

# Interaction between colloidal particles in chiral nematic liquid crystals

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University of Colorado  
Boulder



Institute for Complex  
Adaptive Matter



# Outlines

## 1. Introduction:

1. Defects structure around beads in Nematic Liquid Crystals.
2. Defects structure around beads in Chiral Nematic Liquid Crystals.

## 2. Experimental set up

1. Holographic Optical Tweezers (HOT)
2. Multi-mode Fluorescence Optical Microscopy

## 3. Results & Discussion

1. Effect of homeotropic confinement and D/P ratio  $0.5 \sim 1.0$
2. Investigation of defects structure around particles by TPL
3. Interaction between particles decorated with defect structure.
4. Assembly of particles decorated with defect structure.
5. Creation of Defect structure around particles with LG beams.

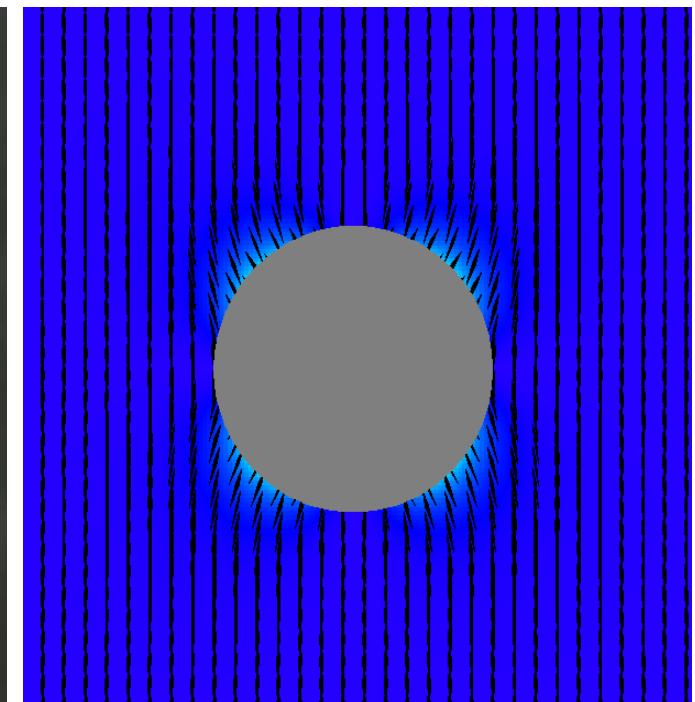
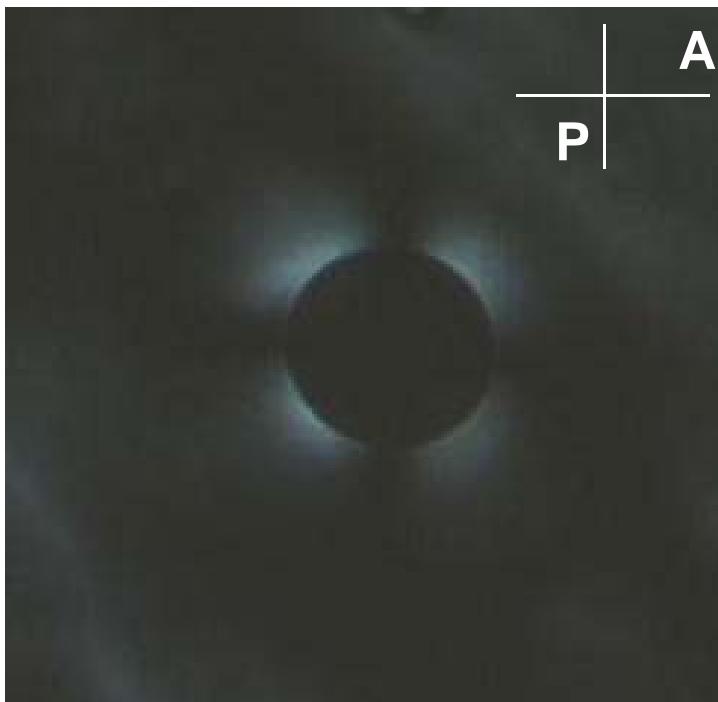
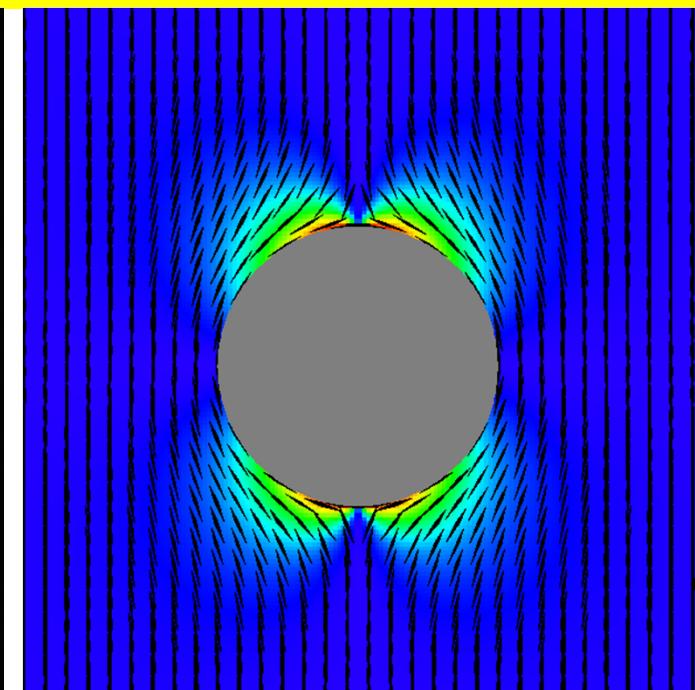
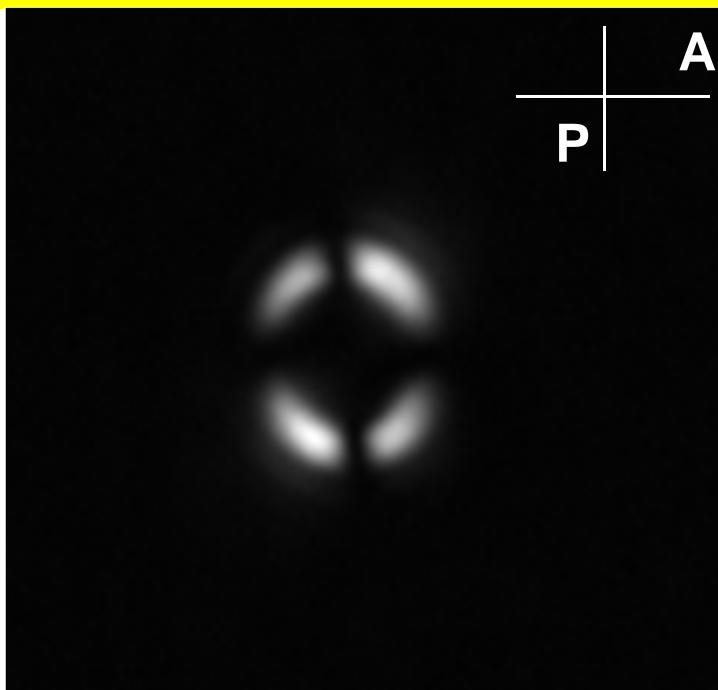
## 4. Conclusions

# Defect structures around beads in Nematics

## Tangential anchoring

Two surface point defects  
(boojums) at poles

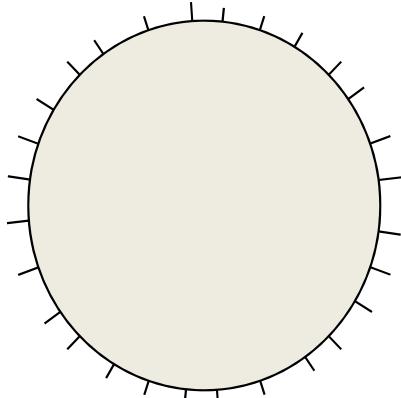
$$\hat{\mathbf{n}}_0$$



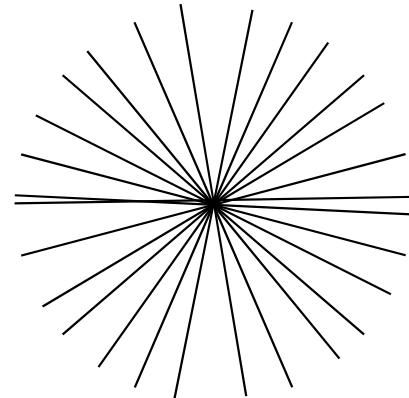
## Weak homeotropic surface anchoring

# Defect structure around beads in Nematics

Homeotropic anchoring

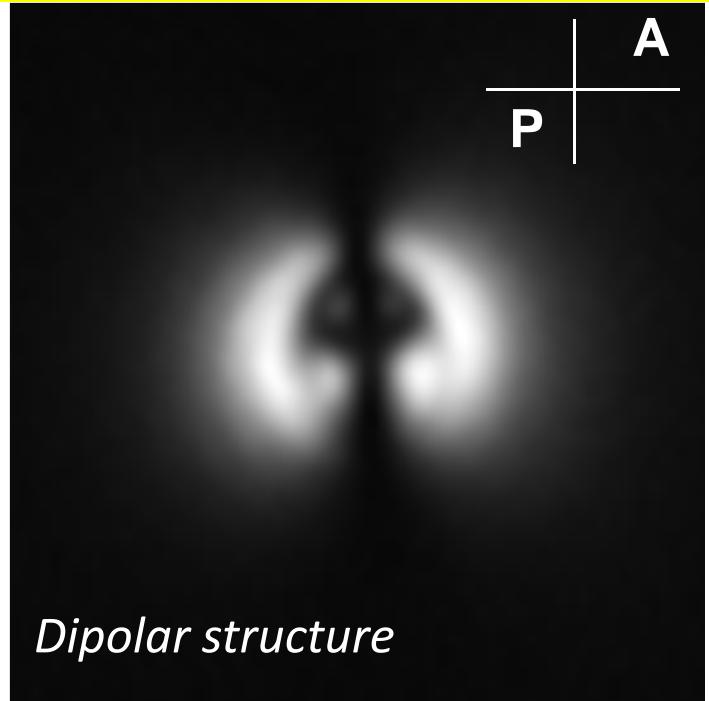
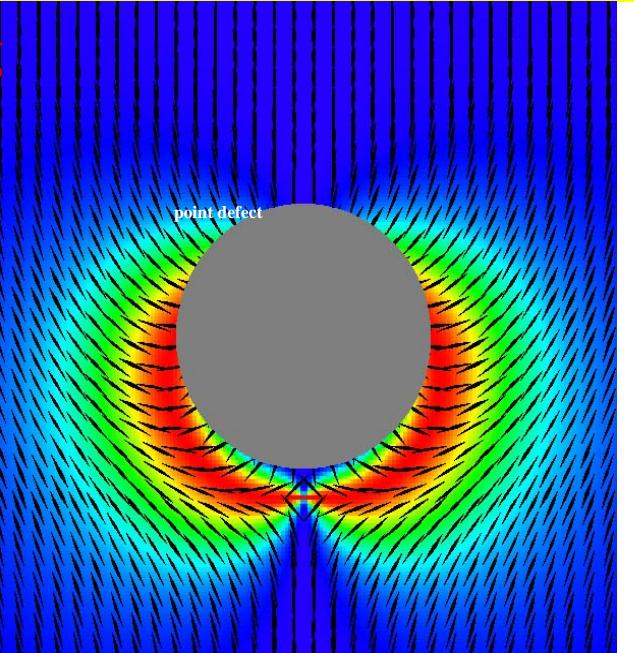


Equivalent to:

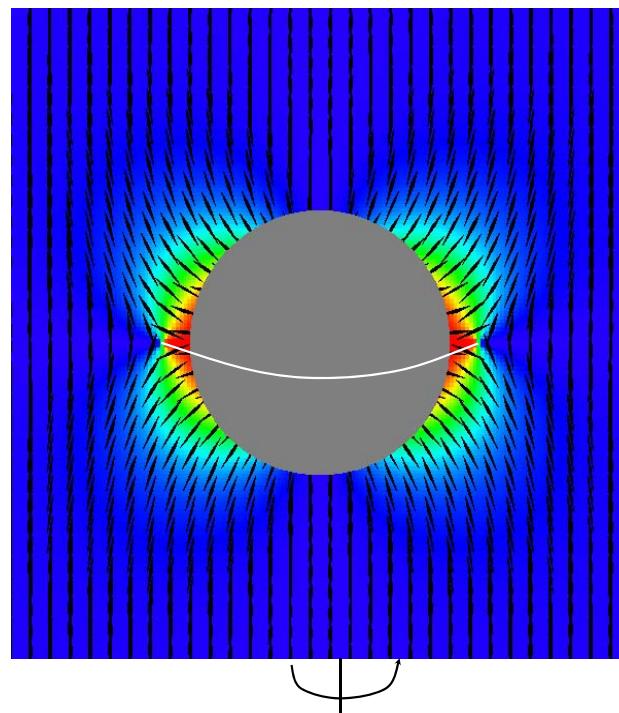


Disclination ring  
 $s=-1/2$  around bead

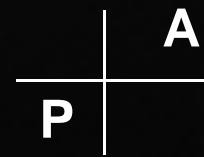
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Dipolar structure

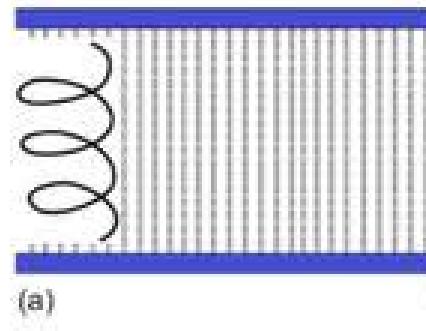


Quadrupolar “Saturn Ring” structure

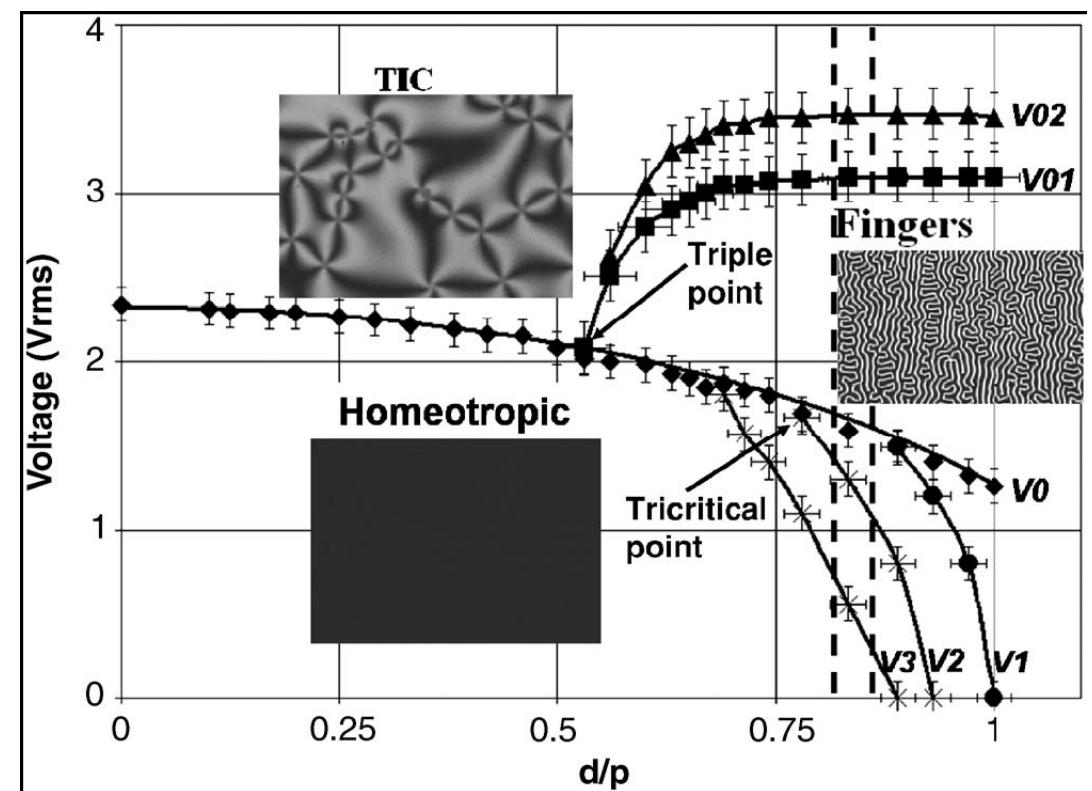


# What will be defect structure around beads in Cholesteric LC?

1. It will depend upon confinement and alignment Boundary condition?
2. Confinement will depend upon D/P ratio?

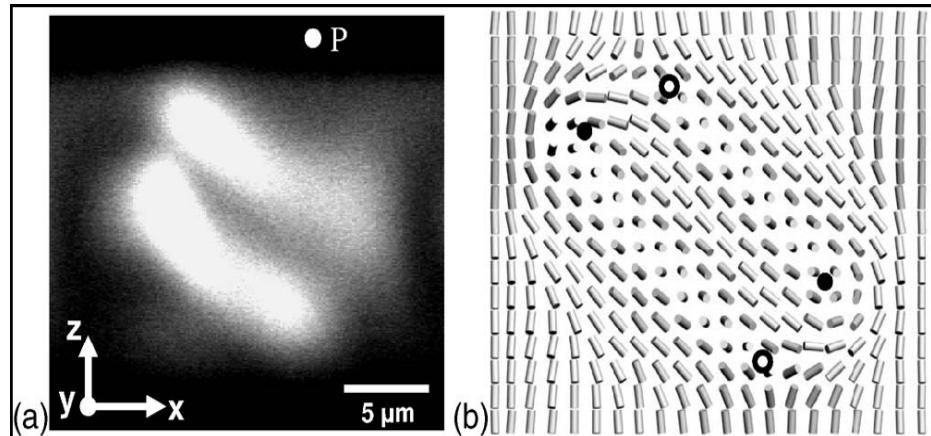


P. Ribiere, S. Pirkl, and P. Oswald,  
Phys. Rev. A **44**, 8198  
1991.

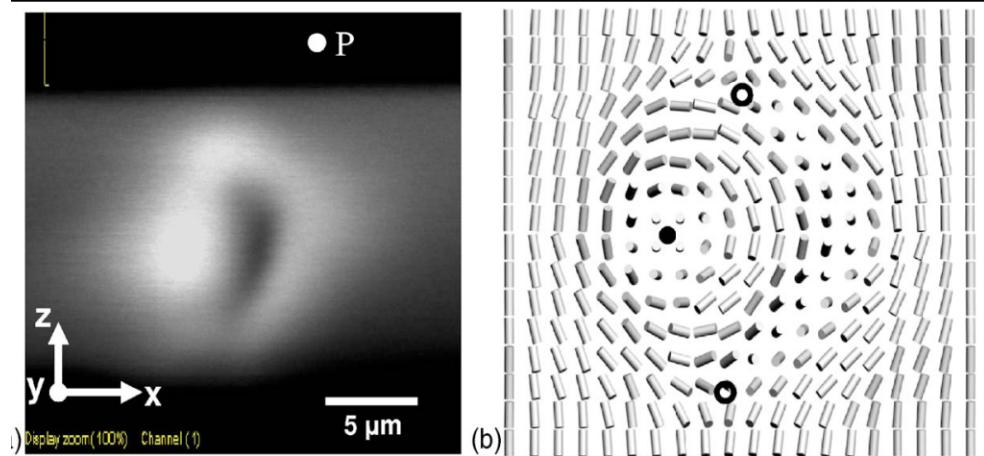


# Twisted structure in homeotropic cell

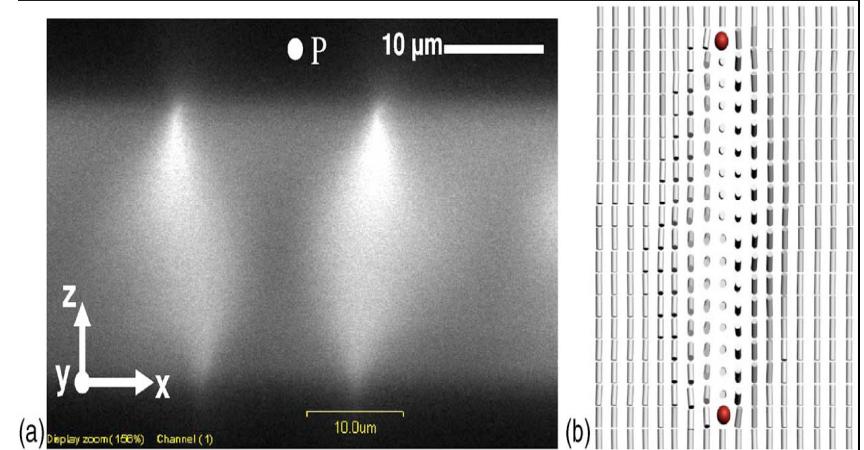
CF1,  $\bullet\lambda^{+1/2}\circ\lambda^{-1/2}$



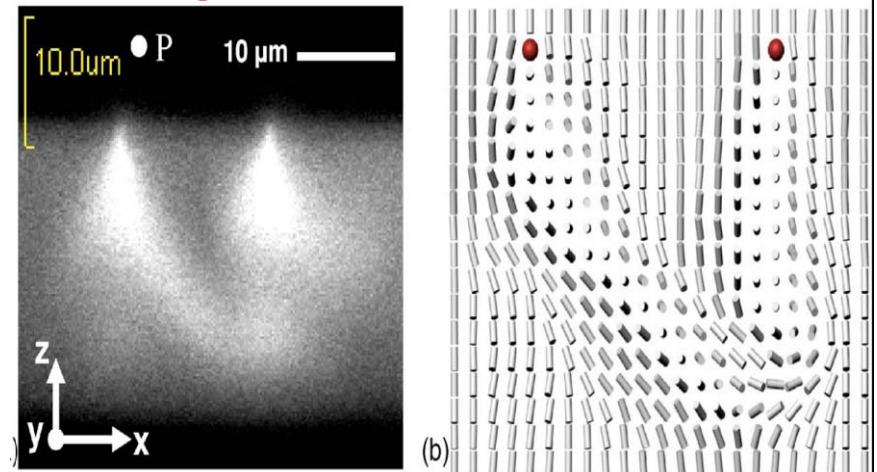
CF2,  $\bullet\lambda^{+1}\circ\lambda^{-1/2}$



CF3, Singular



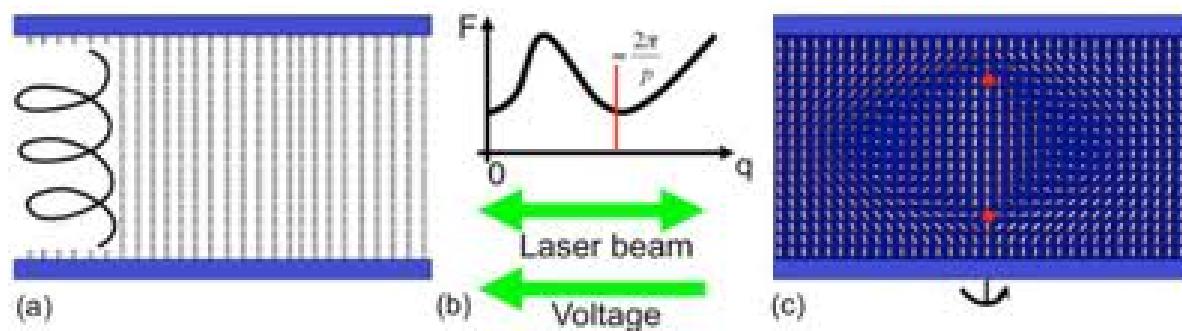
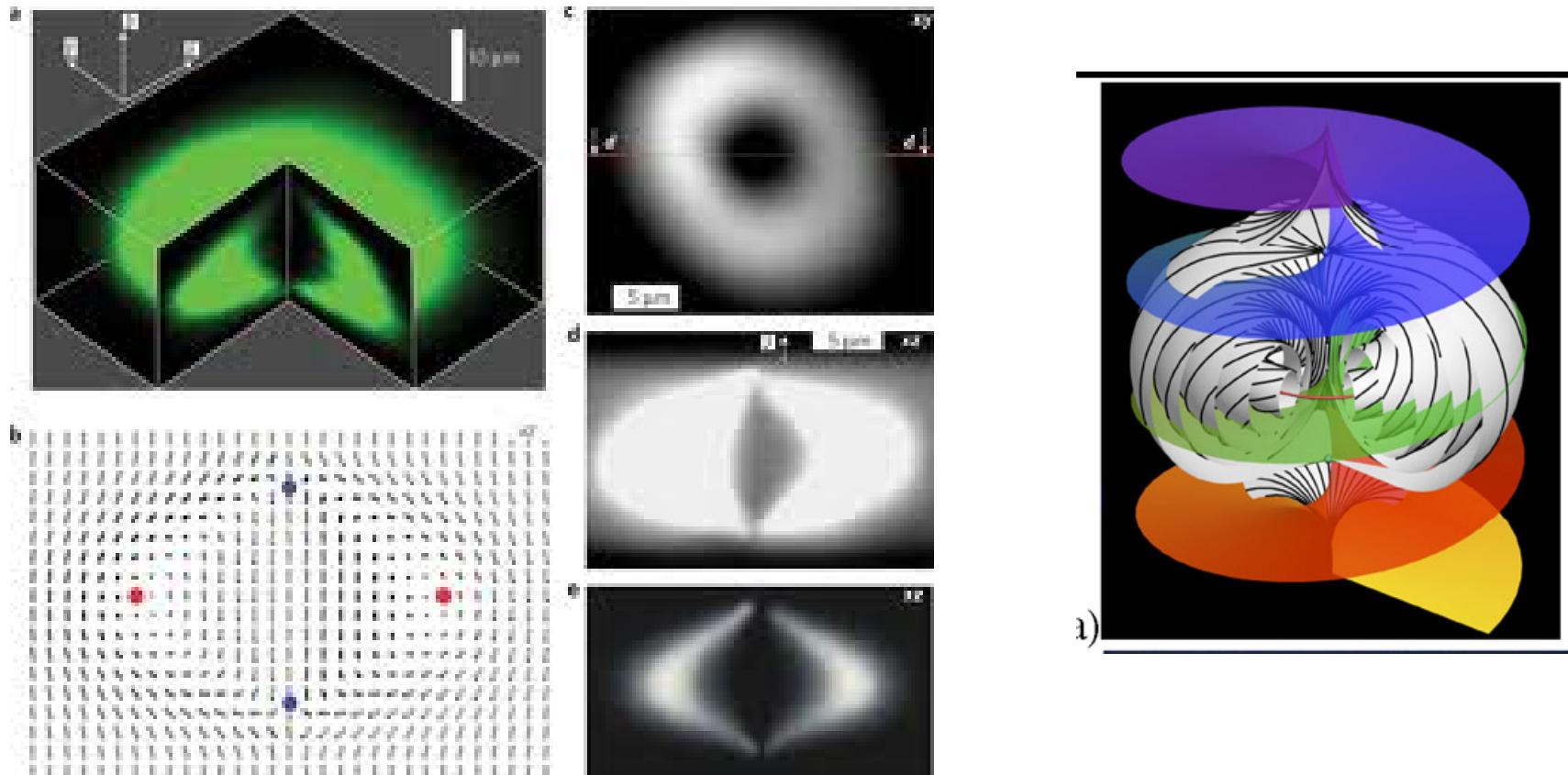
CF4, Singular



Cholesteric Fingers

Smalyukh et al, PHYSICAL REVIEW E 72, 061707, 2005

# Twisted structure in homeotropic cell



Toron structure

Smalyukh et al, Nat Mat, 9, 139 (2010)

# Materials and cell parameters

Chiral Nematic Liquid Crystals: AMLC doped with S-811

Micro Particles: Melamine Resin – 3 & 7 µm, Si-2 & 4 µm

Cell Boundary condition: Homeotropic cell

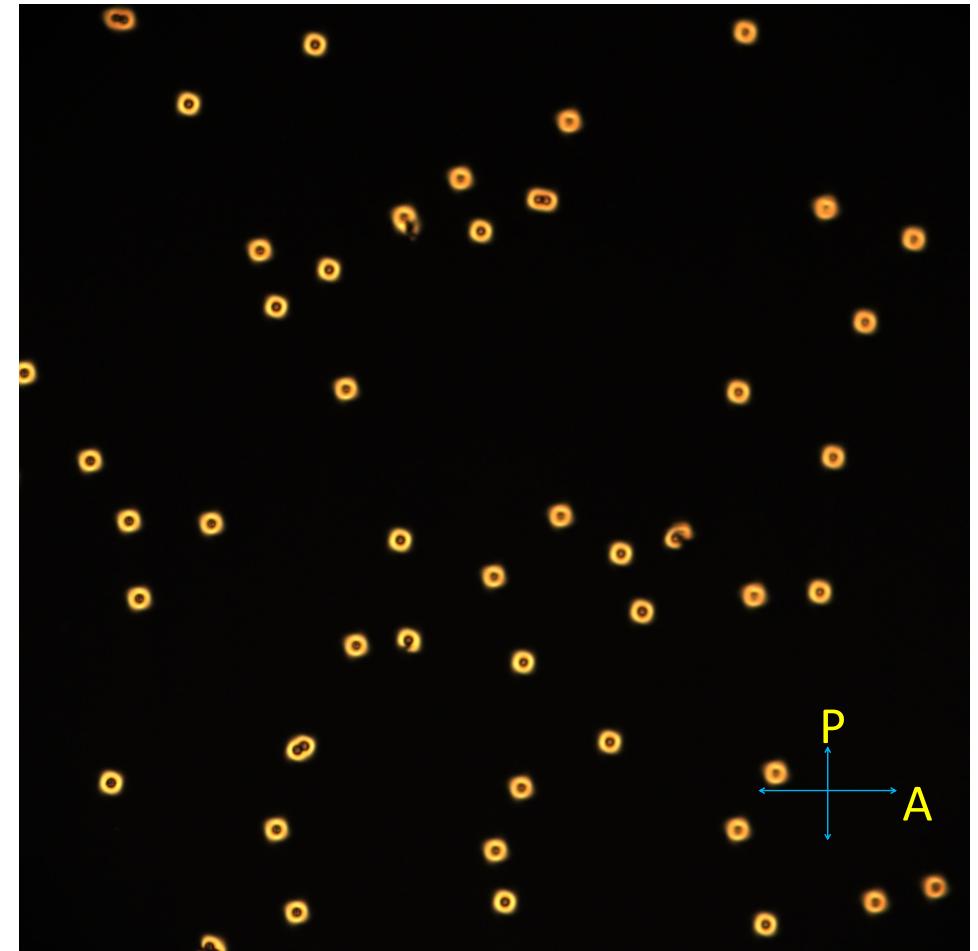
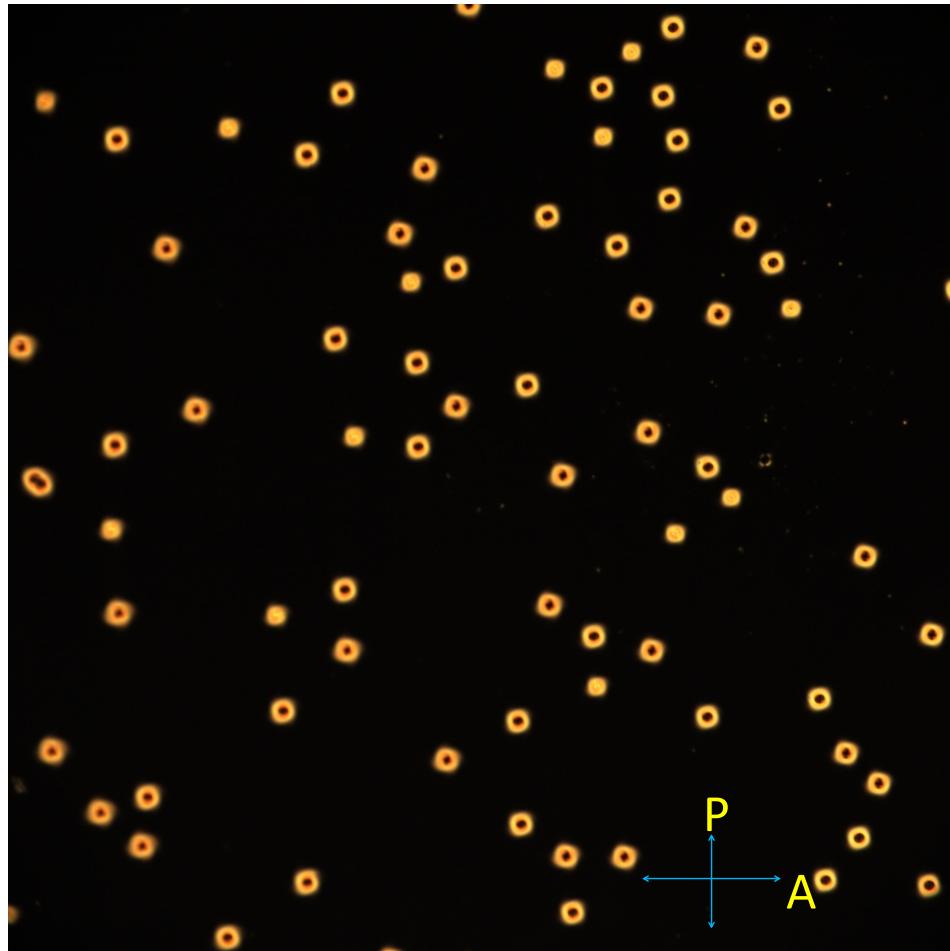
Cell thickness: 10, 15, 25 & 30 µm

HTP of S-811 in AMLC at RT: 10.47/ µm

$$HTP = \frac{1}{c_{ch} \times pitch}$$

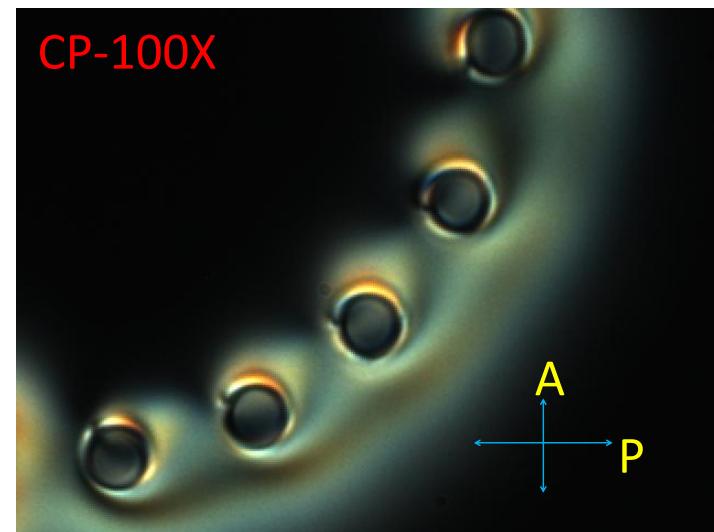
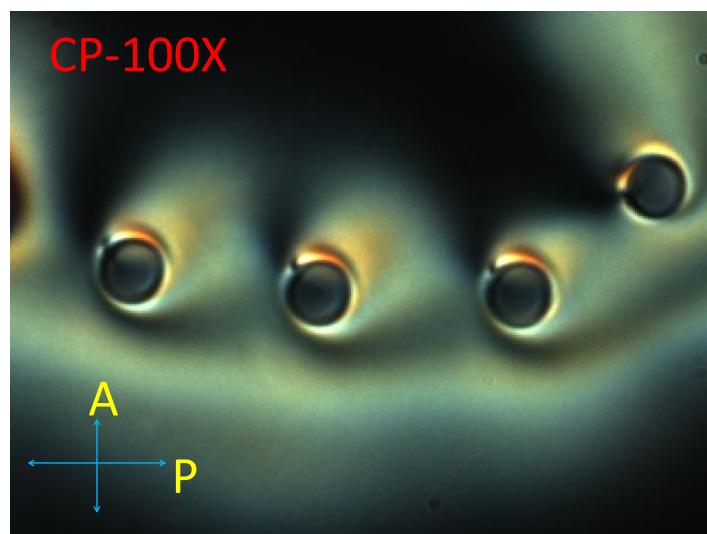
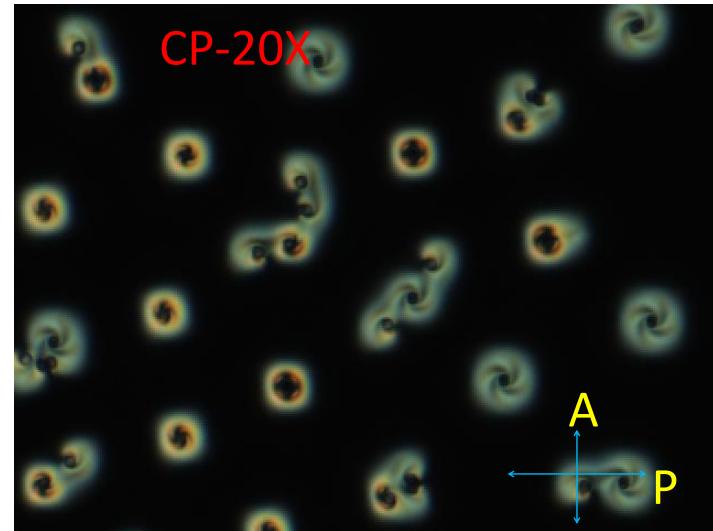
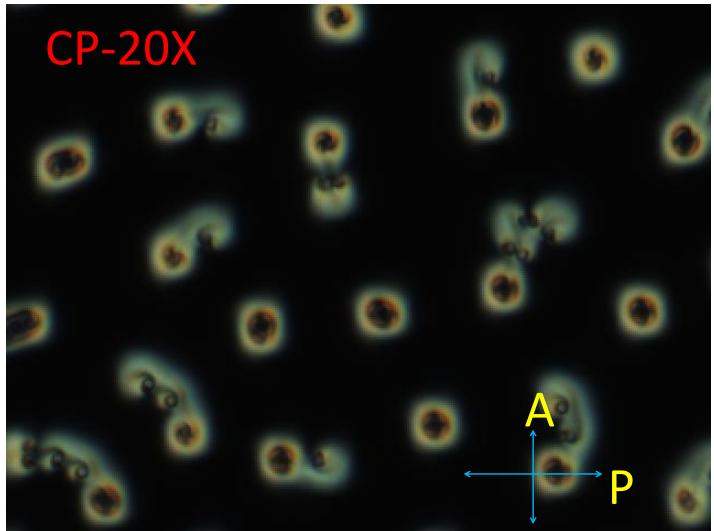
D/P= 0.5 -1.0

# Colloidal particles dressed with twisted structures



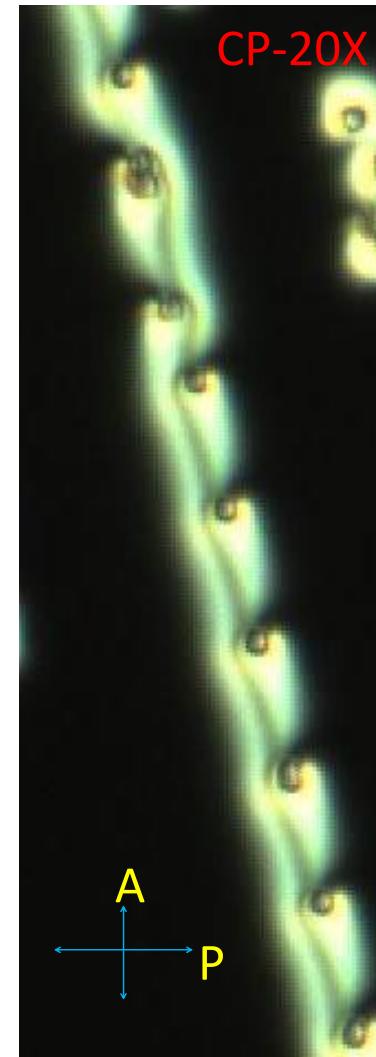
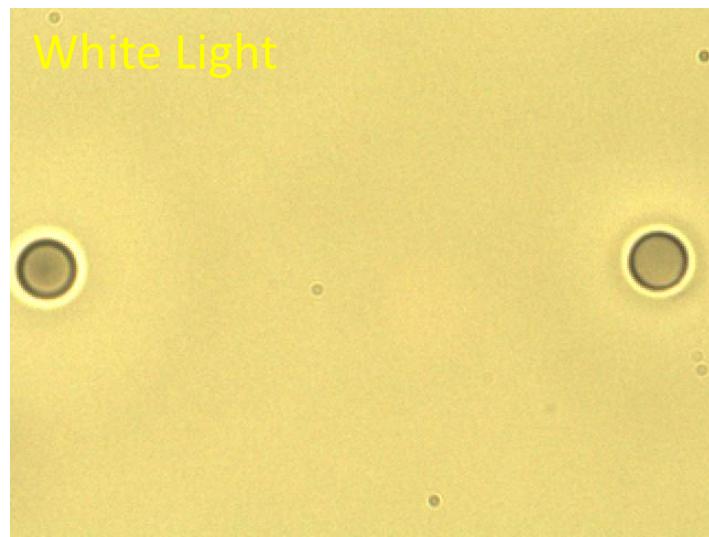
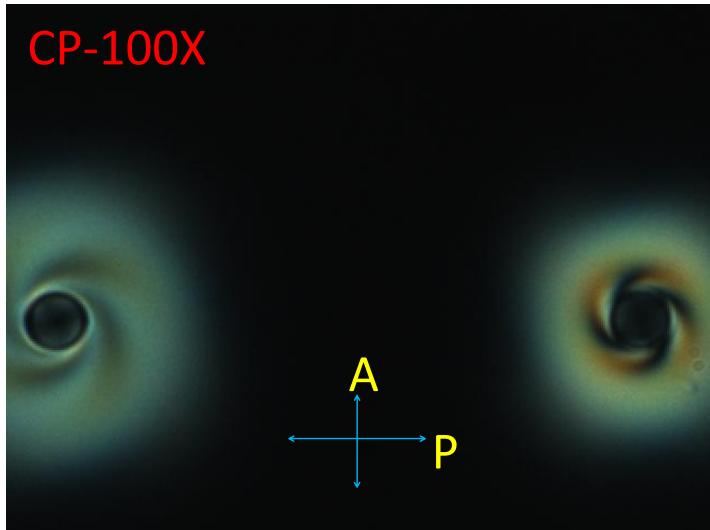
AMLC10.6 $\mu$ m- MR-7 $\mu$ m-10  $\mu$ m hom\_20X\_Cross polarizer

# Particles (Si-4 $\mu\text{m}$ ) dressed with Twisted Structures



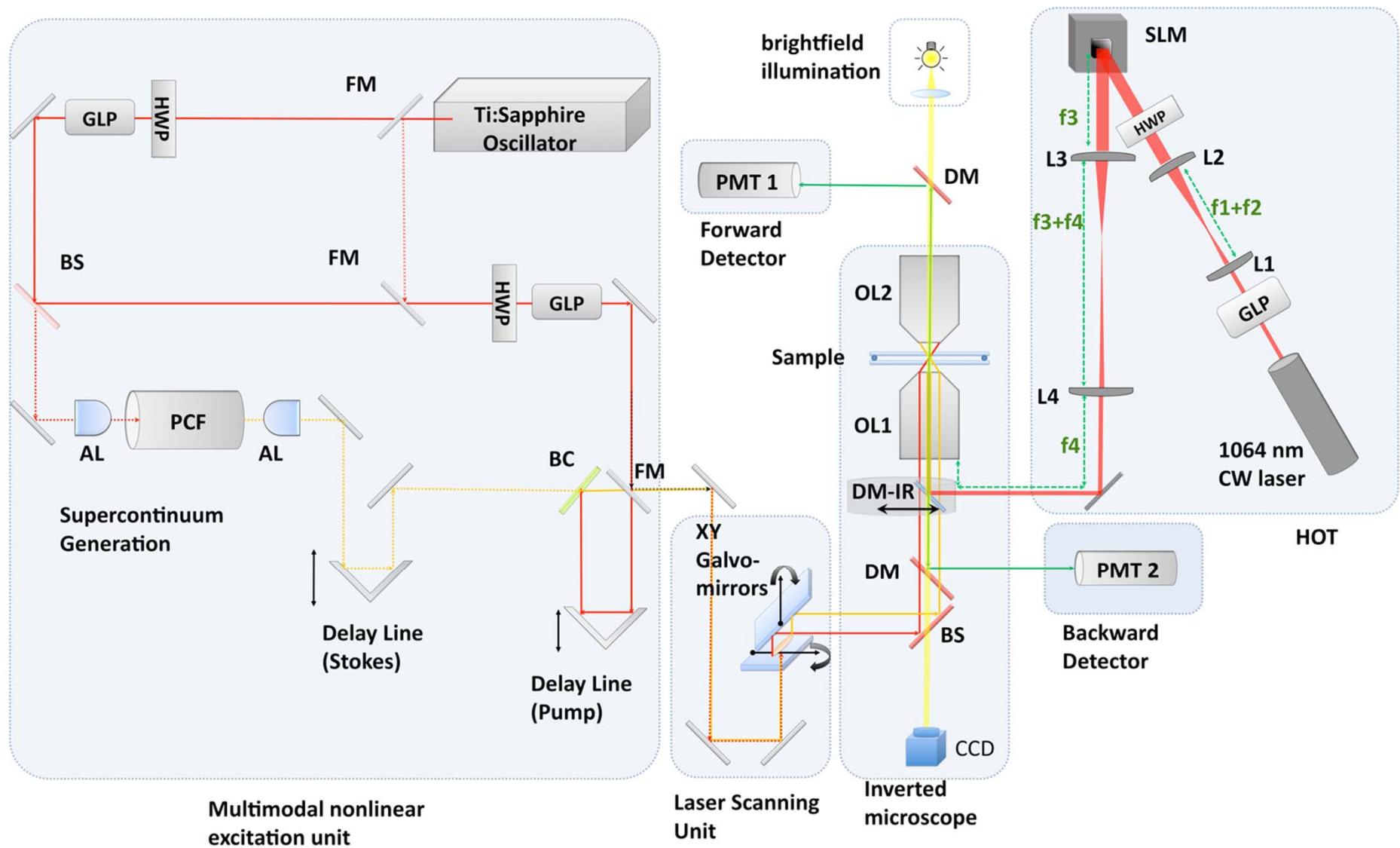
AMLC10.5um-Si4umhom-10um hom cell

# Particles (Si-4 $\mu\text{m}$ ) dressed with Twisted Structures

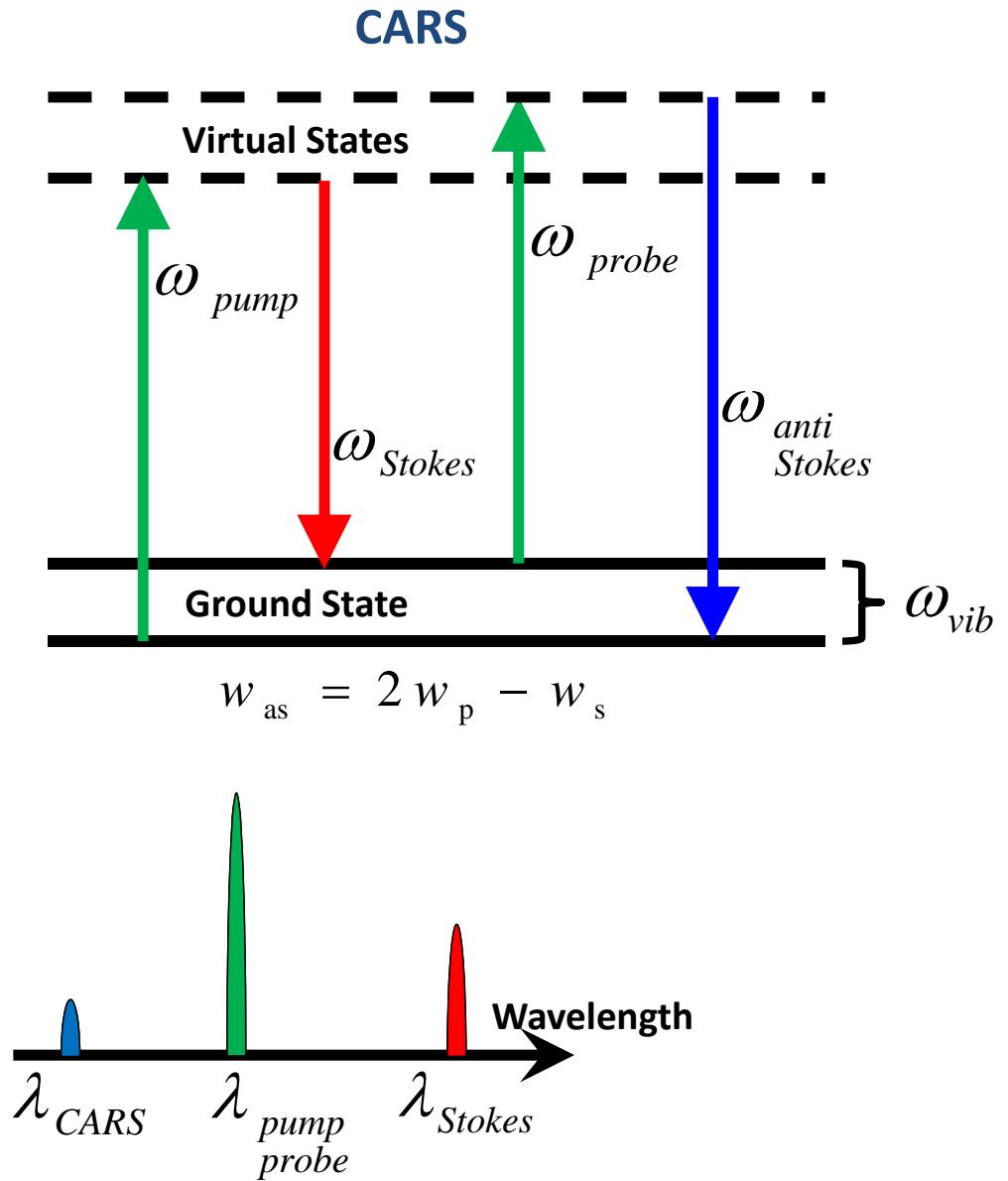
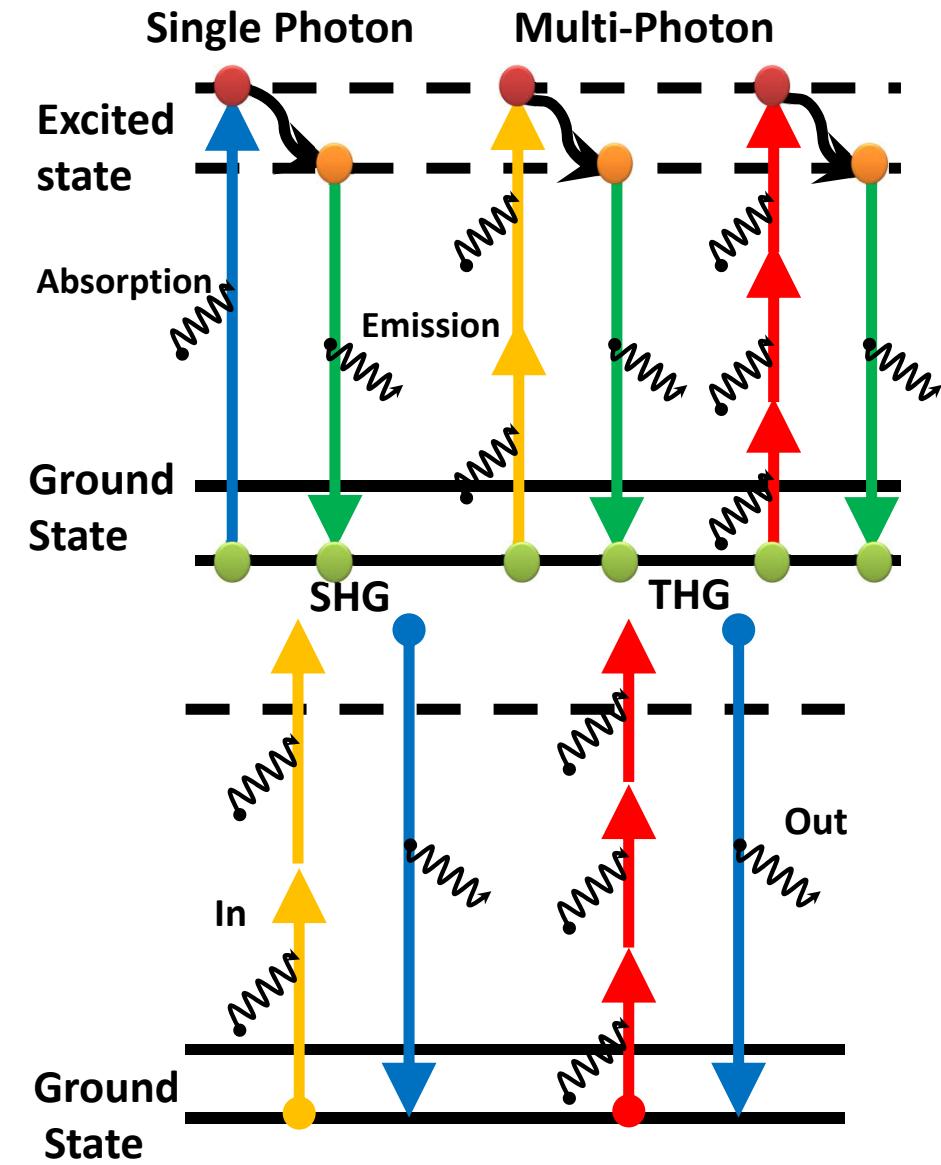


AMLC10.5um-Si4umhom-10um hom cell

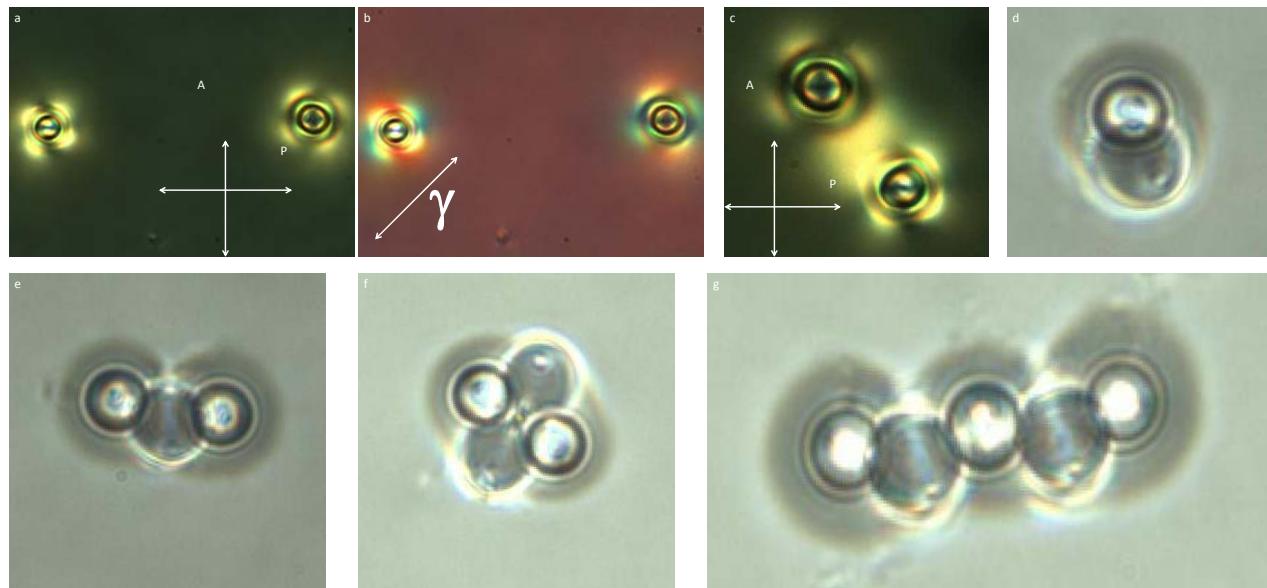
# Integrated Set-up: *HOT* + *MNOPM*



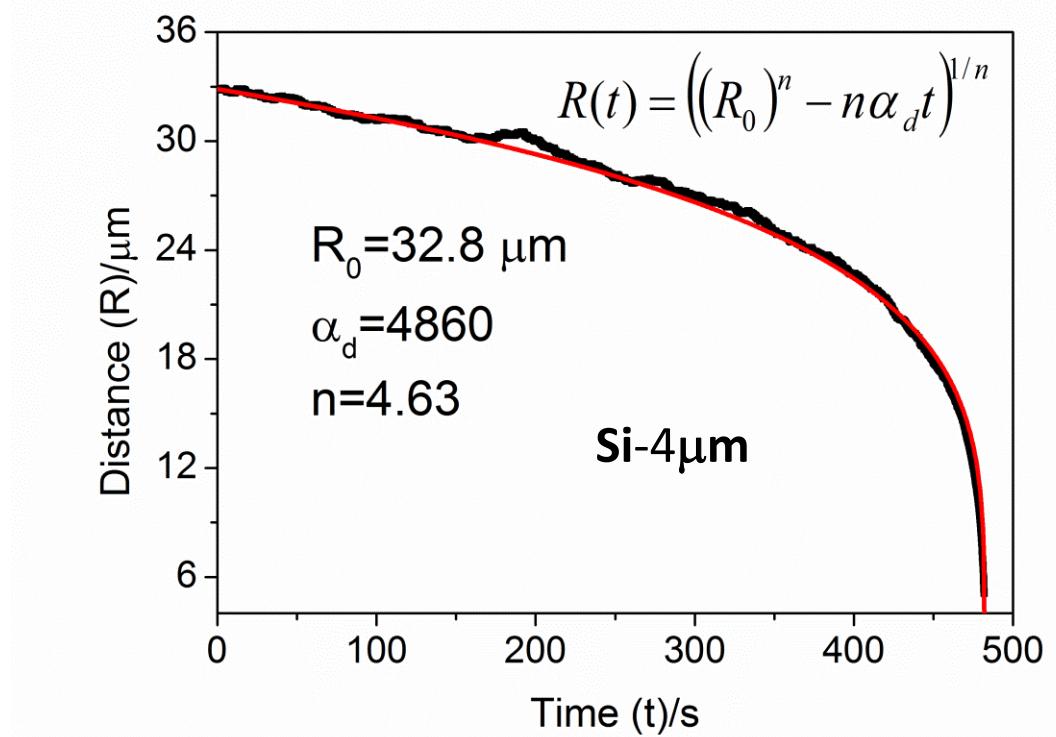
# Nonlinear Optical Imaging Techniques



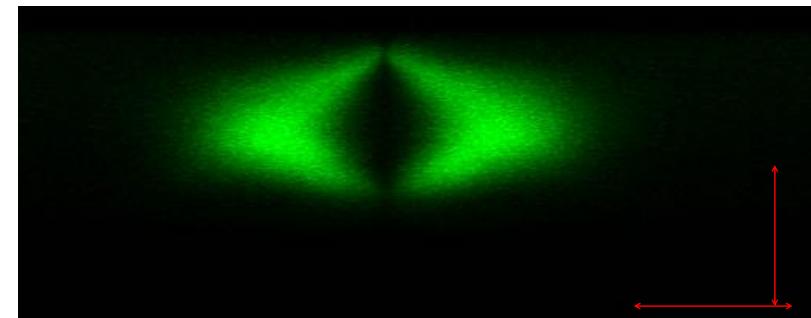
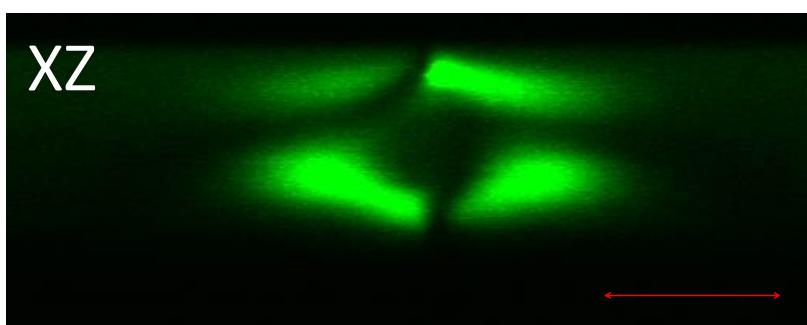
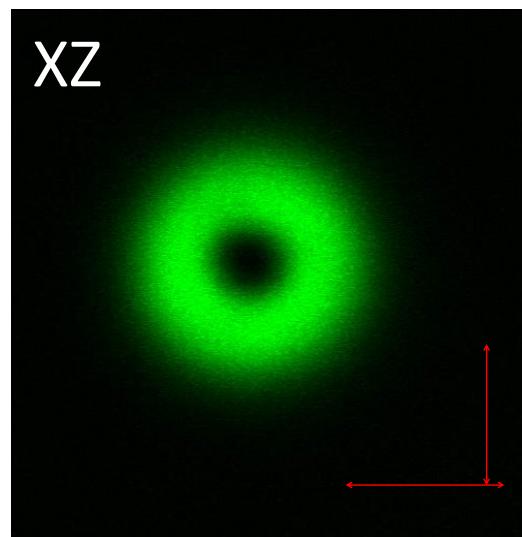
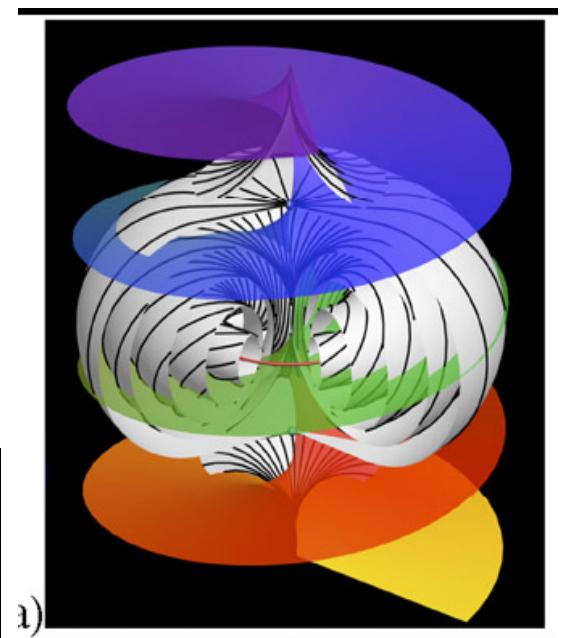
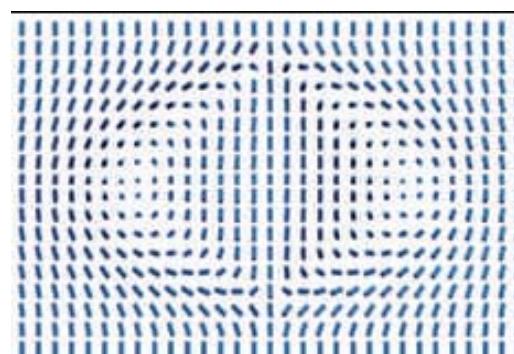
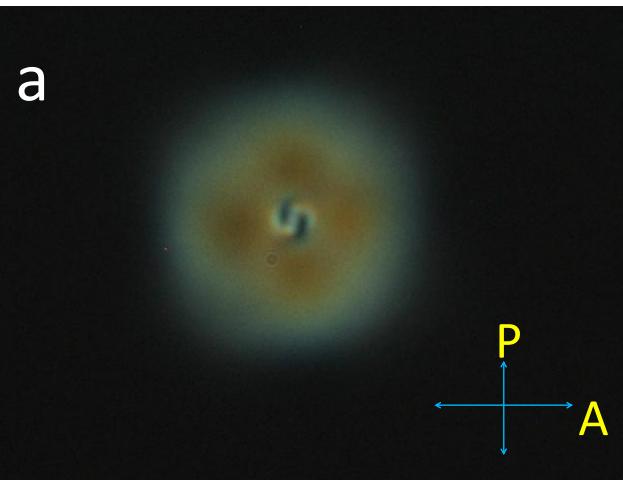
# Assembly of colloids and Interaction between particles



D/P=0.5

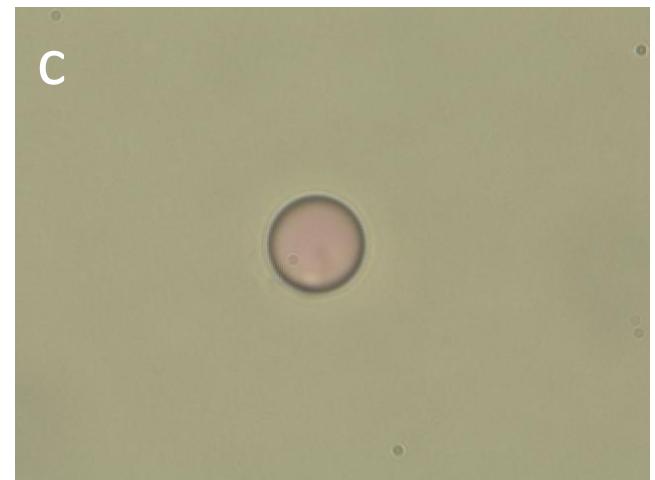
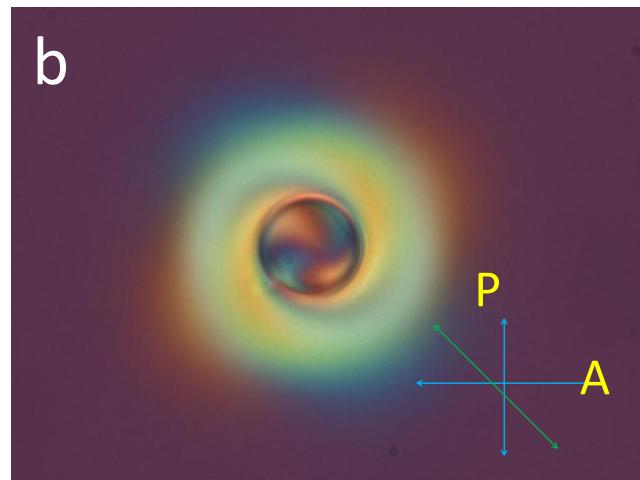
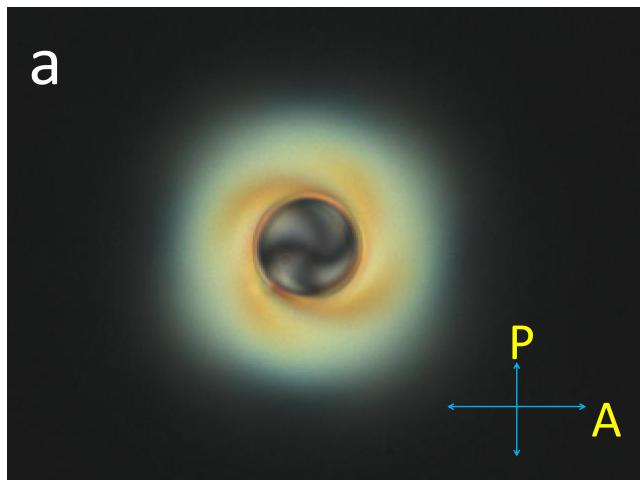


# Toron structure imaged by TPL

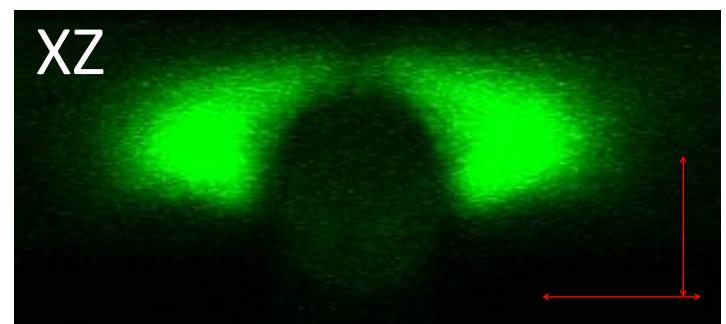
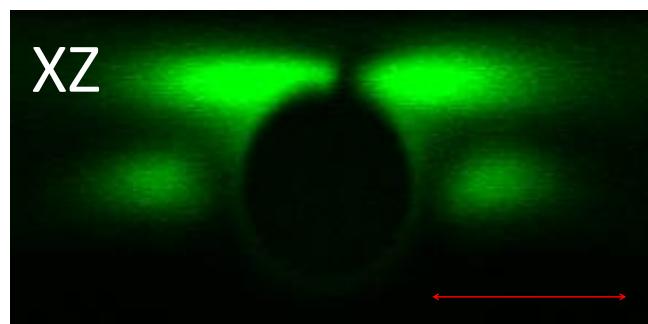
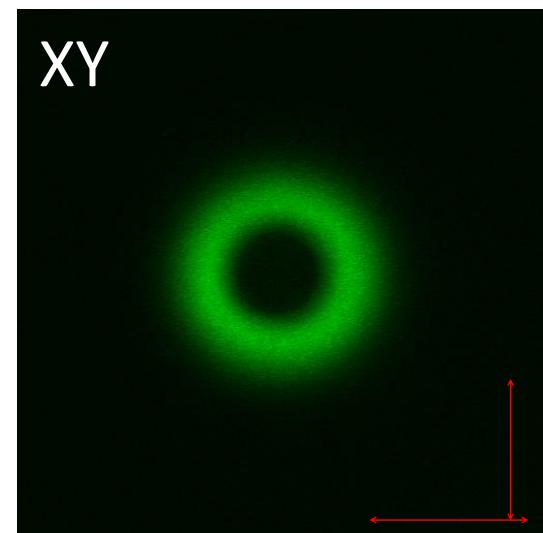
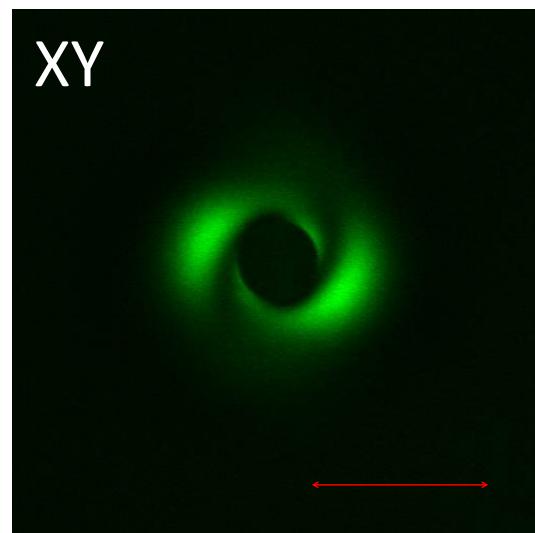


AMLC-10.6um-E31-2%\_7umMR\_10um Hom cell

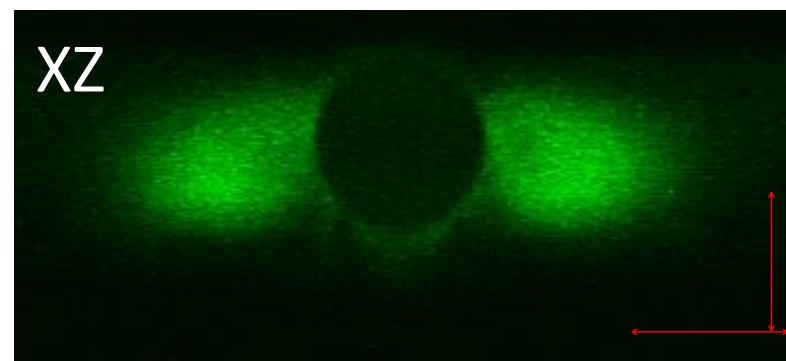
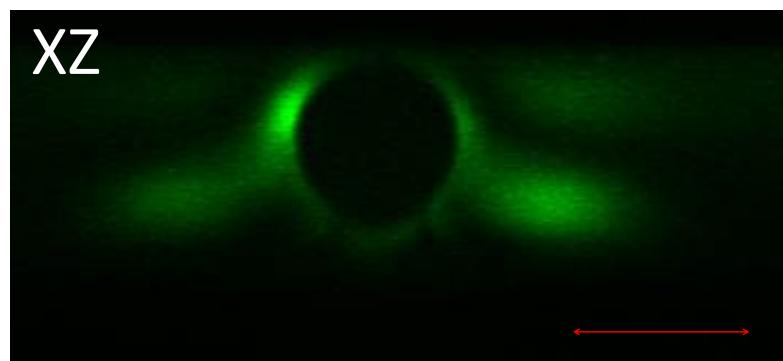
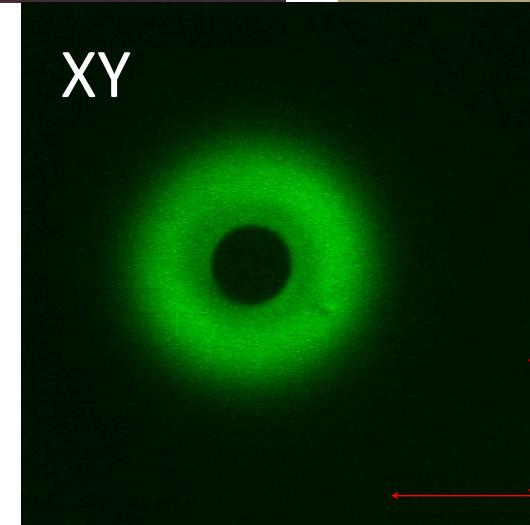
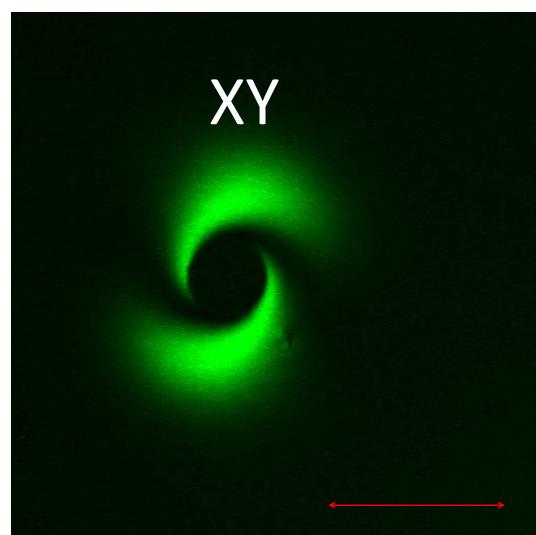
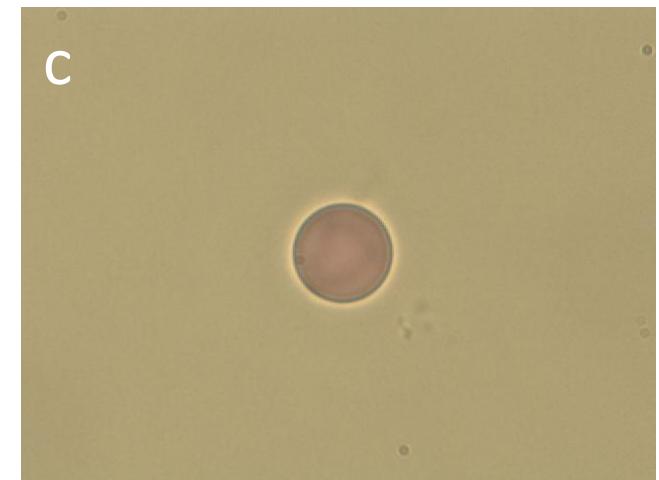
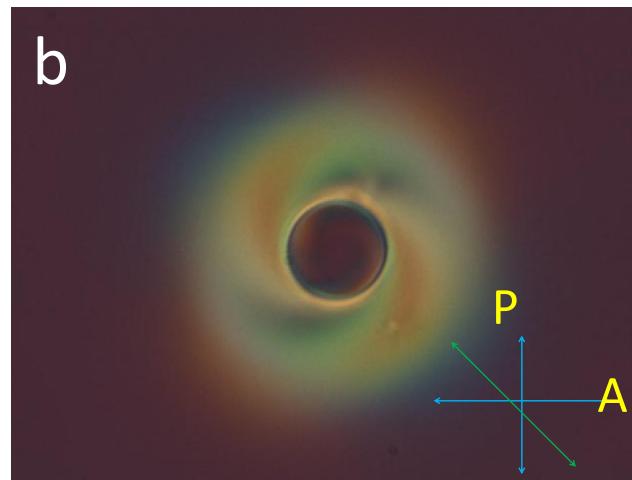
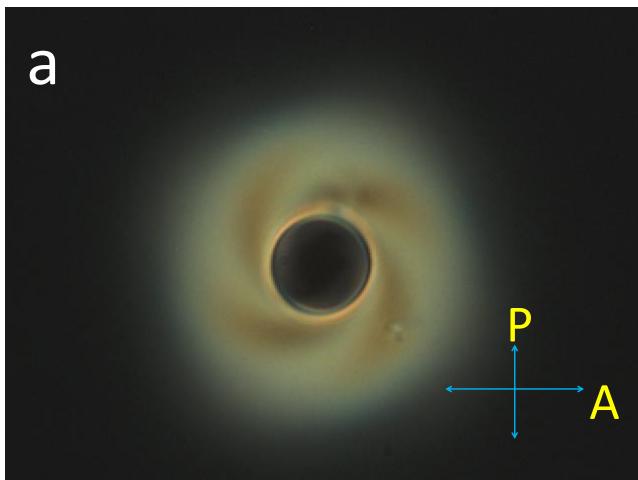
# MR Particle dressed with Twisted Structure (1)



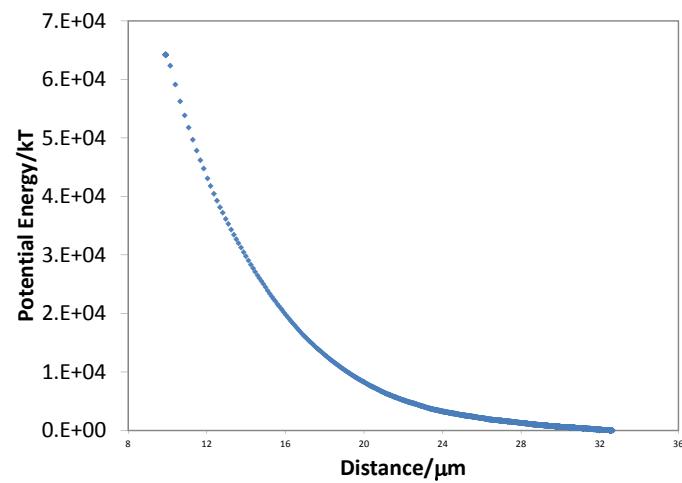
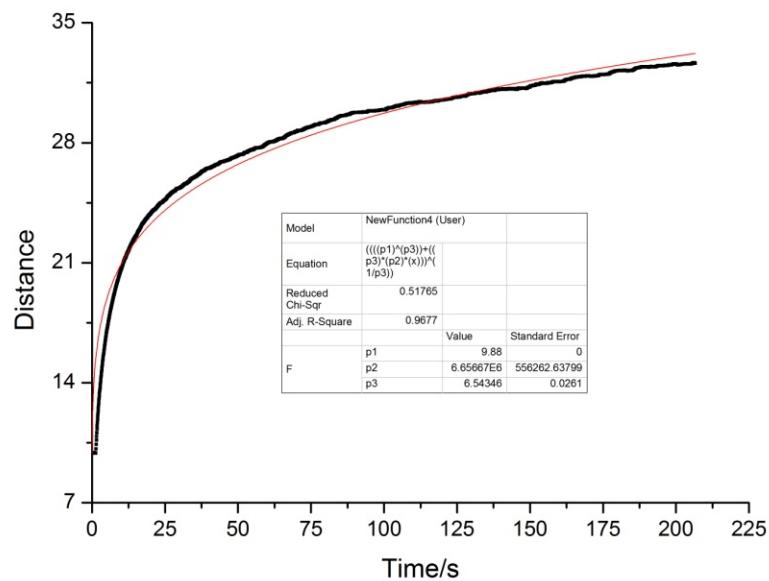
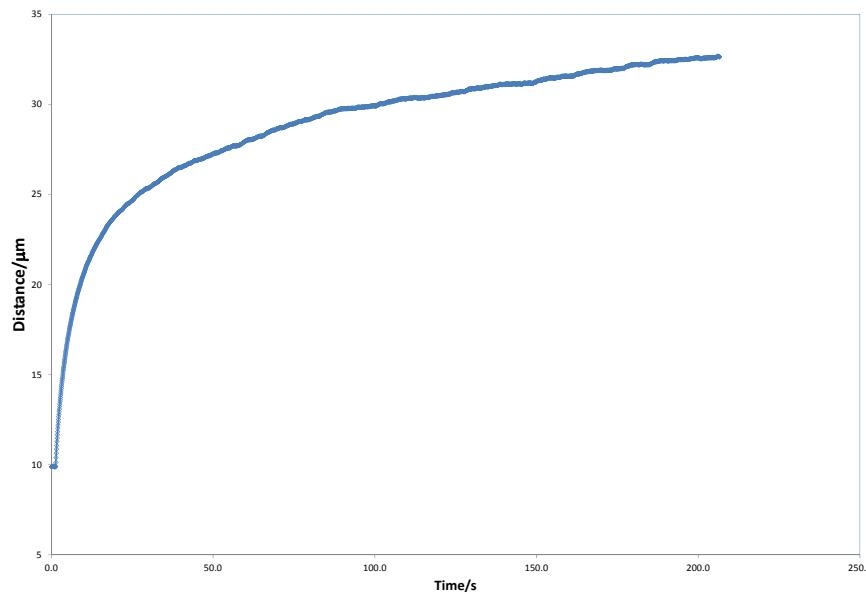
AMLC-10.6um-E31-2%\_7umMR\_10um Hom cell



# MR Particle dressed with Twisted Structure (2)

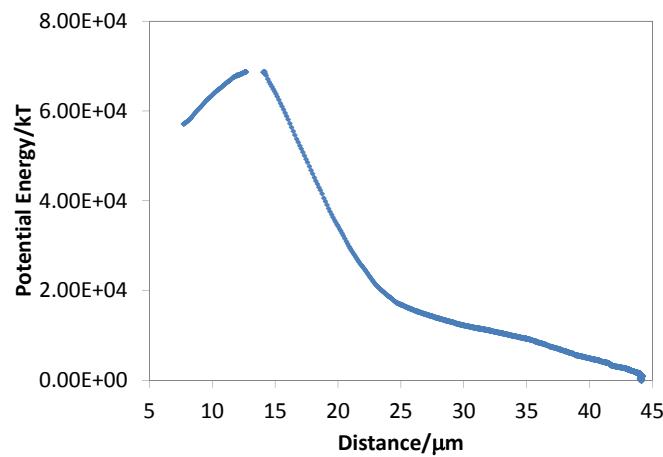
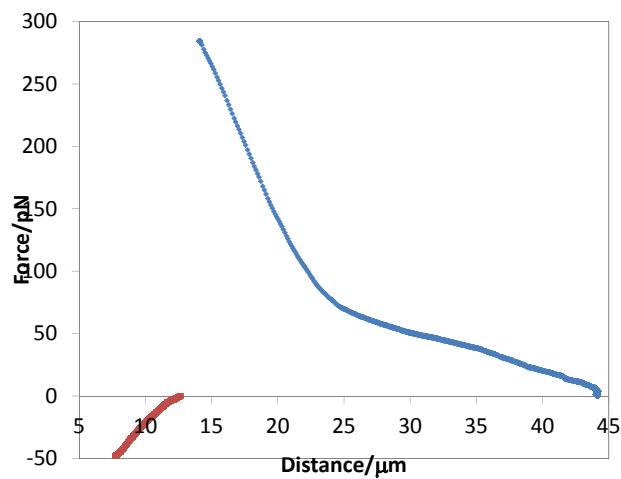
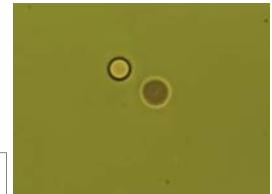
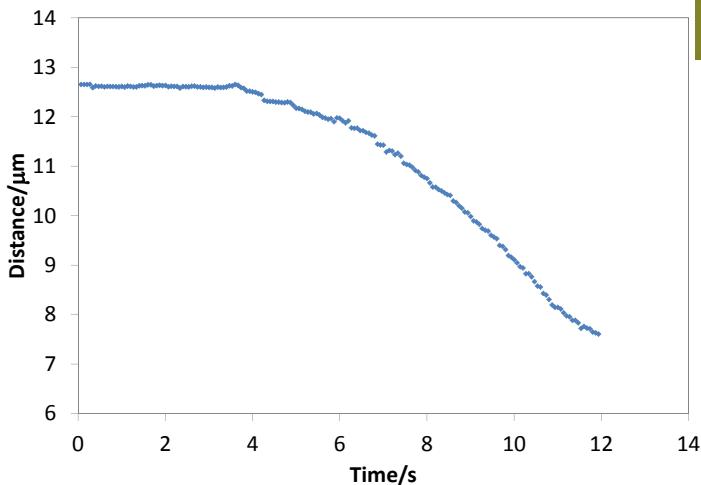
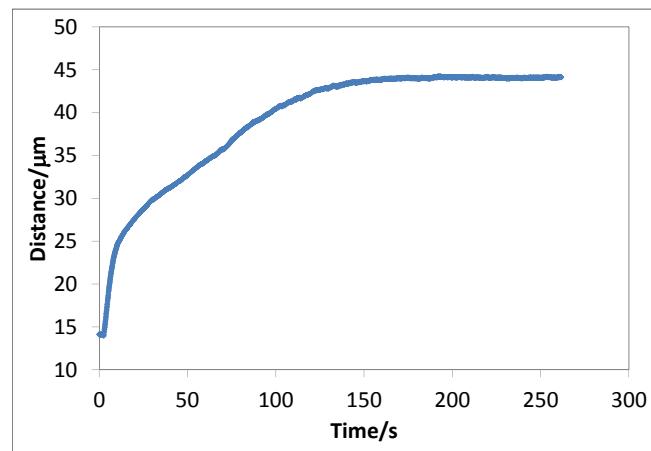
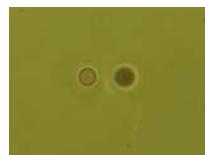


# Repulsive interaction between particles with structure 1

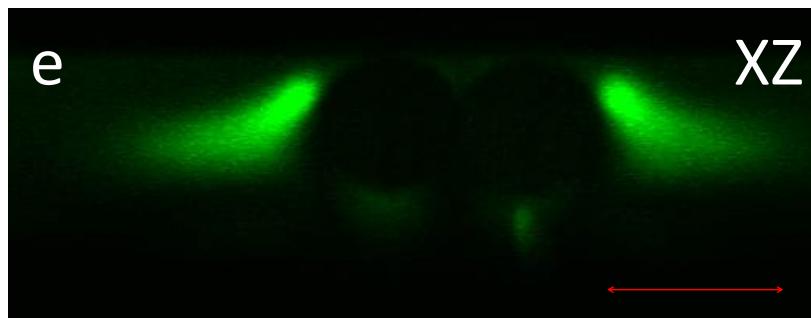
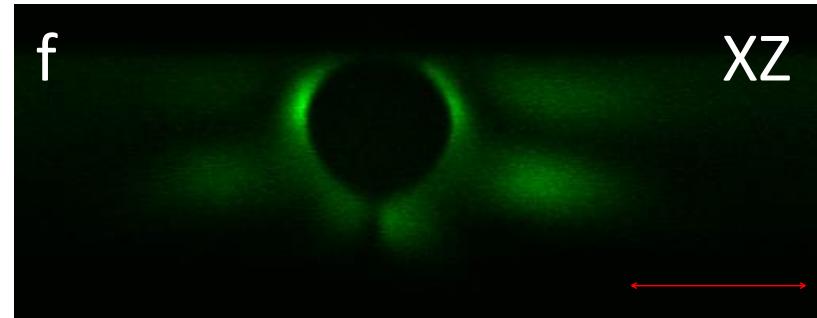
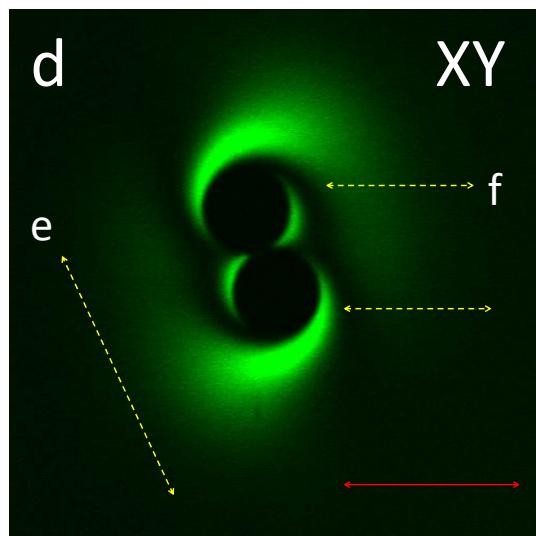
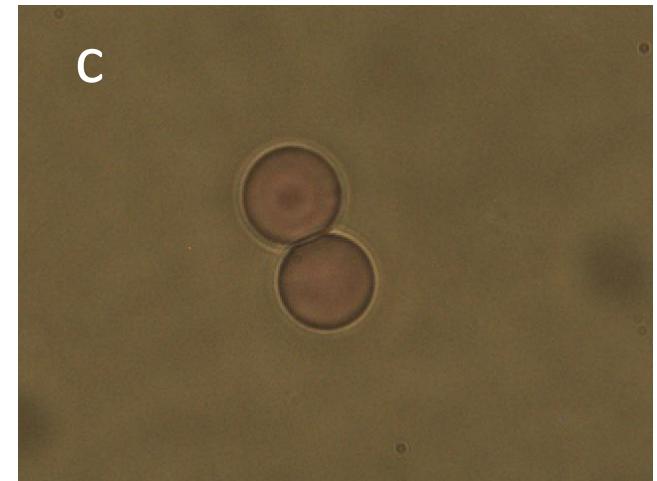
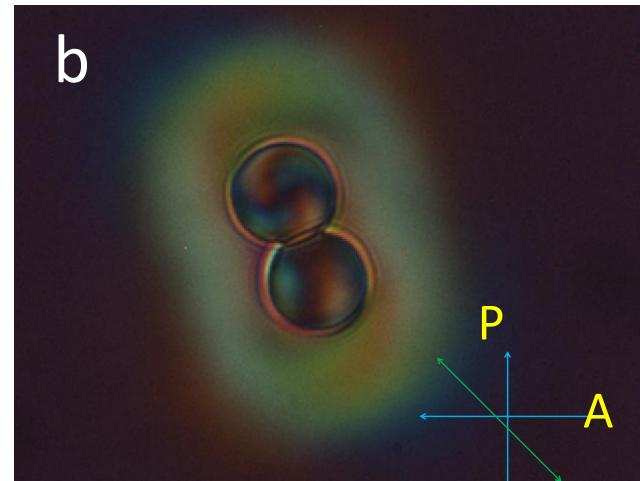
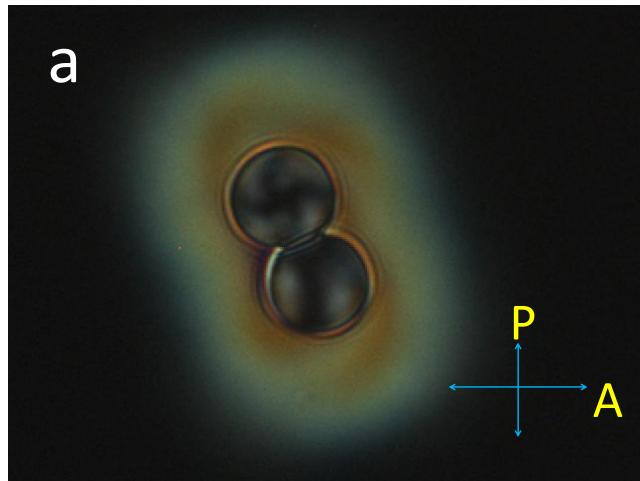


AMLC-10.6um-E31-2%\_7umMR\_10um Hom cell

# Distance dependence interaction between particles dressed with structure 1 and 2

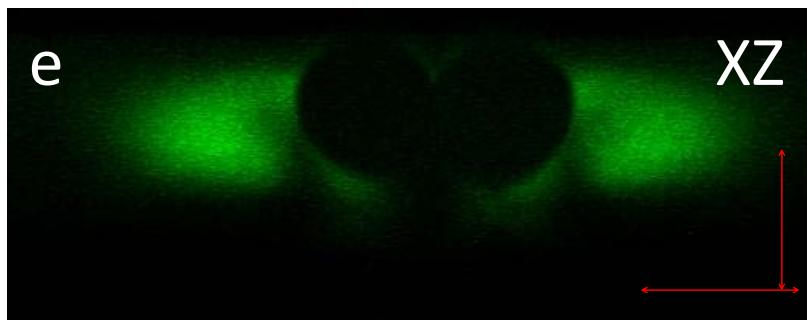
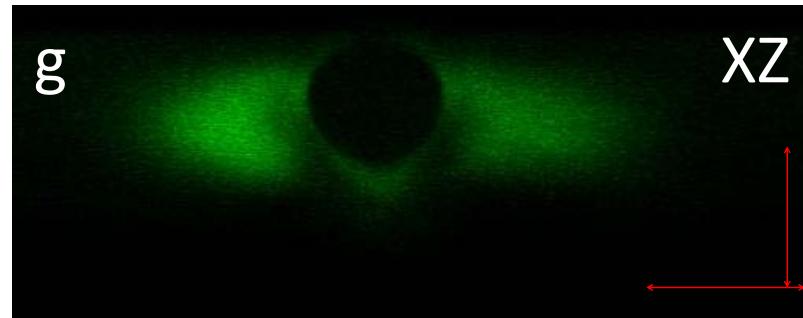
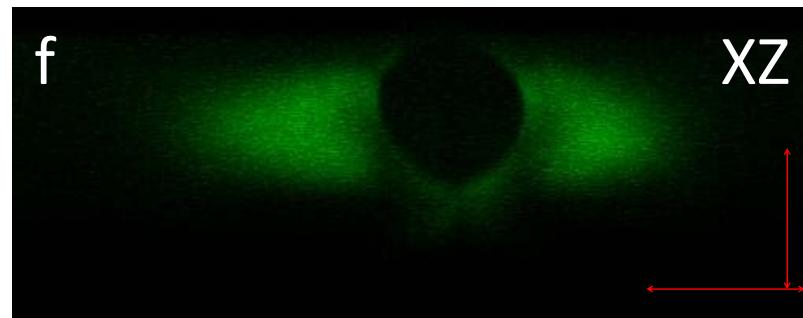
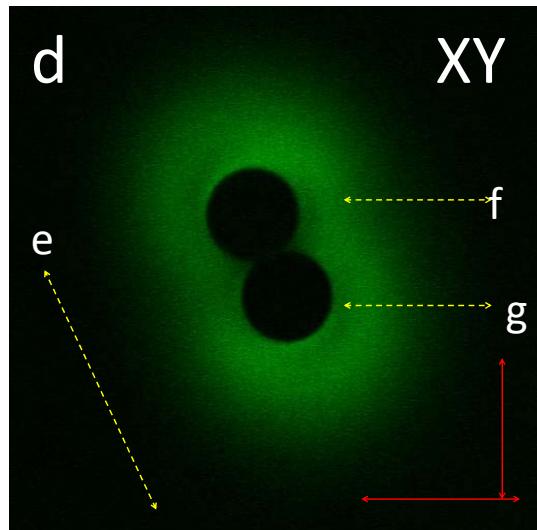
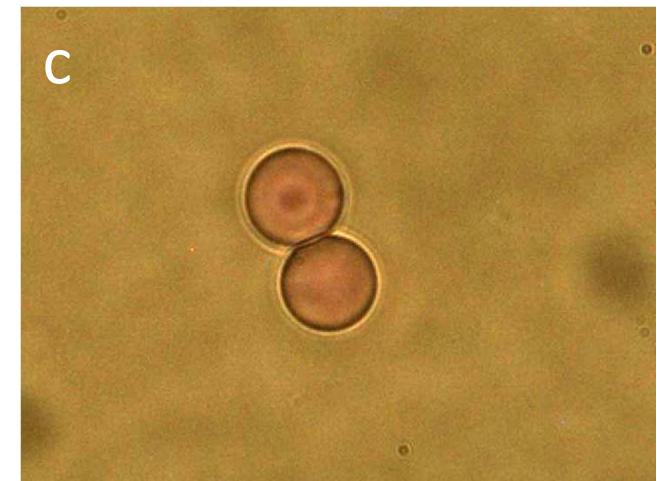
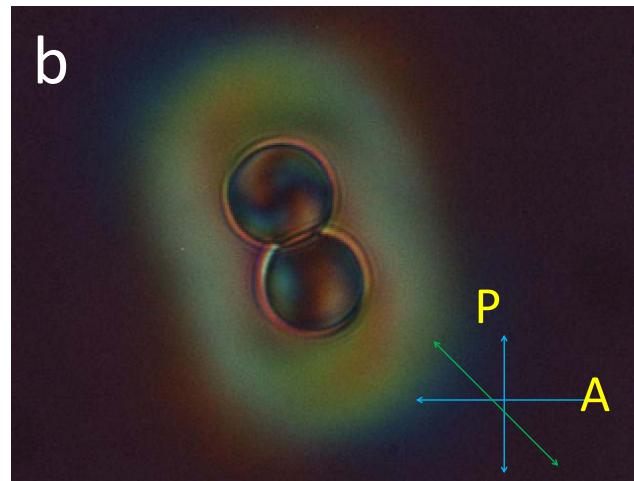
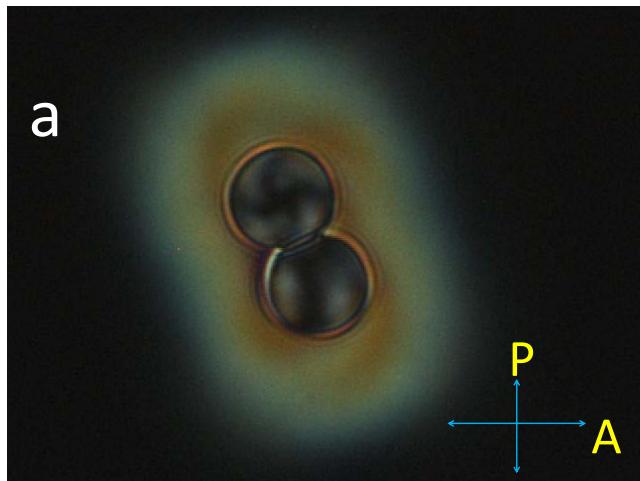


## Two MR dressed with Twisted structure imaged by TPL



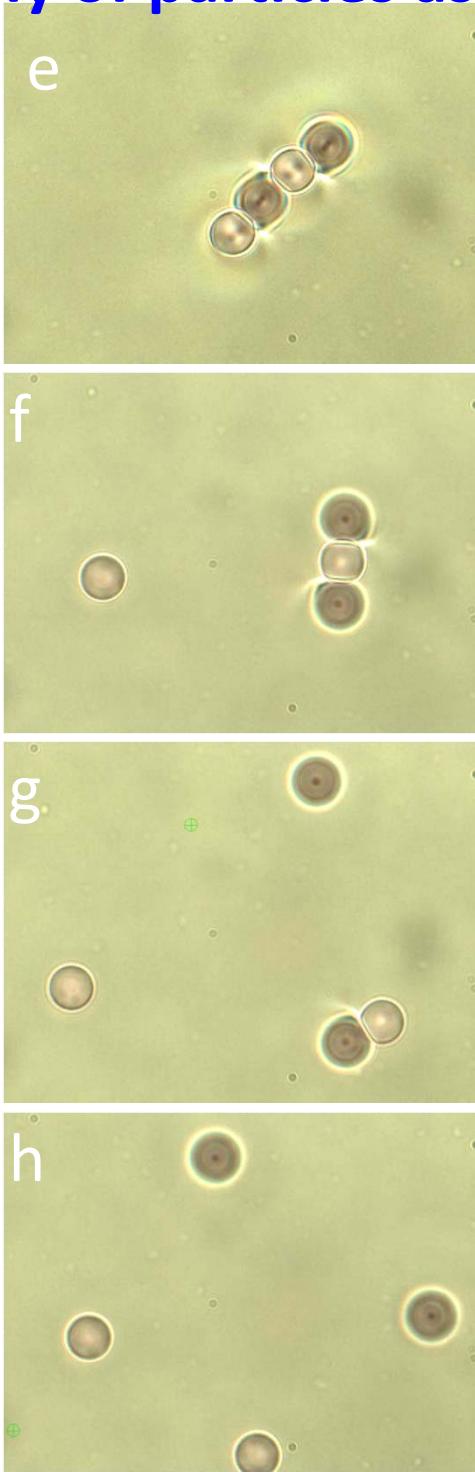
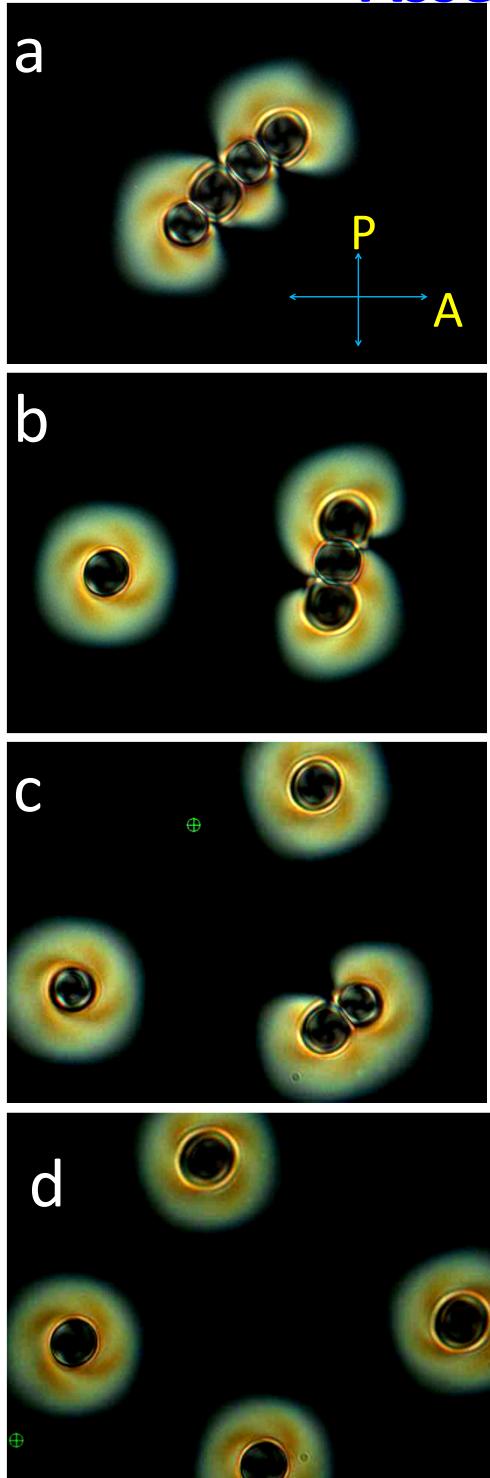
AMLC-10.6um-E31-2%\_7umMR\_10um Hom cell

# Two MR dressed with Twisted structure imaged by TPL

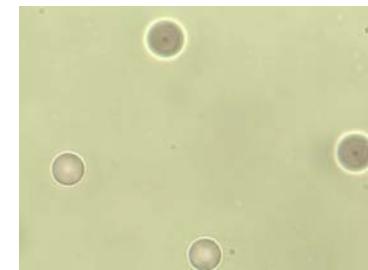


AMLC-10.6um-E31-2%\_7umMR\_10um Hom cell

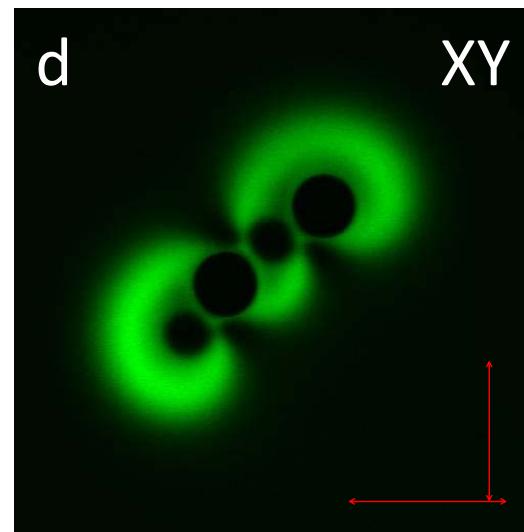
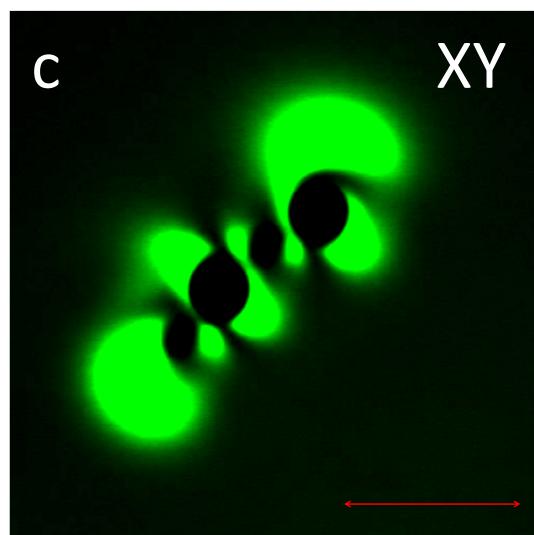
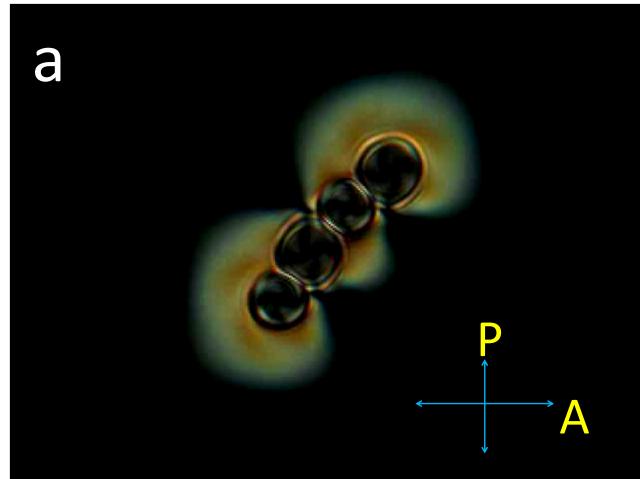
# Assembly of particles assisted by optical trap



AMLC-10.6um-E31-2%\_7umMR\_10um Hom cell

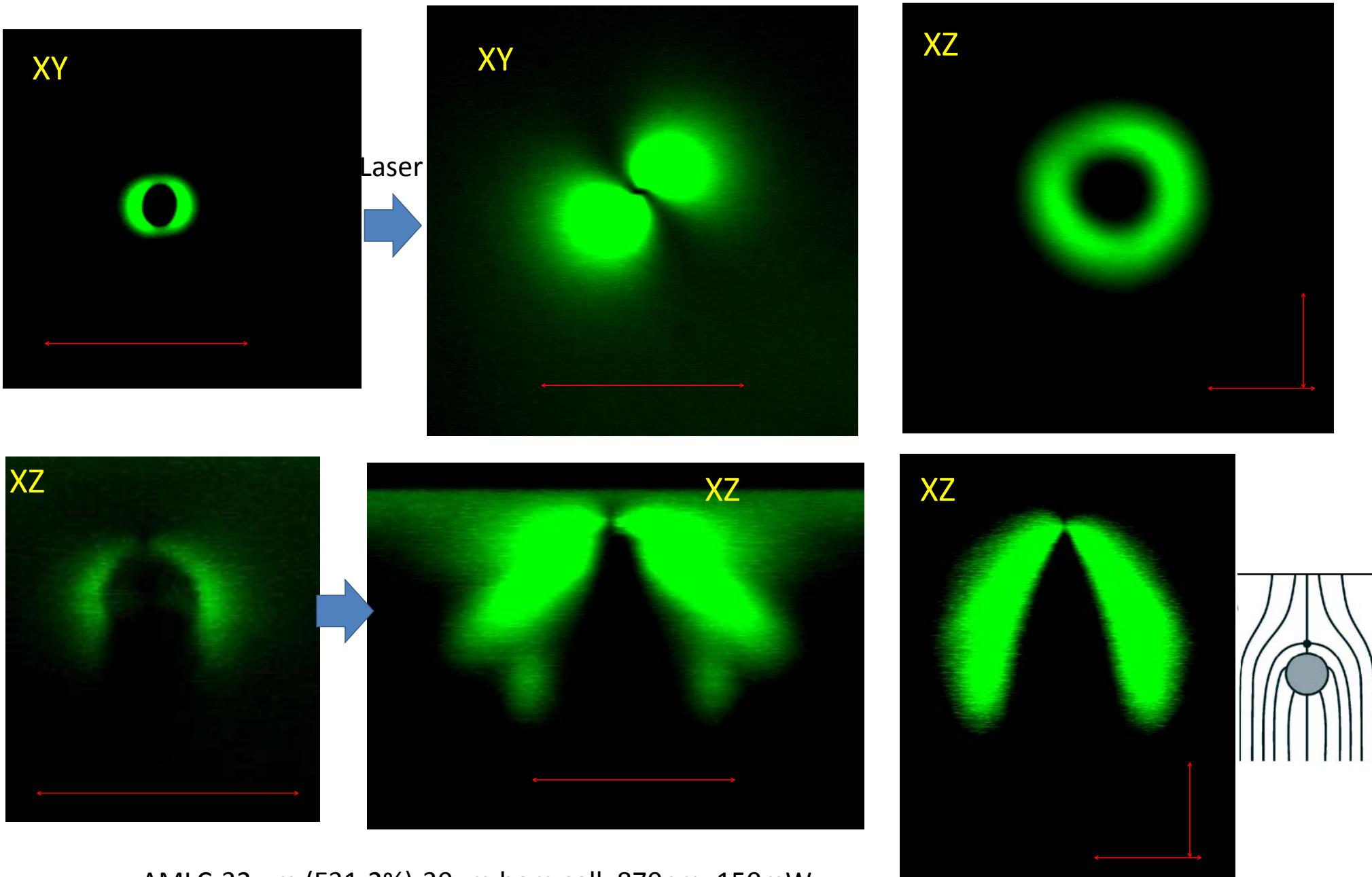


# Assembly of four MR particles dressed with Twisted structure imaged by TPL

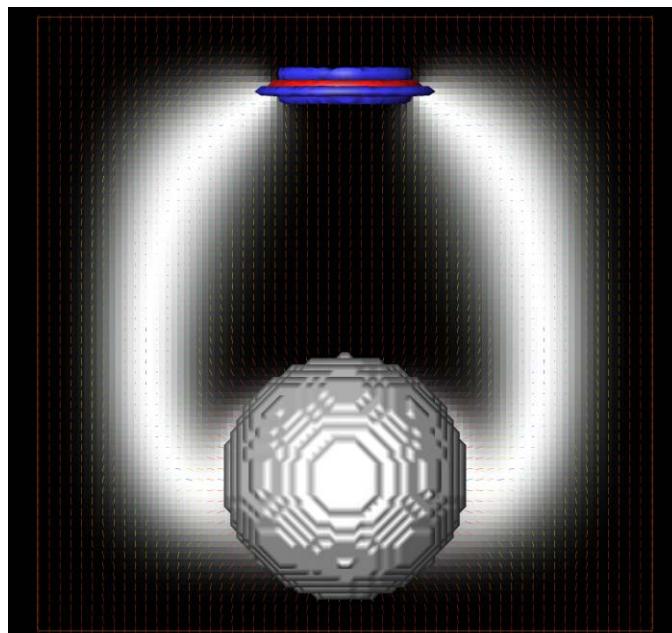
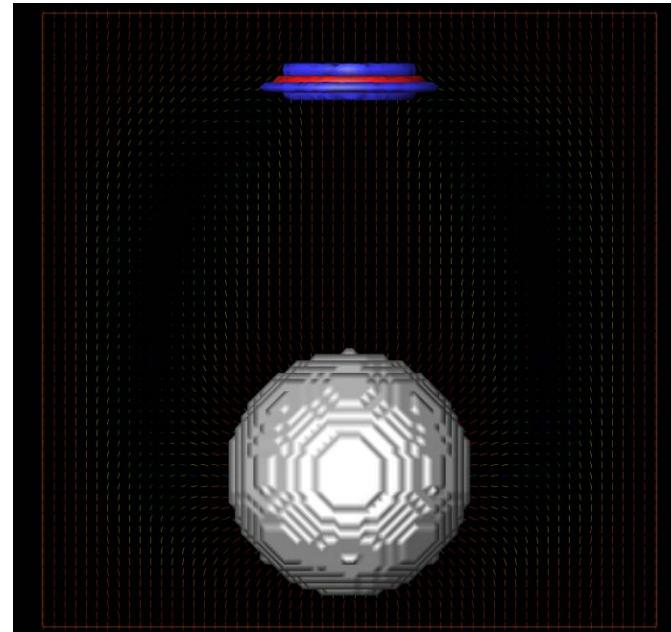
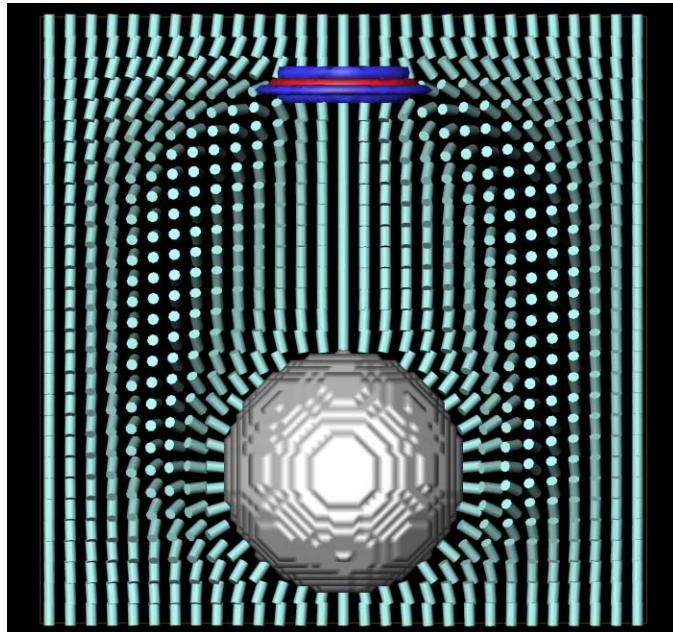


AMLC-10.6um-E31-2%\_7umMR\_10um Hom cell

# Generation of Twisted structure around particle (Si) by LG beam and imaged by TPL

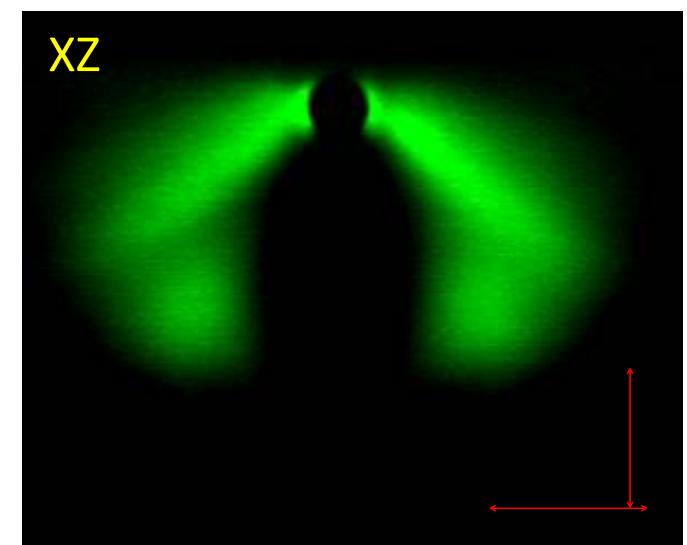
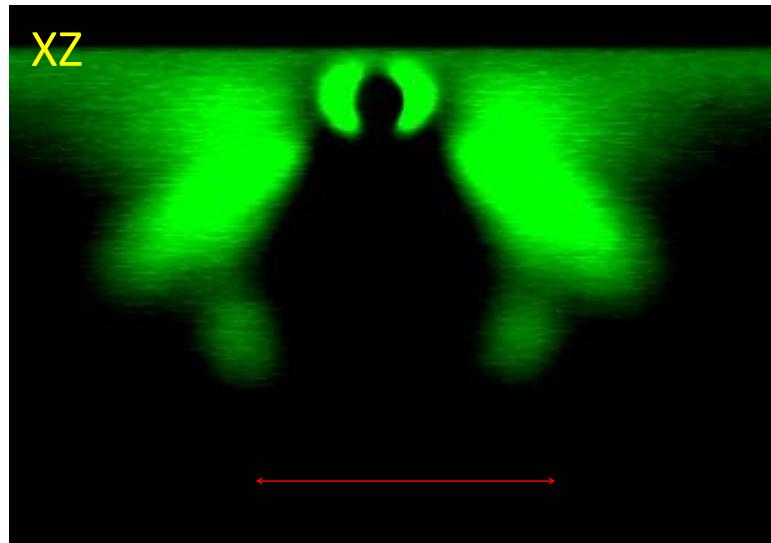
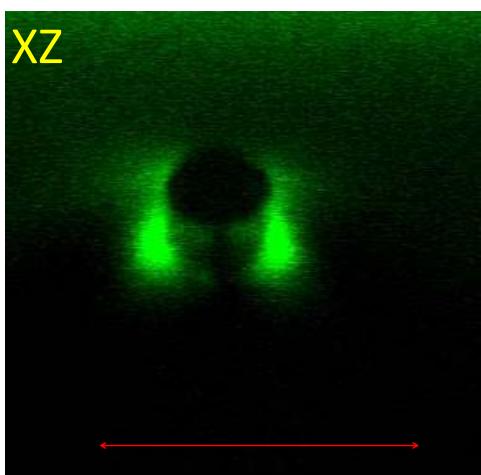
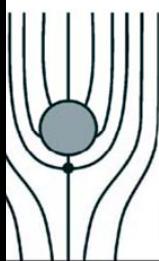
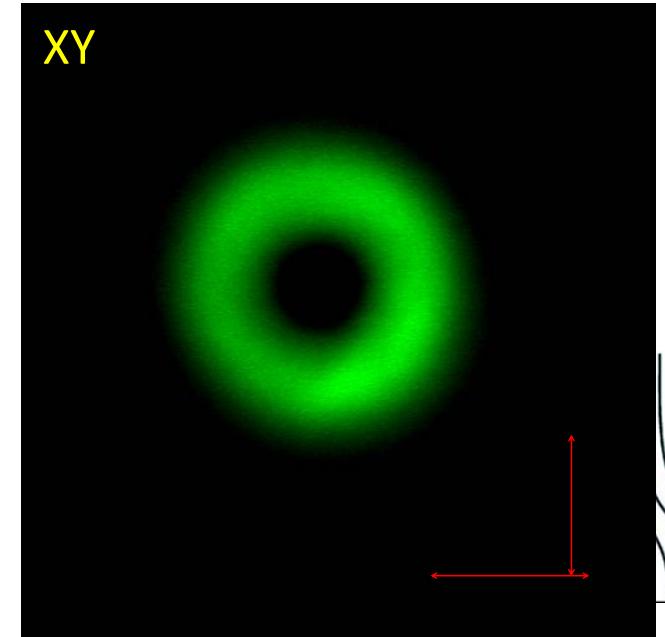
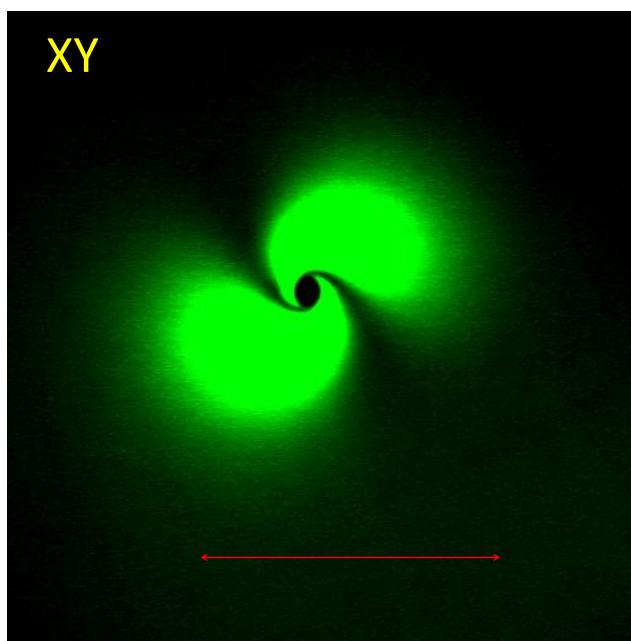
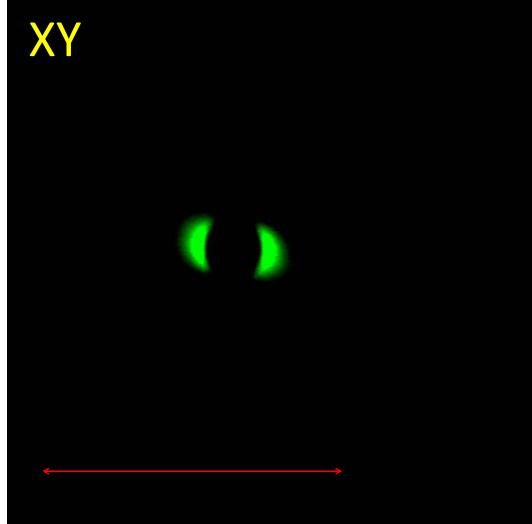


# Director profile and structure around particle in homeotropic Chiral nematic-simulation results



Prof. Zumer  
and co-  
workers

# Generation of Twisted structure around particle (Si) by LG beam and imaged by TPL



AMLC-32 um (E31-2%)-30um hom cell, 870nm, 150mW

# Conclusions

1. Interaction between colloidal particles, Nature of interaction and its range depend upon the defect structure around the particles.
2. Micro-particles always trapped at the point where defects has maximum energy.
3. It is possible to control the defects between colloidal particles.
4. Specific defects structure could also be created around the particles by using LG beams with different charges.
5. Cholesteric Liquid Crystals is a promising media to create colloids dressed with twist bound structure with different topological charges.

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Thank you for kind attention!

Comments, suggestions and ?