Ultrafast optical switching for polyarylates with allylic groups
by Nd: YAG Sagnac interferometer

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Ultrafast optical switching for thin polymer films (polyaryls with allylic groups) was
realized by Nd:YAG Sagnac interferometer.

I. Introduction

All optical switching as one of the most important process of optics telecommunication is
realized today in many configurations – both for organic and inorganic materials. In this
work photonics switching is presented based on nonlinear polymers, polyaryls with allylic
groups, generated in Nonlinear Optics Loop Mirror (NOLM) setup with Nd:YAG pulse laser.
Telecommunication optical systems in recent years are strongly conditioned by emergency of
development of faster data transfer [1]. New all optical devices are constructed. Fast reaction
on changes of external electric field of nonlinear optics polymers classified these materials for
such applications. For measurement of nonlinear parameters of novel materials different
optical techniques are used [2]. Polymers are presented as good candidates to produce hybrid
structures for light beam control in i.e. Sagnac, Mach-Zender, UNI, SOA configurations [3,4].
All optical interferometric operations are recognized as optimal tool to photonic signal
processing [5-8].
Presently, there is an intensive search for novel nonlinear optical (NLO) materials to design and prepare improved waveguide devices for nonlinear optical applications. Organic materials present a number of advantages over inorganic crystals because of their high and ultra fast nonlinear response and low dielectric constant, as well as the enormous design flexibility allowed by molecular engineering. Some novel strategies are now being actively pursued to optimize physical and nonlinear performance - the guest-host approach, and on the other hand, polymers with side-chain groups. The main goal is to obtain a good medium for all-optical applications, by enhancing 3-rd order nonlinear Kerr effect. New polymer material: polyarylates with allylic groups with p-nitroaniline in guest-host configuration has been synthesized [9] which show promising performance in NLO applications and acceptable properties for technological preparation of channel waveguides.

II. Experimental setup

For nonlinear switching measurement Sagnac interferometer, Babinet-Soleil compensator and beam attenuator were used. Source of light was pulse laser (Q-switched Nd:YAG) with SH 532nm and 9ns duration and maximum power of 2.7 MW. Nonlinear switching on Sagnac interferometer is based on two opposite parallel light beams passing through the sample – the first one with low intensity of light and the second one with high intensity that generates nonlinear effect.

Sample and attenuator are placed asymmetric so both pulses never are at the same moment in the sample. 9ns pulses take in space about 2.7 m, so interferometer mirrors must be located in adequate distance to guarantee time separation of pulses passing through sample. The experimental setup is shown at fig. 1.

High energy pulse on laser output passes through rotating $\lambda/2$ plate so polarization is changed to circular, then passes through polarizer turned to an angle of 45°. Intensity of light can be fluently regulated by rotating $\lambda/2$ plate. Polarizing beam splitter (PBS), splits beam on two beams, each 50% of power, with different polarizations. The first beam prior to passing through the sample passes through the attenuator where 90% of its power is lost. The second one with its full power passes through the sample and next through the attenuator. Low optical power beam generates only standard phase shift in sample without any nonlinear effect. High intensity light beam passing through polymer sample generates not only standard phase swift but also extra nonlinear phase shift (Kerr effect) depending on intensity of the
light. Geometry of the interferometer cause that both beams never pass through the sample in the same moment, so only one changes its phase. Both beams pass through the sample precisely in the same place, so all thermal effects and other low relaxation changes of refractive ratio have the same impact on both waves. At the end both beams come back to PBS and interference is observed at two different outputs.

Methodology of light switching is based on calibration of interferometer to reach minimum or maximum of interference at output 1 for low intensity of light on detector. In the first situation where experimental setup was dedicated for minimum of interference (during the increasing of the beam power), normalized signal on detector increases faster than in linear situation (Kerr nonlinearity) and reaches maximum when nonlinear phase shift is $\pi$. In the second situation when the beam power is increasing, normalized signal on detector decreases and reaches minimum when nonlinear phase shift is equal $\pi$. Babinet-Soleil compensator was used because samples should have at least 2 cm of thickness to reach $\pi$ value.

![Figure 1. The scheme of measurement setup - asymmetric Sagnac interferometer.](image)

Minimum of signal on output 1 corresponds with maximum on output 2 because interference images on outputs are moved by $\pi$. 

Detailed description of synthesis and properties of polymers mentioned above was published in work [9]. Final phases of synthesis of particular compounds are presented at Fig.1, and basic chemical properties are shown in table 1.

![Figure 2. Basic formula of polymer synthesis 2, 4, 5, 6](image)

<table>
<thead>
<tr>
<th>Polymer notation</th>
<th>Percentage of monomer (%)</th>
<th>Intrinsic viscosity $[\eta]$ [100 cm$^3$/g]</th>
<th>Glass temperature [$^\circ$C]</th>
<th>Temperature of decomposition [$^\circ$C]</th>
</tr>
</thead>
<tbody>
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<td>2</td>
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<td>0.915</td>
<td>120</td>
<td>231</td>
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<tr>
<td>4</td>
<td>10</td>
<td>0.770</td>
<td>102</td>
<td>252</td>
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<tr>
<td>5</td>
<td>8</td>
<td>0.673</td>
<td>111</td>
<td>245</td>
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<tr>
<td>6</td>
<td>6</td>
<td>0.863</td>
<td>120</td>
<td>246</td>
</tr>
</tbody>
</table>

Light switching was observed on the control interference fringes picture when intensity of the beam was strongly changed - figure 4. The obtained light switching is caused by nonlinear properties of polymer material. Changes of detected transmissions of split beam as a function of power are presented at figure 3.
Figure 3. Light switching - experimental results by Sagnac interferometer for selected polymers
Values of nonlinear refractive ratios $n_2^I$ were measured with similar method for selected polymers only and can be found at [10].

III. Conclusions

We have demonstrated possibility of all-optical switching in Nd:YAG Sagnac interferometer with nonlinear polymers – poliarylans with allylic groups. Nonlinear optics properties caused that investigated polymers are suitable candidates for further research to produce all optical switching devices as elements of integrated optics telecommunication systems. Structure of investigated polyarylates caused differences in values of nonlinear refractive ratios. Allylic groups caused better photocrosslinking in UV light so p-nitroaniline is better trapped and mechanical properties of layers are improved. The better entrapment of PNA leads to potentially higher EO effects after polarization process. However 3-rd order optical nonlinearity does not require any polarization. The optical Kerr effect is much higher when PNA is introduced to the polymer.
References


