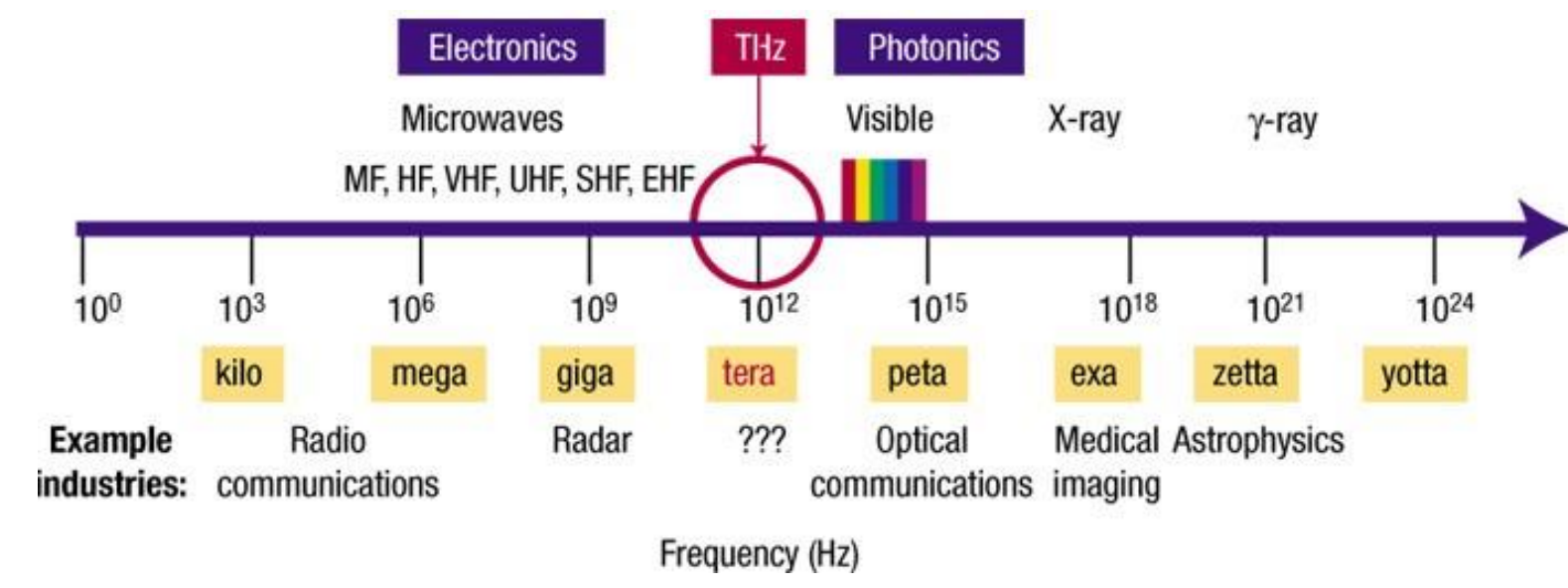


W.T. Qin¹, S.X. Chen², J.Y. Liu², X.K. Wang², Y. Zhang², Y.Z. Wu¹

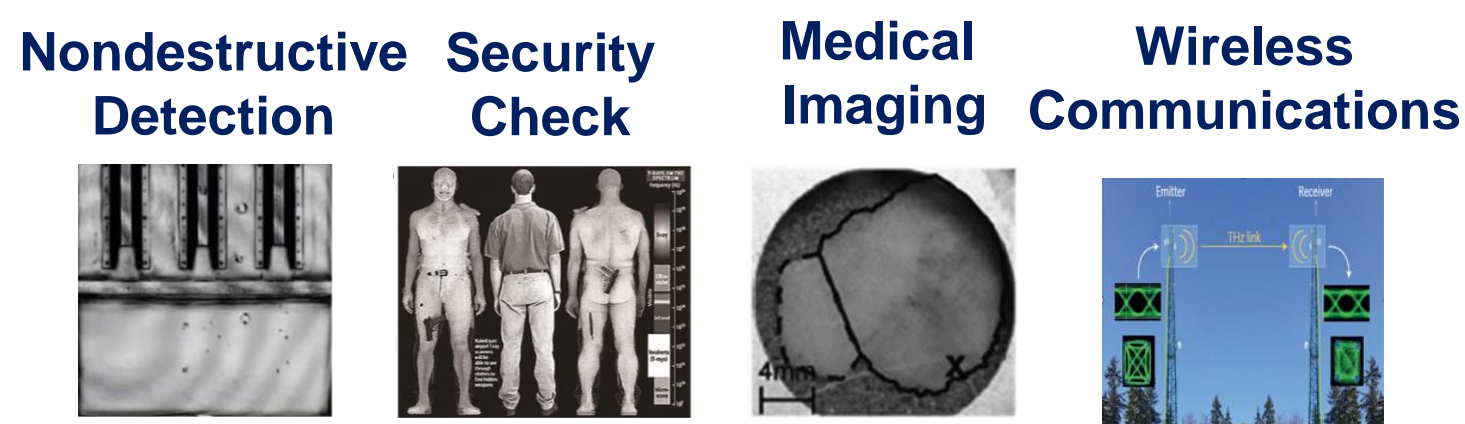
¹ Department of Physics, Fudan University, Shanghai, China
² Department of Physics, Capital Normal University, Beijing, China

Introduction

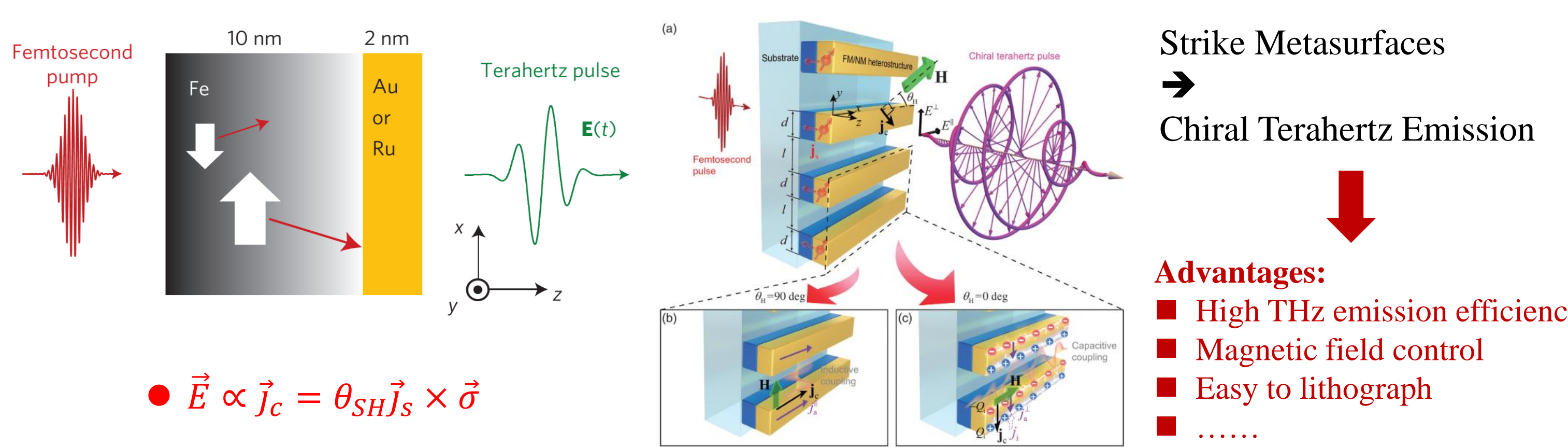
Wide THz Applications



B. Ferguson *et al.* Nature Materials 1, 26-33 (2002)



New Spintronic THz emitter and metasurfaces Modulation



$$\vec{E} \propto \vec{j}_c = \theta_{SH} \vec{j}_s \times \vec{\sigma}$$

T. Kampfrath *et al.* Nature Nanotech 8, 256-260 (2013)

C. Q. Liu *et al.* Advanced Photonics 3, 056002 (2021)

Strike Metasurfaces
 → Chiral Terahertz Emission

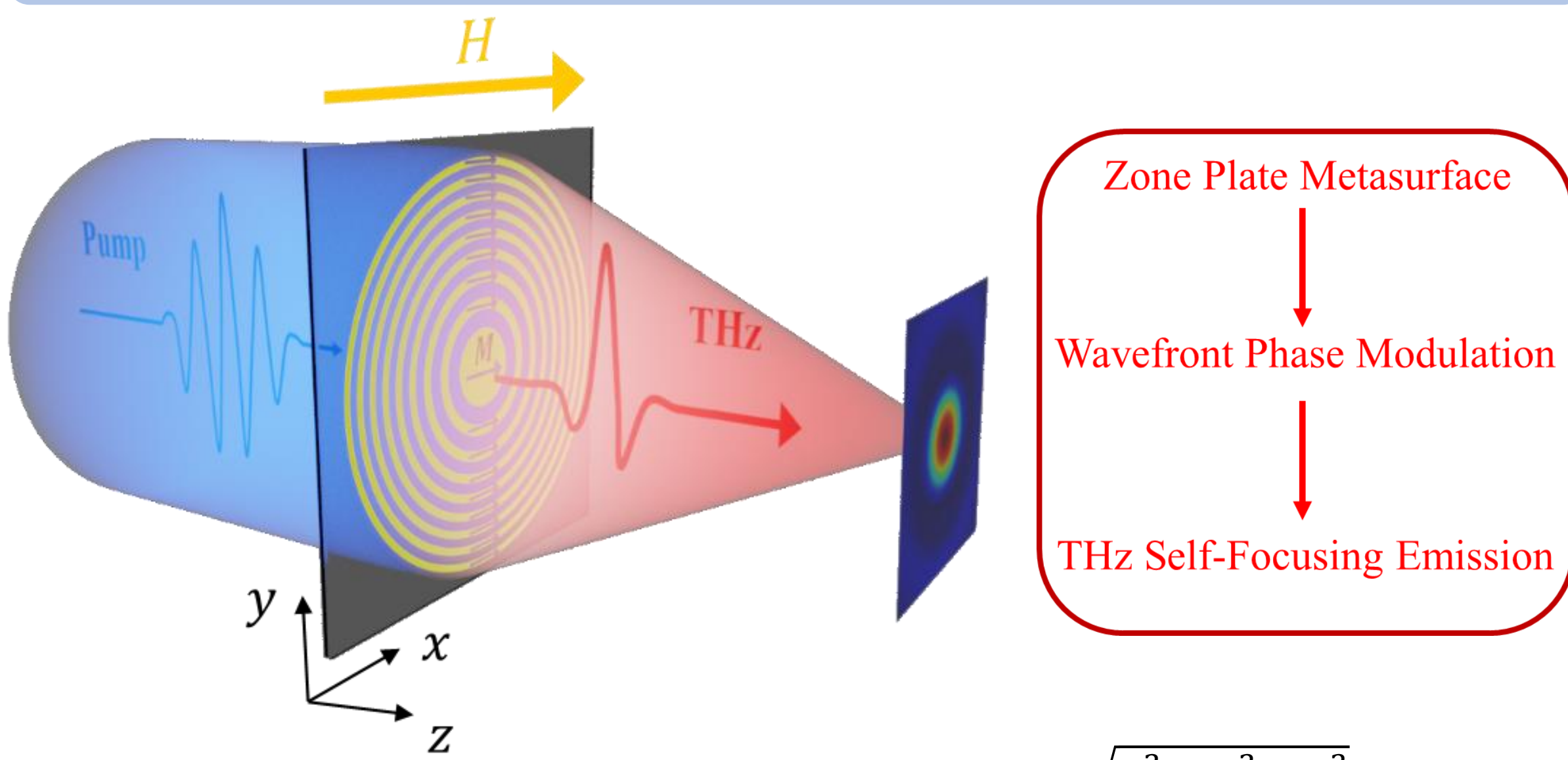
Advantages:

- High THz emission efficiency
- Magnetic field control
- Easy to lithograph
-

Spintronic THz Emitter + Metasurfaces → THz Focusing Modulation ?

THz Emission Controlled by Metasurfaces

Terahertz Self-Focusing Emission with Zone Plate Metasurfaces



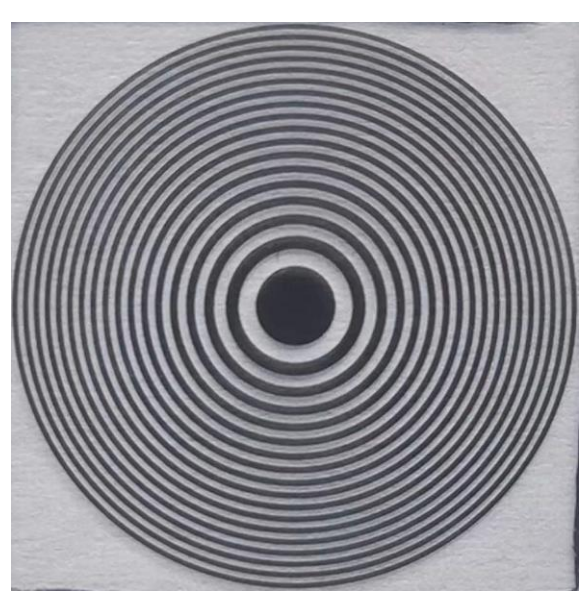
■ The Design of Zone Plate metasurfaces $\Delta\phi = 2\pi \cdot \frac{\sqrt{x^2 + y^2 + z^2} - z}{\lambda_{THz}}$

All Point Sources on the Sample Surface Satisfy:

$2n\pi \leq \Delta\phi \leq (2n+1)\pi$ ($n = 0, 1, 2, \dots$) → Interference Enhancement Achieved by Phase Modulation at the Focal Point

2D Zone Plate Metasurface

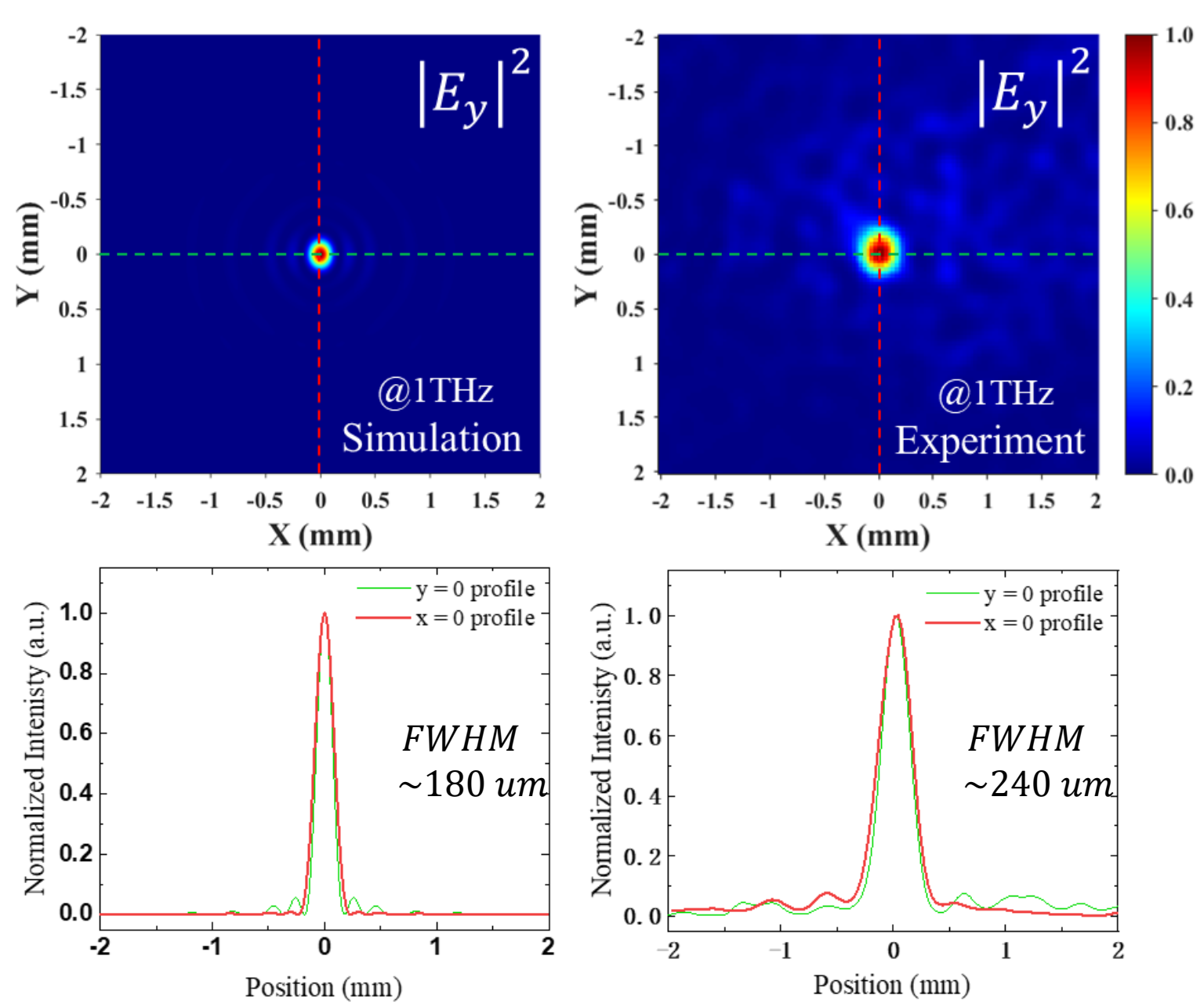
- Frequency $f = 1 \text{ THz}$
- Focal length $z = 6 \text{ mm}$



Metasurface heterostructure:
 W(2nm)/CoFeB(1.6nm)/ Pt(2nm)

The spatial distribution of THz Intensity

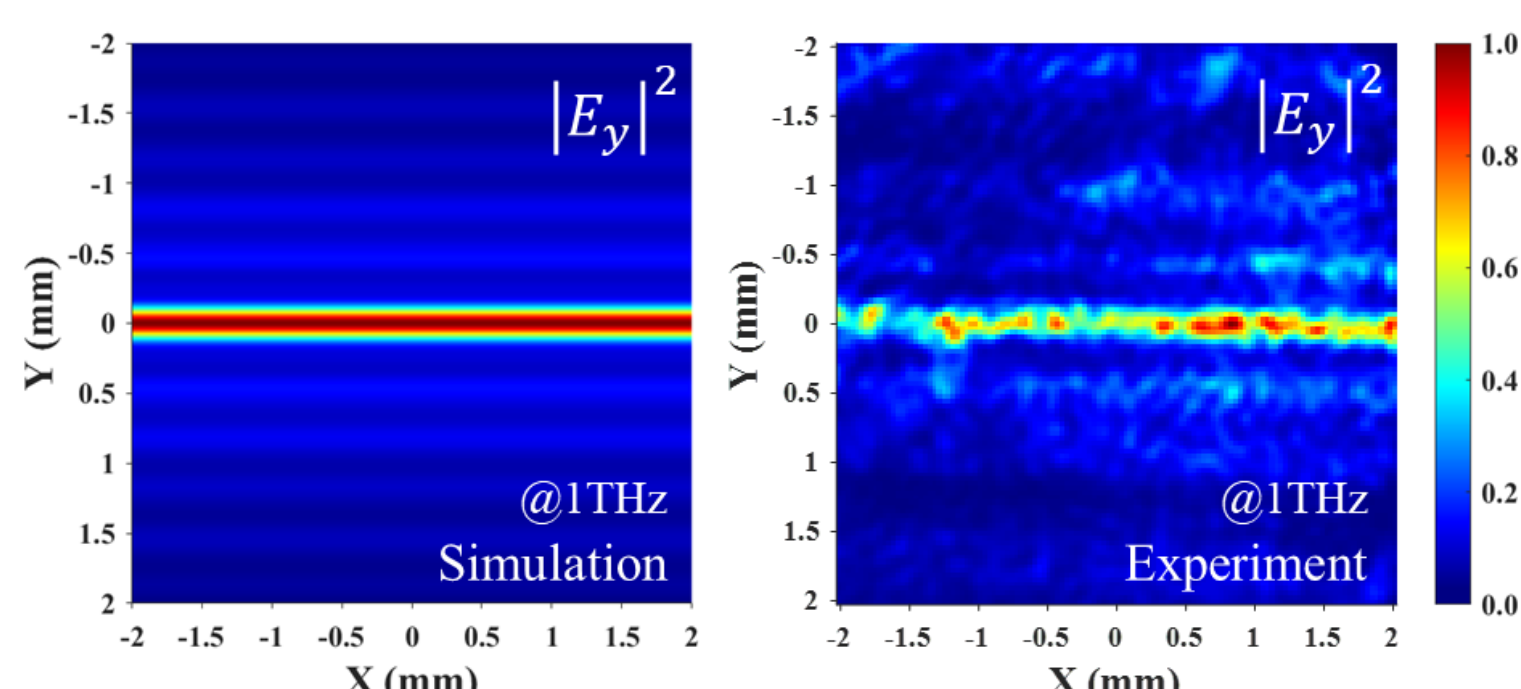
Terahertz Propagation Simulation:
 Fresnel Diffraction Integral Formula



1D Zone Plate Metasurface

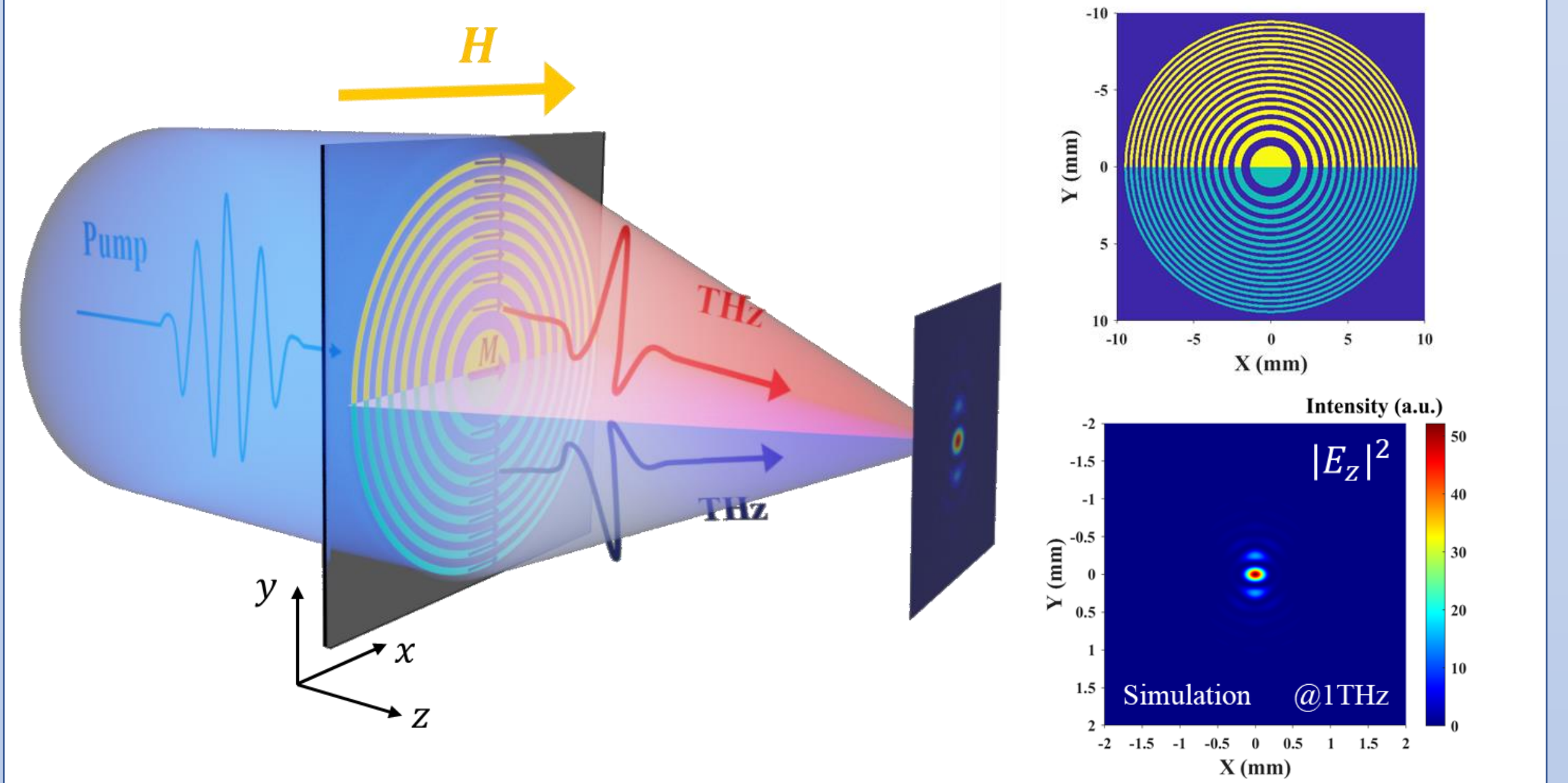


The spatial distribution of THz Intensity



THz Longitudinal Polarization Focusing

Terahertz Longitudinal Polarization Focusing Emission

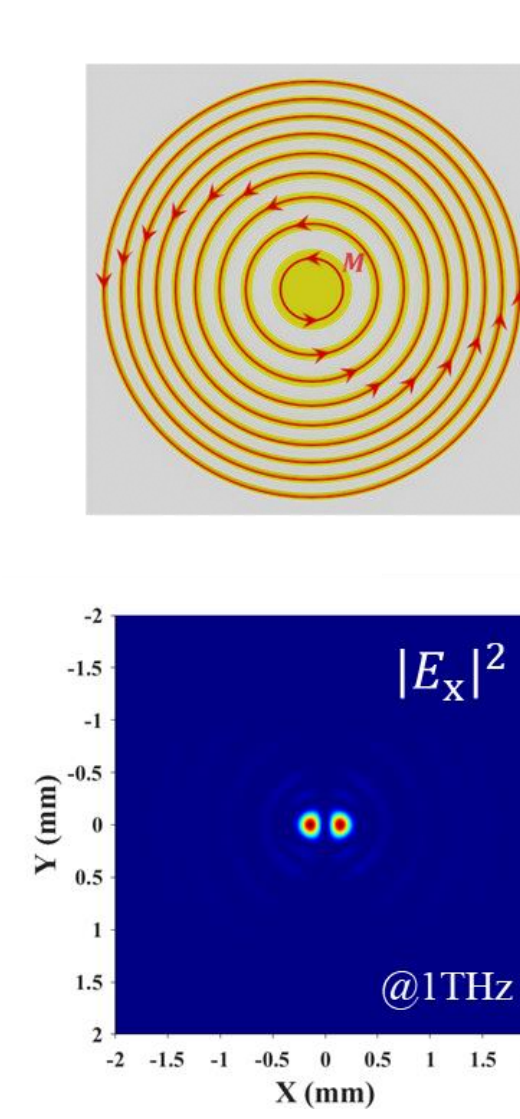
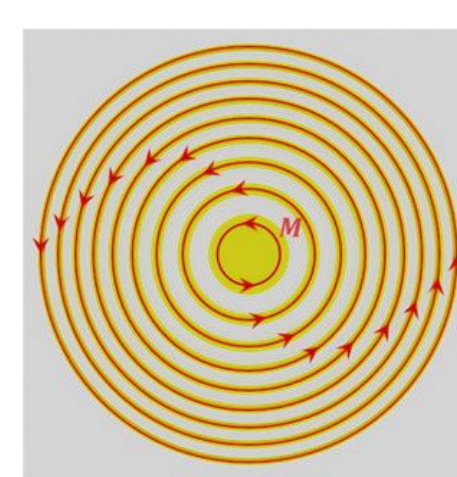


Designs for Enhanced Focusing Efficiency

Special Magnetic Moment Distribution

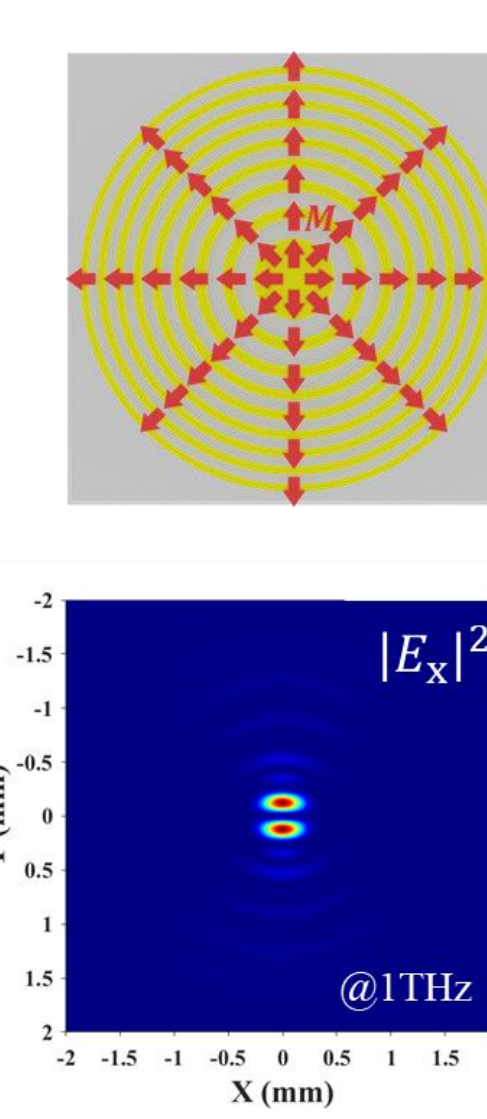
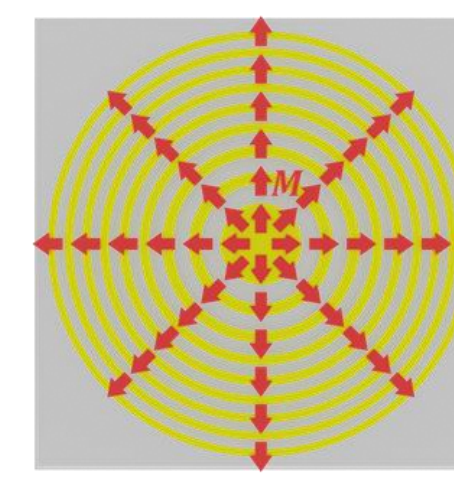
Vortex Distribution

- Vertical Electric Field Pulse
- Radial THz Beam



Radial Distribution

- Vertical Magnetic Field Pulse
- Azimuthally Polarized THz Beam



Summary

- Spintronic THz emitters utilizing zone plate metasurfaces enable THz self-focusing emission without the need for additional optical elements.
- On the basis of zone plates, we propose several sample configuration capable of achieving longitudinal polarization focusing or vertical electromagnetic field pulses at THz frequency.