Optical Ring Lattice Generation from a Microlaser

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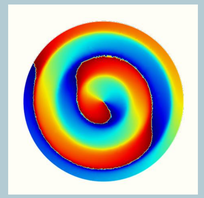
Background

- Laguerre-Gaussian (LG) light beams exhibit orbital angular momenta (OAM) associated with an azimuthal phase dependence $e^{il\theta}$, creating an optical vortex. The center of LG beams is a phase singularity, thereby exhibiting zero intensity field. (Allen at el., 1992)



Phase profile of an LG beam of azimuthal order $l = -1$

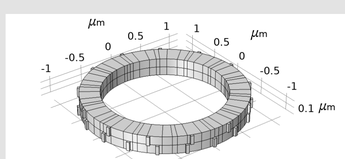
- Multiplexing two LG beams of different OAM orders l_1 and l_2 produces regions of constructive and destructive interference, generating an array of $|l_1 - l_2|$ phase singularities and an intensity-varying pattern of an optical ring lattice. (Franke-Arnold et al., 2007)
- It was previously demonstrated that OAM light can be generated with an on-chip microring resonator, using complex refractive index modulation to break the chiral symmetry and an angular grating to produce vortex emission. (Miao et al., 2016)

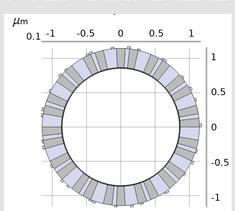
Objectives

- Modify the OAM microlaser to produce two multiplexed beams of different azimuthal orders.
- Simulate the generation of optical lattice from the on-chip device.

Methodology

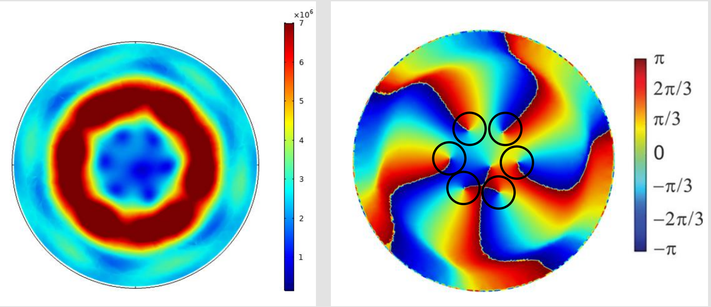
- A series of FEA simulations of a microlaser was systematically conducted using COMSOL Multiphysics software.
- The simulated device features complex refracting index modulations for unidirectional flow, and two rows of angular gratings on the outer sidewall of the resonator. Each row consists of a different number of equi-distant scatters to produce light beams of two distinct OAM orders from the same device.



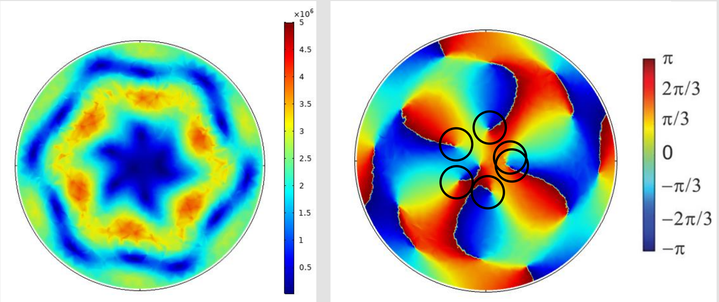


Results

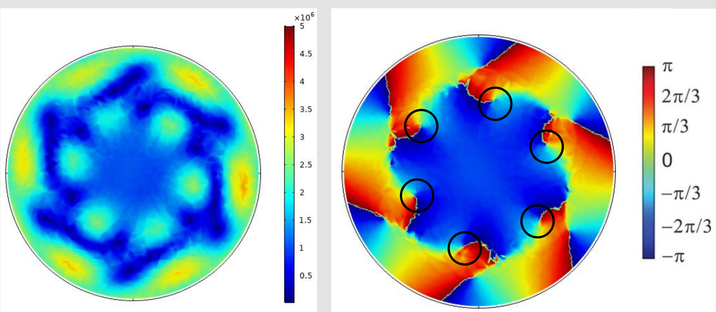
- An optical lattice emission containing a ring array of 6 singularities has been obtained from the device.



Simulated intensity and phase distributions with non-filtered spin featuring the combination of $l = 1$ and $l = -5$.



Simulated intensity and phase distributions with left-hand circular polarization ($E_x - iE_y$) featuring the combination of $l = 4$ and $l = -2$.



Simulated intensity and phase distributions with right-hand circular polarization ($E_x + iE_y$) featuring the combination of $l = 6$ and $l = 0$.

Conclusion

- This work demonstrates the potential of generating optical ring lattices with an on-chip microlaser by multiplexing two OAM beams of different azimuthal orders.
- By changing the number of sidewall scatters the number of phase singularities in a ring can be manipulated. Resonant frequency and the order of the circulating whispering-gallery mode can also be adjusted by controlling geometry and the number of refractive index gratings. (Miao et al., 2016)
- Such an emission exhibits structured light with a unique intensity pattern, which can be applied, for instance, for confinement and manipulation of ultracold atoms in condensed-matter physics simulations. (Greiner & Fölling, 2008)
- Another potential application of an optical ring lattice is trapping and rotation of microparticles (MacDonald at el., 2002)

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References

- L. Allen, M. W. Beijersbergen, R. J. C. Spreeuw, J. P. Woerdman, Phys. Rev. A 45, 8185–8189 (1992).
- S. Franke-Arnold et al., Optics Express 15.14, 8619 (2007)
- M. Greiner, S. Fölling, Nature 453, 736–738 (2008)
- M. P. MacDonald et al., Science 296, 1101-1103 (2002)
- P. Miao et al., Science 353, 464–467 (2016).