Progress of the Development of High Performance Removable Storage at InPhase Technologies for Application to Archival Storage

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InPhase Background

- **InPhase Technologies was created to commercialize holographic media and systems technology developed at Bell Labs (Lucent)**
  - **Incorporated September 2000; setup in Longmont, CO in January 2001**
- We are applying this technology to address the limitations of conventional removable media products (magnetic, optical, and Flash)
  - Removable media with huge storage capacity, high transfer rates, and random access
- InPhase owns or has exclusive access to >40 Bell Labs patents in high capacity polymer media and in holographic multiplexing techniques
  - Continue to maintain technology leadership and enlarge patent portfolio (21 patent disclosures since inception)
- **We are working with storage industry partners to create storage and distribution systems using our holographic media and drive technology**

Product Development

Recordable

NOW — Customer testing

Media

2006 — Under Development

Drives

2006

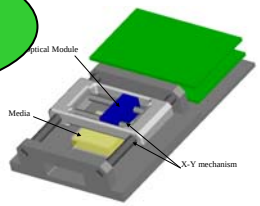
ROM

NOW — Customer testing

Media

2007 — IP development in Process

Drives



Rewritable

2005/6 — Research in Process

Media

2007 — Modify recordable drive

Drives

2007

InPhase Timeline

ROM drives and media

Rewritable drives and media

Volume drive and media shipments

2007

2006

2005

Demo 200 Gb/in2

Prototype Drive

2004

Drive Tester Revenue

2003

Media Interchange

Media Revenue

2002

Rewritable Media

ROM Replication/ Polytopic Mux

2001

InPhase Technologies spun Out of Lucent, Bell Labs

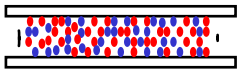
Temperature compensation

2000

Data Channel

1999

RECORDABLE 2-chemistry material



1998

1997

Zerowave Media Manufacturing

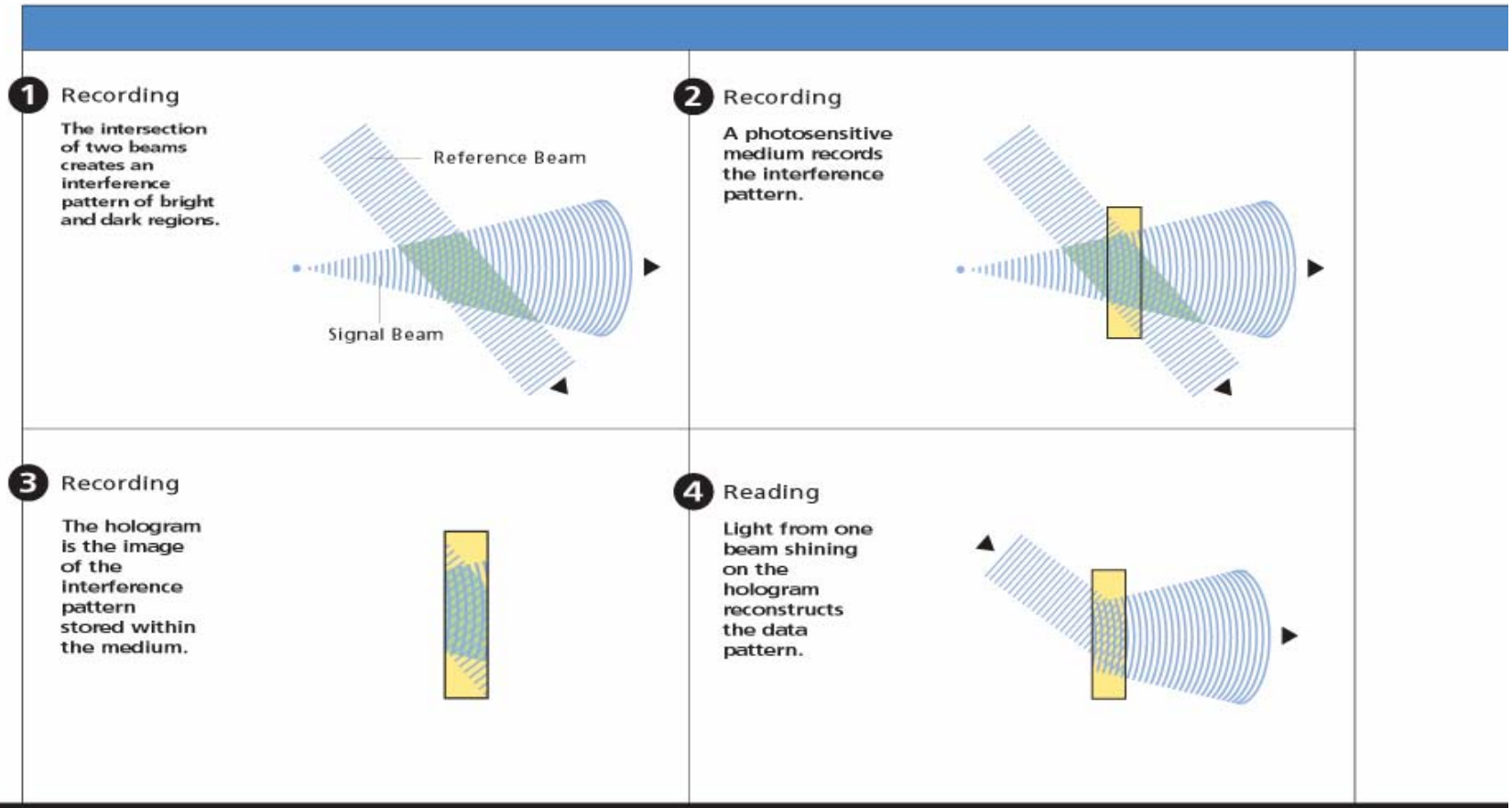
1996

Multiplexing Techniques

1994

Photopolymer media development

What is a Hologram?



InPhase TECHNOLOGIES

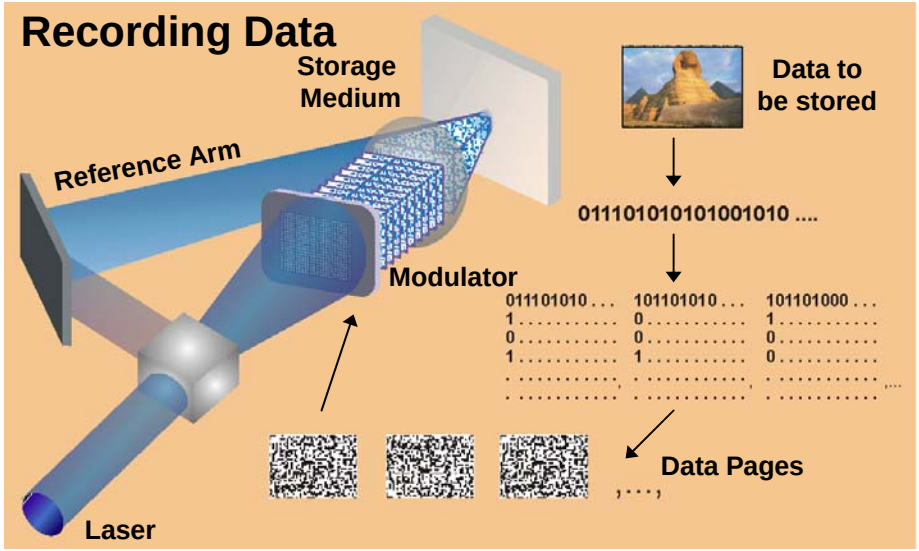
Holographic Data Storage - Recordable

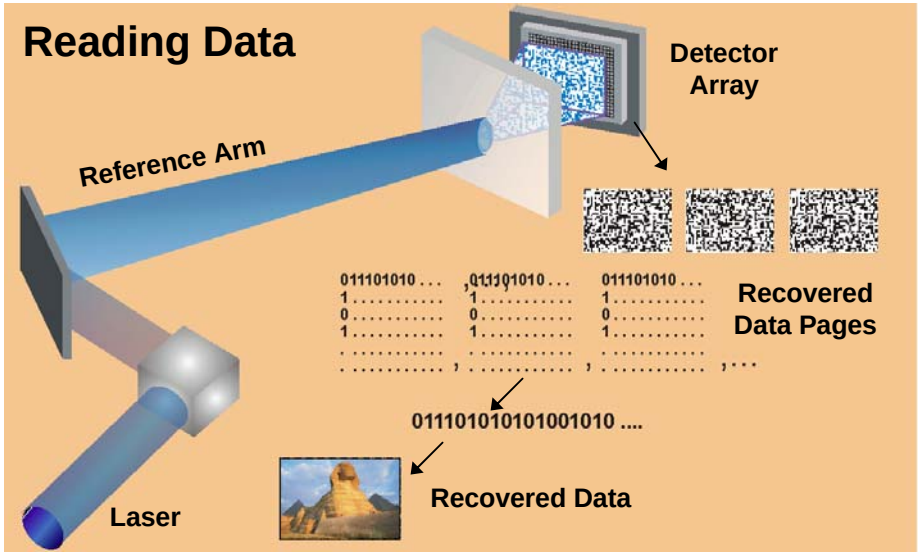
Feature	Benefit
▪ Parallel access to data	▪ Fast data transfer rates
▪ Multiplex data pages in one location	▪ Ultrahigh storage densities
▪ Removable Media	▪ Transportability

Record by crossing signal beam with a reference beam

Readout by presenting reference beam to the media

Media does not need to spin



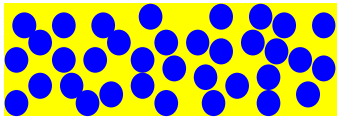


Why Holographic Storage for Digital Content?

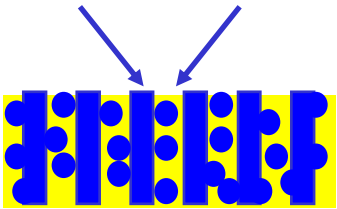
- high capacity & performance
  - Highest optical densities and fast parallel transfer rates
  - Random access – time to data
- low cost
  - media up to 8 X less expensive than tape
- 50 year archive life
  - no special handling required
- broad design flexibility
  - chip/credit card for consumers
  - disk for professionals
  - Blue, red, and green media
- ***robust content protection & security***
  - custom encryption

Grating Formation in Conventional Photopolymer Media

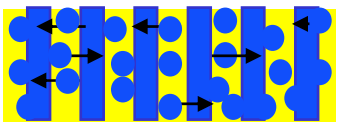
Mechanism



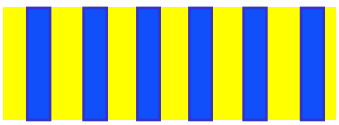
System consists of monomers dissolved in a matrix.



Holographic exposure produces a spatial pattern of photoinitiated polymerization.



Concentration gradient in unreacted monomers induces diffusion of species.



Diffusion produces a compositional gradient, establishing a refractive index grating (Δn).

Advantages

- High photosensitivity
- Permanent holograms
- Low cost

Concerns

- Recording-induced dimensional & bulk refractive index changes
- Thickness
- Optical Quality & Scatter

Requirements For Holographic Storage Media

High Storage Capacity

Rapid Write/Read Rates

Dynamic Range - High storage densities & rapid read rates

Photosensitivity - Rapid write rates

Millimeter Thickness - High storage densities

Dimensional Stability - High fidelity data recovery

Optical Flatness - High fidelity imaging of data pages

Low Scatter - Low levels of noise in data recovery

Processing - Heat/Solvent Free

Non-volatile readout

Long shelf-life of media

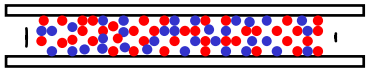
Long archival life of stored data

Environmental/thermal stability

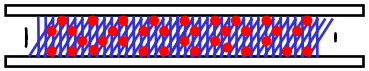
InPhase Photopolymer Media

Two Chemistry Approach

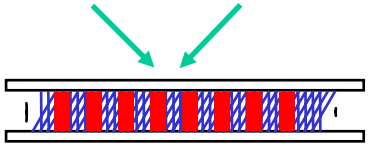
Media are fabricated from independently polymerizable and compatible matrix and imaging components



Resin consists of matrix precursors and imaging components



In-situ formation of cross-linked matrix



Writing chemistry is independent of host formation chemistry

In-situ matrix formation: thick, optically flat formats

Cross-linked matrix: stable holographic gratings

Compatible matrix and monomer systems: optical clarity and low levels of light scatter

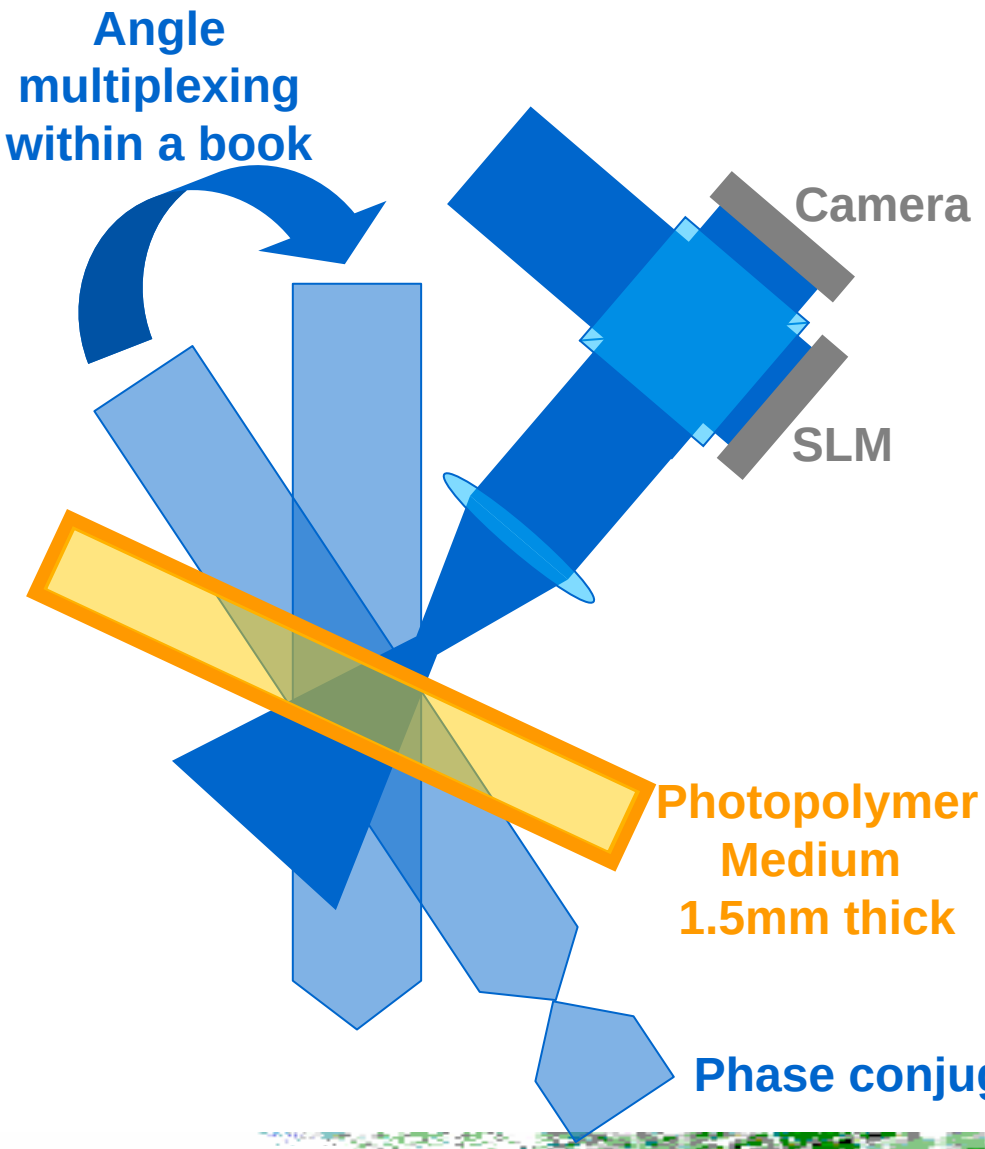
Independent matrix and monomer systems: no cross-reactions to dilute refractive index contrast. Allows optimization of dimensional stability.

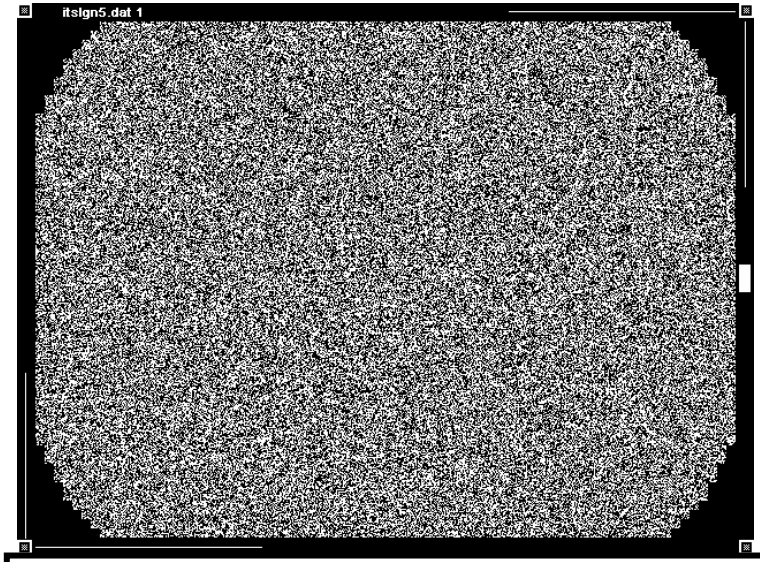
Media suitable for all holographic

Storage paradigms!

Optics Letters, 24(7), 487 (1999)

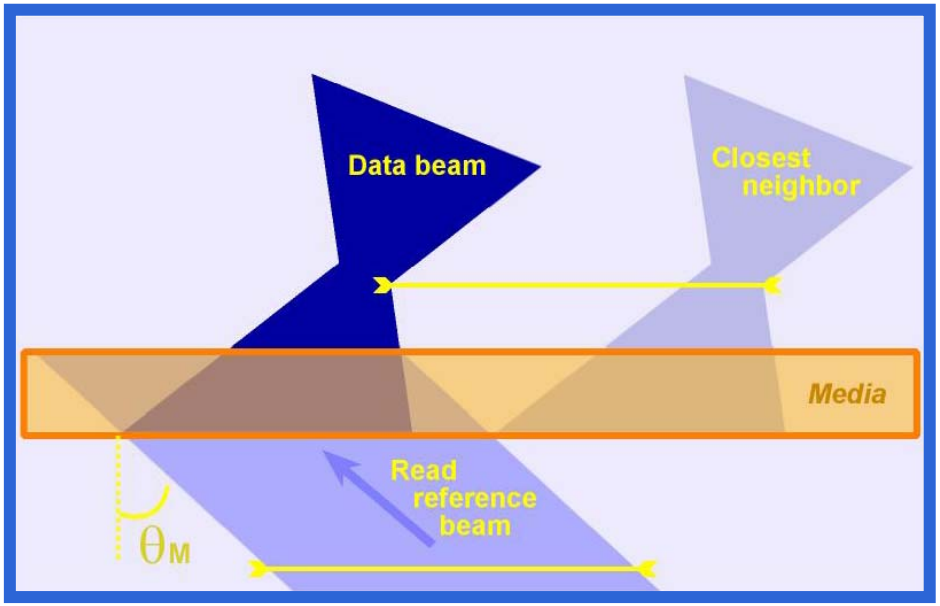
Our system's basic geometry



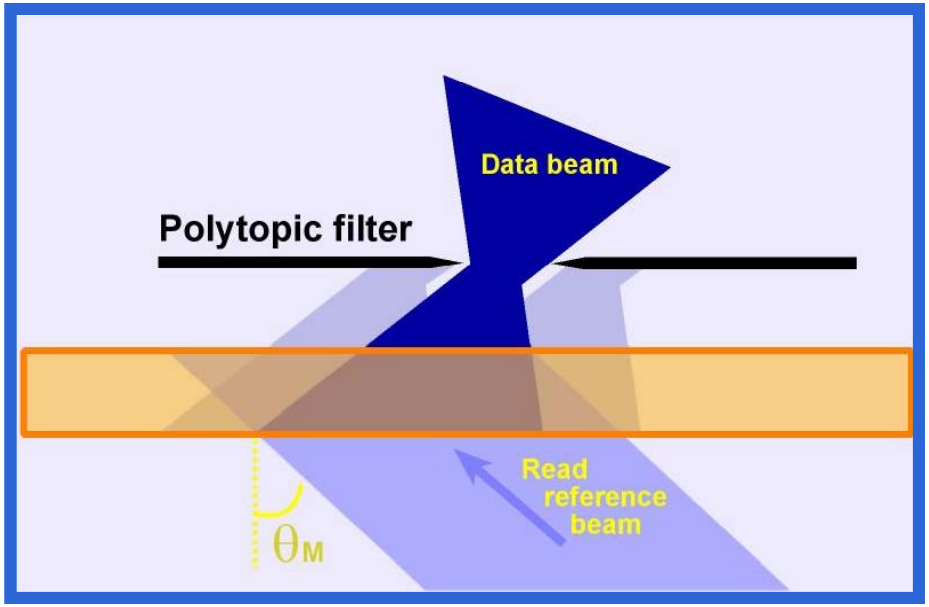


SLM data page of 1.2 mega pixels

Density with a polytopic filter



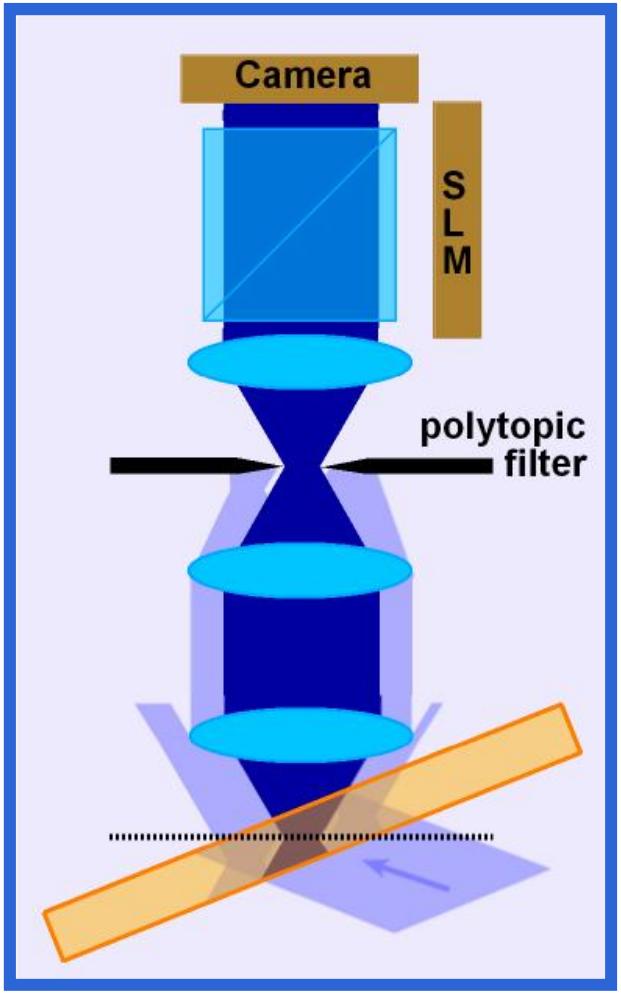
Traditional minimum book spacing



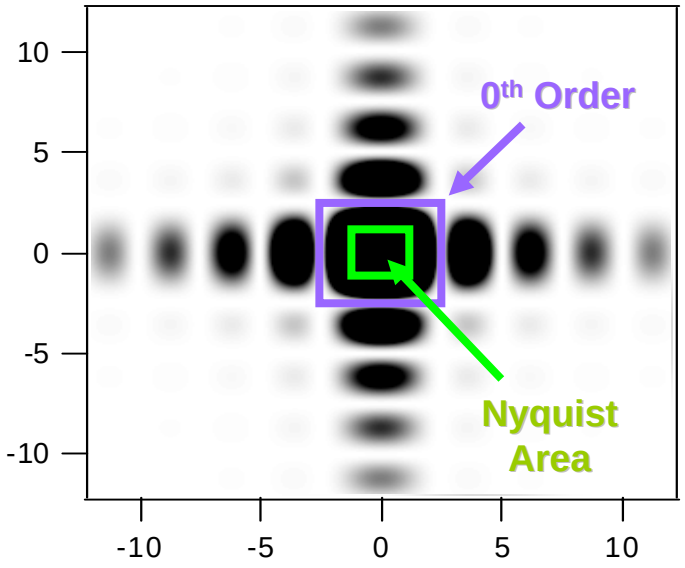
Book spacing with a polytopic filter

Additional polytopic filter benefit

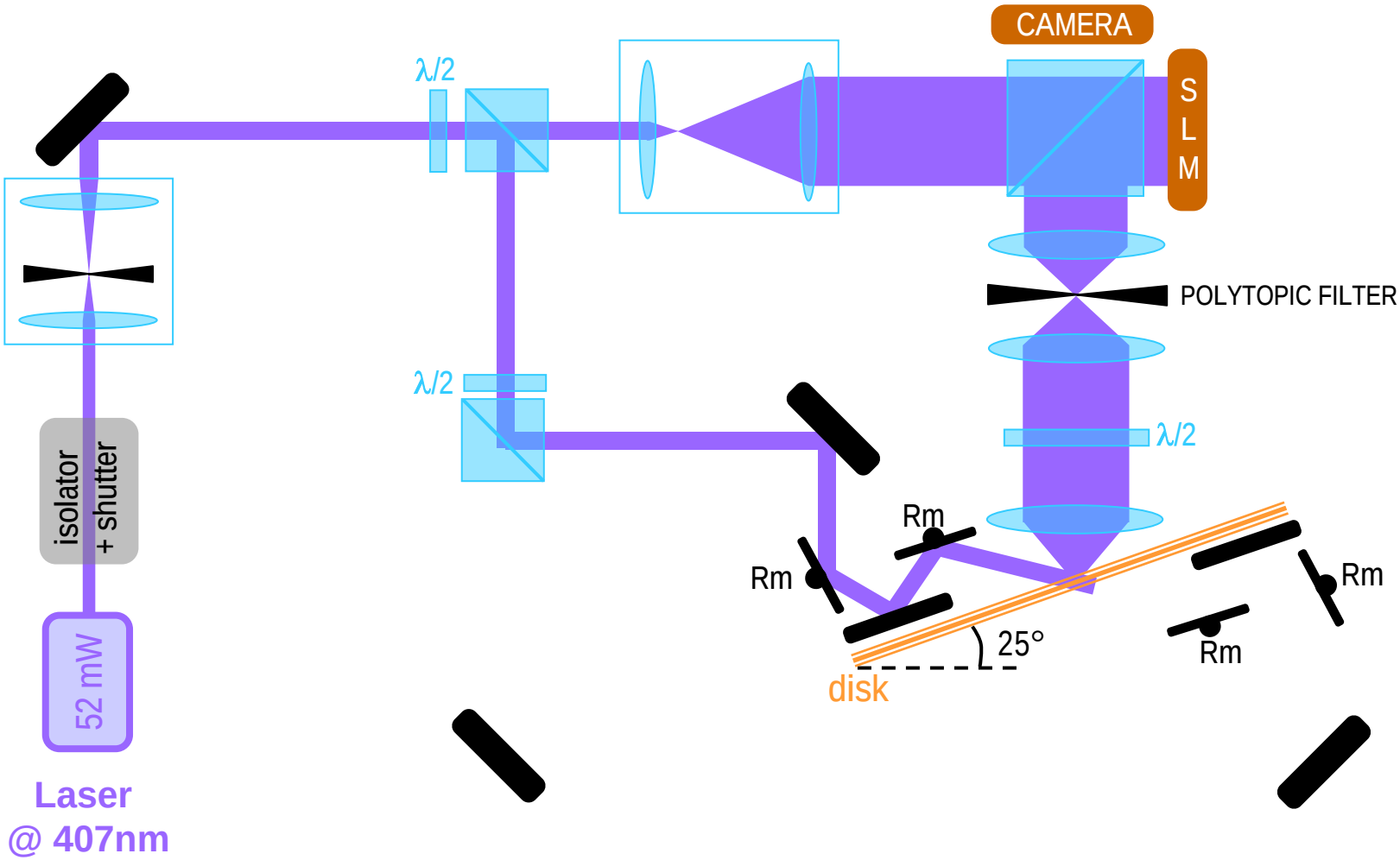
Polytopic filter placement freedom



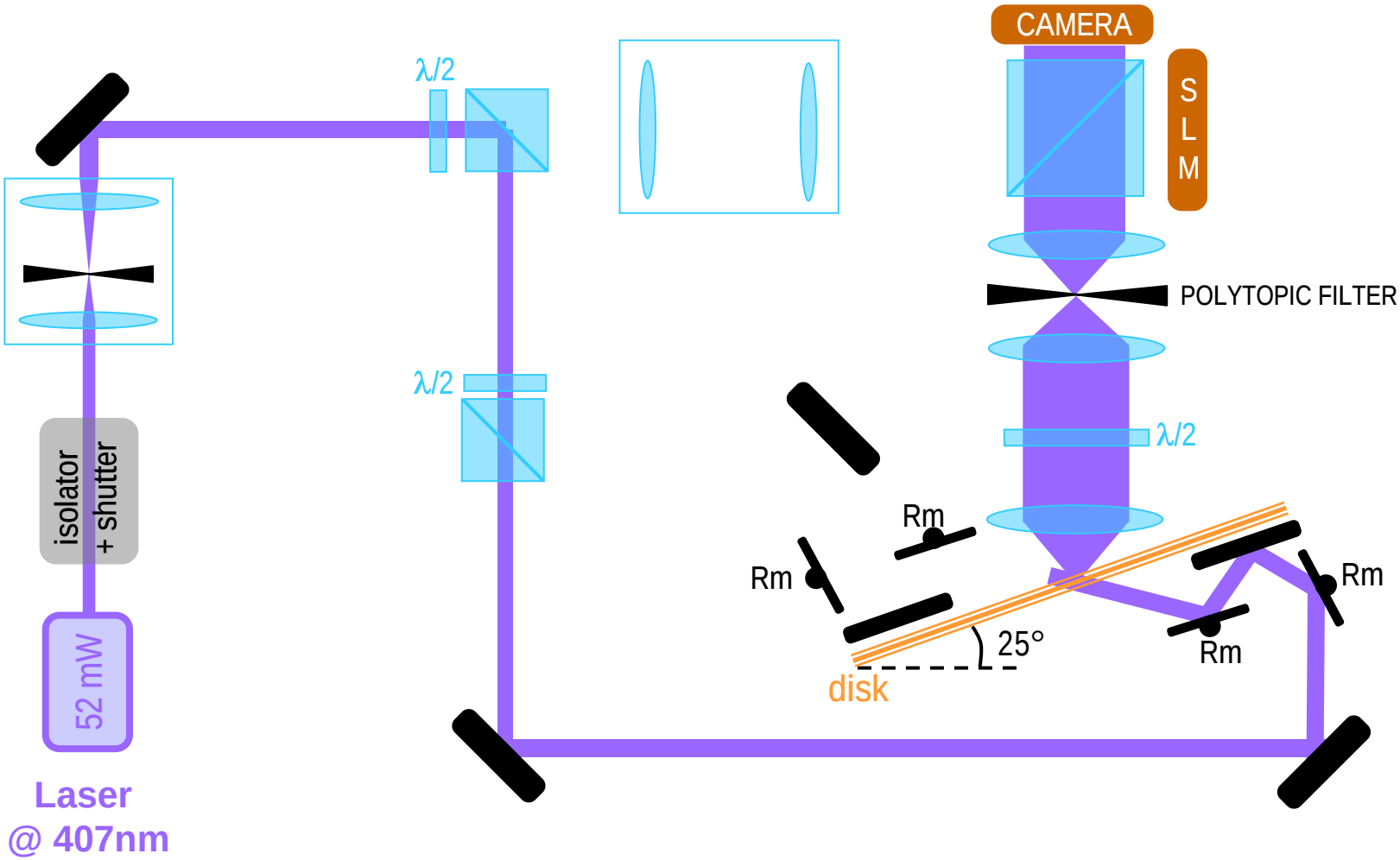
Nyquist filtering during recording



System architecture - write



System architecture - read



Higher densities

200Gbit/in^2

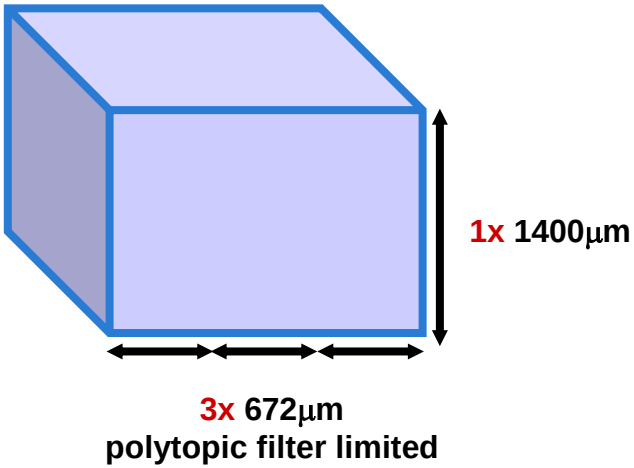
x40 DVD$^{(1L)}$, x8 Blue-Ray $^{(1L)}$

@ 24Mb/s write user transfer rate

@ 37Mb/s read user transfer rate

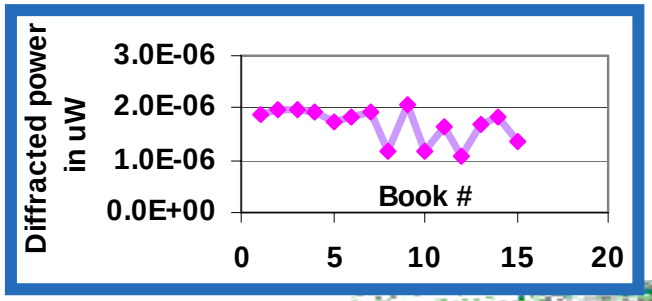
# of pixels per page = 1,144,640

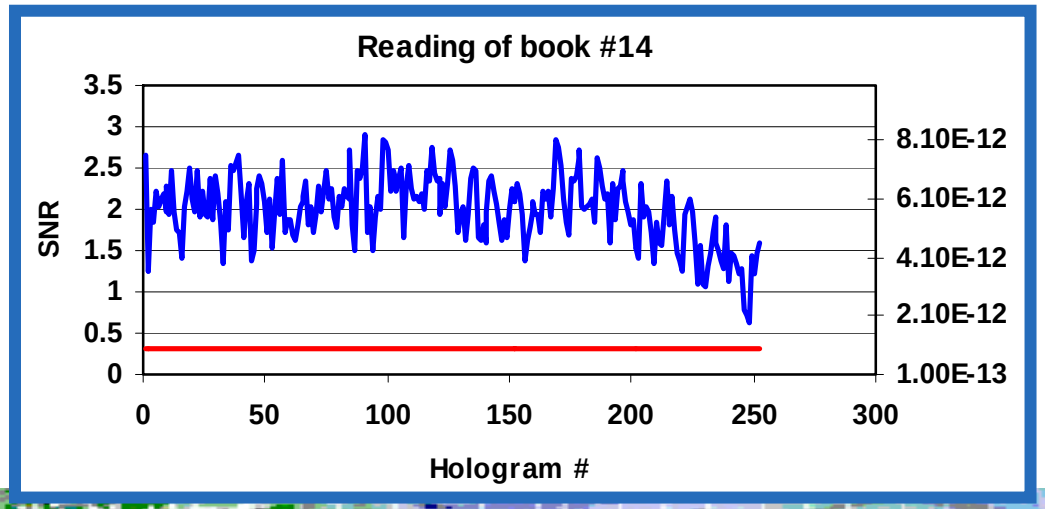
# of pages per book = 252



Layout of our demonstrations:

L1	L7	L13	L2	L8
L3	L9	L14	L4	L10
L5	L11	L15	L6	L12





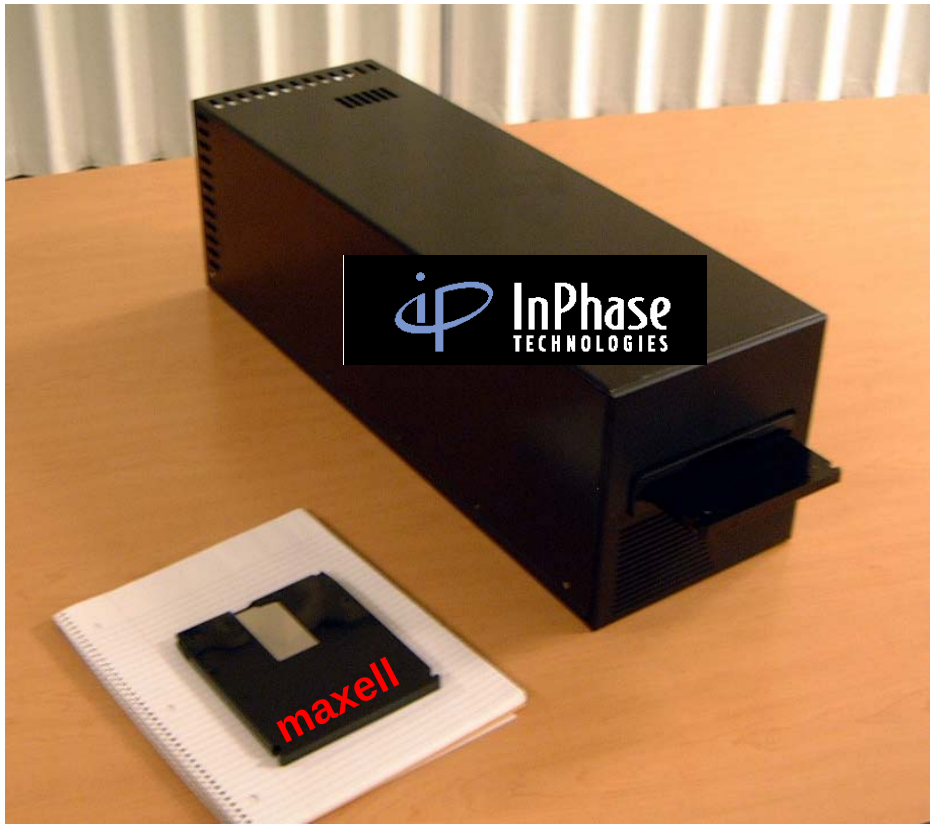
Recordable Technology Roadmap

	P1	P2	P3
Specs	300 Gb/in2 20 MB/s	800 Gb/in2 80 MB/s	1600 Gb/in2 120 MB/s
# of pages per book	131	370	753
Reference Beam Sweep (degrees)	10	25	30
Hologram pitch (θ, r) (mm)	0.82, 0.48	0.82, 0.48	0.82, 0.48
NA of object beam	0.65	0.65	0.65
Bragg Null	2nd	2nd	1st
SLM Pixels	1200x1200	1200x1200	1200x1200
Camera Pixels (4/3 OS)	1696x1664	1696x1664	1696x1664
Wavelength (nm)	407	407	407
Material Thickness (mm)	1.5	1.5	1.5
M# of media @1.5mm	33.3	90	135

Angle and Polytopic Multiplexing

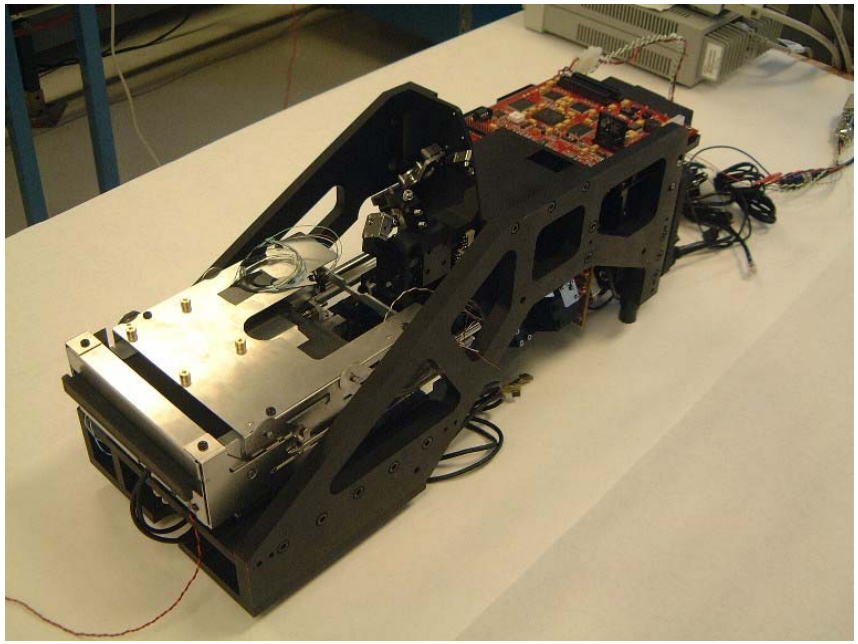
Compatible with RW media

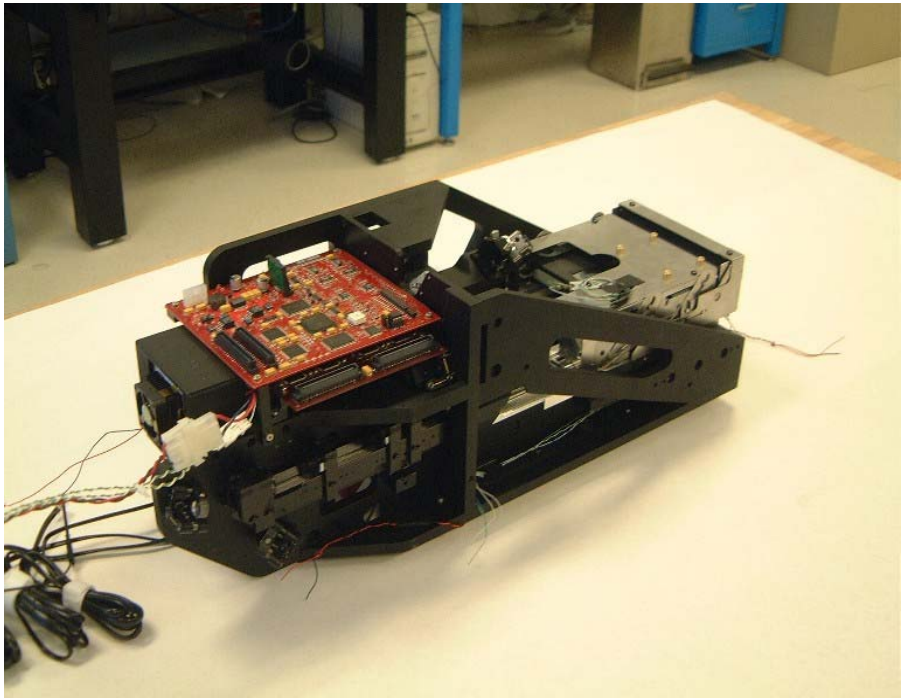
InPhase delivers the World's first Holographic Drive Proto



- completed October 2004
- media
  - 2-chemistry photopolymer
  - Write Once Read Many (WORM)
  - 130 mm disk
  - 407 nm wavelength sensitive
  - 1.5 mm thickness of material
  - 5.25" cartridge
- drive
  - records and reads data to/from entire 130 mm disk
  - WORM
  - Integrated control system
  - Works through SCSI interface

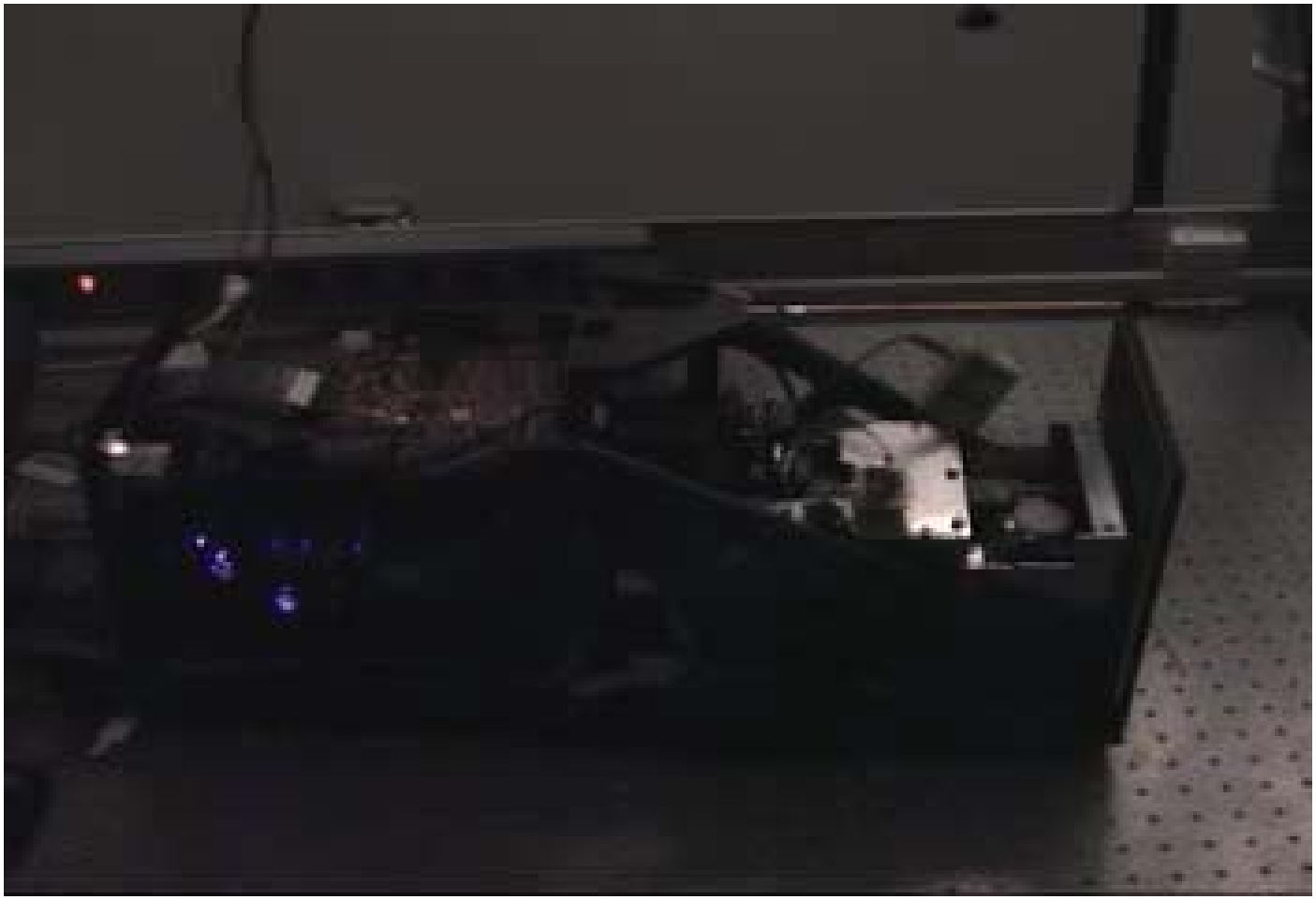
Prototype Drive (internal view)



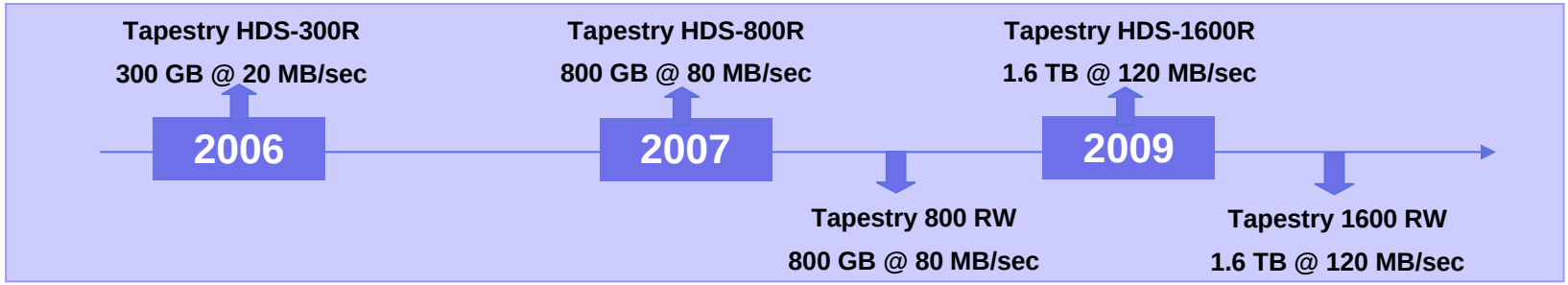


“Inside the box” video

Prototype in audio playback



Roadmap for Professional Products



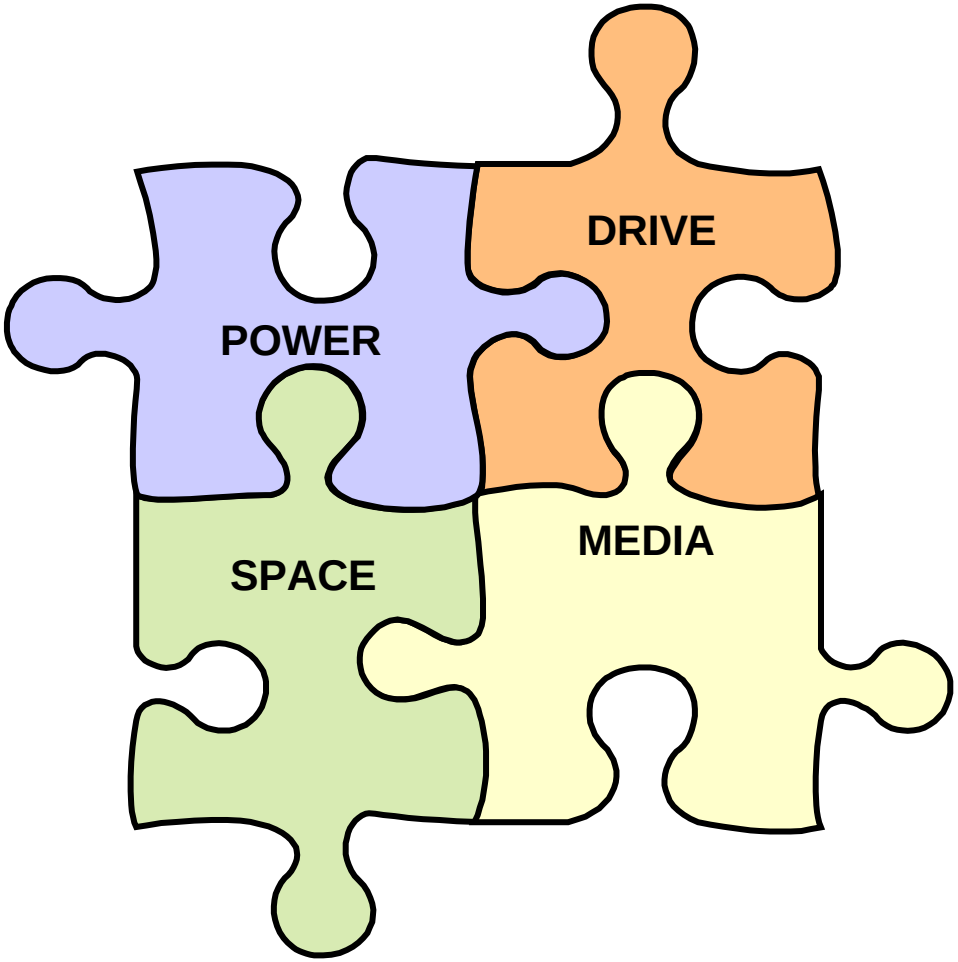
media

- backward read compatible
- theoretical capacity of 17 TB

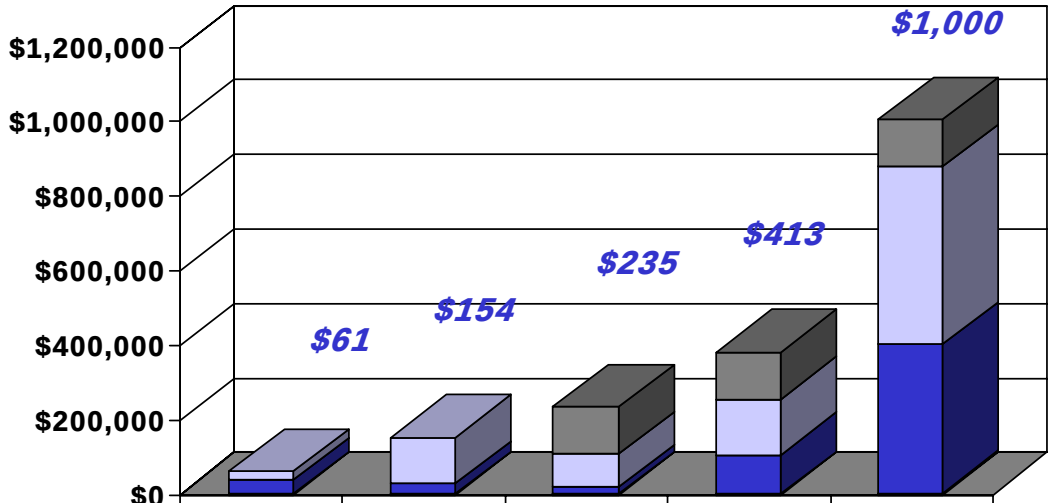
drive

- camera and slm
  - higher sensitivity/ faster
  - more pixels per page
- **laser**
  - higher power for improved performance
- firmware
  - more pages per book
  - more complex recording schedule

Customer's TOTAL COST OF OWNERSHIP



15 Year TCO for Media, Drive, Space, Power for 100 TB



	Tapestry	Blu-ray	LTO Tape	1/2"	D5
Data Migration $			$126,000	$126,000	$126,000
100 TB Media	$20,040	$125,000	$90,000	$150,000	$477,000
Total $ of Drives	$40,000	$27,000	$18,000	$105,000	$400,000
Yrly $ Sq Ft	$210	$990	$300	$450	$750
Yrly $ KWH	$600	$1,125	$600	$1,245	$3,810

Assumptions: 1 drive for every 200 pieces of media
Drives replaced 1 time
Data on tape migrated to new media every 5 years
Data migration cost, labor & system expenses
Warehouse Sq Ft. cost = $10.00
KWH = $.08

Partnerships move from “technology to solution”

Strategic Components

Development Partners

Drive Mechanics
ALPS

SLM
DisplayTECH

Laser
SONY

Detector
Fillfactory image sensors

OMA
Large Company

Media
maxell

Chemicals
Bayer MaterialScience

Manufacturing Partners

Drive

(*Under discussion*)

Media

maxell

Bayer MaterialScience

Customers & Integration Partners

OEM
Drives, Media, Archival Solutions

Robotics
ASACA
BDT

Software & Solution Integrators
MASSTECH GROUP
PEGASUS