

Lithographic Phase Masks for Spatial Control of Squeezed Light

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Primary CNF Tools Used: Heidelberg MLA150 maskless aligner, Oxford 81 reactive ion etcher, AJA sputtering deposition system

Abstract:

We have fabricated low-loss silica-based phase plates to induce coherent phase control onto light. This is a preliminary step towards broader spatial-mode control of squeezed light.

Summary of Research:

In this project, we are developing a coherent control scheme for shaping quantum light. Recent work from our group points to the possibility that, by sending spatially phase-modulated light into a nonlinear medium such as a fiber, quantum statistical properties such as squeezing can be steered into different transverse modes supported by the fiber [1]. These modes can be filtered out by means of a phase plate at the output of the fiber. In particular, one wants to reflect the light exiting the fiber off a phase plate which imparts a phase profile corresponding to a higher-order mode, and then pass it through a lens and pinhole to filter out higher-order modes. A phase plate is created by etching variable thicknesses into silica to introduce position-dependent phases, hence the need for nanofabrication. The use of phase plates is important because it enables filtering out a particular higher-order mode with very little loss, as low as 5 or 10%. In contrast, if an SLM is used to do output filtering, although one has greater control over the output beam profile, the combined reflection and diffraction losses would be at best 15% but are often larger in practice. By keeping loss confined to 10%, it enables observing levels of squeezing up to 10 dB below the shot noise level.

The phase plates are created in house at Cornell NanoFacility by photolithographic etching of silica wafers. An example of phase plates that we have produced in order to isolate the first two higher-order modes of a GRIN fiber, and their superpositions, are shown in Fig. 1. In particular, by making SiO₂-Cr-photoresist trim-layer structures and wet/dry etching with Cr-etchant photolithography.

The next steps are now to perform the quantum light measurements: our new lab now has demonstrated capabilities to send spatially-phase-modulated femtosecond pulses through nonlinear fibers, and perform the needed mode-filtering with the phase plates. We are now working to demonstrate squeezing of controllable spatial modes.

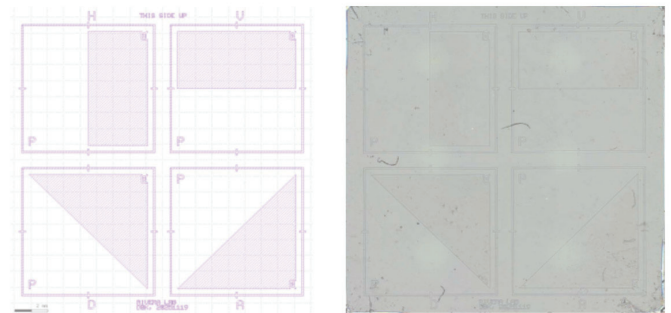


Figure 1: Preliminary results on phase plate nanofabrication. (Right) layout and (Left) microscope images of phase plates we have produced based on photolithography. The plates are designed such that the one half of the phase plate imparts a phase shift of π relative to the other for light with a wavelength of 1550 nm. The two plates on the top are designed for high efficiency filtering of the first two higher-order "dipolar" modes of a graded index multimode fiber with orientations in the x and y (top-bottom) directions respectively. The plates on the bottom isolate superpositions of the x- and y- oriented higher-order modes.

References:

- [1] Sloan, Jamison, et al. "Programmable control of the spatiotemporal quantum noise of light." arXiv preprint arXiv:2509.03482 (2025).

