Metasurface-based spin-selective optical cavity

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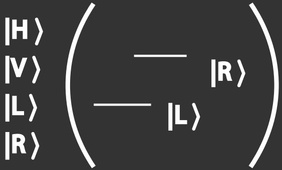
Outline

- Motivation
- Introduction to the problem
- Proposed cavity design
- Metasurface optics
- Conclusion

Goals and motivation

We seek a cavity which **differentiates between left- and right-handed light** within the cavity volume.



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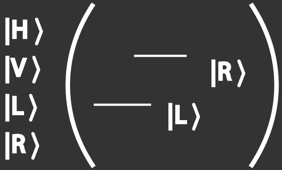

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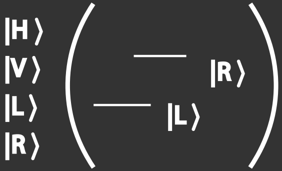

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- quantum information processing

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where Z_1, Z_2 are the impedences of air and the conductor respectively, and $Z_1 \gg |Z_2|$.

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Hence, **$\mathbf{E}_R$ gains a uniform π phase shift and is "reflected" with no preferred transverse axis**.

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In particular, for circularly polarized incident light,

$$|R\rangle \to |L\rangle \,;\; |L\rangle \to |R\rangle$$

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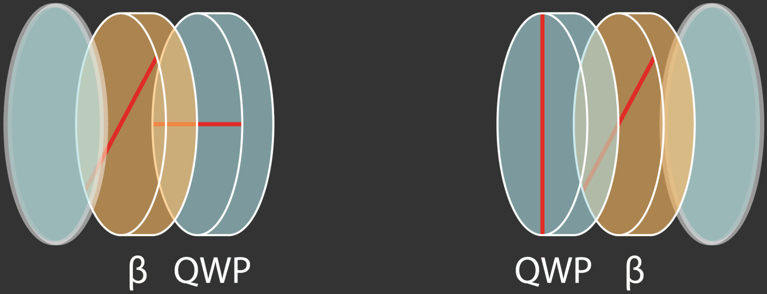
It is useful to preserve one handedness in our cavity: hence, we may use a quarter wave plate preceding the mirror to "preserve" spin after reflection.

Proposed cavity design

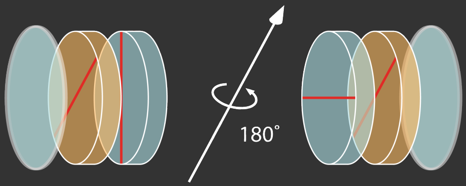
We use birefringent materials to impose polarization-dependent path lengths.



Proposed cavity design

Some nice symmetries

Rotation:



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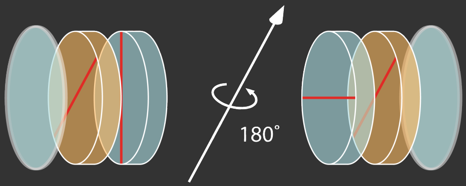
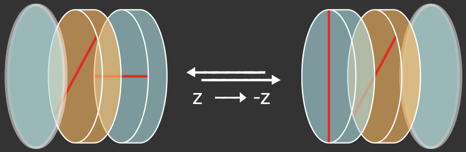


Reflection:



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(iv) $\hat{U}(z_1)\hat{U}(z_2) = \hat{U}(z_1 + z_2)$.

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For an orthonormal polarization basis $\hat{\imath}$, $\hat{\jmath}$, denote

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Then we may define the expected *local* rotation operator,

$$R(\theta) := \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix}.$$

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Hence we define propagation in some birefringent region aligned with our polarization basis

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and the cavity roundtrip operator follows:

$$\hat{T} = \hat{Q}(\alpha + \delta, \alpha) R\left(\frac{\pi}{4}\right) \hat{Q}(2\beta, 0) R^\dagger \left(\frac{\pi}{4}\right) \dots$$
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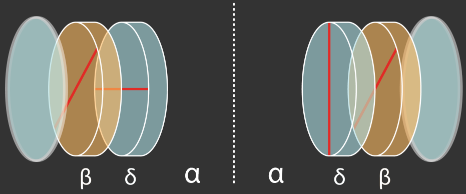

Proposed cavity design

$$\hat{T} = \frac{1}{2}\left(\hat{U}(4\alpha + 2\delta) + \hat{U}(4\alpha + 4\beta + 2\delta)\right) I_2 + \frac{1}{2}\hat{U}(4\alpha)\left(\hat{U}(4\beta) - 1\right)\begin{pmatrix} 0 & \hat{U}(3\delta) \\ \hat{U}(\delta) & 0 \end{pmatrix}$$

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Hence, we find (normalized) eigenvectors of

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with eigenvalues of

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that is,

$$\hat{U}(4\alpha + 4\beta + 2\delta), \quad \hat{U}(4\alpha + 2\delta)$$

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If we allow birefringence:

Half wave plate:

$$\phi_x = \pi;\ \phi_y = 0$$

Quarter wave plate:

$$\phi_x = \frac{\pi}{2};\ \phi_y = 0$$

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Arbabi *et al.* implement arrays of **elliptical, subwavelength high-contrast posts to exhibit birefringence**.

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RCWA is used to determine phase and amplitude for a given parameter set.

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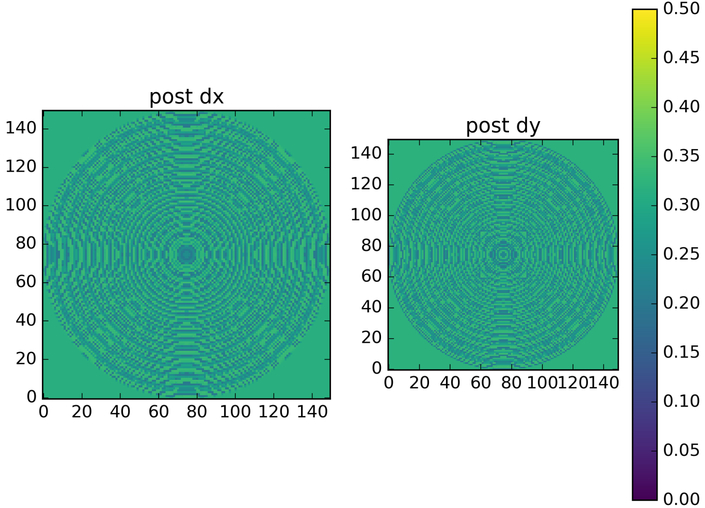

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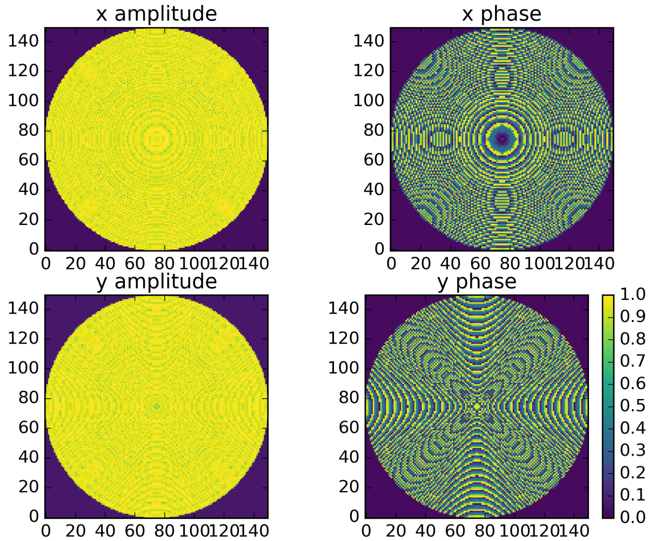

Designing metasurface-based optics

Silicon nitride-based metasurfaces

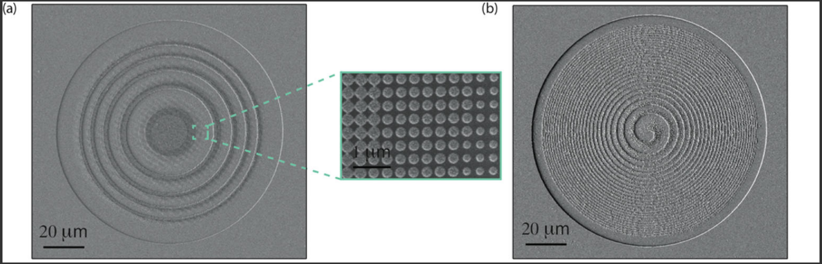

Figure: low-contrast metasurface optics (SEM).[3] (a) lens, (b) vortex beam generator.

[3] Zhan *et al.*. Low-contrast dielectric metasurface optics. *ACS Photonics.* (2015).

Further work

- Complete characterization of cavity modes
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  - Explicit definition of propagation operator and mode functions

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  - Transverse modes (cavity as system of coupled harmonic oscillators)
  - Explicit definition of propagation operator and mode functions
- Simulate elements, cavity with FDTD

Acknowledgements

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Thank you to the INT REU directors and administrators for all of their time and attention in support of this summer.