

Reversible birefringence in microstructures fabricated by two-photon polymerization

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- Motivation
- Resin preparation
- Azoaromatic compound and orientation
- Optimization of the resin
- Fabrication of microstructures via 2PA polymerization
- Birefringence in the microstructures
- Conclusions

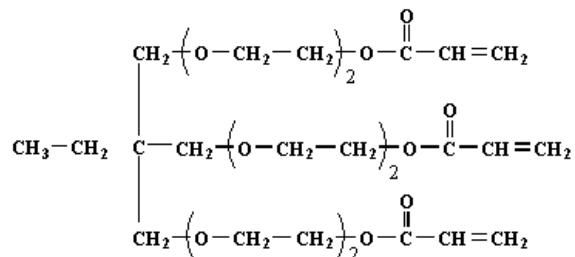
Two-photon absorption polymerization have been used to fabricate 3D micromechanical actuators, photonic crystals, optical devices , etc

Most of the structures reported until now are passive elements, whose properties cannot be changed by external means.

Here we demonstrate the fabrication by two-photon absorption polymerization of an optically active microstructure whose birefringence can be optically induced and erased.

Resin Composition

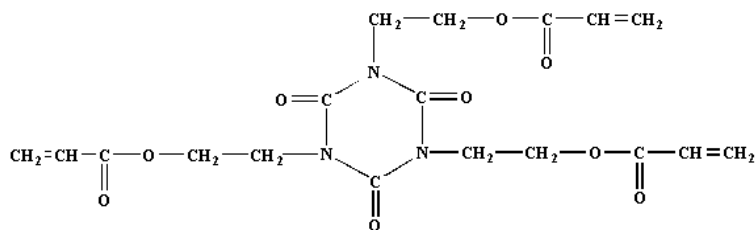
SR499



ethoxylated(6) trimethyl-lolpropane triacrylate

reduces the shrinkage upon polymerization

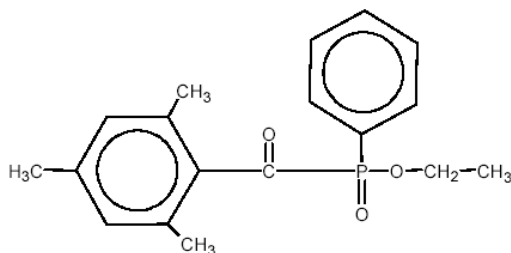
SR368



tris(2-hydroxyethyl)isocyanurate triacrylate

gives hardness to the polymeric structure

Lucirin TPO-L

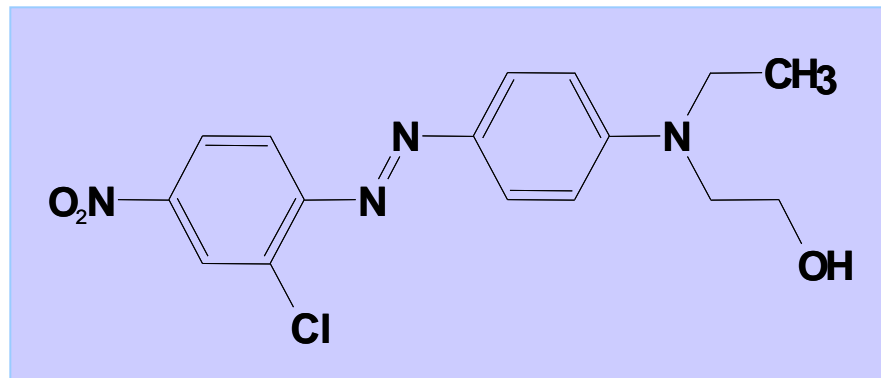


ethyl-2,4,6-Trimethylbenzoylphenylphosphinate

photoinitiator

Optically induced birefringence

To this resin we add the azodye Disperse Red 13 – DR13

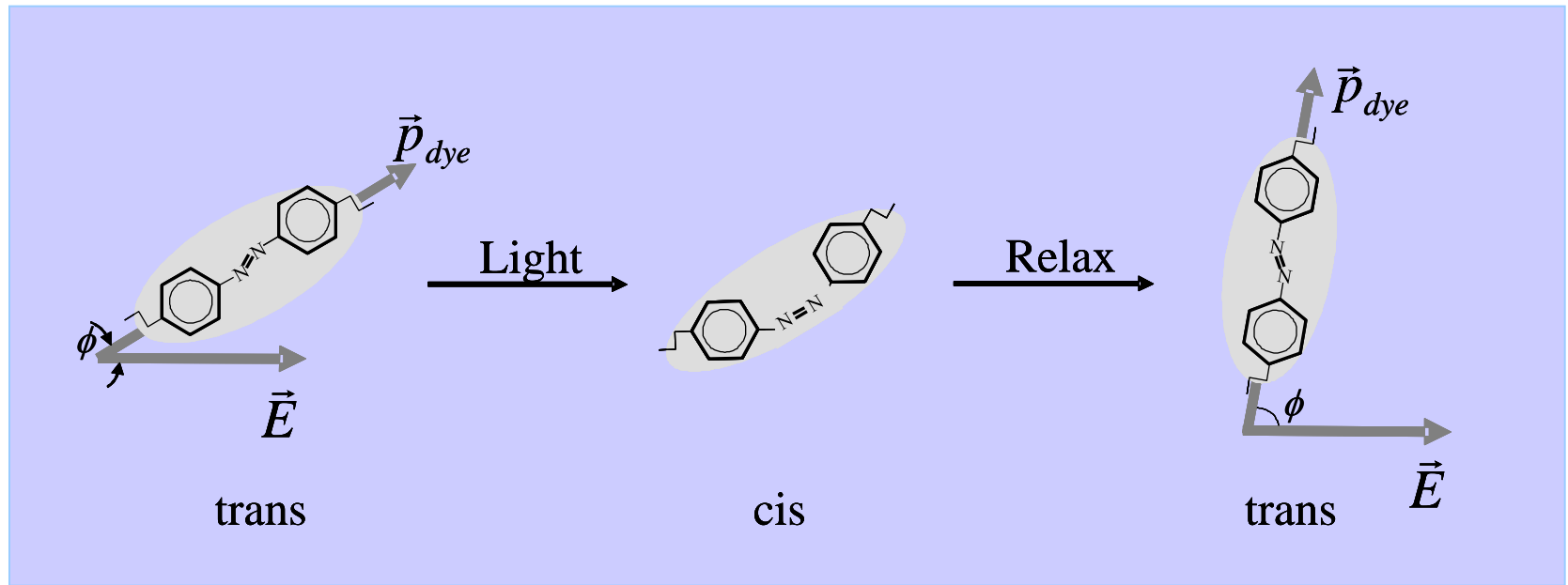


Molecular orientation by excitation with linearly polarized light

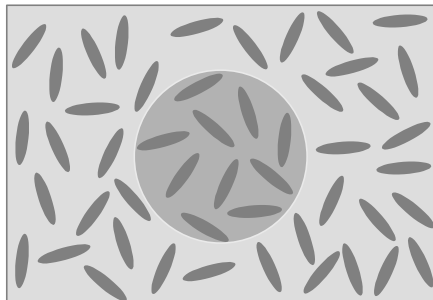


Optically Induced **birefringence**

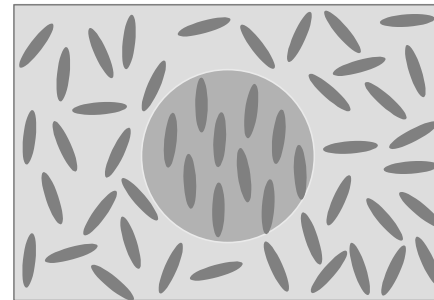
Optically induced birefringence mechanism



Before alignment



After alignment



Different compositions were studied

SR368 % : SR499 %

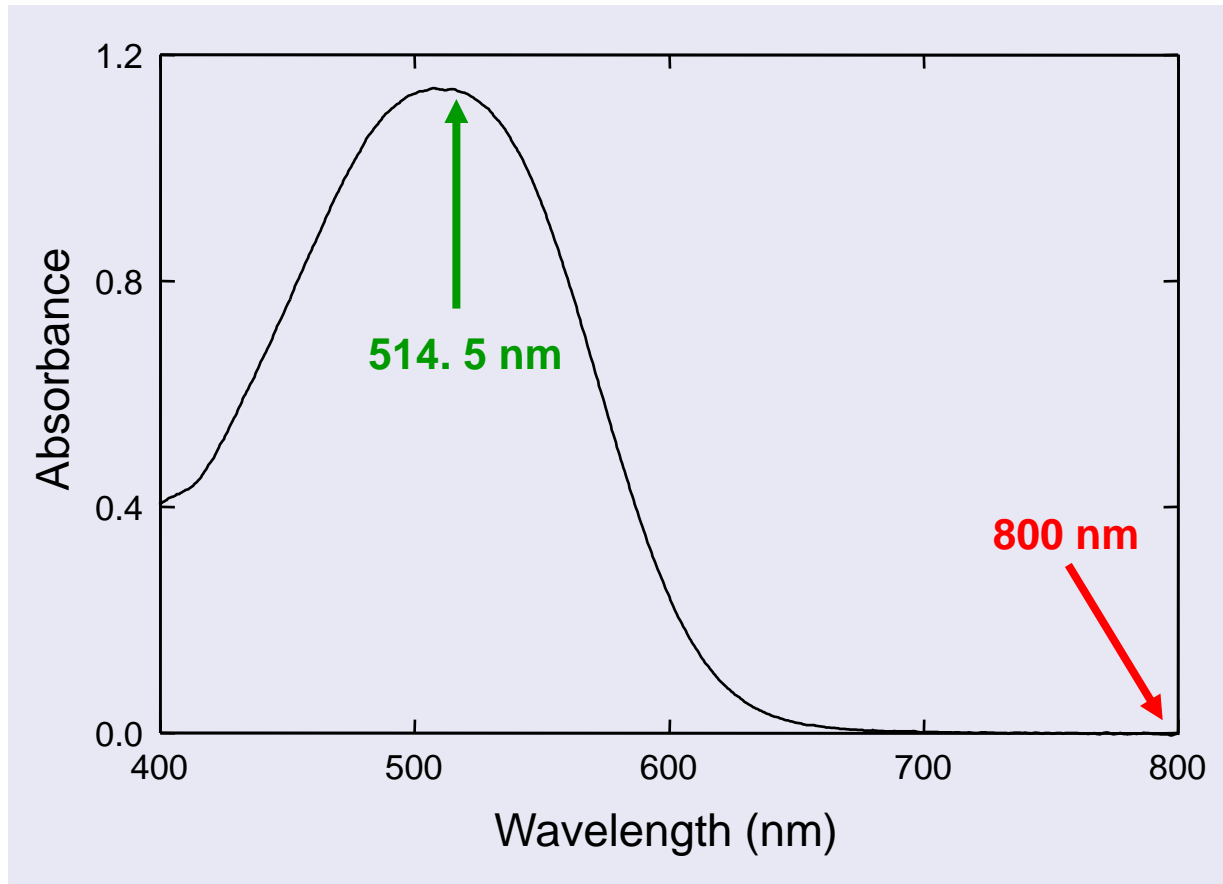
0	:	100
30	:	70
50	:	50
70	:	30
100	:	0

To **optimize** the birefringence features of the composition we prepare films:

Films prepared

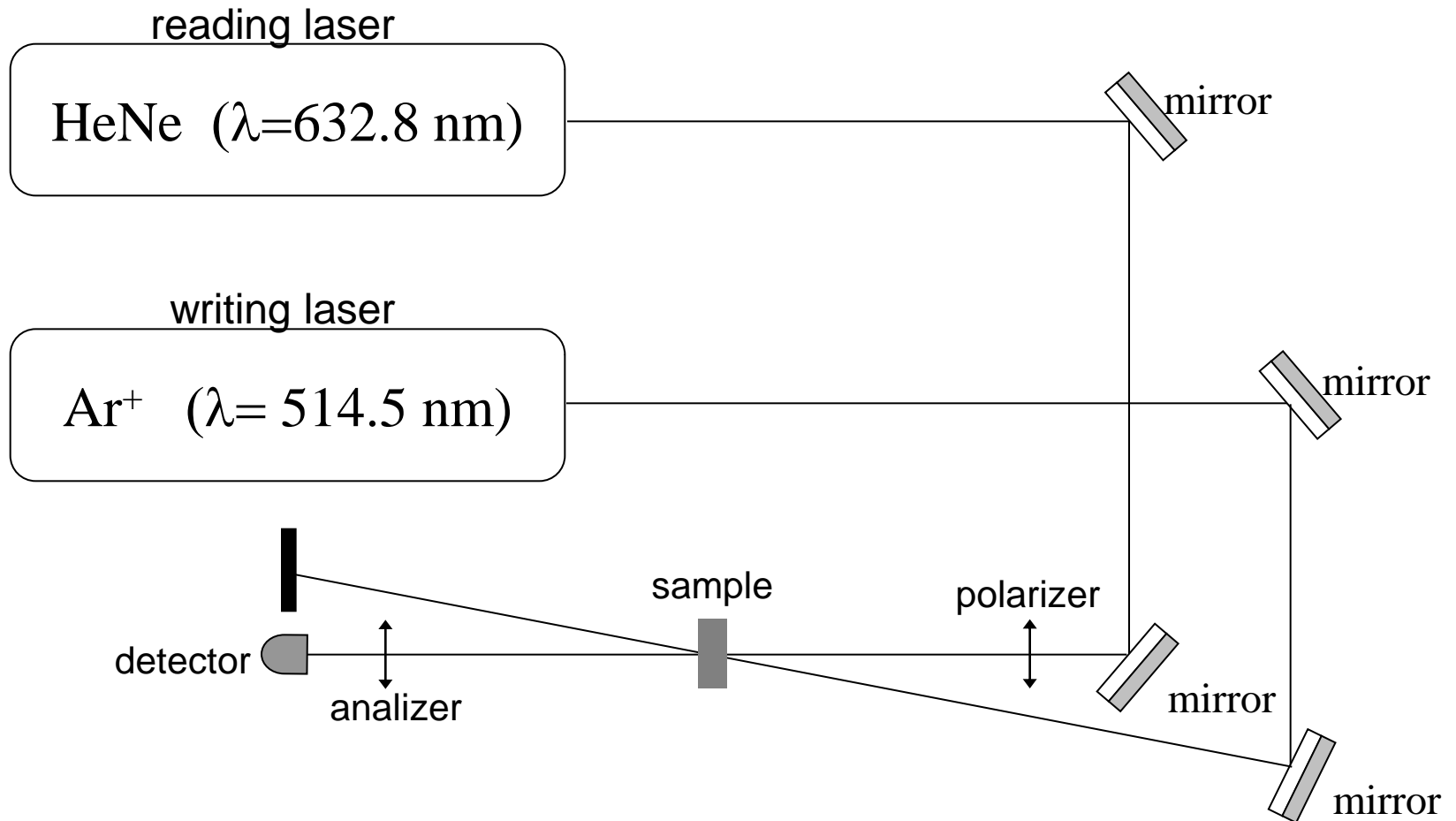
- L= 200 μm
- 1% DR13

Absorption spectrum of the resin with DR13



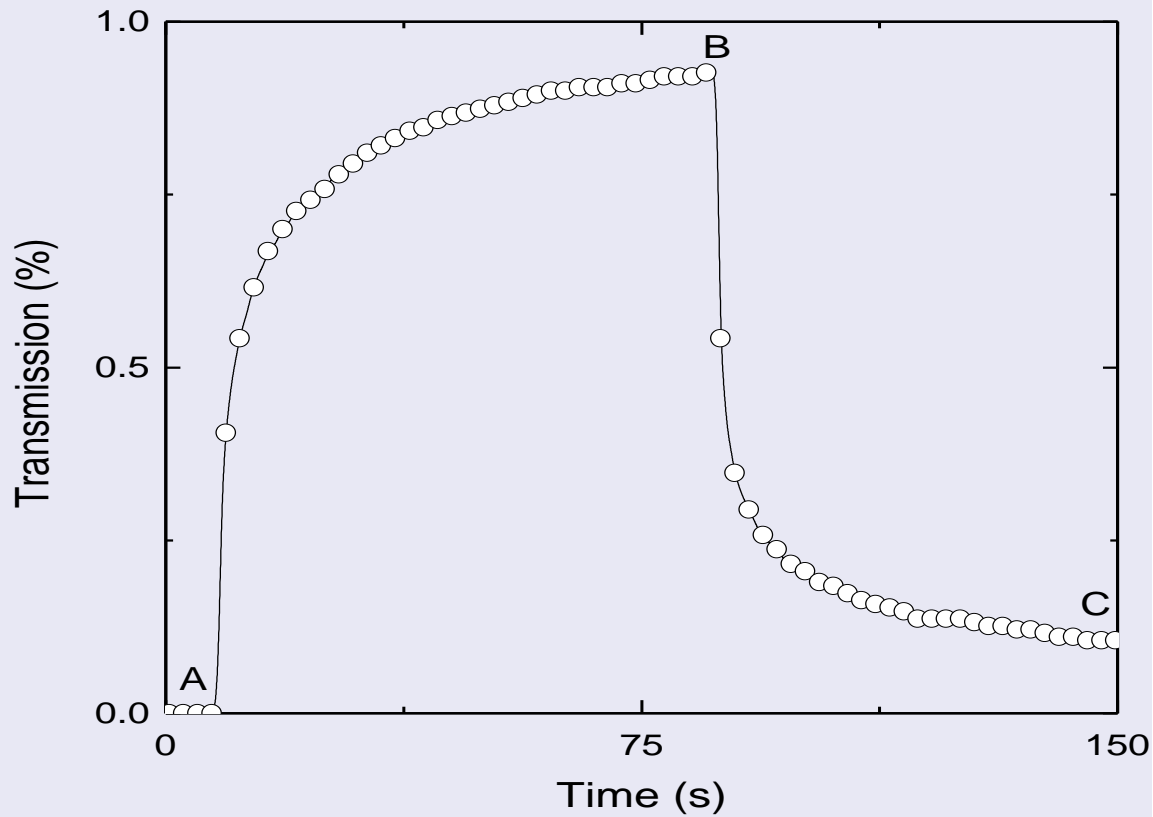
Sample 70:30 % (SR368: SR499)

Experimental setup for birefringence measurement in films



Optimization of the resin

Sample 70:30 % (SR368: SR499)



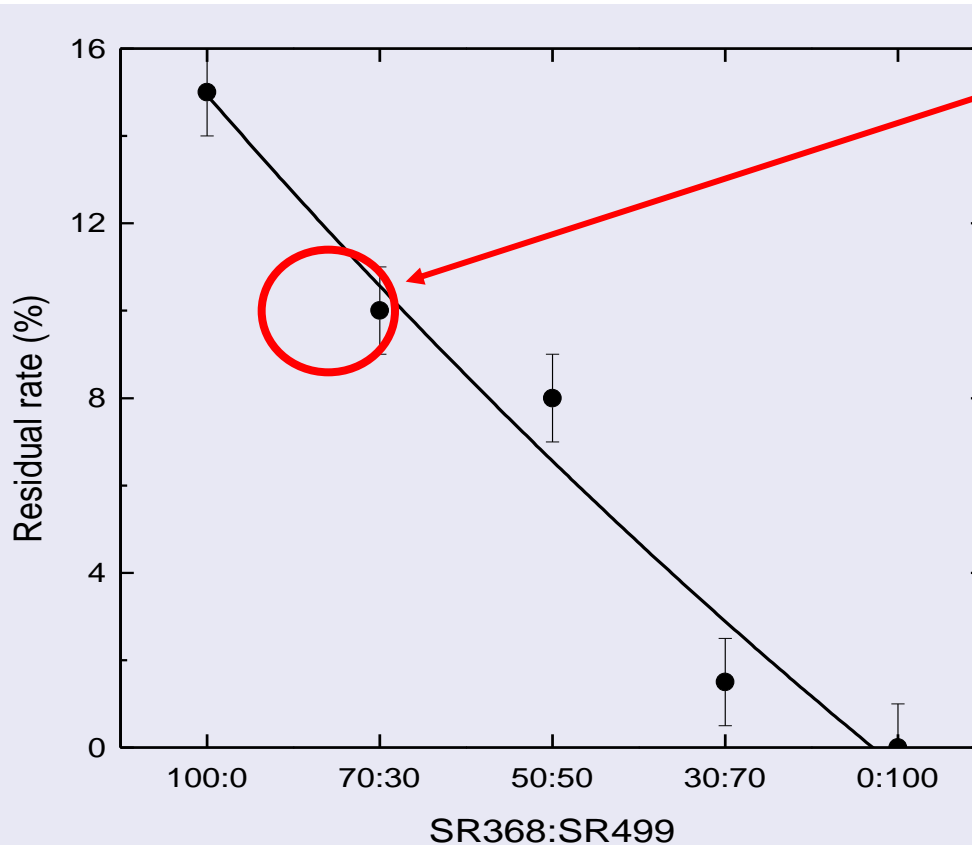
$I = 600 \text{ mW/cm}^2$

Maximum birefringence $\Delta n = 10^{-4}$

Residual birefringence $\Delta n = 3 \times 10^{-4}$

Optimization of the resin

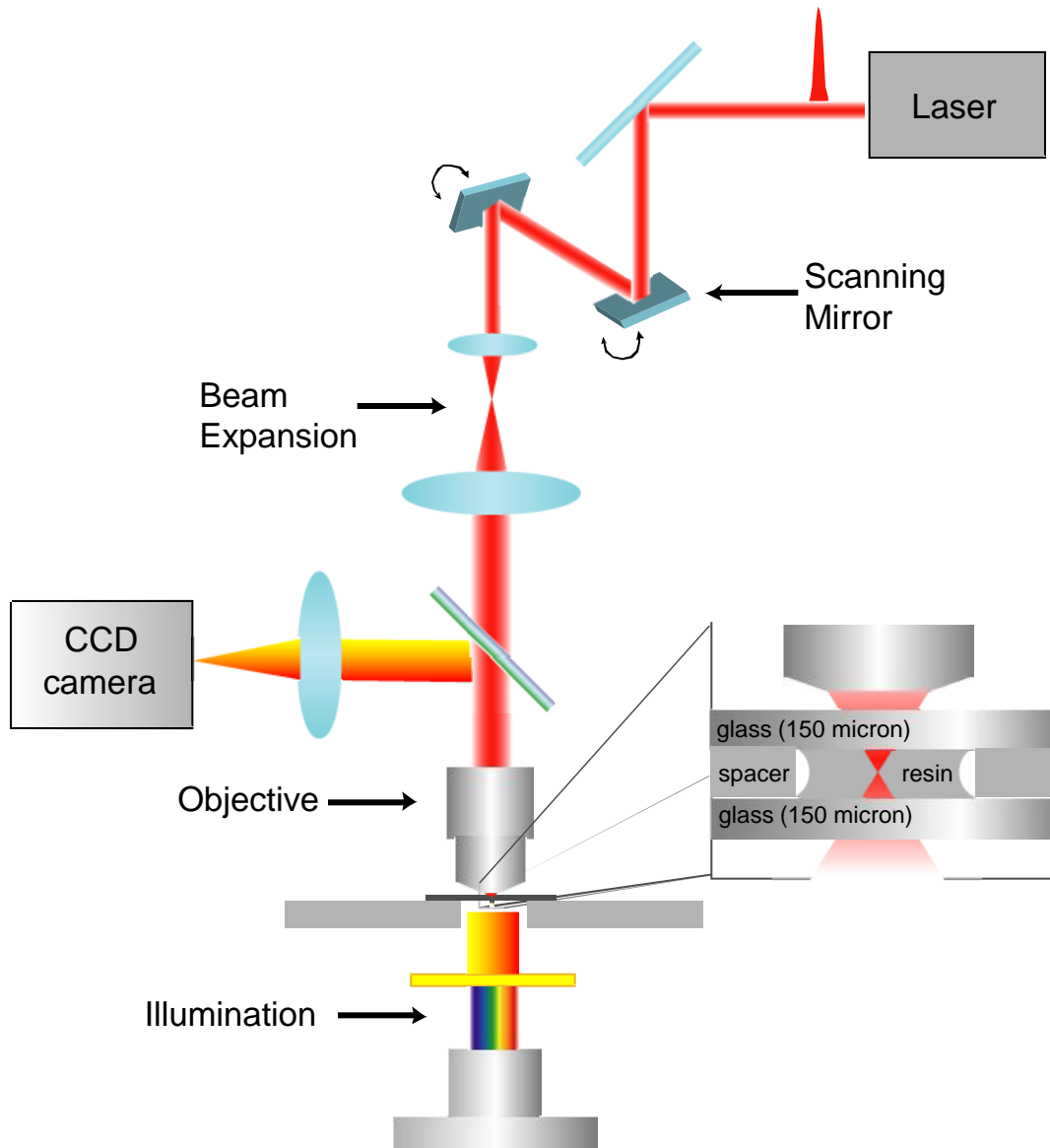
Residual rate for different compositions



SR368 : SR499
70 : 30 %

- 1 - more stable birefringence
- 2 - enough amount of SR499 to reduce microstructure shrinkage

Two-photon polymerization setup



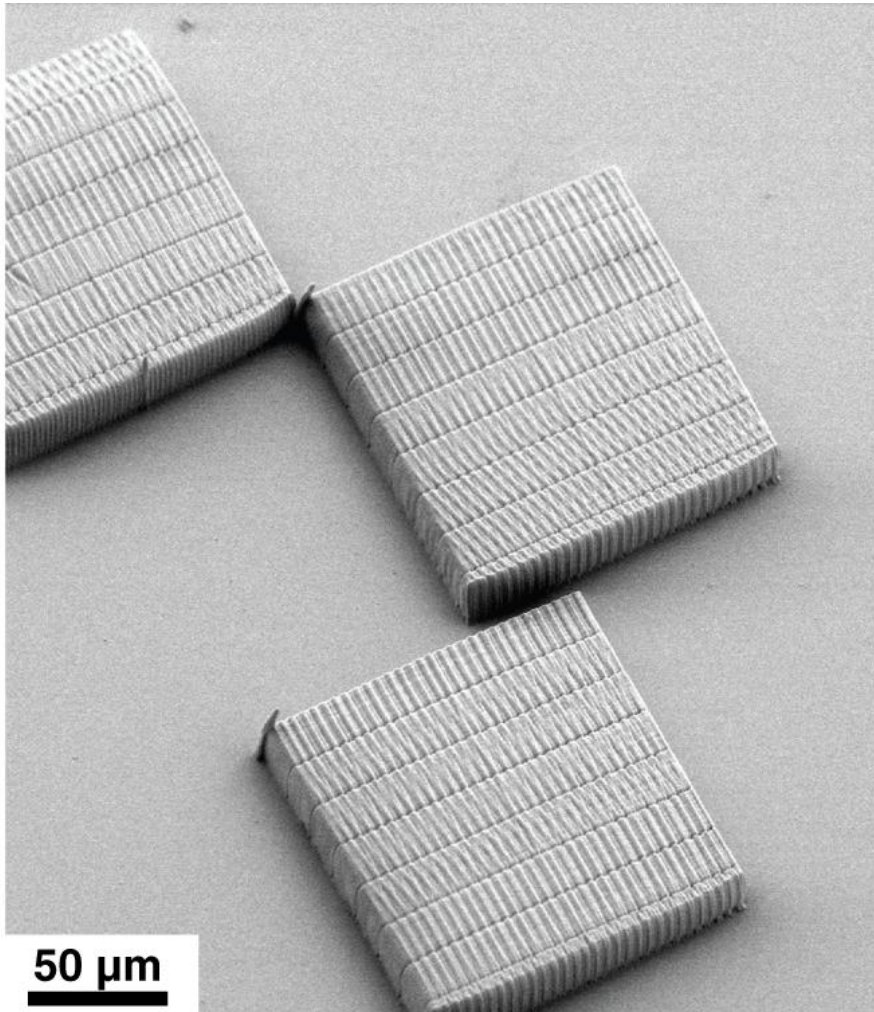
Ti:sapphire laser oscillator

- 130 fs
- 800 nm
- 76 MHz
- 20 mW

Objective

40 x
0.65 NA

Scanning electron micrograph of a solid square structures containing DR13 fabricated by 2PA polymerization.



- good structural integrity and definition

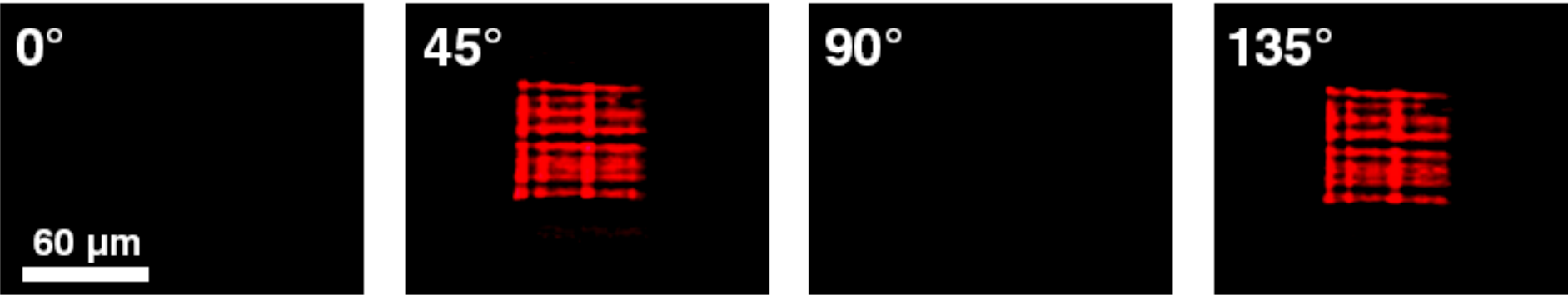
We induce optical birefringence in the fabricated microstructures

Ar⁺ ion laser irradiation

- 514.5 nm
- one minute
- intensity of 600 mW/cm²

Birefringence in the microstructure

The sample was placed under an optical microscope between crossed polarizers and its angle was varied with respect to the polarizer angle

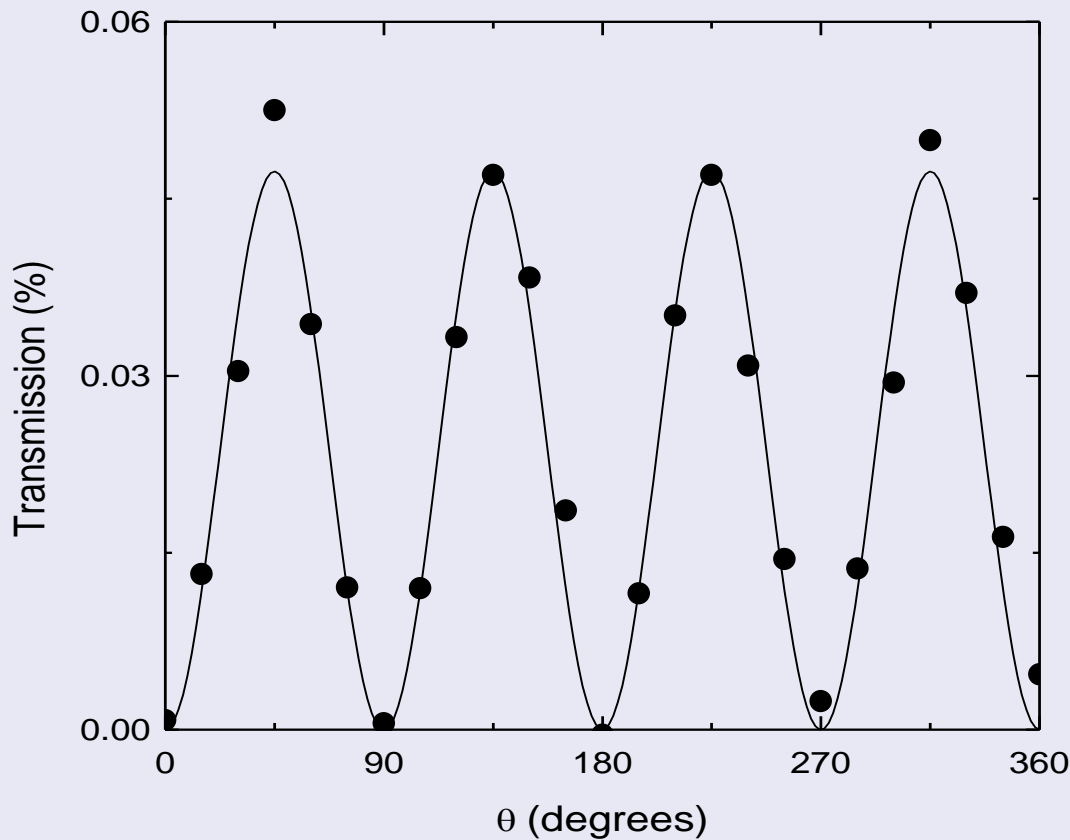


The structure is visible when the angle between the birefringence axis and the polarizer is an odd multiple of 45°

This birefringence can be completely erased by irradiating the sample with circularly polarized light for three minutes.

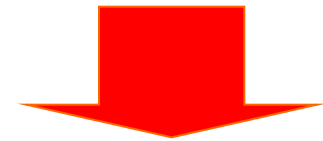
Birefringence in the microstructure

Transmitted light through the analyzer as a function of θ , for the previous microstructure



Sinusoidal behavior typical of the birefringence

$$T = \sin^2\left(\frac{k\Delta n L}{2}\right) \sin^2(2\theta)$$



$$\Delta n = 5 \times 10^{-5}$$

In summary we use 2PA to fabricate structures doped with an azoaromatic compound in which birefringence can be optically induced and erased. Such results open a new opportunities for the development of optical storage devices and photonic applications such as optical switches and connectors.

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