The effect of surface plasmon resonance to reduce the time constants in the inorganic/organic interface

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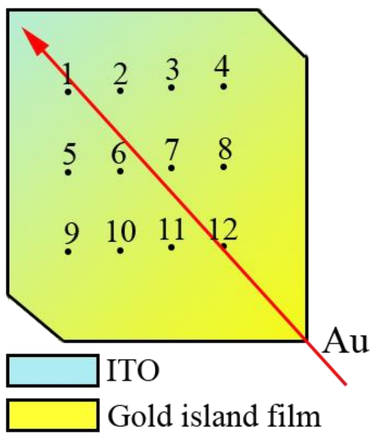
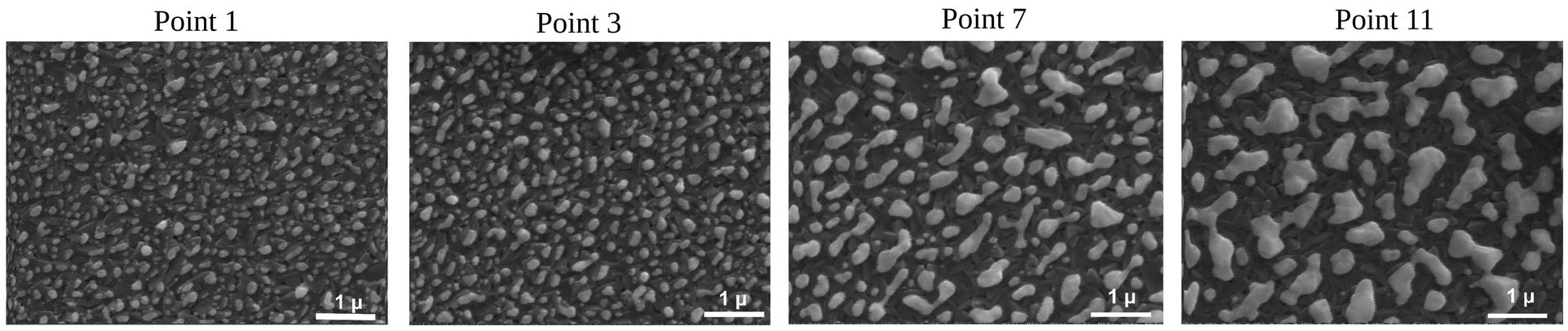
Introduction: Composite liquid crystals (CLC) cells having a nanostructured surface are promising materials for many practical applications, including spatial light modulators (SLM) [1]. We have investigated nonlinear-optical response in CLC cells using two-wave mixing technique with continuous frequency doubling Nd:YAG laser (λ=532 nm, power in each beam $I_{10} = I_{20}$ = 12.5 mW). The CLC cell includes a gold nano-island film deposited onto an ITO electrode on one of the substrates. The aim of our research was experimental determination of response time dependence on morphology of a gold nano-island film. In addition, detailed characterization of the morphology of gold films was performed.

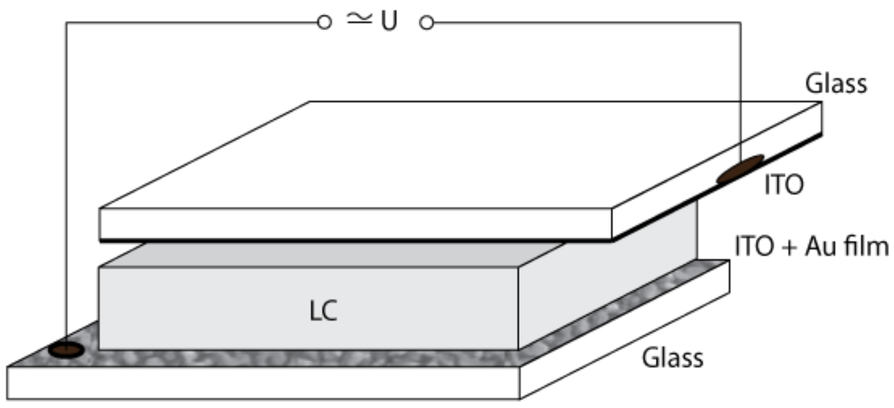
Methods and Results: Gold film was developed on ITO surface by the vacuum thermal evaporation. Than it was heated at 550 °C for 1h in air. The size of gold nanoparticles increases from 0.1 μm to 1 μm. The red arrow in the figure indicates the direction of the nanoparticle size change. SEM images were taken for 12 different points of the obtained sample of the gold island film. In the above images, one can see the change in the size of the nanoparticles of the gold island film.



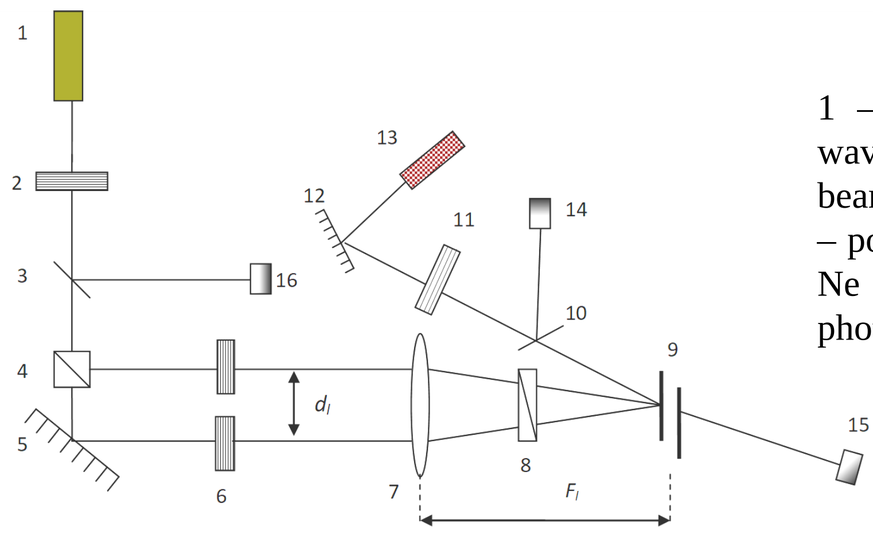


SEM images of gold island film with different size of nanoparticles deposited on ITO with rough surface.

Liquid crystal cell preparation:

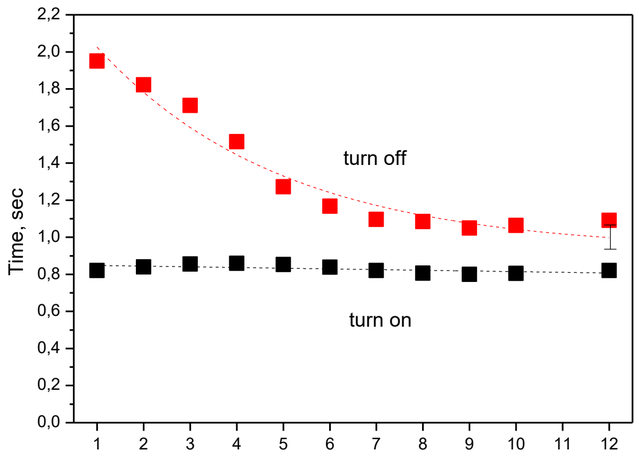


Experimental set-up for diffraction efficiency measurements:

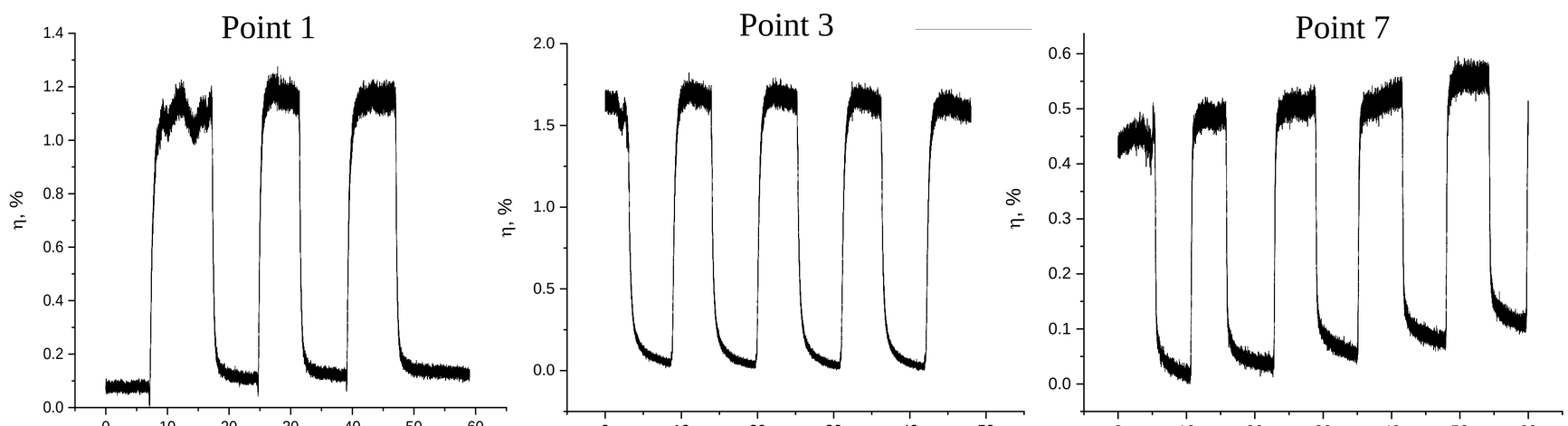


1 – DPS Laser (λ = 532 nm); 2– λ/2-waveplates; 3, 10 – beam-splitter plates; 4 – beam-splitter cube; 5, 12 – mirrors; 6, 8, 11 – polarizer; 7 – lens; 9 – sample; 13 – He-Ne laser (λ = 632.8 nm); 14, 15, 16 – photodiodes.

Dynamic gratings recording and relaxation times:



Diffraction efficiency measurements:



Conclusions: The experiments have shown that CLC cells demonstrate two different response times: τ_1 and τ_2 for dynamic grating recording and relaxation, correspondingly. Relaxation time τ_2 depends on the size of gold nanoparticles, decreasing as the average nanoparticle diameter increases from 0.1 μm to 1 μm. But recording time τ_1 in contrast to $\tau_1$doesn't depend on nanoparticle size. We also have found that response time depends on the roughness of the ITO surface onto which a gold film is deposited.

Our experiments showed low diffraction efficiency for samples with small gold nanoparticles. Also we have found, that for samples with large nanoparticles only quasi-stationary gratings were recorded.

Our studies let us suggest a theoretical model of surface-induced photorefractive effect (SIPE) in CLC cells, which is based on a formation of unstable space charge field on nanostructured surface. The experiments prove that this process relies on surface plasmon resonance excited by light beams in gold nanoparticles.

References:

1. *Bugaychuk S, Viduta L., Gridyakina A., Bordyuh H., Styopkin V., Tarakhan L., Nechytaylo V.,* Faster nonlinear optical response in liquid crystal cells containing gold nano-island films // Appl.Nanosci. - 2020.-10-P. 4965.
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3. *Zwick S., Haist T., Warber M., Osten W.,* Dynamic holography using pixelated light modulators// Applied Optics. – 2010. - 49(25). – pp. F47-F58.