Multi-terabyte holographic data storage demonstrator

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ABSTRACT

Holographic data storage (HDS) is transitioning to second-generation technologies in order to meet the demands of big data. Akonia Holographics is developing an advanced HDS demonstrator platform featuring a high NA recording geometry, novel multiplexing methods, and coherent channel techniques to meet these challenges.

1. INTRODUCTION

Holographic data storage remains a promising, if elusive, technology for preserving vast amounts of digital data. Despite a number of highly publicized efforts, no commercial HDS product has ever been sold to a general market. The most recent effort was launched by InPhase Technologies, Inc., which produced an advanced pre-production HDS drive design capable of storing 300 GB on a removable 5 ¼" disk [1]. InPhase closed its doors in 2010 after failing to secure $50M investment to take its mildly competitive 300GB product into manufacturing during the peak of the economic downturn.

While a 300 GB product is no longer commercially viable, fundamental physical limits suggest that holographic technology can still be highly competitive in a multi-terabyte industy. HDS is especially attractive for archival purposes because data are stored in a solid inert photopolymer medium in the form of thermally-stable covalent bonds. Accelerated age testing demonstrated that the archival life of the InPhase medium exceeds 50 years. This stands in sharp contrast to magnetic and electronic flash memories, which are fundamentally meta-stable; especially as bit densities increase. Optical storage technologies based on degradable dyes are similarly afflicted.

Akonia was founded in 2012 by senior technologists from InPhase and has acquired most of InPhase's equipment and entire patent portfolio. Akonia has embarked on a program to advance holographic storage technology to a new generation of record breaking densities with a newly designed platform that implements many new advances from Akonia that have not yet been seen in holographic data storage.

2. DEMONSTRATOR ARCHITECTURE

The starting point of the Akonia demonstrator platform is a system known as the *monocular* architecture [2]. The monocular architecture was the result of a joint development project between InPhase and Hitachi, Ltd., that was introduced after the off-axis architecture of the 300 GB product was locked down. The monocular architecture increases storage density by a factor of approximately three by delivering both the reference and object beams through a single 0.85 NA objective lens. The higher NA objective improves the volumetric resolution of the recording field, or, equivalently, increases the band volume of the holographic gratings that may be recorded. The design of such a fast lens over a wide field proved quite challenging, and novel techniques were developed to achieve it [3]. The monocular architecture otherwise shares many features with the proven InPhase product architecture, including angle multiplexing; polytopic multiplexing [4]; and a phase-conjugate geometry.

The Akonia demonstrator also incorporates many other elements of the InPhase design, including custom electronics, FPGAs, control firmware, servo code, and opto-mechanics representing many hundreds of man-years of development. A custom-developed tunable ECDL at 405 nm will enable thermal compensation algorithms. The mature FPGA-based oversampled data channel will decode the holographic images [5], and extant algorithms will perform the complex multi-axis recovery alignment processes [6]. Thus the demonstrator, as it is developed, will be born into a state of extraordinarily high functionality.

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3. THE SECOND GENERATION INNOVATIONS

The Akonia demonstrator platform has been designed to develop and validate four key innovations that will propel HDS into the big data era. They are:

1) DRED^{TM} Media Formulation

The DRED formulation represents a major advance over the two chemistry recording medium developed by researchers from InPhase. The two chemistry medium is so-named because it consists of two separate, intermixed polymer systems. The first system, the *matrix*, forms the solid recording layer, and the second remains unpolymerized until exposed to light [7]. Akonia has already demonstrated a factor of four increase in dynamic range using DRED technology, and is currently optimizing it for commercialization.

2) Dynamic Aperture Multiplexing

Dynamic aperture multiplexing is an exclusive Akonia invention that fully capitalizes on the shared beam path of the monocular objective lens. Dynamic aperture multiplexing increases the angular scan range, increasing storage density by 250% or more.

3) Quadrature Homodyne Detection

Homodyne detection is the method of blending a coherent reference field with a signal and detecting the interference pattern between the two. This has the effect of amplifying the signal, eliminating nonlinear effects of coherent noise, and allowing the detection of phase as well as amplitude. Homodyne detection normally requires careful phase control of the reference field and the signal, requiring complex adaptive optics and/or phase servo loops. Akonia has instead developed a novel algorithm that allows homodyne detection to be performed simply by combining two blended signals with the reference phase changed by 90^o. Akonia estimates this will boost the signal to noise ratio enough to nearly double storage density, as well as providing a host of other benefits [8].

4) Phase Quadrature Holographic Multiplexing

The ability to detect the phase of a hologram presents another opportunity to increase storage density. A second hologram can be recorded with each reference beam (i.e., two holograms at each reference beam angle), and the holograms will not cross talk provided they have a 90^o difference in phase. Thus, the technique of *phase quadrature holographic multiplexing* provides yet another doubling of storage density [9].

4. CONCLUSION

We have introduced Akonia's new demonstration platform designed to develop four second-generation innovations for holographic data storage. These innovations will yield multi-terabyte product designs, allowing HDS to be competitive in the big data era and beyond.

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