Holographic Data Storage

DOE Nuclear Physics Phase II

Fasttrack

Dr. Ken Anderson, CEO, PI

DOE Phase II SBIR Conference

August 6th, 2015

Akonia Holographics

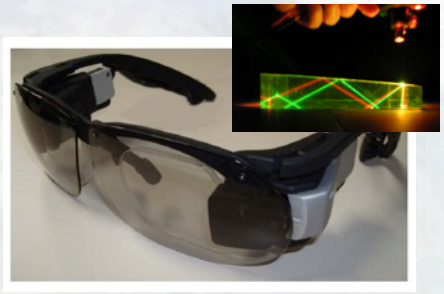
Akonia Holographics is the world leader in the development of ultra-high performance Holographic Data Storage for the backup and archive storage market

Company Overview

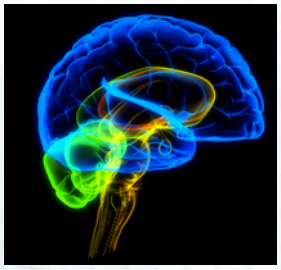
- **Founded in August 2012**
- **Early technology development from Bell Labs and InPhase Techologies**
- **18 employees/contractors**
- **> 165 US and Foreign patents in drive and media**
- **12,000 sqft facility with over $20M in electronics/optical equipment**
- **<u>Expertice:</u> holography, optical design, photopolymer chemistry, data storage, electronics/FPGA design**

Akonia's Active Areas of R&D

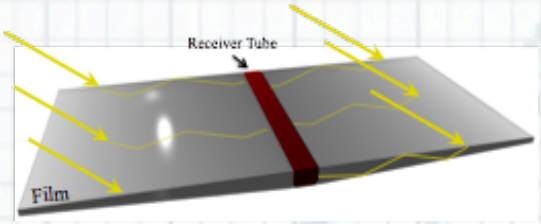
Applications of Holography and Photopolymer media



Head Mounted Displays



Holographic Printer



Holographic Solar Concentrator

Holographic Data Storage

Optically Programmable Index Structures

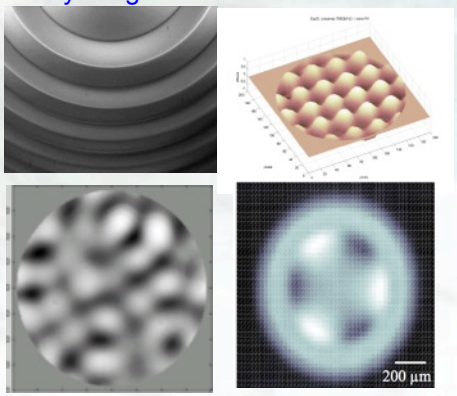


Image of Microscope
Extended Depth of focus

Polymer Chip to Chip
Waveguide
Communications

Motivation/Problem Statement

- "Large scale data storage systems are needed to **store, access, retrieve, distribute**, and process **data** from experiments conducted at large facilities. The experiments at such facilities are extremely complex, involving thousands of detector elements that produce raw experimental data at rates up to a GB/sec, resulting in the annual production of data sets containing hundreds of **Terabytes (TB) to Petabytes (PB)**."

- "The DOE is looking for new techniques for **multi-petabyte-scale systems** that are optimized for **infrequent data access**, emphasizing **lower cost per byte** than current disk systems, **lower power usage** than most disk systems, and **lower access latency** to data than current tape systems."

** Excerpts from DOE SBIR 2014 Solicitation*

The Potential of Holographic Data Storage

AKONIA HOLOGRAPHICS
BRINGING DATA STORAGE SOLUTIONS TO LIGHT

- VS -

(Tape)

- ✓ 10x Better Cost/TB (Media)
- ✓ 10x Better Cost/TB (System)
- ✓ 15x Better Total Cost of Ownership
- ✓ 30x Latency Improvement (time to first data)
- ✓ 11x Energy Savings
- ✓ 2x-4x Better Footprint (high density)

Holographic Storage Wins:
Cost, Footprint, Speed, and Reliability

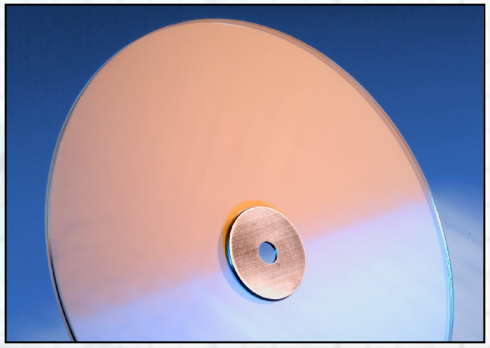
*Note: Comparisons are made using best estimated future projections in 2020.

Because it's 3D data storage!

800 DVDs, 160 BluRay

2D

1 HDS disc



All data storage solutions are 2D and are layering to mimic 3D

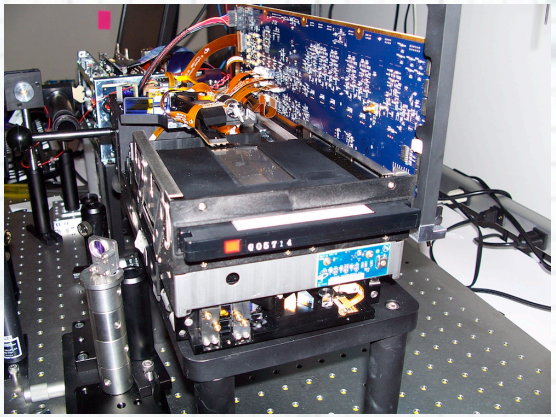
Tape—winds around a spool
HDD's—stacking of platters
SSD—stacking of silicon layers
Blu-ray—stacking partially reflective layers

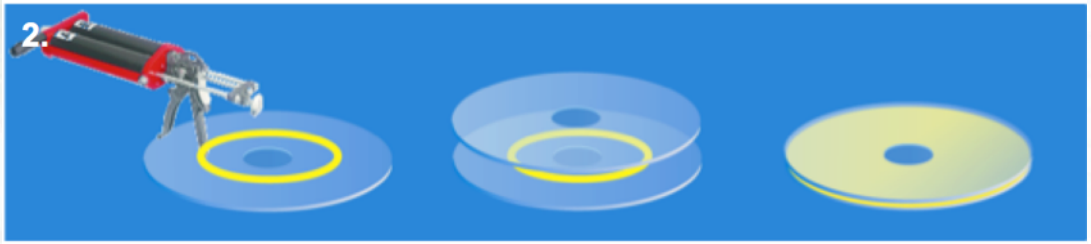
3D + Plastic = Huge Cost Advantage

How close is this technology to being realized?

Video Demonstration of Gen 1 Prototype

Prior Development:
Fully functional prototypes
300GB/disc
Light Tight Cartridge





How does Holographic Storage Work?

- How is data recorded?

  Data is first encoded into a 10 megapixel image. Using a laser, the data is then focused into a 600um x 600um spot within the media during a 300us exposure. The media records the data using a “reference beam” to create a unique pattern in the media.

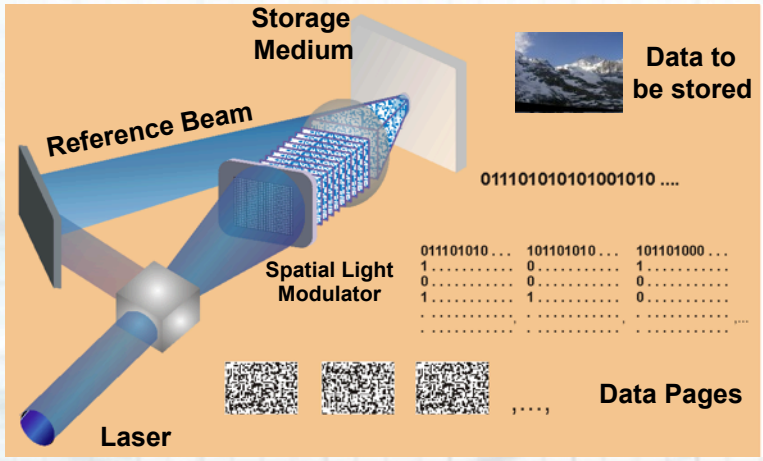
- How is capacity achieved?

  More than 400 images are recorded into each spot, each with its own unique angular address. In one disk, up to 28k spots are recorded giving a capacity of 2TBytes: the equivalent of 425 DVD’s or 80 BluRay disks.

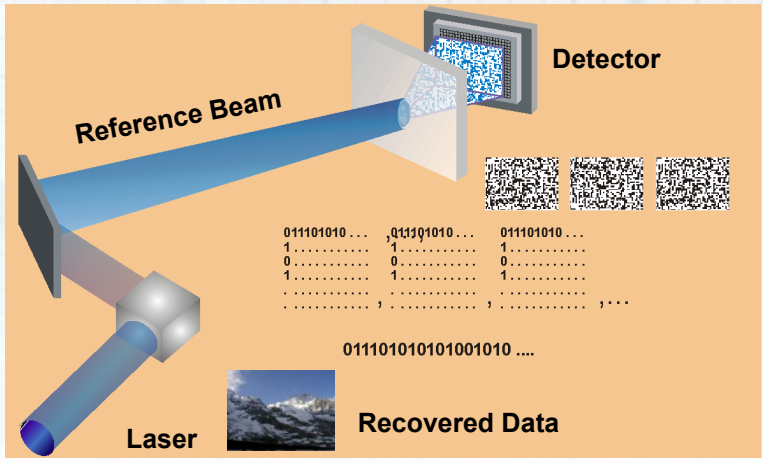
- How is information read out?

  Readout is done by Illuminating the spot with a laser at the appropriate angle and then using a high speed camera to capture the data image at over 500fps.

Recording Data



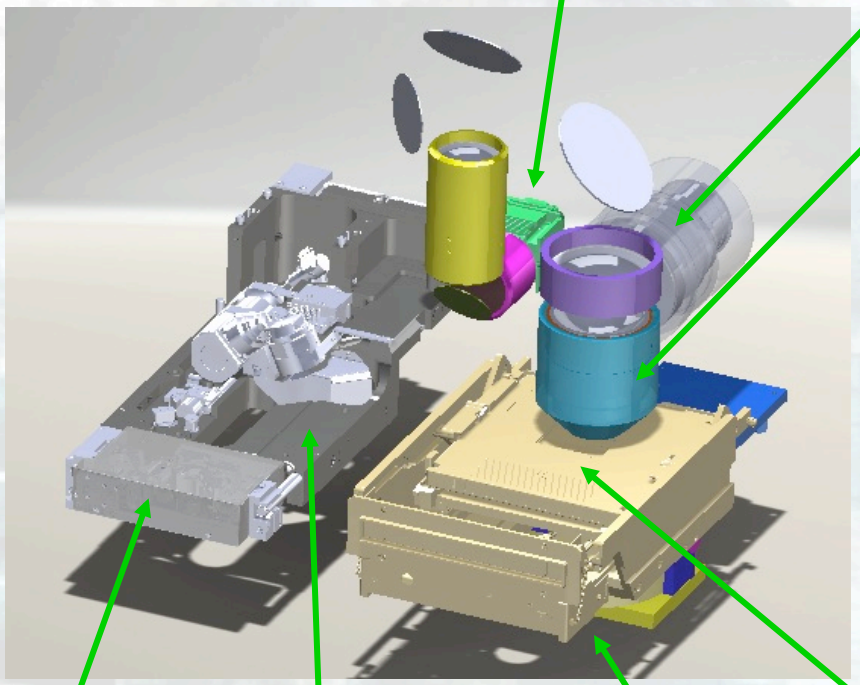
Reading Data

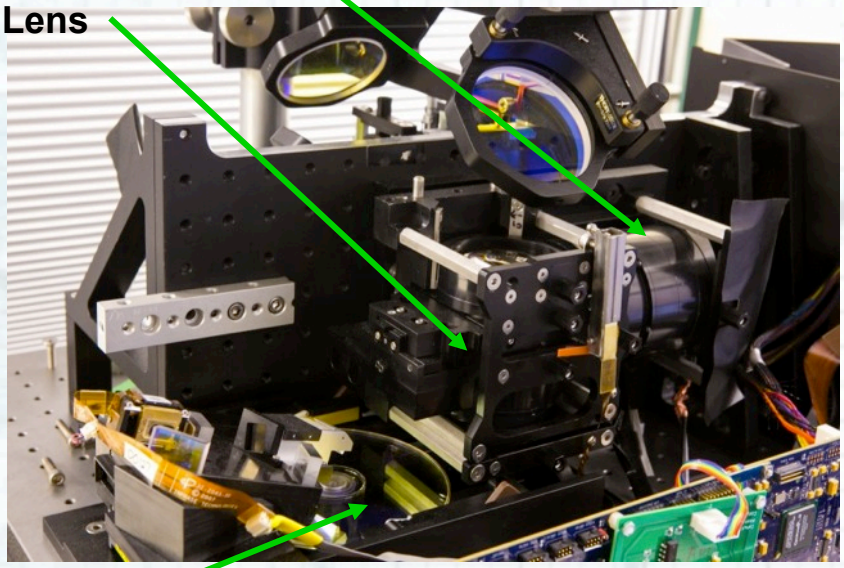


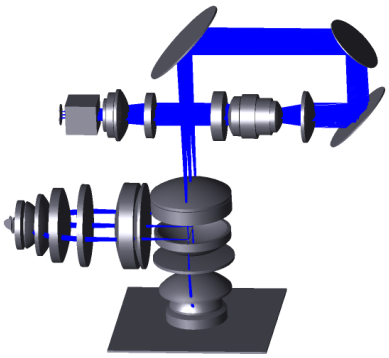
Akonia's SBIR Main Objectives

- ✓ Improve Storage Density by 5x (2TB/disk)
- ✓ Investigate and Develop Tape Library Compatible Designs
- ✓ Improve Media performance by 5x
- **Improve critical drive components to increase transfer rate by 5 to 10x**

New: Lab Demonstration Built



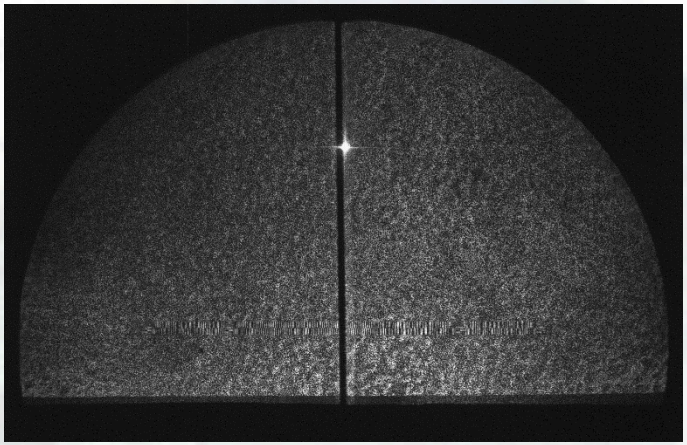




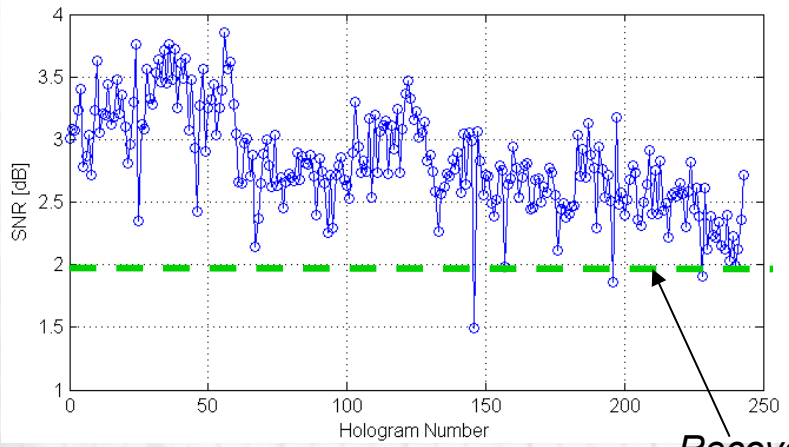
New Optical Head Demonstration

2.0 Tb/in^2 Density Experiment Results

Hologram Image



SNR



Diffracted Power Scan

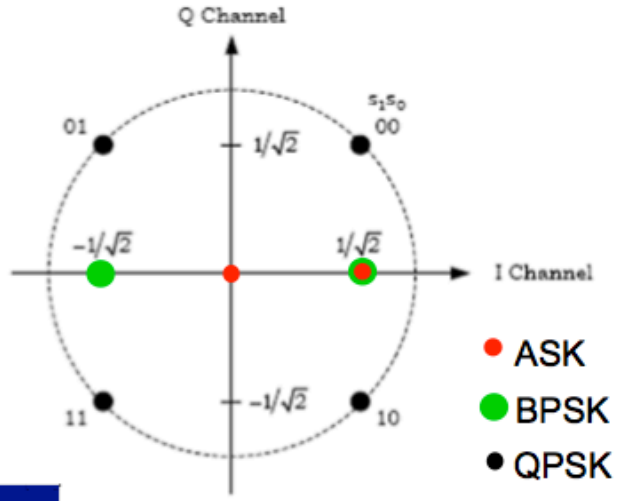
2.0 Tb/in^2 density book:

- Avg. SNR: 2.8 dB
- 98% above threshold
- DRED media filtering improvements lowered noise

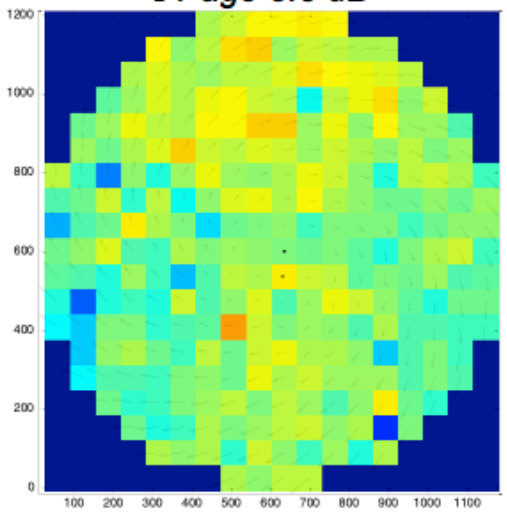
World Record in Bit Density gives 2TB/disk capability!

New Technique Developed for Higher Capacity!

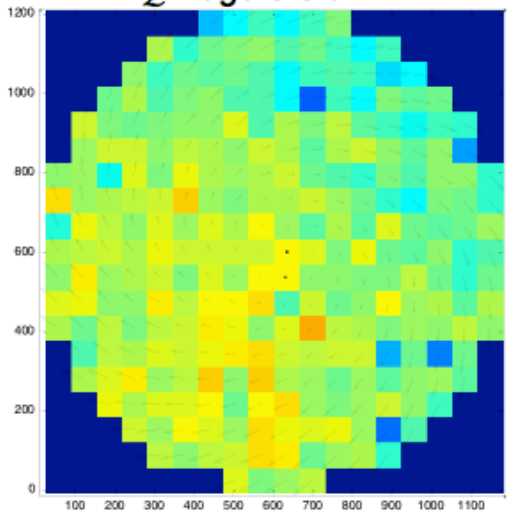
- ☑ Homodyne channel detects phase ⇒ QPSK modulation possible
- ☑ Method: record two holograms at each reference angle (*1 Tbit/in²*)



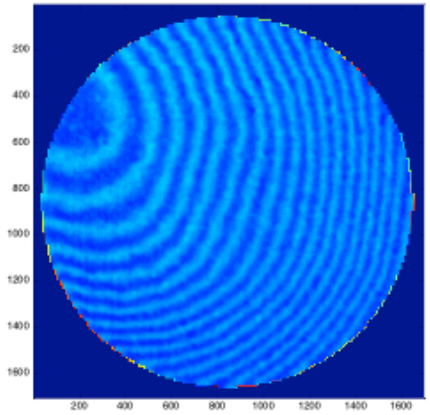
I Page 5.8 dB



Q Page 5.8 dB

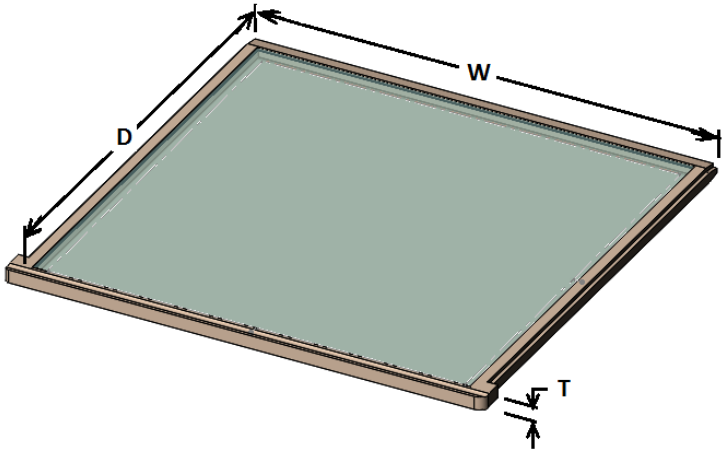


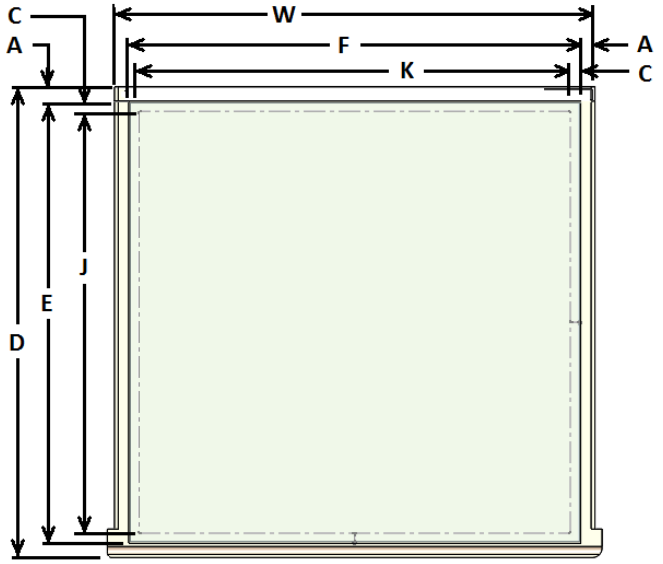
Avg. Δϕ 85.6°

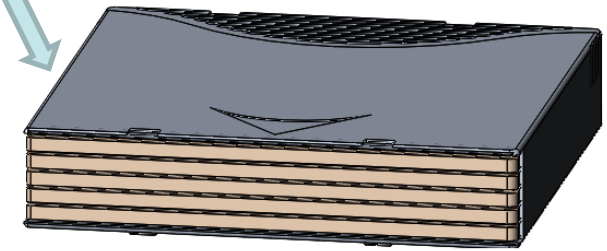


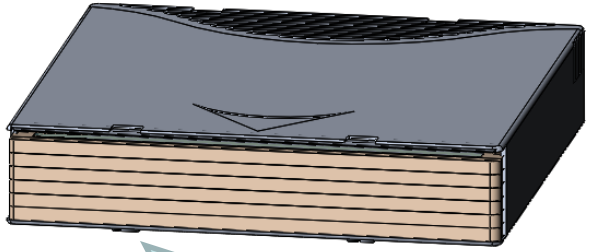
Say Goodbye to Discs!
Hello to Cards & Magazines

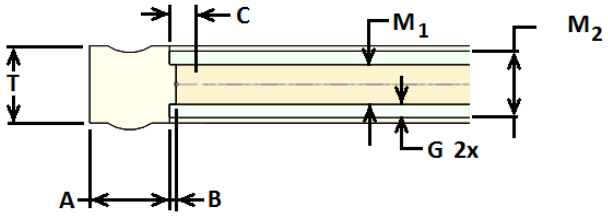
5 coupon form factor
(Recommended)





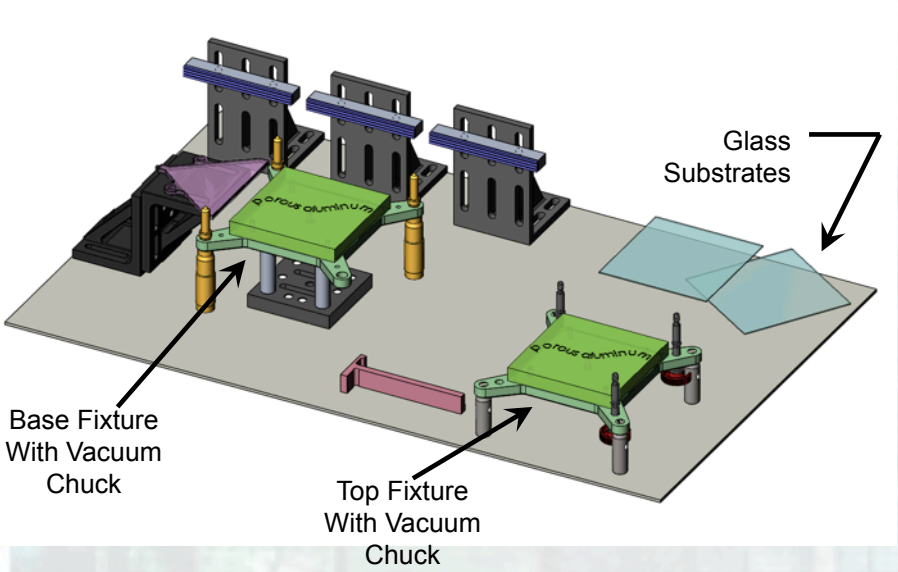


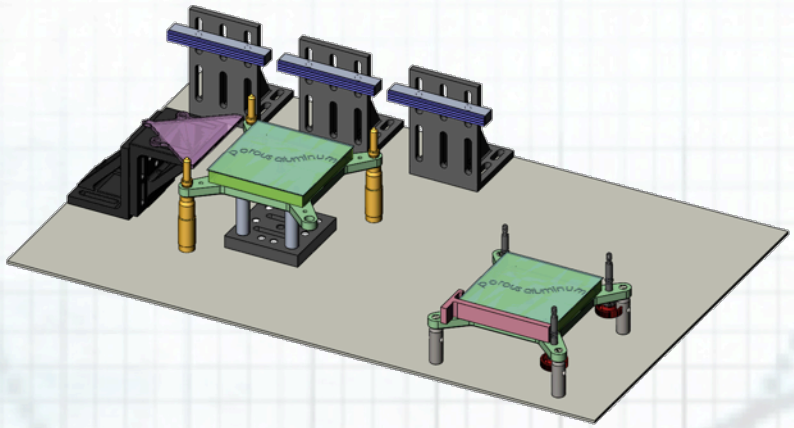


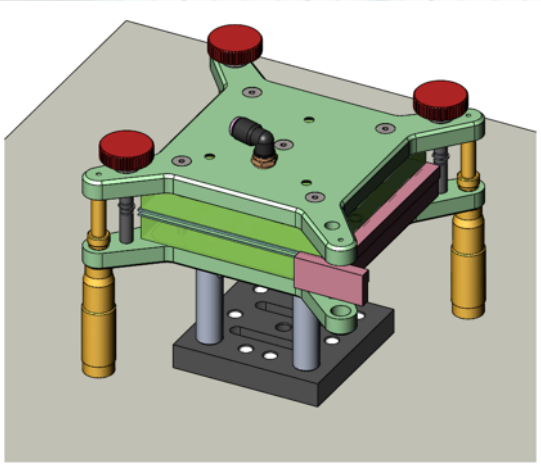


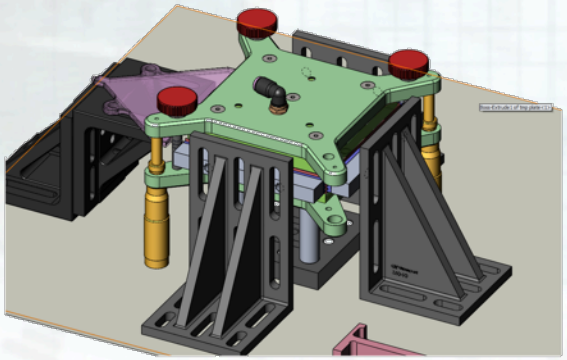
6 coupon (alternate tight pack form factor)

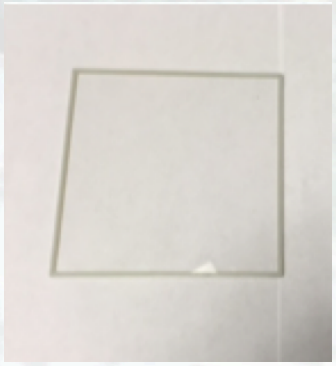
How to manufacture media card?





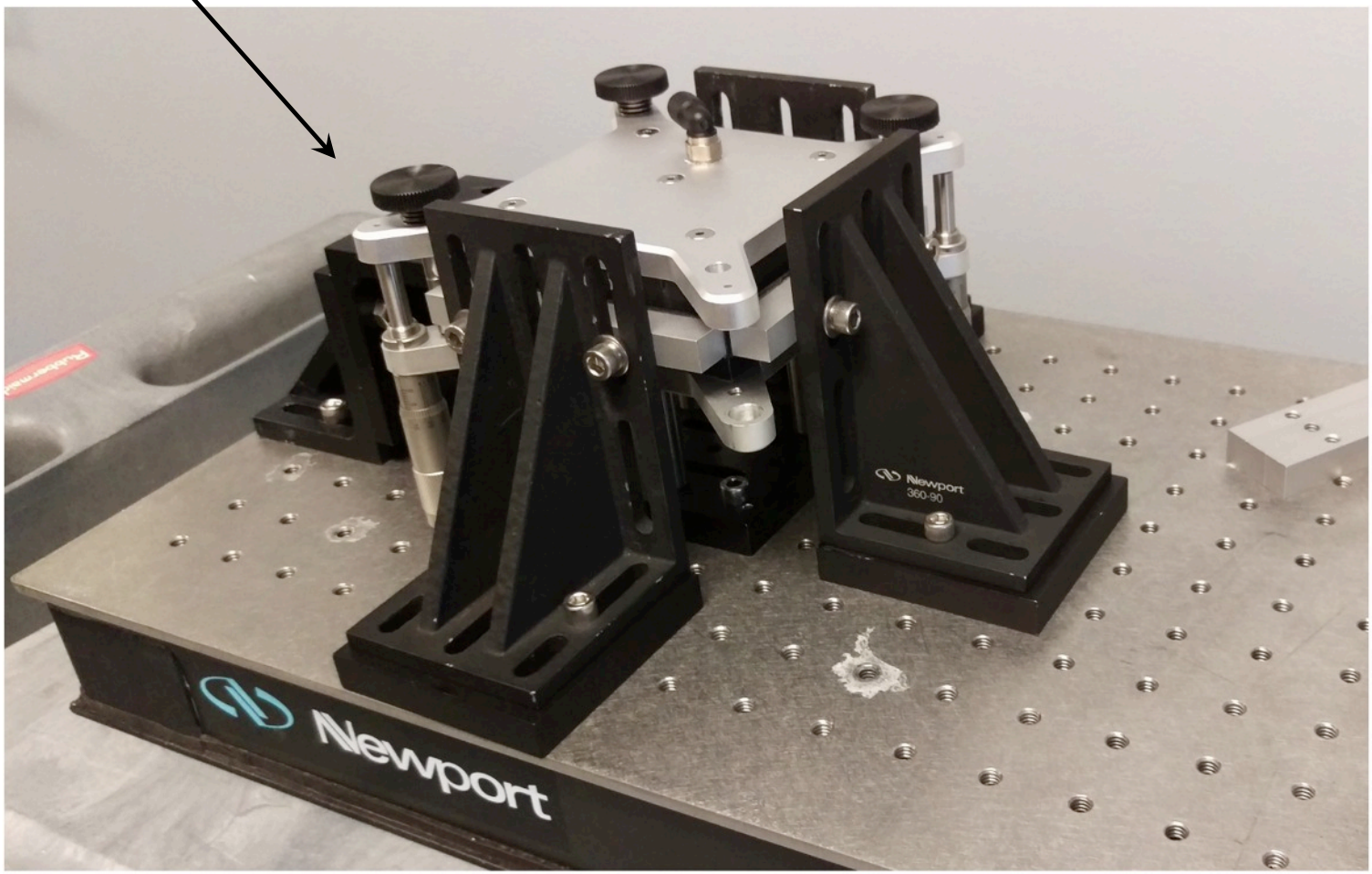






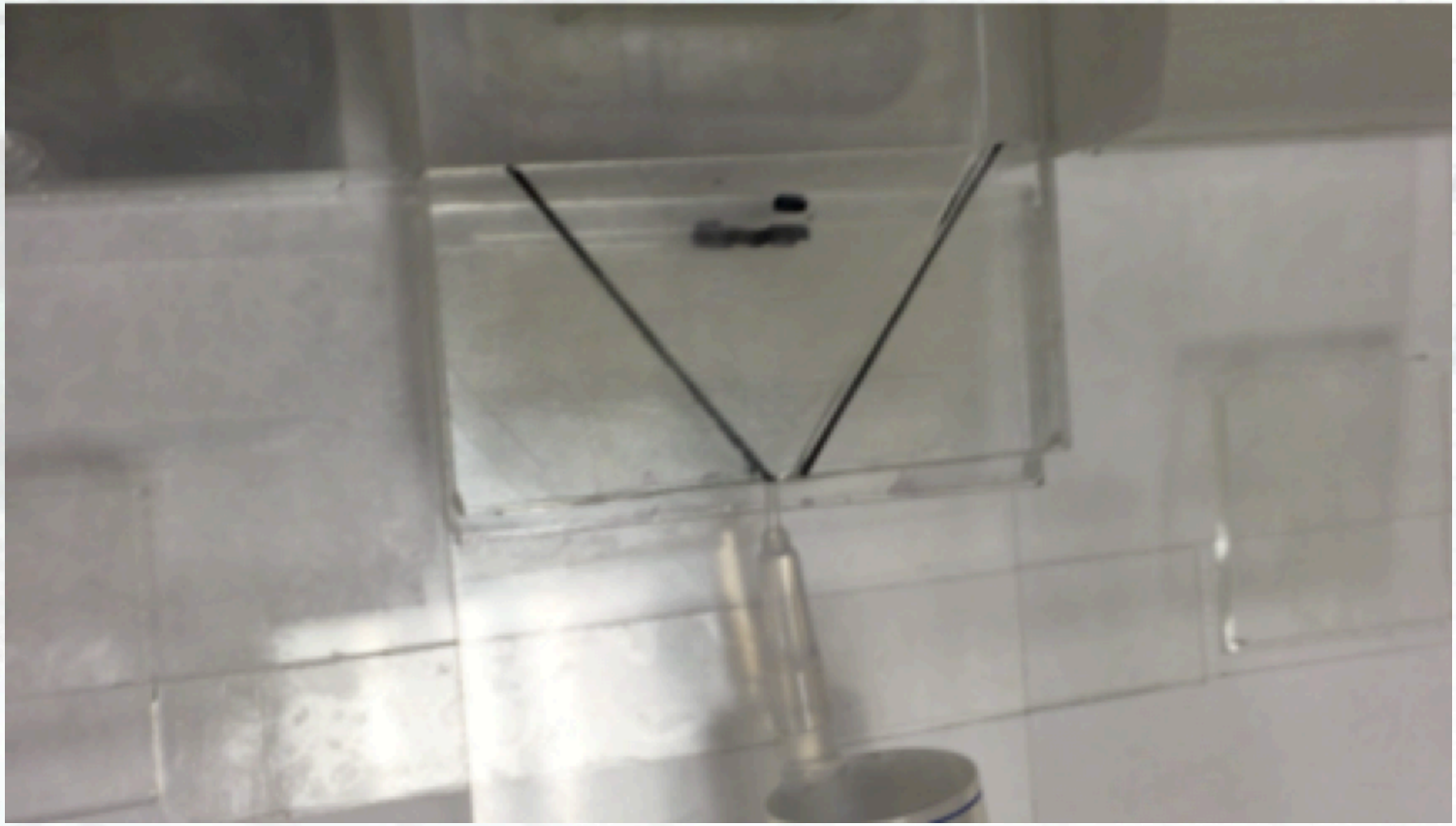
Prototyping Media Manufacturing Concepts

Ready to inject media



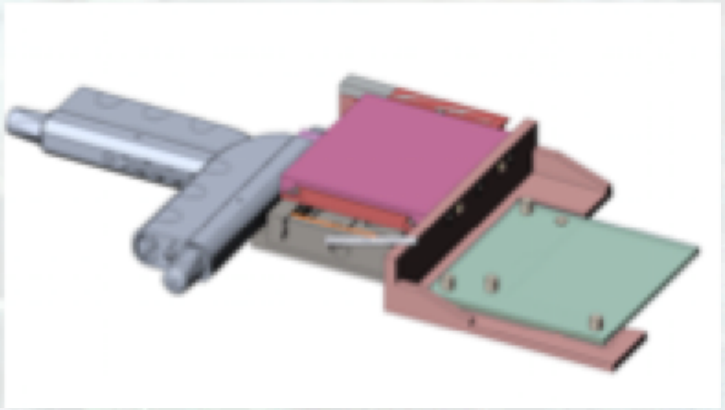
How do make holographic media in a card format?

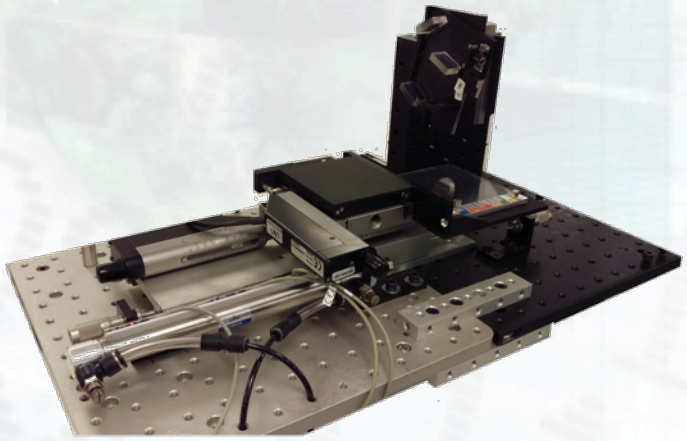
1. Polymer starts as the consistency of honey and then sets-up into a rubber like consistency
2. How do we “fill” a card with media?



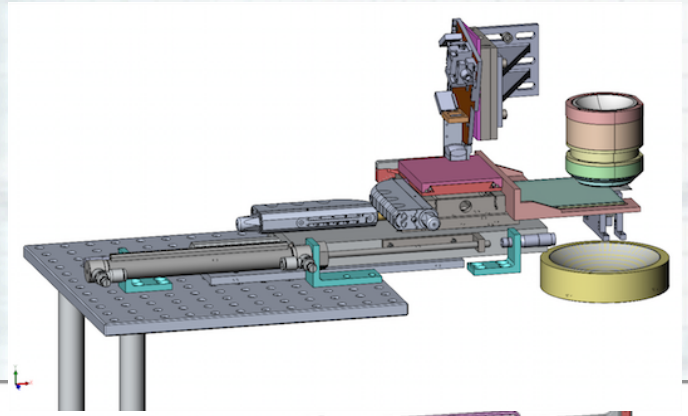
Testing of Media Cards in Testbed

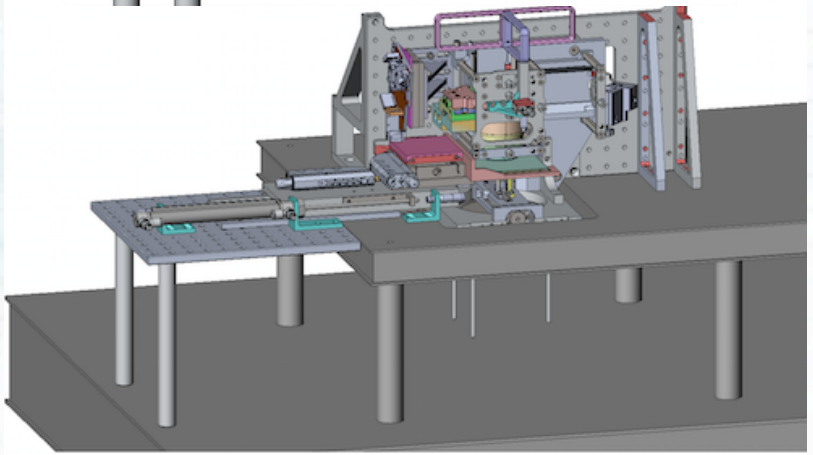
Prototype X-Y positioning





Installing XY into testbed





Summary of Results of Phase II

- Achieved 2Tb/in2 (Goal of 2Tb/in2 by end of Phase II)
- Fill Technique developed and tested – Works great
- Prototype media manufacturing jigs complete and ready to be tested
- Laboratory X-Y card positioner designed and built
- Mechanical prototype of media built

Future Plans

- Year 2 of SBIR with be focused on development of component technologies to improve overall system performance: Laser, high speed media positioning, etc
- We are actively seeking investment to begin building manufacturing prototypes for commercialization
- Akonia anticipates first beta units could be produced within 24 of funding.
- We are seeking a large scale manufacturing partner to help with DFM (Design for manufacturing)

Thank You!

AKONIA HOLOGRAPHICS

BRINGING DATA STORAGE SOLUTIONS TO LIGHT

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Milestones and Progress

Milestones	Task Completion Date										
	Phase 1			Phase 2, Year 1				Phase 2, Year 2			
Phase 1											
Complete concept holographic library design	✔										
Assessment of integrating holographic drive and media into LTO libraries complete			✔								
Concept designs complete of square holographic media			✔								
SLM specification complete		✔									
1 Tb/in2 bit density demonstrated		✔									
Phase 2, Year 1											
Form factor of library drive complete						✔					
Prototype of new media formats complete				✔							
Media sensitivity of >2x completed and initial tests finished									✔		
Initial design of media XY stage complete							✔				
AR coating manufacturing chosen						✔					
New ECDL (Laser) prototype design complete										✔	
Laboratory proof-of-concept of low power laser complete									✔		
Phase 2, Year 2											
Prototype design of media XY stage complete and built					✔						
Prototype manufacturing process for square media complete						✔					
Prototype media magazine complete				✔							
Laboratory proof-of-concept of high power laser complete									✔		
2 Tb/in2 bit density demonstrated						✔					
Holographic model of wavefront tolerance complete								✔			

We are well ahead of Schedule!

New Use Models for Holographic Storage:

10x faster reads than tape

- Typically, 90% of files/objects in archive are <1GByte
- Worldwide data reports that 35% of all archive data is <1GByte in size
- Due to random access of Holographic disks, holographic drives can read data 10x faster than tape for <1Gbyte files

1 Holographic Drive = 10 Tape drives

Direct Contributions to Energy Efficiency

- Energy improvement for small file reads
  - Energy usage of 1PB of HDD = 8,217 kW-hr
  - Energy usage of 1PB of holographic =1,752 kW-hr
  - Energy usage of 1PB of tape (<100MBfiles) =21,846 kW-hr*

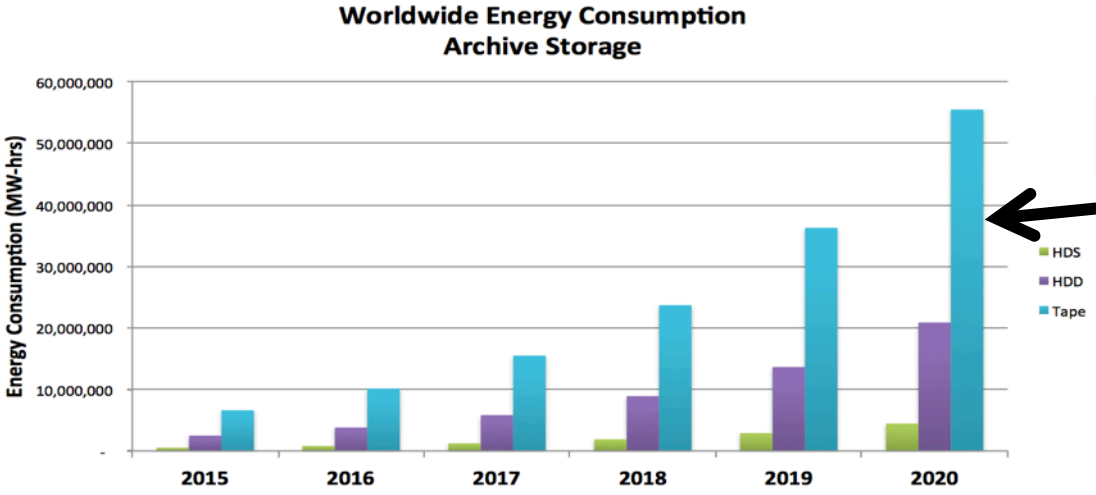
    *Note: This assumes 1GB/s aggregate bandwidths are sustained

Data Center Temperature and Energy

- For every 1.8°F that you raise the temperature in your data center, you save 2-4% of your total energy bill.
- Holography performs more optimally at hotter temperatures due to faster media diffusion
- Example: Facebook **cannot** use tape drives in its energy efficient data centers due to higher temperature
  - "Open air" data centers with PEU ~1.1 run at >90degrees
- "Data storage devices dictate the highest temperature of a data center" – Kevin Regimbal (NREL)

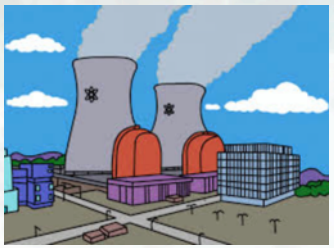
How Big is the Archive Energy Impact?

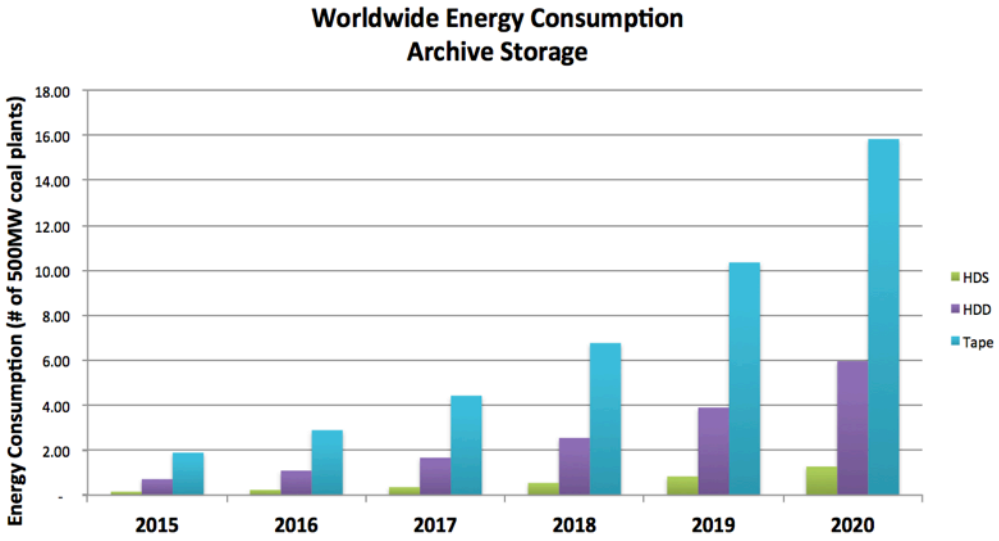
Total Worldwide Archive Energy Usage



This amount of Energy…

Means this many Coal Plants





Small File Archives (<1GB) are 35% of total Archive data storage