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OPTOELECTRONIC DEVICES AND APPLICATIONS IN INFORMATION TECHNOLOGY

Summary of PhD thesis

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Objectives

In modern appliances, for example in the fields of information processing or data storage, use of optical, optoelectronic devices is recently often preferred to the conventional pure electronic solutions. In my thesis I investigated certain optoelectronic devices and their special applications, and by this I propose examination methods and new solutions with their use.

The most important light sources of the modern optical appliances are the lasers. Examination, qualification of them was one field of my researches. The coherence properties of the light source are important in most applications. In some cases the lasers with high coherence are applicable or convenient to use; in other cases the interference of the beams disturbs the functioning of the appliance, and thus small coherence length is favorable. The interferometric method for measuring the coherence function is often difficult and slow, so I found and investigated another measurement method.

Liquid crystal displays (LCD) are mainly used for displaying information for the user, but as they can modulate different properties of light, they can be applicable as spatial light modulators (SLM) for other tasks in information processing.

Many optical data processing and storage systems and also other applications require phase rather than intensity modulation of light. In practical systems it is advantageous to realize it with available components; I searched for a solution with LCD and polarization elements.

Holographic method is a promising solution for high density data storage. It is advantageous to record the Fourier transform of the data page in the hologram, but high intensity peaks are present in the Fourier transform of the LCD displaying bright and dark data pixels, which can reduce the recording quality because of the saturation of the holographic media. To avoid this effect, phase mask can be used, which introduces different phase shifts of the light coming from the bright pixels and smoothes the Fourier plane in this way, but it can also induce other difficulties. It would be better to realize complex ternary modulation of the SLM itself, i.e. to use two levels with high transmission and opposite phase (+1, -1) and a low transmission level instead of simple intensity modulation. Besides data storage it would also be useful in optical correlators and other applications.

At the Department of Atomic Physics of Budapest University of Technology and Economics (BUTE) we designed and built an experimental model of an acousto-optic delay line of a phased array antenna for true-time delay of broad band signals with the realization of the theory of path-length dispersion developed at the Faculty of Electrical Engineering and Informatics. The setup generated frequency dependent phase shift with a stepped mirror, this way the time delay of the system was not adjustable, limiting the practical importance of the experimental results. Proving the theory requires adjustable frequency dependent phase shifts realizing controllable true-time delay.

New scientific results

1. I developed a new indirect method for measuring the coherence function of lasers operating in few longitudinal modes. The base of the method is that the diffraction efficiency of the polarization holograms recorded in erasable and rewritable media with beams of various path-length differences is proportional to the coherence degree of the recording beams; thus the temporal coherence function can be defined easily and fast by measuring the diffraction efficiency. I applied the method for qualifying a frequency doubled Nd:YAG laser and experimentally proved its applicability. [5, 9]

2. I showed that by optimizing the angles of the polarization elements in a polarization optical system containing a simple, mass produced twisted nematic liquid crystal display, using laser light of 406 nm wavelength, complex ternary modulation can be achieved, which can be effectively used in holographic data storage to homogenize the Fourier-plane and thus to improve data recording, since the two high transmission states (+1, -1) have exactly opposite phase and their polarization intensity loss is small (<20%), and the transmission of the low state (0) causes negligible noise because of the contrast of 1:200. The setup optimized with the mathematical model has also been verified experimentally. [2, 4]

3. I recognized that the mass produced twisted nematic (TN) liquid crystal displays (LCD) widely used for intensity modulation are applicable as spatial phase modulators in optical setup consisting of wave retarders and polarizers for example for optical data storage or signal processing systems. Mathematically modeling the polarization optical system containing the TN LCD I found its low loss and approximately constant transmission phase modulating adjustment. I verified the calculated results with use of red, green and blue laser light. [3, 4]

4. I proposed the application of liquid crystal display operating as spatial phase modulator in acousto-optical delay line, which in this way generates long and adjustable true-time delay with path-length dispersion. It is principally useful in phased array antennas for radiating broad band signals. Frequency-dependent, controllable phase shifts can be introduced into the signal dispersed to frequency components by an acousto-optic cell; this results in frequency-independent time delay of the signal after recombination of the frequency components and reconverting into the radio frequency range. This can prove the theory of path-length dispersion. [1, 6, 7, 8]

Publications related to the thesis

1. P. Maák, J. Reményi, L. Jakab, P. Richter, I. Frigyes, I. Habermayer: „True time delay for short pulses based on optical path-length dispersion: Experimental proof of functioning" *Proceedings 2000 IEEE International Conference on Phased Array Systems and Technology* (Dana Point, USA, 2000) 449-452

2. L. Domján, P. Koppa, G. Szarvas, J. Reményi: „Ternary phase-amplitude modulation with twisted nematic liquid crystal displays for Fourier-plane light homogenization in holographic data storage" *Optik,* 113 (2002) 382-390

3. J. Reményi, P. Koppa, L. Domján, E. Lőrincz: „Phase modulation configuration of a liquid crystal display" *ICO XIX: Optics for the quality of life* conference, (Florence, Italy, 2002) 793-794

4. J. Reményi P., Várhegyi, L. Domján, P. Koppa, E. Lőrincz: „Amplitude, phase and hybrid ternary modulation modes of a twisted-nematic liquid-crystal display at ~400 nm" *Applied Optics*, 42 (2003) 3428-3434

5. J. Reményi, E. Lőrincz: „Coherence function measurement of a multi-mode laser by polarization holography" *European Conference on Lasers and Electro-Optics (CLEO-Europe 2003)* (Munich, Germany, 2003)

6. J. Reményi, P. Maák, I. Frigyes, L. Jakab, P. Richter: „Demonstration of continuously variable true time delay in frequency dependent phase compensating system with acousto-optics and liquid crystal modulator" *Optics Communications,* 226 (2003) 211-220

7. J. Reményi, P. Maák, I. Frigyes, L. Jakab, P. Richter: „Variable true time delay realized with acousto-optics and liquid crystal spatial light modulator" *Microwave Photonics 2003* conference (Budapest, Hungary, 2003)

8. J. Reményi, P. Maák, L. Jakab, P. Richter, I. Frigyes: „Improvements in optically generated variable delay lines for phased array antennas" *INICA 2003 International ITG-Conference on Antennas* (Berlin, Germany, 2003)

9. J. Reményi, E. Lőrincz: „Coherence function measurement of a multi-mode laser by polarization holography" (in Hungarian) *Kvantumelektronika 2003* conference (Budapest, Hungary, 2003)

Other scientific publication

10. J. Reményi, Ch. Carré, G. Pauliat, G. Roosen: „Development of a confocal DIC microscope to follow the kinetics of photopolymerization" *COST P8 workshop* (Paris, France, 2004)