

**INFORMATION SOCIETIES TECHNOLOGY
(IST)
PROGRAMME**



1st Public PROGRESS REPORT

IST-2001-34168 - TwoDOS
Two-Dimensional Optical Storage

Public Report N°: 1
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TwoDOS/IST-2001-34168

Public Progress Report N° 1

(Period: 1 April 2002 / 31 March 2003)

Objectives (of the total project):

The further growth of today's information society will require larger storage capacities and faster access to ever growing data bases and digital content. The classical roadmap for optical storage seems to come to an end, both in capacity and in data rate. We propose to develop a new and challenging concept for optical storage in which the information written on the disc fundamentally has a two-dimensional character. We call this new concept TwoDOS (Two-Dimensional Optical Storage). The aim is to generate key technologies that realize an **increase over the 3rd generation** of optical storage with a **factor of two in data density** and a **factor of 10 in data rate** for an optical read-only system, based on innovative two-dimensional channel coding and advanced signal processing, in combination with a read-channel consisting of a multi-spot light path realizing a parallel read-out. TwoDOS will achieve a capacity of at least 50 GB for a 12 cm disc, with a data rate of at least 300 Mb/s.

A. Achievements (during the 1st half of the reporting period April 2002 - March 2003):

Considerable progress has been achieved on different fronts. The iterative loop that has to take place between the various Work-Packages (and partners) has already been started successfully. As major achievements, we distinguish:

(1) LBR-Mastering

the first successful mastering of LBR TwoDOS Discs (WP1) with random data (TwoDOS Phase-1 density, low-NA path) has been achieved using a write-strategy with one pit-hole per pit-bit;

(2) Test-Player

the test-player (WP5) has become almost fully operational (in its low-NA version for a 7-row spiral), with the integration of blue-laser, diffraction grating, high-NA lens and 7-spot photo-detector, and through the implementation of some new algorithms for servo-control;

(3) Signal Processing Architecture

the (algorithmic) structure of the complete TwoDOS receiver has been defined in detail for the signal processing (WP3). It consists of a number of blocks such as ADCs, Noise-Filters, Delay-Compensation block, DC-Control and VGA-Control block, non-linearity compensation block, 2D Equalization block (partly adaptive), Sample-Rate-Conversion block, Bit-Detector block and Control/Acquisition block. An early version of a software receiver has become operational and is tested on the synthetic scalar diffraction signals;

(4) Signal Processing: Bit Detection

a number of candidate 2D bit-detectors (duo-binary hexagonal response bit-detector, iterative soft-decision bit-detector, stripe-wise bit-detector) has been generated, with current focus on the duo-binary hexagonal bit-detector;

(5) Signal Processing: Hardware

the basic architectural choices for the TwoDOS hardware platform have been made;

(6) Channel Modelling

the signal-generation model for binary modulation based on a scalar diffraction approach has almost been completed; this model has been used as input to research on signal processing algorithms (bit-detection), and has delivered the parameters for the LBR and EBR mastering; it has further revealed a typical non-linearity problem that needs extra measures in the signal processing and/or in the write-channel; with the same formalism, a scalar-diffraction model for M-ary (multi-level) modulation in TwoDOS has also been realized;

(7) **Channel Characterization**

channel characterization software has been generated, tested and evaluated for the first time;

(8) **Channel Modulation Code**

a 2D modulation code has been designed, which eliminates worst-case patterns for TwoDOS bit-detection;

(9) **Overall Work-Plan of the TwoDOS -project**

last, but not least: one of the important iteration loops of the TwoDOS Work-Plan has been closed for the very first time:

LBR-Disc-Mastering <=> Test-Player <=> Channel Characterization <=> Signal Processing

B. Achievements (during the 2nd half of the reporting period April 2002 - March 2003):

Considerable progress has been achieved on different fronts. As major achievements, we distinguish:

(1) **LBR – Mastering**

A further successful optimization of LBR discs has been carried out for the Low-NA Path with very low Media Noise; we have achieved an increased contrast with very steep edges of the pitholes, hereby combatting the observed proximity-effect in the land-areas on the disc that are located between many pit-holes.

(2) **Signal Processing: Algorithms (1)**

We have developed a decision-directed zero-forcing (ZF) timing recovery algorithm integrated with fast adaptive control for gain variation and offset variation which turned out to be significant from experimental replay signals on LBR discs; from this, a considerable improvement in channel characterization and bit-detection is realized compared to frame-based timing recovery as applied in the original approach.

(3) **Signal Processing: Algorithms (2)**

A new "Phase-2 Compatible" bit-detection scheme has been devised that is based on a "sum-product" algorithm with a very special impulse response.

(4) **Signal Processing: Algorithms (3)**

We have designed efficient algorithms for preamble detection and frame synchronization.

(5) **Signal Processing: Bit-Detection**

Additional measures have been taken in the "Stripe-Wise" bit-detector for severe complexity reduction of the associated hardware without a significant reduction in performance. The "Stripe-Wise" bit-detector has been chosen as the final bit-detector for the project.

(6) **Channel Modeling**

We have gained conceptual new insights of performance-limiting channel nonlinearities based on clusters with all-pit neighbours (prohibiting the optimum receiver of reaching its maximum performance).

(7) **Channel Coding**

We have devised a 2D channel code addressing the "worst-case behaviour" by a kind of scrambling code tailored to the hexagonal lattice and its 7-bit clusters.

(8) Test-Player: Evaluation of Bit-Error Rate on LBR-Discs

Phase-1 Low-NA Path bit-detection on Experimental Replay Waveforms has been realized, yielding a bit-error rate (BER) of below $5E-05$ for at least two types of bit-detectors (e.g. stripe-wise bit-detector, and a two-stage gradient bit-detector designed for media noise) with more than 90% of the bit-errors caused by small error-bursts. We have realized three light-paths with different NA's in Test-Player for scaled "Low-NA Path" evaluation of LBR mastered discs.

(9) Signal Processing: Hardware

We have devised an efficient and integrated concept for the Software-Receiver design in view of an efficient transfer from WP3 towards WP4 (hardware development at HWCComms).

The hardware has reached the completion of the most complex FPGA card, which is the FPGA daughter card on which the Virtex-II FPGA will reside.

(10) Test-Player: Photo-Detector IC

Availability of the 11-spot PDIC (testing in June 2003)

Papers :

- [1] W.M.J. Coene
"Two-Dimensional Optical Storage"
Optical Data Storage (ODS) Conference, Vancouver, May 11-14, 2003,
Technical Digest, pp. 90-92 (paper TuB1).
- [2] A.H.J. Immink, W.M.J. Coene, A.M. van der Lee, C. Busch, A.P. Hekstra,
J.W.M. Bergmans, J. Riani, S.J.L. v. Beneden, T. Conway
"Signal Processing and Coding for Two-Dimensional Optical Storage"
Paper submitted to Globecom, Global Communications Conference, San Francisco,
December 1-5, 2003.
- [3] J. Riani, J.W.M. Bergmans, S.J.L. van Beneden, W.M.J. Coene, A.H.J. Immink
"Equalization and Target Response Optimization for High Density Two-Dimensional
Optical Storage"
Paper submitted to 24th Symposium on Information Theory in the Benelux (WIC,
Werkgemeenschap Informatie en Communicatie-Theorie), Veldhoven, May 22-23, 2003.
- [4] W.M.J. Coene
"Non-Linear Signal Processing Model for Scalar Diffraction in Optical Recording"
Applied Optics (Information Processing), Vol. 32 (No. 32), Nov. 2003, pp. 6525-6535.
- [5] A. Moinian, L. Fagoonee, B. Honary, W. Coene
"Linear Channel Model for Multilevel Two Dimensional Optical Storage"
Paper submitted to Seventh International Symposium on Communication Theory and
Applications (ISCTA'03), 13th -18th July 2003, Ambleside, Lake District, UK.
- [6] Y. Mulero, T. Conway
"Decision Feedback Equalization on a Hexagonally Sampled Two-Dimensional Signal",
Paper submitted to "Irish Signals and Systems Conference" (ISSC), Limerick, July 1-2
2003.
- [7] R. Conway
"Fixed-Point Arithmetic",
Paper submitted to "Irish Signals and Systems Conference" (ISSC), Limerick, July 1-2
2003.
- [8] L. Fagoonee, A. Moinian, B. Honary and W. Coene
"Non-Linear Signal Processing Model for Signal Generation in Multilevel Two
Dimensional Optical Storage"
Paper to be submitted to OSA Optics Letters, June 2003.

