The Future of Content Distribution

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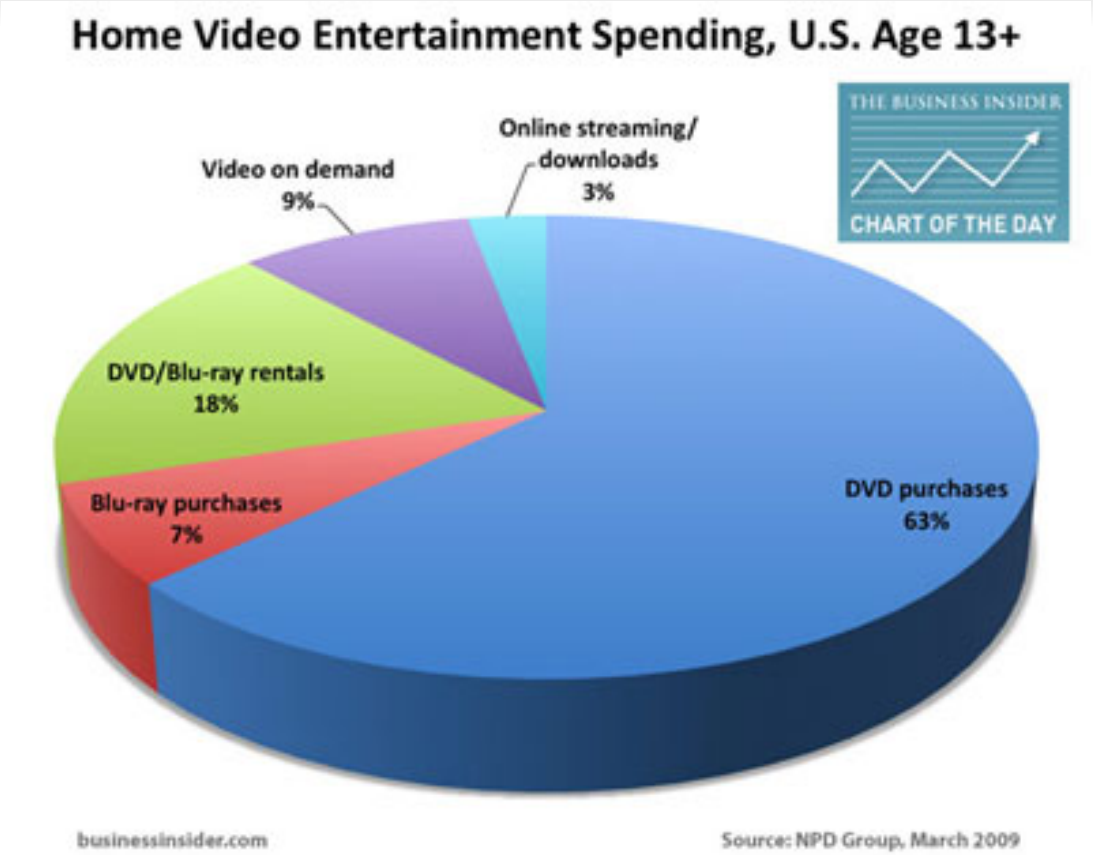
Outline

- What do consumers want?
- The current state of content distribution
- Future distribution technologies
  - Optical storage
  - Magnetic storage
- Discussion
- Summary

What Do Consumers Want?

- Anywhere, Anytime access to their content on Any Device
  - iPod, iPhone, PC, TV, Media Player, phone
  - Relax DRM restrictions

What Are Consumers Doing Today?

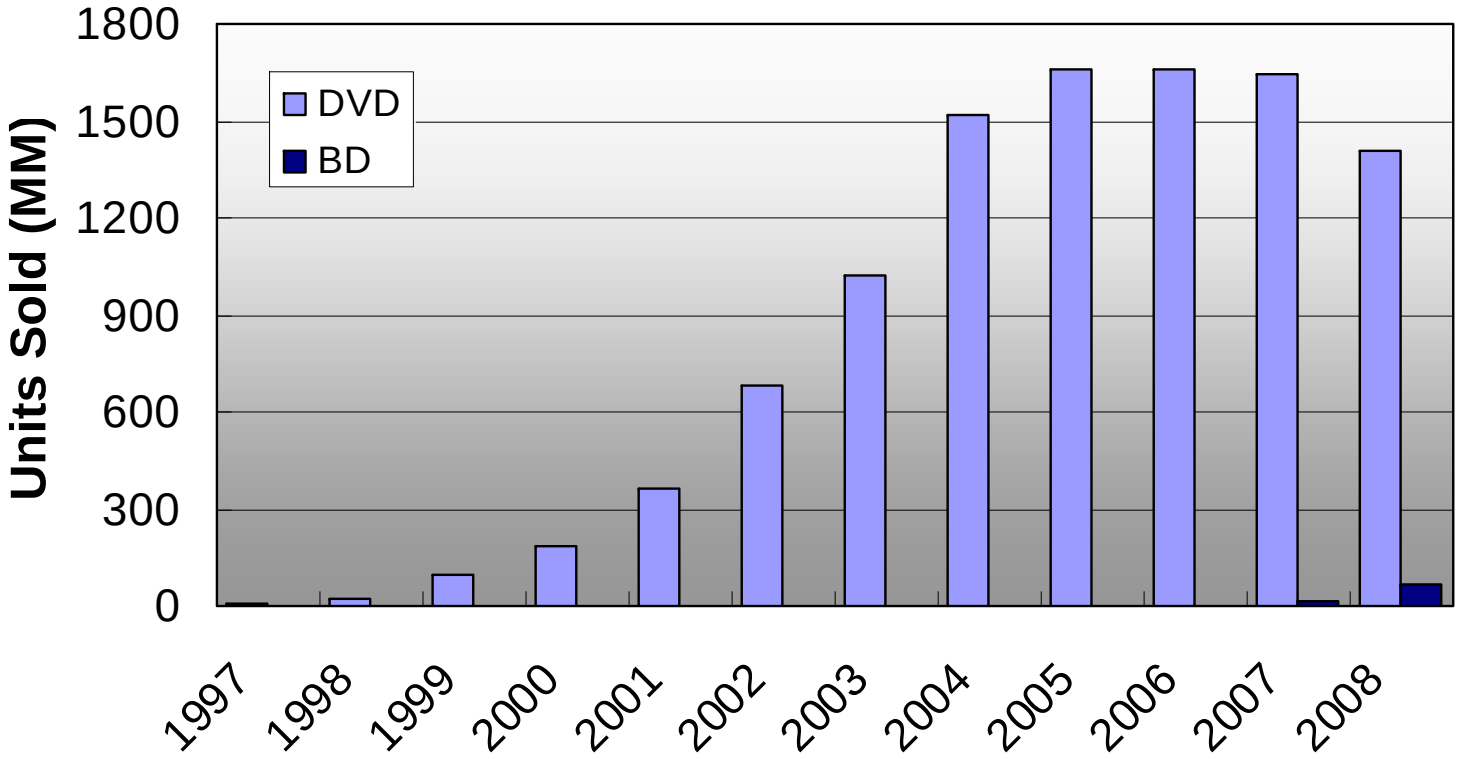


- Physical media dominate
  - There is a lot of inertia in the market
    - Digital delivery is taking a foothold, with lots of room to grow
- People like to own content

Content Distribution Today

- **DVD sales declining**
- **BD sales on the rise**

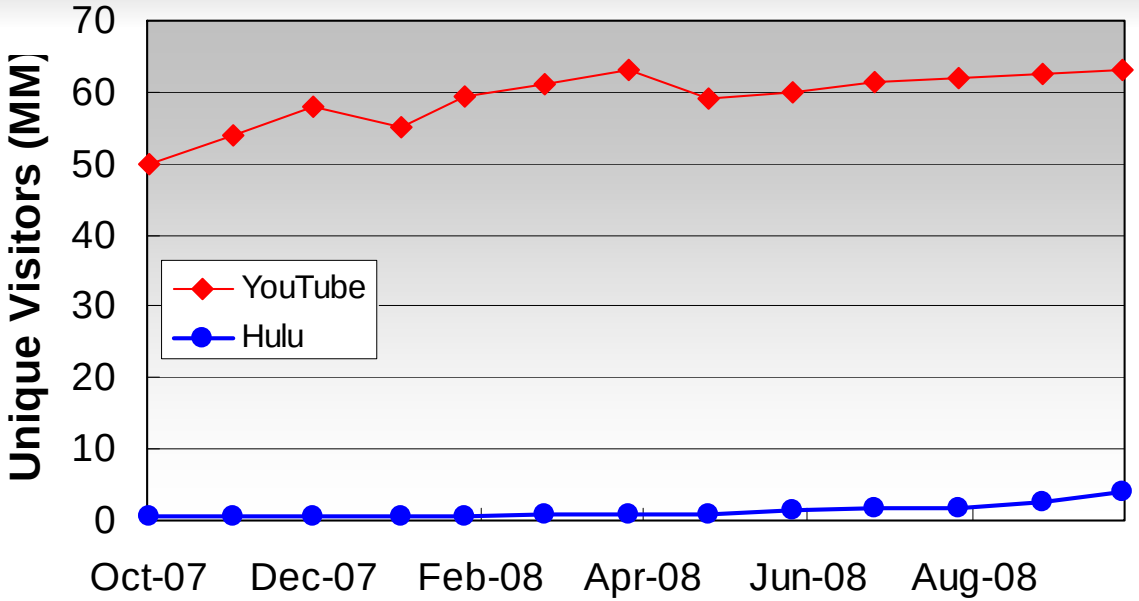
Source: DVD Entertainment Group (www.dvdinformation.com)



Content Distribution Landscape

Streaming:

Source: FutureSource Consulting



Hulu starting to stream HD content

- **Compressed stream**
- **2.5 Mbps transfer rate**

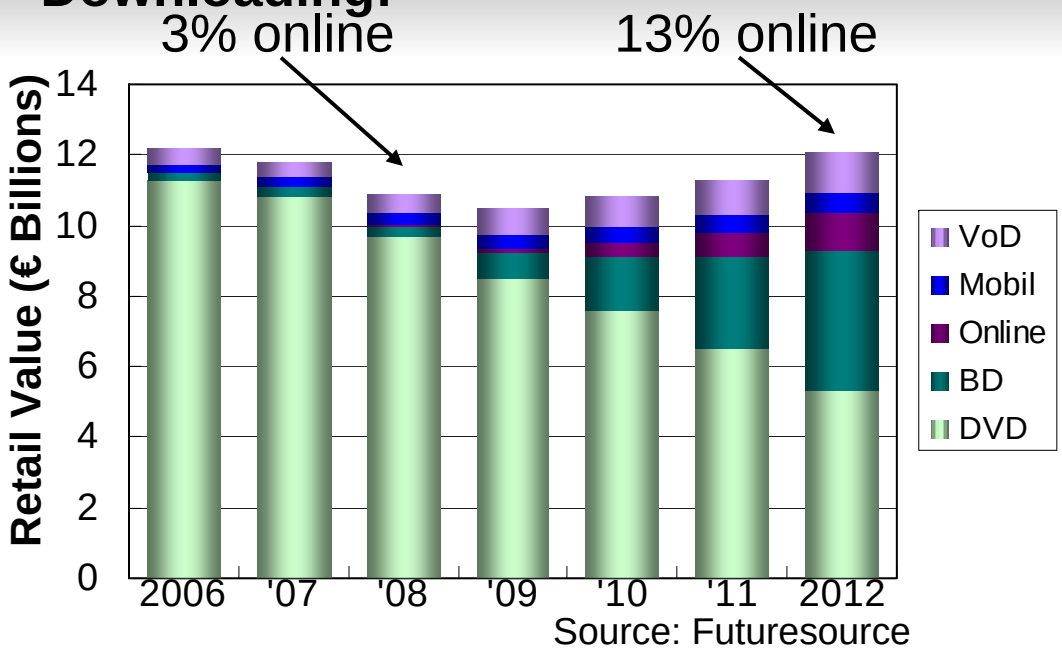
Revenue (US)

	2008	2009 (est.)
YouTube	**$100MM**	**$180MM**
hulu	**$70MM**	**$180MM**

Source: Arash Amel, Screen Digest

Content Distribution Landscape

Downloading:



Source: Futuresource

RoadRunner:
- 1 – 15 Mbps
- $20 - $35/mo

Verizon FiOS:
- 10 – 50 Mbps
- $45-$140/mo

Comcast:
- 6 – 16 (50*) Mbps
- $50-$140*/mo

*DOCSIS 3.0 (30% penetration)

Source: Time Warner, Verizon, & Comcast plans

"Real-time" download

↓

>25 Mbps
(Assumes BD quality)

	Subscribers	Available Homes	Penetration (130 MM homes)	Growth (MM/yr)
Time Warner	**8.7 MM (33%)**	**27MM**	**7%**	**1.0**
Verizon FiOS	**2.8 MM (27%)**	**9.7MM**	**2%**	**1.0**
Comcast	**15.3 MM**	**---**	**11.5%**	**1.3**

Source: Time Warner, Verizon, and Comcast Q1-2009 quarterly reports

Internet Traffic versus Disk Content Delivery

	2009	2010	YOY Growth
Web, email, transfer	325 PB/m	425	30%
P2P	507 PB/m	562	11%
Internet video to PC	346 PB/m	449	30%
Internet video to TV	301 PB/m	492	63%
DVD disks	542 PB/m	458PB/m	-8%
BD disks	200PB/m	440 PB/m	120%

DVD content distribution is equivalent to about 50% of all Internet distribution now!

Market Perspective

What about internet infrastructure and HD content?

- Assume BD-quality (1080p, compression, 4:2:2 color sampling, 24 fps…)
- Assume consumers desire at least “real-time” download (> 25 Mbps)
- Only highest-speed FiOS & Comcast can meet demand (50 Mbps)
- Current growth rates = ~20 MM subscribers in 2013 **(< 15% of US homes)**

What about expanding content?

- Digital cinema in the home (4k2k and 4k4k)
- Super Hi-Vision (8k4k)
- 3D TV

} **Growing bandwidth demand**

Interim Conclusions

1. **Technology landscape changing with generations**
   - DVD sales slowing, BD sales starting to rise
   - Streaming revenue growing
   - Video downloading growing
   - How do we protect content/copyrights?

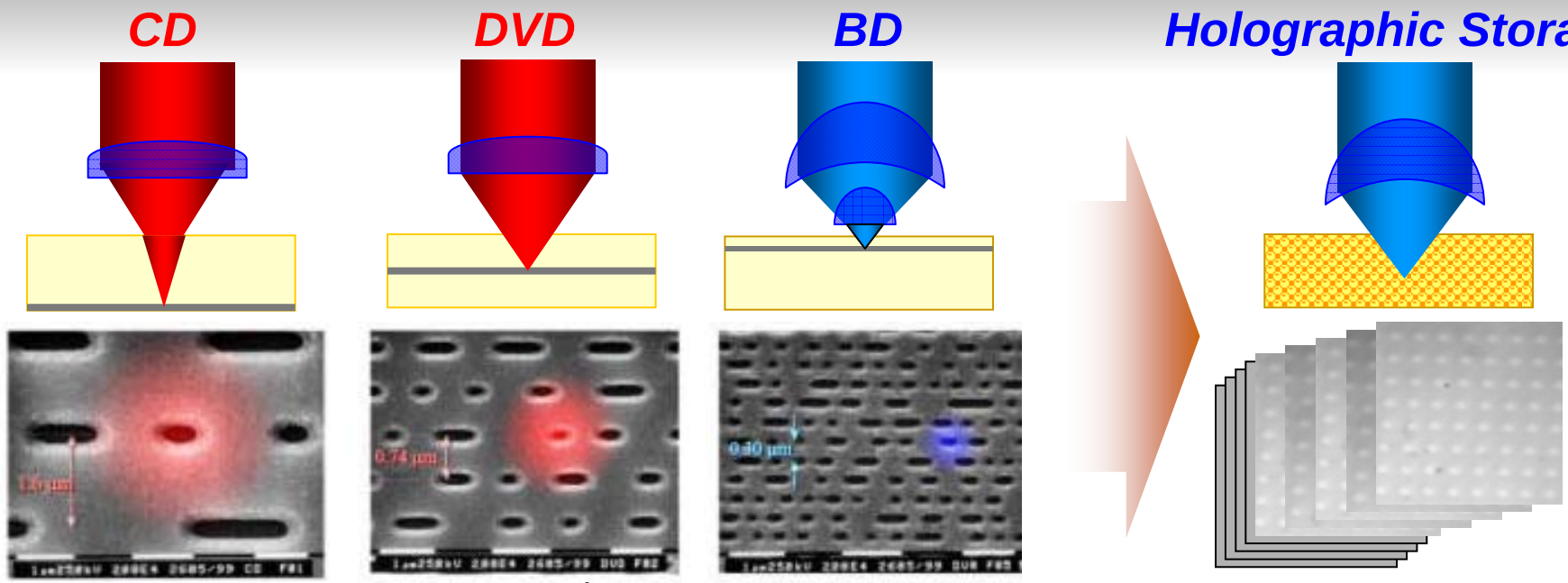
2. **Market will evolve over the next 5 years**
   - Internet infrastructure expanding, fast enough (regional variation)?
   - Content formats/applications poised to grow, demand?
   - Race between growing subscriber base and growing bandwidth demand is critical for future distribution

3. **Holographic storage can support future distribution**
   - Increased capacity for increased resolution/content (3D)
   - Cost-effective drives and high-volume media potential (<$0.02/GB?)
   - Capable of supporting high-speed replication of TB discs
   - Pre-recorded distribution **OR** consumer content archiving
   - Opportunities for enhanced function/DRM/copy-protection

Content Distribution via Optical Disk or Internet?

- Next generation optical storage
  - Near field recording
  - Holographic recording
- Next generation magnetic storage
  - Heat assisted magnetic recording

Micro-Holographic Storage



Source: Blu-ray Disc Association

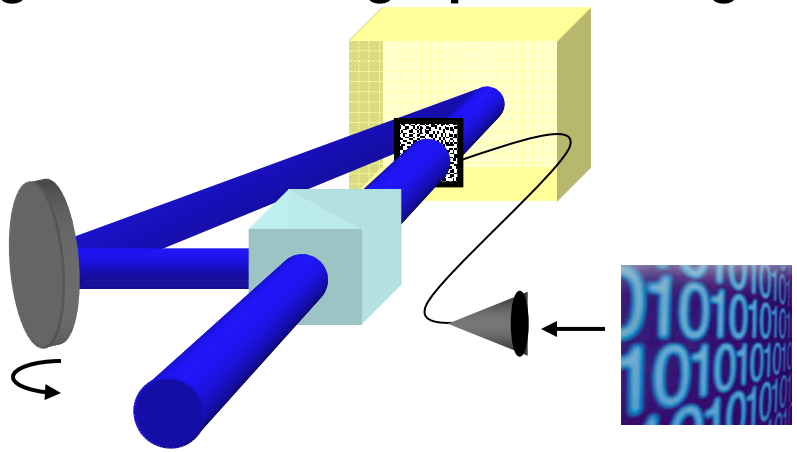
- **New optical systems, holographic media, & replication**
- Leverages existing storage technology – comparable drive cost
- Simple, robust, & backward compatible hardware

Courtesy GE

Holographic Storage Technology

Need: cost-effective drives & media; content replication

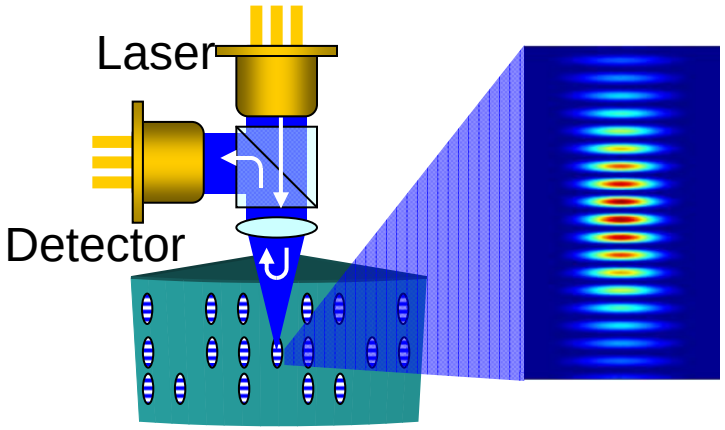
Page-based Holographic Storage:



- 10^4-10^6 bits/hologram
- Capacity: selective to angle or position

- Cost-effective consumer drive designs
(InPhase Technologies, ODS 2009, paper TuC2)
(LG, ISOM 2007))
- Concepts for content replication
(InPhase Technologies, ISOM 2007)

Single-bit μ-Holographic Storage:



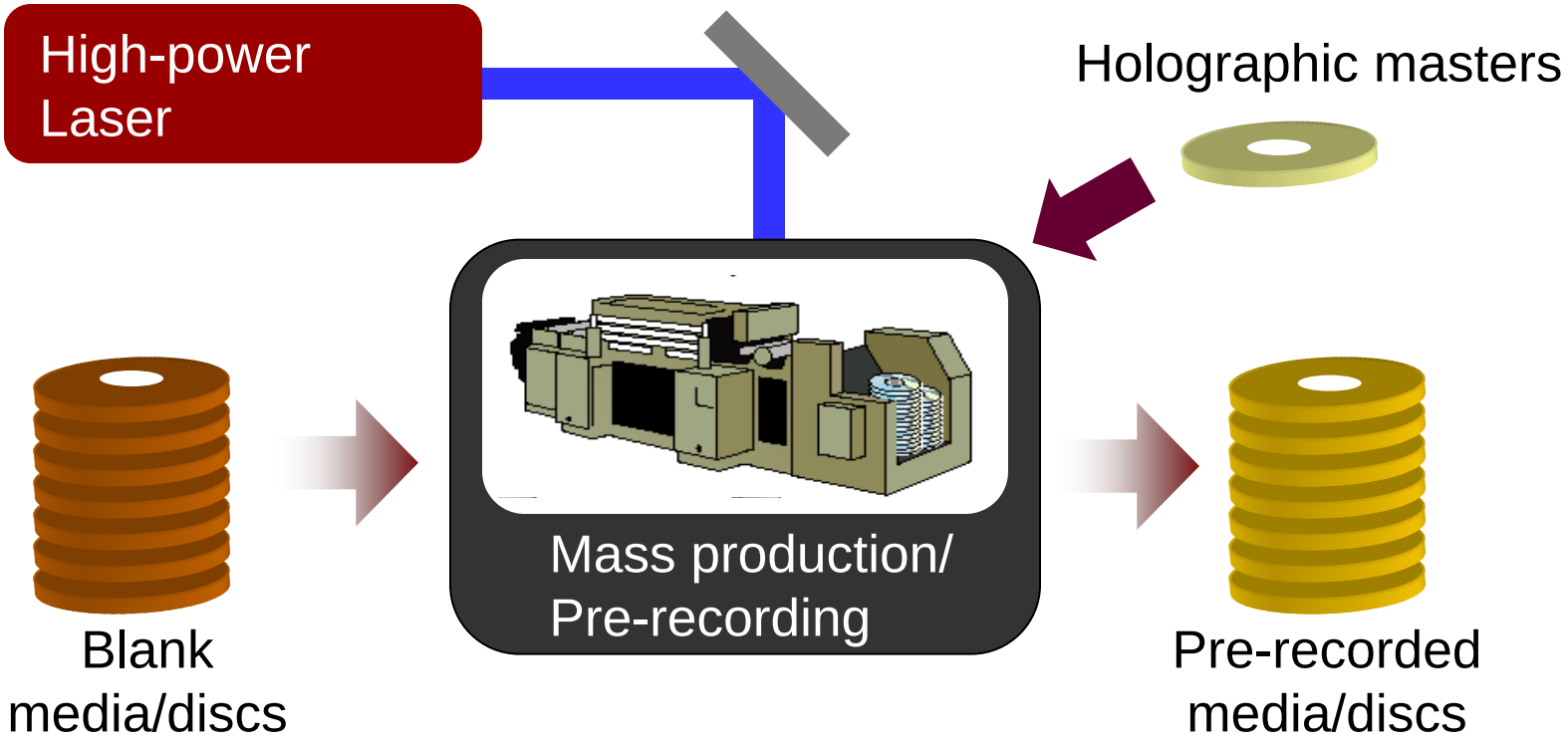
- 1-few bits/hologram
- Capacity: multiple virtual layers

- Leverages existing drive technology
- Cost-effective robust media & drives
(SONY, Samsung, Tech. Univ. Berlin, Univ. of Colo., & GE, Stanford University)

Courtesy GE

Holographic Media Manufacturing

Technology to Mass-produce pre-recorded discs/media



GE Replication concepts:

- Use available high-power lasers
- **1+ TB duplicated in 5-10 sec**

InPhase Replication concept:

- Sub-mask approach
- **1 TB in 2-5 sec**

Courtesy GE

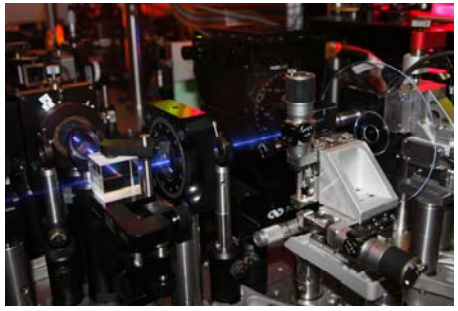
GE μ-HDS Technology

Combined efforts to develop hardware and media

Media development

- Injection-moldable threshold holographic media for micro-holographic storage
- Leverage manufacturing base for **cost-effective** high volume media production

Systems development (Stanford)



- Optical drives to read/write μ-holographic format
- Systems leveraging current optics/electronics
- Backward compatible, **cost-effective** drives

Leveraging existing formats with critical technical developments to enable cost-effective consumer systems

Courtesy GE

Content Distribution via Optical Disk or Internet?

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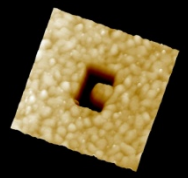
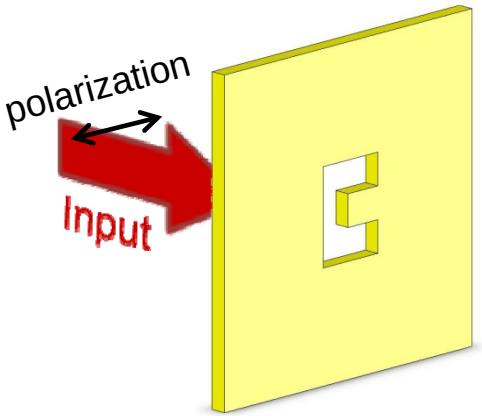
- Next generation magnetic storage
  - Heat assisted magnetic recording

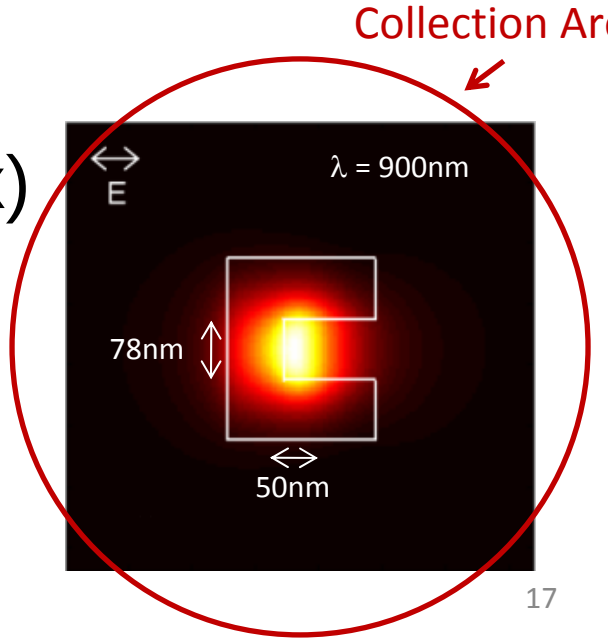


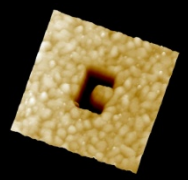
Introduction

- Heat Assisted Magnetic Recording (HAMR)
  - Need to produce a small, high intensity optical spot

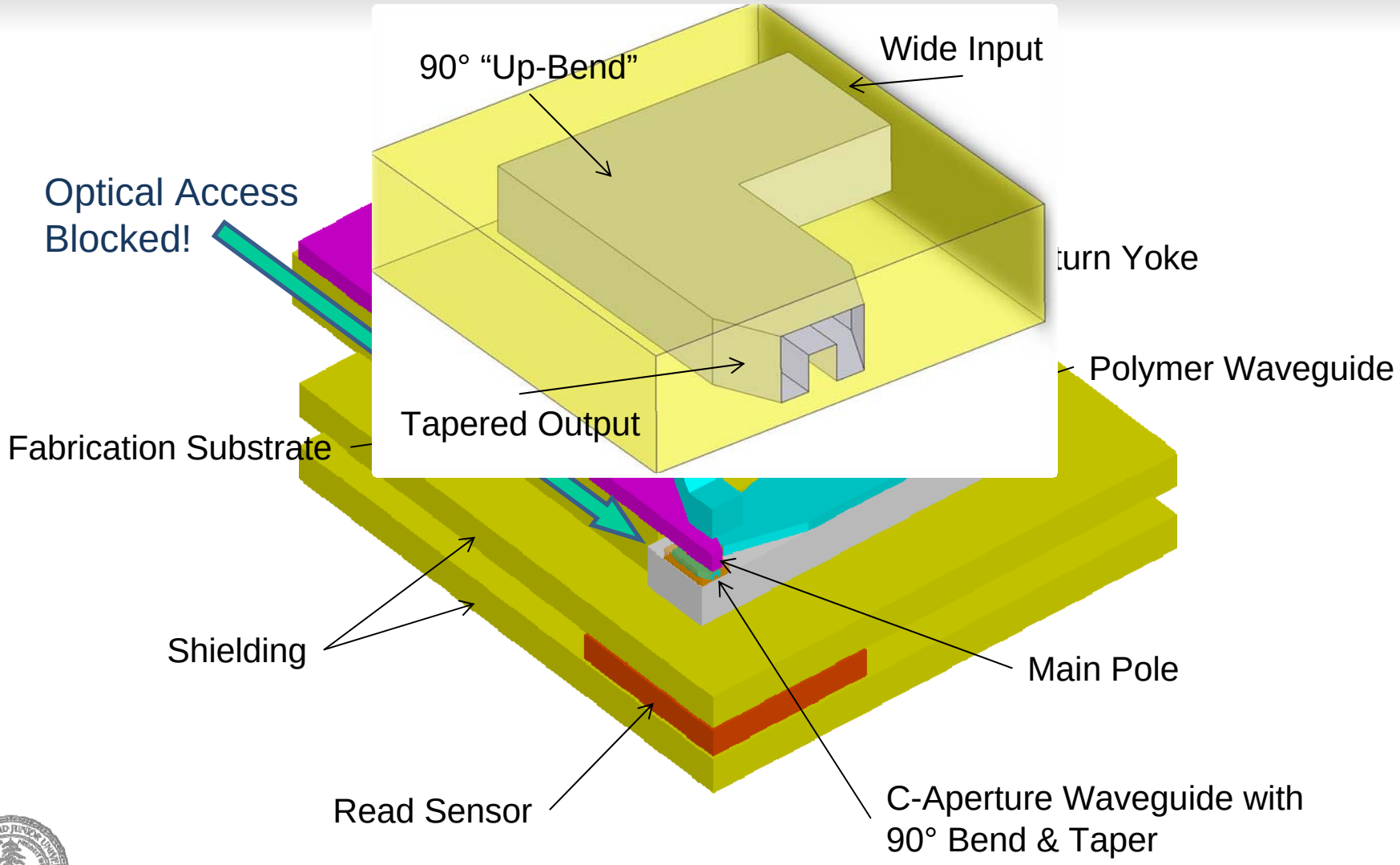


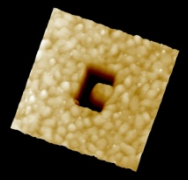
- C-Apertures/C-Waveguides
  - High optical intensity (10-100x)
  - Very small spots (~λ/10)





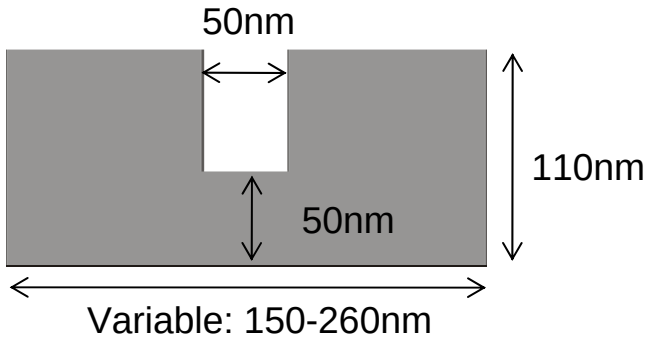
Optical Access

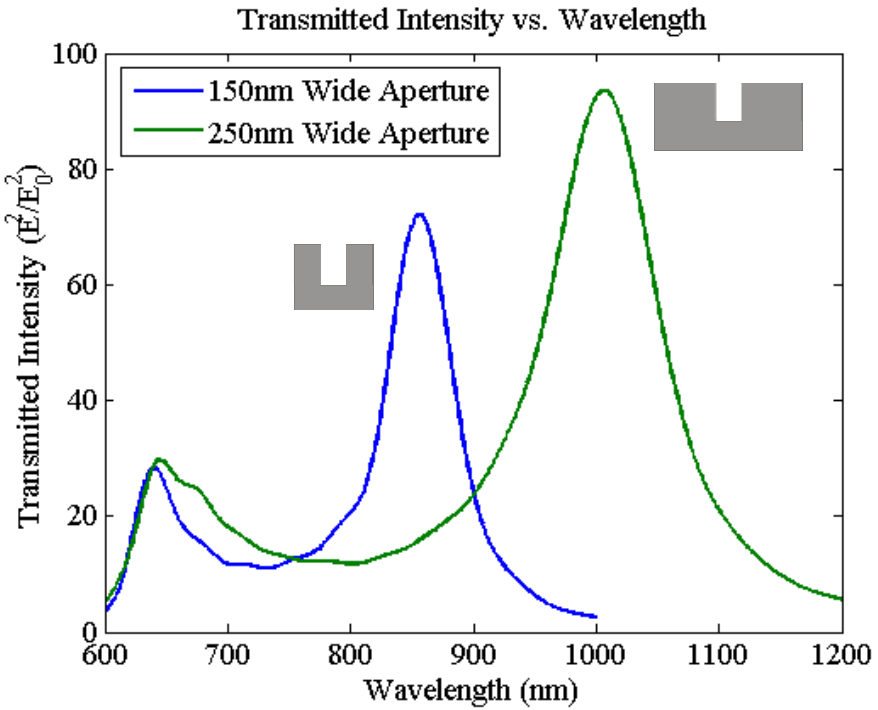


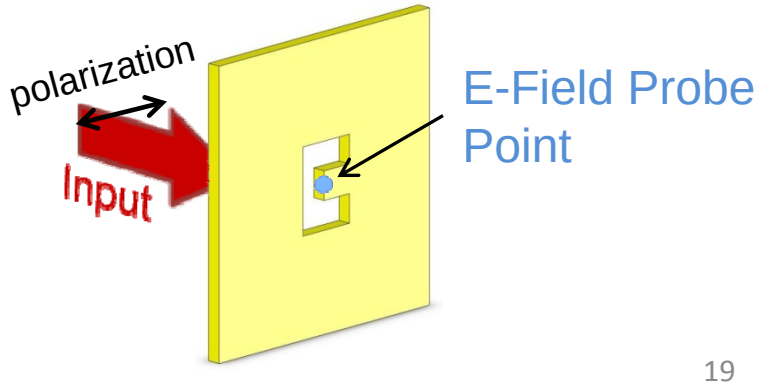


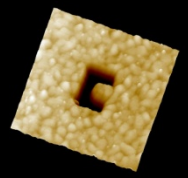
Aperture Resonance

- FDTD Simulation
  - Drude metal model (Au fit from 0.6-1.2μm)
  - Pulsed, plane wave excitation
- Aperture Dimensions





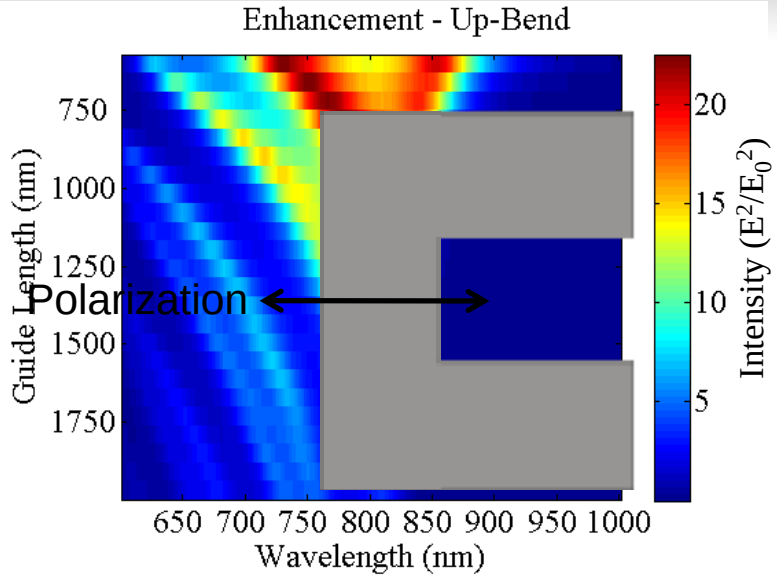


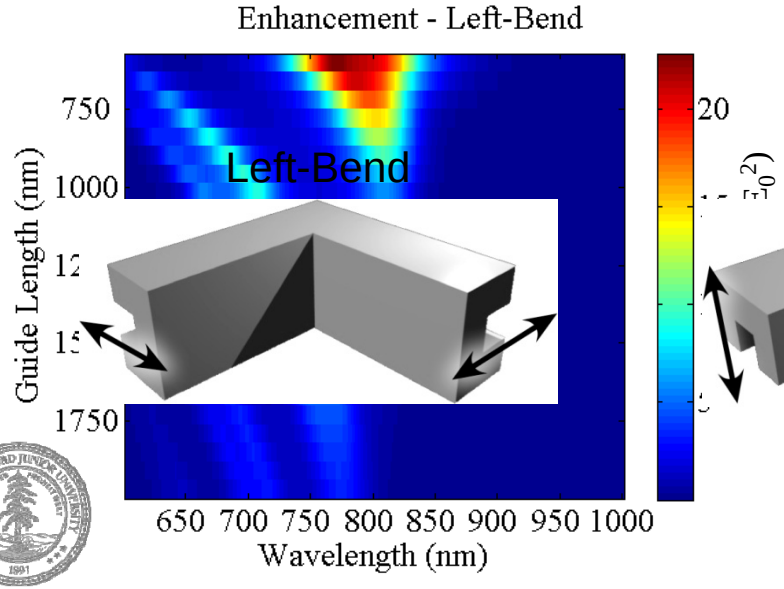


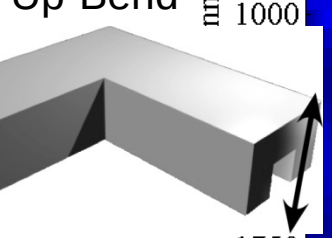
90° Bend

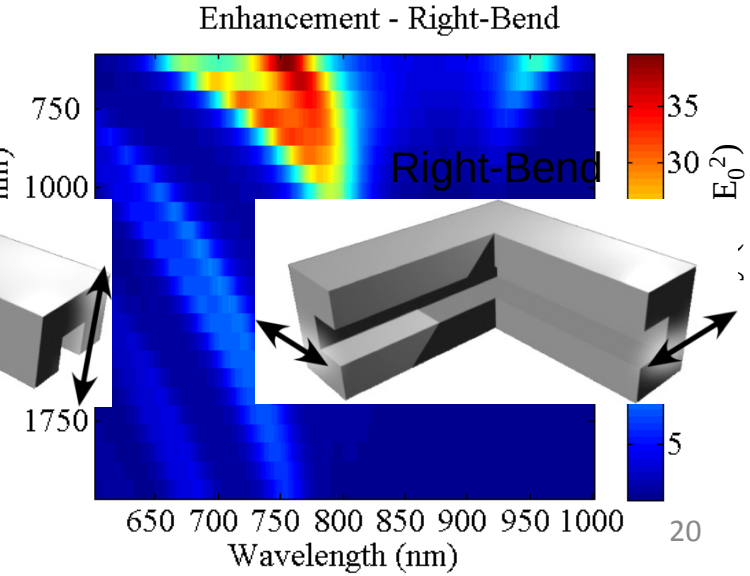
- Bend can have 3 unique orientations
- “Up-bend” does not rotate polarization
- “Up-bend” yields best long guide performance

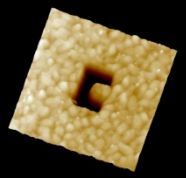
[1]Hansen, P., Hesselink, L., Leen, B., Optics Letters, Accepted March 2007





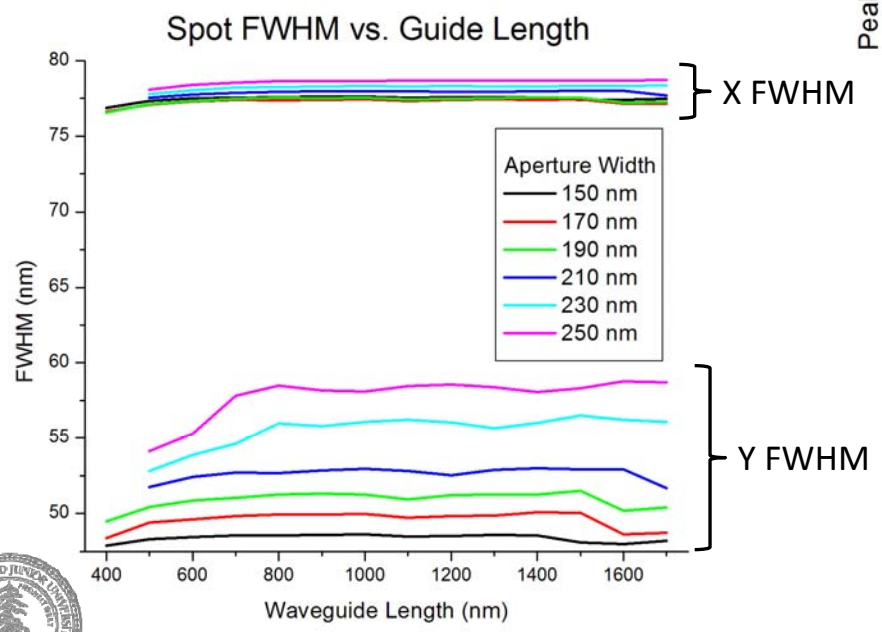


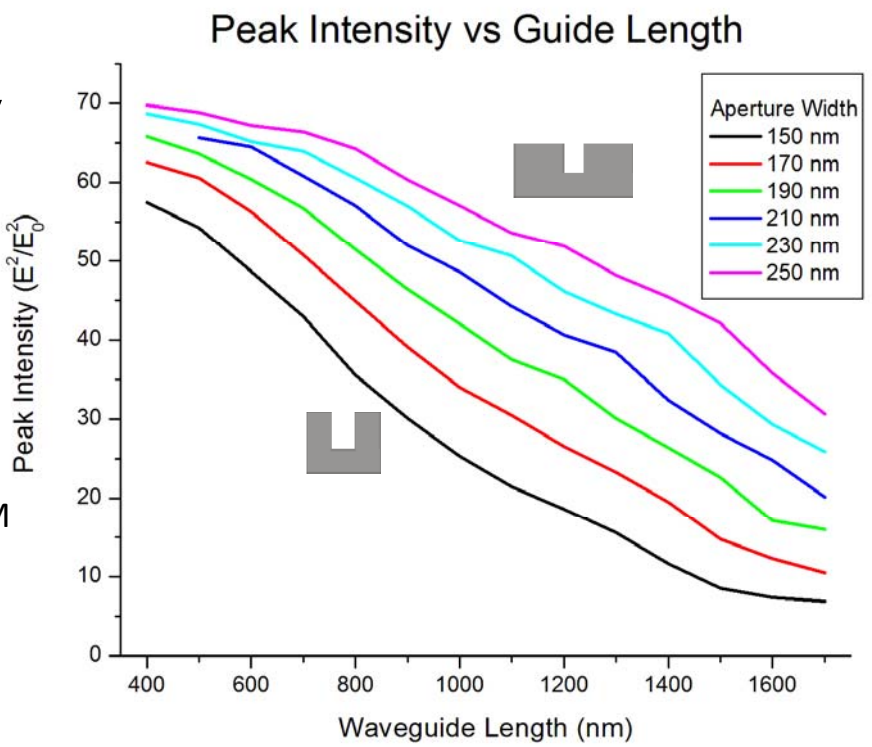


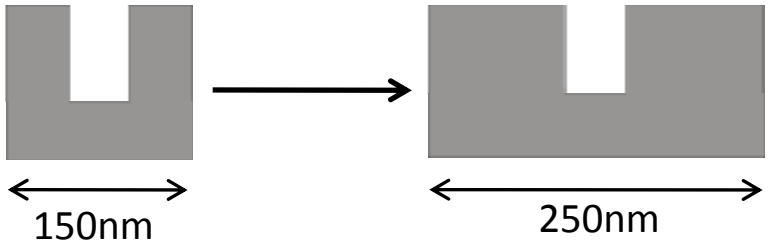


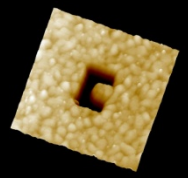
Increasing Width

- Increasing width increases spot intensity
- Spot size increases
- Wavelength red shifts



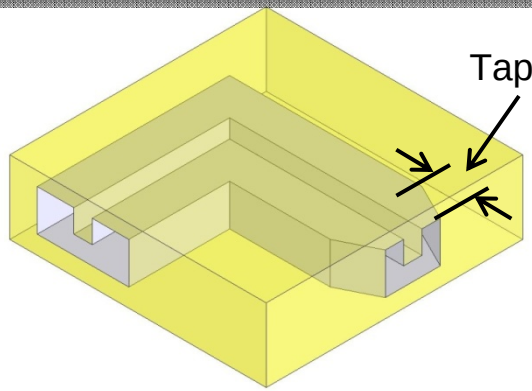


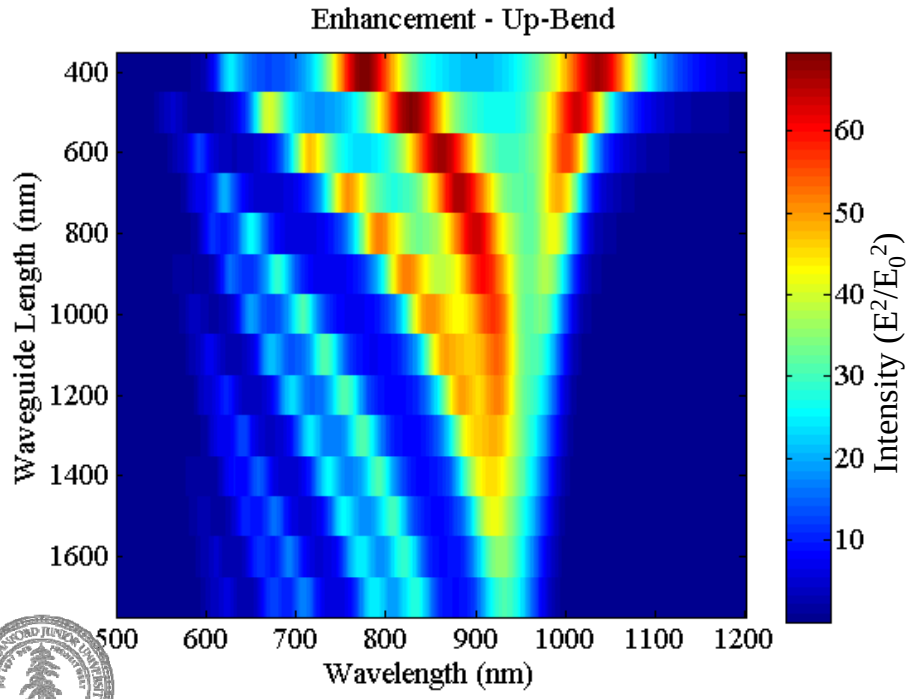


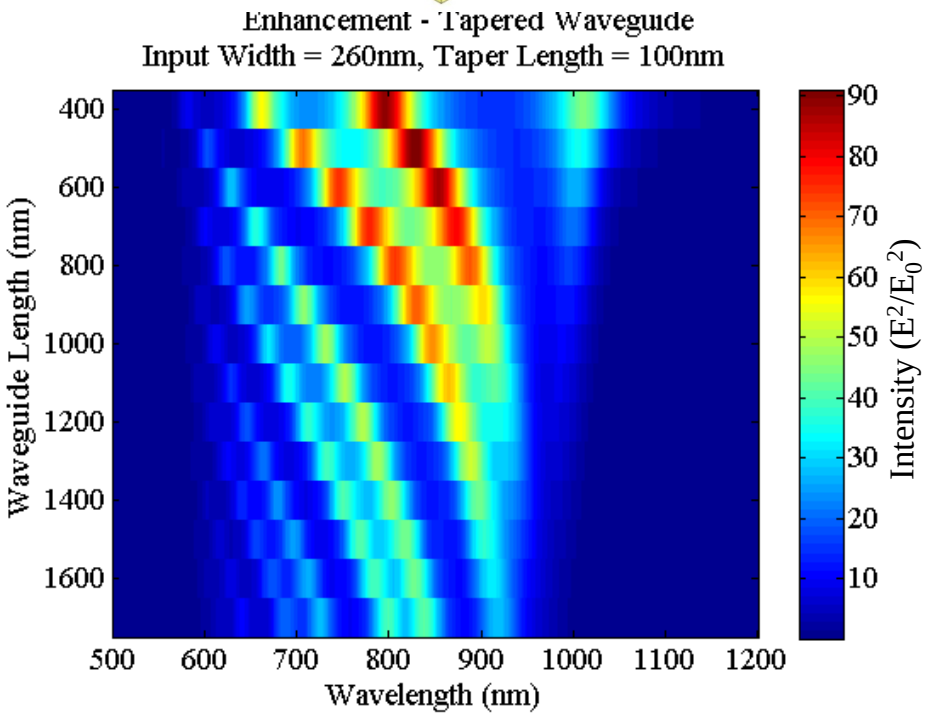


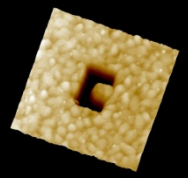
Tapered Output

- Tapered output further increases the peak intensity



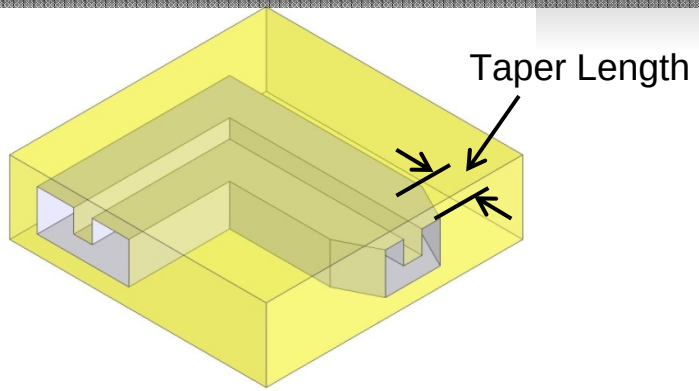


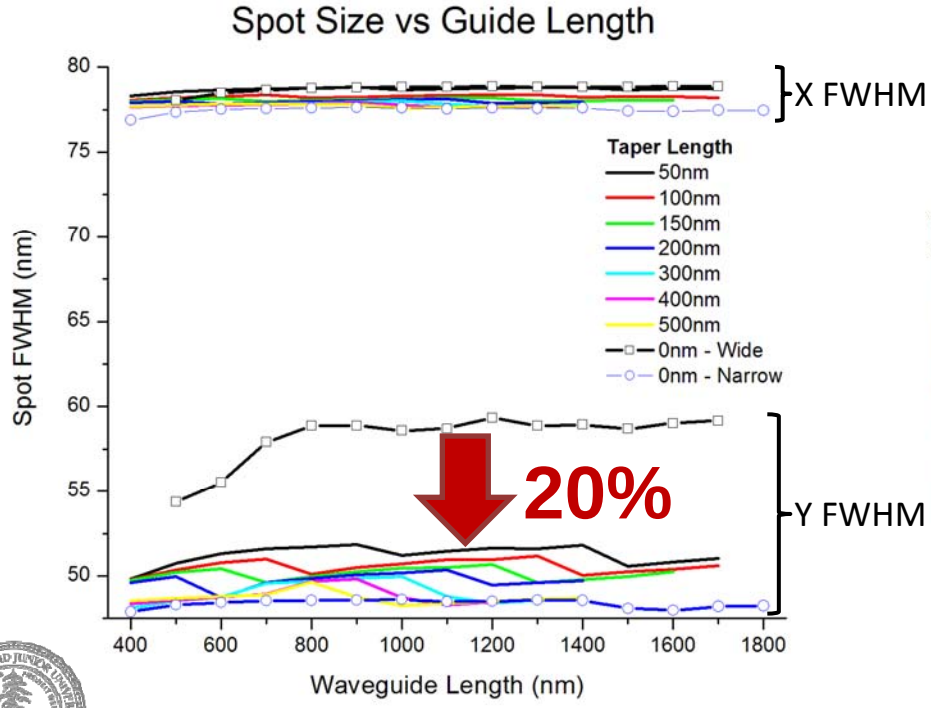


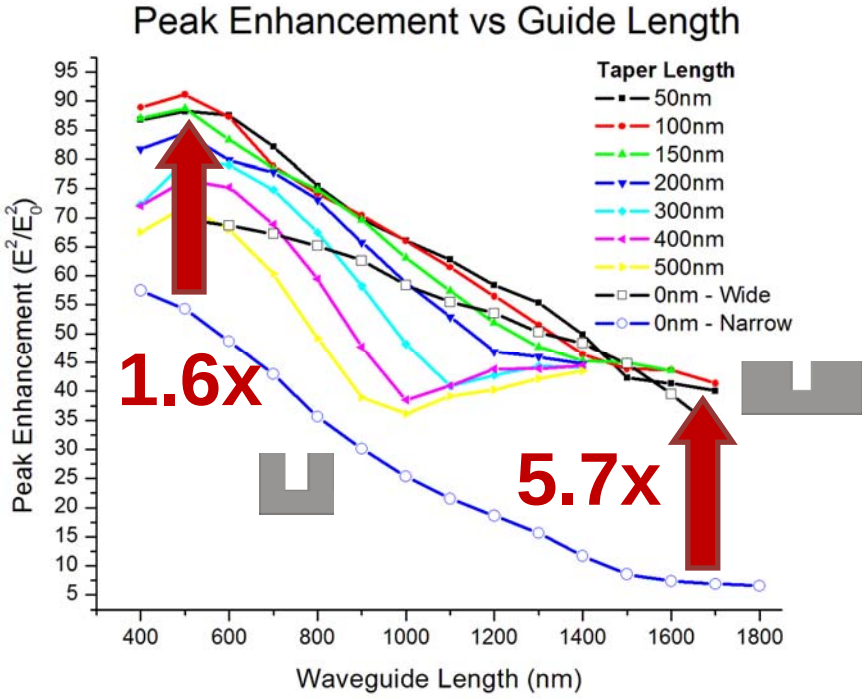


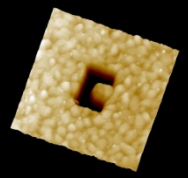
Tapered Output

- Up to 5.7x increase in intensity
- Spot size decreases









Interim Conclusions

- C-apertures produce very small spots with intensity higher than the incident light
- The gain in intensity is maintained around a 90° bend
- Performance is improved with a wide input and tapered output
- The small device footprint allows integration into conventional magnetic write heads
- 50x78nm spot and 40x+ increase in intensity

Acknowledgments

- Brian Leen, Paul Hansen, Yuzuru Takashima, Stanford
- Brian Lawrence, GE team
- Western Digital

Summary

- Race is on between optical and internet content distribution
- Business and technology issues come into play:
  - Available bandwidth and an affordable cost
  - DRM agreements among content owners, dsitributors and consumers
  - Technology roadmaps for optical and magnetic
    - Holography versus next generation magnetic?
- Interesting technology and business challenges and opportunities remain!