Optical Chirality in the Stacked 3D Nanoring/Split Ring

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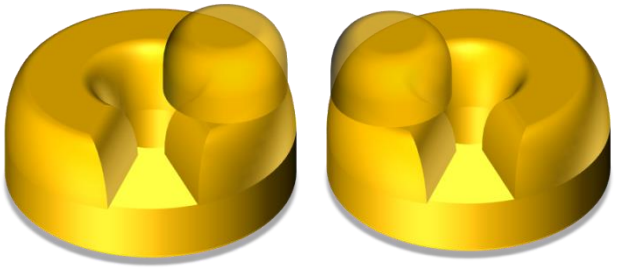
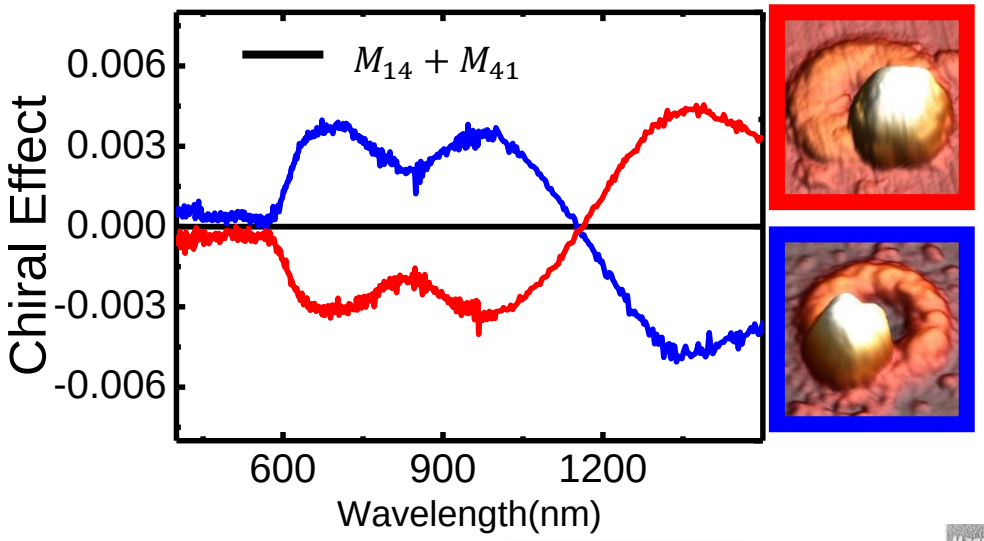
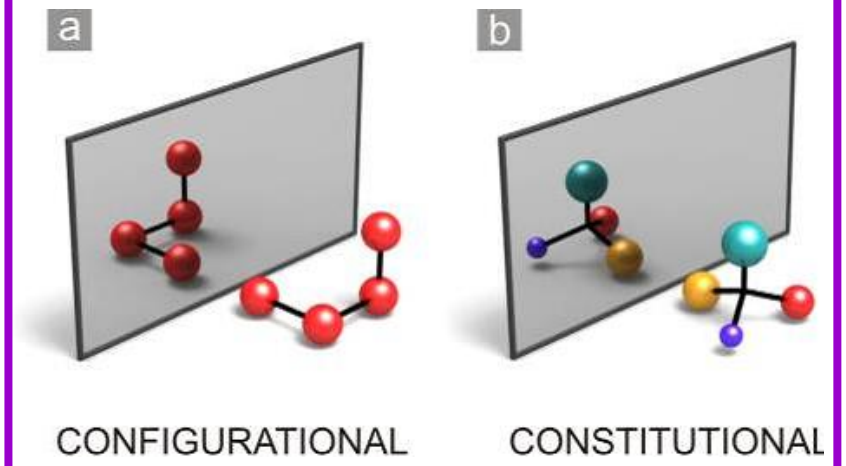
Outline

- 3D Chiral Stacked Ring/Split Ring
- Mueller Matrix for Chiral Effect
- Optical Chirality in the 3D Nanostructure

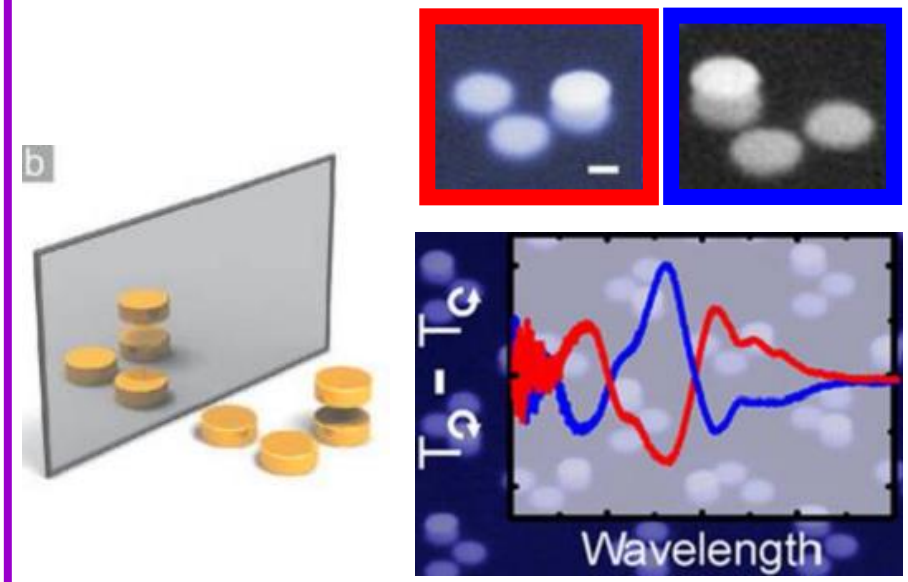




3D Chiral Stacked Ring/Split Ring



Chiral : Mirror Image ≠ Itself



Our Purpose:

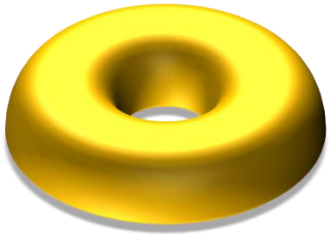
Chiral Effect in **Visible and NIR**

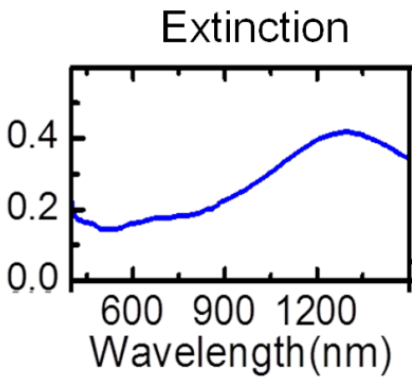
Future: **Magnetism + Chirality**

M. Hentschel, et al, Nano Lett. **12**, 2542.

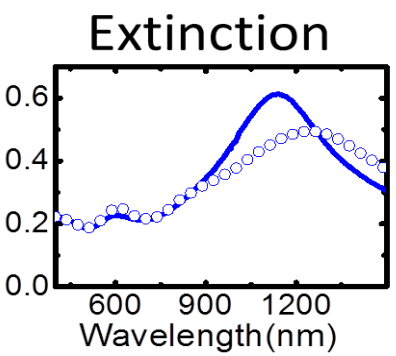
3D Chiral Stacked Ring/Split Ring

Non-chiral

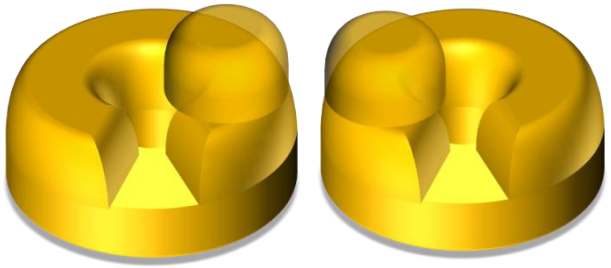


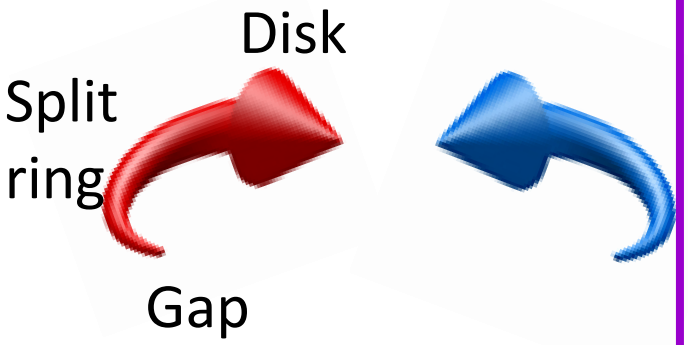


Non-chiral Optical Anisotropy

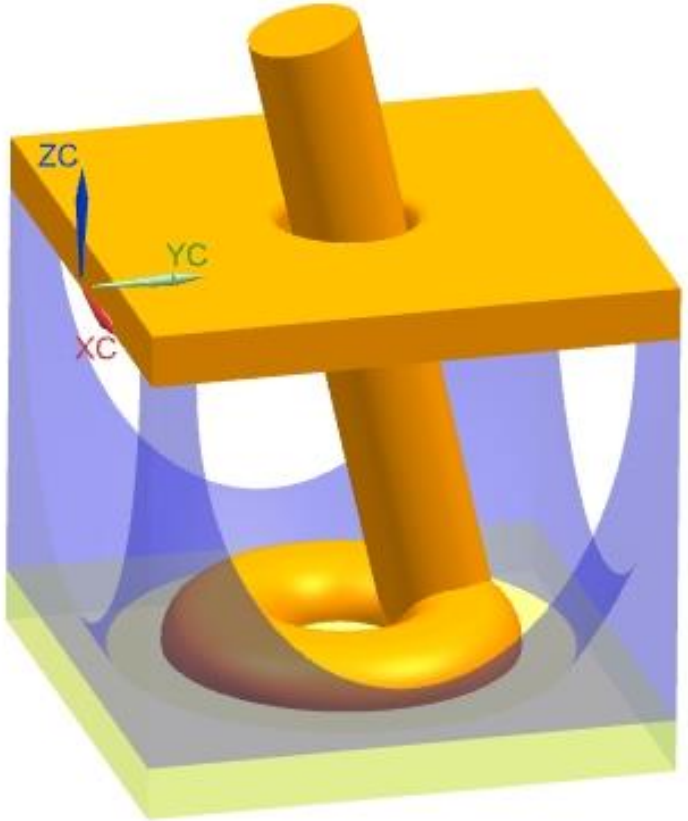


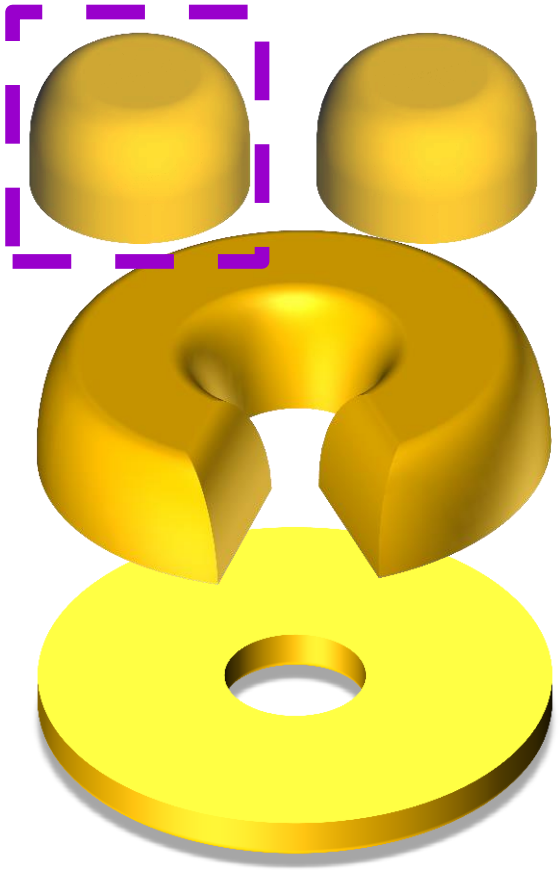
Chiral





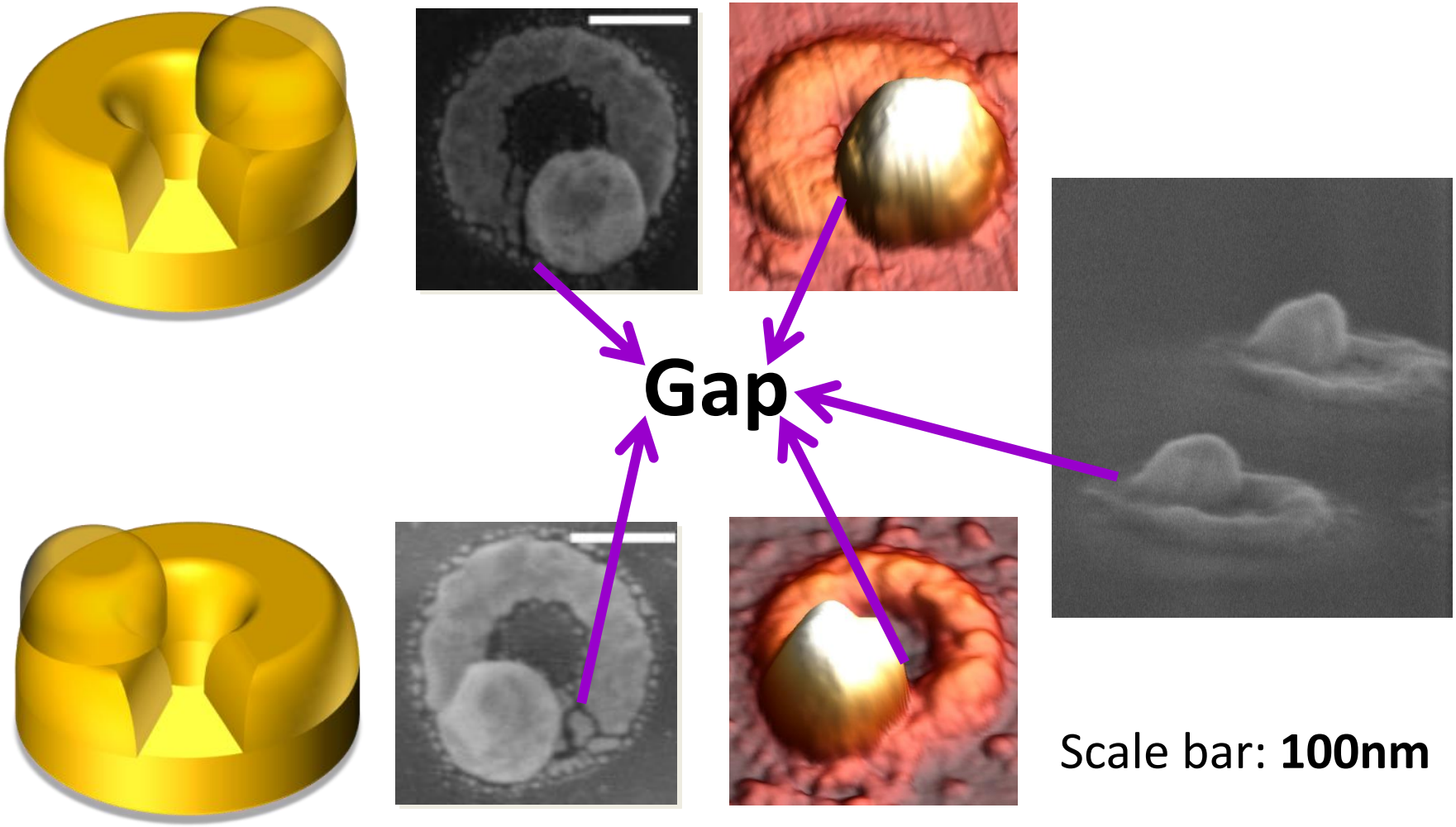
3D Chiral Stacked Ring/Split Ring



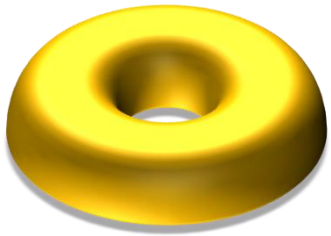
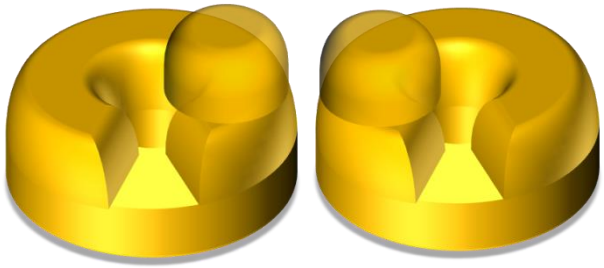


Hole-mask
Colloidal Lithography

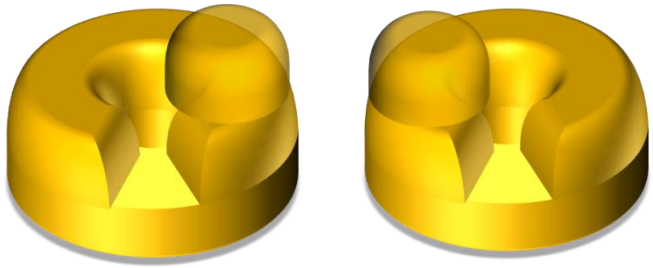
3D Chiral Stacked Ring/Split Ring



Mueller Matrix for Chiral Effect

	In-plane Isotropy Non-chiral	Optical Anisotropy Non-chiral	Optical Anisotropy Chiral
			
Jones Matrix	$\begin{pmatrix} t_{xx} & 0 \\ 0 & t_{xx} \end{pmatrix}$	$\begin{pmatrix} t_{xx} & 0 \\ 0 & t_{yy} \end{pmatrix}$	$\begin{pmatrix} t_{xx} & t_{xy} \\ t_{yx} & t_{yy} \end{pmatrix}$ $t_{xy} \neq t_{yx}$

Mueller Matrix for Chiral Effect



$$t_{xy} \neq t_{yx}$$

$$\begin{pmatrix} t_{xx} & t_{xy} \\ t_{yx} & t_{yy} \end{pmatrix} \Rightarrow \begin{pmatrix} t_{xx} & t_{sy} + t_a \\ t_{sy} - t_a & t_{yy} \end{pmatrix}$$

"Optical Anisotropy" $t_{sy} = \frac{1}{2}(t_{xy} + t_{yx})$

Chiral effect $t_a = \frac{1}{2}(t_{xy} - t_{yx})$

How to obtain???

Mueller Matrix for Chiral Effect

Jones Matrix

$$\begin{pmatrix} t_{xx} & t_{sy}+t_a \\ t_{sy}-t_a & t_{yy} \end{pmatrix}$$

Mueller Matrix

$$\begin{pmatrix} M_{11} & M_{12} & M_{13} & M_{14} \\ M_{21} & M_{22} & M_{23} & M_{24} \\ M_{31} & M_{32} & M_{33} & M_{34} \\ M_{41} & M_{42} & M_{43} & M_{44} \end{pmatrix}$$

$$M_{14} = -Im\left((t_{xx}^* - t_{yy}^*)t_{sy}\right) - Im\left((t_{xx}^* + t_{yy}^*)t_a\right)$$

$$M_{41} = Im\left((t_{xx}^* - t_{yy}^*)t_{sy}\right) - Im\left((t_{xx}^* + t_{yy}^*)t_a\right)$$

H. Fujiwara, *Spectroscopic Ellipsometry: Principles and Applications* (John Wiley & Sons, 2007)

Mueller Matrix for Chiral Effect

CD:
Circular Dichroism

$$\sim \frac{I_{LCP} - I_{RCP}}{I_{LCP} + I_{RCP}}$$

$$M_{14} = -Im\left((t_{xx}^* - t_{yy}^*)t_{sy}\right) - Im\left((t_{xx}^* + t_{yy}^*)t_a\right)$$

$$M_{41} = \quad Im\left((t_{xx}^* - t_{yy}^*)t_{sy}\right) - Im\left((t_{xx}^* + t_{yy}^*)t_a\right)$$

$$M_{14} + M_{41} = -2Im\left((t_{xx}^* + t_{yy}^*)\boldsymbol{t_a}\right) \sim \frac{I_{LCP} - I_{RCP}}{I_{LCP} + I_{RCP}}$$

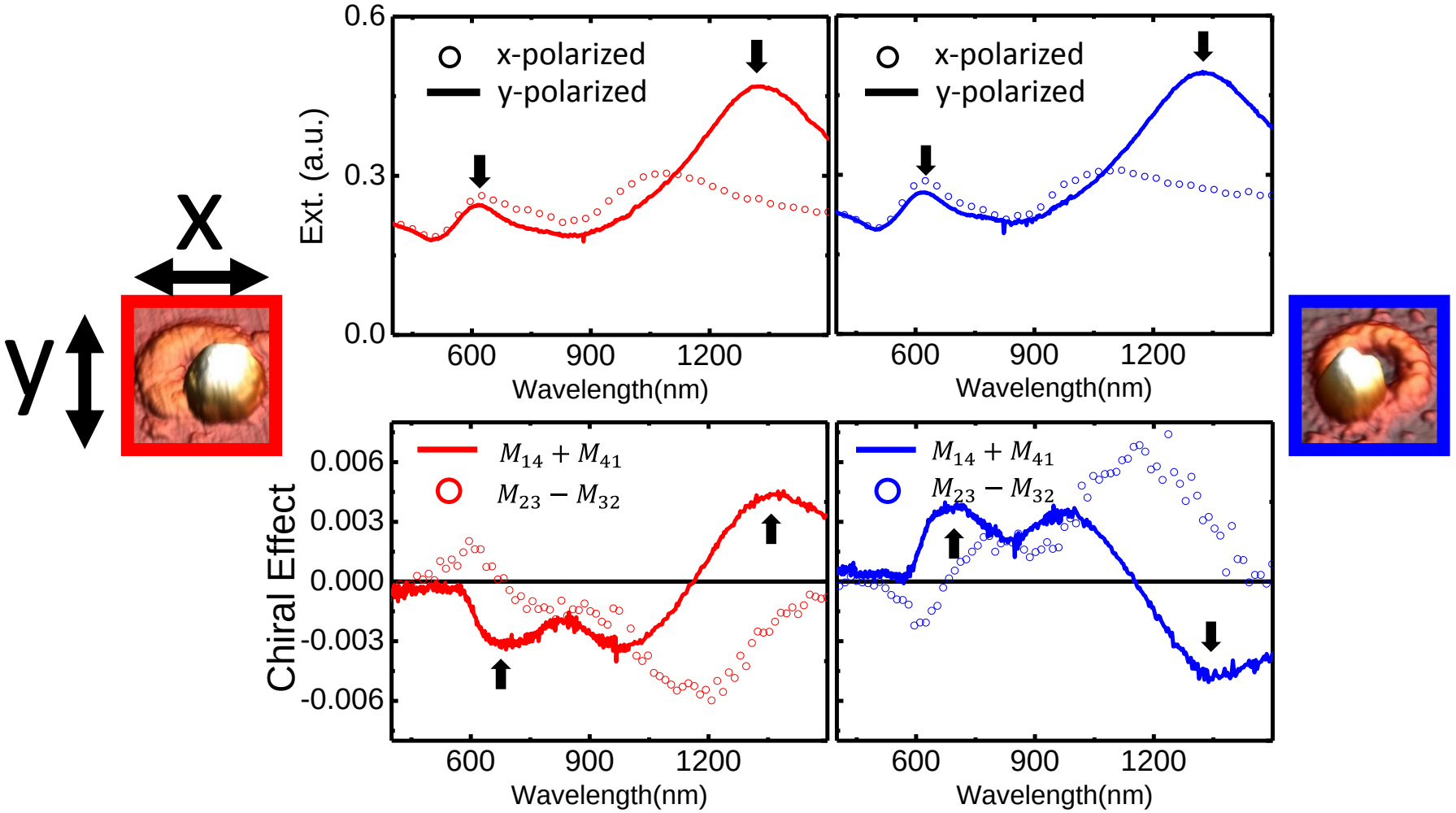
Optical Activity

$$M_{23} = \quad Re\left((t_{xx} - t_{yy})t_{sy}^*\right) + Re\left((t_{xx} + t_{yy})t_a^*\right)$$

$$M_{32} = \quad Re\left((t_{xx} - t_{yy})t_{sy}^*\right) - Re\left((t_{xx} + t_{yy})t_a^*\right)$$

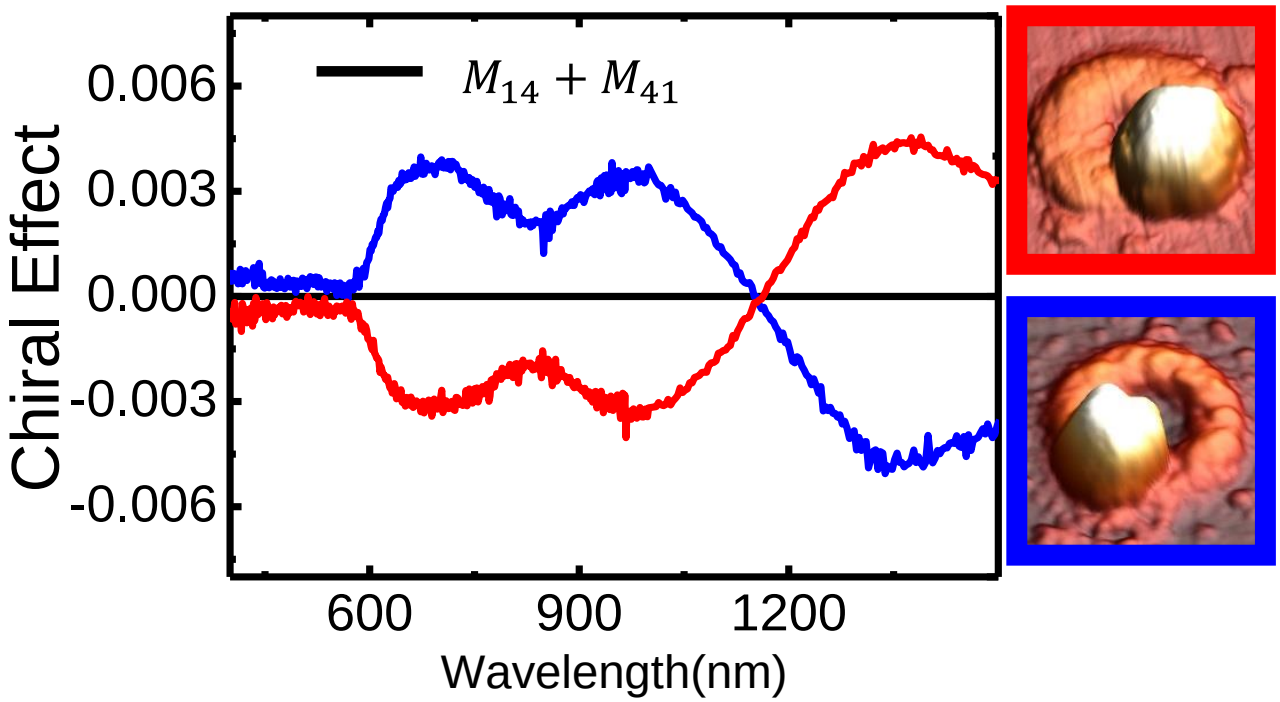
$$M_{23} - M_{32} = 2Re\left((t_{xx} + t_{yy})\boldsymbol{t_a^*}\right)$$

Chiral Effects in the 3D Nanostructure



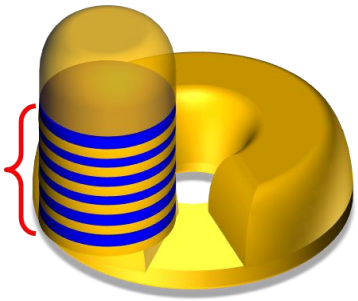
Chiral Effects in the 3D Nanostructure

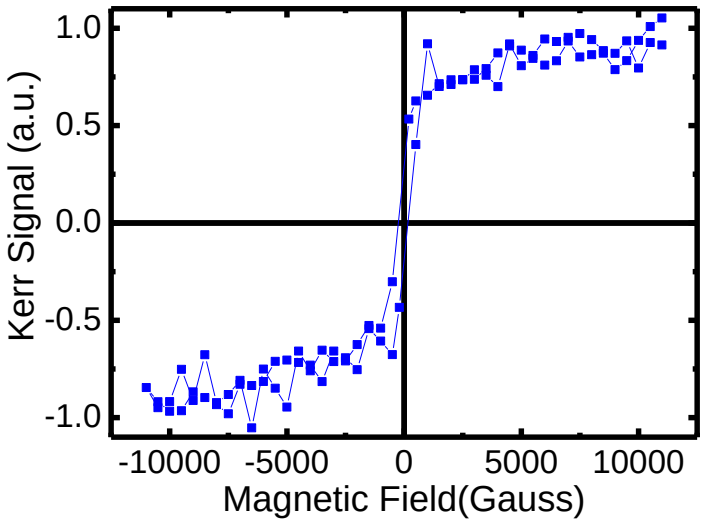
$$CD=\frac{1}{2}(M_{14}+M_{41})=\frac{I_{LCP}-I_{RCP}}{I_{LCP}+I_{RCP}}$$



Magnetism + Chirality ?

(1.5nm Co
+
2.5nm Au) ×12

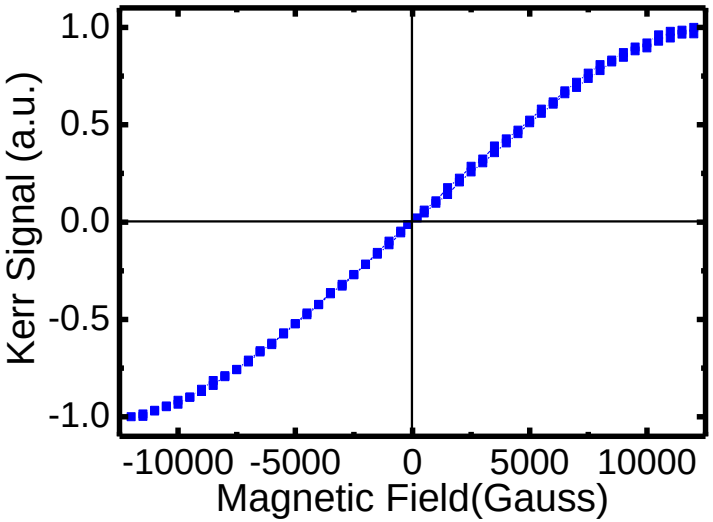




Out-of-plane loop

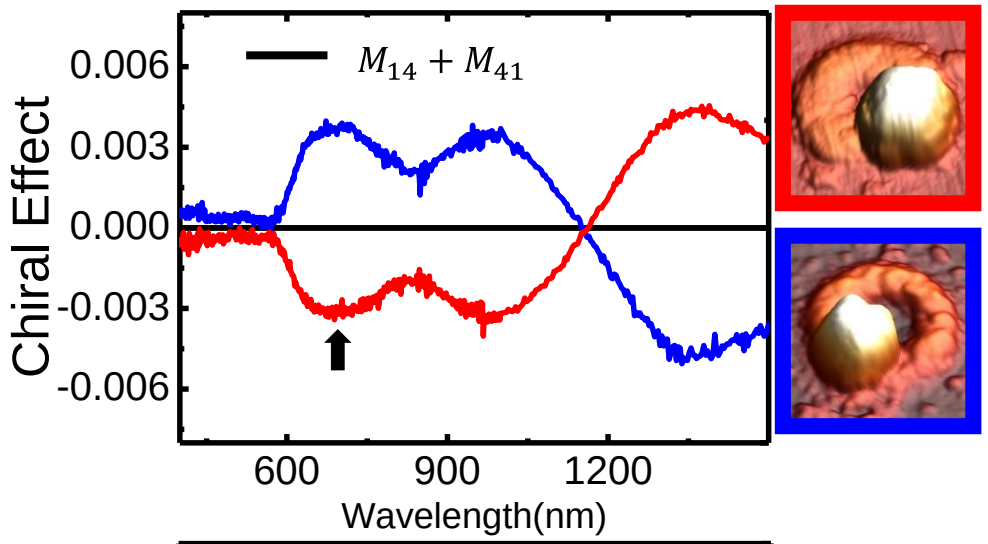
Perpendicular Magnetic Anisotropy

6nm Co

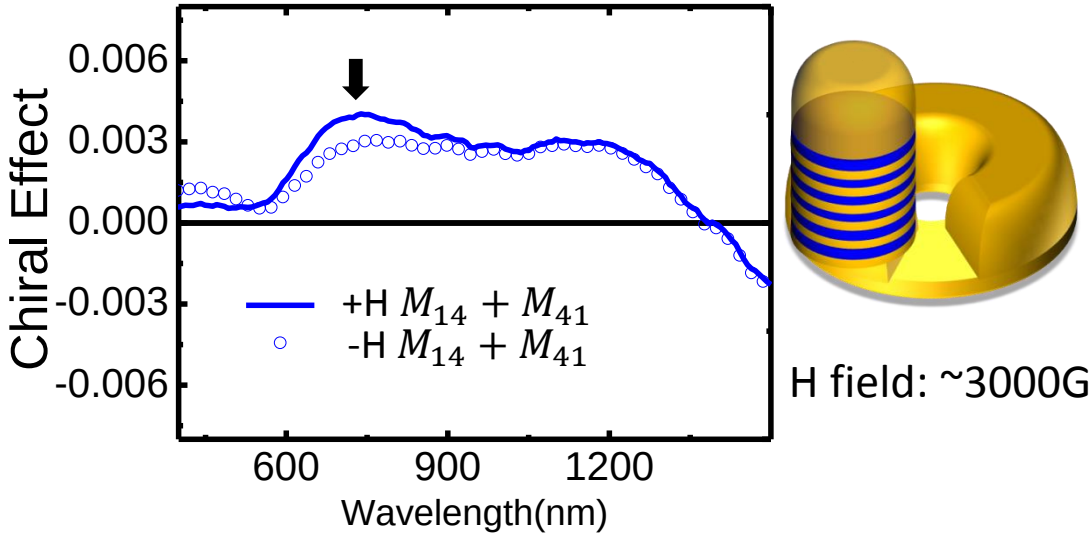


Magnetism + Chirality ?

No *Co*



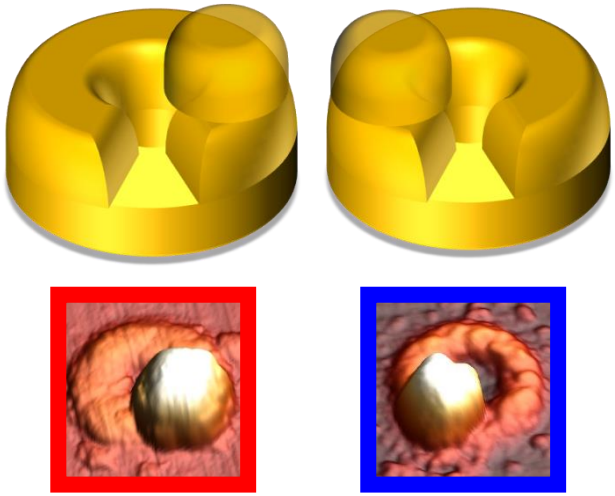
With *Co*
±H



H field: ~3000Gauss

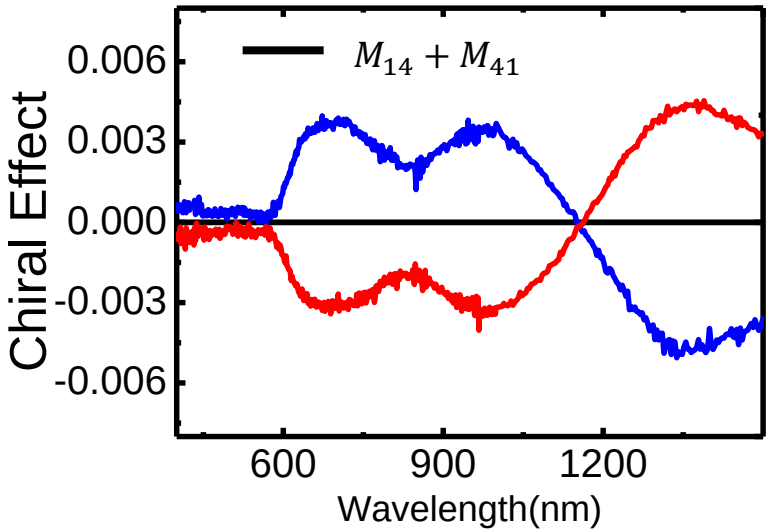
Conclusions

3D Chiral
Stacked Ring/Split Ring



+

Mueller Matrix



Thank you!

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Thank you!