Holographic Data Storage

DOE Nuclear Physics Phase II
Fasttrack

Dr. Ken Anderson, CEO, PI
DOE Phase II SBIR Conference
August 10th, 2016

Overview

- Company Overview
- Motivation for Holographic Data Storage
- What is Holographic Data Storage?
- SBIR Goals and Accomplishments
  - Phase I & 2 Goal Overview
  - Storage Density Demonstrations
  - Media Development
  - Laser Development

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
- 15 employees/contractors
- Leveraging over $100M in technology development from Bell Labs and InPhase Techologies from 1995 to 2010
- > 165 US and Foreign patents in drive and media
- 12,000 sqft facility with over $20M in electronics/optical equipment
- Expertice: holography, optical design, photopolymer chemistry, data storage, electronics/FPGA design

DOE Motivation/Problem Statement

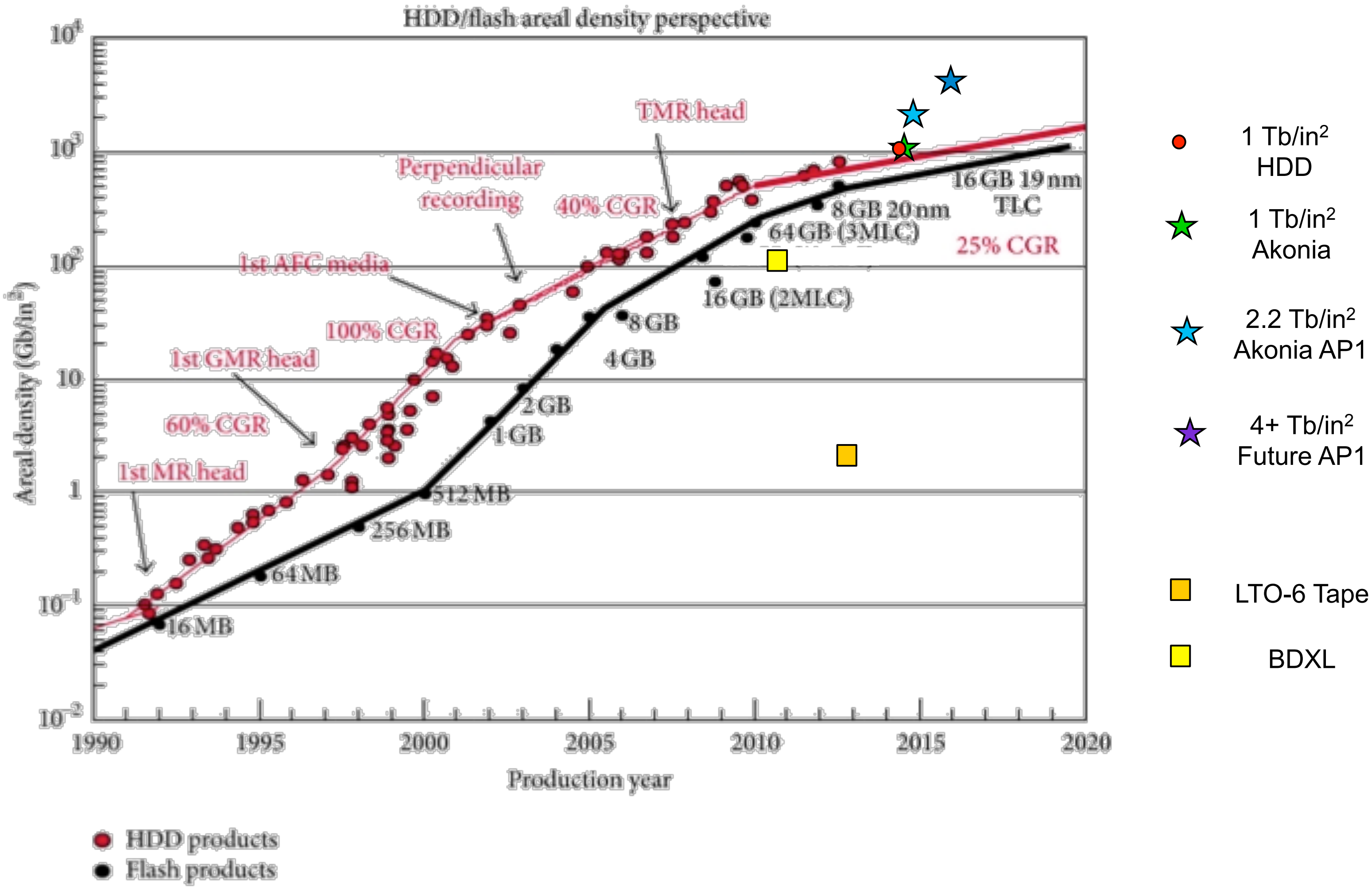
- "Large scale data storage systems are needed to **store, access, retrieve, distribute**, and process **data** from experiments conducted at large facilities. The experiments at such facilities are extremely complex, involving thousands of detector elements that produce raw experimental data at rates 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."*

… In a nut shell, you guys store a lot of data, want To store it cheaply, and want faster access to it

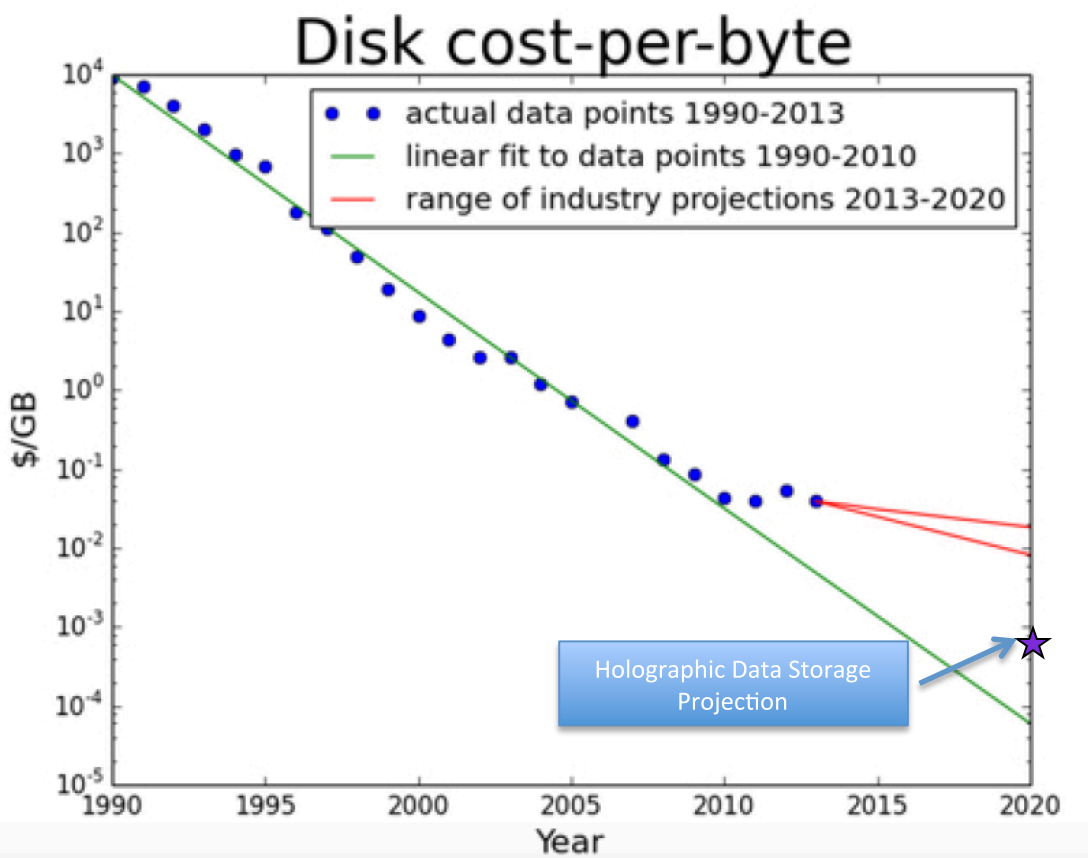
** Excerpts from DOE SBIR 2014 Solicitation*

Motivation 2: Areal Density Trends are Slowing



Marchon, et al., "The Head-Disk Interface Roadmap to an Areal Density of 4Tbit/in²," Advances in Tribology, vol. 2013

$/Gbyte is going to become a dominant IT cost



Because…
Demand for Data Storage Is still increasing at 40% per year

Current:
HDD: $24/TB
Holographic: $12/TB

2020:
HDD: $10/TB
Holographic: <$1/TB

A Brief Background on Holographic Data Storage

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.

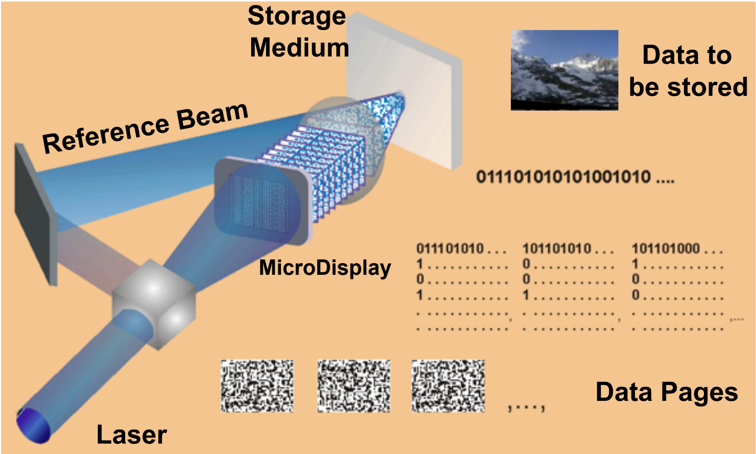
- How is capacity achieved?

  More than 600 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.

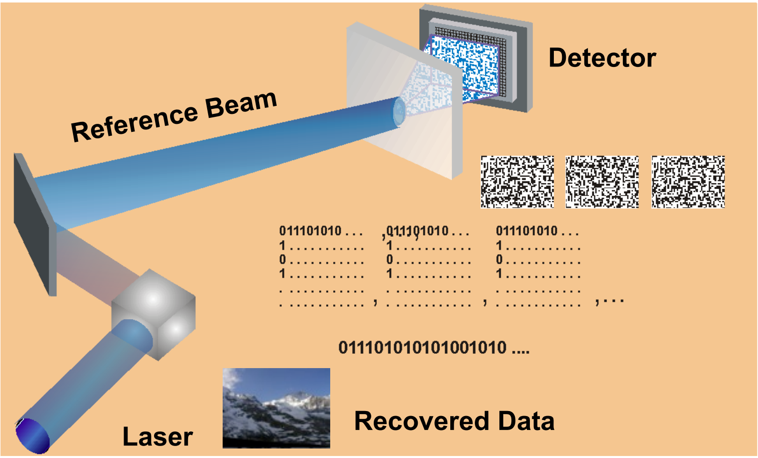
- How is information read out?

  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



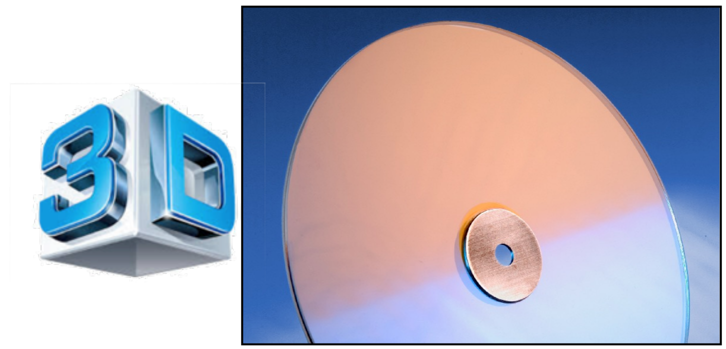
Reading Data

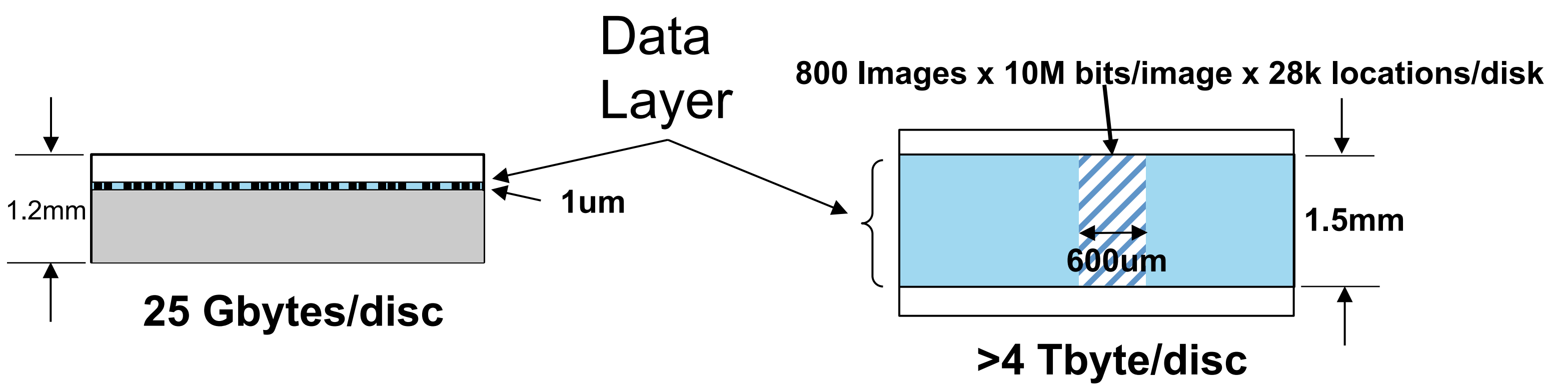


Surface Versus Volumetric Recording

Blu-ray
data stored on **2D surface**

Holographic
data stored in **3D volume**





160x Data Capacity Improvement Over Blu-Ray

3D + Plastic = Huge Cost Advantage

The Potential of Holographic Data Storage

AKONIA HOLOGRAPHICS
BRINGING DATA STORAGE SOLUTIONS TO LIGHT

- VS -

(Tape)

- ✓ <$1/TB Media Cost by 2020
- ✓ 5x Better Cost/TB (System)
- ✓ 10x Better Total Cost of Ownership
- ✓ 30x Latency Improvement (time to first data)
- ✓ 11x Energy Savings
- ✓ 2x-4x Better Footprint (high density)

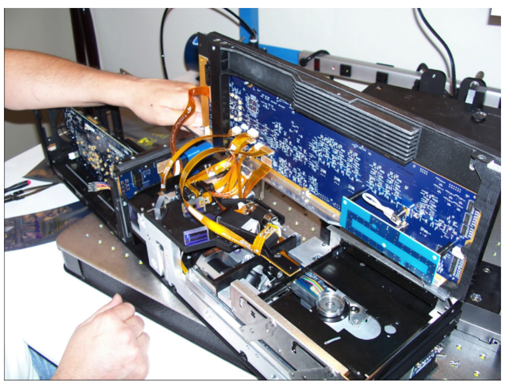
Holographic Storage Wins:
Cost, Footprint, Speed, and Reliability

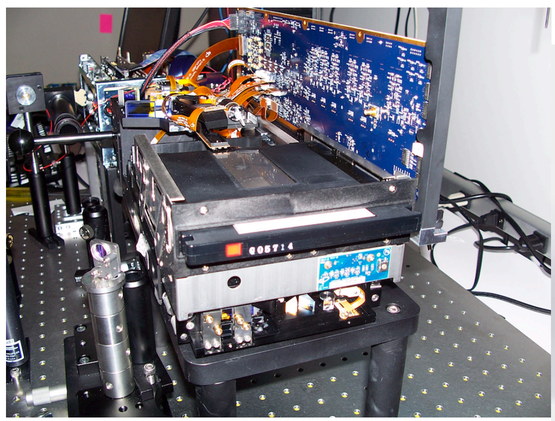
*Note: Comparisons are made using best estimated future projections in 2020.

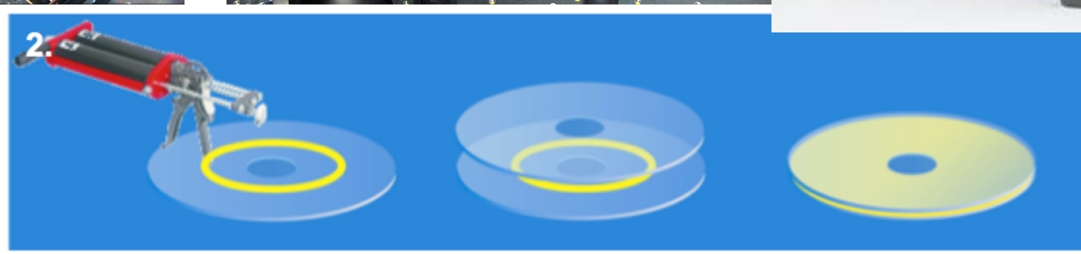
AKONIA HOLOGRAPHICS

How close is this technology to being realized?

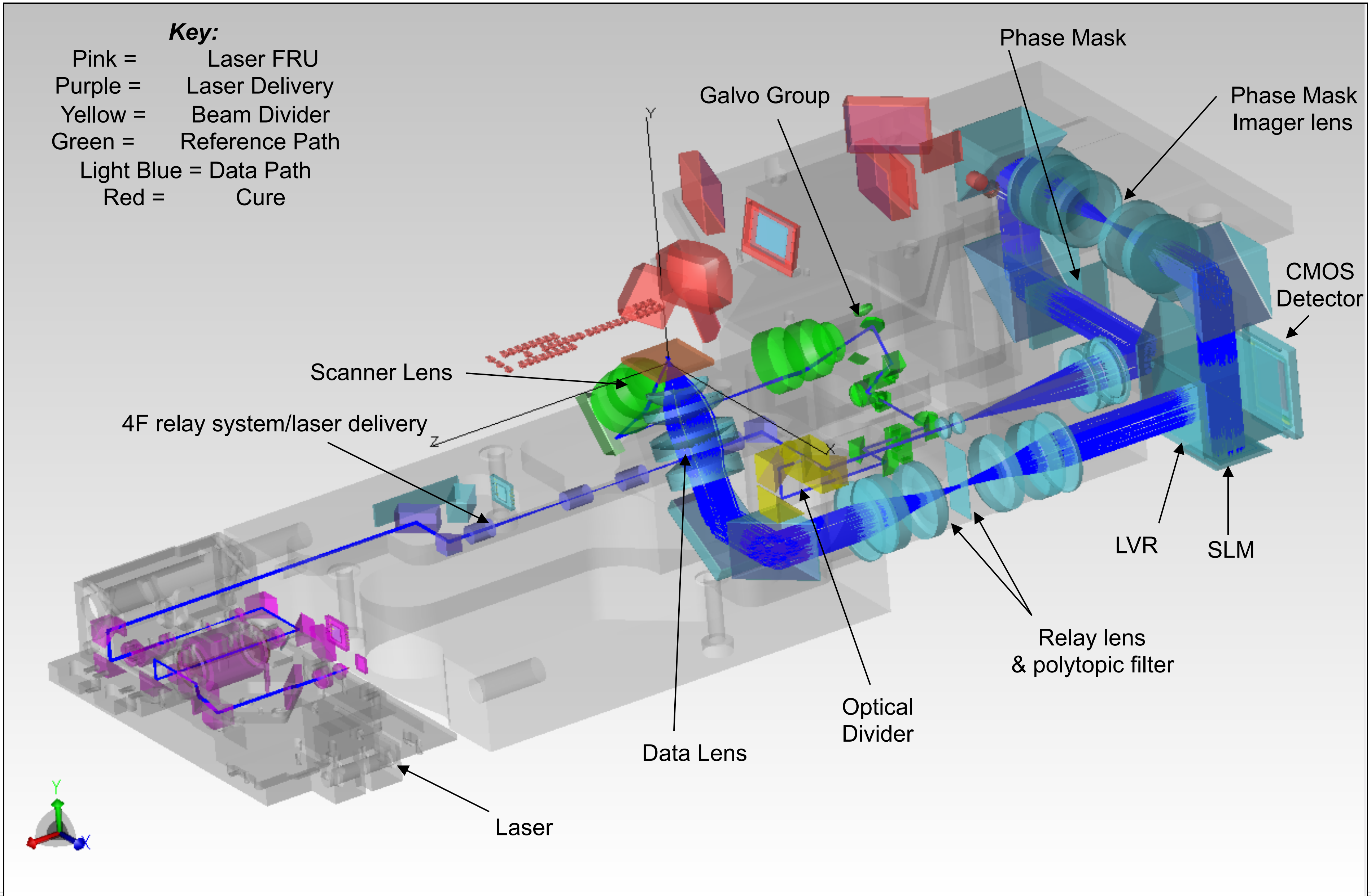
- ✓ 52 Fully functional prototype drives built
  - ✓ Improved from 300GB/disk to 1TB/disk with DOE SBIR
  - ✓ Fully automated hardware-based (FPGA) operation under host command interface
- ✓ 2.2 TB/card (Equivalent) Demonstrated on Testbed in Dec 2015
- ✓ 4.0 TB/card - possible by 2017
- ✓ $10M Media manufacturing build line built and refined





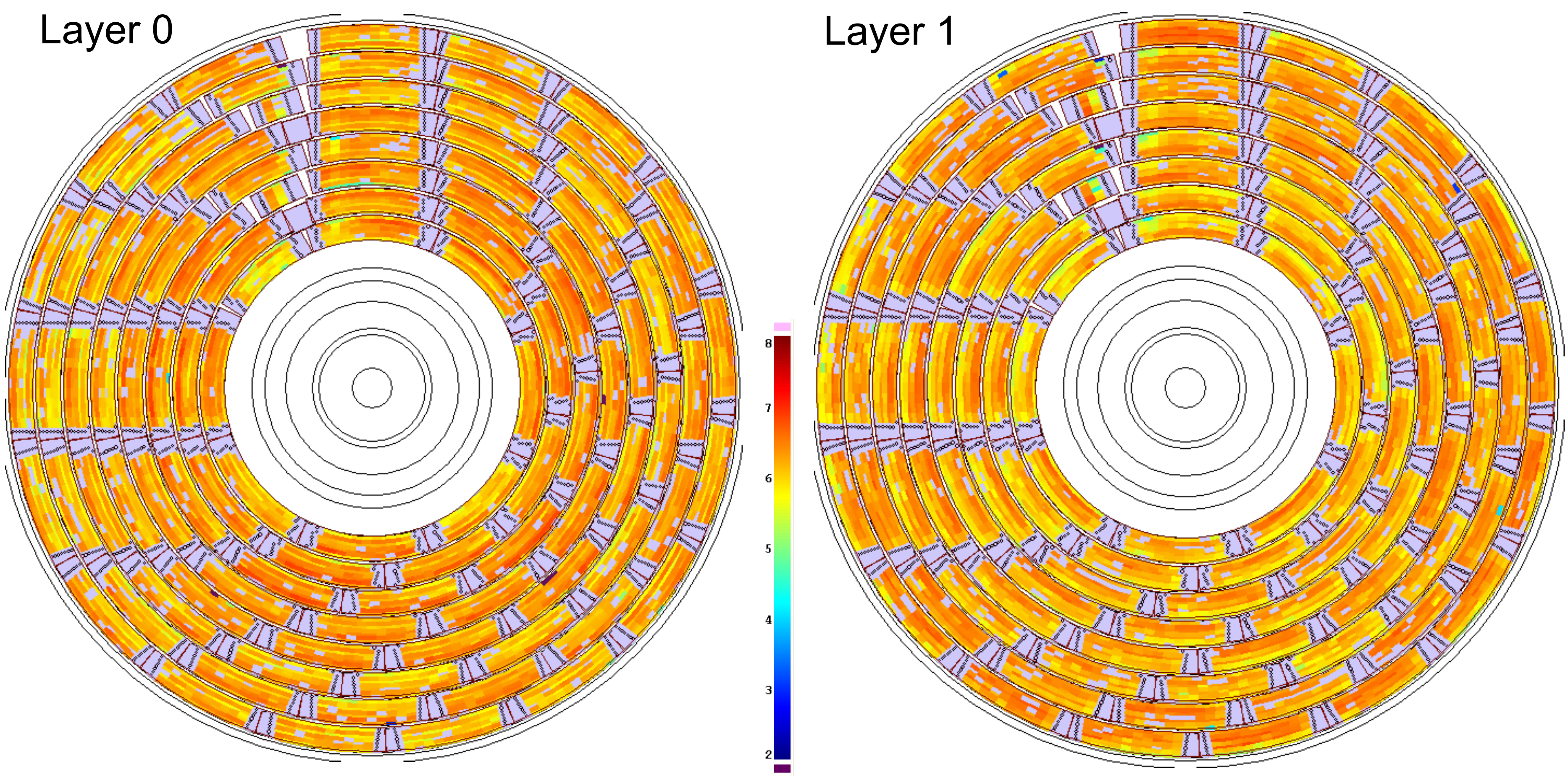


Previous Work: 52 prototype drives built



Previous Work: Disk Format

- 16524 books (2838 dummy books)
  - Avg. SNR ~6.1dB



DOE SBIR Grant Accomplishments: Phase 2, Year 2, Month 9 (FastTrack)

… Almost Done

DOE Phase 2 SBIR Goals

- ✓ Improve Storage Density to 2Tb/in2
- ✓ Investigate and Develop Tape Library Compatible Designs
- ✓ Improve Holographic Media Dynamic Range by 5x
- ✓ Improve critical drive components to increase transfer rate from 20MB/s to >100MB/s

Performance Metric	Start	Goal	Demonstrated	DOE funded Improvement	Units
Bit Density	0.3	2	2.2	7.3x	Tbit/in2
Media Dynamic Range	4	16	60	15x	
Laser Power	30	60	35	1.17x	mW
Media Sensitivity	5.00E-06	1.00E-05	1.10E-04	22x	cm^2/mJ
Media positioning speed	500	100	30	16.7x	ms
Mirror positioning speed	1	0.1	0.1	10x	ms
Microdisplay pixel count	1.4	5	10	7.1x	MegaPixels

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Phase 2, Year 2 Emphasis

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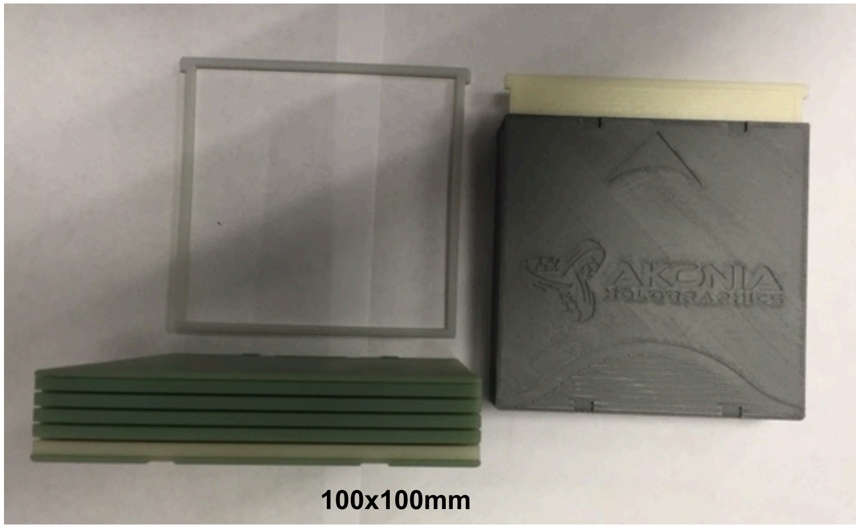
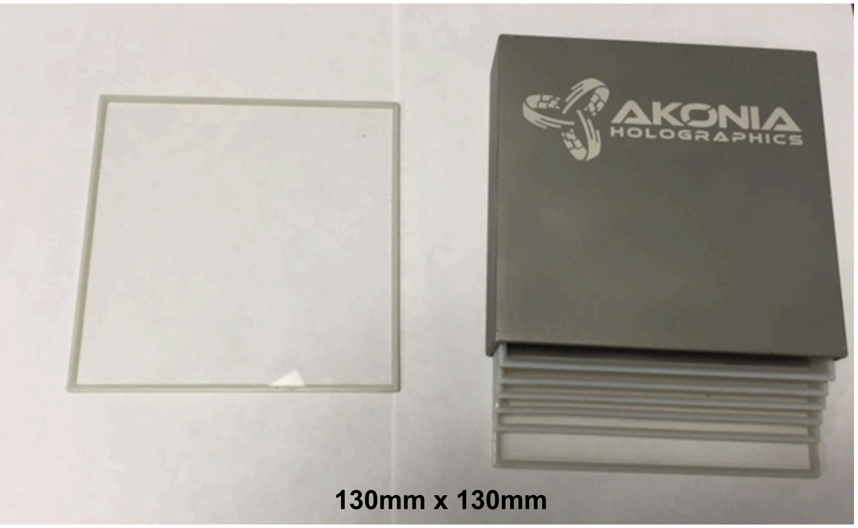
DOE Work: 2 Card Formats Developed

LTO size



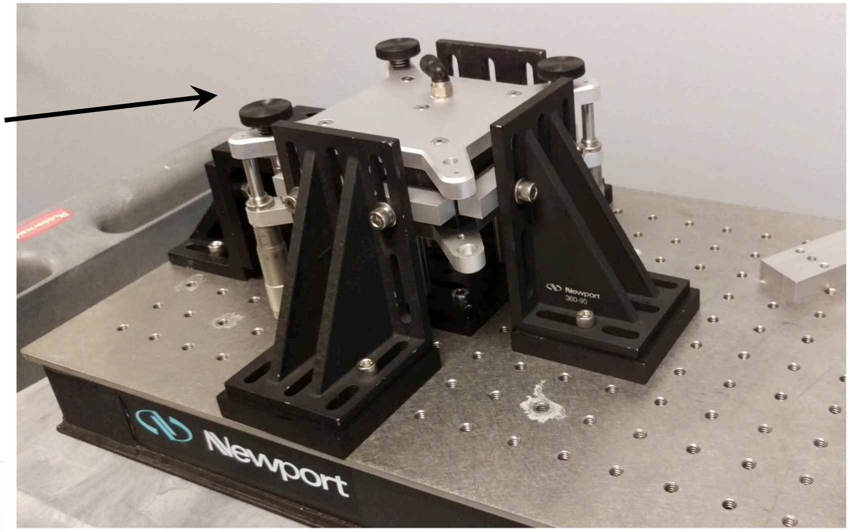
100x100mm

BluRay Magazine Size

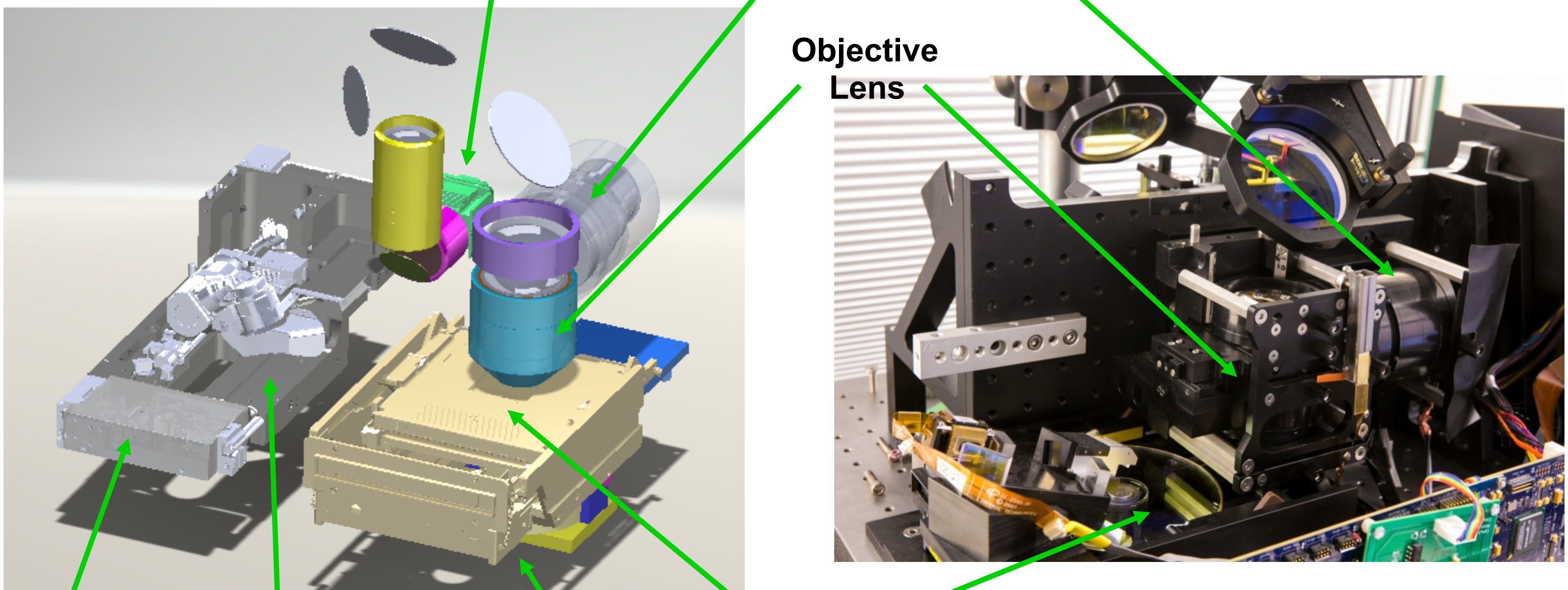


130mm x 130mm

Ready to inject media

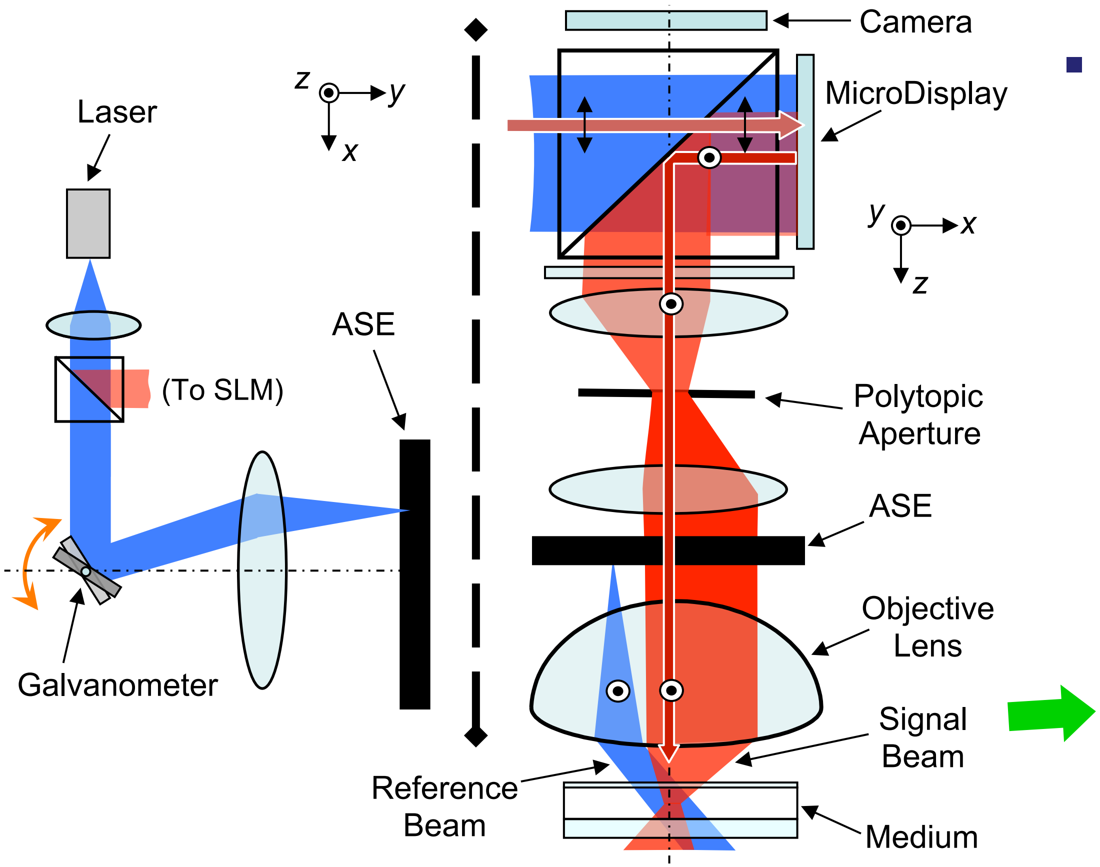


Bit Density Testbed (AP1)



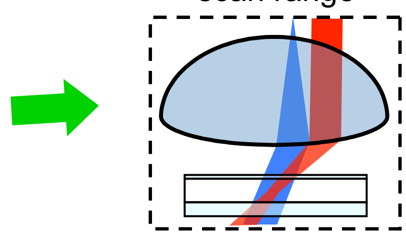
System Architecture

- Dynamic aperture recording implemented by scanning galvo while composing shrinking pages on the SLM



- Aperture sharing element (ASE) folds reference beam into signal path

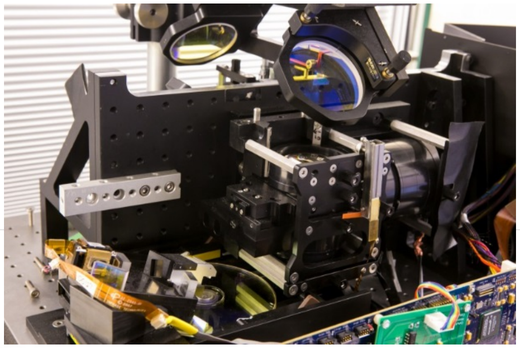
Beams near end of scan range



DOE SBIR Bit Density Demonstrations

- March 2014: 1st Holograms written and recovered
- May 2014: 1.0 Tbit/in^2 demonstrated
- June 2014: 1.35 Tbit/in^2 (*static page*)
- August 2014: 1.52 Tbit/in^2 (*dynamic aperture*)
- November 2014: *Converted to coherent channel*
- February 2015: 2.0 Tbit/in^2 demonstrated
- December 2015: 2.2 Tbit/in^2 (*current areal density world record*)

Magnetic Disk Areal Density ~ 1Tb/in2

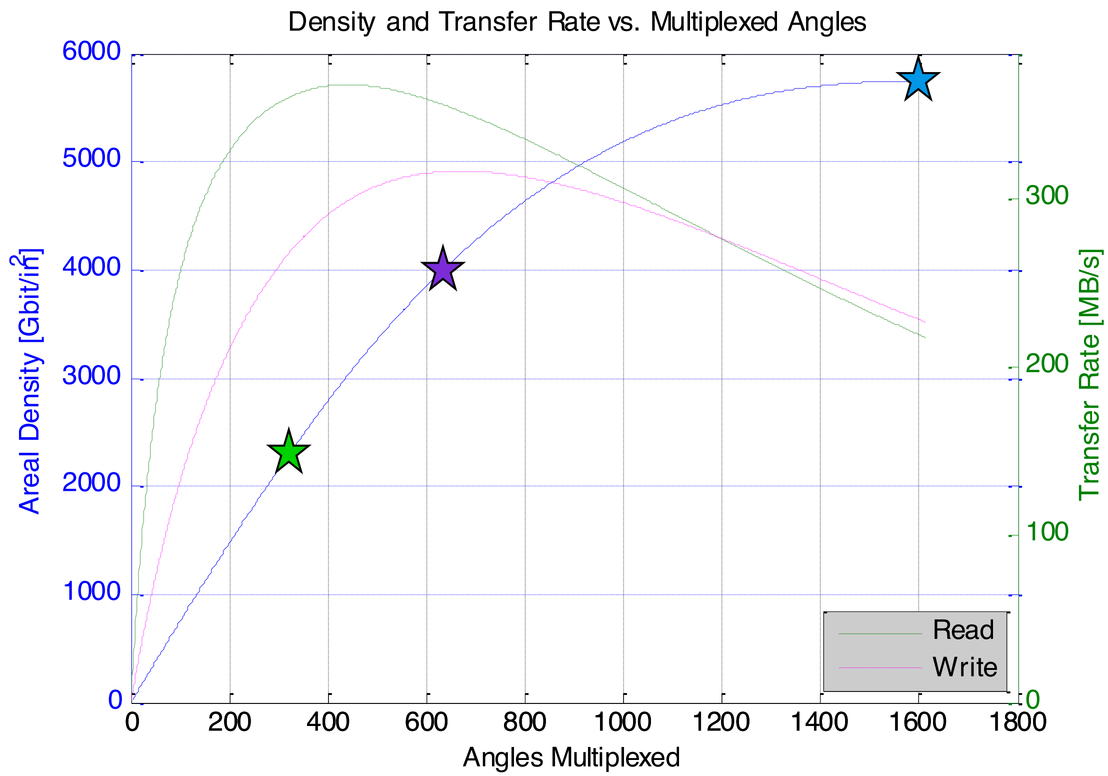


What's next… >4 Tbit/in²?

Testbed is capable of 5.75 Tbit/in² in current configuration

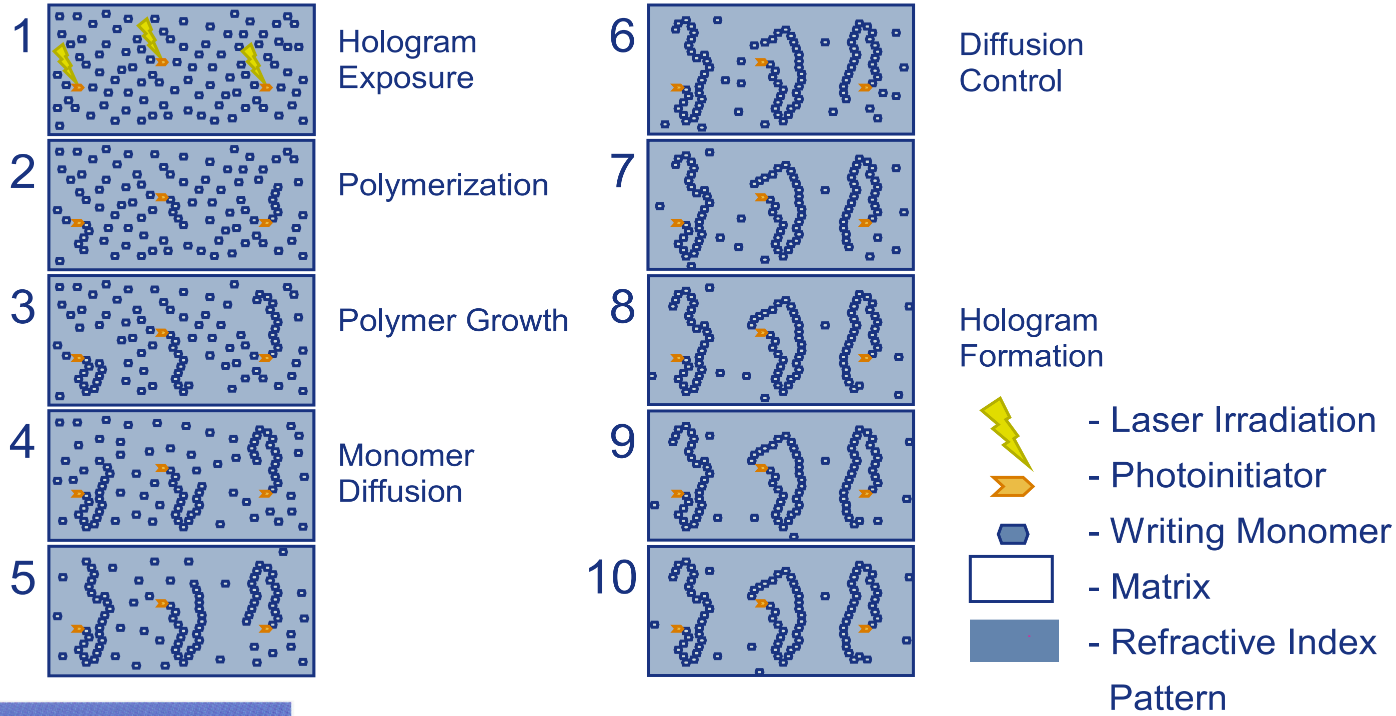
… but Media Dynamic Range prevents us reaching this

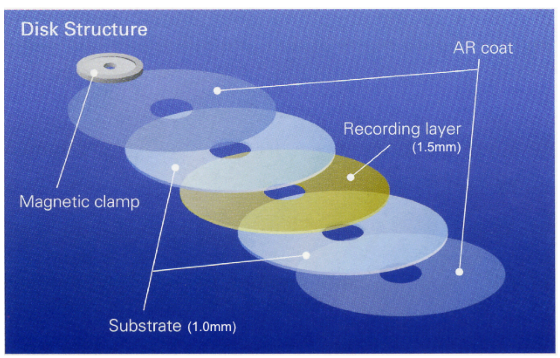
- ★ 2.2 Tbit/in² 640 pages
- ★ 4.0 Tbit/in² 1272 pages
- ★ 5.75 Tbit/in² 3228 pages



Higher capacity requires better media
<u>AND</u> a bigger microdisplay

Akonia's Proprietary Holographic Recording Medium

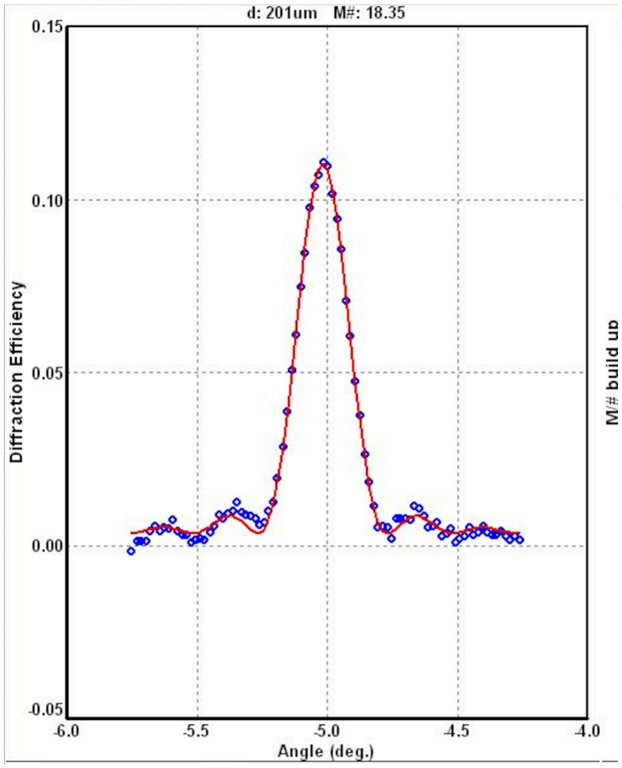


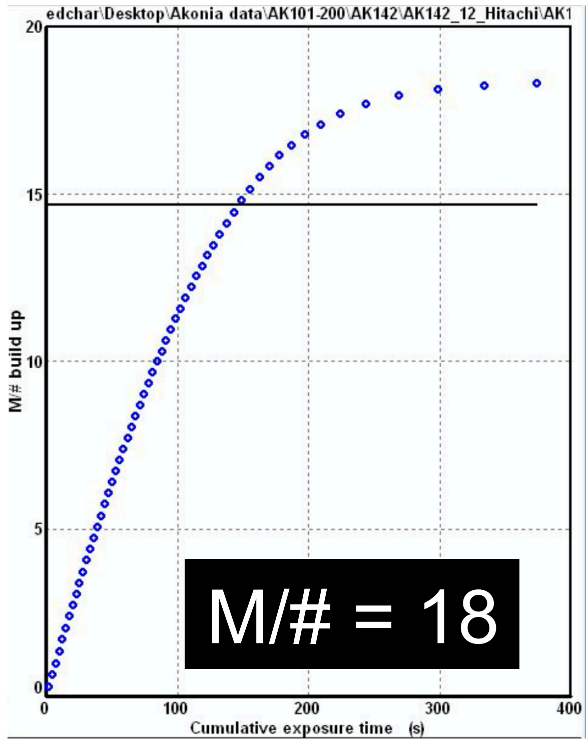


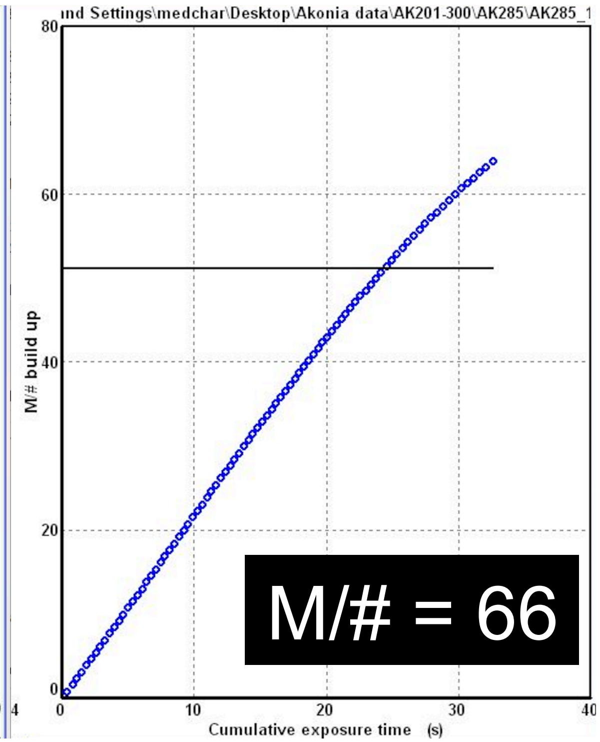
- Important properties:
  - ☑ High photosensitivity and dynamic range (*M/#*)
  - ☑ Low shrinkage
  - ☑ High optical quality (*Flatness, absorption, scatter…*)
  - ☑ High archival stability ("*Like DNA fossilized in amber*"*…*)

New Media Breakthrough!

3.7x Dynamic Range Improvement, 22x Media Sensitivity
Demonstrated: August 2016

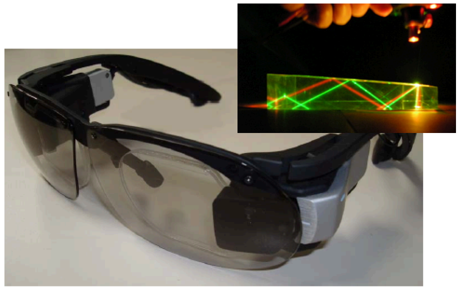




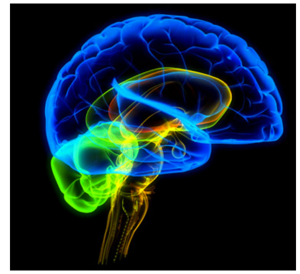


2012 Performance: M#=4
(16.5x Improvement in 4 years)

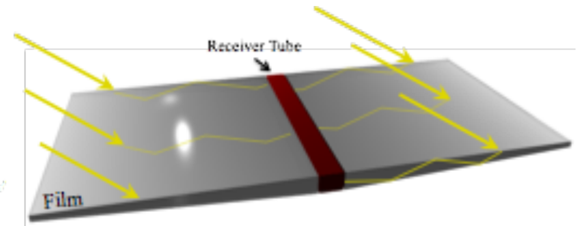
Applications of Holographic Media



Augmented Reality



Holographic Printer



Holographic Solar Concentrator

Holographic Data Storage

Optically Programmable Index Structures

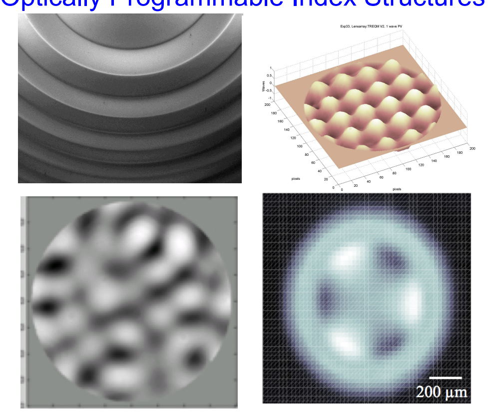


Image of Microscope
Extended Depth of focus

Polymer Chip to Chip
Waveguide
Communications

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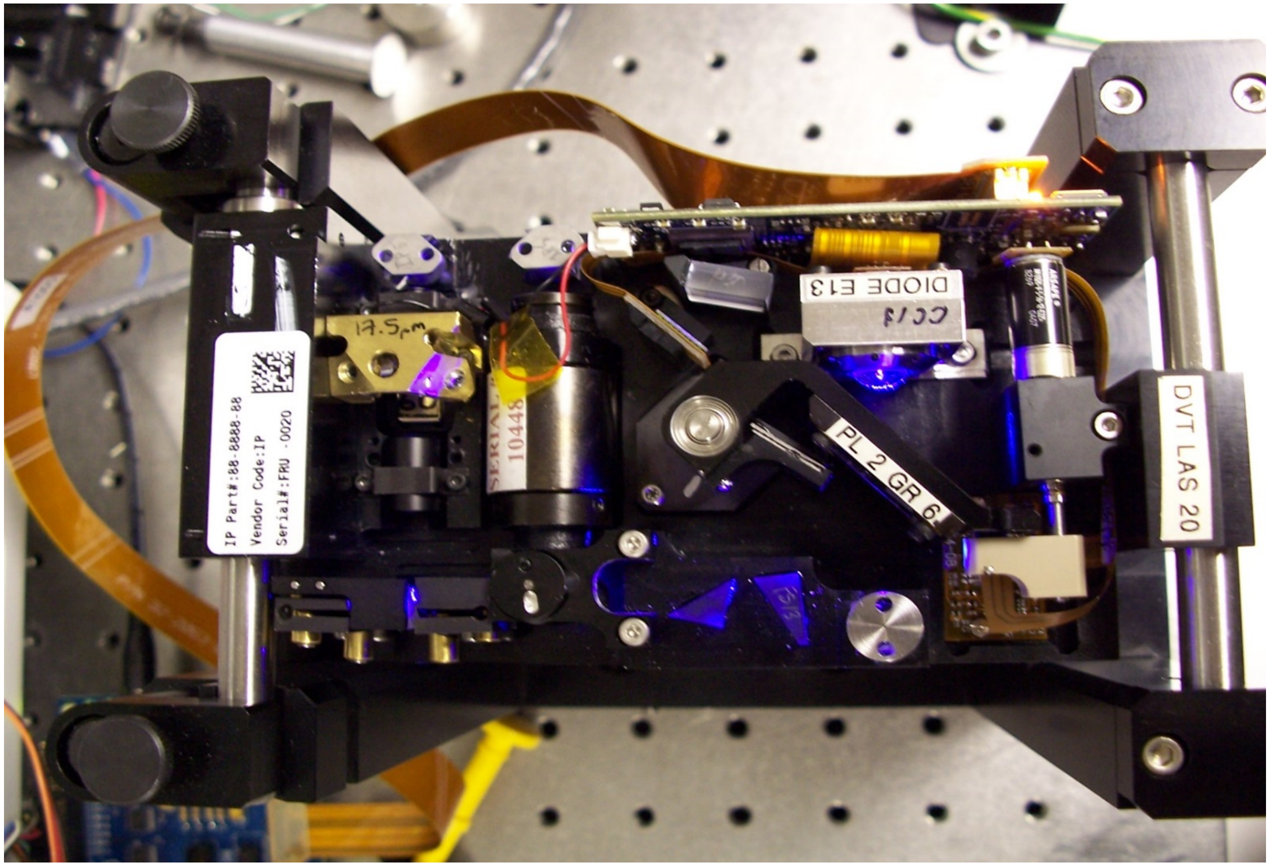
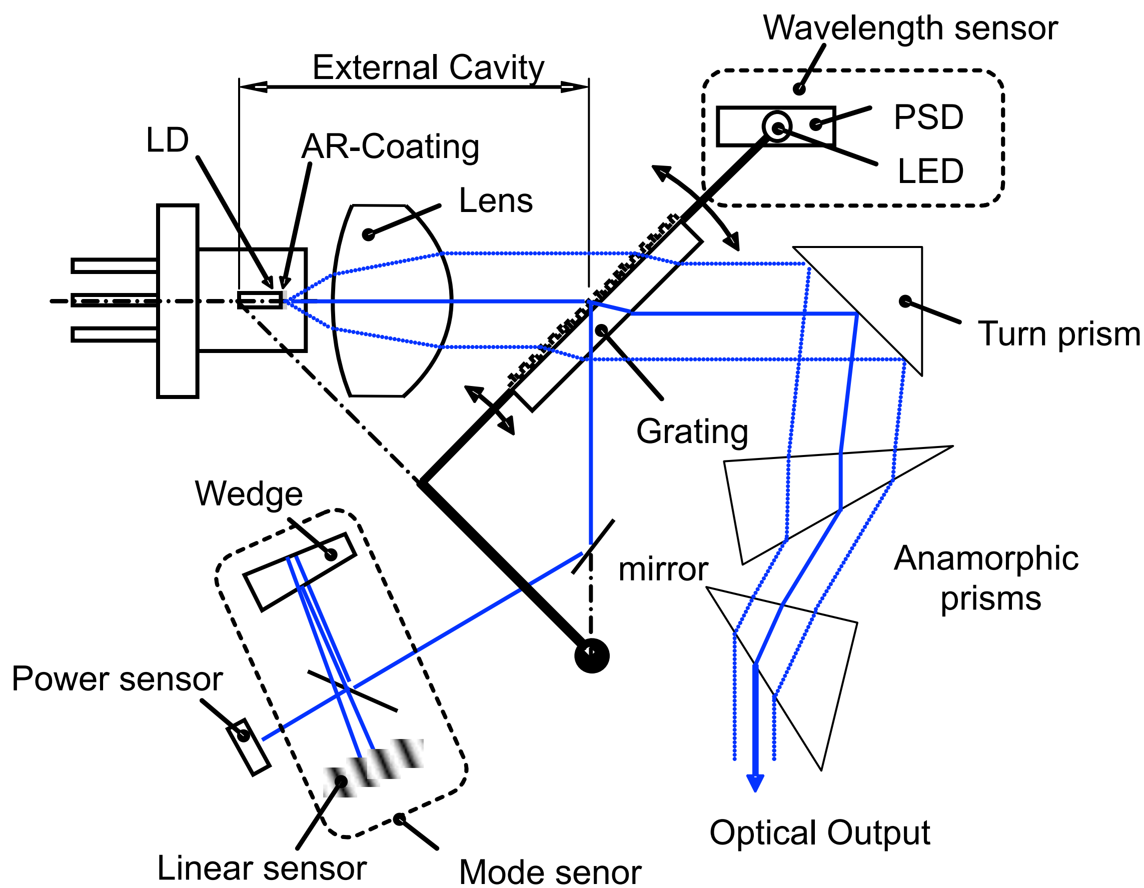
Akonia’s Laser System – Turns a Blu-Ray laser diode into a high coherence laser

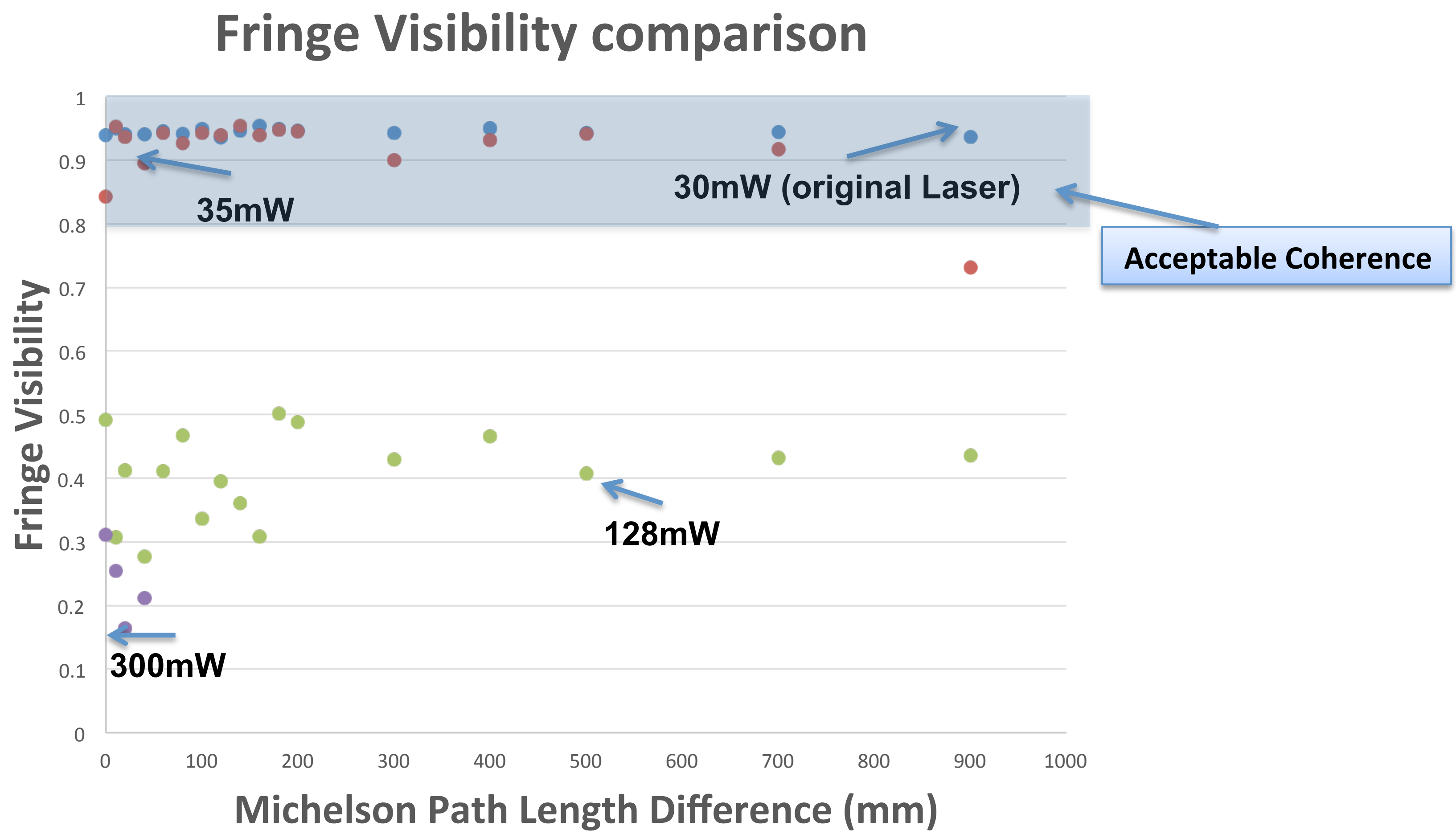


ECDL FRU Diagram

- Features
  - High power 45 mW Blu-Ray laser diode
  - Tunable 402-408 nm
  - Single mode operation
  - Stable beam pointing
  - Field-replaceable



DOE Goal: Improve Laser Power Beyond 30mW



Note: Newer 300mW blue diodes Failed To Achieve High Coherence
Minor increase in power achieved of 5mW

Milestones: Completed, Failed, New

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					✔							
Establish high-bandwidth SLM and Camera vendors										✔		
Media sensitivity of >2x completed and initial tests finished						✔						
Initial design of media XY stage complete								✔				
Investigate off-the-shelf solutions for XY media positioning										✔		
Improve Media Dymamic Range by 2x								✔				
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 (Failed)										x		
2 Tb/in2 bit density demonstrated							✔					
Holographic model of wavefront tolerance complete									✔			
Media sensitivity by >20x												✔
Improve Media Dynamic Range by 4x											✔	
Process development for optically flat square holographic media											✔	
Demonstrate 2.2Tb/in2 bit density (world record)											✔	

Future Plans

- We are actively seeking $25M in investment to begin building new manufacturing prototypes for commercialization

- Akonia anticipates first beta units could be produced within 24 months of funding.

- We are seeking a large scale manufacturing partner to help with DFM (Design for manufacturing)

Thank You!

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