Advances in Optical Storage Medium

(Blu-ray Disc and HD DVD)

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Table of Contents

Chapter- 1

Blu-Ray Disc

Blu-ray Disc

Media type	High-density optical disc

Encoding	MPEG-2, H.264/MPEG-4 AVC and VC-1
Capacity	25 GB (single-layer) 50 GB (dual-layer) 100/128 GB (BDXL)
Block size	64 kb ECC
Read mechanism	405 nm laser: 1× @ 36 Mbit/s (4.5 MByte/s)
Developed by	Blu-ray Disc Association
Usage	Data storage 1080p High-definition video High-definition audio stereoscopic 3D

Blu-ray Disc (official abbreviation **BD**) is an optical disc storage medium designed to supersede the DVD format. The format defines as its standard physical media a 12 cm (same as DVDs and CDs), 25 GB per-layer optical disc, with dual layer discs (50 GB) the norm for feature-length video discs and additional layers possible later.

The name *Blu-ray Disc* refers to the blue laser used to read the disc, which allows for six times more storage than on a DVD. The term *Blu* was used instead of the correct *Blue* which is commonly used in English (and therefore not registrable as a trademark).

Blu-ray Disc was developed by the Blu-ray Disc Association, a group representing makers of consumer electronics, computer hardware and motion pictures. As of June 2009, more than 1,500 Blu-ray Disc titles were available in Australia and the United Kingdom, with 2,500 in the United States and Canada. In Japan as of July 2010 more than 3,300 titles were released.

During the high definition optical disc format war, Blu-ray Disc competed with the HD DVD format. Toshiba, the main company that supported HD DVD, conceded in February 2008, releasing their own Blu-ray Disc player in late 2009.

History

Commercial HDTV sets began to appear in the consumer market around 1998, but there was no commonly accepted, inexpensive way to record or play HD content. In fact, there was no medium with the storage required to accommodate full-length video encoded with HD codecs, except for JVC's Digital VHS and Sony's HDCAM. Nevertheless, it was well known that using lasers with shorter wavelengths would enable optical storage with higher density. Shuji Nakamura invented the practical blue laser diode; it was a sensation

among the computer storage-medium community, although a lengthy patent lawsuit delayed commercial introduction.

Origins

Sony/Philips started two projects applying the new diodes: UDO (Ultra Density Optical) and DVR Blue (together with Pioneer), a format of rewritable discs that would eventually become Blu-ray Disc (more specifically, BD-RE). The core technologies of the formats are similar.

The first DVR Blue prototypes were unveiled at the CEATEC exhibition in October 2000. A trademark for the "Blue Disc" logo was filed February 9, 2001. On February 19, 2002, the project was officially announced as Blu-ray Disc and Blu-ray Disc Founders was founded by the nine initial members.

The first consumer device arrived in stores on April 10, 2003: the Sony BDZ-S77, a US$3,800 BD-RE recorder that was made available only in Japan. But there was no standard for prerecorded video and no movies were released for this player.

Hollywood studios insisted that players be equipped with Digital Rights Management before they would release movies for the new format and they wanted a new DRM system that would be more secure than the failed Content Scramble System (CSS) used on DVDs.

On October 4, 2004, the name "Blu-ray Disc Founders" was officially changed to the Blu-ray Disc Association (BDA) and 20th Century Fox joined the BDA's Board of Directors.

The Blu-ray Disc physical specifications were completed in 2004.

In January 2005, TDK announced that they had developed a hard coating polymer for Blu-ray Discs. Cartridges, originally used for scratch protection, were no longer necessary and were scrapped.

The BD-ROM specifications were finalized in early 2006.

AACS LA, a consortium founded in 2004, had been developing the DRM platform that could be used to securely distribute movies to consumers. However, the final AACS standard was delayed and then delayed again when an important member of the Blu-ray Disc group voiced concerns. At the request of the initial hardware manufacturers, including Toshiba, Pioneer and Samsung, an interim standard was published that did not include some features, such as managed copy.

Launch and sales developments

The first BD-ROM players were shipped in mid-June 2006, though HD DVD players beat them to market by a few months.

The first Blu-ray Disc titles were released on June 20, 2006: *50 First Dates*, *The Fifth Element*, *Hitch*, *House of Flying Daggers*, *Underworld: Evolution*, *xXx* (all Sony) and MGM's *The Terminator*. The earliest releases used MPEG-2 video compression, the same method used on standard DVDs. The first releases using the newer VC-1 and AVC codecs were introduced in September 2006. The first movies using 50 GB dual-layer discs were introduced in October 2006. The first audio-only release was made in March 2008.

The first mass-market Blu-ray Disc rewritable drive for the PC was the BWU-100A, released by Sony on July 18, 2006. It recorded both single and dual-layer BD-Rs as well as BD-REs and had a suggested retail price of US $699.

End of the format war and future prospects

On January 4, 2008, a day before CES 2008, Warner Bros. (the only major studio still releasing movies in both HD DVD and Blu-ray Disc format) announced that it would release only in Blu-ray Disc after May 2008. This effectively included other studios that came under the Warner umbrella, such as New Line Cinema and HBO—though in Europe, HBO distribution partner, the BBC, announced it would, while keeping an eye on market forces, continue to release product on both formats. This led to a chain reaction in the industry, with major U.S. retailers such as Best Buy, Wal-Mart and Circuit City and Canadian chains such as Future Shop dropping HD DVD in their stores. A former major European retailer, Woolworths, dropped HD DVD from its inventory. Netflix and Blockbuster—major DVD rental companies—said they would no longer carry HD DVDs. Following these new developments, on February 19, 2008, Toshiba announced it would end production of HD DVD devices, allowing Blu-ray Disc to become the industry standard for high-density optical discs. Universal Studios, the sole major movie studio to back HD DVD since its inception, said shortly after Toshiba's announcement, "While Universal values the close partnership we have shared with Toshiba, it is time to turn our focus to releasing new and catalog titles on Blu-ray Disc." Paramount Studios, which started releasing movies only in HD DVD format during late 2007, also said it would start releasing in Blu-ray Disc. Both studios announced initial Blu-ray lineups in May 2008. With this, all major Hollywood studios now support Blu-ray.

According to Adams Media Research, high-definition software sales in the US were slower in the first two years than DVD software sales. 16.3 million DVD software units were sold in the first two years (1997–98) compared to 8.3 million high-definition software units (2006–07). One reason given for this difference was the smaller marketplace (26.5 million HDTVs in 2007 compared to 100 million SDTVs in 1998). Former HD DVD supporter Microsoft has stated that they are not planning to make a Blu-ray Disc drive for the Xbox 360.

Blu-ray Disc began making serious strides as soon as the format war ended. Nielsen VideoScan sales numbers showed that with some titles, such as 20th Century Fox's *Hitman*, up to 14% of total disc sales were from Blu-ray, although the average for the first half of the year was around 5%. Shortly after the format war ended, a study by The NPD Group found that awareness of Blu-ray Disc had reached 60% of U.S. households. In December 2008, the Blu-ray Disc of *The Dark Knight* sold 600,000 copies on the first day of its launch in the United States, Canada and the United Kingdom. A week after launch, *The Dark Knight* BD had sold over 1.7 million copies worldwide, making it the first Blu-ray Disc title to sell over a million copies in the first week of release.

According to Singulus Technologies AG, Blu-ray is being adopted faster than the DVD format was at a similar period in its development. This conclusion was based on the fact that Singulus Technologies has received orders for 21 Blu-ray dual-layer machines during the first quarter of 2008, while 17 DVD machines of this type were made in the same period in 1997. And the other key equipment supplier for optical disc Anwell Technologies Limited had shipped its Blu-ray Disc production equipment to Frankfurt for the largest trade show in the world — MEDIA-TECH Expo in May 2008 and they received new order for the Blu-ray production line also. According to GfK Retail and Technology, in the first week of November 2008, sales of Blu-ray recorders surpassed DVD recorders in Japan. According to the Digital Entertainment Group, the total number of Blu-ray Disc playback devices (both set-top box and game console) had reached 17.3 millions by the end of 2009. According to Swicker & Associates, Blu-ray Disc software sales in the United States and Canada were 1.2 million in 2006, 19.2 million in 2007, 82.4 million in 2008 and 177.2 million in 2009. Some commentators have suggested that renting Blu-ray will play a vital part in keeping the technology affordable while allowing it to move forward. In an effort to increase sales, studios are releasing movies in combo packs with Blu-ray Discs and DVDs as well as "digital copies" which can be played on computers and iPods. Some are released on "flipper" discs with Blu-ray on one side and DVD on the other. Other strategies are to release movies with the special features only on Blu-ray Discs and none on DVDs.

Blu-ray faces competition from video on demand and from new technologies that allow access to movies on any format or device, such as Digital Entertainment Content Ecosystem or Disney's Keychest.

Physical media

Type	Physical size	Single layer capacity	Dual layer capacity
Standard disc size	12 cm	25 GB / 23866 MiB / 25025314816 B	50 GB / 47732 MiB / 50050629632 B
Mini disc size	8 cm	7.8 GB / 7430 MiB / 7791181824 B	15.6 GB / 14860 MiB / 15582363648 B

Laser and optics

While a DVD uses a 650-nanometer red laser, Blu-ray Disc uses a 405 nm "blue" laser. This shorter wavelength allows for over five times more data storage per layer than allowed by a DVD. Note that even though the laser is called "blue", its color is actually in the violet range.

The diodes are GaN (gallium nitride) lasers that produce 405 nm light directly, that is, without frequency doubling or other nonlinear optical mechanisms. Conventional DVDs and CDs use red and near-infrared lasers, at 650 nm and 780 nm, respectively.

Panasonic Internal Blu-ray ROM notebook drive

The minimum "spot size" on which a laser can be focused is limited by diffraction and depends on the wavelength of the light and the numerical aperture of the lens used to focus it. By decreasing the wavelength, increasing the numerical aperture from 0.60 to 0.85 and making the cover layer thinner to avoid unwanted optical effects, the laser beam can be focused to a smaller spot, which effectively allows more information to be stored in the same area.

For Blu-ray Disc, the spot size is 580 nm. In addition to the optical improvements, Blu-ray Discs feature improvements in data encoding that further increase the capacity.

Hard-coating technology

Since the Blu-ray Disc data layer is closer to the surface of the disc compared to the DVD standard, it was at first more vulnerable to scratches. The first discs were housed in cartridges for protection, resembling Professional Discs introduced by Sony in 2003.

Using a cartridge would increase the price of an already expensive medium, so hard-coating of the pickup surface was chosen instead. TDK was the first company to develop a working scratch-protection coating for Blu-ray Discs. It was named Durabis. In addition, both Sony and Panasonic's replication methods include proprietary hard-coat technologies. Sony's rewritable media are spin-coated, using a scratch-resistant and antistatic coating. Verbatim's recordable and rewritable Blu-ray Discs use their own proprietary hard-coat technology, called ScratchGuard.

The Blu-ray Disc specification requires the testing of resistance to scratches by mechanical abrasion. In contrast, DVD media are not required to be scratch-resistant, but since development of the technology, some companies, such as Verbatim, implemented hard-coating for more expensive lineups of recordable DVDs.

Recording speed

Drive speed	Data rate		Theoretical Write time for Blu-ray Disc (minutes)	
	Mbit/s	MB/s	Single-Layer	Dual-Layer
1×	36	4.5	90	180
2×	72	9	45	90
4×	144	18	22.5	45
6×	216	27	15	30
8×	288	36	11.25	22.5
10×	360	45	9	18
12×	432	54	7.5	15

Variants

Mini Blu-ray Disc

The "Mini Blu-ray Disc" (also, "Mini-BD" and "Mini Blu-ray") is a compact 8 cm (~3 in)-diameter variant of the Blu-ray Disc that can store approximately 7.5 GB of data. It is similar in concept to the MiniDVD and MiniCD. Recordable (BD-R) and rewritable (BD-RE) versions of Mini Blu-ray Disc have been developed specifically for compact camcorders and other compact recording devices.

BD9 and BD5

The BD9 format was proposed to the Blu-ray Disc Association by Warner Home Video as a cost-effective alternative to the 25/50 GB BD-ROM discs. The format was supposed to use the same codecs and program structure as Blu-ray Disc video, but recorded onto less expensive 8.5 GB dual-layer DVD. This red-laser media could be manufactured on existing DVD production lines with lower costs of production than the 25/50 GB Blu-ray media.

Usage of BD9 for releasing content on "pressed" discs has never caught on. After the end of the format war, major producers ramped up the production of Blu-ray Discs and lowered their prices to the level of DVDs. On the other hand, the idea of using inexpensive DVD media became popular among individual users. A lower-capacity version of this format that uses single-layer 4.7 GB DVDs has been unofficially called BD5. Both formats are being used by individuals for recording high definition content in Blu-ray format onto recordable DVD media.

Despite the fact that the BD9 format has been adopted as part of the BD-ROM basic format, none of the existing Blu-ray player models support it explicitly. As such, the discs recorded in BD9 and BD5 formats are not guaranteed to play on standard Blu-ray Disc players.

AVCHD and AVCREC also use inexpensive media like DVDs, but unlike BD9 and BD5 these formats have limited interactivity, codec types and data rates.

BDXL

The BDXL format supports 100GB and 128GB write-once discs and 100GB rewritable discs for commercial applications. It was defined in June 2010.

BD-R 3.0 Format Specification (BDXL) defined a multi-layered disc recordable in BDAV format with the speed of 2X and 4X, capable of 100/128GB and usage of UDF2.5/2.6.

BD-RE 4.0 Format Specification (BDXL) defined a multi-layered disc rewritable in BDAV with the speed of 2X and 4X, capable of 100GB and usage of UDF2.5 as file system.

IH-BD

The IH-BD (Intra-Hybrid Blu-ray) format includes a 25GB write-once layer (BD-R) and a 25GB read-only layer (BD-ROM), designed to work with existing Blu-ray Discs.

Software Standards

Filesystem

Blu-ray Disc specifies the use of Universal Disk Format (UDF) 2.50 as a convergent friendly format for both PC and consumer electronics environments. It is used in latest specifications of BD-ROM, BD-RE and BD-R.

In the first BD-RE specification (defined in 2002), the BDFS (Blu-ray Disc File System) was used. The BD-RE 1.0 specification was defined mainly for broadcast recording of High Definition TV. The BDFS was replaced by UDF 2.50 in the second BD-RE specification in 2005, in order to enable interoperability among consumer electronics Blu-ray recorders and personal computer systems. This enabled PC recording and playback of BD-RE. BD-R can use UDF 2.50/2.60.

The Blu-ray Disc application (BDAV application) for recording of digital broadcasting has been developed as *System Description Blu-ray Rewritable Disc Format part 3 Audio Visual Basic Specifications*. The requirements related with file system have been specified in *System Description Blu-ray Rewritable Disc Format part 2 File System Specifications version 1.0* (BDFS).

Initially, the BD-RE version 1.0 (BDFS) was specifically developed for recording of digital broadcasting using the Blu-ray Disc application (BDAV application). To support UDF, these requirements are superseded by the *Blu-ray Rewritable Disc File System Specifications version 2.0* (UDF) (a.k.a. *RE 2.0*) and *Blu-ray Recordable Disc File System Specifications version 1.0* (UDF) (a.k.a. *R 1.0*). Additionally, a new application format, BDMV (*System Description Blu-ray Disc Prerecorded Format part 3 Audio Visual Basic Specifications*) for High Definition Content Distribution was developed for BD-ROM. The only file system developed for BDMV is the *System Description Blu-ray Read-Only Disc Format part 2 File System Specifications version 1.0* (UDF) which defines the requirements for UDF 2.50.

Directory and file structure

All BD-ROM application files are stored under a “BDMV” directory.

- BDMV directory: contains the PLAYLIST, CLIPINF, STREAM, AUXDATA and BACKUP directories.
    - PLAYLIST directory: contains the Database files for Movie PlayLists.
        - xxxxx.mpls files: store information corresponding to Movie PlayLists. One file is created for each Movie PlayList. The filenames of these files are in the form “xxxxx.mpls”, where “xxxxx” is a 5-digit number corresponding to the Movie PlayList.
    - CLIPINF directory: contains the Database files for Clips.
        - zzzzz.clpi files: store Clip information associated with a Clip AV stream file. The filenames of these files are in the form

"zzzzz.clpi", where "zzzzz" is a 5-digit number corresponding to the Clip.

- STREAM directory: contains AV stream files.
  - zzzzz.m2ts file: contains a BDAV MPEG-2 transport stream. The names of these files are in the form "zzzzz.m2ts", where "zzzzz" is a 5-digit number corresponding to the Clip. The same 5-digit number "zzzzz" is used for an AV stream file and its associated Clip information file.
  - SSIF directory: If used, Stereoscopic Interleaved files shall be placed under this directory.
    - zzzzz.ssif file: is a Stereoscopic Interleaved file that is composed from two BDAV MPEG-2 transport streams. Both of the streams include an MPEG-4 MVC view video stream for left eye or right eye respectively. This file is used only when 3D video is played back. The 5-digit number "zzzzz" is the same as the number used for the AV stream file "zzzzz.m2ts" that includes the MPEG-4 MVC Base view video stream.
- AUXDATA directory: contains Sound data files and Font files.
  - sound.bdmv file: stores data relating to one or more sounds associated with HDMV Interactive Graphic streams applications. This file may or may not exist under the AUXDATA directory. If it exists, there shall be only one sound.bdmv file.
  - aaaaa.otf file: stores the font information associated with Text subtitle applications. The names of these files are in the form "aaaaa.otf", where "aaaaa" is a 5-digit number corresponding to the Font.
- BACKUP directory: contains copies of the "index.bdmv" file, the "MovieObject.bdmv" file, all the files in the PLAYLIST directory and all files in the CLIPINF directory.
- index.bdmv file: stores information describing the contents of the BDMV directory. There is only one index.bdmv file under the BDMV directory.
- MovieObject.bdmv file: stores information for one or more Movie Objects. There is only one MovieObject.bdmv under the BDMV directory.

Media format

Container format

Audio, video and other streams are multiplexed and stored on Blu-ray Discs in a container format based on the MPEG transport stream. It is also known as BDAV MPEG-2 transport stream and can use filename extension .m2ts. Blu-ray Disc titles authored with menu support are in the BDMV (Blu-ray Disc Movie) format and contain audio, video and other streams in BDAV container. There is also the BDAV (Blu-ray Disc Audio/Visual) format, the consumer oriented alternative to the BDMV format used for movie releases. The BDAV format is used on BD-REs and BD-Rs for audio/video

recording. BDMV format was later defined also for BD-RE and BD-R (in September 2006, in the third revision of BD-RE specification and second revision of BD-R specification). Blu-ray Disc employs the MPEG transport stream recording method. That enables transport streams of digital broadcasts to be recorded as they are without altering the format. It also enables flexible editing of a digital broadcast that is recorded as is and where the data can be edited just by rewriting the playback stream. Although it is quite natural, a function for high-speed and easy-to use retrieval is built in. Blu-ray Disc Video use MPEG transport streams, compared to DVD's MPEG program streams. This allows multiple video programs to be stored in the same file so they can be played back simultaneously (e.g., with "Picture in picture" effect).

Video

High-definition video may be stored on BD-ROMs with up to 1920×1080 pixel resolution at up to 59.94 fields per second, if interlaced. Alternatively, progressive scan can go up to 1920×1080 pixel resolution at 24 frames per second, or up to 1280x720 at up to 59.94 frames per second:

Resolution	Frame rate[1]	Aspect ratio	Video format restrictions
1920×1080	59.94-i	16:9	2D encodes only
1920×1080	50-i	16:9	2D encodes only
1920×1080	24-p	16:9	
1920×1080	23.976-p	16:9	
1440×1080	59.94-i	16:9 (anamorphic)	MPEG-4 AVC / SMPTE VC-1 only
1440×1080	50-i	16:9 (anamorphic)	MPEG-4 AVC / SMPTE VC-1 only
1440×1080	24-p	16:9 (anamorphic)	MPEG-4 AVC / SMPTE VC-1 only
1440×1080	23.976-p	16:9 (anamorphic)	MPEG-4 AVC / SMPTE VC-1 only
1280×720	59.94-p	16:9	
1280×720	50-p	16:9	
1280×720	24-p	16:9	
1280×720	23.976-p	16:9	
720×480	59.94-i	4:3/16:9 (anamorphic)	
720×576	50-i	4:3/16:9 (anamorphic)	

Notes: [1] The interlaced (i) frame rates are marked as fields per second while progressive (p) frame rates are in frames per second.

For video, all players are required to support MPEG-2 Part 2, H.264/MPEG-4 AVC and SMPTE VC-1. MPEG-2 is the codec used on regular DVDs, which allows backwards compatibility. MPEG-4 AVC was developed by MPEG, Sony and VCEG. VC-1 is a codec that was mainly developed by Microsoft. BD-ROM titles with video must store video using one of the three mandatory codecs; multiple codecs on a single title are allowed.

The choice of codecs affects the producer's licensing/royalty costs as well as the title's maximum run time, due to differences in compression efficiency. Discs encoded in MPEG-2 video typically limit content producers to around two hours of high-definition content on a single-layer (25 GB) BD-ROM. The more-advanced video codecs (VC-1 and MPEG-4 AVC) typically achieve a video run time twice that of MPEG-2, with comparable quality.

MPEG-2 was used by many studios (including Paramount Pictures, which initially used the VC-1 codec for HD DVD releases) for the first series of Blu-ray Discs, which were launched throughout 2006. Modern releases are now often encoded in either MPEG-4 AVC or VC-1, allowing film studios to place all content on one disc, reducing costs and improving ease of use. Using these codecs also frees a lot of space for storage of bonus content in HD (1080i/p), as opposed to the SD (480i/p) typically used for most titles. Some studios, such as Warner Bros., have released bonus content on discs encoded in a different codec than the main feature title. For example, the Blu-ray Disc release of *Superman Returns* uses VC-1 for the feature film and MPEG-2 for bonus content. Today, Warner and other studios typically provide bonus content in the video codec that matches the feature.

Audio

For audio, BD-ROM players are required to support Dolby Digital (AC-3), DTS and linear PCM. Players may optionally support Dolby Digital Plus and DTS-HD High Resolution Audio as well as lossless formats Dolby TrueHD and DTS-HD Master Audio. BD-ROM titles must use one of the mandatory schemes for the primary soundtrack. A secondary audiotrack, if present, may use any of the mandatory or optional codecs.

Specification of BD-ROM Primary audio streams:

	LPCM	Dolby Digital	Dolby Digital Plus	Dolby TrueHD (Lossless)	DTS digital surround	DTS-HD (Lossless)	DRA	DRA Extension
Max. Bitrate	27.648 Mbit/s	640 kbit/s	4.736 Mbit/s	18.64 Mbit/s	1.524 Mbit/s	24.5 Mbit/s	1.5 Mbit/s	3.0 Mbit/s
Max. Channel	8(48 kHz, 96 kHz), 6(192 kHz)	5.1	7.1	8(48 kHz, 96 kHz), 6(192 kHz)	5.1	8(48 kHz, 96 kHz), 6(192 kHz)	5.1	7.1
Bits/sample	16, 20, 24	16–24	16–24	16–24	16, 20, 24	16–24	16	16
Sample frequency	48 kHz, 96 kHz, 192 kHz	48 kHz	48 kHz	48 kHz, 96 kHz, 192 kHz	48 kHz	48 kHz, 96 kHz, 192 kHz	48 kHz	48 kHz, 96 kHz

Bit rate

For users recording digital television programming, the recordable Blu-ray Disc standard's initial data rate of 36 Mbit/s is more than adequate to record high-definition broadcasts from any source (IPTV, cable/satellite, or terrestrial). BD Video movies have

a maximum data transfer rate of 54 Mbit/s, a maximum AV bitrate of 48 Mbit/s (for both audio and video data) and a maximum video bit rate of 40 Mbit/s. This compares to HD DVD movies, which have a maximum data transfer rate of 36 Mbit/s, a maximum AV bitrate of 30.24 Mbit/s and a maximum video bitrate of 29.4 Mbit/s.

Application format

- BDAV or BD-AV (Blu-ray Disc Audio/Visual) – a consumer-oriented Blu-ray video format used for audio/video recording (defined in 2002)
- BDMV or BD-MV (Blu-ray Disc Movie) – a Blu-ray video format with menu support commonly used for movie releases
    - BDMV Recording specification – (defined in September 2006 for BD-RE and BD-R).
        - RREF – (Realtime Recording and Editing Format) – a subset of BDMV designed for realtime recording and editing applications

Player profiles

The BD-ROM specification defines four Blu-ray Disc player profiles, including an audio-only player profile (BD-Audio) that does not require video decoding or BD-J. All three of the video-based player profiles (BD-Video) are required to have a full implementation of BD-J, with varying levels of hardware support.

Feature	**BD-Audio**	**BD-Video**		
	Profile 3.0 [c]	*Grace Period* [d] Profile 1.0	*Bonus View* Profile 1.1	*BD-Live*[e] Profile 2.0
Built-in persistent memory	No	64 KB	64 KB	64 KB
Local storage capability[a]	No	Optional	256 MB	1 GB
Secondary video decoder (PiP)	No	Optional	Mandatory	Mandatory
Secondary audio decoder[b]	No	Optional	Mandatory	Mandatory
Virtual file system	No	Optional	Mandatory	Mandatory
Internet connection capability	No	No	No	Mandatory

a This is used for storing audio/video and title updates. It can either be built-in memory or removable media, such as a memory card or USB flash memory.
b A secondary audio decoder is typically used for interactive audio and commentary.
c Profile 3.0 is a separate audio-only player profile. The first Blu-ray Disc album to be released was *Divertimenti*, by record label Lindberg Lyd and it has been confirmed to work on the PS3.
d Also known as Initial Standard profile.
e Also known as Final Standard profile.

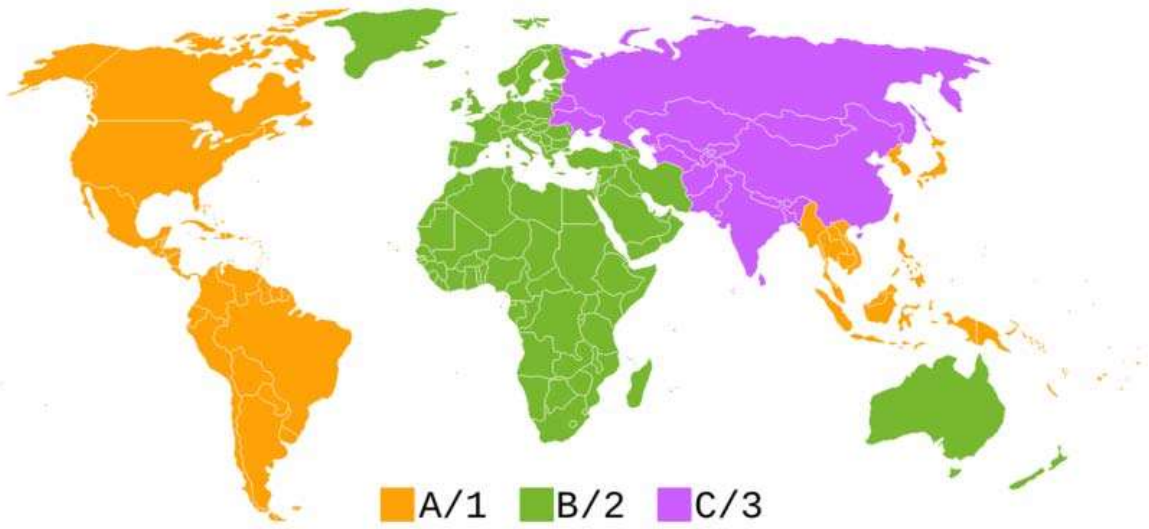
On November 1, 2007, the Grace Period Profile was superseded by Bonus View as the minimum profile for new BD-Video players released to the market. When Blu-ray Disc software not authored with interactive features dependent on Bonus View or BD-Live hardware capabilities is played on Profile 1.0 players, it is able to play the main feature of the disc, but some extra features may not be available or will have limited capability.

BD-Live

The biggest difference between Bonus View and BD-Live is that BD-Live requires the Blu-ray Disc player to have an Internet connection to access Internet-based content. BD-Live features have included automatic firmware updates, checking each time the device is switched on to see if it has been tampered with and report the same, Internet chats, scheduled chats with the director, Internet games, downloadable featurettes, downloadable quizzes and downloadable movie trailers. Note that while some Bonus View players may have an Ethernet port, these are used for firmware updates and are not used for Internet-based content. In addition, Profile 2.0 also requires more local storage in order to handle this content.

With the exception of the latest players and the PlayStation 3, Profile 1.0 players cannot be upgraded to be Bonus View or BD-Live compliant.

Region codes



Regions for the Blu-ray standard:
A/1: The Americas (except Greenland) and their dependencies, East Asia (except mainland China and Mongolia) and Southeast Asia.
B/2: Africa, Middle East, Southwest Asia, Europe (except Belarus, Russia and Ukraine), Australia, New Zealand and their dependencies.
C/3: Central Asia, East Asia (mainland China and Mongolia only), South Asia, Eastern Europe and their dependencies.

As with the implementation of region codes for DVDs, Blu-ray Disc players sold in a specific geographical region are designed to play only discs authorized by the content provider for that region. This is intended to permit content providers (motion picture studios, etc.) the ability to support product differences in content, price, release date, etc., by region. According to the Blu-ray Disc Association, "all Blu-ray Disc players...(and) Blu-ray Disc-equipped computer systems are required to support regional coding." However, "Use of region playback codes is optional for content providers..." Some current estimates suggest 70% of available [movie] Blu-ray Discs from the major studios are region-code-free and can therefore be played on any Blu-ray Disc player, in any region.

Movie studios have different region coding policies. Among major U.S. studios, Paramount Pictures and Universal Studios have released all of their titles region-free. Sony Pictures and Warner Bros. have released most of their titles region-free. Lionsgate and Walt Disney Pictures have released a mix of region-free and region-coded titles. 20th Century Fox and MGM have released most of their titles region-coded.

The Blu-ray Disc region coding scheme divides the world into 3 regions, labeled A, B and C.

- Region A includes most North, Central and South American and Southeast Asian countries plus the Republic of China (Taiwan), Hong Kong, Japan and Korea.
- Region B includes most European, African and southwest Asian countries plus Australia and New Zealand.
- Region C contains the remaining central and south Asian countries, as well as the People's Republic of China and Russia.

In circumvention of region coding restrictions, stand-alone Blu-ray Disc players are sometimes modified by third parties to allow for playback of Blu-ray Discs (and DVDs) with *any* region code. Instructions ('hacks') describing how to reset the Blu-ray region counter of computer player applications to make them multi-region indefinitely are also regularly posted to video enthusiast websites and forums. Unlike DVD region codes, Blu-ray region codes are verified only by the player software, not by the optical drive's firmware.

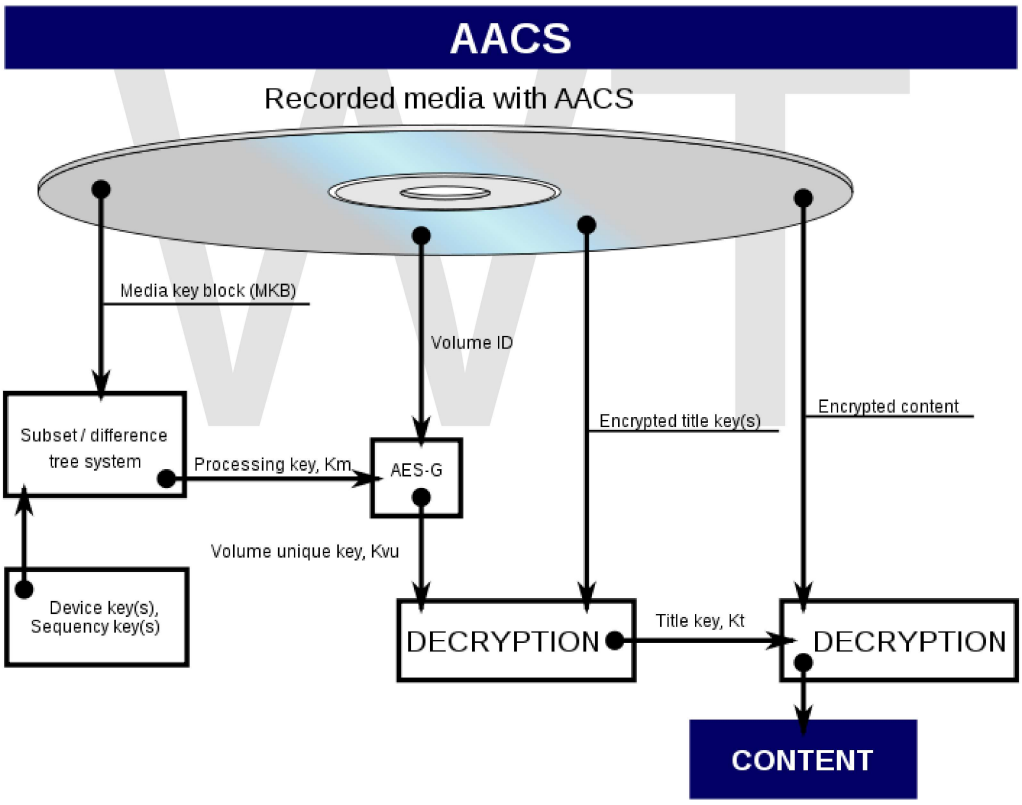
Digital rights management

The Blu-ray Disc format employs several layers of digital rights management (DRM). This has led to extensive criticism of the format by organisations opposed to DRM, such as the Free Software Foundation.

HDCP

Blu-ray equipment is encouraged to implement HDCP. Given certain flags in the media streams, a Blu-ray Disc can enforce its reproduction in a lower resolution whenever a full HDCP-compliant link isn't established all the way from the Blu-ray drive to the rendering devices (i.e. display and speakers).

AACS



The AACS decryption process

The Advanced Access Content System (AACS) is a standard for content distribution and digital rights management. It was developed by AS Licensing Administrator, LLC (AACS LA), a consortium that includes Disney, Intel, Microsoft, Panasonic, Warner Bros., IBM, Toshiba and Sony.

Since appearing in devices in 2006, several successful attacks have been made on the format. The first known attack relied on the trusted client problem. In addition, decryption keys have been extracted from a weakly protected player (WinDVD). Since keys can be revoked in newer releases, this is only a temporary attack and new keys must continually be discovered in order to decrypt the latest discs. This cat-and-mouse game has gone through several cycles.

BD+

BD+ was developed by Cryptography Research Inc. and is based on their concept of Self-Protecting Digital Content. BD+, effectively a small virtual machine embedded in authorized players, allows content providers to include executable programs on Blu-ray Discs. Such programs can:

- examine the host environment to see if the player has been tampered with. Every licensed playback device manufacturer must provide the BD+ licensing authority with memory footprints that identify their devices.
- verify that the player's keys have not been changed.
- execute native code, possibly to patch an otherwise insecure system.
- transform the audio and video output. Parts of the content will not be viewable without letting the BD+ program unscramble it.

If a playback device manufacturer finds that its devices have been hacked, it can potentially release BD+ code that detects and circumvents the vulnerability. These programs can then be included in all new content releases.

The specifications of the BD+ virtual machine are available only to licensed device manufacturers. A list of licensed commercial adopters is available from the BD+ website.

The first titles using BD+ were released in October 2007. Since November 2007, versions of BD+ protection have been circumvented by various versions of the AnyDVD HD program. Other programs known to be capable of circumventing BD+ protection are DumpHD (versions 0.6 and above, along with some supporting software), MakeMKV and two applications from DVDFab (Passkey and HD Decrypter).

BD-ROM Mark

BD-ROM Mark is a small amount of cryptographic data that is stored separately from normal Blu-ray Disc data. Bit-by-bit copies that do not replicate the BD-ROM Mark have no known decoding method. A specially licensed piece of hardware is required to insert the ROM-mark into the media during replication.

Backward compatibility

Though not compulsory, the Blu-ray Disc Association recommends that Blu-ray Disc drives be capable of reading standard DVDs and CDs, for backward compatibility. A few early Blu-ray Disc players released in 2006 could play DVDs but not CDs.

Ongoing development

Front of an experimental 200GB rewritable Blu-ray Disc

Although the Blu-ray Disc specification has been finalized, engineers continue to work on advancing the technology. Quad-layer (100 GB) discs have been demonstrated on a drive with modified optics and standard unaltered optics. Hitachi stated that such a disc could be used to store 7 hours of 32 Mbit/s video (HDTV) or 3 hours and 30 minutes of 64 Mbit/s video (Cinema 4K). In August 2006, TDK announced that they have created a working experimental Blu-ray Disc capable of holding 200 GB of data on a single side, using six 33 GB data layers.

Also, behind closed doors at CES 2007, Ritek revealed that they had successfully developed a High Definition optical disc process that extends the disc capacity to ten layers, which increases the capacity of the discs to 250 GB. However, they noted that the major obstacle is that current read/write technology does not support the additional layers.

JVC has developed a three-layer technology that allows putting both standard-definition DVD data and HD data on a BD/(standard) DVD combination. If successfully commercialized, this would enable the consumer to purchase a disc that can be played on current DVD players and can also reveal its HD version when played on a BD player. Japanese optical disc manufacturer Infinity announced the first "hybrid" Blu-ray Disc/(standard) DVD combo, to be released February 18, 2009. "Code Blue" will feature

four hybrid discs containing a single Blu-ray Disc layer (25 GB) and two DVD layers (9 GB) on the same side of the disc.

In January 2007, Hitachi showcased a 100 GB Blu-ray Disc, consisting of four layers containing 25 GB each. Unlike TDK and Panasonic's 100 GB discs, they claim this disc is readable on standard Blu-ray Disc drives that are currently in circulation and it is believed that a firmware update is the only requirement to make it readable to current players and drives.

In December 2008, Pioneer Corporation unveiled a 400 GB Blu-ray Disc (containing 16 data layers, 25 GB each) that will be compatible with current players after a firmware update. Its planned launch is in the 2009–10 time frame for ROM and 2010–13 for rewritable discs. Ongoing development is under way to create a 1 TB Blu-ray Disc as soon as 2013.

At CES 2009, Panasonic unveiled the DMP-B15, the first portable Blu-ray Disc player and Sharp introduced the LC-BD60U and LC-BD80U series, the first LCD HDTVs with integrated Blu-ray Disc players. Sharp has also announced that they will sell HDTVs with integrated Blu-ray Disc recorders in the United States by the end of 2009.

As of April 2008, a joint licensing agreement for Blu-ray Disc has not yet been finalized. A joint licensing agreement would make it easier for companies to get a license for Blu-ray Disc without having to go to each individual company that owns a Blu-ray Disc patent. For this reason, a joint licensing agreement was eventually made for DVD by the DVD6C Licensing Agency.

On Jan. 1, 2010, Sony, in association with Panasonic, announced plans to increase the storage capacity on their Blu-ray Discs from 25GB to 33.4 GB via a technology called i-MLSE (Maximum Likelihood Sequence Estimation). The higher-capacity discs, according to Sony, will be readable on current Blu-ray Disc players with a firmware upgrade. No date has been set to include the increased space, but according to Blu-ray.com "it will likely happen sometime later this year."

On July 20, 2010, the research team of Sony and Japanese Tohoku University announced the joint development of a blue-violet laser, which will help in creating Blu-ray discs with a capacity of 1 TB (dual layer).

Blu-ray 3D

Blu-ray 3D logo

The Blu-ray Disc Association (BDA) created a task force made up of executives from the film industry and the consumer electronics and IT sectors to help define standards for putting 3D film and 3D television content on a Blu-ray Disc. On Dec. 17, 2009 the BDA officially announced 3D specs for Blu-ray Disc, allowing backward compatibility with current 2D Blu-ray players. The BDA has said, "The Blu-ray 3D specification calls for encoding 3D video using the "Stereo High" profile defined by Multiview Video Coding (MVC), an extension to the ITU-T H.264 Advanced Video Coding (AVC) codec currently supported by all Blu-ray Disc players. MPEG4-MVC compresses both left and right eye views with a typical 50% overhead compared to equivalent 2D content and can provide full 1080p resolution backward compatibility with current 2D Blu-ray Disc players." This means the MVC (3D) stream is backward compatible with H.264/AVC (2D) stream, allowing older 2D devices and software to decode stereoscopic video streams, ignoring additional information for the second view.

Sony has released a firmware upgrade for PlayStation 3 consoles that enables 3D Blu-ray Disc playback. However, when playing in 3D mode, the PlayStation 3 will downgrade high-def audio (such as Dolby TrueHD or DTS-HD) to standard Dolby Digital or DTS, as HDMI 1.3 does not provide enough bandwidth for both 3D video and high-def audio. They previously released support for 3D gaming on April 21, 2010 (followed by availability of 3D Movies).

Chapter- 2

High Definition Optical Disc Format War

The **high definition optical disc format war** was a format war between the Blu-ray Disc and HD DVD optical disc standards for storing high definition video and audio.

These standards emerged between 2000 and 2002 and attracted both the mutual and exclusive support of major consumer electronics manufacturers, personal computer manufacturers, television and movie producers and distributors and software developers.

Blu-ray and HD DVD players became commercially available starting in 2006. In early 2008, a tipping point was passed when several studios and distributors shifted to Blu-ray disc. On February 19, 2008, Toshiba officially announced that it would stop the development of the HD DVD players, conceding the format war to the Blu-ray Disc format.

Background

The Blu-ray/HD DVD conflict resembled the earlier videotape format war between VHS and BetaMax, partly because of Sony's strong involvement in both episodes. These format wars have often proved destructive to both camps because consumers, afraid of committing to a losing standard, will refrain from purchasing either. Format wars have been avoided in notable cases such as the DVD Forum for the unified DVD standard, the Grand Alliance for the HDTV standard and the Wi-Fi Alliance for wireless networking standards.

The emergence of high definition players followed the entry of HDTV televisions into the mainstream market in the mid-2000s. Consumer-grade high definition players required an inexpensive storage medium capable of holding the larger amount of data needed for HD video. The breakthrough came with Shuji Nakamura's invention of the blue laser diode, whose shorter wavelength opened the door to higher density optical media following a six year patent dispute.

Sony started two projects applying the new diodes: Ultra Density Optical and, with Pioneer, DVR Blue. The first DVR Blue prototypes were unveiled at the CEATEC exhibition in October 2000. In February 2002, the project was officially announced as Blu-ray and the Blu-ray Disc Association was founded by a consortium of nine electronics companies.

The DVD Forum, chaired by Toshiba, was deeply split over whether to go with the more expensive blue lasers, whose discs initially required a protective caddy to avoid mis-handling, making the medium more expensive and physically different from DVDs. In March 2002, the forum voted to approve a proposal endorsed by Warner Bros. and other motion picture studios that involved compressing HD content onto dual-layer DVD-9 discs. In spite of this decision, the DVD Forum's Steering Committee announced in April that it was pursuing its own blue-laser high-definition solution. In August, Toshiba and NEC announced their competing standard Advanced Optical Disc, which was finally adopted by the DVD Forum and renamed "HD DVD" the following year after being voted down twice by Blu-ray Disc Association members, prompting the U.S. Department of Justice to make preliminary investigations. Three new members had to be invited and the voting rules changed before the initiative finally passed.

The competing standards had significant differences that made each incompatible with the other.

Attempts to avoid a format war

In an attempt to avoid a costly format war, the Blu-ray Disc Association and DVD Forum started to negotiate a compromise in early 2005. One of the issues was that Blu-ray's supporters wanted to use a Java-based platform for interactivity (BD-J), while the DVD Forum was promoting Microsoft's "iHD" (which became HDi). A much larger issue, though, was the physical formats of the discs themselves; the Blu-ray Disc Association's

member companies did not want to risk losing billions of dollars in royalties as they had done with standard DVD. An agreement seemed close, but negotiations proceeded slowly.

At the end of June 2005, Sun announced that the Blu-ray Association had chosen the Java-based BD-J interactivity layer instead of Microsoft's HDi. This was based on a BDA board vote favouring BD-J 10 to 4, despite a technical committee previously favoring HDi by a vote of 7 to 5. At the same time, Microsoft and Toshiba jointly announced that they would cooperate in developing high-definition DVD players. In a top-level meeting in July, Microsoft's Bill Gates argued that the Blu-ray standard had to change to "work more smoothly with personal computers". The Blu-ray Disc's representatives defended the technology.

On August 22, 2005, the Blu-ray Disc Association and DVD Forum announced that the negotiations to unify their standards had failed. Rumors surfaced that talks had stalled; publicly, the same reasons of physical format incompatibility were cited. In the end of September, Microsoft and Intel jointly announced their support for HD DVD.

Hewlett Packard (HP) proposed an ultimatum for the Blu-ray Disc Association: Adopt Microsoft's proprietary HDi (instead of the Java based system) and a mandatory managed copy feature, or HP would support HD DVD instead. In a research report, Gartner analysts Van Baker, Laura Behrens and Mike McGuire wrote that if HP's proposal were accepted, Blu-ray would become the winner of the format war. Though the Blu-ray Disc group did add mandatory managed copy to Blu-ray, they did not add HDi.

HD DVD players and movies were released in the United States on April 18, 2006, The first Blu-ray Disc titles were released on June 20, 2006 and the first movies using dual layer Blu-ray discs (50 GB) were introduced in October 2006.

Alliances

The Blu-ray Disc Foundation was formed by Hitachi, LG, Panasonic, Pioneer, Philips, Samsung, Sharp, Sony and Thomson on May 20, 2002. Other early supporters included Dell, HP, Mitsubishi and TDK. The Blu-ray Disc Association was inaugurated on October 4, 2004 by 14 companies of Board of Directors which added 20th Century Fox to the 13 above-mentioned companies, Contributors of 22 companies, General members of 37 companies and a total of 73 companies.

Acer, Alpine, Asus, HP, Hitachi Maxell, Kenwood, LG, Lite-On, Meridian, Onkyo and Samsung, provided non-exclusive support.

Toshiba, NEC, Sanyo, Memory-Tech Corporation started HD DVD Promotion Group on September 27, 2004. Included Microsoft, RCA, Intel, Venturer Electronics. In Europe, HD DVD was supported either exclusively or non-exclusively by Medusa Home Entertainment, Studio Canal, Universum Films, Kinowelt Home Entertainment, DVD

International, Opus Arte, MK2, Momentum Pictures, Twister Home Video, among others.

During the height of the format war, some studios supported both formats, including Paramount Pictures (including subsidiaries Nickelodeon Movies, MTV Films, DreamWorks Pictures and DreamWorks Animation), BBC, First Look Studios, Image Entertainment (including the Discovery Channel), Magnolia Pictures, Brentwood Home Video, Ryko and Koch/Goldhil Entertainment.

Deciding factors

The format war's resolution in favor of Blu-ray was primarily decided by two factors: shifting business alliances, including decisions by major film studios and retail distributors and Sony's decision to include a Blu-ray player in the PlayStation 3 video game console.

Studio, distributor alliances

Studio alliances shifted over time. Before October 2005 and the release of either format, each had the exclusive support of three of the Big Six. HD DVD had Universal Studios, Paramount Pictures and Warner Bros Pictures, while Blu-ray Disc started out with Columbia Pictures, Walt Disney Pictures and 20th Century Fox. Disney and Fox were both impressed by the extra DRM (BD+ and region coding) that the Blu-ray Disc format provided on paper (ironically, BD+ and region coding were both cracked in their first year). Then HD DVD supporters Warner Bros. and Paramount added support for Blu-ray. But in August 2007, after supporting Blu-ray for over a year, Paramount announced it would release all high-definition content (except titles directed by Steven Spielberg) exclusively on HD DVD. At the same time, DreamWorks Animation SKG, which had not released any high-definition discs, announced it would release exclusively on HD DVD. Explaining their decisions, the companies cited perceived advantages to HD DVD's technology and lower manufacturing costs. The companies together received about $150 million in cash and promotional guarantees, including a Toshiba HD DVD marketing campaign with a tie-in to *Shrek the Third*.

By August 2007, HD DVD appeared to have a promising future, was seeing its highest sales (though still substantially lower than Blu-ray), had support from major big-box retailers such as Wal-Mart due to low prices and had the exclusive support of studios such as Paramount Pictures, DreamWorks SKG/Animation, Universal Studios and several Indie film studios. The format also had non-exclusive though favorable support (through occasional HD DVD exclusive titles) from Warner Bros., the largest home video releaser.

The tipping point came on January 4, 2008 when Warner Bros., which has the largest market share of DVDs, announced plans to drop HD DVD support completely as of the beginning of June 2008. At the Consumer Electronics Show in Las Vegas, some HD DVD-related events and private meetings with analysts and retailers were canceled,

including an event scheduled for the eve of the show sponsored by the North American HD DVD Promotional Group. Toshiba management expressed disappointment over Warner's decision but said that Toshiba would continue promoting the competing format. The following Monday, Toshiba reduced the price of its HD DVD players by 40 to 50 percent, calling price a "deal breaker for the mainstream consumer". At the time, analyst Roger Kay of Endpoint Technologies Associates likened the price cut to the high-stakes Blackjack bet of "doubling down" in an effort to increase market share and "win back the studios". Richard Greenfield of Pali Capital called the move a gimmick and predicted that HD DVD would not become widely adopted. Gartner analyst Hiroyuki Shimizu predicted that while the price cut might extend HD DVD's life somewhat, the limited title library would ultimately "inflict fatal damage on the format", leaving Blu-ray the victor by the end of 2008.

Warner Bros.' sister studio New Line Cinema followed suit, canceling tentative plans to release titles on HD DVD. Other small studios and producers moving exclusively to Blu-ray included National Geographic Society, Constantin Film and Digital Playground.

Warner's move also caused a chain reaction among DVD distributors, most prominently in the form of Wal-Mart's February 15, 2008 decision to phase HD DVD out completely by June 2008. Wal-Mart is the largest DVD retailer in the United States and its decision prompted the *New York Times* to run a mock obituary for the HD DVD format. The newspaper quoted technology analyst Rob Enderle's contention that if Wal-Mart "says HD DVD is done, you can take that as a fact." Four days earlier, Best Buy began recommending Blu-ray Disc as the customer's digital format choice and Netflix, the largest online video rental service, began phasing out its HD DVD inventory after stocking both formats since early 2006.

These shifts were preceded by Blockbuster, the largest U.S. movie rental company, which in June 2007 had moved to Blu-ray exclusively in 1450 stores after test-marketing both formats at 250 stores and finding that more than 70% of high definition rentals were Blu-ray discs. In July 2007, Target Corporation, began carrying only Blu-ray standalone players in its stores, promoting them with end cap displays featuring Blu-ray Disc movies from Sony and Disney. In January 2008, UK retailer Woolworths Group plc said it would stock only Blu-ray discs in its 820 stores beginning in March 2008.

PlayStation 3

Sony's decision to incorporate a Blu-ray Disc player as a standard feature of the PlayStation 3 video game console also helped ensure the format's eventual triumph. By the time Toshiba ceded the market, about 10.5 million of the Sony consoles had been sold worldwide versus an estimated 1 million HD DVD players – including both standalone units and the add-on player for Microsoft's Xbox 360 console, which did not use the HD DVD add-on for gaming unlike the PS3 which had games that used the Blu-ray's added storage capacity. This equipment gap was a factor in Blu-ray titles (including the ones bundled with the PS3) outselling their HD DVD counterparts two to one in the United States and three or four to one in Europe. Sony's strategy came at a cost. The company

initially sold the PlayStation 3 at an estimated loss of more than US$200 per unit that resulted in a total loss estimated about $3 billion, but analysts, such as Richard Cooper, with Screen Digest, expect Sony to recoup far more than that.

Toshiba announcement and aftermath

On February 19, 2008, Toshiba announced it would cease developing, manufacturing and marketing HD DVD players and recorders. On that same day, Universal Studios announced it would release its titles in the Blu-ray Disc format, following two years of exclusive HD DVD support. The studio subsequently released its final two HD DVD titles: *Fletch* on March 13, 2008 and *Atonement* on March 18. On February 20, 2008, Paramount Pictures announced it would back Blu-ray, becoming the last of the major studios to do so. Paramount ceased HD DVD production on February 28, 2008, with *Things We Lost in the Fire* and *Into the Wild* becoming the studio's last HD DVD releases, both released March 4, 2008. The studio scrapped the HD DVD version of *Bee Movie*, which, on May 20, 2008, joined *Face/Off* and *Next* in becoming the studio's first Blu-ray releases since becoming HD DVD exclusive. In April 2009, Warner Home Video announced it would trade up to 25 HD DVD discs for the Blu-ray equivalents, charging only for shipping and handling.

Microsoft ceased production of Xbox 360 HD DVD players while considering how its HDi and VC-1 technologies could be applied to other platforms. Microsoft's VC-1 codec is already in use in Blu-ray titles; Warner Bros. encodes the main features of all titles in the format but encodes supplements and bonus content in MPEG-2. Microsoft has since entered into talks with Sony regarding Blu-ray, although Windows Vista has supported basic filesystem and shell functionality for both Blu-ray Disc and HD DVD since launch, relying on third parties to implement movie playback. Rumors of a Blu-ray drive for the Xbox 360 have been officially denied by Microsoft.

Toshiba's pull-out did not have an immediate significant effect on stand-alone Blu-ray player sales, which rose 2 percent from February to March, 2008, after falling 40 percent between January and February, according to NPD Group. NPD noted that upconverting DVD player sales rose 5 percent in the first quarter of 2008 over the same quarter of 2007 but did not release a comparison of first quarter Blu-ray sales compared to the same quarter of 2007. At the time of the report, upconverting DVD players cost around $70 versus $300 for Blu-ray players. But in spring 2009, the number of Blu-ray players nearly doubled its year to date 2009 sales over the same period 2008: about 9 million high-definition units sold in the U.S. from January through March, up from the 4.8 million that sold during first-quarter 2008, according to Adams Media Research. In April 2008, the firm estimated a total of 10.5 million Blu-ray households, including Blu-ray consoles and Blu-ray-enabled PlayStation 3s.

Chapter- 3

Blu-Ray Disc Recordable

A blank rewritable Blu-ray disc (BD-RE)

Blu-ray Disc recordable (or **BD-R**) refers to two optical disc formats that can be recorded with an optical disc recorder. **BD-R** discs can be written to once, whereas **BD-RE** (**Blu-ray Disc Rewritable**) can be erased and re-recorded multiple times. Disc capacities are 25 GB (23.28 GiB) for single-layer discs and 50 GB (46.57 GiB) for double-layer discs.

Version

There are four versions of Blu-ray Disc Rewritable (BD-RE) and three versions of Blu-ray Disc Recordable (BD-R). Each version includes three *Parts* (a.k.a. *Books*): Basic Format Specifications, File System Specifications, Audio Visual Basic Specifications. Each part has sub-versions (e.g. R2 Format Specification includes *Part 3: Audio Visual Basic Specifications Ver.3.02*, *Part 2: File System Specifications Ver. 1.11*, *Part 1: Basic Format Specifications Ver. 1.3*).

BD-RE versions

Version 1.0—RE 1.0

- defined in 2002
- unique BD File System (BDFS)
- not computer compatible
- BDAV (Blu-ray Disc Audio/Visual) application format
- BDCP as content protection

Version 2.0—RE 2.0

- defined in 2005
- UDF 2.5 file system for computer use
- the use of AACS
- added Hybrid Format—defined for combined discs of BD/CD or BD/DVD. However, BD recording medias (BD-RE and BD-R) are inapplicable. This book is attached to "Part 1 Basic Format Specifications" of every format, except BD-RE Version 1.
- BD-R Version 1.0 follows this specification

Version 3.0—RE 3.0

- defined in September 2006
- camcorder (8 cm) discs added—camcorder is added as one of BD product categories
- backward compatible with Version 2.0
- added BDMV (Blu-ray Disc Movie) application format
- BD-R Version 2.0 follows this specification

Version 4.0—RE 4.0—(BDXL)

- defined in June 2010
- a multi-layered rewritable in BDAV with the speed of 2× and 4×
- capable of 100GB and usage of UDF2.5 as file system and Professional Device is a newly added as one of BD product categories

BD-R versions

Version 1.0—R 1.0

- defined in 2005
- UDF 2.5 file system for computer use
- the use of AACS
- BD-R Version 1 Part 3 is the same book as BD-RE Version 2 Part 3

- add BD-R Low To High (BD-R LTH) standard.

Version 2.0—R 2.0

- defined in September 2006
- camcorder (8 cm) discs added—camcorder is added as one of BD product categories
- backward compatible with Version 1
- added BDMV (Blu-ray Disc Movie) application format
- BD-R Version 2 Part 3 is the same book as BD-RE Version 3 Part 3

Version 3.0—R 3.0—(BDXL)

- defined in June 2010
- a multi-layered recordable in BDAV with the speed of 2× and 4×
- capable of 100/128GB and usage of UDF2.5/2.6 as file system and Professional Device is a newly added as one of BD product categories

Speed

Drive speed	Data rate			BD-R write time	BD-R DL write time
1×	36 Mbit/s	4.5 MB/s	4.29 MiB/s	~95 min.	~190 min.
2×	72 Mbit/s	9 MB/s	8.58 MiB/s	~47 min.	~94 min.
4×	144 Mbit/s	18 MB/s	17.16 MiB/s	~24 min.	~48 min.
6×	216 Mbit/s	27 MB/s	25.75 MiB/s	~16 min.	~32 min.
8×	288 Mbit/s	36 MB/s	34.33 MiB/s	~12 min.	~24 min.
10×	360 Mbit/s	45 MB/s	42.92 MiB/s	~10 min.	~20 min.
12×	432 Mbit/s	54 MB/s	51.50 MiB/s	~8 min.	~16 min.

Pricing

As of October 2010 (approximate pricing)

- **BD-R/RE internal drive** US$99.99–200;
- **4× double-layer BD-R disc** (50 GB) US$12.99 each;
- **4× single-layer BD-R disc** (25 GB) US$2–5 in quantity;
- **2× single-layer BD-RE disc** (25 GB) US$5–12 each;
- **2× double-layer BD-RE disc** (50 GB) US$20–40 each;

BD-R LTH (Low To High)

BD-R LTH is a write-once Blu-ray disc format that features an organic dye recording layer. The advantage of BD-R LTH is it can protect a manufacturer's investment in DVD-R/CD-R manufacturing equipment. Only modifications are required to current equipment; no investment in new production lines is required. It is believed this can lower the cost of discs.

Old Blu-ray players and recorders can not utilize BD-R LTH, however, a firmware upgrade could enable the device to access BD-R LTH. Panasonic has already released such a firmware update in November 2007 for its DMR-BW200, DMR-BR100 and the MR-BW900/BW800/BW700 models. Pioneer is also expected to ship the first LTH BD drives in Spring of 2008. Furthermore, Sony's PlayStation 3 received firmware upgrade to enable BD-R LTH reading in March, 2008.

Chapter- 4

BD-J

BD-J, or **Blu-ray Disc Java**, is a specification supporting Java ME (specifically the Personal Basis Profile of the Connected Device Configuration or CDC) Xlets for advanced content on Blu-ray Disc and the Packaged Media profile of Globally Executable MHP (GEM).

BD-J allows bonus content on Blu-ray Disc titles to be far more sophisticated than bonus content provided by standard DVD, including network access, picture-in-picture and access to expanded local storage. Collectively, these features (other than internet access) are referred to as "Bonus View" and the addition of internet access is called "BD Live." BD-J was developed by the Blu-ray Disc Association. All Blu-ray Disc players supporting video content are required by the specification to support BD-J. Starting on October 31, 2007, all *new* players are required to have hardware support for the "Bonus View" features, but the players may require future firmware updates to enable the features. "BD Live" support is always optional for a BD player.

Sony's PlayStation 3 has been the de facto leader in compliance and support of BD-J. The PlayStation 3 added Blu-ray Profile 1.1 support with a firmware upgrade and was used to showcase BD-Live at CES 2008 in January.

BD-J Xlet Capabilities

- The invocation of BD-J Xlets are triggered by events occurring around them - for example, by the selection of a movie title, or by the insertion of a new disc. Xlets in turn can then call other Xlets into play.

- Security in BD-J is based on the Java platform security model. That is, signed applications in JARs can perform more tasks than a non-signed, such as Read/Write access to local storage, network access, selection of other titles on the BD-ROM disc and control of other running BD-J applications.

- Xlets (as part of the CDC Personal Basis Profile) have no GUI (i.e. no AWT widgets such as java.awt.Button), so additional classes are called into play for generating animation and GUI. The BD-J uses the Havi UI device model and widget set for remote control use, but it is extended to allow for the BD supported resolutions and BD supported A/V controls.

- BD-J has classes that allow you to synchronize accurately to specific frames in the movie.

- There are two types of video synchronizations allowed, one called "loose synchronization", which uses a call back method and is accurate to within several frames of the event and the other being "tight synchronization", which uses the package org.bluray. Tight synchronization allows applications to synchronize accurately to the exact frame using timecodes from the package javax.media.Time of JMF (Java Media Framework).

- A BD-J application's GUI can be operated with a remote control with a required set of keys and an optional pointing device. The set of required keys includes at least the keys needed to support the User Operations in HDMV applications.

- The GUI framework in BD-J includes the HAVi(6) UI framework mandated by [GEM]; it is not a desktop GUI framework like Swing or AWT. The GUI framework is based on the core of AWT as specified by PBP, but the widget set includes mechanisms for remote control navigation from GEM and easy customization of look and feel from HAVi.

- BD-J includes a media framework similar to JMF for the playback of media content related to the BD-ROM disc. It is assumed that the BD-ROM disc will be the prime source for media files, but it will not be the only one; other sources could be the studio's web server and local storage.

- BD-J includes standard Java libraries for decoding and displaying images in JFIF (JPEG), PNG and other image formats. These images can be displayed on the Java graphics plane using standard Java graphics functions. An image can also be rendered in the background plane using a BD-J specific package.

- Text can be rendered using standard Java text functions. These text-rendering functions are extended with a more advanced text layout manager that integrates with the BD-J UI framework. The text is rendered using a vector-based font either coming from the disc, the player (default font) or downloaded from the network.

- Button sounds from HDMV can also be used by the Java UI framework. Sound files can be loaded and rendered as a reaction to the user pressing a key, or as a reaction on a marked event related to the movie - or as a reaction to any event generated by a BD-J Application.

- Authenticated applications can use a (signed) permission request file to acquire permissions that go beyond the BD-J sandbox. Permissions can be acquired for:
    - Reading and writing to local and system storage
    - Using the network connection (to connect to defined servers)
    - Access of the file system on the BD-ROM disc
    - Title selection of other titles on the BD-ROM disc

    - Control of other running BD-J applications

- BD-J applications can use the java.net package to connect to servers on the Internet. The physical connection might differ between implementations e.g. Ethernet, telephone line, etc. At the network level, TCP/IP is supported and the HTTP protocol may be used. Moreover, the Java package for secure connections is included (JSSE) as part of the BD-J platform. Before a BD-J application can use the network connection, it must be authenticated and have suitable permission to use the network.

- The web sites to which the application will go are under full control of the Content Provider. This control is guaranteed in two ways:
    - Only (disc) authenticated BD-J applications are allowed to run when the disc is played. The application controls the use of the network connection.
    - In addition, permissions defined on the disc can restrict the use of the (TCP/IP) network connection to certain sites.

- BD-J will include support for storage. Two flavors of storage are included – mandatory System Storage and optional Local Storage. All storage is accessed using methods from the Java IO package. The path for local storage is as specified by [GEM].

- System storage is storage that will be present in all BD-J players. The required minimum size of this system storage will permit storage of application data like settings, high-scores etc. It will not be big enough to store downloaded AV material. For this purpose, optional local storage is available. Typically system storage will be implemented using Flash memory and the optional local storage will be implemented on a HDD.

- Since storage is a shared resource between all discs played on the player, Java access control is part of BD-J. BD-J applications can only access a disc specific part of the storage space and cannot access the part belonging to other discs.

Content development

Content authors have a variety of development strategies available, including the use of traditional Integrated Development Environments (IDE's) like NetBeans or Eclipse, non-programming graphical environments similar to Macromedia Director, or via rendering engines which consume standard data formats such as HTML, XML, or SVG. Having a full programming environment available on every Blu-ray Disc player provides developers with a platform for creating content types not bound by the restrictions of standard DVD. In addition to the standard BD-J APIs, developers may make use of existing Java libraries and application frameworks, assuming they do not use features outside the constraints of the BD-J platform, include that Java ME only supports Java version 1.3 class files.

A set of freely-available tools that allow Java developers to produce complete disc images incorporating BD-J is available from the HD Cookbook Project. In order to test content in a typical development environment (MS Windows), one needs either a Playstation 3 or a third-party software player for Windows, paying attention to player versions to ensure that the player supports BD-J.

Because of the many different standards and components involved, creating unified documentation on BD-J has proven to be a challenge.

BD-J Sample Code

The BD-J environment is designed to run Xlets with non-javax.* packages available to take advantage of the features particular to this platform beyond that defined by Java TV.

Even a simple example such as FirstBDJApp.

A developer might choose to use not javax.* packages and instead use:

1. HAVi classes in package tree org.havi.*: alternative classes to obtain, for example, an org.havi.ui.HScene far beyond what is provided by javax.tv.graphics.TVContainer (they are both extensions of java.awt.Container)
2. Digital Video Broadcasting (DVB) classes in package tree org.dvb.*: alternative classes to, for example, the org.dvb.event.UserEventListener interface rather than java.awt.event.KeyListener for support for key presses and keycodes specific to popular CDC devices.
3. Blu-ray Disc classes in the package tree org.bluray.*: the DAVIC and DVB classes depend upon to recognize additional events peculiar to the BD-J platform such as popup menus and to locate media on the Blu-ray disc.
4. DAVIC API classes in package tree org.davic.*: A small set of classes wrapping or extending other network and media resources peculiar to interactive TV the HAVi, DVB and Blu-ray classes use for locators and specialized exceptions beyond the realm of JMF (such as content authorization).

A working example of a program using some features from each of the class trees would be the BdjGunBunny Xlet (a very simple version of Space Invaders using an image of a rabbit as the shooter and turtles as the targets) provided as an example in the Java ME 3.0 SDK.

```
import javax.tv.xlet.XletContext;

import org.havi.ui.HScene;
import org.havi.ui.HSceneFactory;

import java.awt.Container;
import javax.tv.graphics.TVContainer;

// Getting a container for the screen could be
```

```
public void initXlet(XletContext context) {

//Java TV API to be compatible with Java TV
TVContainer scene = TVContainer.getRootContainer(context);

// Or for BD-J, to utilize HAVi features not available in Java TV
HScene scene = HSceneFactory.getInstance().getDefaultHScene();

// Or perhaps more generally...
Container container = null;
boolean realBDJ = true;
if(realBDJ)
        container = HSceneFactory.getInstance().getDefaultHScene();
else
        container = TVContainer.getRootContainer(context);
...

}
```

and the same for the other non-javax.* packages. Likewise, when trying to play a video, one might call the Blu-ray and DAVIC utility rather than using generic JMF:

```
import javax.media.Player;
import org.bluray.net.BDLocator;
import org.davic.media.MediaLocator;

   MediaLocator stars = new MediaLocator(new
BDLocator("bd://0.PLAYLIST:00003"));
   Player player = Manager.createPlayer(stars);

// rather than traditional and portable but more limited pure JMF

import java.net.URL;
import javax.media.Manager;
import javax.media.Player;

    Player mediaPlayer = Manager.createRealizedPlayer( new
URL("file:/mymovie.mov" ));
```

BD-J Enhanced Movie Titles

In alphabetical order, here are some titles that already use the features that the BD-J platform offers:

- 21 (Blackjack Game)
- 3:10 To Yuma (Complete BD-J enhanced interactive menu)
- Batman Begins ("In-Movie Experience" picture in picture commentary [Profile 1.1])
- Behind Enemy Lines (enhanced menu)
- The Beyoncé Experience Live! (Complete BD-J enhanced interactive menu)
- Big Fish (enhanced menu)
- Cars (Enhanced menus, CarFinder In-movie game)

- Chicken Little (Game, filmmaker Q&A)
- Crank (enhanced menu, Interactive PiP video commentary)
- The Day After Tomorrow (Also D-BOX Enhanced, "Global Warming Interactive Trivia" game and "Global Warming Trivia Track.")
- The Descent(PiP video commentary, enhanced menus)
- Doctor Strange (enhanced menu)
- Dragon's Lair (Game, Authored entirely in BD-J, PiP Video Commentary)
- Fantastic Four: Rise of the Silver Surfer (Also D-BOX Enhanced, Games - "Who Dares Defy Galactus?" and "The World's Greatest Comic Magazine.")
- Ghost in the Shell (Anime - in-movie menu)
- Good Luck Chuck (Complete BD-J enhanced interactive menu)
- Guardian (Filmmaker Q & A)
- League of Extraordinary Gentlemen (enhanced menu, game)
- Mad Men: Season One (enhanced menus, bookmarking, on-screen AV controls)
- Mamma Mia! The Movie (PiP Behind the scenes & Behind the Songs)
- Men in Black (trivia game, BD-Live information and features)
- The Patriot (in-movie menu)
- Pirates of the Caribbean: Curse of the Black Pearl (enhanced menu, Interactive in-movie feature)
- Pirates of the Caribbean: Dead Man's Chest (Game)
- Pirates of the Caribbean: At World's End (enhanced menu)
- Ratatouille (enhanced menus, game, Behind the scene PiP)
- Space Ace (Game, Authored entirely in BD-J, PiP Video Commentary)
- Speed (enhanced menu, game)
- Spider-man (enhanced menus)
- Spider-Man 3 (enhanced menus)
- Sunshine (PiP, A Brilliant Vision, D-BOX Motion Feedback Track)
- Surf's Up
- Transformers (enhanced menu, first disc of two)
- True Blood: Season Two (enhanced menu, Live Feed connects Facebook & Twitter)
- Ultimate Avengers (enhanced menu)
- National Lampoon's Van Wilder (enhanced menu, Interactive Games, Commentary)
- Waiting... Unrated & Raw (enhanced menu, In-Movie remote, Interactive PiP video commentary)
- Walk Hard: The Dewey Cox Story (enchanced menu)
- V for Vendetta ("In-Movie Experience" picture in picture commentary [Profile 1.1])
- War (Complete BD-J enhanced interactive menu, Bookmarks, Blu-line Slider, Interactive PiP video commentary, Trivia mode, Yakuza Fighter Game)
- Weeds: Season One (enhanced menu, two discs)
- Weeds: Season Two (enhanced menu, two discs, trivia tracks on all episodes, "Test Your Short-Term Memory" game)

BD-J Upcoming Titles

The Pink Panther 2, Pirates, Digital Playground Adult Film (enhanced menu, bookmarking, bd-live access)

Chapter- 5

BD+

BD+ is a component of the Blu-ray Disc Digital Rights Management system. It was developed by Cryptography Research Inc. and is based on their Self-Protecting Digital Content concept. Its intent was to prevent unauthorized copies of Blu-ray discs and the playback of Blu-ray media using unauthorized devices.

While BD+ has not stemmed the flow of 'cracked' high definition content, it has made it necessary for those who wish to copy Blu-Ray movies to reinvest resources to break each new version of security code.

BD+ played a pivotal role in the format war of Blu-ray and HD DVD. Several studios cited Blu-ray Disc's adoption of the BD+ anti-copying system as the reason they supported Blu-ray Disc over HD DVD. The copy protection scheme was to take "10 years" to crack, according to Richard Doherty, an analyst with Envisioneering Group.

On 19 November 2007, Macrovision announced that it planned to acquire the SPDC technology (including patents and software code) from CRI for US$45 million in cash plus stock warrants. As of 19 March 2008, SlySoft, makers of media software circumvented the first iteration of BD+. Blu-Ray titles starting with Jumper were introduced with slightly changed BD+ protection. However, in a short time it was also circumvented. A third iteration of BD+ was released in November 2008 and was announced to be cracked by Slysoft with the release of AnyDVD HD 6.5.0.2 on 29 December 2008. A fourth version of BD+ security code was discovered with the movie Australia on 13 February 2009, thwarting the effectiveness of Slysoft's software. On 19 March 2009, AnyDVD HD 6.5.3.1 was released, adding support for some titles with the new BD+ iteration of security code including titles such as Australia.

Capabilities

BD+ is effectively a virtual machine embedded in authorized players. It allows content providers to include executable programs on Blu-ray Discs. Such programs can:

- examine the host environment, to see if the player has been tampered with. Every licensed playback device manufacturer must provide the BD+ licensing authority with memory footprints that identify their devices.
- verify that the player's keys have not been changed.

- execute native code, possibly to patch an otherwise insecure system.
- transform the audio and video output. Parts of the content will not be viewable without letting the BD+-program repair it.

If a playback device manufacturer finds that its devices have been hacked, it can potentially release BD+-code that detects and circumvents the vulnerability. These programs can then be included in all new disc releases.

The specifications of the BD+ virtual machine are only officially available to licensed device manufacturers. A list of licensed adopters is available from the BD+ website. Both SlySoft and members of the Doom9 forum have reverse engineered the virtual machine specification, however.

According to the reverse-engineered specification, the virtual machine consists of a 32-bit big endian DLX like processor with 4MB of RAM. It has 32 32-bit registers available for use. A TRAP instruction is used to allow the virtual machine host to perform more complex actions as system calls.

To prevent simple, static disassembly of the BD+ code, an instruction filter is available that can perform an XOR operation on an opcode before executing it. By varying the instruction filter at runtime, the compiler can force an adversary to trace through the code at runtime before they can fully disassemble it.

Virtual machine

This program which can be found inside the BDSVM directory of a BD+ protected disc is called content code. The content code is executed on a virtual big endian DLX-like processor interfacing 4MB of memory. The processor supports 59 different instructions and a register set consisting of 32 general purpose registers and three special purpose registers for the instruction filter, the clock cycle counter and the program counter. The BD+ Virtual Machine applies memory protection by masking memory access addresses to prevent them from falling outside of the designated memory areas. The execution of content code starts at address 0x1000 relative to the beginning of the payload of the first block of the file 00001.svm (located inside the BDSVM directory).

Traps

While the BD+ virtual machine is extremely simple, the interface between the virtual machine and the player is somewhat more complicated. BD+ provides the content code with 25 system calls or "traps". An overview is given in the table below. Note that the bits 00-07 of the trap id uniquely identify each trap within a group. The group id itself is specified by the bits 08-16 of the trap id. The group ids seen so far are 00 (event handling), 01 (cryptography operations), 02 (arithmetic operations), 03 (memory operations), 04 (slot memory access), 05 (device access) and 80 (debugging).

Group ID	Trap ID	Name	Parameters
00	000010	TRAP_Finished	0
	000020	TRAP_FixUpTableSend	2
01	000110	TRAP_Aes	5
	000120	TRAP_PrivateKey	5
	000130	TRAP_Random	2
02	000140	TRAP_Sha1	4
	000210	TRAP_AddWithCarry	3
	000220	TRAP_MultiplyWithCarry	4
03	000230	TRAP_XorBlock	3
	000310	TRAP_Memmove	3
	000320	TRAP_MemSearch	5
	000330	TRAP_Memset	3
04	000410	TRAP_SlotAttach	2
	000420	TRAP_SlotRead	2
	000430	TRAP_SlotWrite	1
05	000510	TRAP_ApplicationLayer	3
	000520	TRAP_Discovery	4
	000530	TRAP_DiscoveryRAM	3
	000540	TRAP_LoadContentCode	5
	000550	TRAP_MediaCheck	6
	000560	TRAP_RunNative	4
	000570	TRAP_???	0
80	008010	TRAP_DebugLog	2
	008020	TRAP_???	?
	008030	TRAP_???	?

Each of these system calls can be invoked by the TRAP instruction (opcode 0x39). By convention register 29 is used as the stack pointer holding the memory address of the parameters. After parameter validation the system call is executed and a return code is written to register 1. During its execution the content code performs a series of tests to verify it is being executed in a trusted environment. One of these tests involves asking the player for its certificate with `TRAP_Discovery`. The RSA signature of this certificate is later verified by the content code using the public key of the license administration which is (optionally in obfuscated form) also stored in the content code. Later the player is asked to sign a random message with ECDSA by calling `TRAP_PrivateKey`. The generated signature is subsequently verified using the player's public key stored in the previously verified certificate.

Events

The BD+ virtual machine is event-driven. Five callbacks (events) are defined by the interface which the player may invoke to notify the content code of a variety of events, including the playback of various parts of the movie, shutdown, media eject events, or player security operations. The event data is exchanged using a dedicated memory area (0x00-0x3F). `TRAP_Finished` is invoked whenever the content code has finished processing an event. The first event invoked is `EVENT_Startup` which starts the execution of the content code.

Group ID	Event ID	Name	Parameters
00	000000	EVENT_Startup	1
	000010	EVENT_Shutdown	1
01	000110	EVENT_PlaybackFile	2
02	000210	EVENT_???	2
	000220	EVENT_PlaybackSegment	3

Conversion table

Before a BD+-capable disc is mastered, random sections of the .m2ts files are overwritten by random data, effectively corrupting parts of the content. The original data is stored encrypted and obfuscated within the BD+ content code. After the content code has verified the security of the execution environment, it sends a table with repair instructions (the "conversion table" or "fix-up table") to the player using the system call `TRAP_FixUpTableSend`. The conversion table consists of one subtable for each .m2ts file on the disc. A subtable consists of multiple, possibly empty, segments which contain the repair descriptors. Each repair descriptor then provides the raw data and the offset needed to repair a small section of a .m2ts file, replacing the corrupted part of the file with the original data.

Reverse engineering and emulation of BD+ implementations

On November 8, 2007, SlySoft announced that BD+ discs can be copied with their AnyDVD HD software. This was possible because first generation BD+ titles didn't check if AACS was present. This allowed a user to copy a BD to the harddrive and play it back from there using only a specific version of Cyberlink's PowerDVD (3319a), but not to transcode, otherwise manipulate the content or play it back from a burned BD-R or BD-RE. Updated versions of BD+ security code plugged this hole.

On January 9, 2008, engadgethd.com reported that Fox has stated that BD+ has yet to be compromised. When asked how many hi-def 20th Century Fox titles had become available online, the rep reported that the titles were available as HD DVDs in Europe.

On March 3, 2008, SlySoft updated AnyDVD HD allowing the full decryption of BD+, allowing for not only the viewing of the film itself but also playing and copying disks with third-party software.

On March 19, 2008, a new version of AnyDVD HD was released (6.4.0.0) that supports the full removing of the BD+ copy protection for all titles released to date.

In May 2008 the Blu-Ray release of Jumper introduced a modified version of BD+ security code which prevented the Slysoft AnyDVD HD software from removing BD+. This modified version was again circumvented by Slysoft several months after Jumper hit the streets.

In August 2008, members of the Doom9 forum began work on an independent project to create an open-source implementation of BD+.

In late October 2008, the same Doom9 members made the first working repaired BD+ movie with the previously developed open source tools and as of November 1, 2008, have created code to debug content produced for BD+'s virtual machine.

On November 2, 2008, Doom9 forums announced that early (pre-May 2008) BD+ discs can be played back using open source software only.

In early November 2008 multiple versions of BD+ security code were released which, according to Slysoft, may take a few months to circumvent.

On December 29, 2008 Slysoft announced that AnyDVD HD 6.5.0.2 decrypts copy protection on all current Blu-ray movies.

On February 13, 2009 a 4th version of BD+ security code was discovered on the movie Australia, rendering Slysoft's existing AnyDVD HD software ineffective.

On March 19, 2009 Slysoft announced that AnyDVD HD 6.5.3.1 adds support for some new BD+ protection in movies, e.g. Australia, The Robe, South Pacific. Some BD+ movies were not supported by Slysoft's update, e.g. Slumdog Millionaire, The Day the Earth Stood Still, Marley & Me, X-men Trilogy. Since then, Slysoft has released several updates adding support for newer titles.

Chapter- 6

AVCHD

AVCHD (**A**dvanced **V**ideo **C**oding **H**igh **D**efinition) is a format for the recording and playback of high definition video.

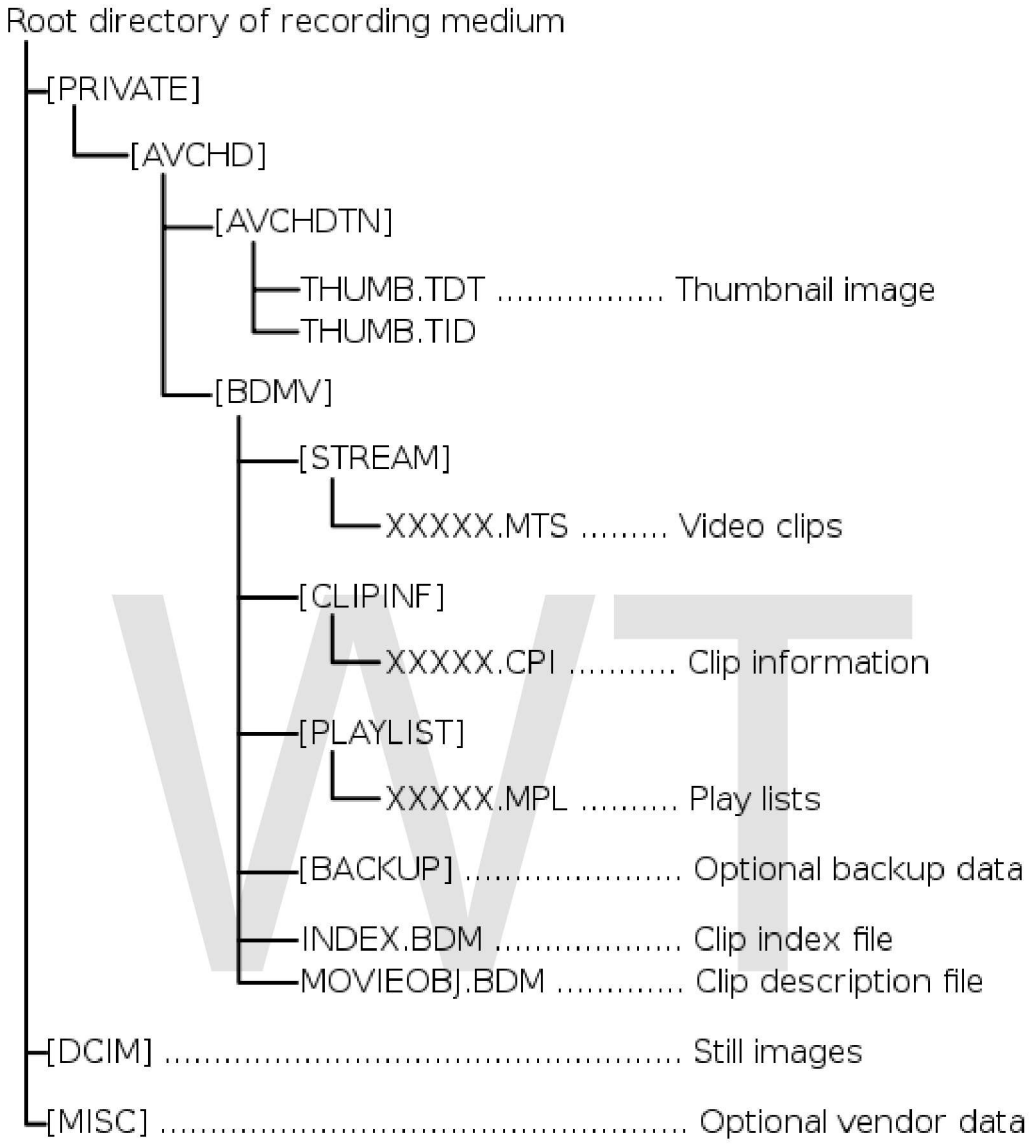
Developed jointly by Sony and Panasonic, the format was announced in 2006 primarily for use in high definition consumer camcorders. AVCHD is a file-based format and does not use magnetic tape. Instead, video can be recorded onto DVD discs, hard disk drives, non-removable solid-state memory and removable flash memory such as Secure Digital and Memory Stick cards.

Sony and Panasonic released the first AVCHD camcorders in autumn of 2006, followed by Canon and JVC. Favorable comparisons of AVCHD against HDV and XDCAM EX solidified perception of AVCHD as a format acceptable for professional usage. As the standard matured, Panasonic released the first professional AVCHD camcorder in autumn of 2008, followed by Sony in the first quarter of 2010.

AVCHD has been designed to be compatible with Blu-ray Disc format and can be authored without re-encoding on Blu-ray or DVD discs, though not all Blu-ray Disc players are compatible with AVCHD video authored on DVD media, a format known as *AVCHD disc*.

AVCHD and its logo are trademarks of Panasonic corporation and Sony corporation.

Overview



File organization on Panasonic and Canon solid-state AVCHD camcorders

AVCHD utilizes MPEG-4 AVC/H.264 (AVC) video coding and either Dolby AC-3 (Dolby Digital) or uncompressed linear PCM audio coding. Uncompressed audio is not supported in existing consumer devices, but is offered in several professional models.

Aside from recorded audio and video, AVCHD includes features to improve media presentation: menu navigation, slide shows and subtitles. The menu navigation system is similar to DVD-video, allowing access to individual videos from a common intro screen. Slide shows are prepared from a sequence of AVC still frames and can be accompanied by a background audio track. Subtitles are used in some camcorders to timestamp the recordings.

Audio, video, subtitle and ancillary streams are multiplexed into an MPEG transport stream and stored on media as binary files. Usually, memory cards and HDDs use the FAT32 file system, while optical discs employ UDF or ISO9660.

At the file system level, the structure of AVCHD is derived from the Blu-ray Disc specification, but is not identical to it. In particular, known Canon and Panasonic implementations use legacy "8.3" file naming convention, while Blu-ray Discs utilize long filenames. Another difference is location of the BDMV directory, which contains media files (BDMV: *B*lu-ray *D*isc *Mo*v*i*e). On a DVD-based camcorder the BDMV directory is placed at the root level, as on the Blu-ray Disc. On the HDD-based Canon HG10 camcorder the BDMV directory is located in the AVCHD directory, which is placed at the root level. Solid-state Panasonic and Canon camcorders nest the AVCHD directory inside the PRIVATE directory. Following a standard agreed upon by many still camera manufacturers, solid-state camcorders have a root-level DCIM directory for still images.

AVCHD recordings can be transferred to a computer by connecting the camcorder via the USB connection. Removable media like SDHC and Memory Stick cards or DVD discs can be read on a computer directly. Copying files from an AVCHD camcorder or from removable media can be performed faster than from a tape-based camcorder, because the transfer speed is not limited by realtime playback.

Just as editing DVCPRO HD and HDV video once demanded an expensive high-end computer, AVCHD editing software requires powerful machines. Compared to HDV, AVCHD requires 2-4x the processing power for realtime playback, placing a greater burden on the computer's CPU and graphics card. Improvements in multi-core computing and graphics processor acceleration bring AVCHD playback to mainstream desktops and laptops.

Media

AVCHD specification allows using recordable DVD discs, memory cards, non-removable solid-state memory and hard disk drives as recording media. AVCHD camcorders are file-based and do not use magnetic tape.

DVD disc

Conventional 12 cm disc (left) compared to 8 cm disc (right)

When AVCHD standard was first announced, recordable DVD disc was the only recording medium. To reduce camcorder size, manufacturers opted for a 8 cm disc, sometimes called miniDVD. Recording capacity of a 8 cm disc ranges from 1.4 GB for a single-sided single layer disc to 5.2 GB for a double-sided double layer disc.

Pros:

- DVDs are familiar to most consumers, thus considered user-friendly.
- Recordable DVDs are relatively cheap.
- Recorded disc can be played back in most Blu-ray Disc players.
- Discs can be used for long-term storage of recorded video.

Cons:

- The longevity of recordable DVDs is argued to be much shorter than expected.
- Rewritable DVDs cost more than write-once discs.
- DVDs have to be "finalized" to be played back on set-top players.
- Double-layer recording is less robust than single-layer recording.
- To use both sides of a double-sided disc it must be flipped over, because camcorders have pickup from one side only.
- AVCHD DVDs cannot be played back on regular DVD players.

- The AVCHD specification limits data rate for DVD-based AVCHD camcorders to 18 Mbit/s, but no DVD-based AVCHD camcorder manufactured to date is capable of recording at data rate higher than 12 Mbit/s (Canon, Sony) or 13 Mbit/s (Panasonic).
- A single-sided single-layer 8 cm DVD can fit only 15 minutes of video at 12 Mbit/s, 14 minutes at 13 Mbit/s.
- DVD pickup mechanism is very susceptible to vibration.
- 8 cm DVDs cannot be used in many slot-loading drives and may even damage the drive.
- The capacity of DVD discs has reached its limit.

As capacity of memory cards grew while their price dropped, 8 cm DVD discs quickly fell out of favor. No DVD-based AVCHD camcorders have been produced since 2008.

While DVD discs are no longer used for acquisition, the conventional 12 cm discs are becoming popular as distribution media for playback on Blu-ray Disc players. Many authoring programs offer "AVCHD" profile for recording high definition video on a DVD disc in format compatible with most Blu-ray Disc players.

Hard disk drive

Canon HG10 HDD-based AVCHD camcorder

A hard disk drive was added as an optional recording medium to AVCHD specification shortly after the new video standard had been announced. Presently, capacity of HDDs ranges from 30 GB to 240 GB.

Pros:

- Higher capacity than other media types, which allows for longer continuous recording.

Cons:

- Sensitive to atmospheric pressure. Most HDD-based camcorders cannot be operated at altitudes above 10,000 feet (3,000 m).
- Vulnerable to mechanical shock or fast movement.
- All HDD-based AVCHD camcorders employ non-removable disks. To transfer video to a computer the camcorder must be connected with a USB cable. Most camcorders require using an AC power adapter for this operation.
- The sound of moving magnetic heads may be heard in the recorded video when recording in quiet environment.
- Replacing a damaged HDD requires disassembling a camcorder and cannot be done by a consumer.

Solid-state memory card

Canon HF100 camcorder with a partially inserted Secure Digital card

Many tapeless camcorders record to memory cards, such as SD/SDHC cards or "Memory Stick" cards. Solid-state memory cards offer rewritable storage in a compact form factor with no moving parts. With transfer speeds ranging from 10 MByte/s to 20 Mbyte/s, it takes about 1 minute to transfer 1 GB of video.

Historically, flash memory capacity and pricing have improved steadily since introduction to the consumer market.

Panasonic and Sony chose removable flash memory as recording media in their professional AVCHD lineups, AVCCAM and NXCAM respectively.

Pros:

- Compact and lightweight.
- Does not require time for spin-up and initialization.
- Not vulnerable to magnetic fields.
- Can withstand a wider range of air pressure, humidity and vibration than HDDs.
- Can be easily backed up to DVD for viewing and for long-term archiving.
- Can store mixed media content, including still images like snapshot photos and still-frame captures.
- The recording section contains no moving parts, thus operation is almost silent; also a camera can be made more compact and less prone to mechanical damage in case of being dropped.
- Most new computers, some TVs and Blu-ray Disc players, as well as many personal portable media players have built-in card readers and can play AVCHD video directly from a card.

Cons:

- More expensive per minute of recording than a built-in HDD or DVD media.
- Cards may wear out more rapidly than expected.[dead link]
- Not reliable for long term storage, especially the cards made with MLC technology, because of narrower acceptable level of discharge compared to SLC cards.
- Vulnerable to electrical damage, such as static discharge.
- A bad memory card can cause data corruption, causing loss of one or more clips.
- Loss of data can occur if a card is removed or power is turned off while the card is being recorded to.
- Older card readers designed for MMC and SD cards may not read high capacity cards.
- Easy to misplace due to small form factor.

Non-removable solid-state memory

Some AVCHD camcorders come with built-in solid-state memory either as a sole media, or in addition to other media.

Pros:

- Allows making a camcorder smaller if no other media is used
- Always available for recording, in case other type of media is full or missing

Cons:

- Because recording media is non-removable, a camcorder must be connected to a computer with a USB cable to transfer video. Usage of an AC power adapter is often needed as well.
- Non-removable media cannot be shared, sent or stored separately of the camcorder.
- If damaged or worn out, non-removable media cannot be replaced like a memory card.

Video formats

AVCHD specification allows for both high definition and standard definition recording. For high definition, all major variations are supported, including 720p, 1080i and 1080p.

Standard definition recording

No camcorder released to date uses AVCHD for recording of standard definition video. Sony camcorders that offer standard definition recording use the MPEG-2 compression in a format that is compatible with the DVD-Video specification. Some consumer Panasonic models record standard definition video using the MJPEG format storing it in a QuickTime container, while the professional AG-HMC80 camcorder records standard definition video in a proven DV format.

720p

The AVCHD specification supports 720-line progressive recording mode at frame rates of 24 and 60 frames/s for 60 Hz models and 50 frames/s for 50 Hz models. Compared to HDV 720p, AVCHD uses higher data rate (up to 24 Mbit/s VBR vs. 18.3 Mbit/s CBR) and a more advanced compression format (AVC vs. MPEG-2).

Many of digital compact cameras made by Panasonic, such as the DMC-ZS3/DMC-TZ7, DMC-FT1, DMC-FZ35/DMC-FZ38 and DMC-ZS-7/TZ-10 offer 720p video recording with effective frame rate of 25 or 30 frames/s in a format called *AVCHD Lite* (see below).

In the professional market, the AG-HMC150 and AG-HMC40 were the first AVCHD models to offer 720p recording in addition to 1080i and 1080p. They have been joined with the NXCAM models from Sony.

1080i

An example of interlace combing

All AVCHD camcorders except for AVCHD Lite models are capable of recording 1080i interlaced video. For some models this is the only recording mode offered. Early models captured anamorphic video with horizontal resolution reduced to 1440 pixels. Newer models offer higher data rate and full 1920x1080 resolution, while in some cases keeping the anamorphic format for use with lower recording data rates.

Interlaced video had been originally designed for watching on a cathode-ray tube television set. Material recorded for interlaced presentation may exhibit combing or ghosting when it is rescaled, filmed out or watched on a computer or another progressive-scan device without proper deinterlacing.

All modern flat-panel television sets have a built-in deinterlacing engine to cope with interlaced video. When watching interlaced video on a computer some software video players blend two fields of each interlaced frame together, causing combing; when such video is scaled down it may exhibit ghosting instead of combing. Better codecs and media players either use content-adaptive algorithms or allow choosing a deinterlacing scheme manually. Video hosting websites like YouTube use progressive scanning for streaming videos and automatically deinterlace interlaced videos. Automatic deinterlacing does not always produces the best possible quality, thus YouTube suggests its users deinterlace their videos prior to uploading.

Some 1080i AVCHD camcorders can capture progressive video and record it within an interlaced stream, borrowing techniques from television industry. In particular, Progressive segmented frame (PsF) is utilized in some Panasonic (25p Digital Cinema), Canon (PF25, PF30) and Sony camcorders. The 2:3 pulldown technique is used in some 60 Hz versions of Canon (PF24) and Panasonic (24p Digital Cinema) camcorders and in the Panasonic GH1 hybrid digital still/video camera for recording 24-frame progressive video. Most editing tools treat progressive video recorded within an interlaced stream as interlaced, though some editing systems and most standalone Blu-ray Disc players are capable of recognizing the pulldown pattern to recover the original frames using the process known as inverse telecine.

1080p

Native Progressive logo (Canon)

In the professional and prosumer markets, AVCHD camcorders such as the Panasonic AG-HMC150, the Panasonic AG-HMC40, the Sony HDR-AX2000 and the Sony HXR-NX5U, are capable of recording in all three high definition formats: 1080i, 1080p and 720p. Sony camcorders do not support film-like frame rates — 24p, 25p, 30p — in 720p mode.

In the consumer market, 60 Hz versions of the Panasonic HDC-SD9/HDC-HS9, Panasonic HDC-HS100/HDC-SD100 and Canon HF S21/HF S20/HF S200 models are capable of recording native 1080p24 video. Panasonic models have no visual designation of 24p capability, whereas the Canon models have a prominent *24p Native Progressive* mark.

In 2010, Panasonic introduced a new lineup of consumer AVCHD camcorders (HDC-HS700/HDC-TM700/HDC-SD700) with 1080-line 50p/60p progressive-scan mode (frame rate depending on region). While this mode is not compliant with current AVCHD specification, it uses the same compression schemes for video and audio, packaged into the same container and stored in the same folder as AVCHD-compliant files. Panasonic advises that not all players that support AVCHD playback can play 1080-line 50p/60p video.

Branding

Panasonic and Sony developed several brand names for their professional as well as simplified versions of AVCHD.

AVCHD Lite

AVCHD Lite identifies a subset of AVCHD format, in which HD-recording is limited to 720p/30. The 720p/30 video is recorded in the AVCHD 720p/60 format by storing every other frame and using a bitstream flag to tell the playback device to play each frame twice. Announced in January 2009, the Panasonic DMC-ZS3/DMC-FT1/DMC-TZ7 digital cameras were the first digital cameras to offer AVCHD-lite movie mode. Since then, Panasonic has added AVCHD-lite to more of its digital cameras, such as the Lumix GF1 Micro Four Thirds, Panasonic Lumix DMC-G2, Lumix DMC-FZ35/38, Lumix DMC-TZ10/ZS7, Panasonic Lumix DMC-FX75, Panasonic LX5, LEICA D-LUX 5, LEICA V-LUX 2.

AVCCAM

Panasonic AG-HMC150 AVCCAM camcorder

AVCCAM is the name of Panasonic Broadcast's professional video lineup employing the AVCHD format. Before Panasonic adopted this name, it used to describe its professional AVCHD-based models as "AVCHD with professional features".

There are no major differences in video stream encoding or in the file structure between AVCCAM and AVCHD. Professional features of AVCCAM, outlined by Panasonic in its marketing materials, such as 1/4-inch progressive CCD sensors or XLR microphone inputs or solid-state media, are not unique to AVCCAM. Many of these professional features are not unique to AVCHD either. Some features are being lost in newer models, for example, the AG-HMC40 uses 3MOS imaging system instead of 3CCD.

All AVCCAM camcorders record to Secure Digital memory cards. Newer members of AVCCAM lineup like the AG-HMC150 and the AG-HMC40 have recording bitrate to 24 Mbit/s, while consumer Panasonic models are limited to 17 Mbit/s. Other vendors such as Canon, JVC and Sony offer 24 Mbit/s in their consumer camcorders.

NXCAM

NXCAM is the name of Sony's professional video lineup employing the AVCHD format. NXCAM offers 1080i, 1080p and 720p recording modes with data rate up to 24 Mbit/s. Unlike other variants of AVCHD available on the market, NXCAM offers uncompressed

PCM audio recording. Unlike AVCCAM, NXCAM does not offer film-like frame rates — 24p, 25p, 30p — in 720p mode.

NXCAM camcorders, as well as consumer Sony AVCHD camcorders unveiled in 2010, record onto widespread SDHC cards as well as onto Memory Stick Pro Duo/Pro HG Duo cards.

Playing back AVCHD video

Recorded AVCHD video can be played back in a variety of ways:

- Directly from a camcorder on an HD television set, through HDMI or component-video cable.
- Burned onto DVD disc in AVCHD format, then played on most Blu-ray Disc players or on a Playstation 3 gaming console.
- Recorded on an SDHC in AVCHD format, then played on select Blu-ray Disc players and HDTV sets and on a Playstation 3 gaming console.
- On a computer, played from the camcorder connected via USB as an external storage device, or from removable media or from the computer's internal hard disk drive. Presently, the default media players from Apple (QuickTime) will not play AVCHD natively, additional (free) software is required. Windows 7 is able to import and play AVCHD video natively, having files with extensions M2TS, MTS and M2T pre-registered in the system. Windows Media Player is able to index content of these files, while Windows Explorer is able to create thumbnails for each clip. Windows 7 does not support importing of AVCHD video metadata such as thumbnail images, playlists and clip index files. Joining AVCHD video files during the import is not supported either.

Compatibility within brands

There is incompatibility within the Panasonic brand. Panasonic's latest version of the HDwriter (HD Writer AE) will not recognise AVCHD video from camcorders released before 2009 (such as the HDC-SD1/5/7/9 series).

AVCHD as distribution format

AVCHD has been designed to be compatible with Blu-ray Disc format and can be used for distribution of high definition video, albeit with reduced quality and interactivity compared to Blu-ray Disc.

Authored *AVCHD discs* use DVD media, simple menus, AVC encoding and limit data rate to 18 Mbit/s. A conventional single-layer 12 cm DVD disc can store approximately half an hour of video recorded at this rate.

AVCHD content can also be mastered on SDHC cards and played by certain Panasonic and JVC television sets and Blu-ray Disc players. Data rate on memory cards is limited to 24 Mbit/s.

Blu-ray Disc media is not supported by AVCHD specification, though some software packages allow authoring AVCHD content on Blu-ray Discs. AVCHD encoding and container are compatible with Blu-ray Disc format, but naming convention is different. For better compatibility with Blu-ray Disc players, AVCHD video can be converted into Blu-ray Disc format without re-encoding audio/video streams. The resultant disc will play in any Blu-ray Disc player including those that do not explicitly support the AVCHD format.

Many software vendors support AVCHD mastering. In particular:

- Nero Vision 9 can create an AVCHD disc with data rate up to 18 Mbit/s, or an AVCHD-compliant folder for distribution on an HDD or a memory card with data rate up to 24 Mbit/s.
- Cyberlink PowerProducer can author a compliant AVCHD disc, or BDMV on DVD media.
- Ulead DVD MovieFactory Plus 6 with HD Power Pack can master AVCHD discs with menus.
- Various Sonic products can author AVCHD discs using HD/BD Plug-in.
- Compressor 3.5 is capable of authoring AVCHD discs; subtitles are not supported.
- Sony DVD Architect 5 can author AVCHD-compliant discs with menus using AVC encoding as well as non-standard discs using MPEG-2 encoding. In both cases data rate is limited to 18 Mbit/s.
- Panasonic HD Writer 3.0 can author AVCHD content on DVD discs, BD discs and on SD cards.
- MultiAVCHD can author AVCHD discs as well as Panasonic-compliant AVCHD memory cards.
- Magix Movie Edit Pro 15 Plus with updates can author AVCHD content on DVD discs, BD discs.

Blu-ray Disc players with "AVCHD" logo play AVCHD discs authored either on 8 cm or 12 cm DVD discs. Players without such a logo are not guaranteed to play AVCHD discs.

Compatibility with Blu-ray Disc players

Although AVCHD shares many format similarities with Blu-ray Disc, it is not part of the Blu-Ray specification. Consequently, AVCHD-playback is not universally supported across all Blu-ray Disc players. In addition, non-standard developments such as 1080-line 50p/60p recording mode employed in some Panasonic camcorders, are neither AVCHD- nor Blu-ray compliant.

As the creators of AVCHD, Sony and Panasonic support AVCHD playback in their Blu-ray Disc players. In particular, the Sony BDP-S1, Sony BDP-S300, Sony BD507, the Panasonic DMP-BD10, the Panasonic DMP-BD30K, the Panasonic DMP-BD35, the Panasonic DMP-BD60K, the Panasonic DMP-BD80K and the Playstation 3 can play AVCHD discs. In addition, some Panasonic and JVC Blu-ray Disc players (e.g. Panasonic DMP-BD60K, Panasonic DMP-BD80K) support AVCHD playback from SDHC memory cards.

In one instance, AVCHD playback was removed from a Blu-ray Disc player already on the market, the Samsung BD-P1200. Firmware update 2.3 removed AVCHD support from the BD-P1200.

Blu-ray Disc players known to play AVCHD discs

Make and model	Media	FullHD	Comment
Oppo BDP-83	Recordable DVD, USB	No info	Supports AVCHD playback from a USB device; also supports the main menu.
Oppo BDP-93	Recordable DVD, USB	Yes	Supports AVCHD playback including FullHD videos (firmware revision 1108).
Panasonic DMP-BD60/BD80	Recordable DVD, SD card	Partial	FullHD video plays with hiccups from a DVD-R disc, plays normally from an SD card.
Panasonic DMP-BD85/BD65/BD45	Recordable DVD, SD card	No info	
Pioneer BDP-51FD	Recordable DVD	Partial	DVDs recorded in the AVCHD format can be played. FullHD video plays with hiccups.
Pioneer BDP-320	Recordable DVD	Yes	DVDs recorded in the AVCHD format can be played. FullHD videos can be played (firmware revision 3.69a).
Samsung BD-P1400	Recordable DVD	No info	Supports playback of AVCHD discs as of firmware release 1.6.
Seiki BD660	Recordable DVD	Yes	Plays AVCHD discs including FullHD (firmware release BDP V4.2 F6).
Toshiba BDX2000	Recordable DVD, SD card	No info	Supports playback of AVCHD format files recorded on disc or SD card

Hardware products

Canon

Canon AVCHD camcorders offer 1080-line recording at bitrates up to 24 Mbit/s in native interlaced, progressive-scan and native progressive formats depending on model.

- HR10 (DVD)
- 2007: HG10 (40 GB HDD)
- April 2008: HF10 (SDHC, built-in 16GB flash memory), HF100 (SDHC)
- September 2008: HF11 (SDHC, built-in 32GB flash memory), HG20 (60GB HDD, SDHC), HG21 (120GB HDD, SDHC)
- January 2009: HF S10 (SDHC, built-in 32GB flash memory), HF S100 (SDHC), HF20 (SDHC, built-in 32GB flash memory), HF200 (SDHC)
- August 2009: HF S11 (SDHC, built-in 64GB flash memory, wired LANC remote capability)
- January 2010: HF S21 (two SDHC slots, 64GB flash memory, electronic viewfinder), HF S20 (two SDHC slots, 32GB flash memory), HF S200 (two SDHC slots); HF M31 (SDHC, 32GB flash memory), HF M30 (SDHC, 8GB flash memory), HF M300 (SDHC); HF R11 (32GB flash memory), HF R10 (SDHC, 8GB flash memory), HF R100 (SDHC)

Hitachi

- 2008: DZ-BD10HA (Three-media recording: Blu-ray Disc, AVCHD on HDD, AVCHD on SDHC)

JVC

- June 2008: GZ-HD10 (HDD, MicroSDHC), GZ-HD30/GZ-HD40(HDD, MicroSDHC card, dual AVCHD and TOD recording)
- January 2009: GZ-HD320 (120 GB HDD, MicroSD), GZ-HD300 (60 GB HDD, MicroSD), GZ-HM200 (dual SDHC)
- February 2009: GZ-X900 (SD/SDHC card)
- September 2009: GZ-HM400
- December 2009: GZ-HD620
- March 2010: GZ-HM1

Leica Camera

Digital still cameras

- 2010:LEICA D-LUX 5, LEICA V-LUX 2

Panasonic

Panasonic AVCHD camcorders offer interlaced, progressive scan or native progressive recording and combinations of these modes depending on a particular model. 1080-line and 720-line recording is possible depending on a model.

Panasonic AVCHD camcorders use AVC with High Profile @ Level 4.0 for all modes except 1080p50/1080p60, which are encoded with High Profile @ Level 4.2. Maximum

data rate is limited to 24 Mbit/s for AVCCAM models, to 17 Mbit/s for most consumer models and to 28 Mbit/s for 1080p50/1080p60 recording modes.

In 2009 Panasonic introduced AVCHD Lite to selected members of its Lumix line of digital cameras.

- December 2006: HDC-DX1 (DVD), HDC-SD1 (SDHC)
- HDC-SD3 (SDHC, available in Japan only)
- AG-HSC1U (SDHC, comes with portable 40 GB HDD storage)
- August 2007: HDC-SD5 (SDHC), HDC-SX5 (DVD, SDHC), HDC-SD7 (SDHC)
- January 2008: HDC-SD9 (SDHC), HDC-HS9 (60 GB HDD, SDHC)
- April 2008: AG-HMC70 (SDHC)
- June 2008: HDC-SD100 (SDHC), HDC-HS100 (60 GB HDD, SDHC)
- September 2008: AG-HMC150 (SDHC)
- January 2009: HDC-HS300 (120 GB HDD), HDC-HS200 (80 GB HDD), HDC-TM300 (32 GB built-in flash memory, SDHC), HDC-SD300 (SDHC, available in Europe only), HDC-SD200 (SDHC).
- April 2009: DMC-TZ7(European version, limited to 30 minutes recording due to European specific taxes)/ZS3(Rest of the world) (AVCHD Lite), DMC-TS1/DMC-FT1 (AVCHD Lite)
- June 2009: DMC-GH1 (SDHC; AVCHD for 1080p24, 720p60, MJPEG for 720p30)
- June 2009: HDC-TM30/HDC-TM10 (32 GB built-in flash memory, SDHC), HDC-SD10 (SDHC)
- June 2009: HDC-TM350 (64 GB built-in flash memory, SDHC, available in Japan and as of October 2009, from Panasonic Stores across the UK)
- September 2009: AG-HMC40 (SDHC)
- January 2010: Lumix DMC-ZS7 (DMC-TZ10 outside US)
- February 2010: HDC-TM700/HDC-SD700/HDC-HS700 (introduced 1080p60/1080p50 modes, depending on region)
- March 2010: HDC-SD60/HDC-TM60/HDC-HS60
- December 2010 (announced): AG-AF100/AG-AF101/AG-AF102 (4/3" large sensor camera)

Sony

Currently, all consumer Sony AVCHD camcorders record 1080-line interlaced video only. The prosumer HDR-AX2000 and professional HXR-NX5 cameras are capable of recording in interlaced and progressive formats.

Presently Sony is the only manufacturer that offers PCM audio recording.

In 2010 Sony introduced AVCHD to selected members of its Cybershot line of digital cameras.

- September 2006: HDR-UX1 (DVD), HDR-UX3/UX5 (DVD), HDR-UX7 (DVD)

- October 2006: HDR-SR1 (30 GB HDD)
- June 2007: HDR-SR5 (40 GB HDD), HDR-SR7 (60 GB HDD)
- July 2007: HDR-SR5C (100 GB HDD), HDR-SR8 (100 GB HDD)
- Summer 2007: HDR-CX7 (Memory Stick Duo)
- March 2008: HDR-SR10 (40GB HDD, Memory Stick), HDR-SR11 (60 GB HDD, Memory Stick), HDR-SR12 (120 GB HDD, Memory Stick)
- HDR-TG1/TG3/TG7 (Memory Stick Duo)
- August 2008: HDR-CX12 (Memory Stick Duo)
- March 2009: HDR-XR520V (240 GB HDD), HDR-XR500V (120 GB HDD Version)
- March 2009: HDR-XR200V (120 GB HDD)
- March 2009: HDR-XR200VE (120 GB HDD + GPS)
- March 2009: HDR-XR100 (80 GB HDD)
- July 2009: HDR-CX500E, HDR-CX520E
- October 2009: HDR-CX105 (8GB Memory Stick Duo)
- January 2010: HXR-NX5, HDR-AX2000.
- January 2010: Sony DSC-HX5V (GPS+COMPASS), HX5V-E (European version, limited to 30 minutes recording due to European specific taxes)
- March 2010: HDR-XR550 (240 GB HDD)
- June 2010: Sony NEX-5, NEX-5C (without Eye-Fi support), of both models, variants with AVCHD 1080 50i and AVCHD 1080 60i only exist
- July 2010: Sony HXR-MC50E.

Software

Codecs

- ffdshow is a free, Open Source collection of codecs, including an AVCHD decoder.
- CoreAVC is an H.264 decoder for Windows, which can decode AVCHD as well as a variety of other H.264 formats.

Converters

- Avidemux is a free open-source program that can be used to edit or convert AVCHD and AVCHD Lite files. It is also capable of demuxing and remuxing the audio and video streams into several different container formats including AVI, MP4 and MKV. (When converting AVCHD Lite .mts files from the Panasonic Lumix DMC-ZS3, the framerate must be manually set to 29.97.)
- Badaboom is a media converter that uses NVIDIA GPUs to accelerate conversion of AVCHD to mobile devices.
- HandBrake will convert AVCHD Lite format to MP4 and MKV (tested on OSX; other versions available), AVI and OGM are supported in versions before 0.9.4.
- Roxio Toast 10 Titanium on Mac OS X will convert AVCHD to most computer formats presently available.

- Total video converter is a converter for most video formats, including converting from AVCHD and burning AVCHD disc.

Editors

The following video-editing software features support for the AVCHD format:

- Avid Media Composer (from version 5.0)supports AVCHD through as a transcoded to import. AMA linking is not currently supported.
- Adobe Premiere Pro (from version CS4 onwards; support not included in the trial version - activation must occur to gain AVCHD support).
    - Elemental Accelerator is a third party plug-in for Adobe Premiere Pro CS4 that converts AVCHD to various H.264 or MPEG-2 formats.
- Adobe Premiere Elements (from version 7 onwards)
- Apple's Final Cut Express 4, Final Cut Pro 6.0.1 and iMovie '08-'09 (iMovie is bundled with all new Apple computers; Final Cut Express and Pro are sold separately) do not support editing of AVCHD clips directly. Imported AVCHD clips are automatically converted into the Apple Intermediate Codec format, which requires more hard disk space (40GB per hour as opposed to 13.5GB per hour for Standard Definition DV), a more powerful machine (an Intel-based Mac) and a more recent OS (Mac OS X 10.5). Final Cut Pro 6.0.5 "logs and transfers" the footage from AVCHD to AppleProRes by default and also gives the option of converting to the Apple Intermediate Codec. It does not allow native transferring of the *.m2ts clips nor directly editing them. The latest release of Apple's iLife suite (specifically, iMovie) has added support for AVCHD Lite cameras and camcorders.
- AVS Video Editor supports videos from HD-cameras(HD Video (inc. AVCHD, MPEG-2 HD and WMV HD), TOD, MOD, M2TS.) Burn AVCHD video to CD-R/RW, DVD+/-R, DVD+/-RW, DVD-RAM, Double/Dual Layer on Windows XP, 2003, Vista, 7 (no Mac OS/Linux support).
- Blender supports the AVCHD format on Windows and Linux systems (using a FFmpeg decoder). Blender has a little-known, very powerful video editing system with infinite layer bit-depth and integration with the 3D editing component. BlenderAVC streamlines the process of importing the files, as it is difficult and bug-prone without AVS scripts. Blender supports proxy editing at down to 25% scaling, which helps when editing AVCHD video, which is slow.
- Corel VideoStudio supports importing, rendering and burning of AVCHD format in Windows system.
- Cyberlink PowerDirector 7 is capable of editing AVCHD natively, without transcoding, intermediate formats or proxy files. Using a patented technique (SVRT), AVCHD clips can be edited and output losslessly to AVCHD or Blu-ray Disc. PowerDirector also supports GPU encoding acceleration on both ATI and NVidia graphics platforms. PowerDirector can output the finished movie to a variety of video formats, DVD, AVCHD on DVD, or Blu-ray Disc.

- Grass Valley's Edius 5.5 and Edius Neo 2
- Microsoft's Windows Live Movie Maker
- Dayang's Montage Extreme [ME] 1.2
- Nero Ultra Edition Enhanced (from version 7 onwards) includes the Nero Vision editor and the Nero Showtime player, which both support AVCHD files. NeroVision can author DVDs in the AVCHD format.
- Pinnacle Studio Plus (from version 11 onwards)
- Sony Vegas 7.0e
- Vegas Pro (from version 8 onwards)
- Vegas Movie Studio Platinum (from version 8 onwards)
- Kdenlive for Linux and BSD platforms
- Openshot Video editor for Linux
- Final Cut Pro for Mac OS X. The latest version of Final Cut Pro 7 claims better integration with Apple's other professional applications and improved codec support for editing HD, DV and SD video formats, including encoding presets for devices such as iPod, Apple TV and Blu-ray Discs.

- Other developers have pledged their support but it may still take some time for the implementation.

Open Source codecs

The following open source codecs can decode AVCHD files:

- *ffdshow tryouts*, revision 1971 May 23, 2008, will decode AVC (H.264) format video.
- libavcodec (part of FFmpeg project) is a codec library that supports AVCHD. It is used in Jahshaka and Blender, notably.

Specifications

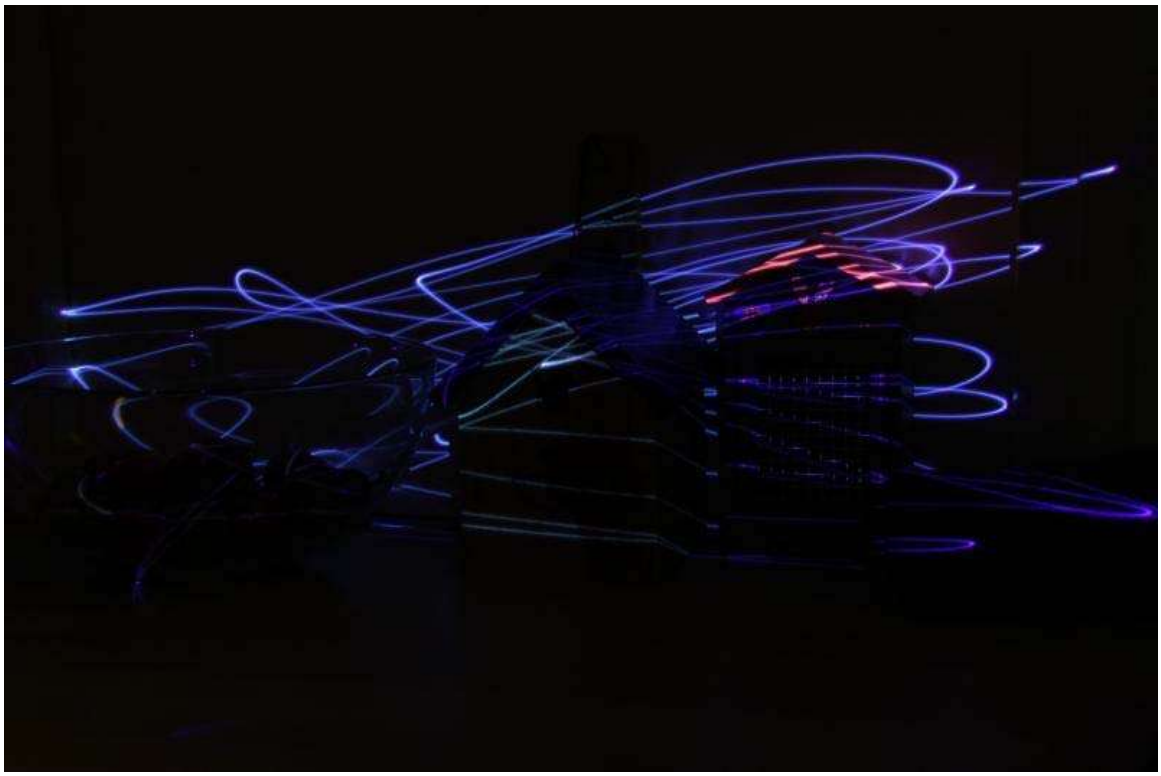
	Video			
Video signal	1080/60i 1080/50i 1080/24p	720/60p 720/50p 720/24p	480/60i	576/50i
Frame size in pixels	1920×1080 1440×1080	1280 x 720	720×480	720×576
Frame aspect ratio	16:9		4:3, 16:9	
Video Compression	MPEG-4 AVC/H.264			
Luminance sampling frequency	74.25 MHz 55.7 MHz	74.25 MHz	13.5 MHz	13.5 MHz

Chroma sampling format	4:2:0	
Quantization	8 bits (both luminance and chrominance)	
	Audio	
Compression	Dolby Digital (AC-3)	Linear PCM
Compressed audio bitstream rate	64 to 640 kbit/s	1.5 Mbit/s (2 channels)
Audio mode	1-5.1 channels	1-7.1 channels
	System	
Stream type	MPEG transport stream	
System data rate	up to 24 Mbit/s (flash and HDD media); up to 18 Mbit/s (DVD media)	
File extension (generally)	mts (on camcorder), m2ts (after import to computer)	
Media	8 cm optical media (DVD) SD/SDHC Memory Card "Memory Stick" Built-in hard-disk or flash Media	

Chapter- 7

Blue Laser and Sony BDP-S1

Blue laser



Trails of a 20mW 405nm blacklight laser show clear fluorescence on some objects

A **blue laser** is a laser which emits EM radiation at a wavelength of between 360 and 480 nanometres. The light from "blue lasers" of shorter wavelengths is sometimes violet to the human eye, a distinctly different color.

Blue lasers are frequently semiconductor laser diodes based on gallium(III) nitride (violet color) or indium gallium nitride (often true-blue in color, but able to produce other colors, as well). Both blue and violet lasers can also be constructed using frequency-doubling of infrared laser wavelengths from diode lasers or diode pumped lasers.

These new devices have applications in many areas ranging from optoelectronic data storage at high density to medical applications.

History

Inventing blue-laser technology

Red lasers can be built on gallium arsenide (GaAs) semiconductors, upon which a dozen layers of atoms are placed to form the part of the laser that generates light from quantum wells. Using methods similar to those developed for silicon, the substrate can be built free of the defects called dislocations and the atoms laid down so the distance between the ones making up the ground and those of the quantum wells are the same.

But the best semiconductor for blue lasers is gallium nitride (GaN) crystals, which are much harder to manufacture, requiring higher pressures and temperatures, similar to the ones that produce synthetic diamonds and the use of high-pressure nitrogen gas. The technical problems seemed insurmountable, so researchers since the 1960s have sought to deposit GaN on a base of readily available sapphire. But a mismatch between the structures of sapphire and gallium nitride created too many defects.

In 1992, Japanese inventor Shuji Nakamura invented the first efficient blue LED and four years later, the first blue laser. Nakamura used the material deposited on the sapphire substrate, although the number of defects remained too high (106-1010/cm^2) to easily build a high-power laser.

In the early 1990s, the Institute of High Pressure Physics at the Polish Academy of Sciences in Warsaw (Poland), under the leadership of Dr. Sylwester Porowski developed technology to create gallium nitride crystals with high structural quality and fewer than 100 defects per square centimeter — at least 10,000 times better than the best sapphire-supported crystal.

In 1999, Nakamura tried Polish crystals, producing lasers with twice the yield and ten times the lifetime — 3,000 hours at 30 mW.

A further development of the technology has led to mass production of the device. Today, blue lasers use a sapphire surface covered with a layer of gallium nitride (this technology is used by Japanese company Nichia, which has an agreement with Sony) and blue semiconductor lasers use a gallium nitride mono-crystal surface (Polish company TopGaN).

After 10 years, Japanese manufacturers mastered the production of a blue laser with 60 mW of power, making them applicable for devices that read a dense high-speed stream of data from Blu-ray, BD-R and BD-RE. Polish technology is cheaper than Japanese but has a smaller share of the market. There is one more Polish high-tech company which creates gallium nitride crystal - Ammono, but this company does not produce blue lasers.

For his work, Nakamura received the Millennium Technology Prize awarded in 2006.

Until the late 1990s, when blue semiconductor lasers were developed, blue lasers were large and expensive gas laser instruments which relied on population inversion in rare gas mixtures and needed high currents and strong cooling.

Thanks to prior development of many groups, including, most notably, Professor Isamu Akasaki's group, Shuji Nakamura at Nichia Corporation and Sony Corporation in Anan (Tokushima-ken, Japan) made a series of inventions and developed commercially viable blue and violet semiconductor lasers. The active layer of the Nichia devices was formed from InGaN quantum wells or quantum dots spontaneously formed via self-assembly. The new invention enabled the development of small, convenient and low-priced blue, violet and ultraviolet UV lasers, which had not been available before and opened the way for applications such as high-density HD DVD data storage and Blu-ray discs. The shorter wavelength allows it to read discs containing much more information.

Variants

Blue and violet diode-pumped solid state (DPSS) laser modules

Blue laser pointers, which became available around 2006, have the same basic construction as DPSS green lasers. They most commonly lase at 473 nm, which is produced by frequency doubling of 946 nm laser radiation from a diode-pumped Nd:YAG or Nd:YVO4 crystal (Nd-doped crystals usually produce a principal wavelength of 1064 nm, but with the proper reflective coating mirrors can be also made to lase at other non-principal neodymium wavelengths, such as 946 nm). For high output power BBO crystals are used as frequency doublers; for lower powers, KTP is used.

Blue lasers can also be fabricated directly with InGaN semiconductors, which produce blue light without frequency-doubling. 445 nm blue laser diodes are currently available on the open market. The devices are brighter than the 405 nm laser diodes, since the longer wavelength is closer to the peak sensitivity of the human eye. Commercial devices like laser projectors have driven down the prices on these diodes, as of March 2010.

Violet lasers may be constructed directly with **GaN** (gallium nitride) semiconductors, as noted. However, a few higher-powered (120 mW) 404-405 nm "violet" laser pointers have become available which are not based on GaN, but also use DPSS frequency-doubler technology starting from 1 watt 808 nm gallium arsenide infrared diode lasers being directly doubled, without a longer-wave neodymium laser interposed between diode laser and doubler-crystal. As with all high powered unfiltered infrared-driven DPSS lasers, such devices are able to pop balloons and light matches, but this is as a result of an unfiltered high-power infrared component in the beam.

Appearance

The violet 405 nm laser (whether constructed from GaN or frequency-doubled GaAs laser diodes) is not in fact blue, but appears to the eye as violet (reddish-purple), a color for which a human eye has a very limited sensitivity. When pointed at many white objects (such as commercial white typing or printing paper) the laser dot changes from violet and appears blue. This color is actually due to blue fluorescence from brightening dyes added to the paper—the same effect as from a blacklight lamp.

For display applications, where the "true blue" color is required, a wavelength of 450-460 nm is required. With advances in production and commercial sales of low cost laser projectors, 445 nm InGaN laser diodes have dropped in price.

(A last challenge in projection laser diodes is related to the construction of a "true green" InGaN laser (around 530 nm). Many companies have demonstrated devices working at only slightly shorter wavelengths: 480-500 nm.)

Applications

Areas of application of the blue laser include:

- Telecommunications
- Information technology
- Environmental monitoring
- Electronic equipment
- Medical diagnostics
- Micro projectors and displays

Sony BDP-S1

The **Sony BDP-S1** is a first generation Blu-ray Disc (BD) Player. It was first released in North America. It was originally scheduled for release in the United States on August 18, 2006 with a MSRP of $999.95. Sony had postponed the release date of this player several times and it was released on December 4, 2006. On November 30, 2006 Sony announced that the player began shipping to major consumer electronics retailers and specialty dealers nationwide. It was available in stores December 2, 2006. As of June 23rd, 2010, the latest firmware release for the BDP-S1 is 5.30.

Network capabilities

The Sony BDP-S1 does not come with a built-in ethernet connection, therefore this player has no online capabilities. Nevertheless, firmware upgrades may be applied by

downloading the upgrade and burning them onto a recordable or rewritable DVD and loading it onto the player.

BD-J compatibility

During its initial release, there were reported issues with certain BD-ROM movie discs, namely BD-J functionality. The discs played incorrectly or would not play at all. Sony solved this issue with a firmware update and the player is now compatible with all BD-J standard discs.

Audio decoding capability

The player is capable of decoding Dolby Digital, Dolby Digital Plus (after firmware upgrade higher than ver.2.00), Dolby TrueHD (after firmware upgrade higher than ver.2.00), LPCM and DTS core. Currently, the player is not capable of decoding DTS-HD High Resolution Audio or DTS-HD Master Audio.

Audio and video output

Audio is sent out of the player via Toslink, HDMI, or analog 5.1 jacks. The player will give you the option to output Dolby Digital or DTS via the Toslink (optical or coax), or selectively downmix either independently to PCM. However the digital output is not necessarily compatible with other surround system decoders. Even standard DVD soundtracks cannot be guaranteed to be correctly decoded by Toslink input equipped decoders. There is a disclaimer in the supplied owners manual to this effect. The player will save your selections allowing for customization of your outputs. The supplied HDMI connection is version 1.2 and does not support Deep Color or Bitstream out for Dolby Digital Plus, Dolby TrueHD, DTS-HD and DTS-HD Master Audio. This feature is not capable of being added later.

Load times

The BDP-S1 being one of the first generation Blu Ray Disc Players has much longer load times than current BD Players, around 2 to 3 minutes from system power up to actual video playback, or 50 to 70 seconds from disc insertion when the unit is already powered up, although this is not as fast as the PlayStation 3. Loading time is also improved from original version when updated to the latest firmware.

DVD-Audio, SACD and CD playback

The player is not compatible with any audio disc format. No announcement has been made as to whether this issue will be resolved. CD playback is possible when using the Asia-Pacific version model no. BDP-S1E.

Chapter- 8

High-definition Video

High-definition video or **HD video** refers to any video system of higher resolution than standard-definition (SD) video and most commonly involves display resolutions of 1,280×720 pixels (720p) or 1,920×1,080 pixels (1080i/1080p). Here we discusses the general concepts of high-definition video, as opposed to its specific applications in television broadcast (HDTV), video recording formats (HDCAM, HDCAM-SR, DVCPRO HD, D5 HD, AVC-Intra, XDCAM HD, HDV and AVCHD), the optical disc delivery system Blu-ray Disc and the video tape format D-VHS.

History

The developmental era (1936–1980s)

From a historical perspective, the first electronic scanning format 405 lines was the first 'High Definition' television system as the previous mechanical systems had far fewer scanning lines.

From 1939, The US and other European countries experimented with 441 lines and 605 lines until the FCC mandated 525 lines for the US from 1941. In Wartime France, René Barthélemy experimented with higher definitions, reaching 1015 and even 1042 lines. Official French transmissions finally began with 819 lines from late 1949, though this standard was abandoned in 1984 upon the adoption of 625-line colour on the TF1 network.

1980s: Great technological leaps into dead ends

Modern HD specifications date to the early 1970s, when Japan developed the HighVision 1,125-line interlaced TV standard (also called MUSE) that ran at 60 frames per second. Japan presented their standard at an international meeting of television engineers in Algiers in 1981 and Japan's NHK presented its analog HDTV system at Swiss conference in 1983.

The NHK system was standardized in the United States as Society of Motion Picture and Television Engineers (SMPTE) standard #240M in the early 1990s, but abandoned later on when it was replaced by a DVB analog standard. HighVision video is still usable for HDTV video interchange, but there is almost no equipment around to perform this

function. Attempts at shoehorning in HighVision into a 6 MHz broadcast channel were mostly unsuccessful. All attempts at using this format for terrestrial TV transmission were forsaken by the mid-1990s.

The Europeans developed HD-MAC (1,250 lines, 50 Hz) as a video standard, but it never took off as a terrestrial video transmission format. HD-MAC was never designated for video interchange except by the European Broadcasting Union.

The current high definition video standards in North America were developed during the course of the advanced television process initiated by the Federal Communications Commission in 1987 at the request of American broadcasters. In essence the end of the 1980s was a death knell for most analog high definition technologies that had developed up to that time.

1990s: DVB and the brushfire of standardization

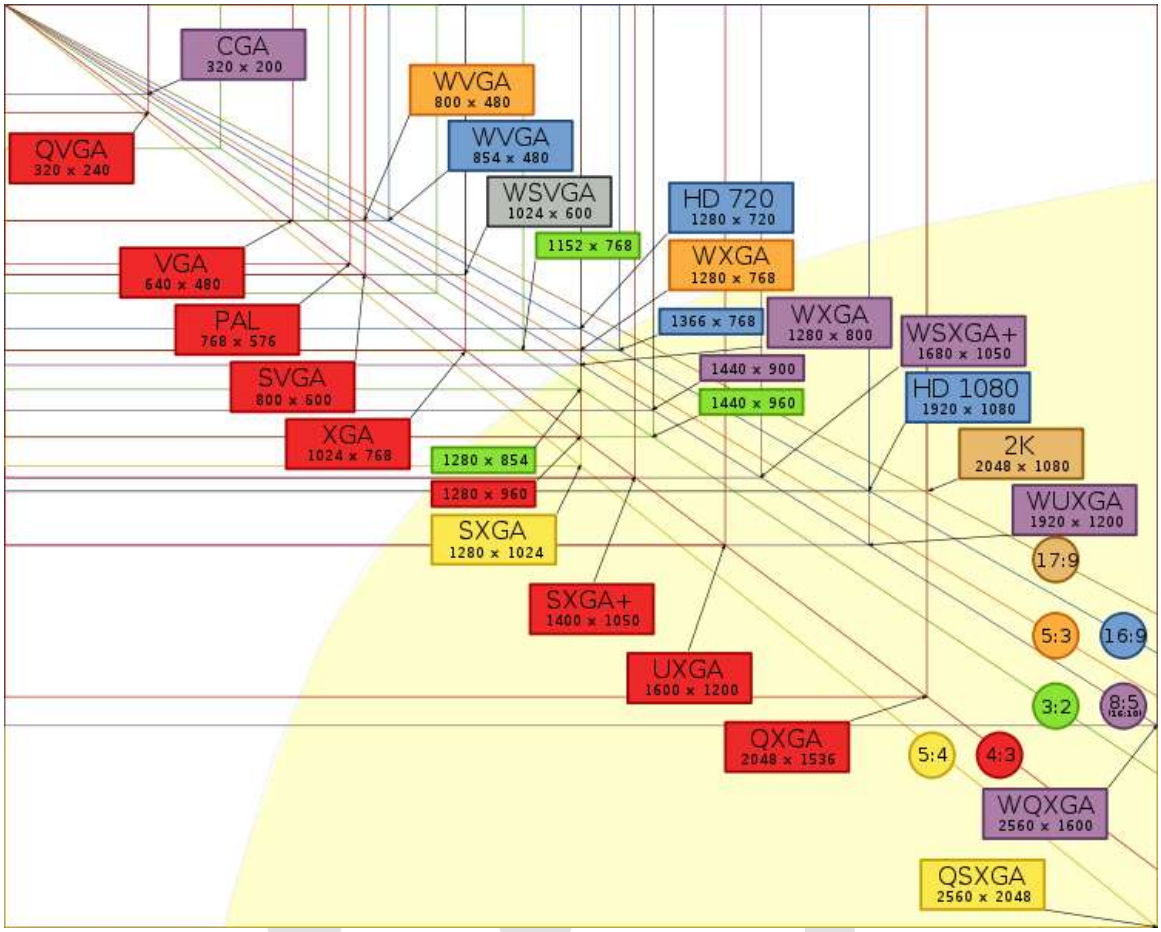
The FCC process, led by the Advanced Television Systems Committee (ATSC) adopted a range of standards from interlaced 1,080 line video (a technical descendant of the original analog NHK 1125/30 Hz system) with a maximum frame rate of 30 Hz and 720 line video, progressively scanned, with a maximum frame rate of 60 Hz.

In the end however the DVB standard of resolutions (1080, 720, 480) and frame rates (24, 25, 30) were adopted in conjunction with the Europeans that were also involved in the same standardization process. The FCC officially adopted the ATSC transmission standard (which included both HD and SD video standards) in 1996, with the first broadcasts on October 28, 1998.

2000s: global HDTV adoption, but standardization deteriorates

In the early 2000s, it looked as if DVB would be the video standard far into the future. However, both Brazil and China have adopted non-standard video codecs (mp4 and an open-source video codec) that somewhat violate the interoperability that was hoped for after decades of largely non-interoperable analog TV broadcasting. As high definition television has evolved into the mathematical representation of a video signal and as computing power is so inexpensive these standardization issues so far have been minor.

Technical details



This chart shows the most common display resolutions, with the color of each resolution type indicating the display ratio (e.g., red indicates a 4:3 ratio)

High definition video (prerecorded and broadcast) is defined threefold, by:

- *The number of lines in the vertical display resolution*. High-definition television (HDTV) resolution is 1,080 or 720 lines. In contrast, regular digital television (DTV) is 480 lines (upon which NTSC is based, 480 visible scanlines out of 525) or 576 lines (upon which PAL/SECAM are based, 576 visible scanlines out of 625). However, since HD is broadcast digitally, its introduction sometimes coincides with the introduction of DTV. Additionally, current DVD quality is not high-definition, although the high-definition disc systems Blu-ray Disc and the defunct HD DVD are.
- *The scanning system: progressive scanning (p) or interlaced scanning (i)*. *Progressive scanning* redraws an image frame (all of its lines) when refreshing each image. *Interlaced scanning* draws the image field every other line or "odd numbered" lines during the first image refresh operation and then draws the remaining "even numbered" lines during a second refreshing. Interlaced scanning

yields greater image resolution if subject is not moving, but loses up to half of the resolution and suffers "combing" artifacts when subject is moving.
- *The number of frames or fields per second*. The 720p60 format is 1,280 × 720 pixels, progressive encoding with 60 frames per second (60 Hz). The 1080i50 format is 1920 × 1080 pixels, interlaced encoding with 50 fields per second. Two interlaced fields formulate a single frame, because the two fields of one frame are temporally shifted. Frame pulldown and segmented frames are special techniques that allow transmitting full frames by means of interlaced video stream.

For commercial naming of the product, either the frame rate or the field rate is dropped; e.g., a "1080i television set" label indicates only the image resolution. Often, the rate is inferred from the context, usually assumed to be either 50 or 60, except for 1080p, which denotes 1080p24, 1080p25 and 1080p30, but also 1080p50 and 1080p60.

A frame or field rate can also be specified without a resolution. For example 24p means 24 progressive scan frames per second and 50i means 25 interlaced frames per second, consisting of 50 interlaced fields per second. Most HDTV systems support some standard resolutions and frame or field rates. The most common are noted below. High-definition signals require a high-definition television or computer monitor in order to be viewed. High-definition video has an aspect ratio of 16:9 (1.78:1). The aspect ratio of regular widescreen film shot today is typically 1.85:1 or 2.39:1 (sometimes traditionally quoted at 2.35:1). Standard-definition television (SDTV) has a 4:3 (1.33:1) aspect ratio, although in recent years many broadcasters have transmitted programs "squeezed" horizontally in 16:9 anamorphic format, in hopes that the viewer has a 16:9 set which stretches the image out to normal-looking proportions, or a set which "squishes" the image vertically to present a "letterbox" view of the image, again with correct proportions.

Common high-definition video modes

Video mode	Frame size in pixels (W×H)	Pixels per image[1]	Scanning type	Frame rate (Hz)
720p	1,280×720	921,600	Progressive	23.976, 24, 25, 29.97, 30, 50, 59.94, 60, 72
1080i	1,920×1,080	2,073,600	Interlaced	25 (50 fields/s), 29.97 (59.94 fields/s), 30 (60 fields/s)
1080p	1,920×1,080	2,073,600	Progressive	23.976, 24, 25, 29.97, 30, 50, 59.94, 60

Extra high-definition video modes

Video mode	Frame size in pixels (W×H)	Pixels per image[1]	Scanning type	Frame rate (Hz)
2K	2,048×1,536	3,145,728	Progressive	
2160p	3,840×2,160	8,294,400	Progressive	
4K	4,096×3,072	12,582,912	Progressive	
2540p	4,520×2,540	11,480,800	Progressive	
4320p	7,680×4,320	33,177,600	Progressive	50, 60

Note: [1] Image is either a frame or, in case of interlaced scanning, two fields. (EVEN and ODD)

HD content

High-definition image sources include terrestrial broadcast, direct broadcast satellite, digital cable, high definition disc (BD), internet downloads and the latest generation of video game consoles.

- Most computers are capable of HD or higher resolutions over VGA, DVI and/or HDMI.
- The optical disc standard Blu-ray Disc can provide enough digital storage to store hours of HD video content. DVDs look best on screens that are smaller than 36 inches (91 cm), so they are not always up to the challenge of today's high-definition (HD) sets. Storing and playing HD movies requires a disc that holds more information, like a Blu-ray Disc.

Types of recorded media

The high resolution photographic film used for cinema projection is exposed at the rate of 24 frames per second but usually projected at 48, each frame getting projected twice helping to minimise flicker. One exception to this was the 1986 National Film Board of Canada short film *Momentum*, which briefly experimented with both filming and projecting at 48 frame/s, in a process known as IMAX HD.

Depending upon available bandwidth and the amount of detail and movement in the image, the optimum format for video transfer is either 720p24 or 1080p24. When shown on television in PAL system countries, film must be projected at the rate of 25 frames per second by accelerating it by 4.1 per cent. In NTSC standard countries, the projection rate is 30 frames per second, using a technique called 3:2 pull-down. One film frame is held for three video fields (1/20 of a second) and the next is held for two video fields (1/30 of a second) and then the process is repeated, thus achieving the correct film projection rate with two film frames shown in 1/12 of a second.

Older (pre-HDTV) recordings on video tape such as Betacam SP are often either in the form 480i60 or 576i50. These may be upconverted to a higher resolution format (720i), but removing the interlace to match the common 720p format may distort the picture or require filtering which actually reduces the resolution of the final output.

Non-cinematic HDTV video recordings are recorded in either the 720p or the 1080i format. The format used is set by the broadcaster (if for television broadcast). In general, 720p is more accurate with fast action, because it progressively scans frames, instead of the 1080i, which uses interlaced fields and thus might degrade the resolution of fast images.

720p is used more for Internet distribution of high-definition video, because computer monitors progressively scan; 720p video has lower storage-decoding requirements than either the 1080i or the 1080p. This is also the medium for high-definition broadcasts around the world and 1080p is used for Blu-ray movies.

HD in filmmaking

Film as a medium has inherent limitations, such as difficulty of viewing footage whilst recording and suffers other problems, caused by poor film development/processing, or poor monitoring systems. Given that there is increasing use of computer-generated or computer-altered imagery in movies and that editing picture sequences is often done digitally, some directors have shot their movies using the HD format via high-end digital video cameras. Whilst the quality of HD video is very high compared to SD video and offers improved signal/noise ratios against comparable sensitivity film, film remains able to resolve more image detail than current HD video formats. In addition some films have a wider dynamic range (ability to resolve extremes of dark and light areas in a scene) than even the best HD cameras. Thus the most persuasive arguments for the use of HD are currently cost savings on film stock and the ease of transfer to editing systems for special effects.

Film to high-definition transfer

Most major motion pictures are shot on film. Film is a very high resolving medium, with resolution measured by testing its ability to resolve pairs of black and white lines, the unit of measurement is cycles/mm – one "cycle" consists of a pair of lines and is equivalent to two pixels, one black and one white. Film by itself can commonly resolve from 50 c/mm to 400 c/mm (100 pixels/mm to 800 pixels/mm) depending on emulsion stock. However, since the image on film is formed by exposing it through a lens and this lens also has its own resolution limits, the final resolution on the photographed negative is always less than each component's individual resolution.

Depending on the year and format a movie was filmed in, the exposed image can vary greatly in size. Sizes range from as big as 24 mm × 36 mm for VistaVision/Technirama 8 perforation cameras (same as 35 mm still photo film) going down through
18 mm × 24 mm for Silent Films or Full Frame 4 perforations cameras to as small as

9 mm × 21 mm in Academy Sound Aperture cameras modified for the Techniscope 2 perforation format. Movies are also produced using other film gauges, including 70 mm films (22 mm × 48 mm) or the rarely used 55 mm and CINERAMA.

The four major film formats provide pixel resolutions (calculated from pixels per millimeter) roughly as follows:

- Academy Sound (Sound movies before 1955): 15 mm × 21 mm (1.375) = 2,160 × 2,970
- Academy camera US Widescreen: 11 mm × 21 mm (1.85) = 1605 × 2970
- Current Anamorphic Panavision ("Scope"): 17.5 mm × 21 mm (2.39) = 2,485 × 2,970
- Super-35 for Anamorphic prints: 10 mm × 24 mm (2.39) = 1,420 × 3,390

In the process of making prints for exhibition, this negative is copied onto other film (negative → interpositive → internegative → print) causing the resolution to be reduced with each emulsion copying step and when the image passes through a lens (for example, on a projector). In many cases, the resolution can be reduced down to 1/6th of the original negative's resolution (or worse). Note that resolution values for 70 mm film are higher than those listed above.

HD on the World Wide Web/HD Streaming

A number of online video streaming/on demand and digital download services offer HD video, among them YouTube, Vimeo, Hulu, Amazon Video On Demand, Netflix Watch Instantly and others. Due to heavy compression, the image detail produced by these formats are far below that of broadcast HD and often even inferior to DVD-Video (3-9 Mbit/s MP2) upscaled to the same image size. The following is a chart of numerous online services and their HD offering

World Wide Web HD resolutions

Source	Codec	Highest resolution (W×H)	Total bit rate/bandwidth	Video bit rate	Audio bit rate
Amazon Video On Demand (formerly "Unbox")	VC-1	1,280×720	2.5 Mbit/s		
BBC iPlayer	H.264	1,280×720	3.2 Mbit/s	3 Mbit/s	192 kbit/s
Blockbuster Online					
CBS.com/TV.com (720p)		1,280×720	2.5 Mbit/s		
CBS.com/TV.com		1,920×1,080	3.5 Mbit/s		

(1080p)					
Hulu	On2 Flash VP6	1,280×720	2.5 Mbit/s		
iPlayerHD	FLV, Quicktime H.264, MP4 H.264	1,920×1,080		5 Mbit/s	
iTunes/Apple TV	QuickTime H.264	1,280×720	4Mbps		
Netflix Watch Instantly	VC-1	1,280×720	5 Mbit/s	2.6 Mbit/s and 3.8 Mbit/s	
PlayStationStore Movies & TV Shows	H.264/MPEG-4 AVC	1,920×1,080		8 Mbit/s	256 kbit/s
Vimeo	H.264	1,920×1,080		4 Mbit/s	320 kbit/s
Vudu	H.264	1,920×1,080	4.5 Mbit/s		
Zune Video (formerly "Xbox Live Marketplace Video Store")		1,920×1,080	3 Mbit/s		
YouTube	H.264/MPEG-4 AVC	4,096x3,072		6.5 Mbit/s	max. 119 kbit/s

HD in video gaming

The PlayStation 3 game console can output to native 1080p through both component and HDMI cables. The Xbox 360 can only upscale to 1080p. Native 1080p produces a sharper and clearer picture compared to upscaled 1080p. Besides increasing the visual quality of games, users can also download HD movies and video clips from the PlayStation Network or Xbox Live Marketplace services to their respective consoles. The PlayStation 3 can also play Blu-Ray discs which hold HD data.

Though only a handful of games available can render in 1080p, all games on the Xbox 360 and many PlayStation 3 games can be scaled up to this resolution. Xbox 360 and PlayStation 3 games are labeled with their output resolution on the back of their packaging. The Wii can output up to 480p (NTSC).

Due to the versatility of the PC as a gaming platform, almost all recent PC games can be rendered in 1,920×1,080 or higher.

The Playstation 2 and the original Xbox had HD support, but few games of that era took advantage of this feature.

HD in video surveillance

High definition (HD) video is becoming the norm in the surveillance industry as an increasing number of manufacturers of security cameras now claim to offer HD cameras. It is understandable since the need for high resolution, colour fidelIty and frame rate is more acute for surveillance purposes to ensure that the quality of the video output is of an acceptable standard that can be used both for preventative surveillance as well as for evidence purposes.

Chapter- 9

HD DVD

HD DVD

Media type	High-density optical disc
Encoding	VC-1, H.264 and MPEG-2
Capacity	15 GB (single layer) 30 GB (dual layer)
Read mechanism	1× @ 36 Mbit/s & 2× @ 72 Mbit/s

Developed by	DVD Forum
Usage	Data storage, 1080p high-definition video

HD DVD (short for **High-Definition/Density DVD**) is a discontinued high-density optical disc format for storing data and high-definition video. Supported principally by Toshiba, HD DVD was envisioned to be the successor to the standard DVD format. However, in February 2008, after a protracted high definition optical disc format war with rival Blu-ray, Toshiba abandoned the format, announcing it would no longer develop or manufacture HD DVD players or drives. However, the HD DVD physical disk specifications (but not the codecs) are still in use as the basis for the CBHD (China Blue High-Definition Disc) formerly called CH-DVD. The HD DVD Promotion Group was dissolved on March 28, 2008.

Because all variants except 3× DVD and HD REC employed a blue laser with a shorter wavelength, HD DVD could store about 3⅕ times as much data per layer as its predecessor (maximum capacity: 15 GB per layer instead of 4.7 GB per layer).

History

In the mid 1990s, commercial HDTV sets started to enter a larger market. However, there was no inexpensive way to record or play back HD content. JVC's D-VHS and Sony's HDCAM formats could store that amount of data, but were neither popular nor well-known. However, it was well known that using lasers with shorter wavelengths would yield optical storage with higher density. Shuji Nakamura invented practical blue laser diodes, however, a lengthy patent lawsuit delayed commercial introduction.

Origins and competition from Blu-ray Disc

Sony started two projects applying the new diodes: UDO (Ultra Density Optical) and DVR Blue together with Philips, a format of rewritable discs which would eventually become Blu-ray (more specifically, BD-RE) and later on with Pioneer a format of read only discs (ROM). The two formats share several technologies (such as the AV codecs and the laser diode). In February 2002, the project was officially announced as Blu-ray and the Blu-ray Disc Association was founded by the nine initial members.

The DVD Forum (which was chaired by Toshiba) was deeply split over whether to go with the more expensive blue lasers or not. Although today's Blu-ray Discs appear virtually identical to a standard DVD, when the Blu-ray Discs were initially developed they required a protective caddy to avoid mis-handling by the consumer. (Early CD-Rs also featured a protective caddy for the same purpose.) The Blu-ray prototype's caddy was both expensive and physically different from DVD, posing several problems. In March 2002, the forum voted to approve a proposal endorsed by Warner Bros. and other motion picture studios that involved compressing HD content onto dual-layer DVD-9

discs. However, in spite of this decision, the DVD Forum's Steering Committee announced in April that it was pursuing its own blue-laser high-definition solution. In August, Toshiba and NEC announced their competing standard Advanced Optical Disc. It was adopted by the DVD forum and renamed to HD DVD the next year.

The HD DVD Promotion Group was a group of manufacturers and media studios formed to exchange thoughts and ideas to help promote the format worldwide. Its members comprised Toshiba Corporation as the Chair Company and Secretary, Memory-Tech Corporation and NEC Corporation as Vice-Chair companies and Sanyo Electric as Auditors; there were 61 general members and 72 associate members in total. The HD DVD promotion group was officially dissolved on March 28, 2008, following Toshiba's announcement on February 19, 2008 that it would no longer develop or manufacture HD DVD players and drives.

Launch

On March 31, 2006 Toshiba released their first consumer-based HD DVD player in Japan at ¥110,000 (US$934), beating Blu-ray to the market by about three months. HD DVD was released in United States on April 18, 2006, with players priced at $499 and $799.

The first HD DVD titles were released on April 18, 2006. They were *The Last Samurai*, *Million Dollar Baby* and *The Phantom of the Opera* by Warner Home Video and *Serenity* by Universal Studios. The first independent HD film released on HD DVD was *One Six Right*.

Sales developments

In December 2006 Toshiba reported that roughly 120,000 Toshiba branded HD DVD players had been sold in the United States, along with 150,000 HD DVD add-on units for the Xbox 360.

On April 18, 2007, one year after the first HD DVD titles were released, the HD DVD group reported that they had sold 100,000 dedicated HD DVD units in the United States.

In the middle of 2007, the first HD DVD Recorders were released in Japan.

In November 2007, the Toshiba HD-A2 was the first high definition player to be sold at a sale price of less than US$100; this was done through several major retailers to make room for the new HD-A3 models. These closeout sales lasted less than a day each due to both limited quantities and high demand at that price point. In the same month, the HD DVD promotion group announced that 750,000 HD DVD players had been sold, which included stand-alone players and the Xbox 360 add-on.

In January 2008 Toshiba announced that close to one million dedicated HD DVD players had been sold.

As of June 24, 2008, 475 HD DVD titles had been released in the USA. As of April 29, 2008, 236 HD DVD titles had been released in Japan.

Decline

On January 4, 2008, citing consumer confusion and indifference as a reason for lackluster high-definition software sales, Warner Bros. announced it would stop supporting HD DVD by June 2008 and the company would release HD titles only on Blu-ray Disc. This was followed by news of Netflix phasing out support for the format and Best Buy's decision to recommend Blu-ray Disc over HD DVD in its retail locations and to remove HD DVD players as part of its ongoing "HDTV advantage" promotion. Finally, retailer Wal-Mart announced that it would be supporting only Blu-ray by June 2008. On February 19, 2008, Toshiba announced plans to discontinue development, marketing and manufacturing of HD DVD players while still providing product support and after-sale service to consumers of the format (including Firmware updates). The company cited "recent major changes in the market". Shipments of HD DVD machines to retailers were reduced and eventually stopped by the end of March 2008.

End of releases

The final HD DVD releases in the United States from a major studio were Warner's *P.S. I Love You* and *Twister*, on May 27, 2008. In June, the final HD DVD to be released was *Freedom: 6* from Bandai Visual. *Disco Pigs* was, however, postponed, with no new date announced for release. Bandai Visual acknowledged the demise of HD DVD, but stated that it wanted to complete the release of the seven-part *Freedom Project*, of which six parts were released. The seventh part, due for August 2008, never saw a release.

Death Proof was released on HD DVD format by Senator Films in Germany on December 15, 2008. This special release also was a steelbook.

On April 3, 2010, tech blog site Engadget reported that Anthem films would release the film *Deadlands 2: Trapped* on HD DVD in a limited run of 500 copies. This eventually happened in the form of an HD DVD-R. *Deadlands* just announced on September 5, 2010 to be release on HD DVD for a limited copies. Just like previous released on *Deadlands 2: Trapped*, the film will pressed on HD DVD-R disc.

On May 30, 2010, MCB Entertainment announced that the first 100 copies of *Smokers* would be released as fully packaged, professionally manufactured HD DVDs with the appropriate cases and inserts.

Warner providing Blu-ray replacements in the US

As of mid-2009, Warner, through its Red2Blu.com site, is offering to replace any HD DVD Warner home video release with a Blu-ray equivalent for US$4.95 each plus US$6.95 shipping to the continental United States or $8.95 to Alaska, Hawaii or Puerto Rico. The deal requires that the HD DVD's original sleeve art be returned to Warner as a

proof of purchase. As of August 2009, the turn-around time for processing is approximately two weeks. Multi-disc sets are exchangeable at a discount, e.g. $14.95 for the 5-disc *Blade Runner* release, rather than $24.75. No exchanges are offered to customers outside of the US.

Technical specifications

The current specification books for HD DVD are listed at the DVD FLLC website.

Disc structure

HD DVD-ROM, HD DVD-R and HD DVD-RW have a single-layer capacity of 15 GB and a dual-layer capacity of 30 GB. HD DVD-RAM has a single-layer capacity of 20 GB. Like the original DVD format, the data layer of an HD DVD is 0.6 mm below the surface to physically protect the data layer from damage. The numerical aperture of the optical pick-up head is 0.65, compared with 0.6 for DVD. All HD DVD players are backward compatible with DVD and CD.

Physical size	Single layer capacity	Dual layer capacity
12 cm, single sided	15 GB	30 GB
12 cm, double sided	30 GB	60 GB
8 cm, single sided	4.7 GB	9.4 GB
8 cm, double sided	9.4 GB	18.8 GB

Recording speed

Drive speed	Data rate		Write time for HD DVD Disc (minutes)	
	Mbit/s	MB/s	Single Layer	Dual Layer
1×	36	4.5	56	110
2×	72	9	28	55

File systems

As with previous optical disc formats, HD DVD supports several file systems, such as ISO 9660 and Universal Disk Format (UDF). All HD DVD titles use UDF version 2.5 as the file system. In this file system, multiplexed audio and video streams are stored in EVO container format.

Audio

The HD DVD format supports encoding in up to 24-bit/192 kHz for two channels, or up to eight channels of up to 24-bit/96 kHz encoding.

All HD DVD players are required to decode uncompressed linear PCM, Dolby Digital AC-3, Dolby Digital EX, DTS, Dolby Digital Plus E-AC-3 and Dolby TrueHD. A

secondary soundtrack, if present, can be stored in any of the aforementioned formats, or in one of the HD DVD optional codecs: DTS-HD High Resolution Audio and DTS-HD Master Audio. For the highest-fidelity audio experience, HD DVD offers content-producers the choice of LPCM, Dolby TrueHD and DTS-HD Master Audio.

Video

HD DVD video can be encoded using VC-1, AVC, or MPEG-2. A wide variety of resolutions are supported, from low-resolution CIF, all SDTV resolutions supported by DVD-Video and of course the HDTV formats: 720p, 1080i and 1080p. All studio-released movie titles have featured video in a 1080-line format, with companion supplements in 480i or 480p. The vast majority of releases were encoded with VC-1 and most of the remaining titles encoded with AVC.

Interactive content

HD DVDs use Advanced Content to allow interactive content to be authored for discs. Microsoft's implementation of Advanced Content is the HDi Interactive Format and "HDi" is frequently used to refer to the Advanced Content system. Advanced Content is based on web technologies such as HTML, XML, CSS, SMIL and ECMAScript (JavaScript), so authoring in Advanced Content should be a fairly easy transition for web developers. No existing DVD authoring experience is required. In comparison Blu-ray Disc content is authored using either a scripting environment (BDMV) or a Java-based platform (BD-J). DVD video discs use pre-rendered MPEG segments, selectable subtitle pictures and simple programmatic navigation which is considerably more limited.

Hardware

Compatibility

Backward compatibility is available with all HD DVD players, allowing users to have a single player to play all types of HD DVD, DVD and CD. There is also a hybrid HD DVD format which contains both DVD and HD DVD versions of the same movie on a single disc, providing a smooth transition for the studios in terms of publishing movies and allowing consumers with only DVD players to still use the discs. DVD replication companies can continue using their current production equipment with only minor alterations when changing over to the format of HD DVD replication. Due to the structure of the single-lens optical head, both red and blue laser diodes can be used in smaller, more compact HD DVD players.

General purpose computers

HD DVD drives can also be used with a desktop/laptop personal computer (PC) running Windows XP, Windows Vista, Mac OS X v10.5 "Leopard" and many varieties of Linux. Third-party player software for Windows and Linux have successfully played HD DVD titles using the add-on drive.

Released at the end of November 2006, the Microsoft HD DVD drive for the Xbox 360 game-console gives the Xbox 360 the ability to play HD DVD movies. The drive was announced with an MSRP of US$199 and includes a USB 2.0 cable for connection to the console. The first drives also included Peter Jackson's *King Kong* or Batman Begins on HD DVD. The final "regular" for the drive was US$129.99 as of February 25, 2008. On February 23, 2008 Microsoft discontinued the Xbox 360 HD DVD player. On February 26, 2008, Microsoft "officially" announced that the Xbox 360 HD DVD add on drive would reflect a heavily discounted price down to $49.99.

Dual-compatibility drives

In 2007, LG and Samsung released standalone consumer players that could read both HD DVD and Blu-ray discs. The machines were sold at premium prices, but failed to sell in large quantities. In May 2008, both companies announced they would stop manufacturing dual-compatibility drives.

A few computer manufacturers (such as HP and Acer) sold computers with combination HD DVD/Blu-ray drives.

HD DVD / Blu-ray Disc comparison

HD DVD competed primarily with Blu-ray Disc. Both formats were designed as successors to DVD, capable of higher quality video and audio playback and of greater capacity when used to store video, audio and computer data. Blu-ray and HD DVD share most of the same methods of encoding media onto disks with each other, resulting in equivalent levels of audio and visual quality, but differ in other aspects such as interactive capabilities, internet integration, usage control and enforcement and in which features were mandatory for players. The storage size also varies: A dual-layer HD DVD holds a maximum of 30 GB of data, while a dual-layer Blu-ray carries 50 GB.

Development

Even after finalizing the HD DVD standard, engineers continued developing the technology. A 51 GB triple-layer spec was approved at the DVD Forums 40th Steering Committee Meeting (held on November 15, 2007). However, no movies had been scheduled for this disc type and Toshiba had declined to say whether the 51 GB disc was compatible with existing drives and players. Specification 2.0 Part 1 (Physical Specification) for triple layer HD DVD had been approved in November 2007.

At the CES 2007, Ritek revealed their high definition optical disc process that extended both competing high definition formats to ten layers, increasing capacity to 150 GB for HD DVD and 250 GB for Blu-ray Disc. However, a major obstacle to implementing this technology in either format (150 GB HD DVD will not be developed due to HD DVD's discontinuation) is that reader-writer technology available may not be able to support the additional data layers.

NEC, Broadcom, Horizon Semiconductors and STMicroelectronics have separately developed a single chip/laser that can read both the HD DVD and the Blu-ray disc standard. Broadcom and STMicroelectronics will be selling their dual-format single chip/laser solution to any OEM willing to develop a product based on the chip.

Variants and Media

HD DVD-R / -RW / -RAM

HD DVD-R is the writable disc variant of HD DVD, available with a single-layer capacity of 15 GB or a dual-layer capacity of 30 GB. Write speeds depend on drive speed, with a data rate of 36.55 Mbit/s (4.36 MB/s) and a recording time of 56 minutes for 1× media and 73 Mbit/s (8.71 MB/s) and a recording time of 28 minutes for 2×.

The Toshiba SD-L902A for notebooks was one of the first available HD DVD writers, although it was not meant for retail. Burning HD DVD (including Dual Layer) with a 1× write speed, it could also burn DVDs and CDs. In a test of the SD-L902A by C't computer magazine with Verbatim discs, the written HD DVD-Rs suffered from high noise levels; as a result, the written discs could not be recognized by the external HD DVD drive of the Xbox 360, though they could be read back by the SD-L902A.

HD DVD-RW is the rewritable disc variant of HD DVD with equal storage capacity to an HD DVD-R. The primary advantage of HD DVD-RW over HD DVD-R is the ability to erase and rewrite to an HD DVD-RW disc, up to about 1,000 times before needing replacement, making them comparable with the CD-RW and DVD-RW standards. This is also of benefit if there are writing errors when recording data, as the disc is not ruined and can still store data by erasing the faulty data.

HD DVD-RAM was the proposed successor to DVD-RAM for random access on optical media using phase-change principals. It would hold 20 gigabytes per layer instead of 15 gigabytes for HD DVD-R, due to differences in recording methods used, yielding a higher density disc.

DVD / HD DVD hybrid discs

There are two types of hybrid formats which contain standard DVD-Video format video for playback in regular DVD players and HD DVD video for playback in high definition on HD DVD players. The Combo disc is a dual sided disc with one side DVD and the other HD DVD, each of which can have up to two layers. The Twin disc is a single sided disc that can have up to three layers, with up to two layers dedicated to either DVD or HD DVD. These hybrid discs make retail marketing and shelf space management easier. Another advantage is hardware cross-compatibility. The average consumer doesn't have to worry about whether or not they can play a hybrid DVD: any standard home DVD player can access the DVD-encoded content and any HD DVD player can access both the DVD- and HD DVD-encoded content.

HD DVD / Blu-ray hybrid discs

Warner Bros. officially announced Total Hi Def (THD or *Total HD*) at CES 2007. THD hybrid discs were to support both HD DVD and Blu-ray, with HD DVD on one side (up to two layers) and Blu-ray on the other side (up to two layers). However, in November 2007, Warner Bros. cancelled THD's development.

3× DVD

The HD DVD format also applies to current red laser DVDs; this type of disc is called "3× DVD", as it is capable of three times the bandwidth of regular DVD-Video.

3× DVDs are physically identical to normal DVDs. Although 3× DVDs provide the same high definition content, their playback time is less. For example, an 8.5 GB DVD can hold about 90 minutes of 1080p video encoded with VC-1 or AVC at an average bitrate of 12 Mbit/s, which corresponds with the average length of Hollywood feature-films. If quality is compromised slightly and good compression techniques are used, most feature films could be encoded with 3x DVD. Due to its much greater resolution, HD-Video also has significantly more redundant information than DVD which newer compression standards can encode more efficiently.

It is technically possible for consumers to create HD DVD compatible discs using low cost DVD-R or DVD+R media. At least one such guide exists. The 3× DVD is comparable to Blu-ray BD5 and BD9 formats.

HD REC

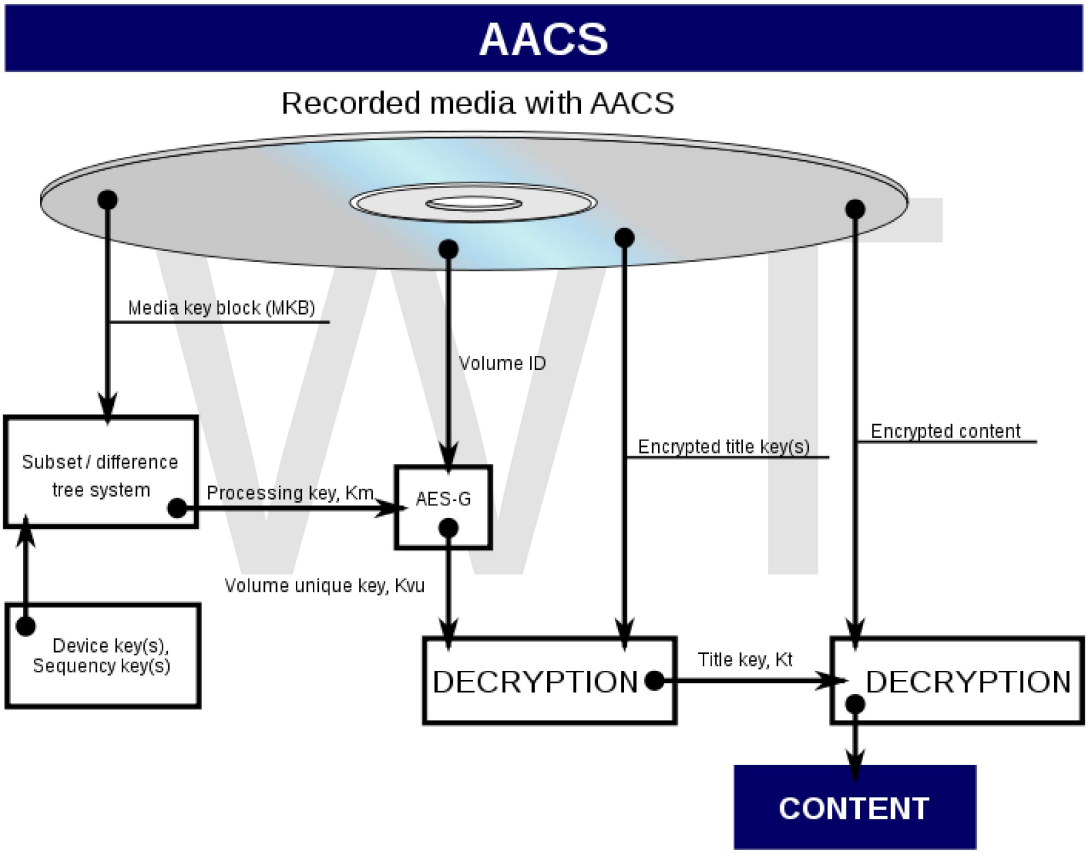
HD Rec is an extension of the HD DVD format for recording HD content on regular red laser DVD-Rs/DVD-RWs using H.264/MPEG-4 AVC compression. It was approved by the DVD Forum on September 12, 2007 It is comparable to Blu-ray's AVCREC.

CBHD

The China Blue High-Definition (CBHD), a high-definition optical disc format, was originally based upon the HD DVD format. Like the HD DVD, CBHD discs have a capacity of 15GB single-layer and 30GB dual-layer and can use existing DVD production lines. Unlike the HD DVD format, industry support for this format has grown steadily.

Chapter- 10

Advanced Access Content System



AACS decryption process

The **Advanced Access Content System** (**AACS**) is a standard for content distribution and digital rights management, intended to restrict access to and copying of the next generation of optical discs and DVDs. The specification was publicly released in April 2005 and the standard has been adopted as the access restriction scheme for HD DVD and Blu-ray Disc (BD). It is developed by **AACS Licensing Administrator, LLC** (**AACS LA**), a consortium that includes Disney, Intel, Microsoft, Panasonic, Warner Bros., IBM, Toshiba and Sony. AACS has been operating under an "interim agreement"

since the final specification (including provisions for Managed Copy) has not yet been finalised.

Since appearing in devices in 2006, several AACS decryption keys have been extracted from weakly protected software players and published on the Internet, allowing decryption by other unlicensed software.

System overview

Encryption

AACS uses cryptography to control the use of digital media. It encrypts content under one or more *title keys* using the Advanced Encryption Standard (AES). Title keys are derived from a combination of a *media key* (encoded in a Media Key Block) and the *Volume ID* of the media (e.g., a physical serial number embedded on a pre-recorded disc).

The principal difference between AACS and CSS, the DRM system used on DVDs, lies in how the device decryption keys are organized.

Under CSS, all players of a given model are provisioned with the same, shared decryption key. Content is encrypted under the title-specific key, which is itself encrypted under each model's key. Thus each disc contains a collection of several hundred encrypted keys, one for each licensed player model.

In principle, this approach allows licensors to "revoke" a given player model (prevent it from playing back future content) by omitting to encrypt future title keys with the player model's key. In practice, however, revoking all players of a particular model is costly, as it causes many users to lose playback capability. Furthermore, the inclusion of a shared key across many players makes key compromise significantly more likely, as was demonstrated by a number of compromises in the mid-1990s.

The approach of AACS provisions each individual player with a unique set of decryption keys which are used in a broadcast encryption scheme. This approach allows licensors to "revoke" individual players, or more specifically, the decryption keys associated with the player. Thus, if a given player's keys are compromised and published, the AACS LA can simply revoke those keys in future content, making the keys/player useless for decrypting new titles.

AACS also has traitor tracing. The standard allows different versions of short sections of a movie to be encrypted with different keys. A certain player will only be able to decrypt one version of each section. By embedding a digital watermark in the different versions and analyzing what sections of the movie the attacker publishes, the compromised keys can eventually be identified and revoked (this feature is called *Sequence keys* in the AACS specifications).

Volume IDs

Volume IDs are unique identifiers or serial numbers that are stored on pre-recorded discs with special hardware. They cannot be duplicated on consumers' recordable media. The point of this is to prevent simple bit-by-bit copies, since the Volume ID is required (though not sufficient) for decoding content. On Blu-ray discs, the Volume ID is stored in the BD-ROM Mark.

To read the Volume ID, a cryptographic certificate (the *Private Host Key*) signed by the AACS LA is required. However, hackers claim to have circumvented that particular protection by modifying the firmware of an HD DVD reader.

Decryption process

To view the movie, the player must first decrypt the content on the disc. The decryption process is somewhat convoluted. The disc contains 4 items—the Media Key Block (MKB), the Volume ID, the Encrypted Title Keys and the Encrypted Content. The MKB is encrypted in a subset difference tree approach. Essentially, a set of keys are arranged in a tree such that any given key can be used to find every other key except its parent keys. This way, to revoke a given device key, the MKB needs only be encrypted with that device key's parent key.

Once the MKB is decrypted, it provides the Media Key, or the km. The km is combined with the Volume ID (which the program can only get by presenting a cryptographic certificate to the drive, as described above) in a one-way encryption scheme (AES-G) to produce the Volume Unique Key (Kvu). The Kvu is used to decrypt the encrypted title keys and that is used to decrypt the encrypted content.

Analog Outputs

AACS-compliant players must follow guidelines pertaining to outputs over analog connections. This is set by a flag called the Image Constraint Token (ICT), which restricts the resolution for analog outputs to 960×540. Full 1920×1080 resolution is restricted to HDMI or DVI outputs that support HDCP. The decision to set the flag to restrict output ("down-convert") is left to the content provider. Warner Pictures is a proponent of ICT and it is expected that Paramount and Universal will implement down-conversion as well. AACS guidelines require that any title that implements the ICT must clearly state so on the packaging. The German magazine "Der Spiegel" has reported about an unofficial agreement between film studios and electronics manufacturers to not use ICT until 2010 - 2012. However, some titles have already been released that apply ICT.

Audio watermarking

On June 5, 2009, the licensing agreements for AACS were finalized, which were updated to make Cinavia detection on commericial Blu-ray disc players a requirement.

Managed Copy

Managed Copy refers to a system by which consumers can make legal copies of films and other digital content protected by AACS. This requires the device to obtain authorization by contacting a remote server on the Internet. The copies will still be protected by DRM, so infinite copying is not possible (unless it is explicitly allowed by the content owner). It is mandatory for content providers to give the consumer this flexibility in both the HD DVD and the Blu-ray standards (commonly called *Mandatory Managed Copy*). The Blu-ray standards adopted Mandatory Managed Copy later than HD DVD, after HP requested it.

Possible scenarios for Managed Copy include (but are not limited to):

- Create an exact duplicate onto a recordable disc for backup
- Create a full-resolution copy for storage on a media server
- Create a scaled-down version for watching on a portable device

This feature was not included in the interim standard, so the first devices on the market did not have this capability. It was expected to be a part of the final AACS specification.

In June, 2009, the final AACS agreements were ratified and posted online and include information on the Managed Copy aspects of AACS.

History

On February 24, 2001, Dalit Naor, Moni Naor and Jeff Lotspiech published a paper entitled "Revocation and Tracing Schemes for Stateless Receivers", where they described a broadcast encryption scheme using a construct called Naor-Naor-Lotspiech subset-difference trees. That paper laid the theoretical foundations of AACS.

The AACS LA consortium was founded in 2004. With DeCSS in hindsight, the *IEEE Spectrum* magazine's readers voted AACS to be one of the technologies most likely to fail in the January 2005 issue. The final AACS standard was delayed and then delayed again when an important member of the Blu-ray group voiced concerns. At the request of Toshiba, an interim standard was published which did not include some features, like managed copy. As of October 15, 2007, the final AACS standard had not yet been released.

Open-source implementations

On December 26, 2006 a person using the alias "muslix64" published a working, open-sourced AACS decrypting utility named BackupHDDVD, looking at the publicly available AACS specifications. Given the correct keys, it can be used to decrypt AACS-encrypted content. A corresponding BackupBluRay program was soon developed, as well as a "ClownBD" program mimicking CloneDVD but for Blu-Ray. SlySoft have stated they are working on CloneBD that supports Blu-Ray.

Security

Both title keys and one of the keys used to decrypt them (known as *Processing Keys* in the AACS specifications) have been found by using debuggers to inspect the memory space of running HD DVD and Blu-ray player programs. Hackers also claim to have found Device Keys (used to calculate the Processing Key) and a Host Private Key (a key signed by the AACS LA used for hand-shaking between host and HD drive; required for reading the Volume ID). The first unprotected HD movies were available soon afterwards. The processing key was widely published on the Internet after it was found and the AACS LA sent multiple DMCA takedown notices in the aim of censoring it. Some sites that rely on user-submitted content, like Digg tried to remove any mentions of the key. The Digg administrators eventually gave up trying to censor submissions that contained the key.

The AACS key extractions highlight the inherent weakness in any DRM system that permit software players for PCs to be used for playback of content. No matter how many layers of encryption are employed, it doesn't offer any true protection, since the keys needed to obtain the unencrypted content stream must be available somewhere in memory for playback to be possible. The PC platform offers no way to prevent memory snooping attacks on such keys, since a PC configuration can always be emulated by a virtual machine, in theory without any running program or external system being able to detect the virtualization. The only way to wholly prevent attacks like this would require changes to the PC platform which could provide protection against such attacks. This would require that content distributors do not permit their content to be played on PCs without trusted computing technology, by not providing the companies making software players for non-trusted PCs with the needed encryption keys.

On April 16, 2007, the AACS consortium announced that it had expired certain encryption keys used by PC-based applications. Patches were available for WinDVD and PowerDVD which used new and uncompromised encryption keys. The old, compromised keys can still be used to decrypt old titles, but not newer releases as they will be encrypted with these new keys. All users of the affected players (even those considered "legitimate" by the AACS LA) are forced to upgrade or replace their player software in order to view new titles.

Despite all revocations, current titles can be decrypted using new MKB v7, v9 or v10 keys widely available in the internet.

Besides spreading *processing keys* on the Internet, there have also been efforts to spread *title keys* on various sites. The AACS LA has sent DMCA takedown notices to such sites on at least one occasion. There is also commercial software (AnyDVD HD) that can circumvent the AACS protection. Apparently this program works even with movies released after the AACS LA expired the first batch of keys.

Patent challenges

On May 30, 2007, Canadian encryption vendor Certicom sued Sony alleging that AACS violated two of its patents, "Strengthened public key protocol" and "Digital signatures on a Smartcard." The patents were filed in 1999 and 2001 respectively and in 2003 the National Security Agency paid $25 million for the right to use 26 of Certicom's patents, including the two that Sony is alleged to have infringed on.

Trivia

- While great care has been taken with AACS to ensure that contents are encrypted right up to the display device, on the first versions of some Blu-ray and HD DVD software players a perfect copy of any still frame from a film could be made simply by utilizing the Print Screen function of the Windows operating system. This was broken in later versions.