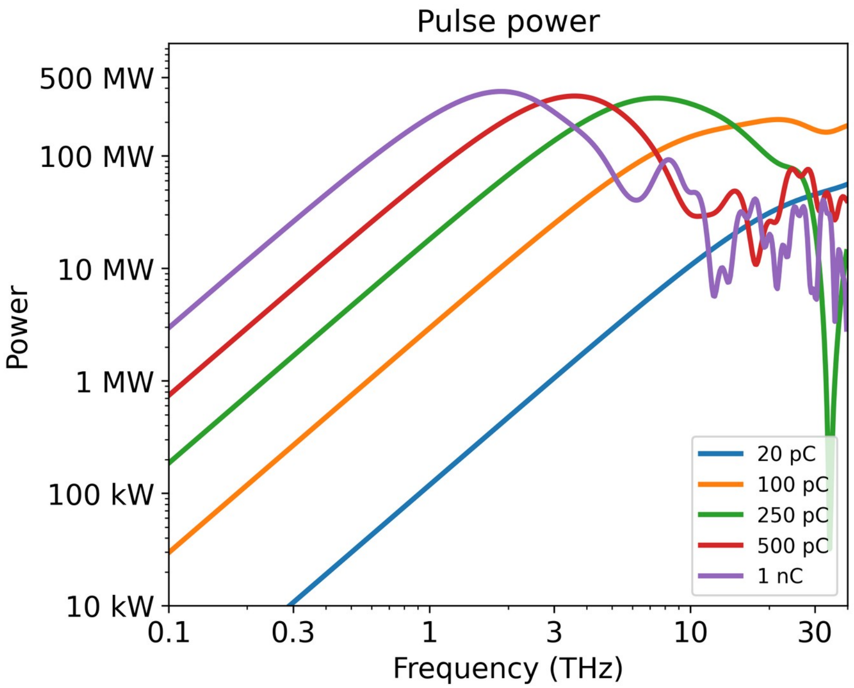
- Array of DLWs to cover freq. spectrum, held together in copper block

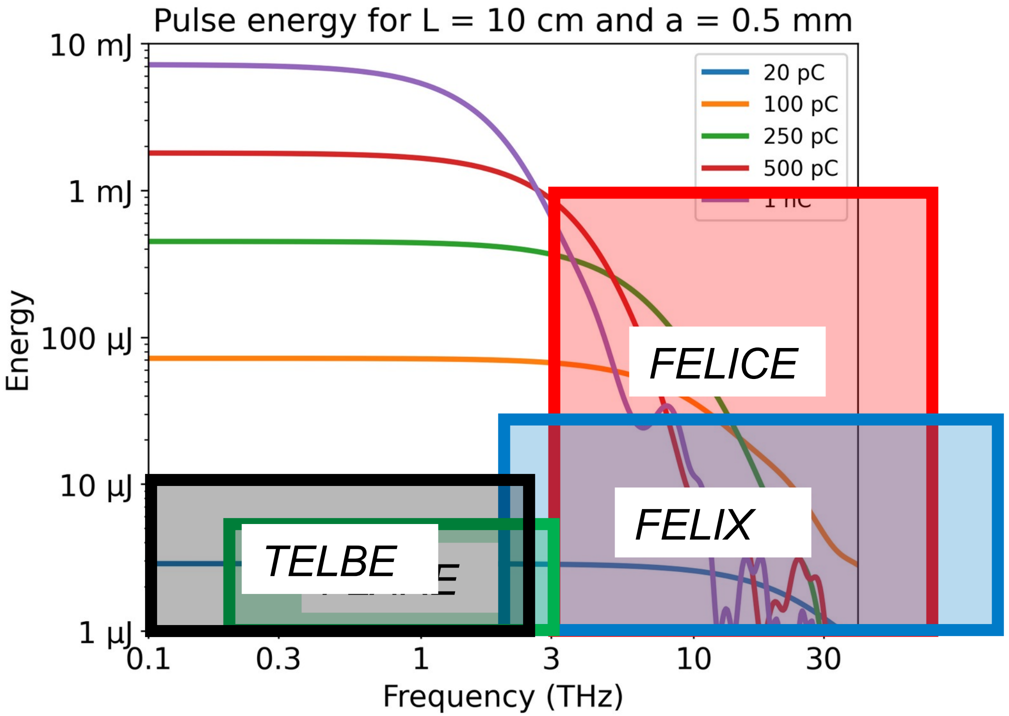




Dielectric loaded waveguides

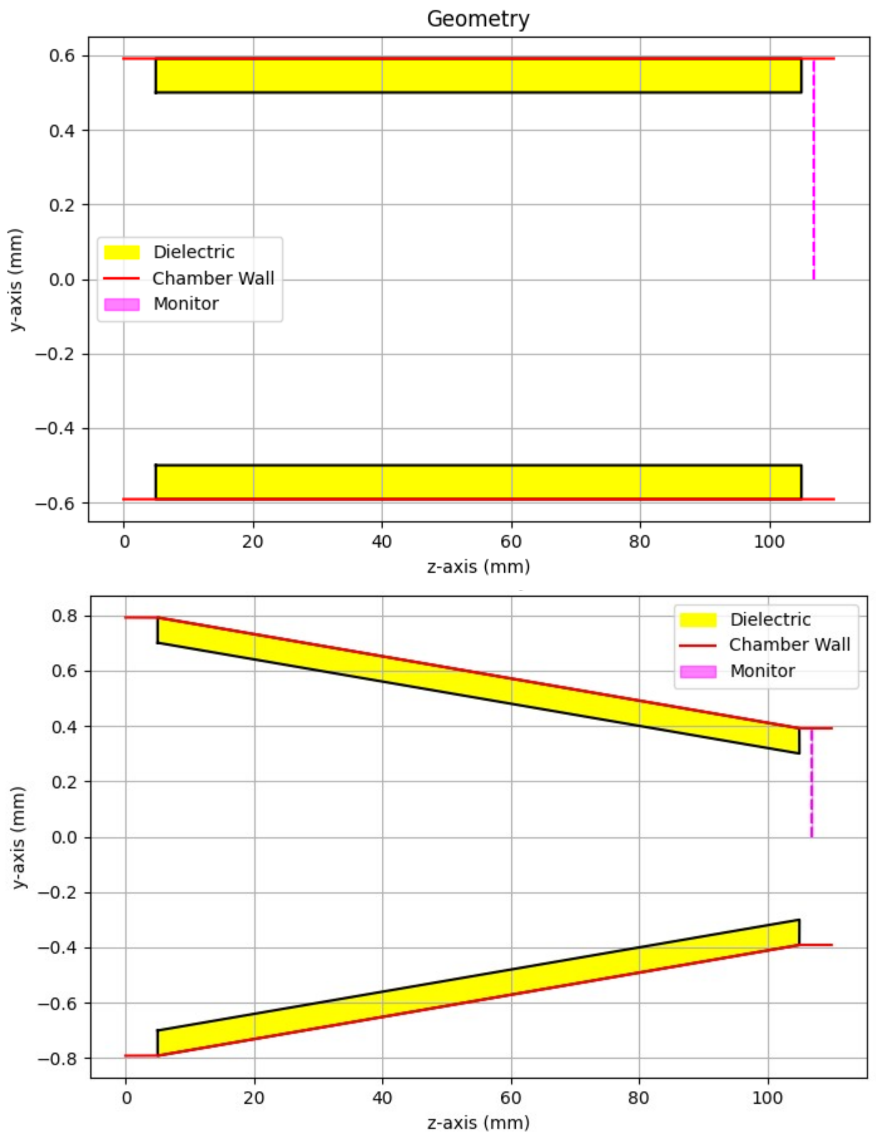
- Array of DLWs to cover freq. spectrum, held together in copper block
- Using varying charge optimizes power/energy for given frequency

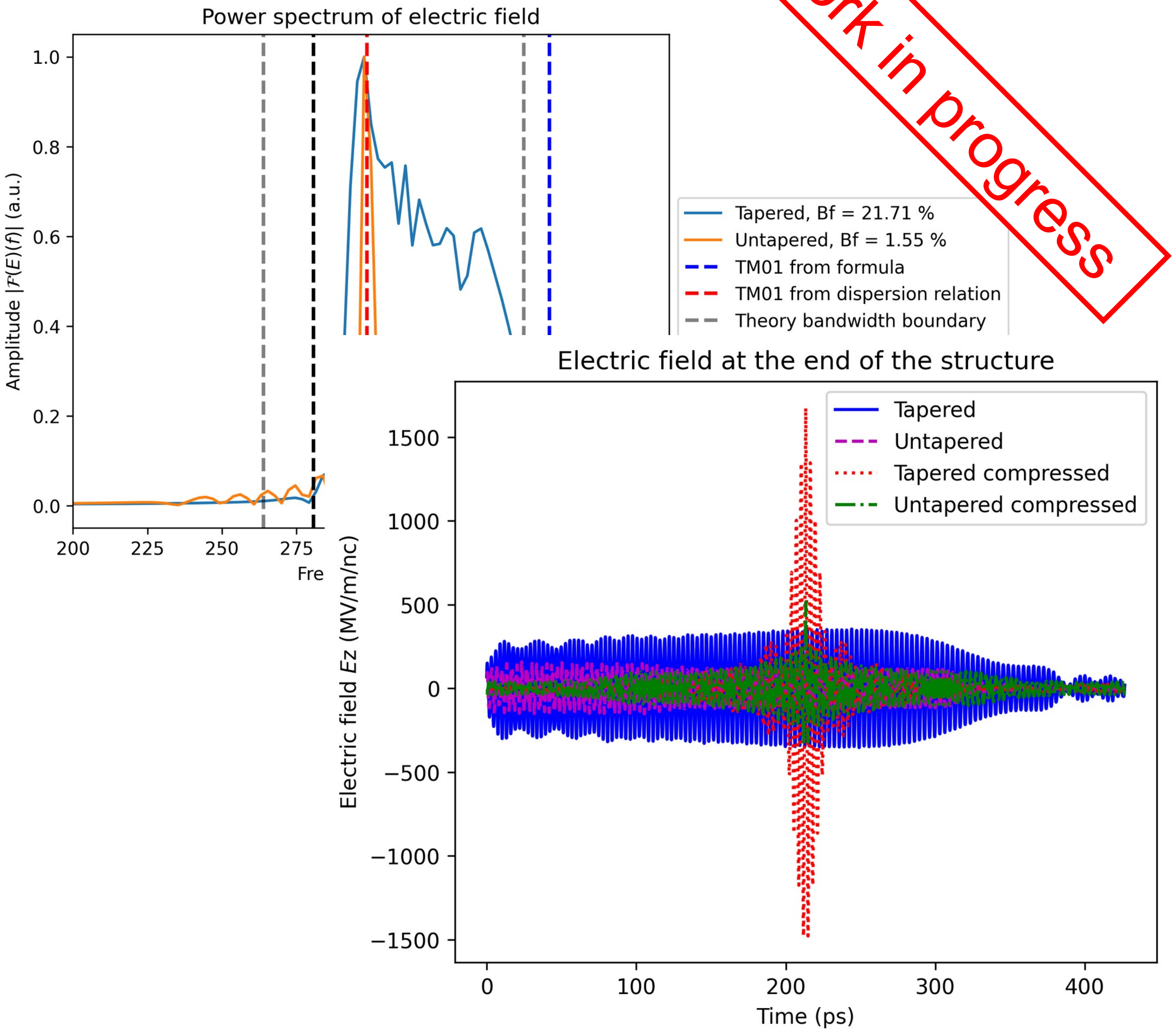




Broadband waveguides: tapering

Work in progress





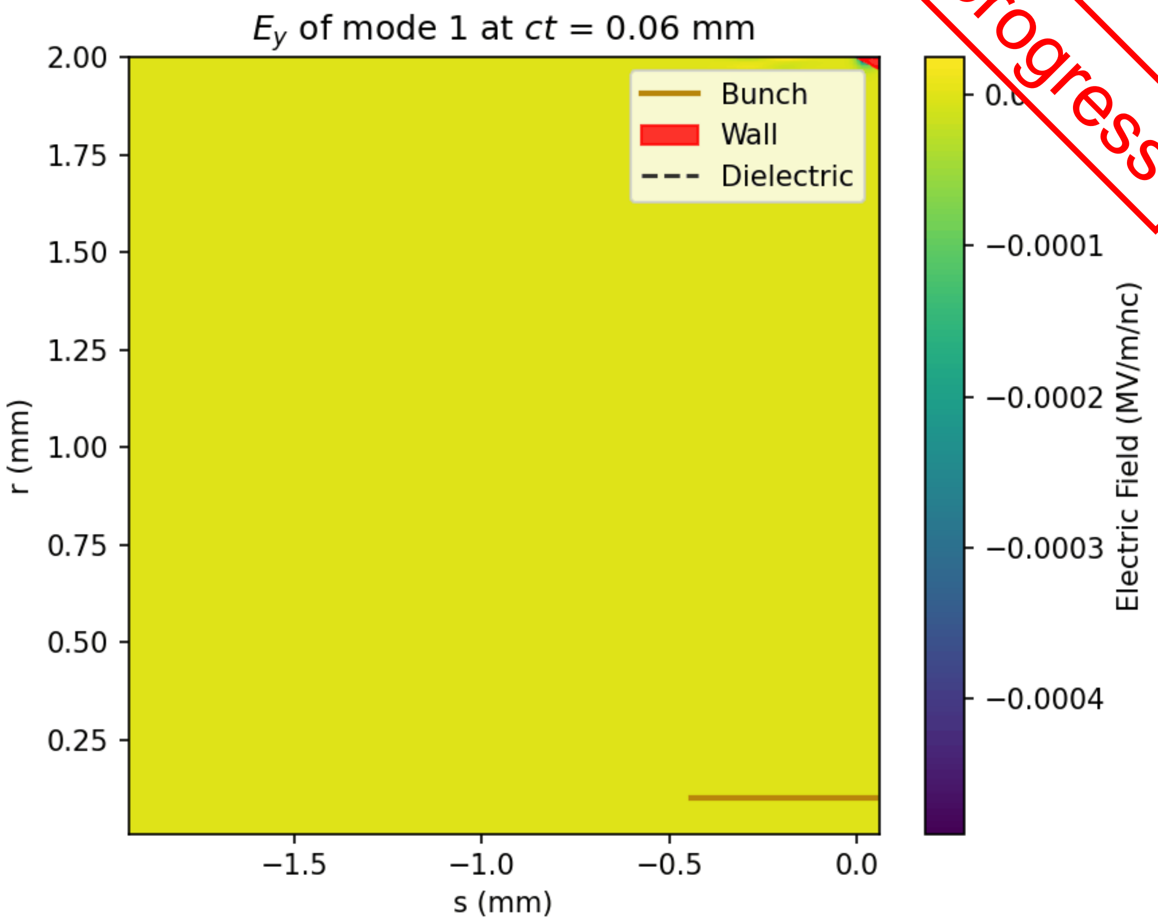
Broadband waveguides: off-axis excitation

Work in progress

- Sending bunch off-axis excites multiple HEM-modes

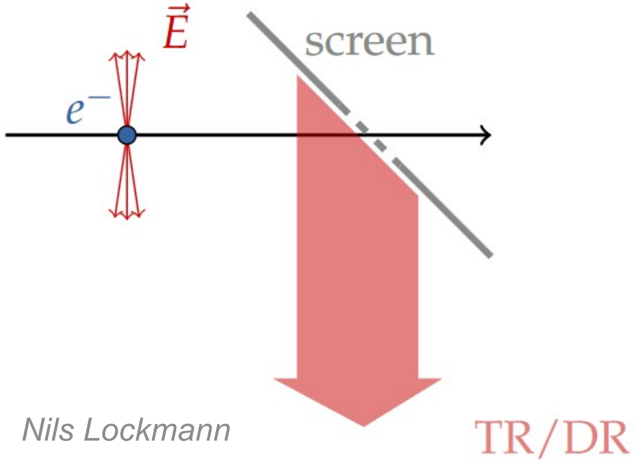
→ Generate broadband pulse

- Incoupling horn to capture more electric field in short structure

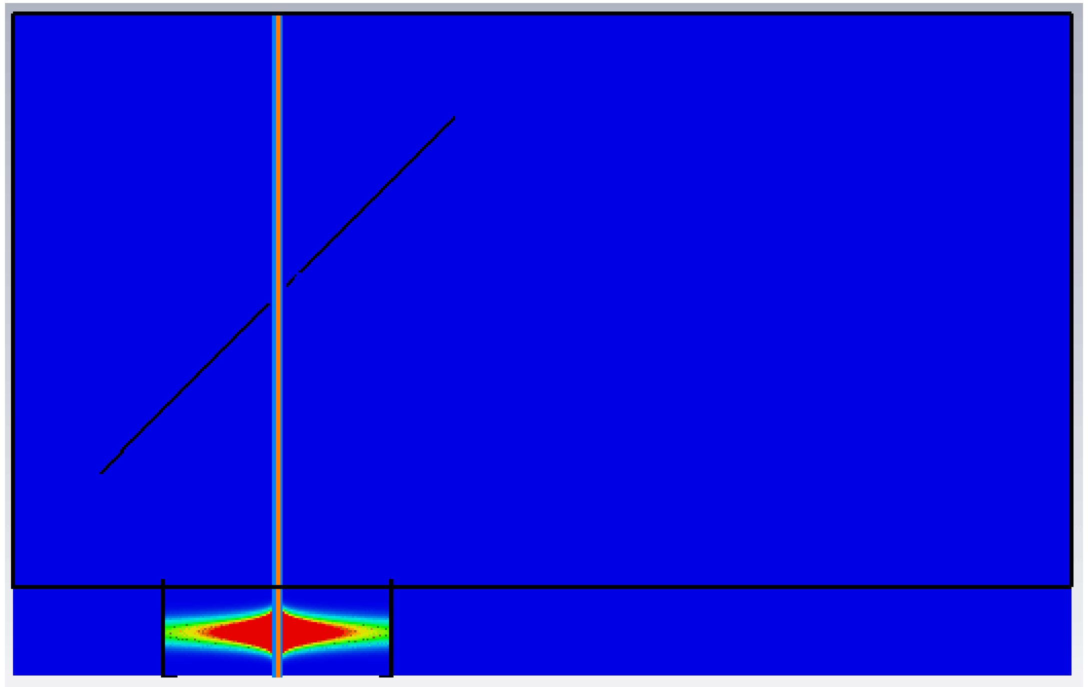


Diffraction radiation

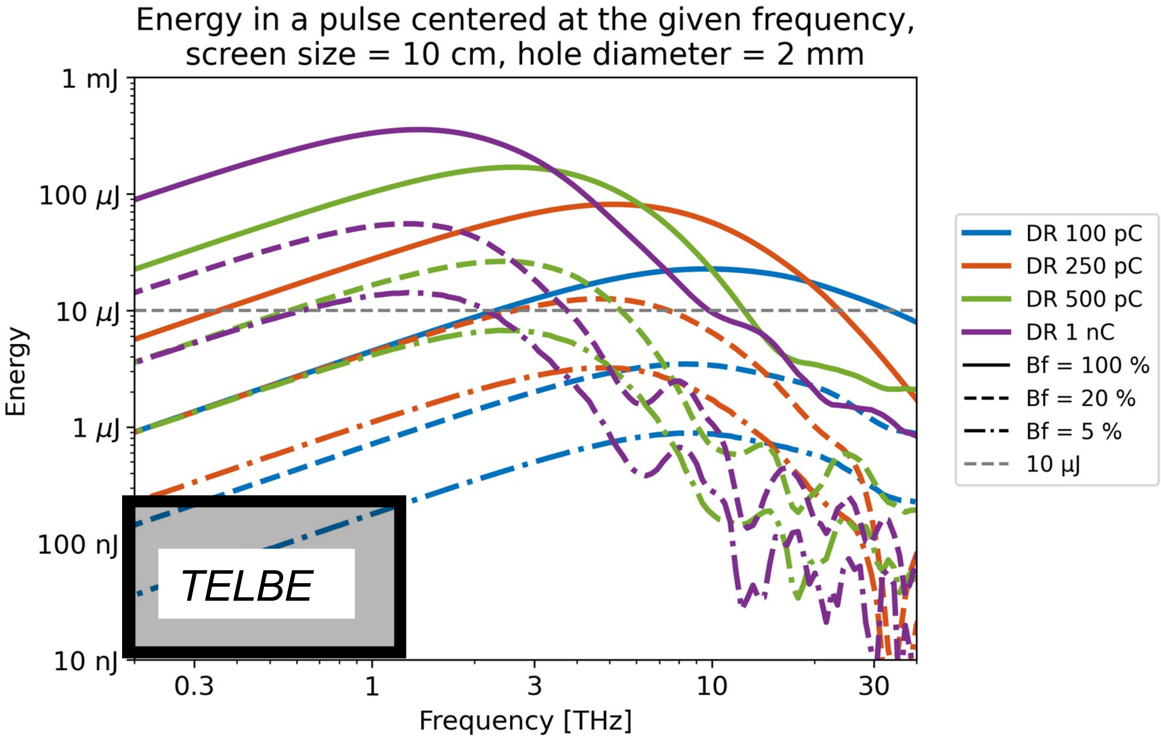
- Beam passes through hole in aluminum sheet → excite broadband spectrum
- Electric field of bunch 'bounces off' and turns into light

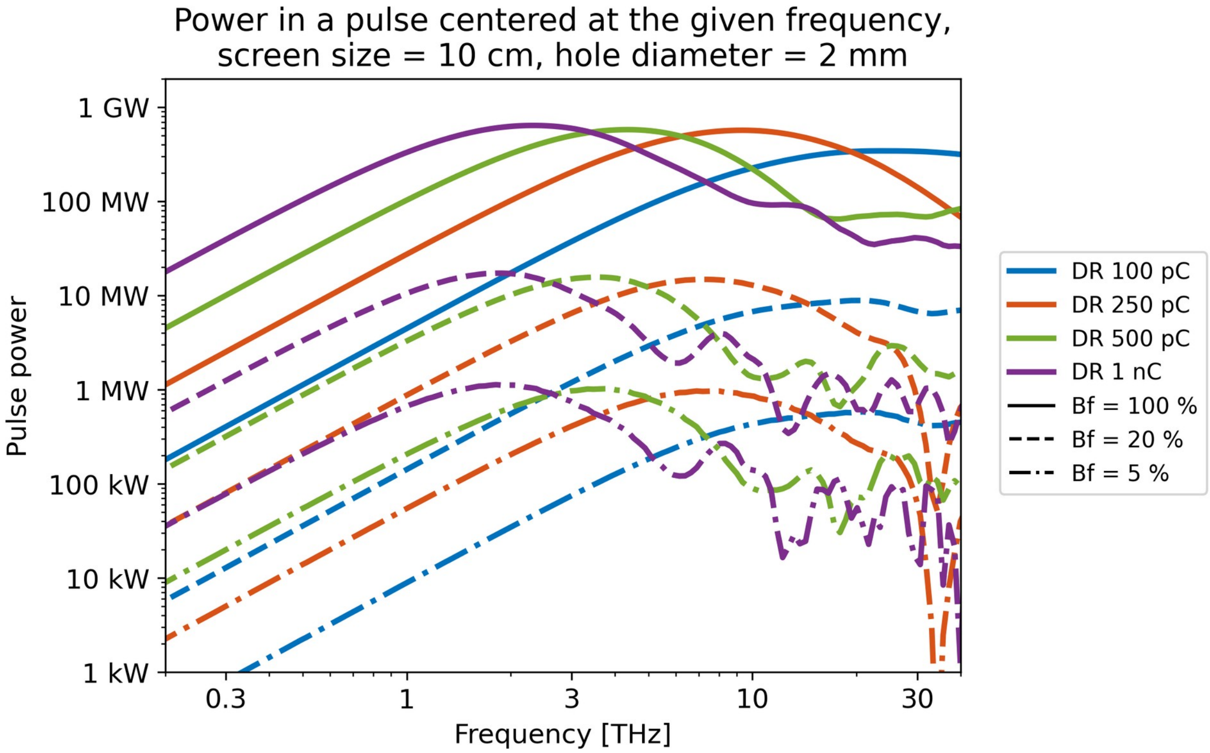


Nils Lockmann



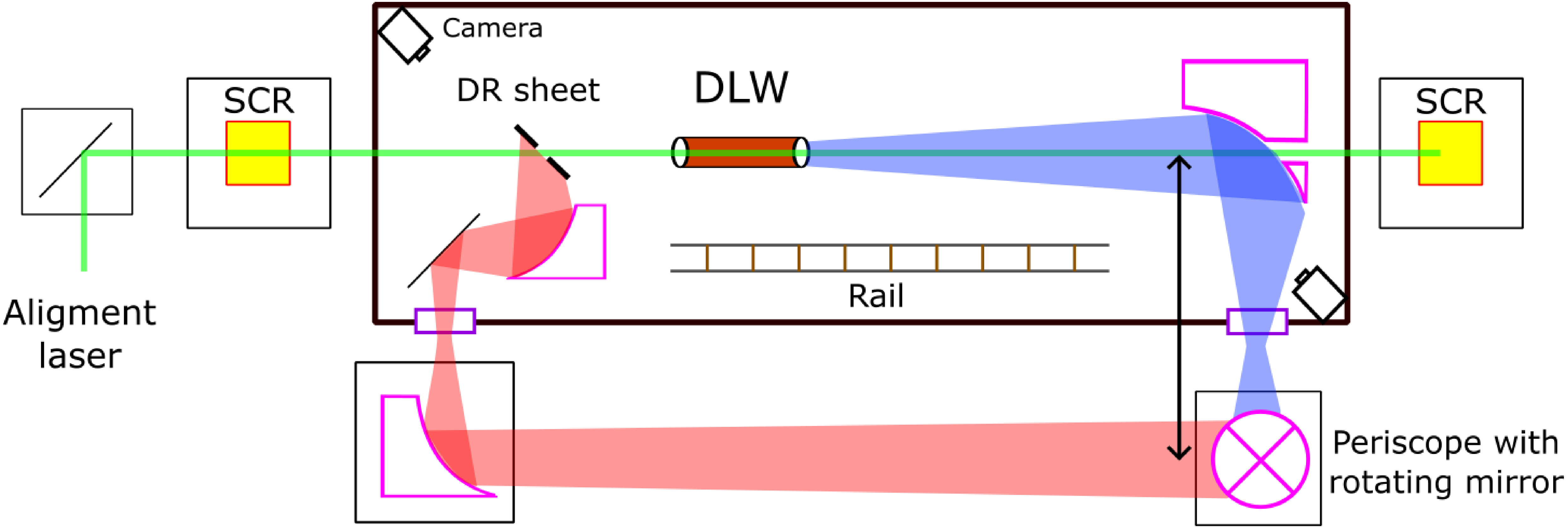
Diffraction radiation: energy

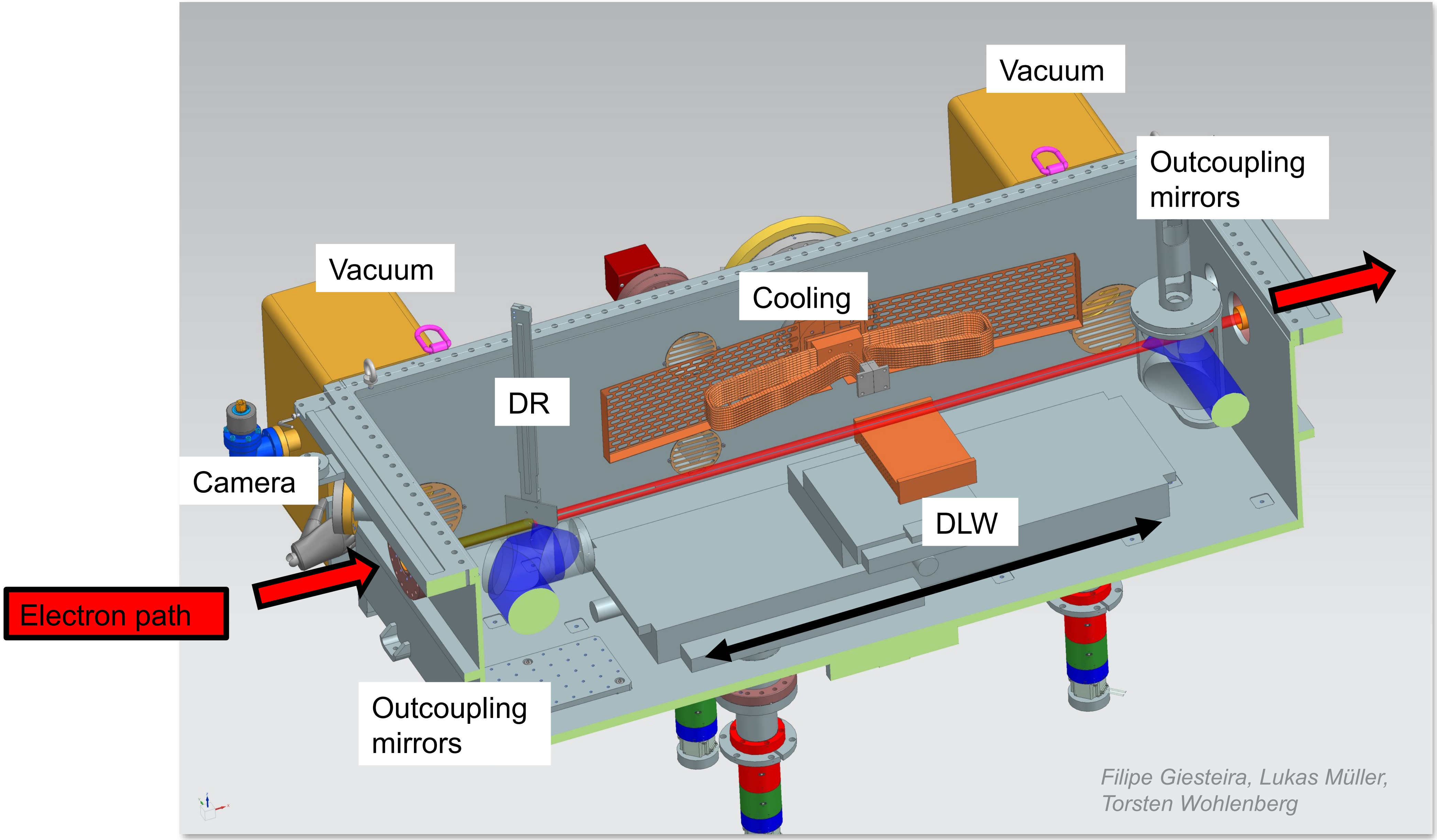




High bandwidth pulses contain enough energy to satisfy user’s wishes

STERN layout



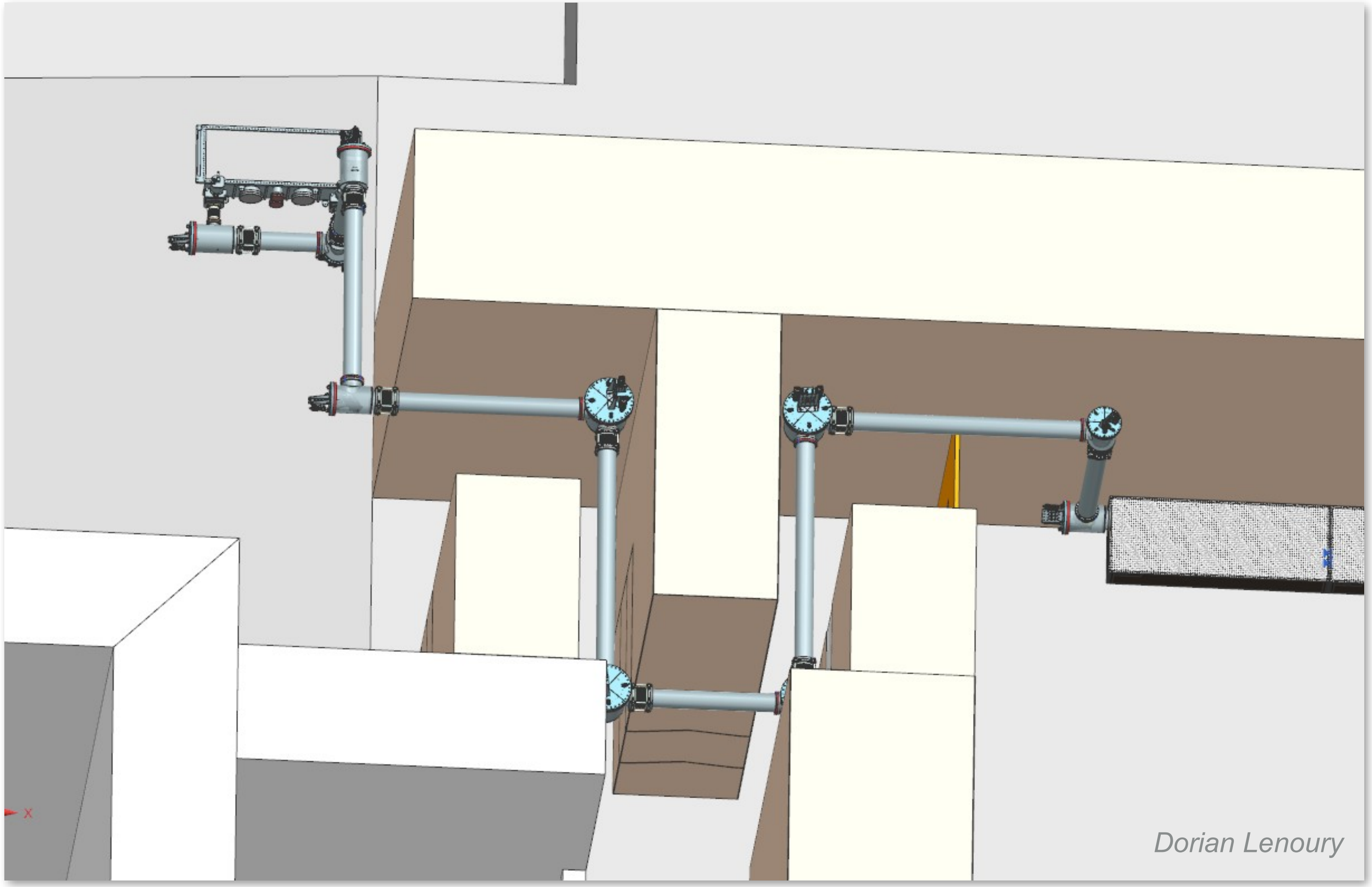


Filipe Giesteira, Lukas Müller, Torsten Wohlenberg

Transport to diagnostics area

- After production, radiation is transported to a safe diagnostics area
- How can we optimize mirror focal lengths for maximal transmission?

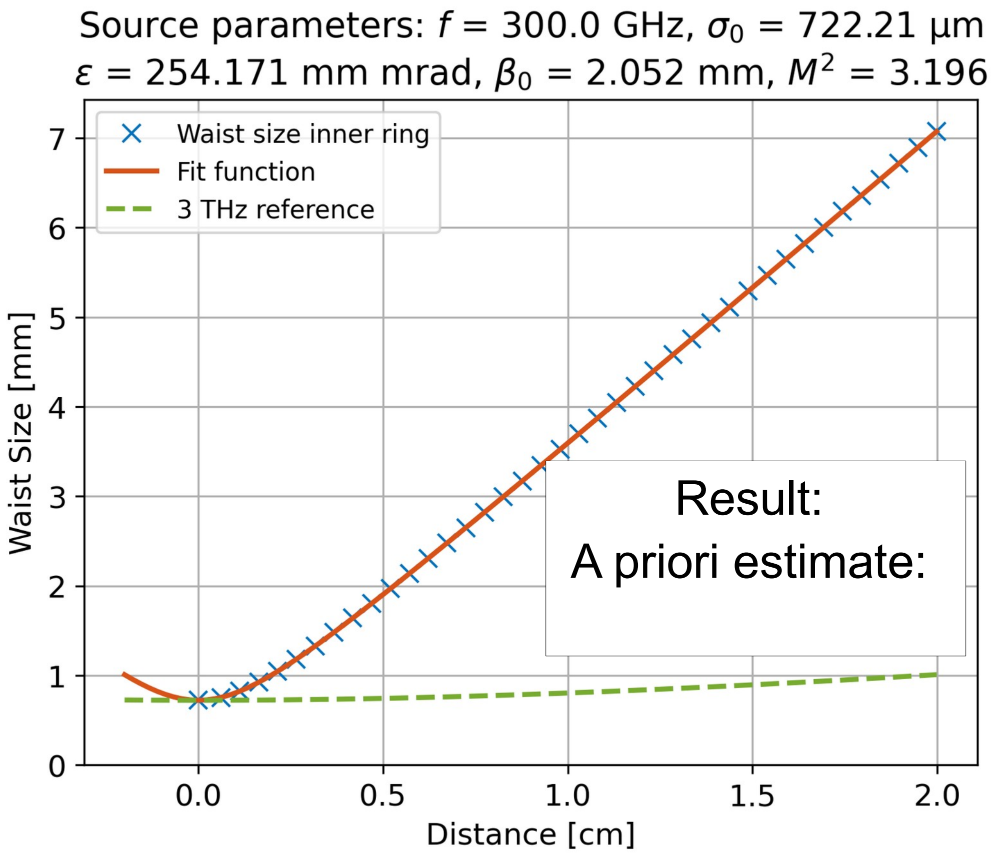
➔ Treat THz beam as a particle beam and use **Ocelot**



Dorian Lenoury

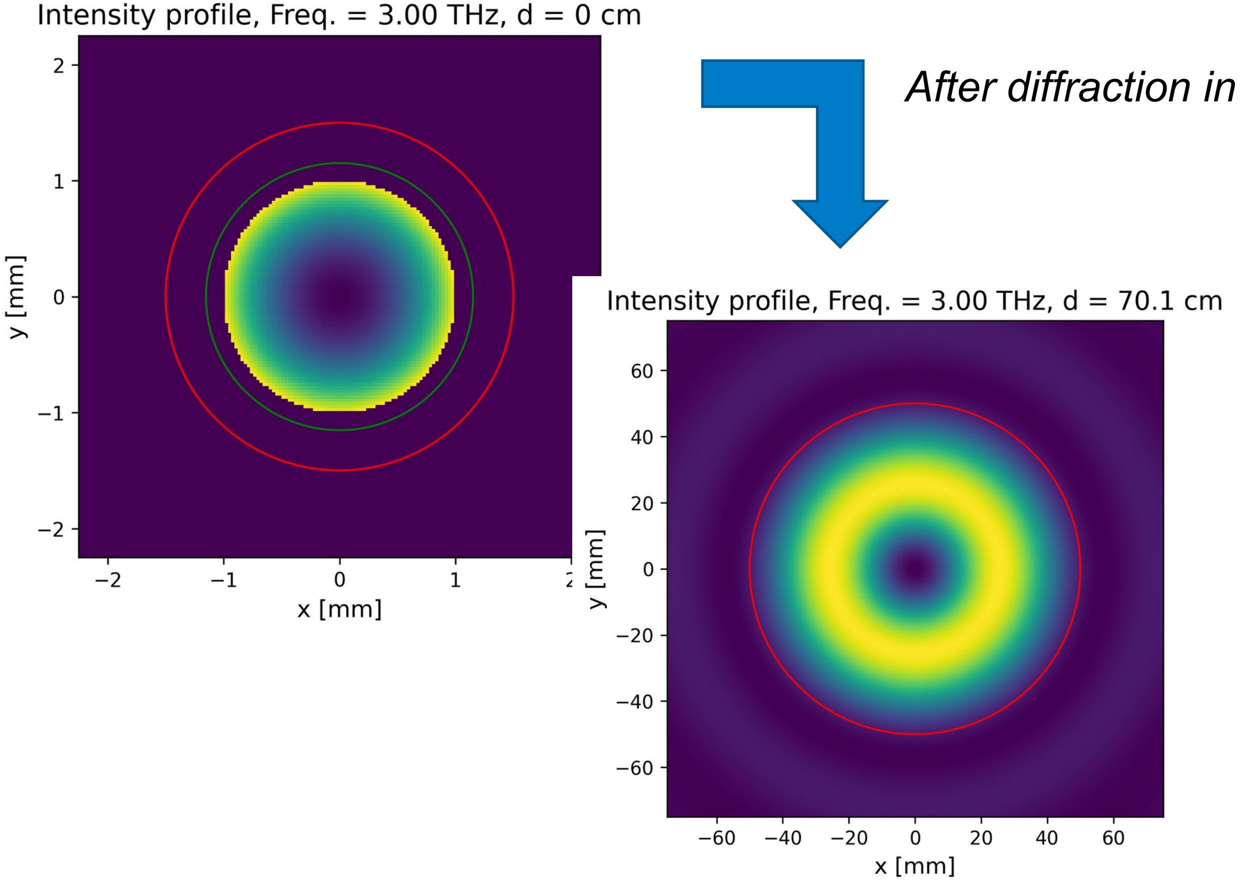
Transport to diagnostics area

- Beam parameters are found by simulating travel through drift,
- Optimization done for inner ring of -field



Result:

A priori estimate:



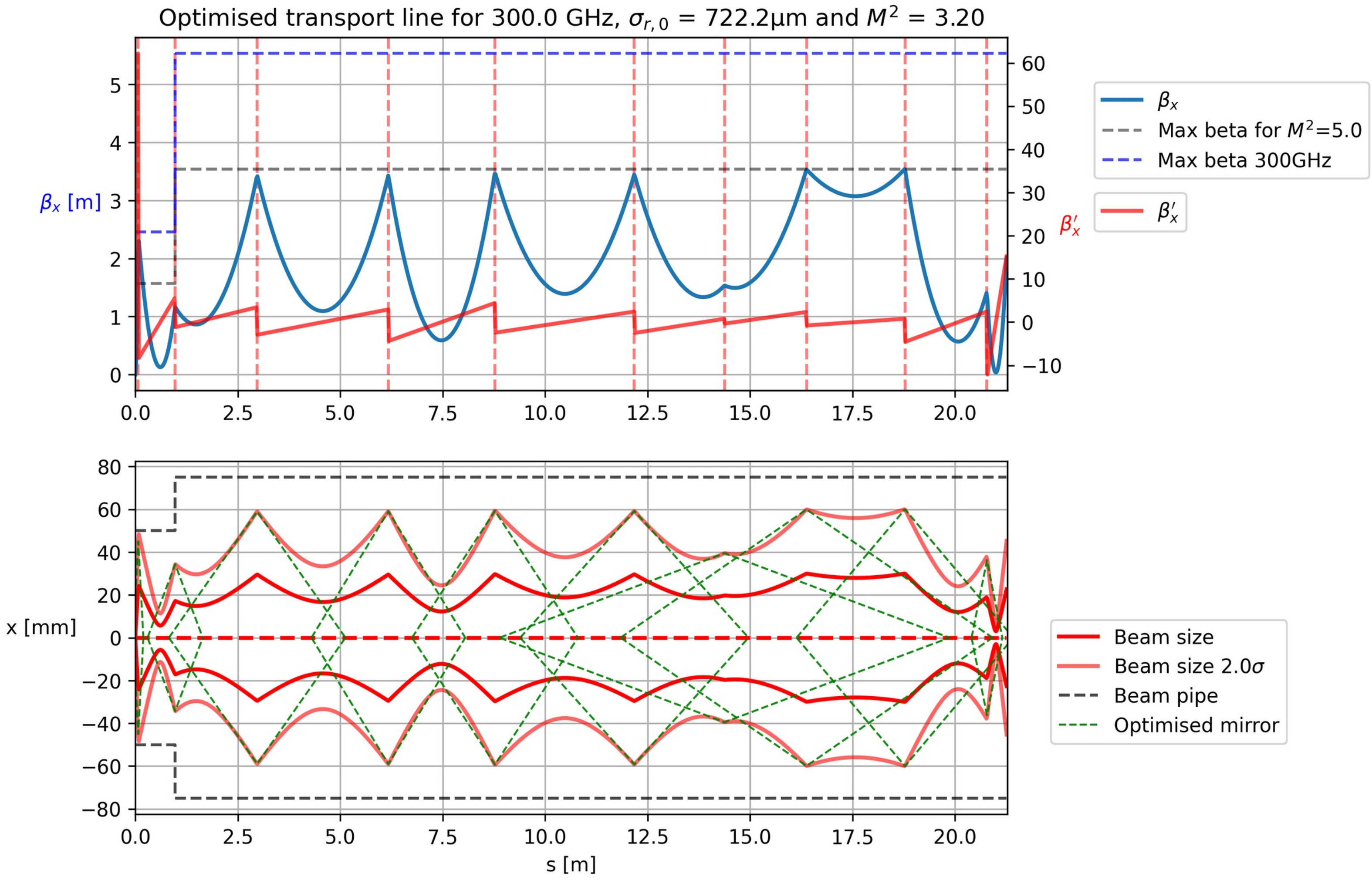
After diffraction in drift

Transport to diagnostics area

- Optimize lattice in Ocelot for lowest frequency

→ Higher frequencies will also pass

- Result is similar to relay imaging

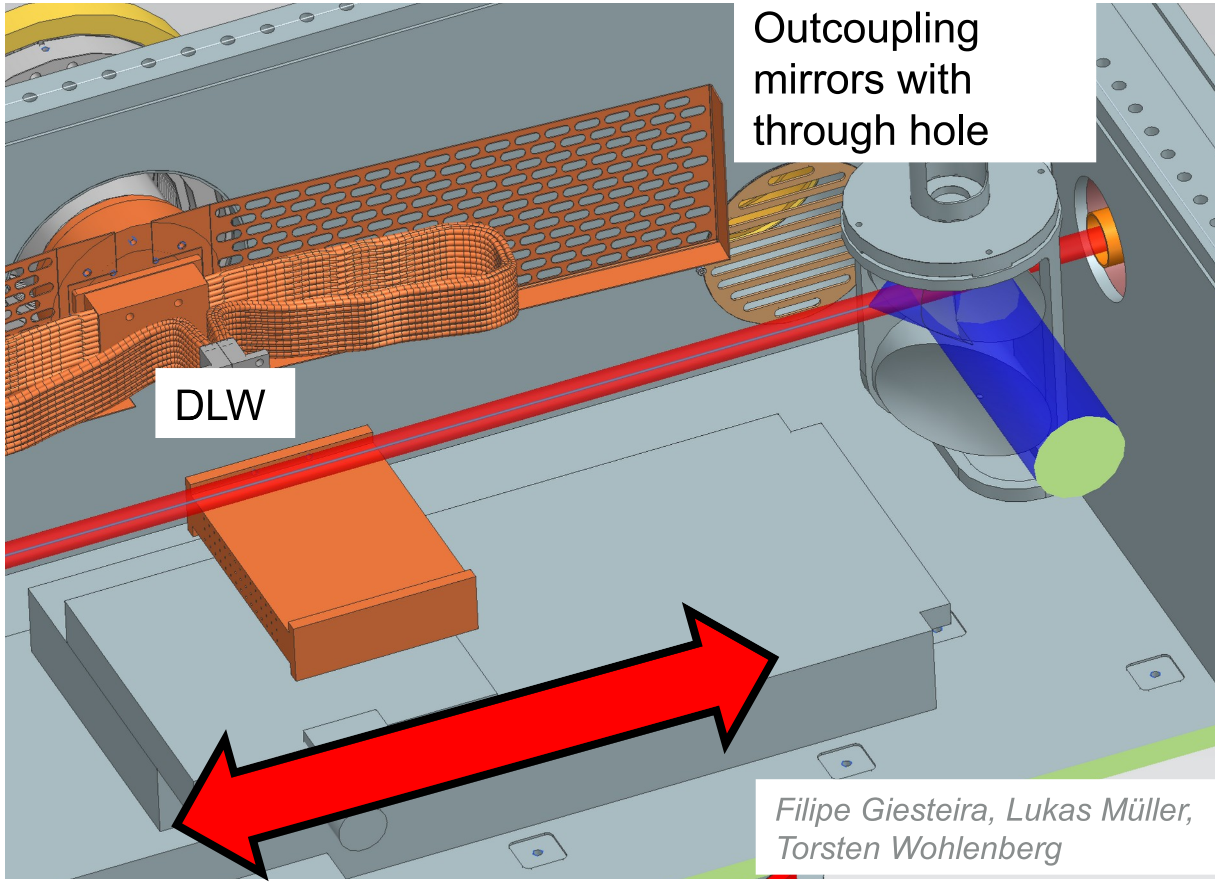


Transport to diagnostics area

Outcoupling:

- Too close → radiation lost in electron through hole
- Too far → radiation lost at mirror edges

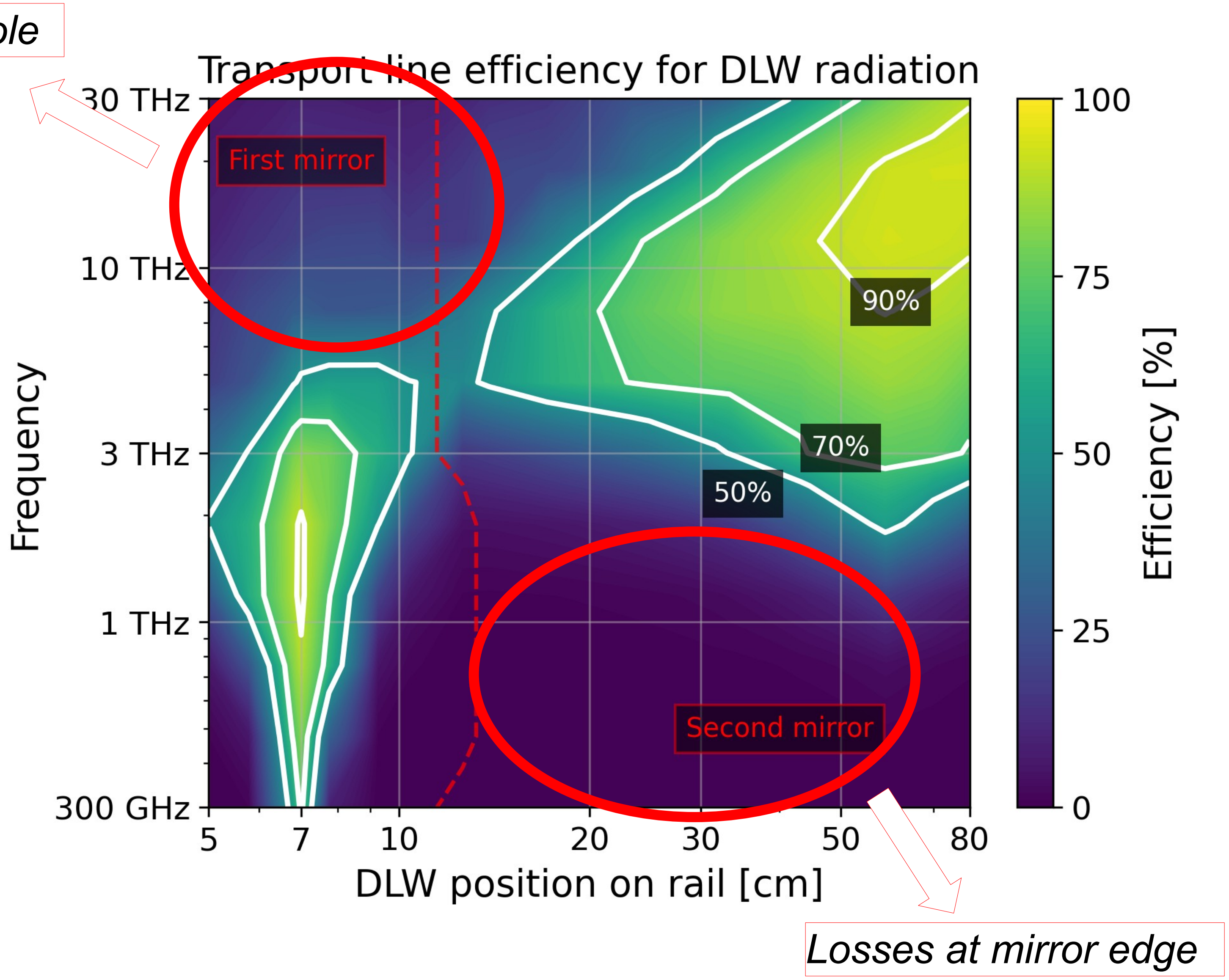
➔ Two mirrors for close and far regime, DLW on sliding rail



Filipe Giesteira, Lukas Müller, Torsten Wohlenberg

Transport to diagnostics area

- First results promising: every frequency captured and transported at **>70% efficiency**
- Dotted line indicates which mirror transports more
- In practice, working point is experimentally determined



Summary

- Radiation generation methods:
  - Narrowband: **dielectric-loaded waveguides**
  - Broadband: tapered waveguides, **diffraction radiation**
- Radiation transport:
  - Modeled THz transport as lattice optimization problem (currently only DLW)
  - Preliminary result: source to lab efficiency of for to

Thank you!

Courtesy GPT-4

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