Transporting the Optical Chirality through the Dynamical Barriers in Optical Microcavities

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1. Journal

- Since 2007
- Impact factor: 8(2014)
- Citation ranking: 4/94(optics)
- Hans A. Bachor founded

https://onlinelibrary.wiley.com/page/journal/18638899/homepage/productinformation.html

1. Author

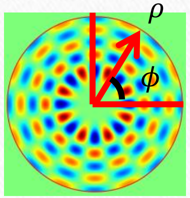
- Name: Shuai Liu
- Degree: Ph.D. in Physical Electronics(Harbin Institute of Technology)
- Major: On-chip optical microcavity, optical interconnection, and optical sensing

- Hui Cao, Jan wiersig, Jinkyu Yang…

https://quantum.lab.arizona.edu/content/4

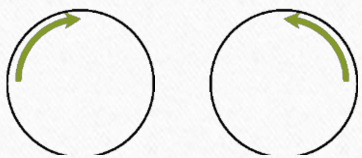
2. What is optical (spatial)chirality?

⚠ Not related with “chiral media” or polarization



$$\psi = \sum_{m=-\infty}^{\infty} \alpha_m J_m(nk\rho)\exp(im\phi)$$

cw　　ccw



$e^{-i\phi}$　　$e^{i\phi}$

$m < 0$　　$m > 0$

$$\sum_{m=-\infty}^{-1} \circlearrowright < \sum_{m=1}^{\infty} \circlearrowleft \Rightarrow \text{CCW mode}$$

$$J_{-m} = (-1)^m J_m$$

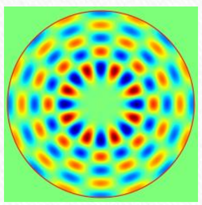
Mirror symmetry ⇔Chiral symmetry

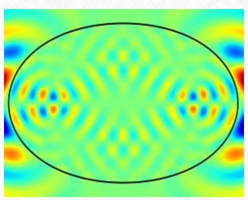
$$\because \rho(-\phi) = \rho(\phi) \Leftrightarrow \psi(\rho,\phi) = \pm\psi(\rho,-\phi) \Rightarrow \alpha_{-m}(-1)^m = \pm\alpha_m \Rightarrow |\alpha_{-m}| = |\alpha_m|$$

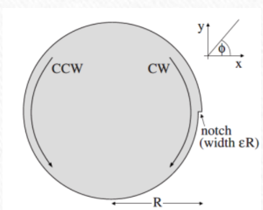
$\mathrm{sgn}(\alpha_m)\mathrm{sgn}(\alpha_{-m}) = \pm 1 \Rightarrow (nearly)$degenerate pair (reciprocity)

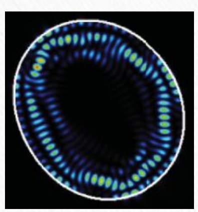
J. Wiersig et al, Phys. Rev. A 2011, 84, 023845.

2. What is optical (spatial)chirality?





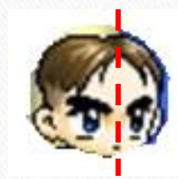




Phys. Rev. A 2008, 78 Phys. Rev. A 2011, 84

Chirality

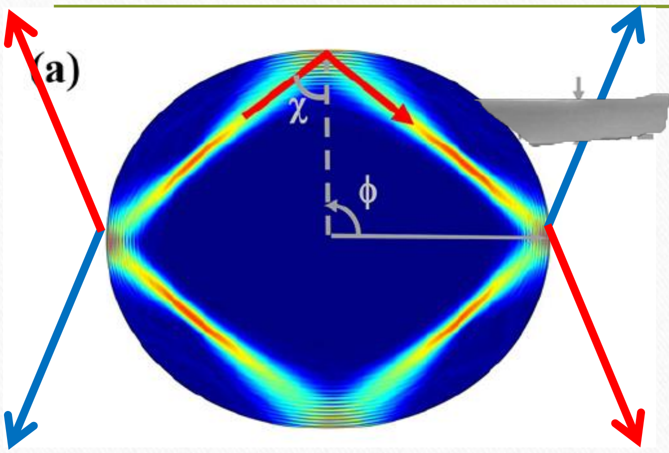
Rotational symmetry $|\alpha_m| = |\alpha_{-m}|$

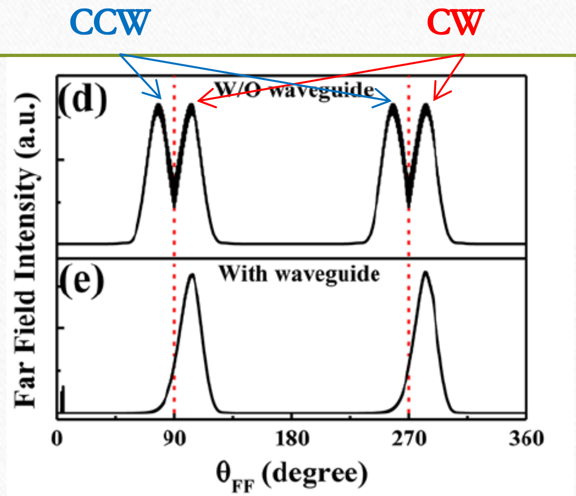


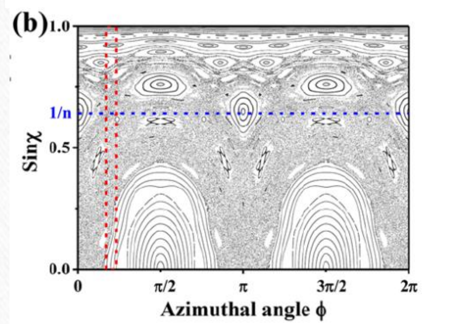
Mirror symmetry $|\alpha_m| = |\alpha_{-m}|$

No mirror symmetry $|\alpha_m| \neq |\alpha_{-m}|$

3. WCQM(Waveguide Connected Quadruple Microdisk)







$\rho(\phi) = R(1 + \epsilon \cos 2\phi)$
$R = 20\ \mu\text{m}$
$\epsilon = 0.08$
$\phi_{waveguide} = 0.2\pi\ \text{rad}$
$w = 4\ \mu\text{m}$

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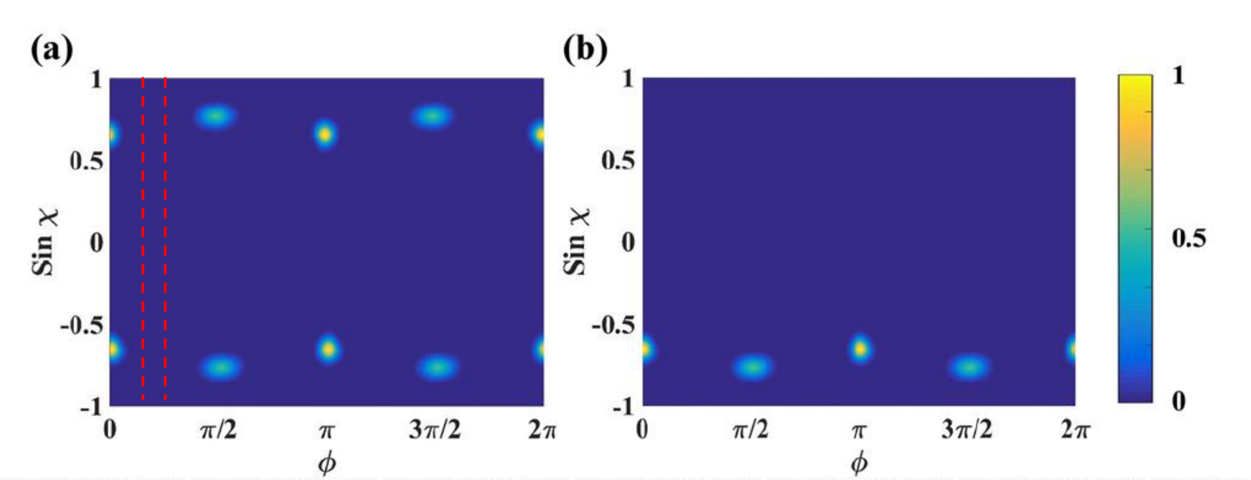
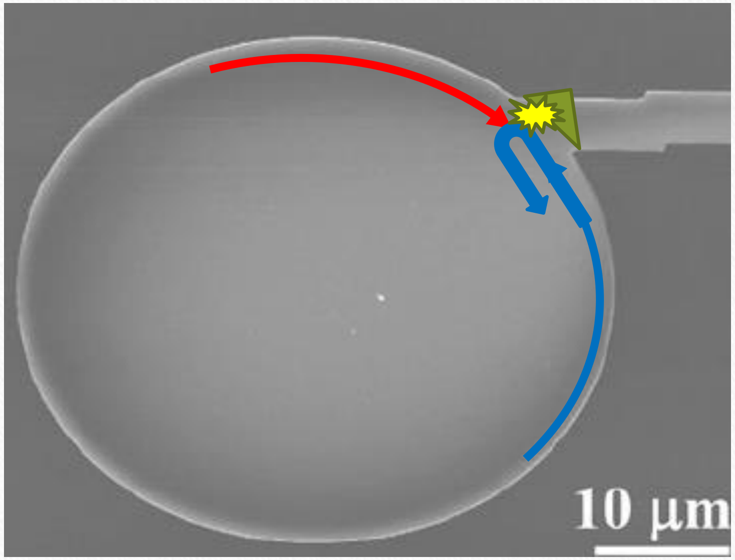


<W/O channeling guide> <With channeling guide>

3. WCQM(Waveguide Connected Quadruple Microdisk)



$CW \rightarrow CCW$ probability: A

$CCW \rightarrow CW$ probability: B

$*$ chirality α

$$\alpha = 1 - \frac{\min(A,B)}{\max(A,B)}$$

4. Theory

- 4×4 non-Hermitian Hamiltonian

$$H = \begin{vmatrix} \Omega_{\text{is}} & V & 0 & 0 \\ V & \Omega_{\text{ch}} & A & 0 \\ 0 & B & \Omega_{\text{ch}} & V \\ 0 & 0 & V & \Omega_{\text{is}} \end{vmatrix}$$

$island\ e^{im\phi}$
$chaotic\ e^{im\phi}$
$chaotic\ e^{-im\phi}$
$island\ e^{-im\phi}$

$$^{*}\circlearrowleft_{island} = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

- V: regular to chaotic(=chaotic to regular) tunneling rate
  A: coupling from CW to CCW components
  B: coupling from CCW to CW components
  Ω_{is},Ω_{ch}:uncoupled stable and chaotic mode frequencies
- Eigenvalues $\Omega_{\pm,\sigma} = \frac{\Omega_{is}+\Omega_{ch}+\sigma\sqrt{AB}}{2} \pm \sqrt{V^2 + \left(\frac{\Omega_{is}-\Omega_{ch}-\sigma\sqrt{AB}}{2}\right)^2}$
- Eigenvectors $\psi_{\pm,\sigma} = \begin{pmatrix} \sqrt{A} \\ \Delta_{\pm,\sigma}\sqrt{A} \\ \sigma\Delta_{\pm,\sigma}\sqrt{B} \\ \sigma\sqrt{B} \end{pmatrix}$ where, $\Delta_{\pm,\sigma} = \frac{\Omega_{\pm,\sigma}-\Omega_{is}}{V}$.
- $\rightarrow \alpha = 1 - \frac{\min[(1+\Delta_{\pm,\sigma}^2)A,(1+\Delta_{\pm,\sigma}^2)B]}{\max[(1+\Delta_{\pm,\sigma}^2)A,(1+\Delta_{\pm,\sigma}^2)B]} = 1 - \frac{\min(A,B)}{\max(A,B)}$

3. WCQM(Waveguide Connected Quadruple Microdisk)