The Next Generation of
5¼-inch Optical Storage Technology

Technology Overview

R J Longman

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UDO Technology Overview

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1 Abstract

This white paper is intended to give the reader a background on the development thinking that resulted in the UDO Optical Media Format. In 1999 Plasmon undertook a survey of the future for optical storage. At that time it was becoming obvious that the ISO MO technology would reach it's capacity limits within the next few years.

This paper draws from the 1999 study and presents a summary of the different optical technology options available. The design brief for the UDO format is then presented and the thinking that led to the UDO road map is discussed in some detail. The paper concludes with a summary of the UDO product family and a glossary of terms for those not familiar with optical recording technology.

2 Optical Storage Background

When the "optical stylus" was first launched with the Videodisc, soon followed by the now ubiquitous audio CD, the areal density it offered exceeded any other media at the time. As a product it represented a removable data storage format, which with its successors of CD-R and CD-RW, has been the basis of a strong consumer market. Although in their non-cartridged form, such products are technically not as robust, they are perceived at present to be the 'consumer market' option, though computer and other niche applications may favour cartridged versions. The current 4.7 GB DVD versions continue to represent cheap removable storage solutions.

Various "professional" laser recordable products were developed, starting in the mid 1980's. The first products were developed in large format (12-inch disks) soon followed by the development of smaller formats initially led by small start-up companies. However, the long-term survivors in the 5¼-inch market were based on Japanese led designs. Of these, by far the most successful is the ISO MO series of drives in both 5¼ and 3½-inch formats. The 5¼-inch series was launched with a capacity of 650MB in the late 1980's. Using Magneto Optic technology, the format was standardised through ECMA and ISO. Following the 650-MB (or 1x product), new formats were introduced at approximately two-year intervals that have seen the capacity rise to 9.1 GB (14x) at the present time.

In addition to the re-writable MO media, two different write-once options have always been available. The first (known as CCW-worm) is based on MO media; in which re-writing is barred by drive firmware that detects the special code in the pre-mastered format. Secondly, 'True WORM', initially using Tellurium ablative media and more recently phase change or alloying films, has been strongly promoted by IBM.

The promoters of the 5¼-inch standards have maintained a policy of publishing a road map showing the backward compatibility and plans for the next capacity point. This has been a key feature in the marketing of these products, which have become the standard storage devices in a significant market for automated optical disk libraries.

3 The End Of The Line for 5¼-inch MO?

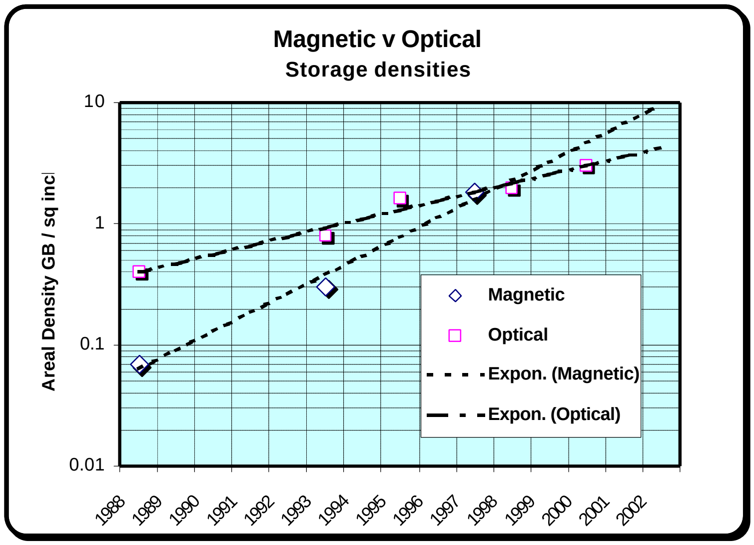
In the last few years it has become apparent that the regular doubling of 5 ¼-inch MO storage capacities is nearing its end due to the fundamental limitations imposed by the desire to maintain backward compatibility with media from earlier versions of the format. The road map that has been publicly displayed for some years shows the capacity of the last generation as 9.1 GB (or 14x) with no plans for a further generation. In addition, as the higher capacity products have been developed, the number of drive and media manufacturers has declined. Sony is the only drive manufacturer of the 14x format. It is generally accepted that this generation (at 14x) will be the last product in the current series due to the technical problems of achieving backward compatibility with the earlier formats. The latest OSTA road maps (OSTA Magneto-Optical Technology Roadmap) show the natural succession of MO technology by UDO.

In the sections below, the issues facing 5¼-inch optical drive and media development are discussed and a proposal for a new family of high-end optical drives is outlined. This paper is based on Plasmon's original proposal for a new series of professional optical storage products. This internal paper was written in 1999 and formed the basis for much of the UDO specification.

4 Data Densities – Optical v Magnetic

Since the early nineties the areal density offered by optical media has been under threat from magnetic HDD (hard disc drive) recording. This has been because the rate of increase of areal density of HDD products has been much greater than that of optical media in the last ten years. (HDD areal densities have increased at a rate of about 1.6 times per year while optical has been increasing at only 1.25 times per year).

This has meant that, in areal density terms, a 'lead' of a factor of five of optical over HDD at the beginning of the nineties has turned into a 'lag' of more than a factor of two.



There is currently much debate over the fundamental limits on both optical and magnetic storage. Magnetic recording areal density has increased by approximately 2.5 million times since 1957 but researchers are now debating the ultimate limits imposed by super paramagnetic effects and media limitations such as grain size. On the optical side, new advances in recording films such as “super resolution” and more sophisticated encoding/decoding schemes are extending fundamental limits imposed by the available laser technologies.

While we have to accept that magnetic storage can achieve fundamentally higher aerial densities, these densities cannot be achieved in a removable environment. In this case it is clear that optical recording will survive by exploiting its other key advantage of easy removability. While immersion lens technology has the potential of achieving higher areal densities it suffers from the same problems of surface contamination as magnetic recording. For this reason it is expected that conventional far field optical recording will dominate in removable data storage applications.

The table below compares the areal density of some current optical storage products. From this, it is clear that 14x MO areal density is lower than the lower cost DVD products and less than half of that achieved by Matsushita, who have shown a technology demonstration of a dual layer re-writable phase change disk.

"Standard" Formats	14x MO	DVD-RAM V1.9 Re-writable	DVD 9 Dual Layer
Single sided capacity GB	4.55	4.7	8.5
Gbits per square inch	1.93	2.36	4.28
Multiplier	1.00	1.22	2.21

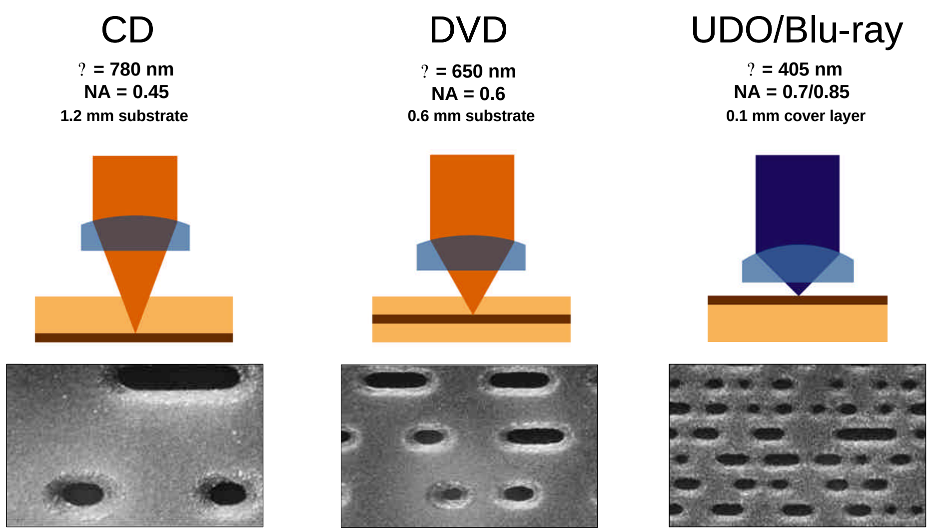
In order to extend the capacity of the current recordable optical disk drives it is clear that significant changes are required. Much work is now being focussed on “low cost” consumer recordable formats, but before the UDO announcement, there was no sign of a successor to the current ISO MO 5¼-inch drive family. Section 4 discusses the issues that had to be addressed in taking optical recording technology to higher capacities.

5 Optical Storage Densities

5.1 Optical Resolution and Numerical Aperture

The smallest optical spot size that can be achieved is determined by the diffraction limit, which is proportional to ?/NA where ? is the optical wavelength and NA is the numerical aperture. The areal density is proportional to the inverse square of this quantity $(NA/?)^2$. The current 14x MO products use shorter wavelength lasers (~660 nm compared with the original 1x lasers at ~830 nm) to achieve part of the increase in storage density. As NA is increased or ? is reduced, the system tolerances become much more severe.

As with all current removable optical systems, the recording film is protected by a transparent substrate. The laser is focussed through this substrate, which is therefore a critical part of the optical design. The major aberrations in the optical spot that limit system performance are due to drive alignment and media variability tolerances. The thicker the substrate, the more critical these tolerances become. In order to exploit the advantages of a high numerical aperture, it is necessary to reduce the substrate thickness still further than the halving from 1.2 mm of CD products to 0.6 mm used in DVD. It has now become widely accepted that a substrate thickness of 0.1 mm will allow the use of NA values over 0.8 without necessitating tightening of tolerances on tilt (one of the most critical substrate parameters in a high NA system).



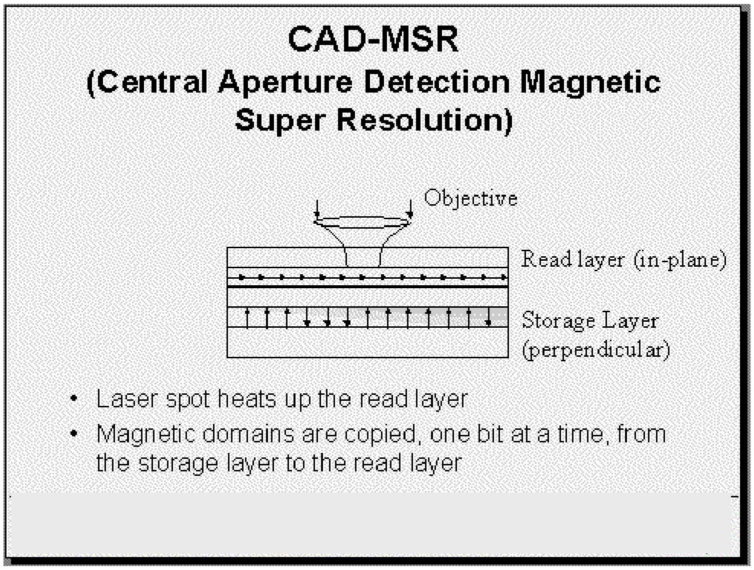
Evolution of Substrate Thicknesses

There has been intense effort focussed on the development of shorter wavelength solid-state lasers in recent years. Various technologies have been researched, including frequency doubling and new material systems. Of the latter, Gallium Nitride appears to be the most advanced at this time, with Nichia being the leading developer. Blue lasers became commercially available in 2001 but it is not expected that the cost will become low enough for consumer products for at least another two or three years. However, the cost projections

The adoption of blue lasers is very attractive as this change of laser wavelength gives a theoretical increase in density of ~ $(660/410)^2$ or 2.6 times.

5.2 Super Resolution

Super resolution is a new technique that has made its appearance in MO products over the last few years. This uses a "masking layer" in the recording film. Writing of marks that are significantly smaller than the diffraction limited laser spot can be achieved by exploiting the non-linear recording characteristics of the media. When the laser power is controlled accurately, it is possible to transform a very small spot in the recording film corresponding to a given temperature contour. During readout of conventional materials this is not possible. "Super resolution" films close to the recording layer undergo a reversible change in optical or magnetic properties (in the case of MO layers) at a well-defined temperature, which is below the temperature required for writing. In this way a small moving window is created at the recording layer, which increases the resolution of the read beam.



Work on a Phase Change equivalent is still in the research phase, although a number of papers have been published showing that this might be possible. It is likely that a write once super-resolution disk would be easier to achieve, as the material only has to withstand the high write energy once.

5.3 Substrate Tolerances

As indicated above, the substrate forms part of the optical system. It is for this reason that the thickness of the DVD substrate was reduced from the 1.2 mm of the CD to 0.6 mm. In order to increase data densities further, it is desirable to use thinner optical protection layers. In this case the "rigid" substrate will probably become a carrier with the recording films protected by an optically clear cover. Various different manufacturing techniques for this cover have been proposed, and much work is underway on development of cost effective production processes. Equally, the use of high NA optics or shorter wavelengths reduces the depth of field necessitating better servo performance and flatter disks. For example, the depth of field in a blue laser system operating at 0.85NA will be less than one third of that in the current DVD products.

Because it is a requirement that there will be backward read compatibility within any new product range it is desirable to maintain a constant optical substrate thickness for all products. For this reason, the availability of a proven manufacturing capability for thinner substrates is a critical element of the new product family. Plasmon has been working for the last two years on two different methods in collaboration with machinery vendors in Japan and Europe. We are now in the process of specifying the production machinery for the media manufacturing line.

5.4 Signal to Noise Limitations

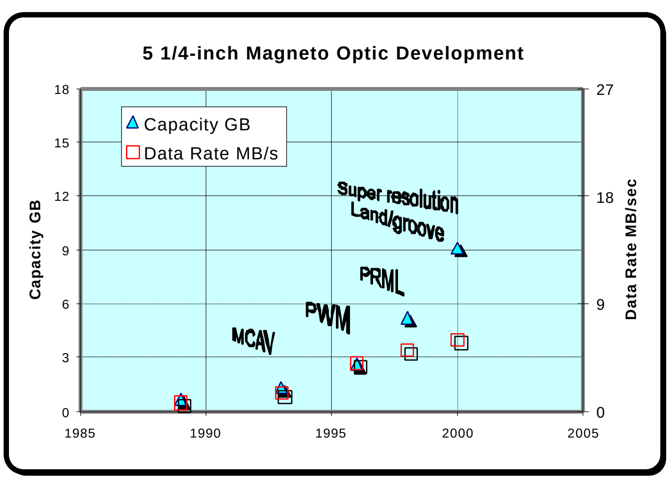
Both drive and media can limit the achievable read channel signal to noise. As the density is increased additional constraints will come into play. Of particular concern are the following:

- Smaller laser spot sizes associated with higher NA optics or shorter wavelengths will necessitate lower read powers to prevent the possibility of thermal damage to the media. This plus the lower responsivity of the signal detectors at shorter wavelengths reduces the available signal.
- As the optical resolution of the pick-up increases, the read beam is able to resolve smaller noise sources and in principle may be able to resolve the grain structure of phase change materials. In the case of re-writable phase change materials jitter associated with growth of the crystalline phase into the amorphised marks is an issue for system performance even at current densities.
- Higher data rates requiring high bandwidth electronics in both the write and read channels impose more severe problems for the analogue electronics at the optical pick-up. More sophisticated data coding (such as the use of multi-level recording) would requires even higher signal to noise.

All of the above issues have been assessed in great detail as part of the UDO design study before finalisation of the initial product specification.

5.5 Optical Recording Layer Limitations

There have been few significant changes in the fundamentals of recordable media technology until the adoption of MSR in the latest 3½-inch and 5 ¼-inch MO drives. The increases in capacity between 1x and 8x 5 ¼ inch drives have been due to changes in the drive rather than the fundamentals of the media.



More efficient formats, improvements in encoding/decoding and a modest change in wavelengths/NA have achieved an 8-fold increase in storage density over the last 9 years.
Up to this time the media technology has not been a serious limitation and manufacturing quality improvements have generally been sufficient to keep pace with drive developments. The move from ablative films to alloying technology as a true WORM layer in 8x MO drives was a sign that film properties are beginning to become a potential limitation on storage capacity. More recently much more work has been published on fundamental advances in the recording film technology. In particular, it has been necessary to incorporate additional layers adjacent to the active recording layer in re-writable phase change media in order to write at the higher data rates.

It is clear that future advances in optical systems, needed to achieve the higher densities, will push the limits of the recording films used today.

5.6 Mastering/Substrate Manufacture

As the areal density increases, the format requirements will become more severe. Most current mastering uses a laser wavelength of around 430 nm and High NA optics (up to 0.9 is commonly available). More recently, UV lasers have become available and electron beam mastering systems are under development. In addition to the mastering requirements, improvements to replication techniques will be necessary. As an indication of the problems, the manufacture of injection moulded substrates for DVD-R was close to the limits of current machine capabilities when the product was launched. However, continuing improvements have overcome these issues and cycle times have fallen over the last two years.

6 Competing Optical Technologies

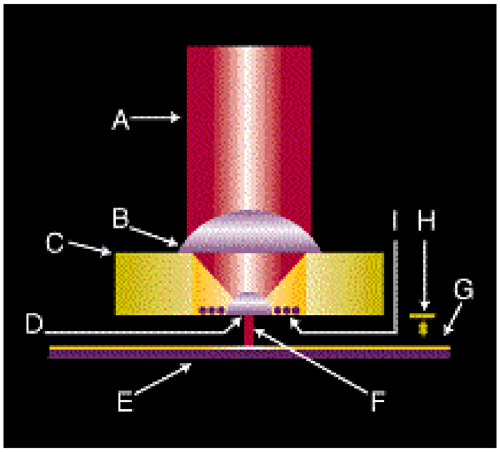
It has been demonstrated that magnetic HDD technology will outperform optical recording in pure areal density terms. The advantage that optical still has is its robustness in a removable environment. As long as the design incorporates a significant thickness of optical protection this advantage will be retained, allowing reliable operation in removable applications such as large automated libraries.
Some of the competing optical storage technologies which have been announced or looked at from a development standpoint are described in the sections which follow.

6.1 Near Field Recording

Several companies have attempted to develop products based on near field recording. By the use of a SIL (Solid Immersion Lens) lens, it is possible to achieve NA values higher than 1, reducing the laser spot size dramatically. However, this requires the recording layer to be very close to the surface of the media in order to couple the light into the recording film before it diverges.

The figure below shows the essential elements of a near field recording system. The distance between the media surface and the exit face of the lens has to be maintained at around 50 nm or less. This is comparable to the flying height used in modern hard disk drives. In order to maintain the cleanliness required to "fly" a pickup at the very low heights necessary, an elaborate cartridge would have been necessary. The practicality of achieving the required cleanliness was one of the major obstacles that proved impossible to overcome.

Near field Recording Principle

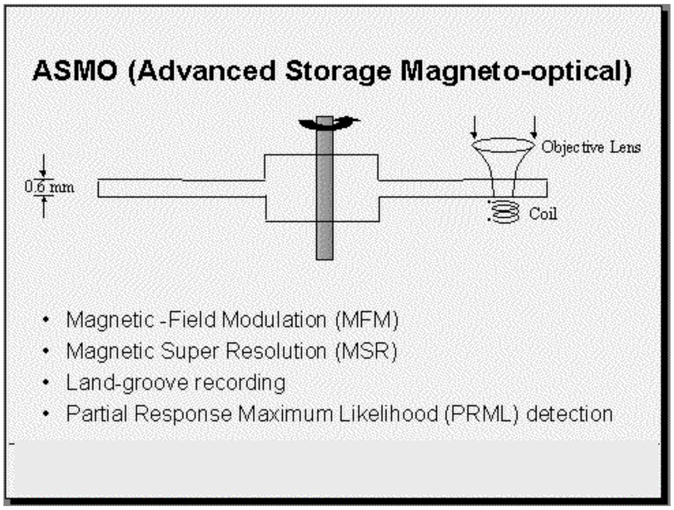


A - Laser Beam
B - Objective Lens
C - Flying Head - Focus controlled by the hard disk-like air bearing
D - Solid Immersion Lens (SIL) – Allows NA > 1.0 thus achieving smaller spot sizes
E - Substrate
F - Evanescent Coupling - Near field coupling creating sub-wavelength recorded feature size
G - First Surface Recording
H - Lens/Substrate Spacing Controlled by Flying Head
I - Magnetic Coil - Magnetic coil in the head allows direct overwrite

While the technology allows writing and reading with significantly smaller spot sizes the concerns over the resistance to contamination meant that the products were not be appropriate to the removable storage market. It may be, however, that the technology will find an application in fixed disk applications. During 2001 this technology moved back into research rather than actual product development.

6.2 ASMO

ASMO is a high capacity; direct overwrite system using MO media. By using MSR media, which has reduced sensitivity to crosstalk, a relatively thin substrate can be used. There was a proposal is for a single 0.6mm thick plastic substrate. But this has yet to be commercialised



As shown in the figure above, a single sided disk has a small magnetic coil close to the recording layer. By using a small coil it is possible to switch the magnetic field at the data rate and achieve direct overwrite.

Clearly this technique cannot be adapted to double-sided media. In order to move to high NA optical systems it is desirable to use thinner substrates. However, in the case of ASMO technology this will require flexible media, which will have to be stabilised in a similar way to a floppy disk

6.3 OSD

Another approach which was proposed was an alternative system design based on MO media with a very thin protective layer, high NA optics and a very small flying magnetic coil which can be switched at data frequencies to allow direct overwrite in a similar way to ASMO technology. The difference in this approach was that the magnetic coil was on the same side of the disk as the optical pickup. While the lens can operate in the conventional “far field” mode with a large gap to the media surface the technology requires the magnetic coil to be very close to the recording film. In order to achieve this it was likely that the coil would have to be mounted in an air bearing flying on the media. The use of hard polymeric coatings can reduce the risk of surface damage, but the stability of the air bearing and hence the reliability of data writing will be critically dependent on surface cleanliness. The need to use MSR media to achieve the stated capacity points with the attendant need for accurately controlled read laser power and magnetic field imposed additional system constraints. This approach has not been commercialised, due in part to the many technical challenges.

6.4 Blu-Ray

Early in 2002, an Industry consortium announced a new technology for the consumer market called ‘Blu-Ray’ which is in essence a new generation of storage products aimed primarily at HD TV recording. This technology was formerly referred to as DVR and a large number of papers describing the principles have been published over the last two years.

Blu-Ray technology forms the basis for many of the UDO specification items and in general it has directed Plasmon’s decisions on the media specifications. The general acceptance of DVR or Blu-Ray has accelerated the development of materials and manufacturing processes. Plasmon has been able to form strong relationships with several leading companies working in this area. These companies are keen to work with Plasmon as a proving ground for their processes and materials.

Blu-Ray will use 405nm lasers with 100-micron cover layer technology and phase change recording films to deliver approximately 25 GB on a single CD sized surface. The use of a 0.85 NA lens is the significant area in which UDO differs from Blu-Ray. As discussed later in this paper, generation 1 UDO will use 0.7 NA to ensure a cost effective system in the timescales required. Later generations will move to 0.85 NA when the lens manufacturing has been developed to a reliable stage.

7 The UDO Design Brief

The design brief for the UDO range included the requirement that the new product roadmap would have a visible technology path that extended to at least three generations. The original requirements were as listed below :

- The drive will be designed as a high reliability product suitable for the professional data storage market.
- No fundamentally new inventions will be required to achieve the first three capacity points.
- The products will support both re-writable and true WORM media.
- The initial capacity must be at least 30GB with a doubling for each succeeding generation.
- Future products must be backward read compatible with at least one, but preferably 2 generations of media.
- The cartridge external form factor will be compatible with the current 5¼-inch MO standard.
- New cartridge design to prevent actual insertion into existing MO drives
- Improved cartridge shutter design to reduce the possibility of contamination

- Shipment date for first product will be mid 2003.

8 Technology Options

Clearly there were many different combinations of technology that could have been used to achieve the objectives set above. However, the intent was to *leverage existing, available technology* without reinvention. The likely list of candidates for inclusion included the following: -

Technology	Estimated capacity increase
Blue Laser at ~ 405 nm.	2.5 times
Higher NA ~ 0.85 - necessitating thin cover layers	2.0
Land/Groove recording	1.0 *
Grey level coding	1.8
Dual layer media	1.8
"Super resolution" at a modest level	~2.0

* See discussion below

8.1 Laser Wavelength

During the life of the anticipated product family we assumed that blue laser technology will be incorporated. The only issue we had to address was the timing of this move and the impact that it would have on backward compatibility. The original proposal in 1999 was to utilise conventional red lasers in generation 1 but as we started working with Nichia and their new 405 nm lasers we became confident that these could be incorporated in the first generation UDO product.

8.2 High NA Optics

As with the laser decision, the advantages of a transition to higher NA and a reduction in substrate optical thickness were too great to ignore. As we desired the substrate to be fixed for all products in the family, this change had to be introduced at the start of the program. In this case, there was good reason to move directly to a higher NA optical design in the first product. The exact NA selected was a trade off between the risks (especially the state of media manufacturing technology) and the ability to meet the capacity point by incorporation of other technologies. The primary risks are focus depth of field, Opto-Mechanical Assembly alignment and disk manufacturing limitations (bearing in mind that the disk manufacturing technology will be very new). The challenge for Blu-Ray is the 0.85 NA lens which requires active spherical aberration correction. However, by limiting the first generation UDO product to 0.7 NA, the lens can be made cost effectively using proven current manufacturing techniques. The transition to the 0.85 NA lens proposed for Blu-Ray is planned for the third generation UDO product.

8.3 Land/Groove Recording

Land/Groove recording has been adopted as a means to increase track densities on MO and phase change materials. The manufacturing tolerances are relatively tight in order to get well-controlled crosstalk cancellation and both DVD-RW and DVD+RW proponents achieve the same areal density with groove only formats. In this case the trade off was likely to be between re-write cycles and recording film technology. If Land/Groove recording was not adopted, the linear density would have to be increased, necessitating a lower jitter material. This would have restricted our choice of recording layers.

A second major advantage of Land/Groove recording is the simplification of the mastering process. The adoption of this route has meant that masters have been reliably made using current mastering technologies. Plasmon is continuing to develop improvements based on our unique Chemical Etching technology as these are reducing media noise resulting in improved system margins.

8.4 Grey Level Encoding

Various write once and re-writable films have been demonstrated to be capable of supporting multiple grey levels. Based on projections from published technical papers and analysis of signals from our test systems, it will be possible to achieve an increase in areal density of around 2 times compared with conventional “single level” coding/decoding.
The necessity to read back data, in future drive generations is a potential issue. As the grey level is largely due to the writing of marks of different widths rather than a true grey scale recording of marks of a fixed size, it is necessary to consider how the read channel with a new (smaller) spot profile will respond to data, which was optimised for an older optical system. This approach is valid for a later generation product where the optical pickup is well defined and there is no requirement to read the data with a reduced beam diameter.

8.5 Dual/Multi Layer Media

This is a very attractive option from the drive design standpoint. The read technology is well established in DVD products. The issues to be faced relate to the media design and manufacture. Achieving a Write-Once media is conceptually straightforward. In particular, a two-layer disk using an organic first layer (with or without a dielectric reflector) could be designed to be very thermally and optically efficient. However, the use of organic films immediately raises the issue of dual wavelength compatibility and for this reason an all “metallic” film is preferable.

Re-writable technology presents more difficulties. Matsushita have demonstrated a dual layer media with limited overwrite cyclability and clearly this could form the basis of a new product. In view of the competitive activities and the attractions from the drive point of view, the use of multi-layer recording media deserved serious attention. Trials during the development phase and the wealth of research from companies developing Blu-Ray products has confirmed the viability of dual layer recordable phase change media.

8.6 Super Resolution

MSR using a three layer magnetic film has been commercialised in the 3½-inch and 5 ¼-inch MO formats. If the decision had been to use MO technology for the new product range, it would have been essential to adopt MSR technology to maximise the areal density. However, the technology for amplitude modulated media such as phase change is in its infancy. While in principle it has the possibility of increasing storage density by a factor of 4 or more it is not realistic to produce a plan that necessitates the use of super resolution materials. For this reason, the UDO road map does not use any form of Super Resolution in any of the announced product generations. Clearly, this decision could be reviewed in the future and if the technology becomes feasible it would allow further generations of the UDO product family.

8.7 Media Technology

While it may be true that MO media has a higher theoretical density limit than phase change technology, the proposed product family is based on re-writable and write once phase change films. This allows direct overwriting with a straightforward film construction and the possibility of achieving at least a dual layer recording film. These materials utilise similar write strategies and simplify the design of the optical system. This decision is in line with the announced Blu-Ray products, which have also followed the Phase Change media route.

Initial indications were that the smaller mark sizes used in UDO would help with cyclability of the media and recent media test data is confirming that this is not an issue.

9 The UDO Technology "Road Map"

It was proposed that the initial product should incorporate the new substrate technology in generation one, as there is to be backward compatibility between products in the family. This posed significant media production challenges as the new manufacturing route had to be proven and disk flatness will be critical with the reduced depth of field discussed earlier.

As discussed previously, the original concept was to use a red laser for the first UDO product. Moving to blue laser technology tightened tolerances further but allowed a 40GB capacity. Based on extensive optical modelling and our experience with sample lenses, it was decided to reduce the numerical aperture to 0.7 on the first blue laser product. However, because of the significant reduction of laser wavelength it is still possible to achieve a capacity of 30 GB. This decision also eases the media manufacturing constraints for the first product.

Based on our experience with dual layer media and the current state of research among major developers of these technologies Plasmon is confident that this approach will allow us to deliver the second-generation capacity of 60GB.

Increasing the numerical aperture of the blue laser system to 0.85 on its own would not be sufficient to increase the capacity by a further factor of two for the third generation UDO product. Therefore it will be necessary to introduce another technique to gain greater data density. It is clear from our signal to noise measurements on current test systems and media that there is significant scope to increase densities by improved channel coding and decoding. A modest gain from techniques such as grey scale would achieve the step to 120GB and indeed, one can extrapolate to even higher densities.

Because there has been a change of substrate thickness in the new product range drives will not be backward compatible with the current installed base of ISO drives. It has been decided to address this issue by using the physical cartridge format of current 5¼-inch MO drives but to include design changes that prevent insertion of an MO disk in a UDO drive and vice versa. In this way, library vendors will be able to supply a mixture of media and drives in the same physical unit to allow end users a smooth transition to the new formats.

As part of the new cartridge, we have adopted a split shutter design. Because there is no requirement to access the top surface of the media during recording on Phase Change media, we can leave the upper shutter door closed. Extensive testing has shown that this will reduce media contamination by a factor of five or more.

10 Conclusion

The UDO road map was designed to use proven technologies at all stages in order to ensure that products could be delivered on time and to budget. Too often, companies try to push a new technology to its limits too early and suffer the inevitable delays to program schedules, cost over-runs and failures to deliver to specifications.

In contrast, UDO takes the existing proven elements of Blu-Ray technology to deliver a family of professional data storage products with the initial generation shipping in 2003. Later generations push the technology further as the industry develops the techniques required to manufacture components required to an acceptable level.

Based on these principles the product family shown in the table below offers a very real improvement in data storage performance in the first generation with an achievable growth path to protect customer's investment in the new technology.

	Generation 1	Generation 2	Generation 3
Capacity	30 GB	60 GB	120 GB
Transfer Rate	8 MB/s	12 MB/s	18 MB/s
RPM	2000 RPM	3000 RPM	3600 RPM
Avg Seek Time	25 msec	25 msec	25 msec
Numerical Aperture	0.7	0.7	0.85
Media Layers	1	2	2
Encoding	1,7	1,7	ML
Sector Size	8KB	8KB	8KB
SCSI Transfer Rate	80 MB/s	80 MB/s	80 MB/s
Load Time	5 seconds	5 seconds	5 seconds
Unload Time	3 seconds	3 seconds	3 seconds
MSBF	750,000	750,000	750,000

11 Glossary of Terms

far field recording - an optical recording method where the focussed laser spot is at a significant distance from the focussing lens. Typically this distance will be half to 1 mm allowing the lens to fly at a safe height from the media eliminating the possibility of head crashes

near field recording – an optical recording method where the focussed laser spot is formed at the surface of the lens. In this case the media has to be very close to the lens in the same way that a Winchester magnetic head flies a fraction of a micron above the magnetic media.

aerial density – the number of data bits that can be recorded on a unit area of the media surface. Usually this is expressed in Gbits per square inch. One Gbit is 10^9 bits.

grey level encoding – in conventional optical recording, and area on the media surface can be considered as having either a high or a low reflectivity to denote a one or a zero. In grey level encoding, several different reflectivities are defined and therefore more bits can be encoded in a given point on the media.

Numeric Aperture (NA) – the Numeric Aperture is equivalent to the f-number familiar to photographers. A high NA equates to a lens which has a large aperture. The large aperture gives better resolution at the expense of a worse depth of field.

super resolution – super resolution is a technique in which the media includes a “smart layer” which acts as a very small window to allow the laser beam to read marks that are smaller than the read spot. Usually this “window” is opened when the read power heats a very small spot in the centre of the beam above a critical temperature and allows the laser to “see” the recorded marks below.

About the Author

Bob Longman graduated from Cambridge University in Mechanical Sciences in 1970. After a variety of roles in research and manufacturing development in the Tube Investments Group he joined PA Consulting Group in 1980 where he was responsible for the development of Plasmon’s patented Moth-Eye Write Once Optical Media. He moved to Plasmon in November 1985 to develop the media manufacturing technology and has held the role of Group Technical Director of Plasmon Plc since January 1990.

During his time in Plasmon Bob Longman has been responsible for the development of many new media formats and for the creation of a significant consultancy business focussed on optical media development and manufacturing.