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Fabrication and characterisation of Spiral Phase Plates generated by 3D Laser Lithography

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Abstract

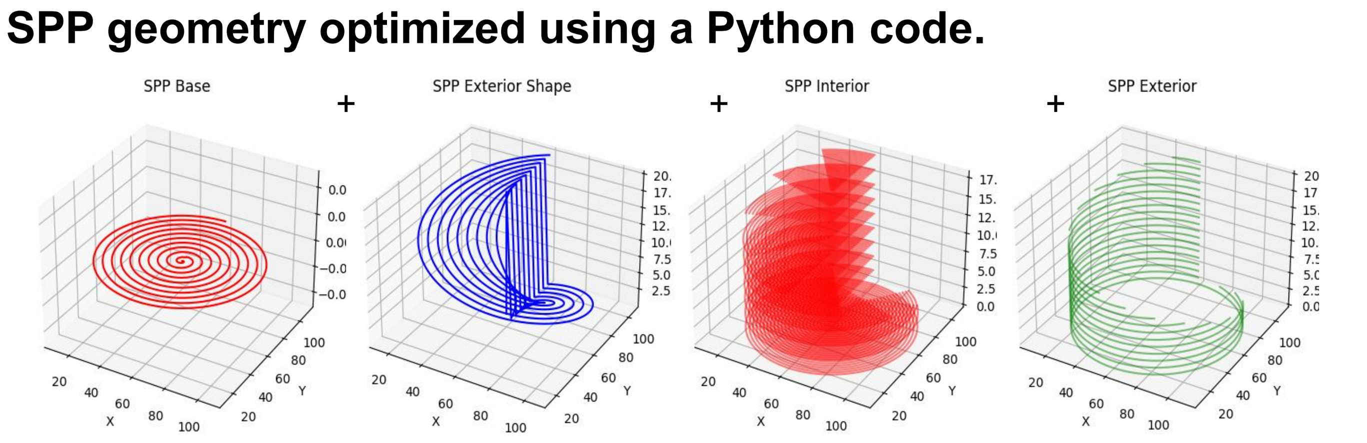
This paper investigates the 3D laser fabrication of spiral phase plates (SPPs) as diffractive micro-optic components for generating and controlling focused light beams with orbital angular momentum (OAM). A series of SPP microstructures, with diameters of tens of micrometers and thicknesses of a few micrometers, was fabricated in the photosensitive polymer IP-L using 3D laser lithography via two-photon photopolymerization (TPP). The beam wavefront modification induced by the fabricated SPPs was assessed using a collimated He-Ne laser beam in a Z-scan configuration by measuring the beam profile in the focal plane of a focusing lens. The ability to fabricate result-yielding SPPs and subsequently OAM beams is essential for integration into advanced photonic devices, with applications ranging from quantum encryption to high-resolution imaging at the micro- and nanoscale.

Objectives

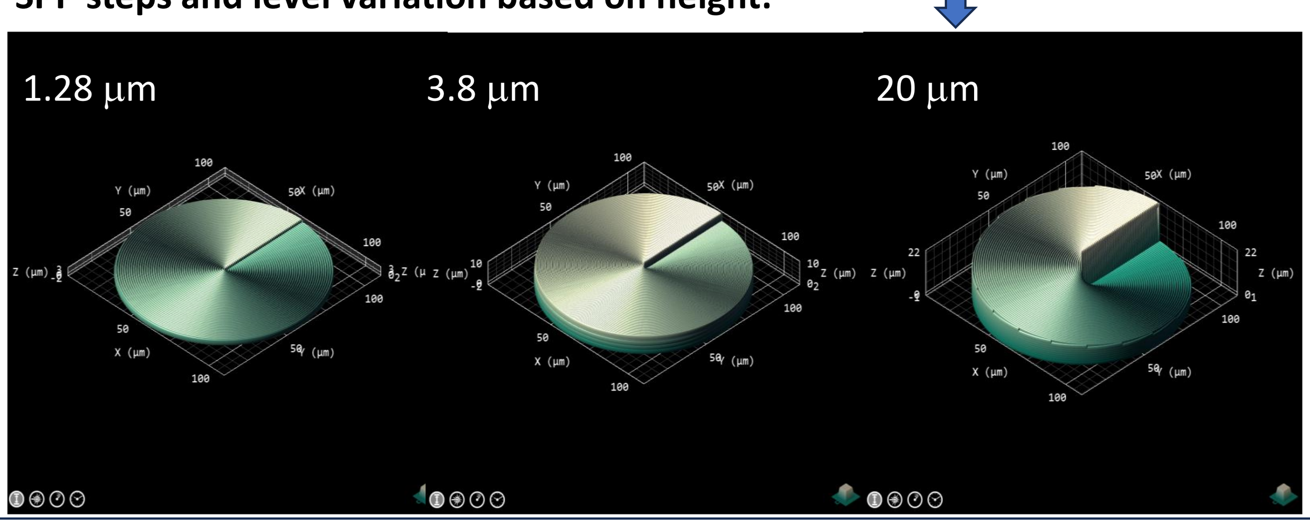
- Experimentally determining the suitable parameters of SPPs fabrication using the 3D Laser Lithography method and Two-Photon Photopolymerization effect.
- Assessment of SPP laser beam wavefront modulation and optical vortex characterization.

Design

SPP geometry optimized using a Python code.

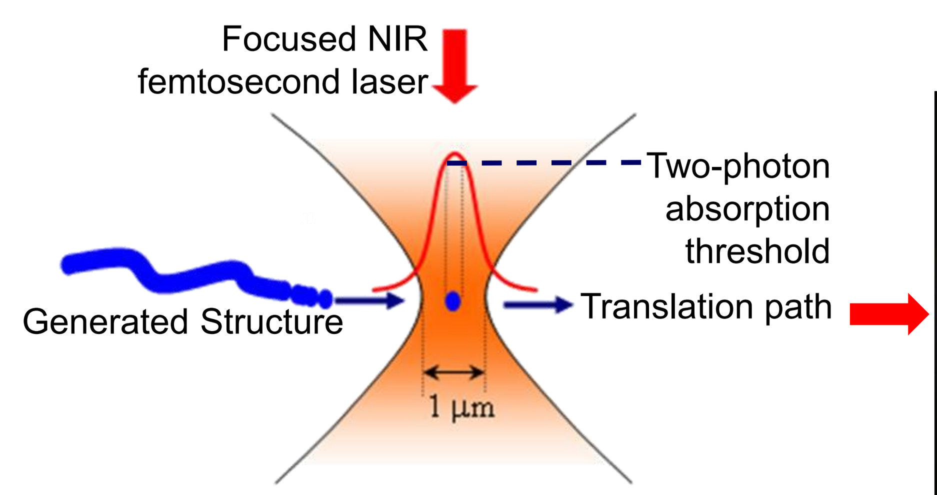


SPP steps and level variation based on height:



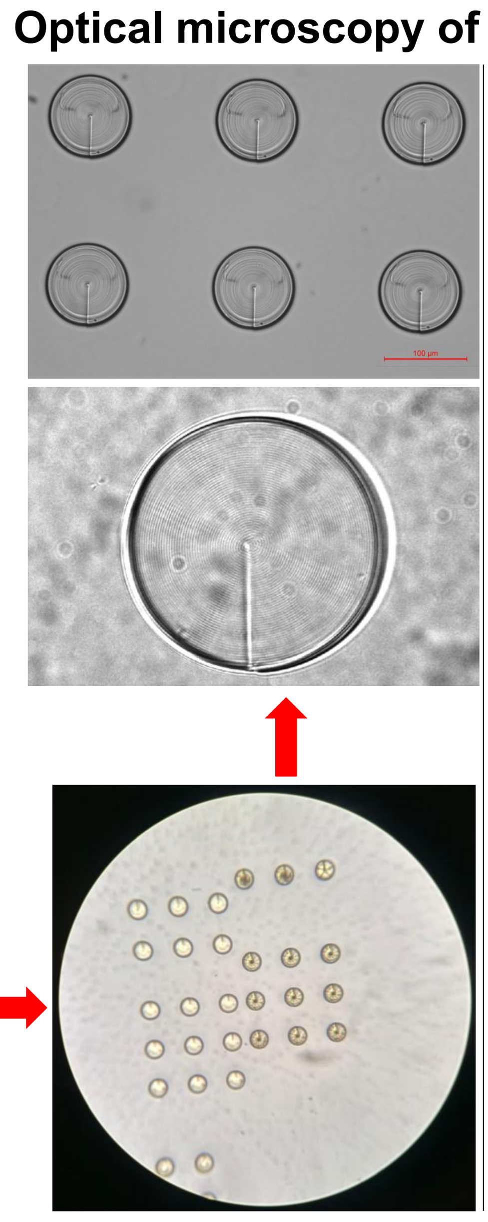
Fabrication & characterization

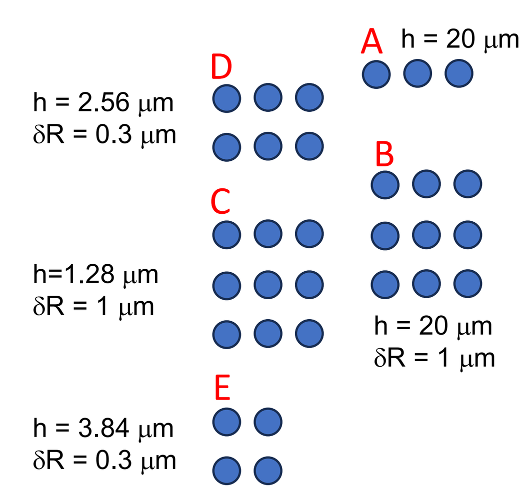
Fabrication method: 3D Laser Lithography



Fabrication steps: Drop casting | Laser irradiation | Development | Microscopy characterization

Optical microscopy of SPP samples

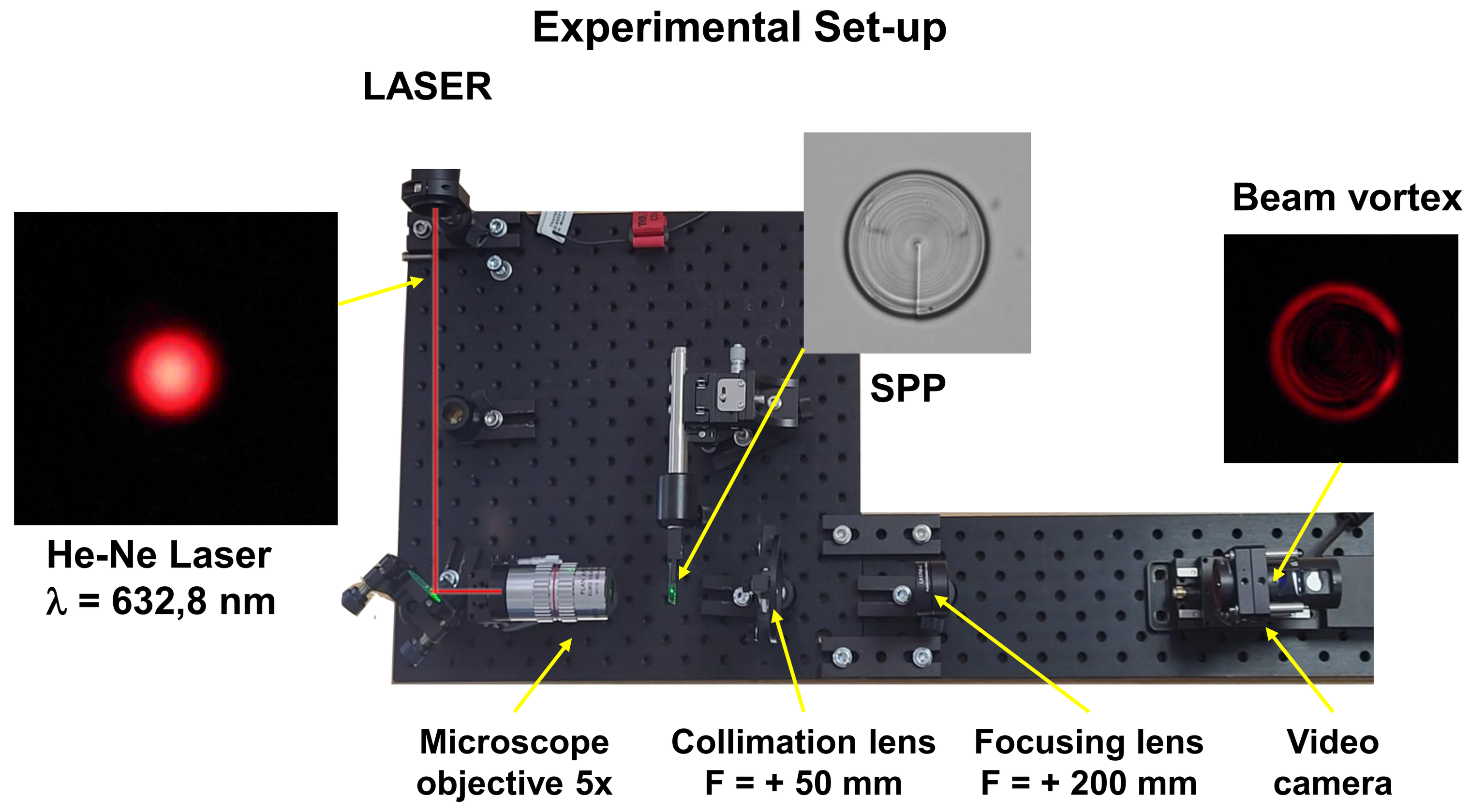




The interior structure of some of the groups of SPPs above had a different interior structure, allowing better performance in generating the OAM beam. A, B, and E presented additional interior radial lines for better support, considering their height. D and C did not include additional radial lines; solely relied on voxel overlapping.

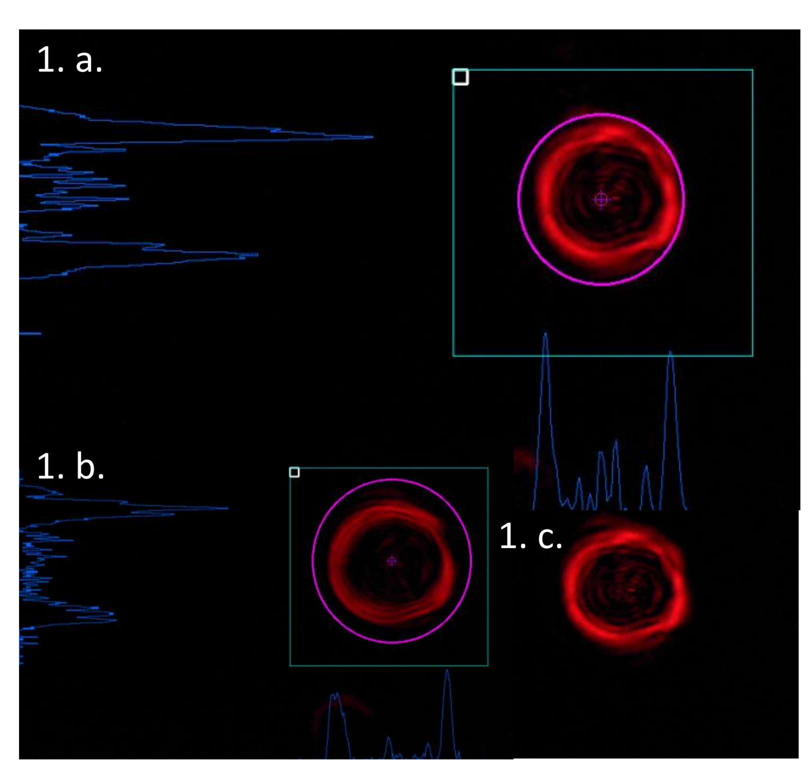
Beam characterisation

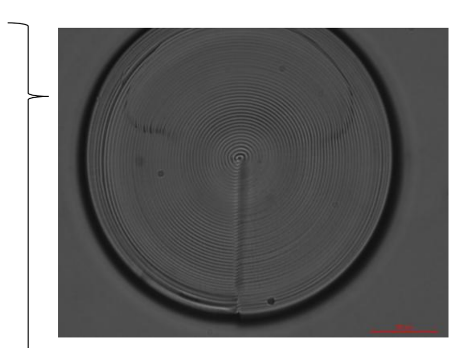
Experimental Set-up



The characterization process serves as the point of testing the structures created. For this purpose, we have designed the configuration of a setup that is used for coupling light into the structure and monitoring the output using real-time cameras. Adjusting the incoming beam through the 5x microscope lens, it is ensured that the beam covers most of an SPP's area. Scanning on the Z axis with the servo-controlled translation stage, the peak of the vortex can be determined and assessed.

Beam profiles of optical vortices





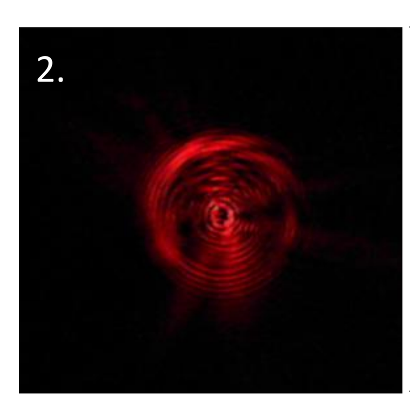
1.a., 1. b., 1. c. were obtained using SPPs in the regions C and D, which did not have additional support microstructures. In addition, their heights corresponded to a phase gap of 2π, 4π, and 6π.

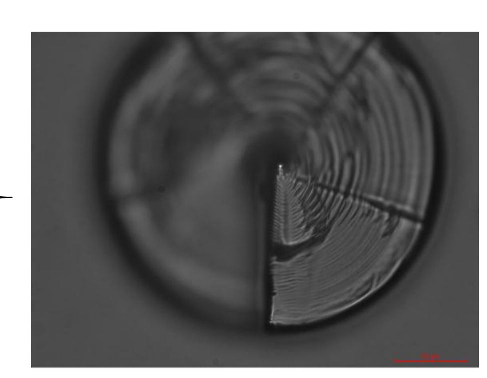
Topological charge:

$$2\pi l = \frac{2\pi}{\lambda}(n_{SPP} - 1)\, h$$

l – OAM order
n_{SPP} - refractive index
h - height of the spiral

The intensity profiles in the graphics clearly illustrates that there is less than 25% of the external ring optical power that falls within the ring. The outline is clear and focused, without major flaws.





Profiles similar to 2. were returned by SPPs in the regions A, B, D, showcasing that a uniform interior is essential for functional SPPs. The outline is not focused solely on a ring, and the interior is clearly lit.

Conclusions

The result yielded was that the interior design of SPPs obtained through TPP lithography would benefit from uniformity, radial lines being a diffraction maker. In addition to this, heights closer to 1,28 and 2,56 um resulted in cleaner OAM beam profiles. The density of interior arcs should be increased for a better voxel-voxel connection and for increased accuracy.

References

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