ELECTRONIC AND ELECTRICAL ENGINEERING

UCL

Paving the Way for Large-Scale arrays of Photonic THz Transmitters

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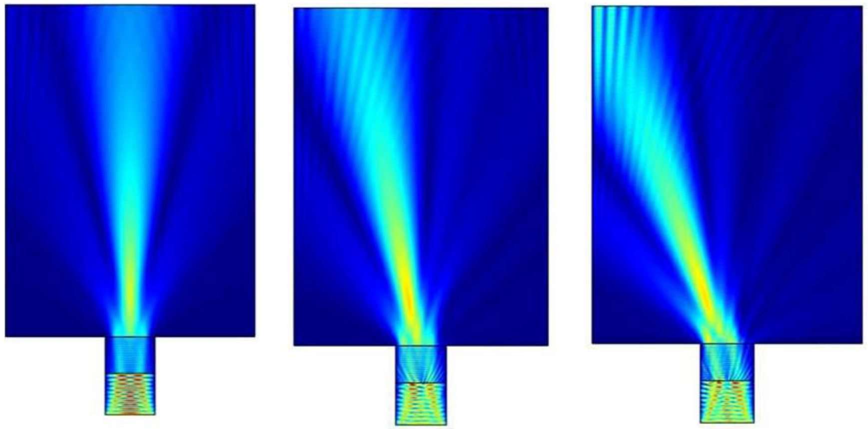
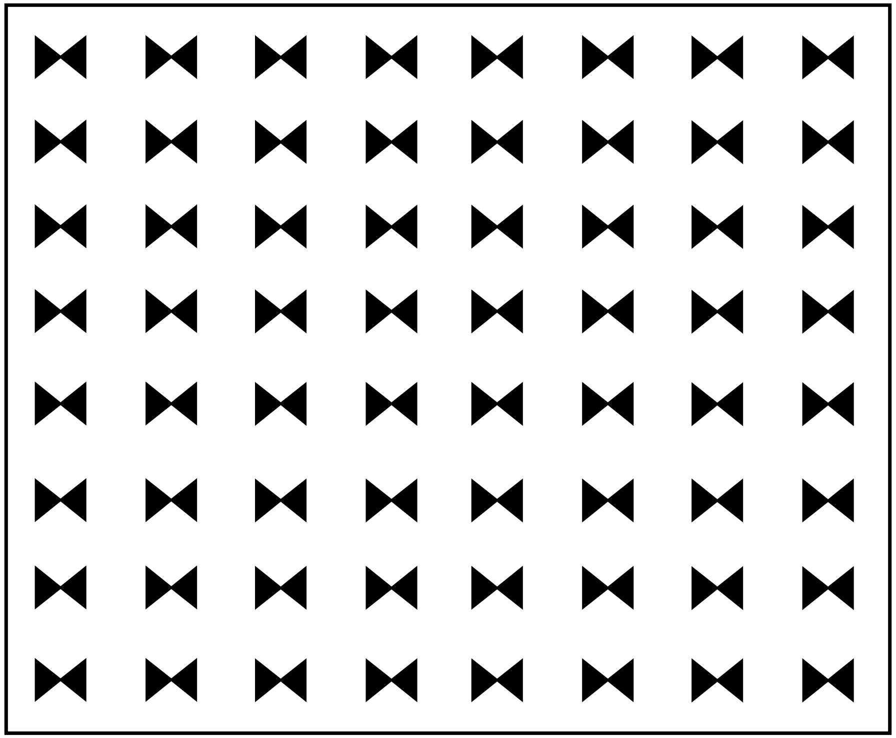
The Wider Vision

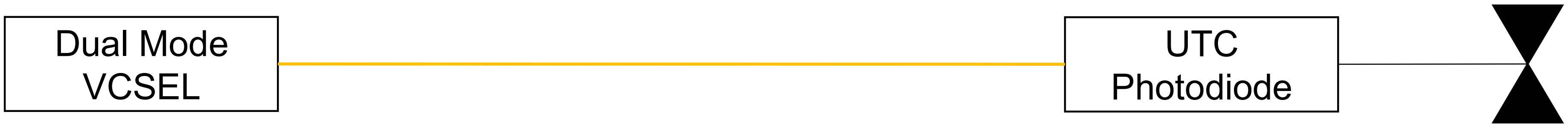
- 300 GHz (Ultra high speed)
- High Power
- Steerable via Phased Array

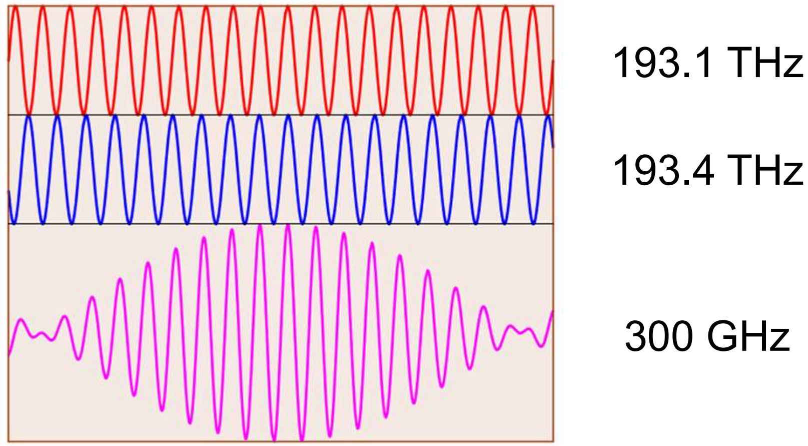




[1, 2]

This Project

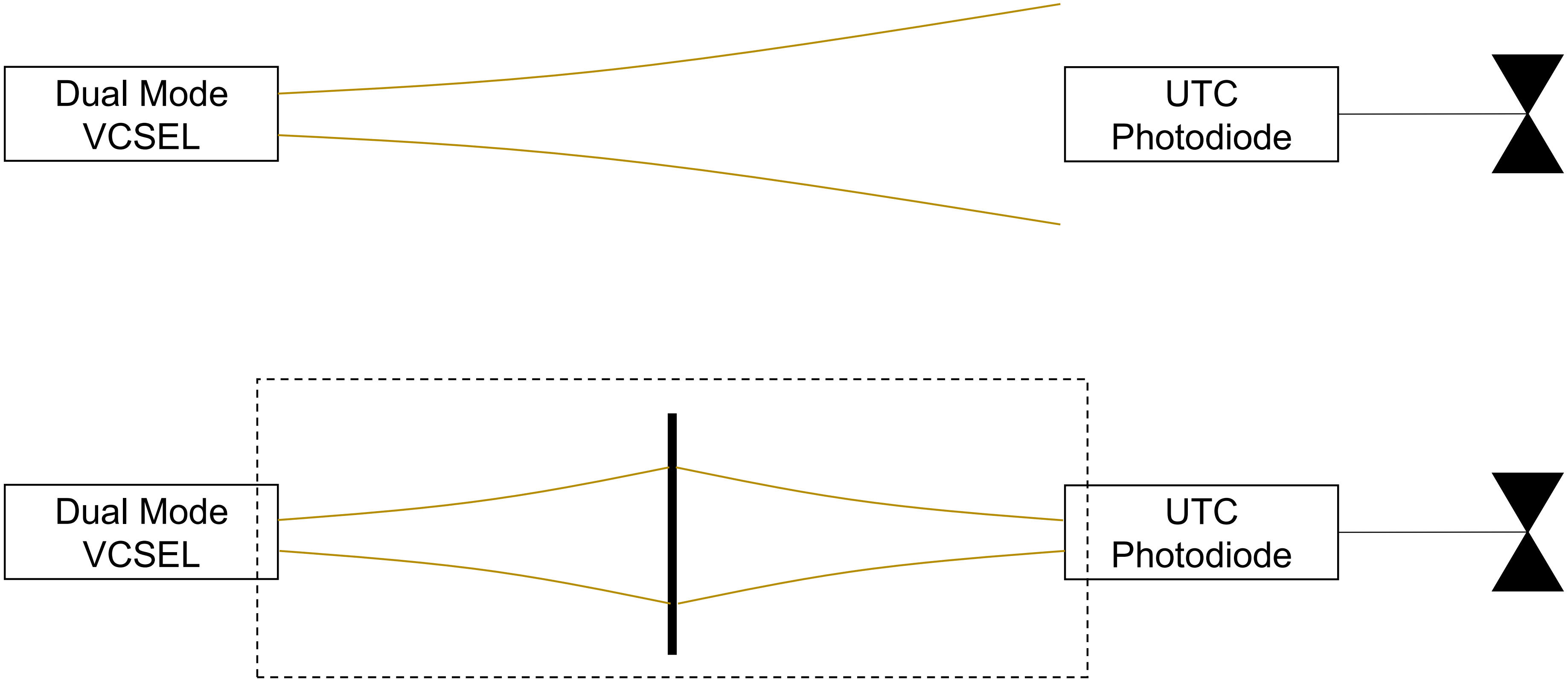




- Laser optically drives PD
- PD drives antenna

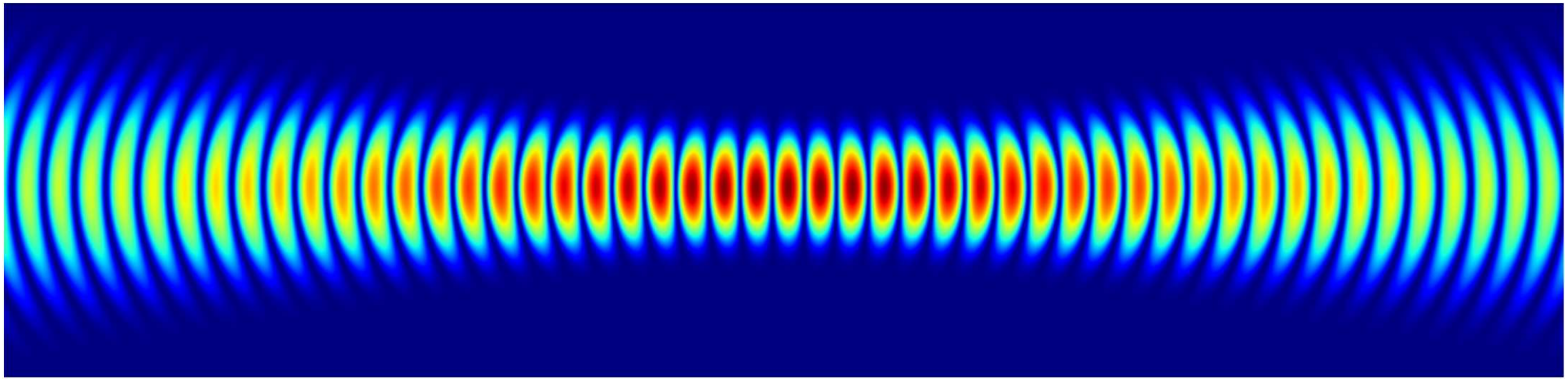
- Photomixed to 300 GHz
- Must be practical

This Project



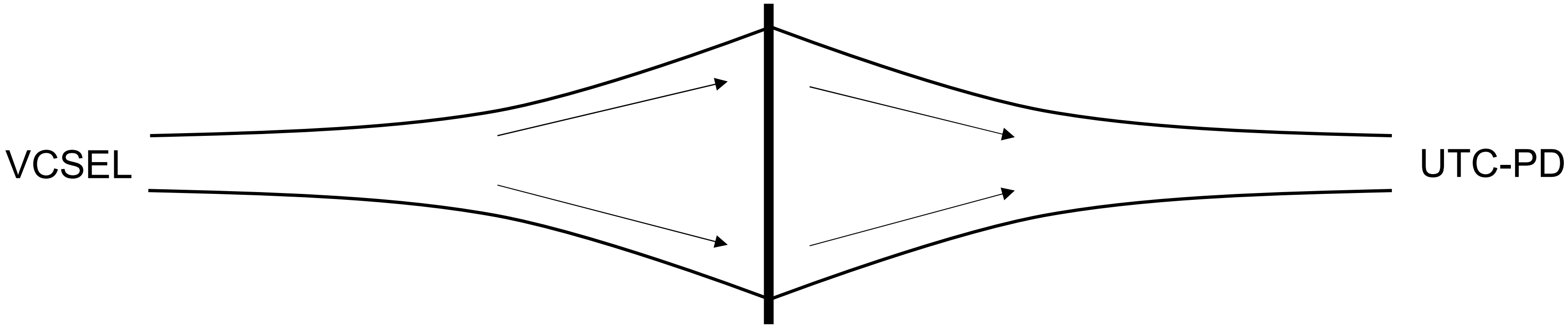
Theory: Gaussian Beam

$$U(\mathbf{r}) = \underbrace{A_0 \frac{W_0}{W(z)} \exp\left[-\frac{x^2+y^2}{W^2(z)}\right]}_{\text{Gaussian Profile}} \underbrace{\exp\left[-jkz - jk\frac{x^2+y^2}{2R(z)} + j\zeta(z)\right]}_{\text{Phase}}$$



[3]

Theory: Lens



$$\frac{1}{f} = \frac{1}{R_A} - \frac{1}{R_B}$$

$$\boxed{U_B(\mathbf{r}) = \exp\left(j\,\frac{k(x^2+y^2)}{2f}\right)U_A(\mathbf{r})}$$

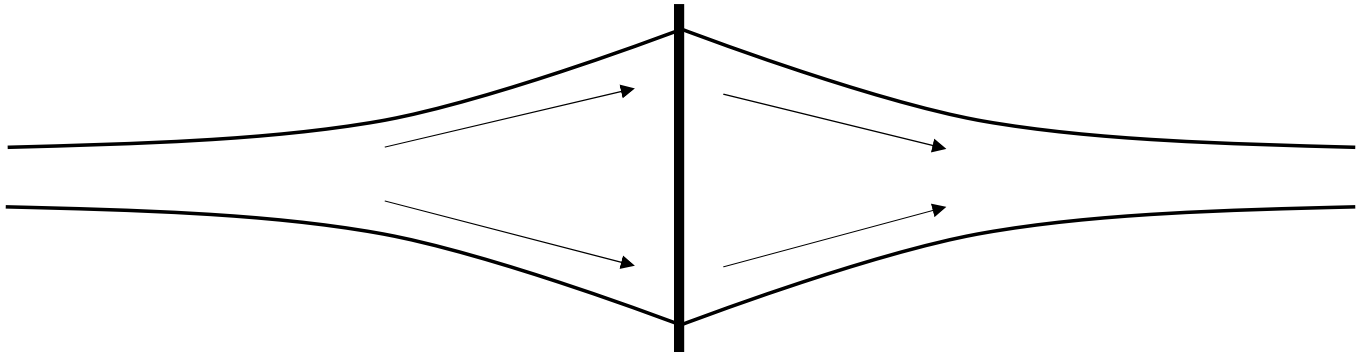
[3]

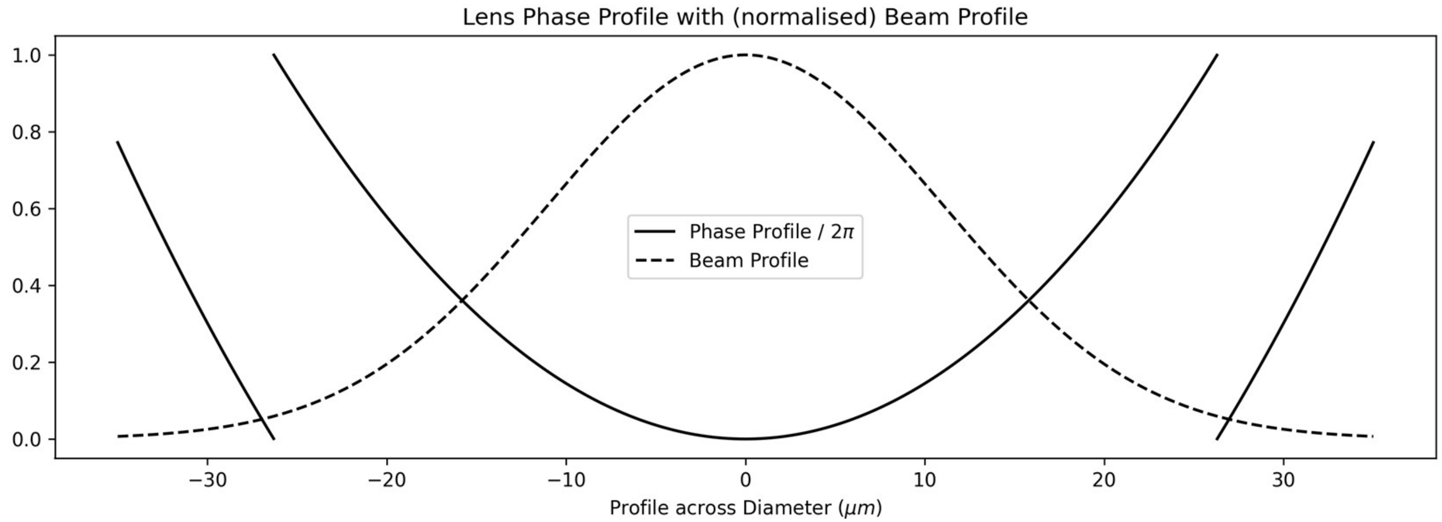
Summary of System

- 400μm + 400μm

- $W_{0A} = 10\mu\text{m}$
- $W_{0B} = 5\mu\text{m}$

- f = 193.4 THz

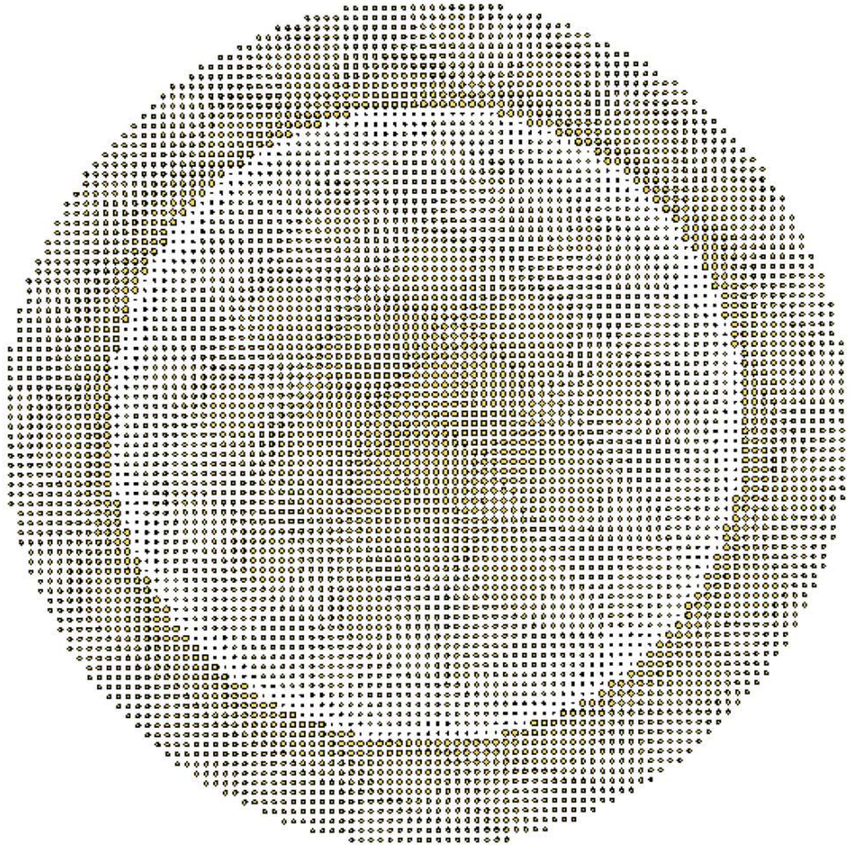




The Approach: Metalens

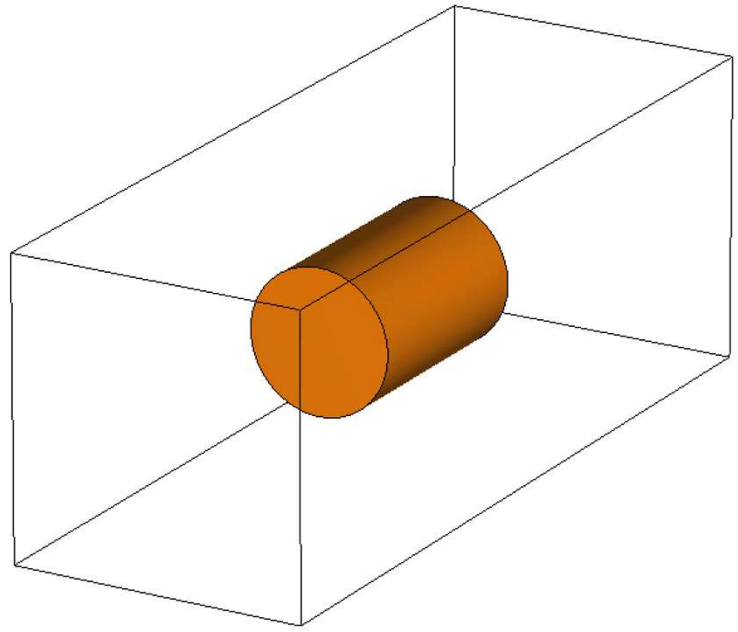
- Metalens:
  - Amorphous silicon rods
  - In Silica
  - Square lattice, 800nm

- Why?
  - Thin lens approximation
  - Numerical aperture [4, 5]
  - CMOS fabrication [5]

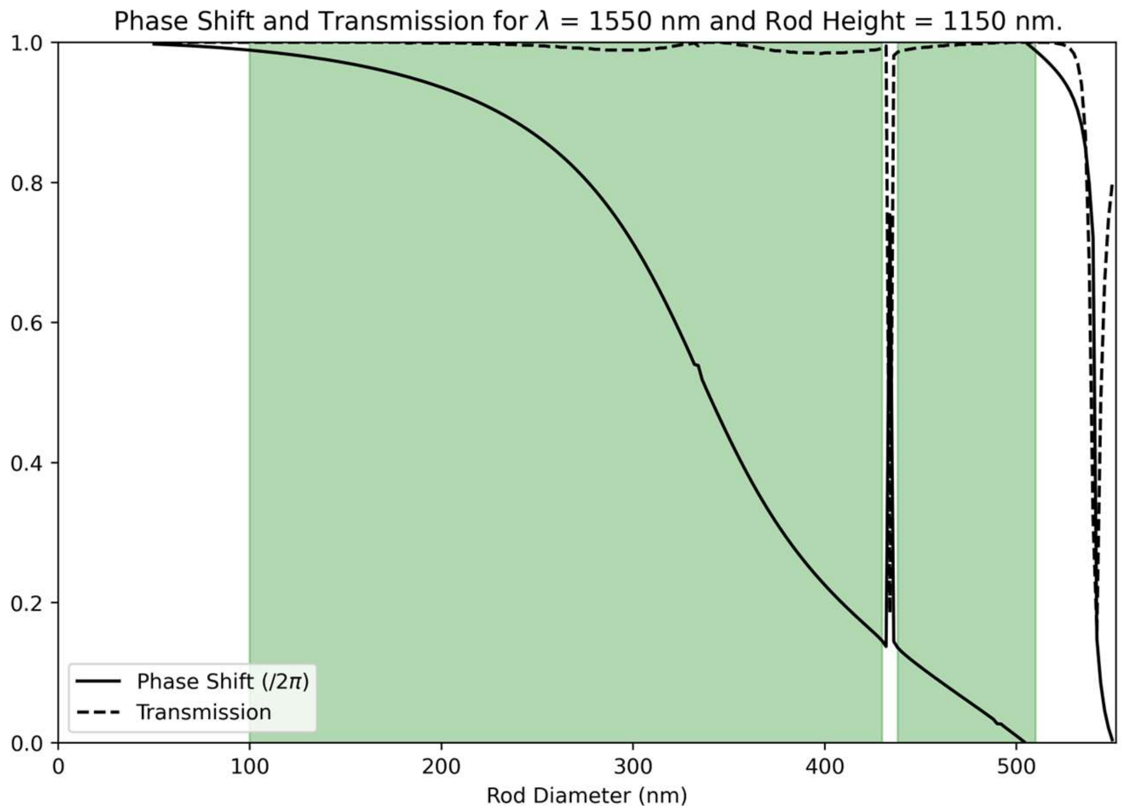


Determining Rod Properties

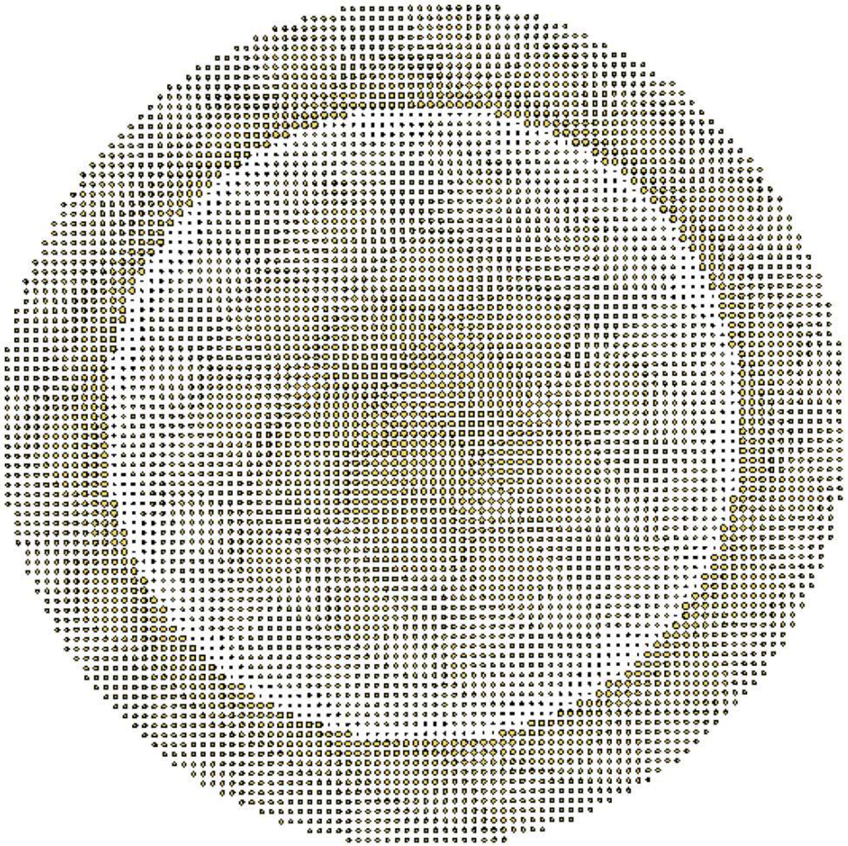
- Needed:
  - Smooth, full range phase modulation
  - High transmission
- Parameters: Height and Diameter
- Periodic Boundary Conditions
  - Easy simulation
  - Nearest rod approximation

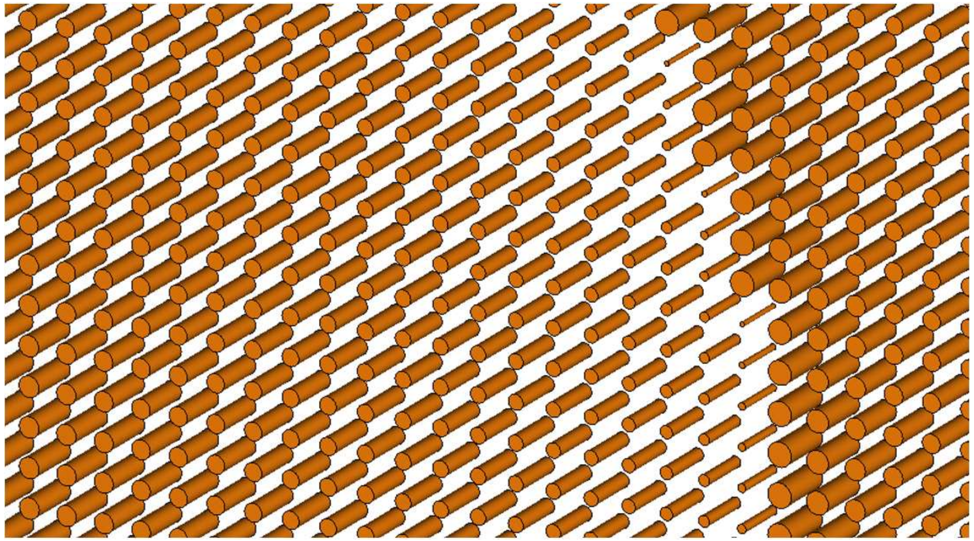


Determining Rod Properties

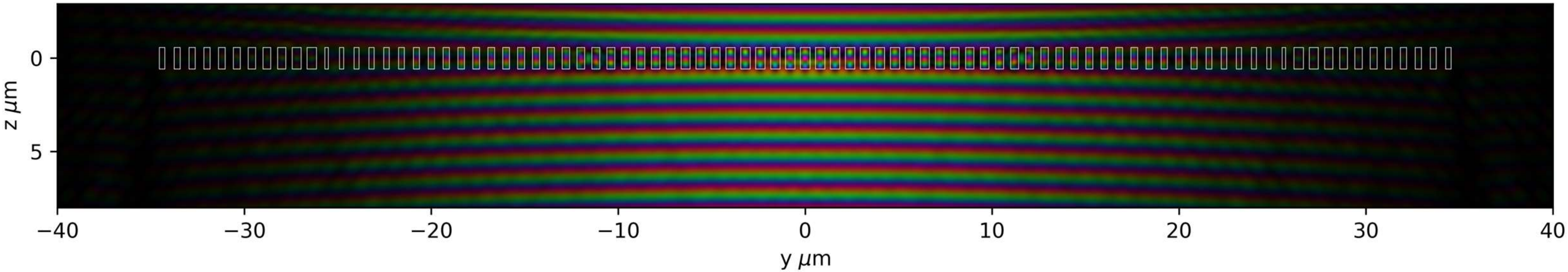


The Metalens

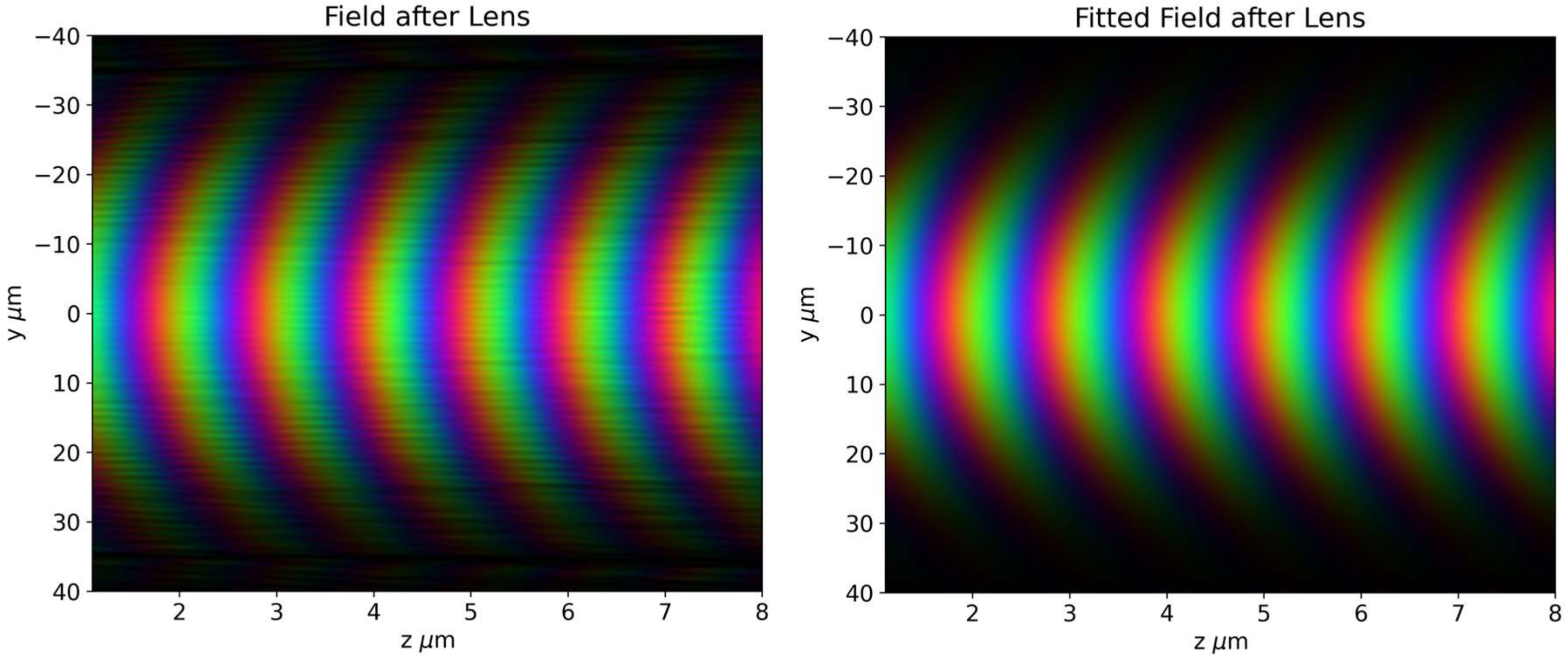




Lens + Laser (Gaussian) Beam



Lens + Laser (Gaussian) Beam



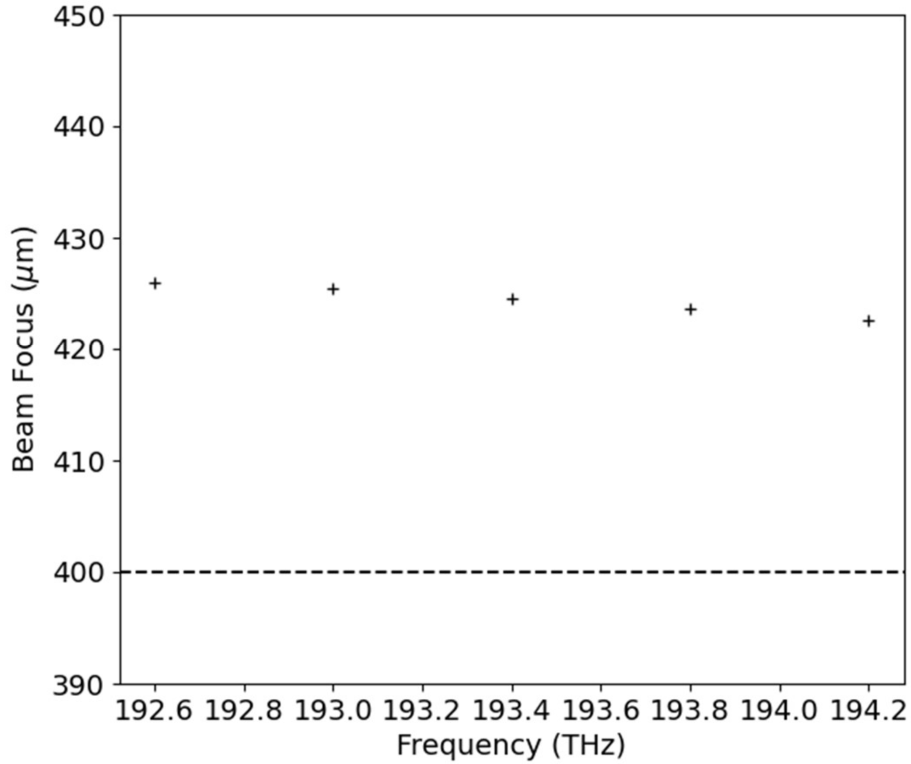
- Waist at PD:
  - $8.55 \pm 0.63\ \mu m$
- Distance to Focus:
  - $424\ \pm 0.37\ \mu m$
  - 6% out
  - Well within depth of focus

Investigating Dispersive Effects

- Two effects:
  - Beam divergence from Laser
  - Lens phase exertion

- Small deviation in power and beam focus length

- Constant ~6% remains



Further Work and Challenges

- Investigate 6% discrepancy
  - Likely radius of curvature issue

- Investigate Parameters
  - Lattice Constant
  - Laser and UTC-PD waists

- Challenge assumptions
  - Radius of curvature
  - Rod coupling
    - 2π discontinuity
  - Gaussian beam validity
  - Astigmatic effects
  - Polarisation Effects
    - Not rotationally symmetric

Summary

Aims

- Framework for metalens design
  - Low loss
  - Practical
  - At least 300 GHz bandwidth
- Correctly focus

Achieved

- Framework for metalens design
  - Low loss
  - Practical
  - At least 1600 GHz bandwidth
- Nearly correctly focusses, likely reasons identified
- Dispersive effects investigated

References

[1] ‘IEEE Standard for High Data Rate Wireless Multi-Media Networks--Amendment 2: 100 Gb/s Wireless Switched Point-to-Point Physical Layer’, IEEE.

[2] P. F. McManamon and A. Ataei, ‘Progress and opportunities in the development of nonmechanical beam steering for electro-optical systems’, *Opt. Eng.*, vol. 58, no. 12, p. 1, 2019.

[3] B. E. A. Saleh and M. C. Teich, *Fundamentals of photonics*. New York: Wiley, 1991.

[4] A. Arbabi, Y. Horie, A. J. Ball, M. Bagheri, and A. Faraon, ‘Subwavelength-thick lenses with high numerical apertures and large efficiency based on high-contrast transmitarrays’, *Nat Commun*, vol. 6, no. 1, p. 7069, 2015.

[5] A. Siemion, ‘Terahertz Diffractive Optics—Smart Control over Radiation’, *J Infrared Milli Terahz Waves*, vol. 40, no. 5, pp. 477–499, 2019.