

Nonlinear Optical Transmission in Composite Liquid Crystals with Gold Nano-island Films

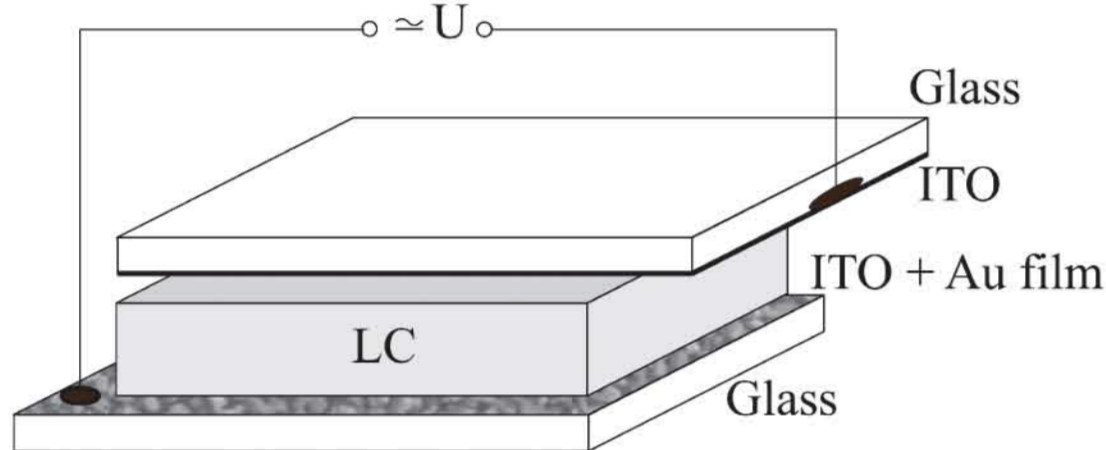
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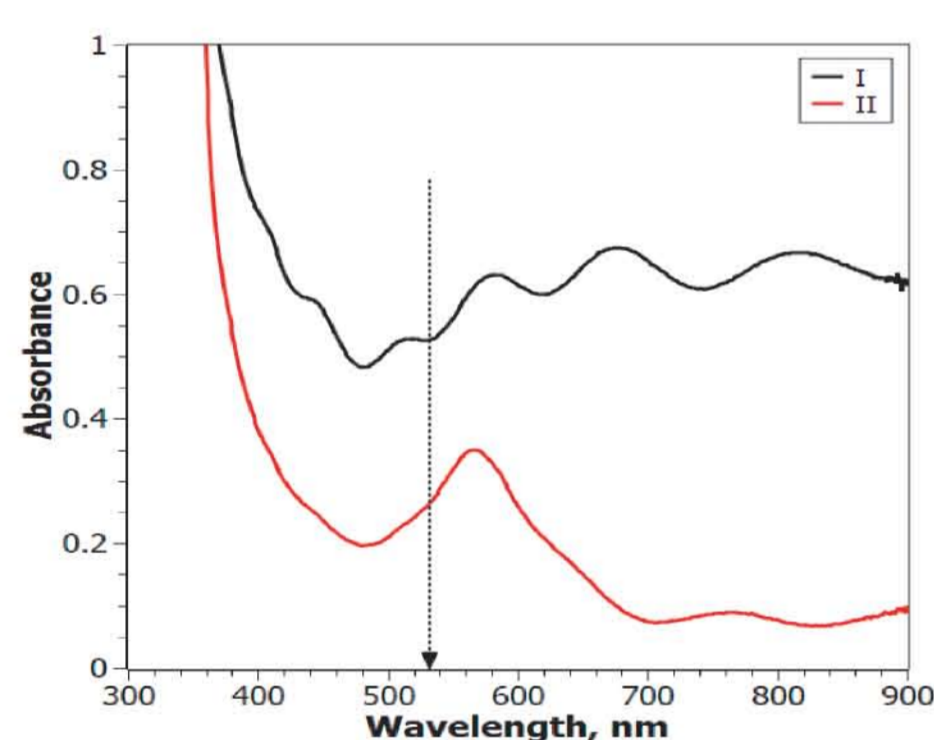
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Abstract: We are considering a new type of electro-optical liquid crystal (LC) cells, which includes a gold nano-island film deposited on ITO electrode of one of the cell substrates. We have revealed a fast nonlinear optical effect in these composite LC (CLC) cells [1-2]. The nonlinear optical properties of these cells are investigated upon excitation by powerful laser pulses. A standard z-scan method was used with applying a Nd:YAG laser ($\lambda=532$ nm, pulse duration $\tau=9$ ns). CLC cells contain nematic mixture E7 and have a thickness of $d=17.6$ μm (Sample 1) and $d=19.3$ μm (Sample 2); the maximal diameter of gold nanoparticles in the film is 9.15 μm . In the close aperture z-scan we have obtained effect of changing the sign of the nonlinear optical coefficient, which is associated with the dynamic of surface plasmon resonance in randomly shaped gold nanoparticles.

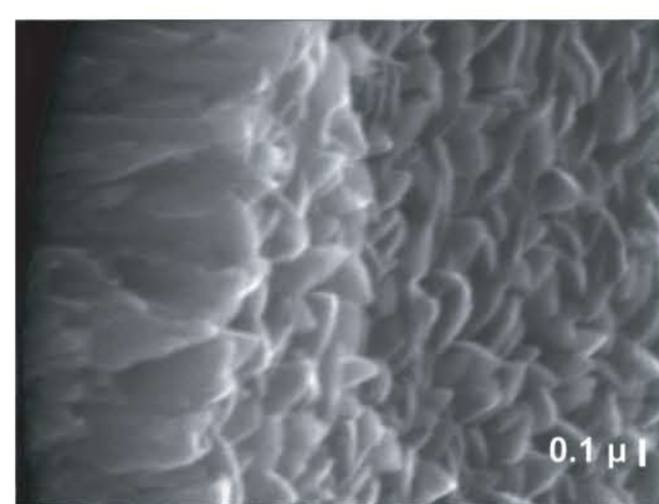
Composite LC cell contains a gold nano-island film on one substrate



Optical spectra exhibit surface plasmon resonance in gold NPs



We develop technique for deposition of Au nano-island films of different morphology on ITO surface

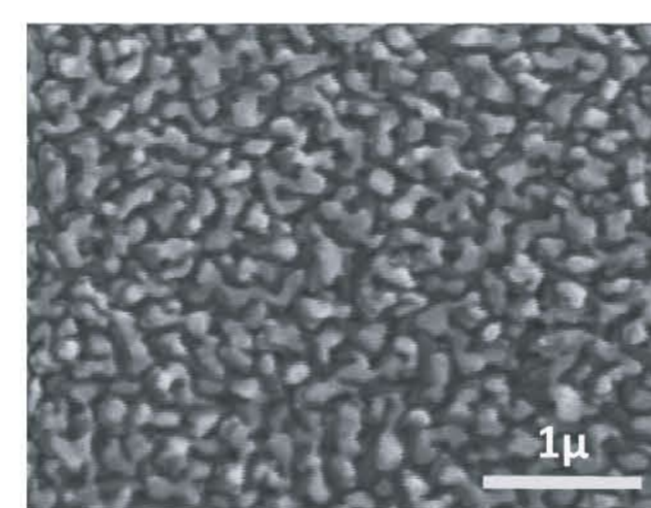


SEM image of an ITO layer on a rough surface (at angle 60°)

The size of roughness is up to 100 nm.

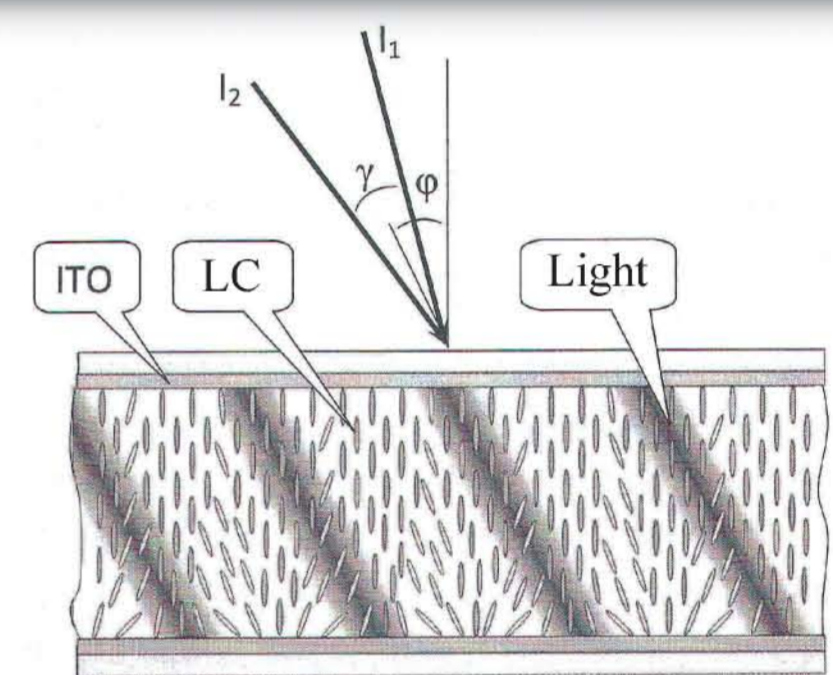
A gold film was deposited on the ITO surface by the vacuum thermal evaporation. Then it was heated at 550°C for 1 h in air.

The film contains gold islands with irregular shape of 100-300 nm of size.

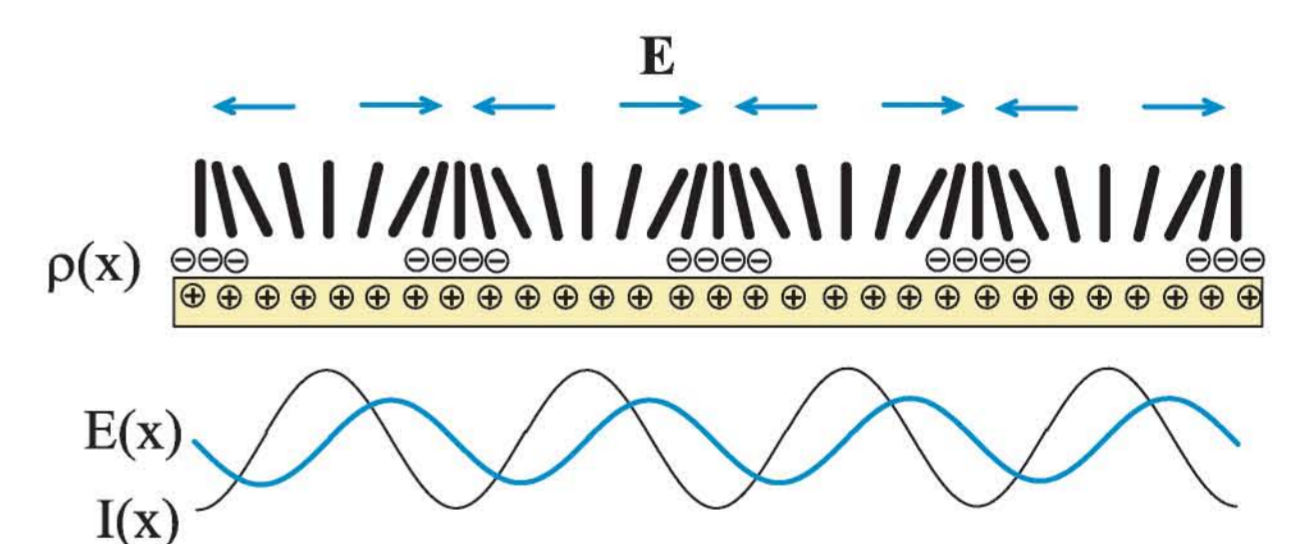
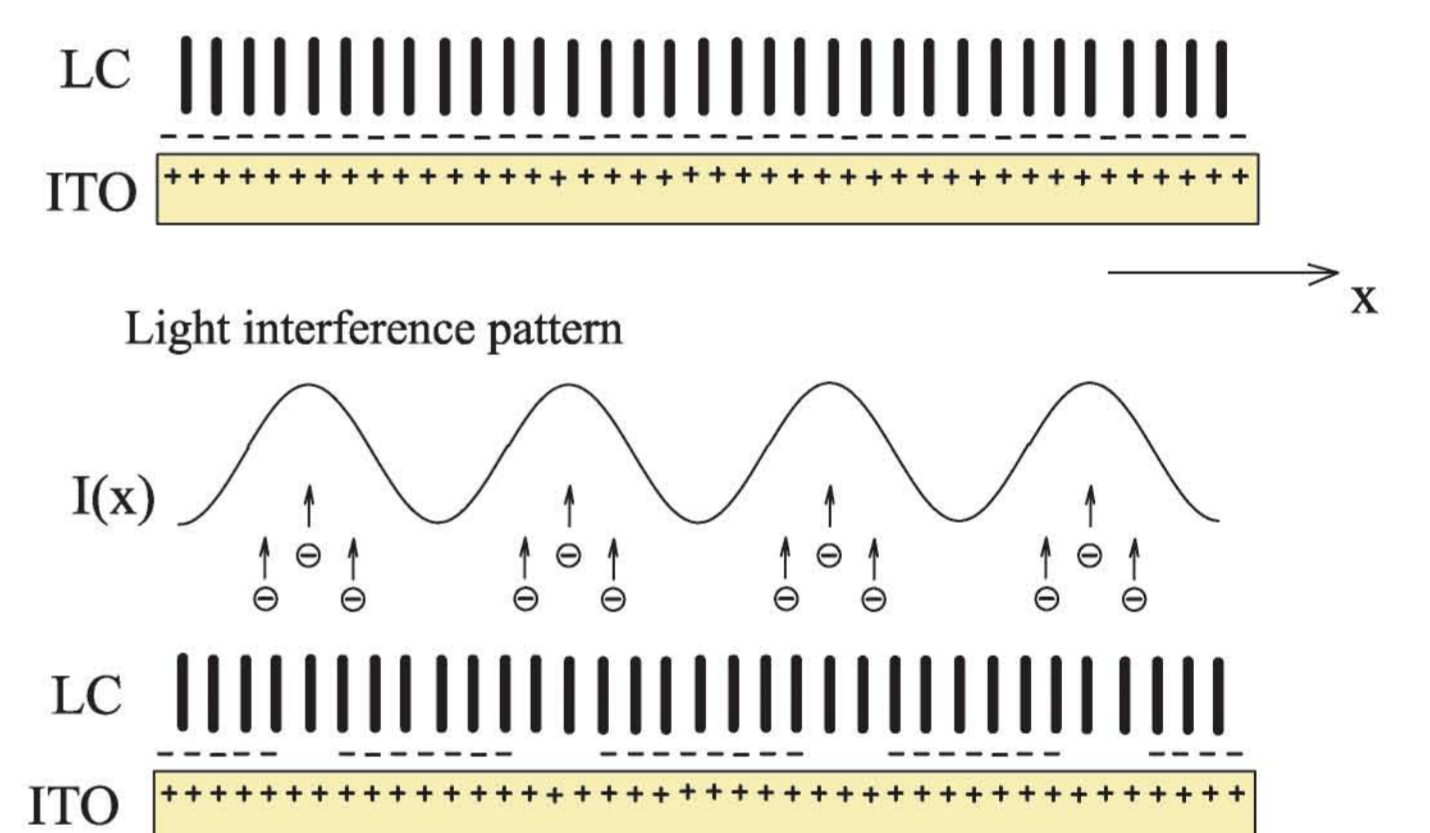


SEM image of a gold island film deposited on ITO with rough surface.

Surface-induced photorefractive effect in pure nematic LC [3]

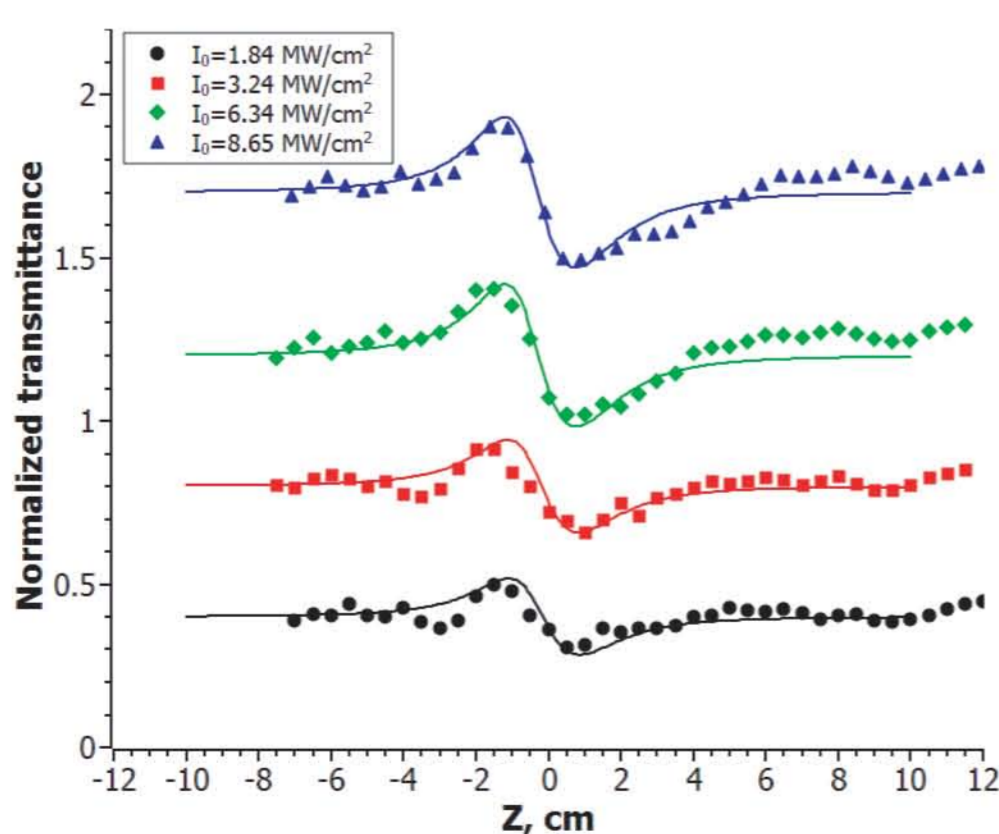


Surface-induced orientation nonlinearity in bulk LC

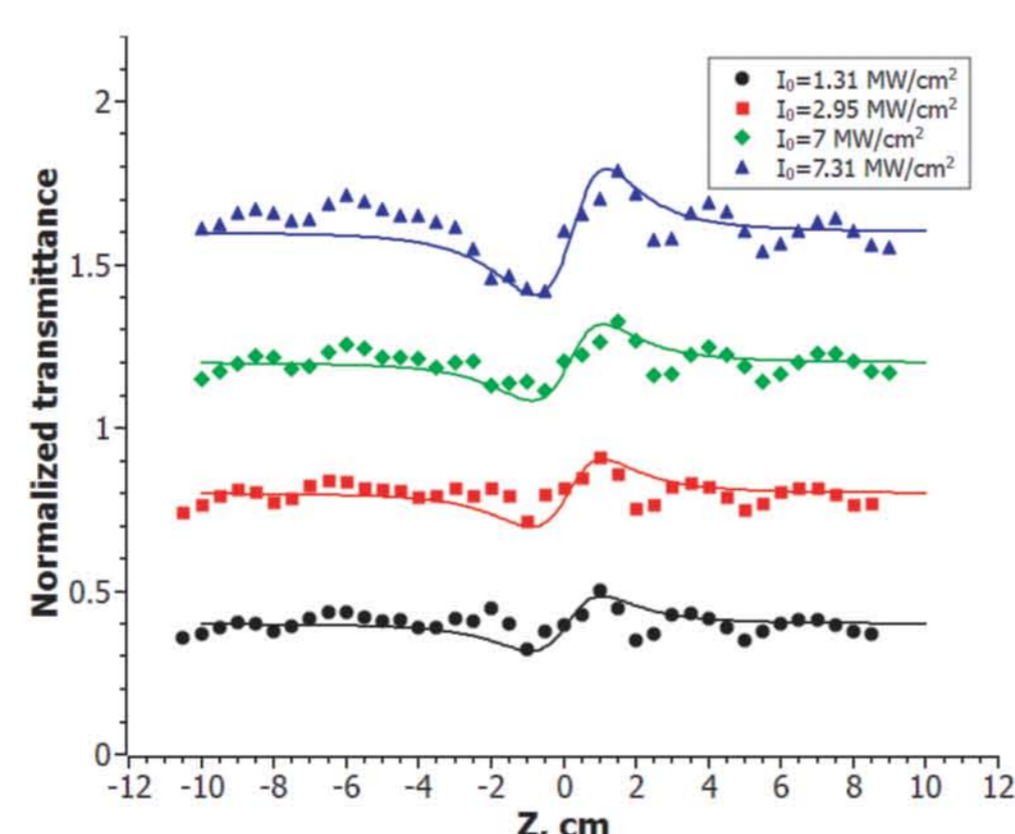


- Desorption of charge from surface to LC bulk under action of light interference pattern $I(x)$
- Formation of space distribution of charge $\rho(x)$ in the interface LC-ITO
- Creation of space periodic distribution of electric field $E(x)$ by unstable charge
- Periodic modulation of the director on the surface of the substrate ($\mathbf{d} \parallel \mathbf{E}$)
- Reorientation of molecules which comes from the surface to the LC bulk

Z-scan experiments with naocomposites



Close aperture z-scan, Sample I, self-defocusing process



Close aperture z-scan, Sample II, self-focusing process

Laser - YAG:Nd, pulse duration 9 ns, $f=0.5$ Hz, $I=2-13$ MW/cm²

Sample I:
 $n_2 = -0.97 \cdot 10^{-9}$ cm²/W,
 $\beta = 0.98 \cdot 10^{-4}$ cm/W;

Sample II:
 $n_2 = 0.72 \cdot 10^{-9}$ cm²/W

Conclusion: Composite LC cells containing gold nano-island films are studied by z-scan method.

The photorefractive mechanism of optical nonlinearity is due to generation of spatially inhomogeneous unstable charge on the interface ITO-gold nano-island film-LC.

We discovered a fast response time with a frequency of applied ac voltage in these LC cells that allows them to be used for practical purposes in electro-optical systems working in real time.

References:

1. S.Bugaychuk, L.Viduta, A.Gridyakina, H.Bordyuh et.al., Faster nonlinear optical response in liquid crystal cells containing gold nano-island films, *Appl. Nanosci.*, pp.1-6, (2020).
2. S.Bugaychuk, L.Viduta, L. Tarakhan et.al., Optical linear and nonlinear properties of hybrid liquid crystal cells containing gold island films, *Mol.Cryst.Liq.Cryst.* **696** (1) 93, (2020).
3. P.Pagliusi, G.Cipparrone, Photorefractive effect due to photoinduced surface-charge modulation in undoped LC, *Phys.Rev.E*, **69**, 061708 (2004).