Eötvös Loránd University

Faculty of Sciences

Doctoral School of Physics

Photoalignment in three dimensions

1[st] Semester Report

Materials Science and Solid State Physics PhD programme

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Introduction

The alignment of nematic liquid crystals (NLCs) on solid substrates is one of the key factors in electro-optic devices. The control of surface orientation of NLCs with the help of polarized light is not only an alternative, contactless method to ensure proper alignment at the cell boundaries, but – because of its reversible character – also opens up new possibilities of applications (rewritable displays, dynamic holography etc.), as well as may lead to unexpected phenomena, such as light-induced dynamic instabilities.
The research work targets basic research related to the photoalignment at the liquid crystal-polymer interface. Photoalignment in NLCs is known for decades, and for a given system, the basic mechanisms are well determined in two dimensions (either in-plane, or out-of-plane, depending on the given system, mainly optimized to the desired type of photoalignment). However, the knowledge about the general, three-dimensional mechanism of the process is extremely scarce. Our work intends to make significant contribution in this particular field, based on certain recent observations, which indicate that the present description of photoalignment is incomplete.
The principal aspect of the research is the study of the in-plane (azimuthal) versus the out-of-plane (zenithal) photoinduced reorientation of the nematic director, and the influence of the nematic liquid crystal (NLC) on the process. The laser-induced reorientation in LC cells with a pump-probe technique are planned for different parameters of the system, such as chemical composition of the photosensitive layer, clearing temperature of the NLC (T_{NI}), and the glass transition temperature of the azo-dye-assisted polymer.

Research work

The aim of the research work this semester was to investigate the role of the molecular structure of the NLC in the photoalignment process. For this purpose, the rigid core of the NLC has been systematically varied from biphenyl (E7 liquid crystal), through phenylcyclohexane (PCH5 and PCH7 NLCs), to bi(cyclohexane) (ZLI1695 NLC). These NLCs have been filled into special LC sandwich-cells prepared in our lab, consisting of a reference glass plate (with rubbed polyimide layer ensuring planar orientation), and a photosensitive glass plate. The preparation of the photosensitive plate includes: ultrasonic cleaning of the glass plates in various solvents, spin-coating of a PMMA polymer functionalized with azo-dye Disperse Red 1 (pDR1 polymer) from a solution in toluene, and baking at 140°C for about 2 hours. Sandwich-cells have been prepared with spacers between the glass plates. The thickness of the assembled LC cells has been measured by interferometric method.
Before filling the NLC, the cells were illuminated with white light, polarized perpendicularly to the rubbing direction. This procedure ensured a good quality planar initial alignment of the nematic liquid crystal. The quality of the planar alignment has been checked with polarizing optical microscope (POM).
Measurements on the photoalignment and photo-reorientation have been performed by the pump-probe optical setup incorporating the lock-in technique (***Figure 1***). The polarized pump beam (DPSS, λ=457nm) entered the cell from the photosensitive side, defocused to a spot size of few mm. The polarized probe beam from a He-Ne laser (λ=633nm) was sent through the cell, entering it at the reference plate. Behind the sample the probe beam was sent through a rotating

polarizer and its intensity was detected by a photodiode; the signal was connected to a lock-in amplifier.

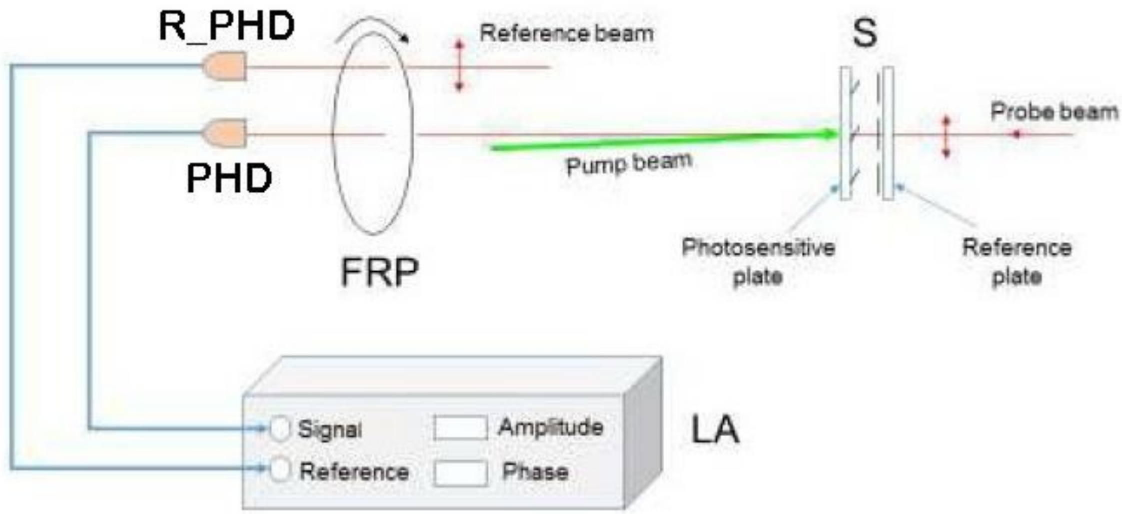

Figure 1. *Experimental setup for the detection of the orientation on the photosensitive plate. The polarization of the pump beam is regulated by a precise rotation of a λ/2 plate (not shown). FRP: fast rotating polarizer. LA: lock-in-amplifier. S: sample. PHD: photodetector for the probe beam. R_PHD: photodetector for the reference beam.*

The setup provides the phase and the amplitude of the probe beam transmitted through the sample. In order to determine the induced twist angle (in-plane photoalignment angle, φ), the probe beam was polarized parallel to the rubbing direction; the twist angle is given by the phase of the signal. To detect the zenithal reorientation, the probe beam was polarized at 45° from the rubbing direction and the amplitude of the signal was measured.
The results of these measurements can be summarized as follows:
(1.) The azimuthal photoalignment extends over a wider temperature range for NLCs with phenylcyclohexane and bi(cyclohexane) rigid cores (PCH5, PCH7 and ZLI1695) than that for NLC with biphenyl core (E7) – see ***Figure 2***.
(2.) In contrast to NLCs with biphenyl rigid core, where zenithal (out-of-plane) photoalignment has also been measured previously **[1]**, no such photoalignment process is detected in NLCs with phenylcyclohexane and bi(cyclohexane) rigid cores.
(3.) The photoalignment process slows down with the increase of the temperature (i.e., with the decrease of T_{NI}-T), and it completely disappears close to the clearing point T_{NI}, presumably due to the temperature induced anchoring transition described previously **[1]**.
(4.) When the pump-beam is switched off, the back-relaxation is also temperature dependent. The speed of the back-relaxation increases with the increase of the temperature.
(5.) Somewhat surprisingly, no systematic sample-thickness dependence of the photoalignment, nor that of the back-relaxation has been found.

These results, together with some additional measurements provide enough material for a publication in a peer-reviewed scientific journal.

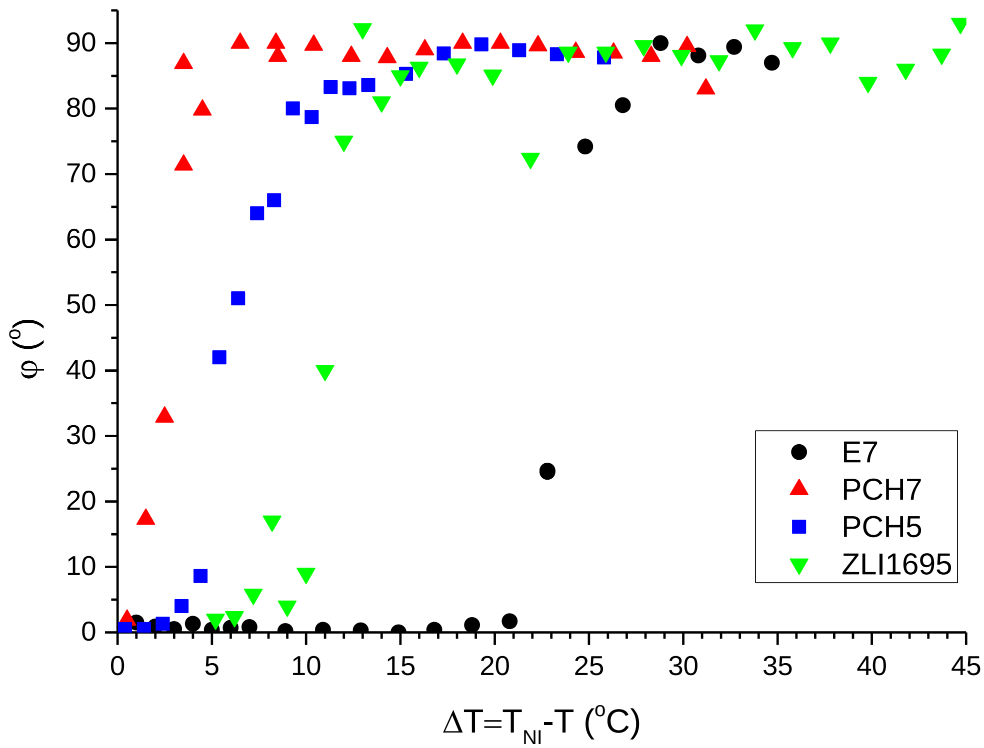

Figure 2. *Temperature dependence of the azimuthal photo-reorientation angle φ, measured in cells filled with various NLCs as indicated in the legend.*

[1] T. Tóth-Katona and I. Jánossy, *Photoalignment at the nematic liquid crystal - polymer interface: experimental evidence of three-dimensional reorientation.* J. Mol. Liq. **285**, 323-329 (2019).

Studies in this semester

- Bulk nanostructured materials (not yet graded)
- Low temperature plasma physics (not yet graded)

The exams will be held on 27-28 of January. I have attended these two courses that are not closely related to my research topic, because more relevant courses have not been announced in NEPTUN for this semester. According the plans, next semester I will attend courses more relevant to my research, such as Liquid Crystals, Polymers, and Micro and nanotechnology 1.

Activities

I have attended several Wigner SZFI seminars.