MediaTest - I
Static test system for optical data storage media

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Introduction

Marks on write-once and rewritable optical data storage media are typically created by a thermal process initiated by a focused laser pulse. While for phase-change (PC) media the local heating induces a physical change between the amorphous and the crystalline phase, for magneto-optical (MO) media heating above the Curie temperature allows the reversal of the magnetic moment. These changes result in a change of the intensity or the polarization state of the reflected beam. For development or optimization of such write-once or rewritable layers a system is helpful, that allows to irradiate the media with a pulsed and diffraction limited laser spot, the pulse power and duration of which can be modified. Fast photodetectors allow measuring the change of intensity and/or polarization during and after the heating process initiated by the laser. These time resolved measurements reflect the dynamics of the media and are very important for the development of recordable media.

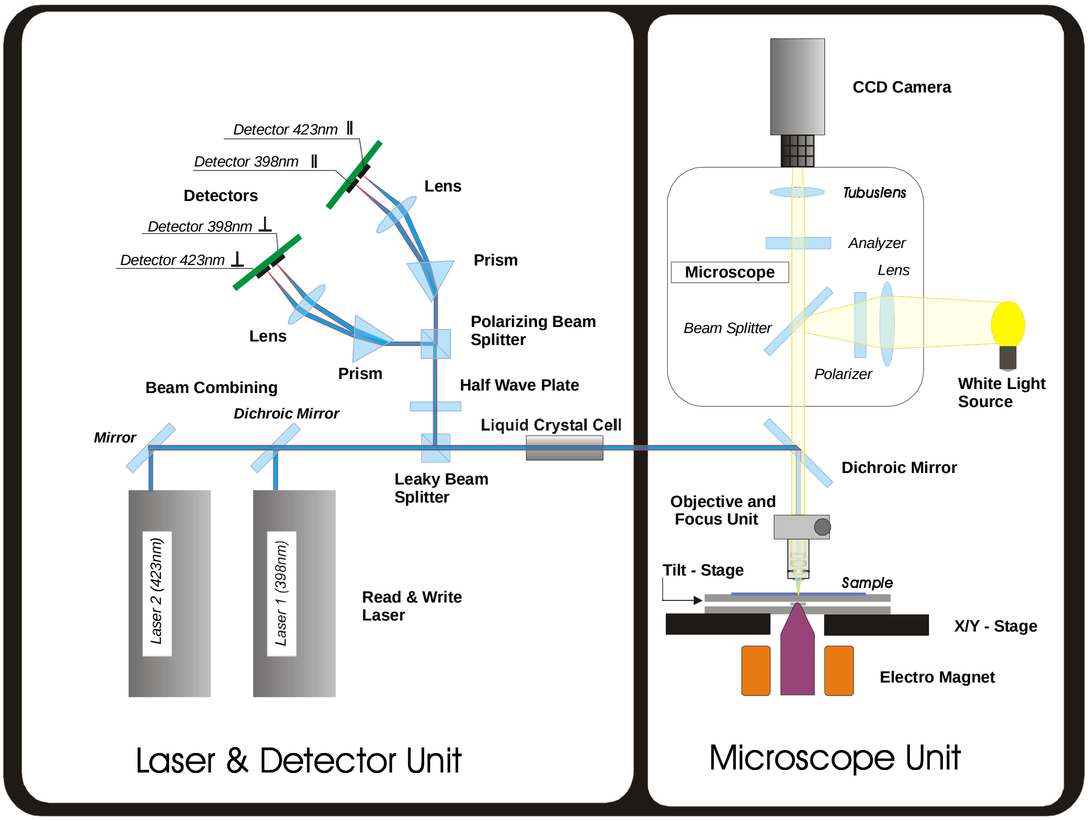

Figure 1: Schematic of the violet laser static test system.

Tester Setup

The system is based on a regular industrial microscope (Fig. 1). The standard part consists of an eyepiece and full color CCD camera for visual inspection of the sample, a white-light source for irradiation of the field of view, polarizer and analyzer for polarization microscopy. This part allows visual inspection of the written marks and is necessary for proper alignment of the instrument.

Connected to an extra port of the microscope a laser and detector unit allows to couple additional laser light into the microscope and to detect the reflected light. In this special type of tester two independently controllable light sources are used: One laser acts as writing source, heating the sample with adjustable pulse intensity and pulse duration (writing laser). The other laser, which operates continuously at low power, acts as the probe, detecting the intensity/polarization changes in the material (reading laser). The advantage of using two lasers is that the measurement of the changes in the material happens independently of the pulse shape or pulse intensity of the strong writing laser. Without that feature often problems with saturation effects or the linear response of the detectors occur such that measurements during the write pulse are hard to obtain.

In order to simultaneously couple the beams of read and write laser into the microscope, their wavelengths are slightly different, enabling the use of dichroic mirrors for the beam superposition. The optical setup of the MediaTest-I is available with lasers and optics sets in different wavelength regimes: a red wavelengths version e.g. with a DVD-compatible wavelength combination of 632nm/658nm is as well available as a violet version with 398nm/423nm for next generation disks (DVR, Blu-Ray).

The beams of the read and write laser modules are combined with a first dichroic mirror and are coupled into the microscope beam path with a second dichroic mirror, transmitting most of the visible range. Both lasers can be operated independently in cw or pulsed mode and include a RF circuit to allow low noise reading.

The leaky polarizing beam splitter (LPBS) transmits 80% of the p-light and reflects 100% of s-light, allowing PC measurements as well as MO measurements with the same setup. The liquid crystal retarder (LCR) is set to quarter-wave operation for PC media. For MO media it allows to introduce a controlled phase-shift between the p- and s-component of the reflected light. This allows correcting for any undesired ellipticity introduced by the MO sample, the substrate or any other component.

The beams are focused on the sample by the well-corrected microscope objective (NA typ. 0.6) and therefore are able to obtain diffraction-limited performance. The objective allows measuring on surface or through different substrate thicknesses by aligning the cover-plate correction collar.

The light backreflected from the sample is reflected by the dichroic mirror inside the microscope, passes the LCR and is directed to the detection section by the LPBS. It first passes a half-wave plate, which for MO media is used to balance the intensity on the two differential detectors. A polarizing beam splitter splits the p- and s-component of the reflected light. In the individual p and s detection paths prisms separate the two wavelengths and direct them to a split photodetector. For MO the p- and s-detectors are combined to obtain the differential signal, for PC only the one set of detectors is basically needed.

The sample is placed on a motorized XY-stage underneath the objective. For MO experiments a strong cylindrical magnet is mounted under the stage. Magnetic fields of up to 8 kOe can be obtained.

The complete system is operated from a personal computer that controls the laser power and pulse length, provides the readout from a digital oscilloscope, acquiring and digitizing the detector signals at high resolution, and controls the XY-table of the sample. The software supports automated experiments and automatically generates report files, logging all important parameters as well as camera images and data file names. The acquired data is saved in ASCII format that easily can be imported in all kind of third-party data-analysis programs.

Laser

The lasers and their drivers support pulses down to 5 ns duration with rising times of 2 - 3 ns. A built in pulse generator can generate single pulses down to 10ns duration. However, with an external pulse generator the full capability of the laser drivers, i.e. shorter pulses or pulse trains, can be exploited.

The high quality optics of the laser modules with wavefront errors below λ/20 assures diffraction limited performance and high resolution.

Sample Stage

The XY sample stage is equipped with encoders and piezo-driven linear-motors enabling backlash-free positioning with +/- 100nm resolution. Furthermore the sample stage is tiltable to allow optimum conditions with perpendicular incidence.

Figure 2:The TOPTICA logo written with a 398nm laser on a rewritable DVD. The logo consists of amorphous marks in a crystalline matrix having a nominal grid spacing of 500nm.

The picture was taken with the integrated CCD camera. The images can easily be saved in standard file formats and as an option the imaging optics of the camera allows variable magnification of the microscope image.

Typical Results

The results given here are examples for measurements that can be performed with the test system.

CD-RW

Fig.3 shows the results of a series of measurements on a commercial CD-RW, performed with a red version of the MediaTest-I, consisting of a read laser with 632nm and a write laser with 658nm. The write pulses in this example have a width of 200ns and the write power is varied between 5mW and 12mW while the read power is always 0.4mW. The curves were obtained by averaging over 15 individual marks. The change of reflectivity is clearly seen in the graph and shows a typical step appearance: The crystalline material is locally heated by the write laser pulse and due to the temperature change shows a different, intermediate reflectivity level during the pulse. After the pulse, the material quickly cools down, changing the reflectivity to a final, lower level belonging to the amorphous phase. A certain power level (5-6mW) is needed to induce the change of reflectivity and the final signal level clearly depends on the power level. The recorded read out signal reflects the reflectivity of the sample, integrated over the finite probing area defined by the read laser's spot size.

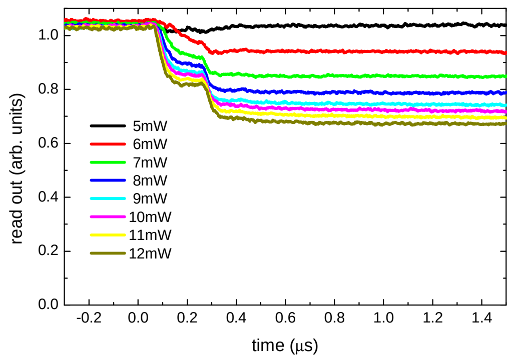

Figure 3: Varying laser powers on CD-RW

Figure 4 shows a microscope image of a pattern of marks resulting from such an automated experiment. For each row of marks a different set of parameters was used (varying write powers and pulse durations) and all marks within one row were used for averaging. The traces shown in Fig. 3 belong to the rows 12 to 5 (counting from top). The mark spacing is 2 micrometer.

The image helps interpreting the timeresolved transients since it shows that the different final signal levels in Fig. 3 are the result of different mark sizes rather than of different reflectivity values of the armorphous phase.

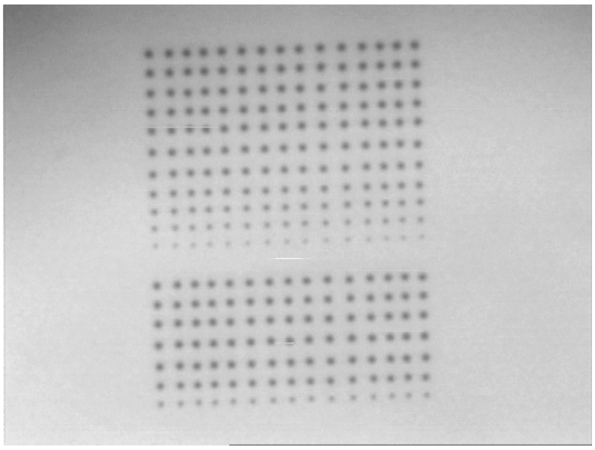

Figure 4: Mark pattern resulting from an automated experiment.

Figure 5 shows an example experiment studying the erasing dynamics of amorphous marks on a CD-RW. The amorphous marks were first written into the crystalline matrix with a 100ns-12mW pulse and were subsequently exposed to a weaker erase pulse of 5mW and varying pulse duration. While a 50ns pulse is not able to permanently change the materials phase back to the crystalline state, longer pulses are able to at least partially erase the marks. The slope of the transients for the longer pulses visualizes the finite 'crystallization speed' of the material.

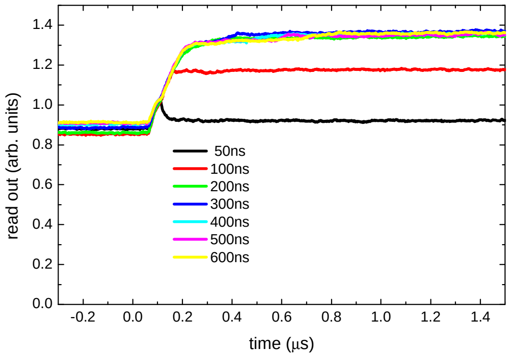

Figure 5: Mark erasing with varying pulse durations on a CD-RW.

DVD-RW

Figure 6 compares two phase-change experiments from the amorphous to the crystalline state on a commercial DVD-RW.

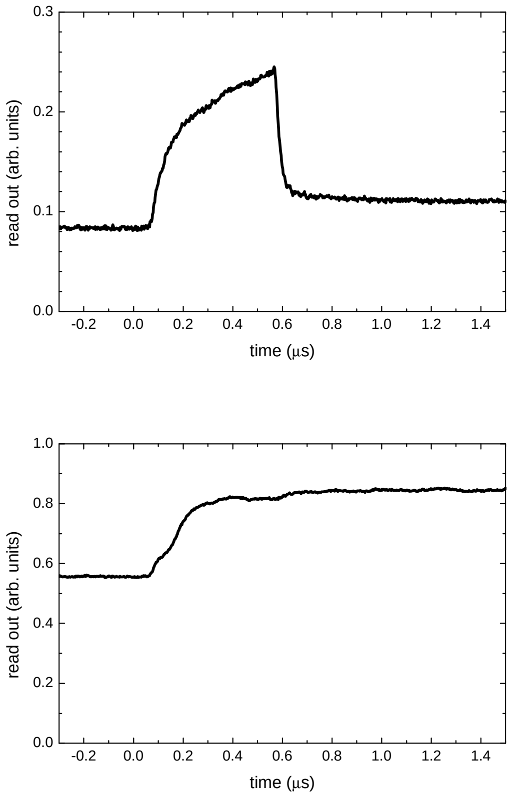

Figure 6: Erasing experiment on as-grown amorphous material (top) and on amorphous marks in a previously annealed area (bottom).

While both traces were recorded with 0.4 mW read power at 632nm and 500ns-5mW write pulses at 658nm, the upper trace shows a more or less fruitless experiment on as-grown amorphous material and the lower one the successful erasure of a written data mark The different results suggest an edge-growth dominated crystallization mode.

Figure 7 shows the microscope image of the area where the second trace was recorded.

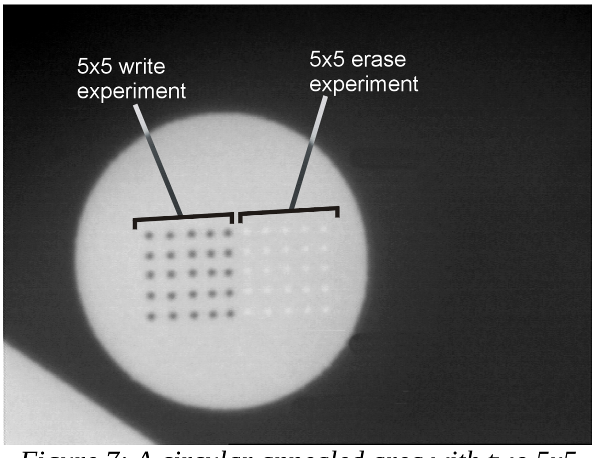

Figure 7: A circular annealed area with two 5x5 mark patterns of a write and an erase experiment.

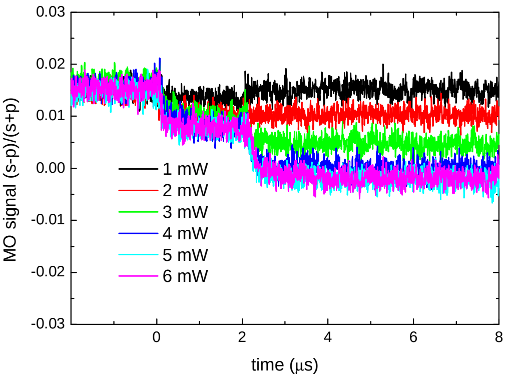

Figure 8: Timeresolved MO recording with varying write laser powers

A circular area was first annealed with a defocused exposure of the write laser. Inside the circle two 5x5 patterns can be seen. While the left pattern of dark, amorphous marks is the result of a write experiment (traces not shown), the hardly recognizable pattern of slightly bright marks is the result of an erase experiment where first marks were written and subsequently were erased (see lower trace of Fig. 6).

Typical MO results

As already mentioned above, also magneto-optical media can be investigated with MediaTest-I. For the detection of the Kerr signal now the complete detector setup of Fig.1 and the strong electro-magnet have to be used. The following paragraphs show results of some typical measurements.

Violet MO recording transients

Figure 8 shows some transients recorded with a set of violet lasers (read laser at 423nm, write laser at 398nm) on a commercial MiniDisc. The cw read laser was fixed at only 0.3mW on sample. The write laser was pulsed with 2μs pulse duration at six different power levels from 1mW to 6mW; additionally a magnetic field of 400 Oe was applied.

Before, a prepulse of 8.5mW and a magnetic field of 1 kOe in the direction opposite to the 400 Oe field applied during the timeresolved measurements initialized the material at each individual position.

Figure 9 shows a differential polarization microscope image of the resulting pattern of MO marks.

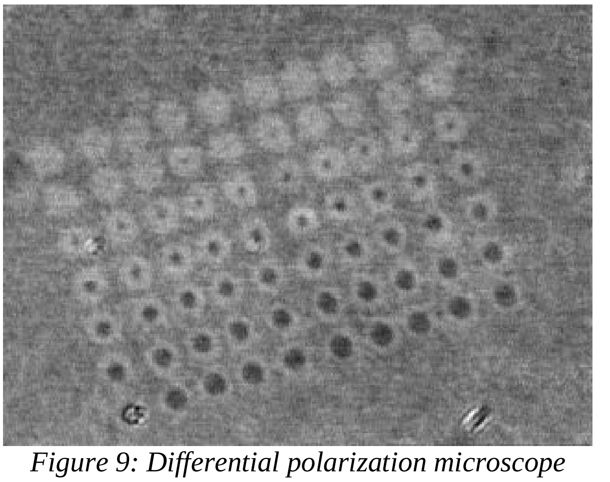

Figure 9: Differential polarization microscope image of the mark pattern.

The distance between the different sampling positions is 5 micrometer. The large, bright, circular marks, on each of the 10x7 positions are the result of the initializing prepulse with the 1 kOe field. The dark marks of varying size belong to the traces in Fig. 8, starting with 1mW write power in the top row up to 7mW write power in the bottom row (trace not shown). Clearly visible is the dependence of mark size on laser power.

Hysteresis loops

Fig.10 shows an example of hysteresis loop tracing performed on a MiniDisc. For this measurement only the read laser at 632nm is used. It was operated with 1mW in cw mode, firstly to detect the Kerr signal and secondly to adjust by its power a certain local temperature on the sample. The magnetic field then was scanned from 0 Oe to +4 kOe then to -4 kOe and so on. The dotted curve shows the originally recorded raw data. As already discussed in [1] the shape of the hysteresis loop looks different from conventionally recorded ones. Possible explanations given in [1] were the non-uniform temperature profile in the laser spot and the influence of the Faraday effect of the microscope objective. Measuring such a 'hysteresis loop' on a piece of silicon wafer indeed reveals an MO signal (s-p)/(s+p) which linearly depends on the magnetic flux of the magnet, supporting the Faraday explanation. The solid curve in Fig. 10 now shows the original data of the MiniDisc (see dotted curve) minus the linear dependence retrieved from the silicon wafer.

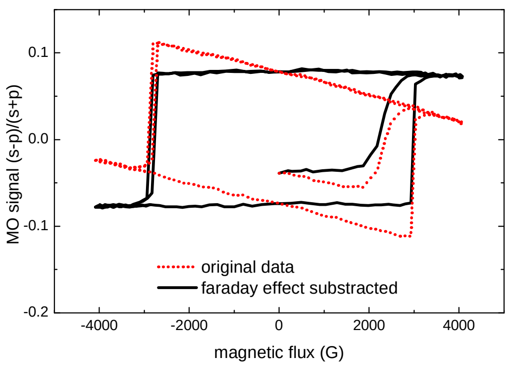

Figure 10: Hysteresis loop on a MiniDisc

Outlook

Due to its versatility the system can be used for other applications like general scanning laser microscopy. A similar instrument could also be used for characterization of the dynamics of magnetic materials via their magneto-optical behaviour.

In addition, the implementation of the pulsed violet laser source with wavelengths in the 400 nm range offers even more interesting possibilities. Media manufacturers can optimize their media for the next generation of optical data storage discs. Moreover, the smaller spot size may be interesting for many other applications like optical lithography and the high photon energy may be advantageous for all kinds of photoluminescence microscopy.

References

[1] M. Mansuripur, J.K. Erwin, W. Bletscher, P. Khulbe, K. Sadeghi, X. Xun, A. Gupta and S.B. Mendes
Static tester for characterization of phase-change, dye-polymer, and magneto-optical media for optical data storage
Appl. Opt. **38**, 7095 – 7104, 1999.