Designing and 3D Printing Customised Phase Plates based on Modified Gerchberg-Saxton Algorithm

Major Category: Optoelectronics (光電領域)

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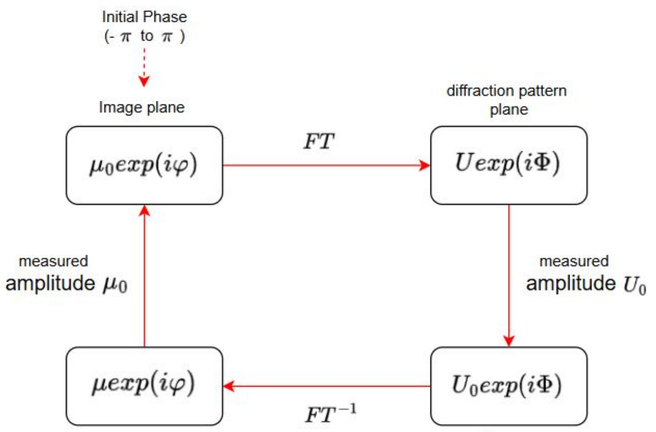
Introduction

- Terahertz (THz) spectroscopy is a powerful tool for imaging and testing applications, where it needs elements to manipulate the intensity and shape of the beam.
- Flexible and rapid prototyping capabilities can be needed for this optical elements
- Code-based design using the Gerchberg-Saxton algorithm allows for an efficient exploration of various target intensity profiles before 3D printing the final phase plate.

Computational Design with Gerchberg-Saxton Algorithm

- Gerchberg-Saxton algorithm: A powerful computational method for designing diffractive optical elements like phase plates.
- GS algorithm uses an Iterative approach
- Key step in each iteration:
  - Forward propagation: Simulate how the light wave propagates from the source plane.
  - Enforcing target intensity: Adjust the wavefront to match the desired intensity pattern at the target plane.
  - Backward propagation: Simulate how the modified light wave propagates back to the source plane.
  - Enforcing input intensity: Adjust the wavefront again to ensure it maintains the original intensity profile at the source plane.



Huygens Principle

Every point on a wavefront acts as a source of secondary spherical wavelets, and the new wavefront is the envelope of these wavelets' forward propagation.

$$E^d_{(x,y)}(x',y') = \frac{A_{(x,y)}}{r_{(x,y),(x',y')}} exp[-ikr_{(x,y),(x',y')} + i\phi].$$

$$E^i_{(x',y')} \propto \sum_{(x,y)} E^d_{(x,y)}(x',y')(1+cos\Omega)$$

Implementation

- Will be done using python language
- Modified GS algorithm integrating the Huygens principle

$$E^d_{(x,y)}(x',y') = \frac{A_{(x,y)}}{r_{(x,y),(x',y')}} exp[-ikr_{(x,y),(x',y')} + i\phi].$$

$$E^i_{(x',y')} \propto \sum_{(x,y)} E^d_{(x,y)}(x',y')(1 + cos\Omega)$$

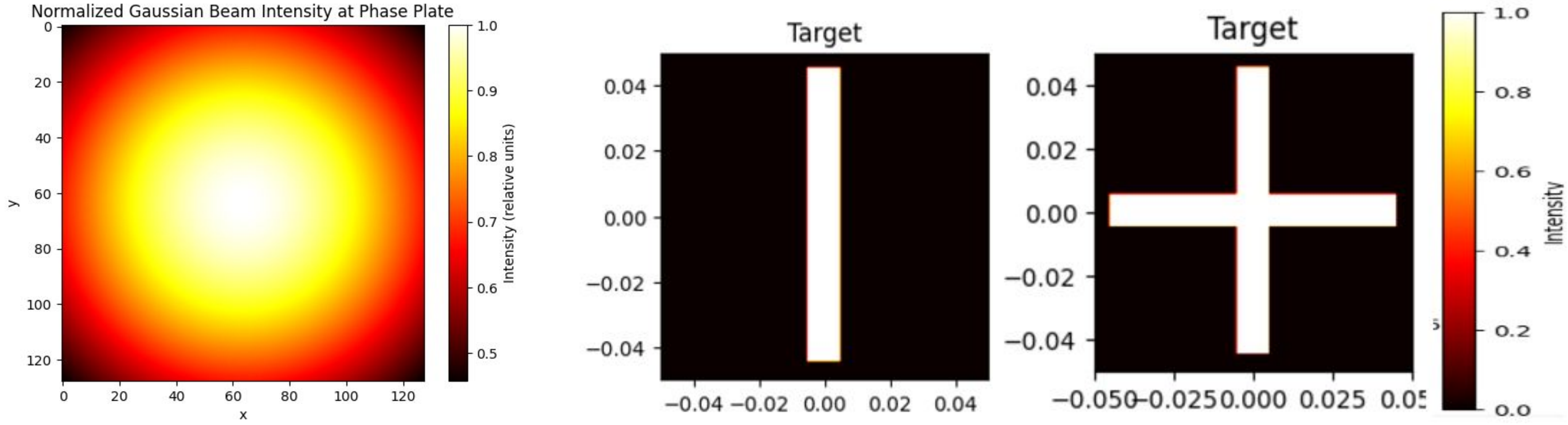
- Inital input Beam set with a beam width of 80 mm and 200 GHz

$$E(x,y) \propto \frac{1}{2\pi\omega^2} exp[-\frac{x^2+y^2}{4\omega^2} + \frac{2i\pi}{\lambda}(\sqrt{l^2+x^2+y^2} - l)]$$

l = 75 mm; distance between the output beam and the phase plate

Implementation

- input and target intensity:



simulation is done with a plate with 128 grid size and *100x100 mm* in size

Implementation

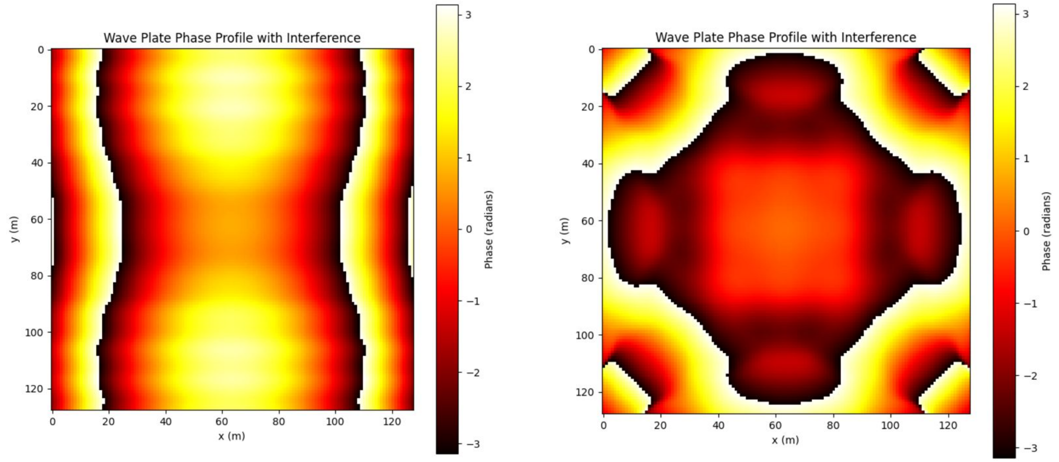
Another formula is also used to calculate the thickness of the calculated phase plate

$$z(x,y) = \frac{\phi(x,y)\lambda}{2\pi(n-1)}$$

n = 1.7

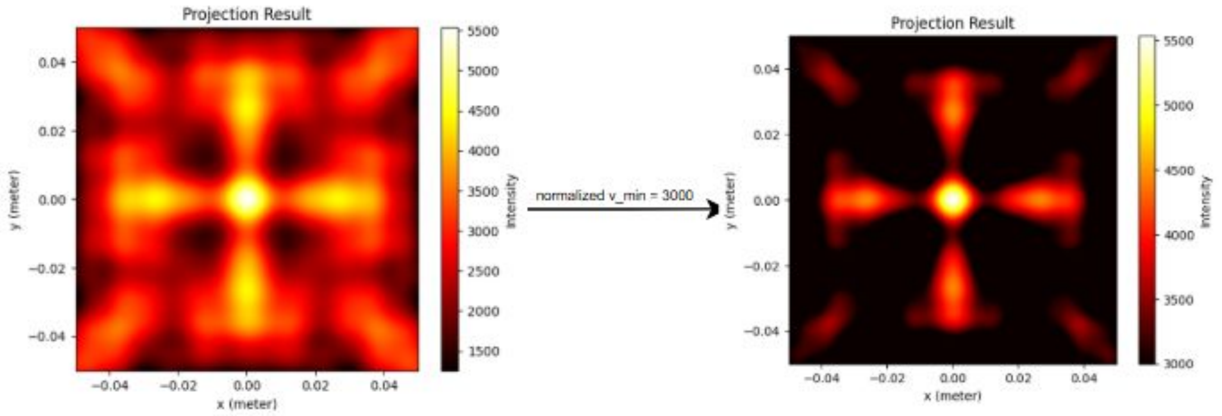
Results

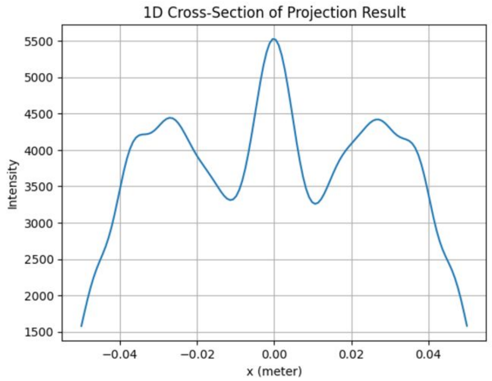
After running the algorithm, the phase profile for both target output intensities is acquired, and the thickness to design the phaes plate can be calculated.

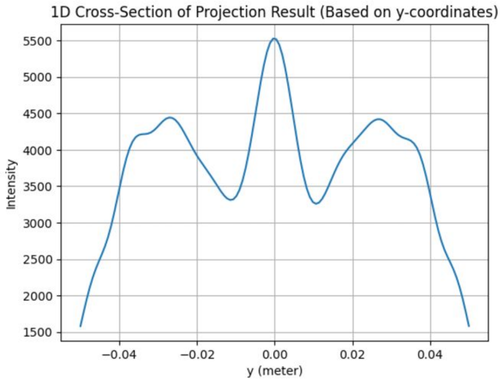


Results

The accuracy of the generated phase plate can be observed by doing another simulation.







Results

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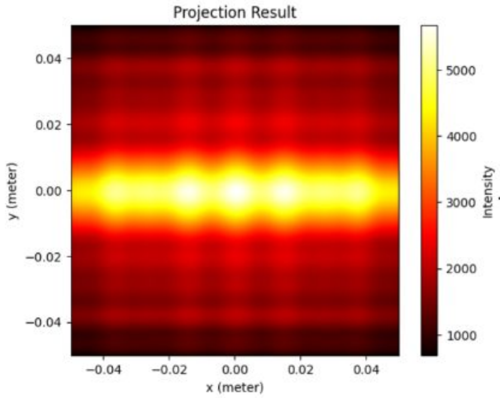
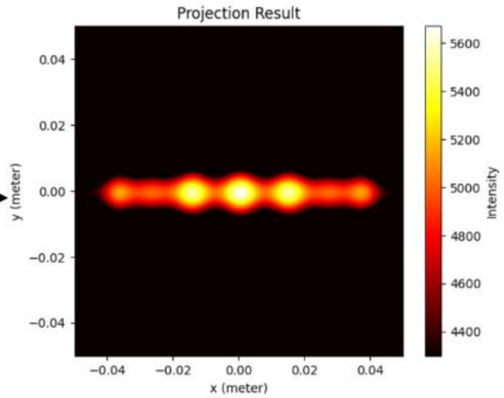
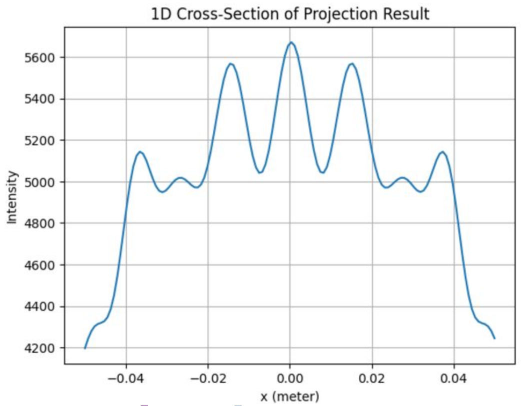
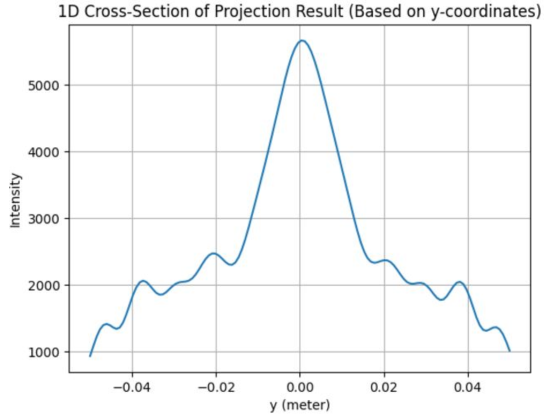


Normalization vmin= 4300







Conclusion

- Simulation results closely matched target intensities, validating the algorithm's effectiveness under simulated conditions.
- Identified Challenges:
  - Mismatched output patterns in some cases.
  - Need for improvements in plotting processes and parameter optimization.
- Based on computational calculations, the methodology offers a robust framework for designing and fabricating THz optical components.
- Demonstrates promising applications in advancing optoelectronic device development.

Citation

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