6 Other publications

[5] F. Ujhelyi, M. Lovász, Z. Göröcs, A. Sütő, P. Koppa, G. Erdei, E. Lőrincz "Phase coded polarization holographic system demonstration, Holography 2005, International Conference on Holography, Varna, Bulgaria, 21-25 May 2005, CongressCenter Frederic Joliot-Curie", Proc. of SPIE 6252 (2006) 209-213 Holography 2005: International Conference on Holography, Optical Recording, and Processing of Information Editor(s): Yury Denisyuk, Ventseslav Sainov, Elena Stoykova

[6] P. Koppa, F. Ujhelyi, P. Varhegyi, T. Ujhelyi, Z. Göröcs, Zs. Nagy, B. Gombkötő, E. Dietz, S. Frohmann, S. Orlic and E. Lőrincz "New results in the modeling and experimental investigation of holographic storage systems," COST P8 Meeting, Loutraki, Greece, 26-27 May 2006

Optical Data Storage and Signal Processing Using Spatial Phase Modulation of Light

Ph.D. Thesis

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Atomfizika Tanszék
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5 Publications connected to the thesis

[1] Zoltán Göröcs, Gábor Erdei, Tamás Sarkadi, Ferenc Ujhelyi, Judit Reményi, Pál Koppa, and Emőke Lőrincz, "Hybrid multinary modulation using a phase modulating spatial light modulator and a low-pass spatial filter," Optics Letters, Vol. 32, Issue 16, pp. 2336–2338 (2007.)

[2] Zoltán Göröcs, Gábor Erdei, Tamás Sarkadi, Ferenc Ujhelyi, Judit Reményi, Pál Koppa, and Emőke Lőrincz, "Application of a phase-SLM and low-pass Fourier filtering to generate spatial patterns simultaneously modulated in phase and amplitude," CLEO 2007, Conference on Lasers and Electro optics, International Quantum electronics Conference, Munich, Germany , 17-22 June (2007)

[3] Zoltán Göröcs, Tamás Sarkadi, Gábor Erdei, Pál Koppa, "Hologram positioning servo for phase encoded data storage systems" submitted to Applied Optics, in review process (2010)

[4] Pal Maák, Zoltán Göröcs, István Frigyes, László Jakab, Péter Richter, "Continuously variable pulse true-time delay system incorporating an AO Bragg cell and an electro-optic modulator," Optical Engineering **43** (5), 1238-1243 May (2004)

compensates for the increased positional precision in phase encrypted holographic data storage systems. [3]

3. I built an optical system which uses an acousto-optic modulator and an electro-optic modulator, specifically designed for this purpose, to create a frequency dependent phase shift on the spectrum of the input signal, which will delay the signal in time. The advantage of this method compared to the former ones is its capability to fully continuously vary the time shift of the electric, microsecond wide pulses in a ±200ns range. [4]

1 Background

In recent years optics and optoelectronics became part of our lives. Optical end electronic applications have bound together in several applications, mostly in the field of information technology. This dissertation contains my results in two of these fields, in optical data storage, and in microwave signal delay lines. Both research topics were already in progress in the Department of Atomic Physics at the Budapest University of Technology and Economics before my research, and several publications were published before my arrival.

Among the Department's results in polarization holography are the publications and Ph.D. dissertations written about the theoretical and experimental study of the holographic material developed by the danish Risø Laboratory, the simulation software of the holographic data storage demonstrator, and the dissertation about the construction of the holographic data storage device. When I joined the research a phase encoded holographic data storage system family was under construction in collaboration with the Bayer Innovation GMBH.

Researchers at the Department of Atomic Physics made several publications about acousto-optic delay lines. The setup used stepped mirrors and later a spatial light modulator to achieve the frequency dependent phase shift, but continuous control of the spectrum was not available.

2 Goals

The most important goal of my research was holographic data storage, more precisely to develop a phase encrypted holographic data storage system which uses polarization holography and records the data to a thin card. My goal was to provide a solution to the problem of creating several compatible reader units, which required solving the problem of matching the position of the hologram and the read-out beam. One of the more troublesome component of the holographic system was the phase mask which made the setup difficult to assemble, and by replacing it I could considerably simplify the optical system. Furthermore, in the Department's research project of True Time Delay lines, my goal was to prove the path-length dispersion theory experimentally, with a continuously variable optical delay line.

3 Methods

During my research I implemented the previous holographic data storage algorithm in Matlab, and improved it to simulate the behavior of multiplexed phase encoded holograms. I also wrote a simulation algorithm which uses the model made by Kakichashvili to calculate the response of the holographic material. I tested the results of these simulation algorithms experimentally.

4 New scientific results

1. I created a simple 4-f optical system capable of simultaneous phase and amplitude modulation using a low-pass spatial filter and a phase-only SLM modulating on a $0 - \pi$ range, and tested the system's performance experimentally. I proved that the designed system can achieve 1/4th of the resolution of the used Spatial Light Modulator while modulating both amplitude and phase. I showed that the designed system can efficiently substitute the phase mask in holographic data storage systems. [1,2]

2. I developed a method to measure and compensate for the hologram shift in phase encrypted holographic data storage systems. I designed a phase modulation pattern with which the system is capable of measuring the displacement of the hologram, but it needs the recording of two holograms to the same area. I experimentally proved that in azobenzene containing polymers it is possible to write two holograms into the same area with the use of phase-code multiplexing. I developed a data page pair which can be multiplexed into the hologram and while they provide lateral shift sensitivity their data density equals the data pages previously used. The advantage of my method compared to the mechanical servo systems is that it corrects the position of the hologram electronically and this