



Increasing Capacity and Transfer Speed in Optical Storage through Pit Depth Modulation

Tom Burke

Calimetrics, Inc

5901 Christie Ave., Ste. 406

Emeryville, CA 94608-1936

Phone: +1-510-420-1211 Fax: +1-510-420-1291

email: trburke@calimetrics.com

Presented at the THIC meeting in Ellicott City, MD on October 15, 1996

Calimetrics: Background

- Incorporated in September 1994 to commercialize a new CD-media storage technology providing 3-5x improvement in speed and storage capacity
- Exclusive licensee of patents issued to U.C. Berkeley; based on work of co-founders Michael O'Neill and Terrence Wong
- Funding from:
 - U.S. Advanced Technology Program (NIST) and California Trade and Commerce Agency grants
 - Private seed financing
- Building coalition of strategic partners to aid the development and launch of Calimetrics' first commercial products (custom ICs)

Commercialization Team

- Presently 10 staff, including
 - Tom Burke (Chairman, CEO): Former McKinsey & Co. consultant, Apple Computer product manager; MBA, Harvard
 - Terry Wong (President, co-founder): Ph.D. from U.C. Berkeley; former research physicist at SRI International; designed and built first laser feedback microscope to image living samples in 3D
 - Mike O'Neill (COO, co-founder): Ph.D. from U.C. Berkeley, co-inventor of four laser feedback interferometry patents, including pit-depth modulated CD-ROM technology
- Investors/advisors include
 - Dale Crane, founder and former chairman of Uniphase Corporation
 - John Messerschmitt, launched CD-ROM while V.P. at Philips
 - Dave Brown, co-founder/former president, Quantum Corporation

Data Storage CD Requirements

- Faster data transfer
- Increased capacity
- Compliance with standards
- Leverage industry infrastructure

Today's Approach: Storage in Two Dimensions

	CD	DVD
Laser Wavelength	780 nm	650 nm
Lens Aperture	0.45	0.60
Track Pitch	1.6 μm	0.74 μm
Minimum Pit Length	0.83 μm	0.40 μm
Capacity (single-side)	680 MB	4.7 GB
Data transfer rate	1.2 MB/sec	1.35 MB/sec
Relative Speed (1x=150 KB/Sec.)	8x	9x

Improving Two-Dimensional Storage

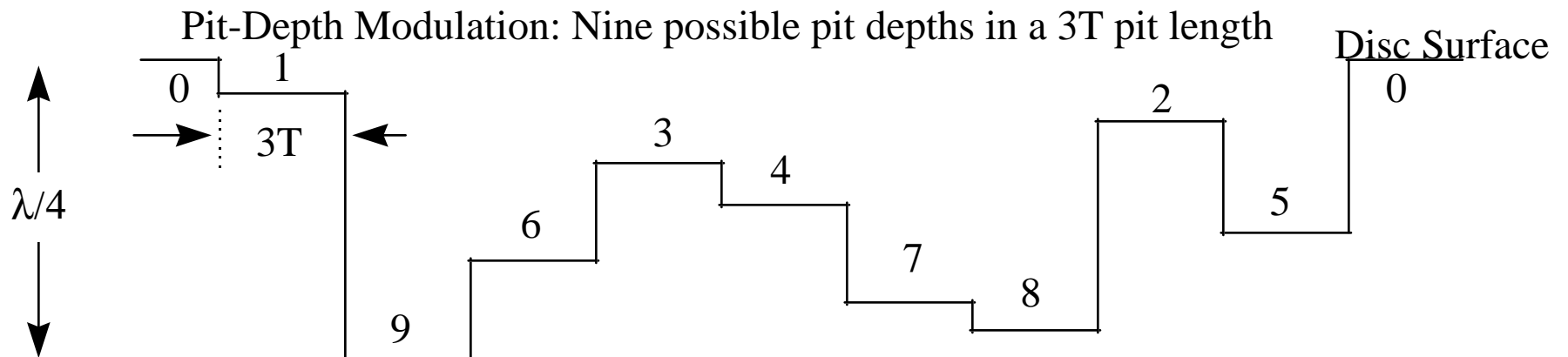
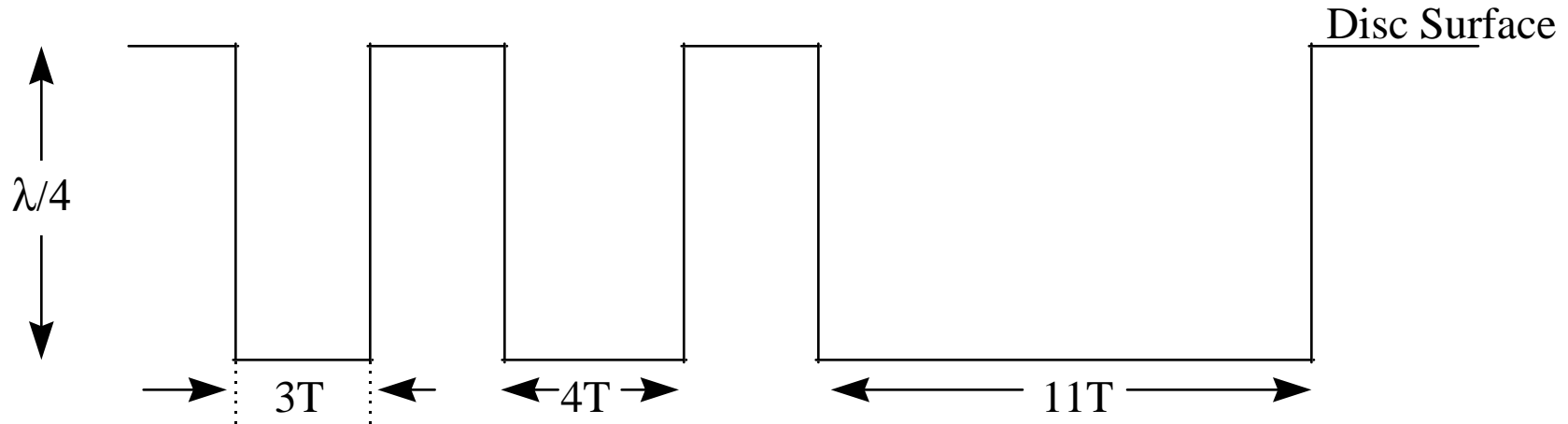
- Increased spin rate (spindle speed) improvements limited by diminishing returns, disc wobble (12x CD-ROM = hard drive rpm)
- Blue semiconductor laser diodes (e.g. 410 nm) for DVD expected early next decade if many challenges can be overcome:
 - Requires cost-effective, compact, long-lasting blue laser diodes and discs with pits made to smaller-than-DVD dimensions
 - Could provide about 2X increase in density, 50% increase in data transfer
- DVD development: increasing performance through
 - Dual layers and double-sided discs
 - Future increases in spindle speed
 - Compression advances?

Calimetrics' Approach: Storage in Three Dimensions

- Pit depth modulation (PDM) technology allows more data to be encoded in the same surface area of a compact disc
 - Pit to pit variations in depth are measured as disc rotates through focal volume of reader head
 - Dynamic range of current drive optics can discern a minimum of nine pit depths
- PDM technology:
 - Initial products provide a three-fold increase in storage capacity and data transfer rate for both CD and DVD systems
 - Is backward compatible with CD-ROM and DVD systems
 - Proposed improvements (dual layers, double-sided discs, faster spindle speeds) have additive impact
 - Uses current disc mastering and replicating equipment (with small modifications) and requires \$30 - \$40 per drive in new components (ICs) to implement

Comparison: standard compact disc encoding versus pit-depth modulation encoding

Standard Compact Disc: Nine possible pit lengths (3T to 11T)



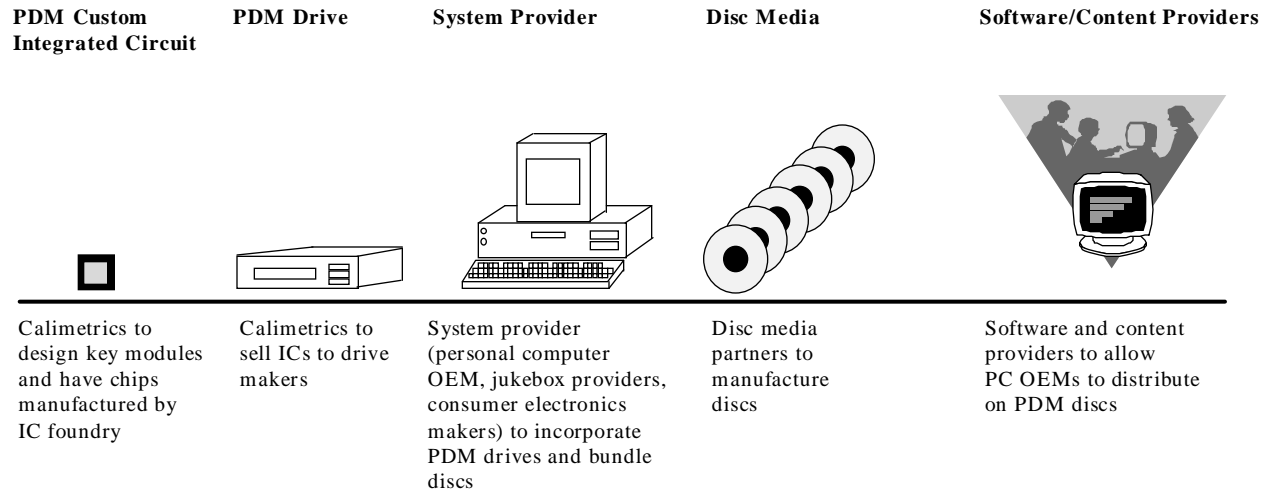
Performance Impact: PDM Technology

	CD-ROM	CD-ROM with PDM	DVD-ROM	DVD-ROM with PDM
Capacity (120mm disc)	0.68 GB	2.2 GB	4.7 GB	14 GB
Data transfer	1.2 MB/sec	3.9 MB/sec	1.35 MB/sec	4.0 MB/sec
Relative speed 1x =150KB/sec.	8x	26x	9x	27x
Estimated PC OEM cost (in large volumes)	\$100	\$150	\$200	\$250

The PDM Approach

- Add custom ICs to standard CD-ROM and DVD drives to read higher-capacity, higher-performance PDM discs
- Make PDM discs using commercially available mastering benches, with minor modifications and standard replicating processes
- Provide three-fold improvement in storage capacity and data rates comparable with current hard disk drives for:
 - Removable desktop data storage (ROM, initially)
 - Specialized high-performance data storage applications (libraries, networked storage)
 - Publishing, distribution and playback of HDTV-quality feature films

Calimetrics' Business Model



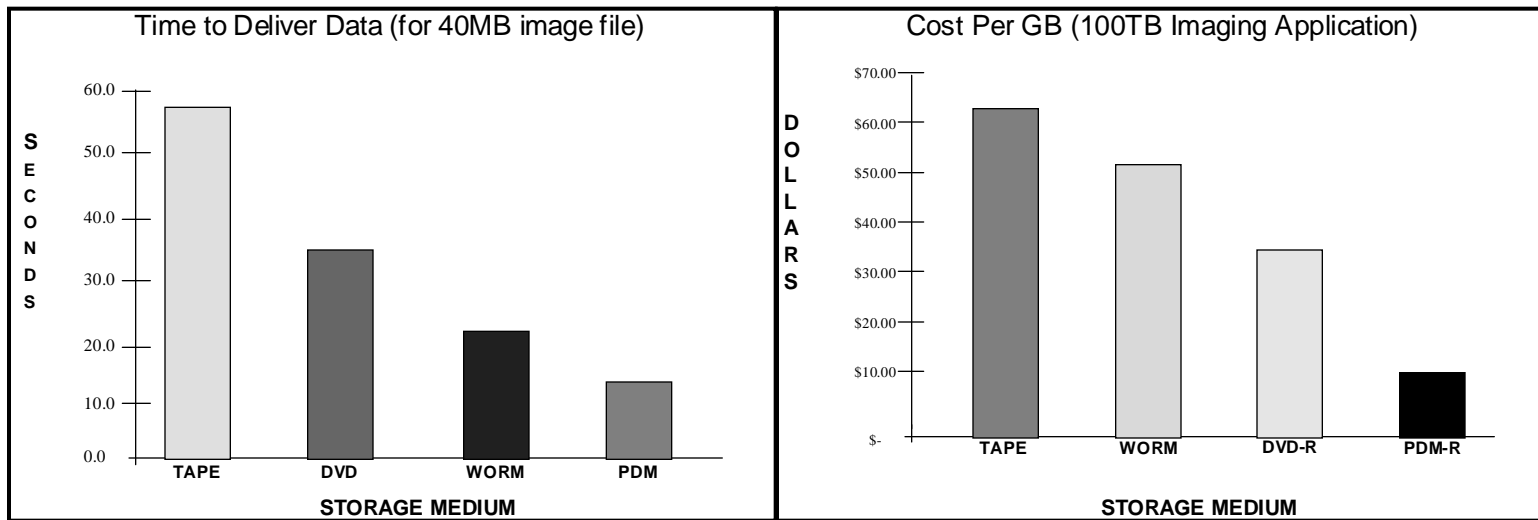
Target Markets, Needs

	1995 Unit Demand	2000 Unit Demand (E)	PDM Provides Differentiation
High-performance Desktop Data Storage	34 mm	50 - 60 mm	<ul style="list-style-type: none"> - Increased data transfer rate, capacity - Backward compatibility and forward upgrade path
High-capacity libraries/networked storage	1 mm	2 mm	<ul style="list-style-type: none"> - High capacity - Quick time to deliver data - Low cost/MB
DVD Player (films)	0	2 - 10 mm	<ul style="list-style-type: none"> - Higher capacity and data rate to support HDTV-quality video - Minimized compression overhead

Source: Calimetrics; consensus forecast derived from separate analyst estimates

PDM Performance and Cost

(High-capacity imaging library application)



Notes: Time to deliver data is the total of search, access, and data retrieval time for a 40MB image file contained within a 100 TB system application using tape, DVD, WORM, and PDM storage libraries. Cost per GB includes both library hardware and storage media costs.

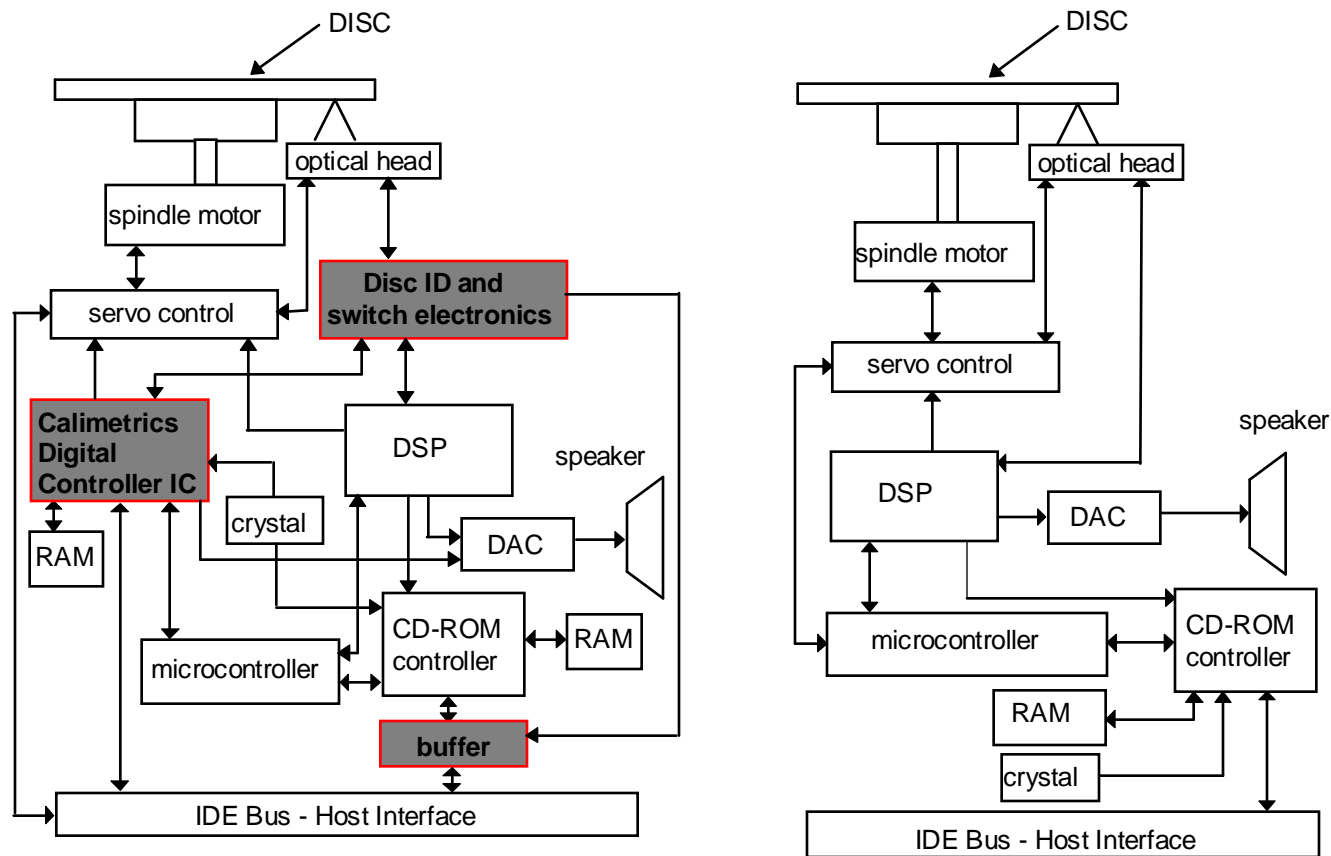
Market Timing

- CD systems may reach peak performance (12x, 16x) based on current technology by early 1997
- Initial DVD systems may reach market in early 1997, cost will remain high well into 1998, and they fail to solve speed problem
- PDM technology targeted for launch in 4Q 98
 - Dramatically improves DVD capacity and performance
 - Improves DVD system economics by reducing cost/MB
- Researching write-once/rewritable PDM
 - Using changes in index of refraction
 - Have identified candidate media for future systems
 - Building disc media and hardware partnerships

Conclusion

- Calimetrics' PDM technology meets the data storage market's need for data transfer performance, capacity improvements, standards compatibility and manufacturability
 - Solution is timely and affordable
 - Benefits from multiplier effect of other technology upgrades
- Current efforts:
 - Get industry feedback and support for a data-storage oriented solution that leverages electronics industry infrastructure
 - Build coalition of strategic partners and customers to aid the development and launch of PDM-enabled data storage systems

PDM Implementation: CD Drives (NOTE: NDA Only)



PDM Implementation: DVD Drives

(NOTE: NDA Only)

