Blu-ray Disc (**BD**) is an optical disc storage medium designed to supersede the DVD format. The plastic disc is 120 mm in diameter and 1.2 mm thick, the same size as DVDs and CDs. Conventional (pre-BD-XL) Blu-ray Discs contain 25 GB per layer, with dual layer discs (50 GB) being the industry standard for feature-length video discs. Triple layer discs (100 GB) and quadruple layers (150 GB) are available for *BD-XL* re-writer drive-.The name *Blu-ray Disc* refers to the blue laser used to read the disc, which allows information to be stored at a greater density than is possible with the longer-wavelength red laser used for DVDs. The major application of Blu-ray Discs is as a medium for video material such as feature films. Besides the hardware specifications, Blu-ray Disc is associated with a set of multimedia formats. Generally, these formats allow for the video and audio to be stored with greater definition than on DVD.

The format was developed by the Blu-ray Disc Association, a group representing makers of consumer electronics, computer hardware, and motion pictures. The first Blu-ray Disc prototypes were unveiled in October 2000, and the first prototype player was released in April 2003 in Japan. Afterwards, it continued to be developed until its official release in June 2006. As of June 2011, more than 2,500 Blu-ray Disc titles were available in Australia and the United Kingdom, with 3,500 in the United States and Canada.[4] In Japan, as of July 2010, more than 3,300 titles have been 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 2006 releasing its own Blu-ray Disc player in late 2009.

History

A blank rewritable Blu-ray Disc (BD-RE).

Origins

The information density of the DVD format was limited by the wavelength of the laser diodes used. Following protracted development, blue laser diodes operating at 405 nanometers became available on a production basis. Sony started two projects in collaboration with Philips 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 by Sony. 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 $3,800 (US) 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 an ultra-hard yet very thin coating polymer for Blu-ray Discs; this was a significant technical advance because a far tougher protection was desired in the consumer market to protect bare disks against scratching and damage compared to DVD, while technically Blu-ray Disc required a much *thinner* layer for the denser and higher frequency blue laser. 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 (e.g. Sony BDP-S1) 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*.[26] 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 formats were introduced in September 2006. The first movies using 50 GB dual-layer discs were introduced in October 2006. The first audio-only albums were released in May 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.

Competition from HD DVD

Main article: High definition optical disc format war

The DVD Forum, chaired by Toshiba, was split over whether to develop the more expensive blue laser technology. In March 2002, the forum approved a proposal endorsed by Warner Bros. and other motion picture studios that involved compressing HD content onto dual-layer standard DVD-9 discs.[32][33] In spite of this decision, however, the DVD Forum's Steering Committee announced in April that it was pursuing its own blue-laser high-definition video solution. In August, Toshiba and NEC announced their competing standard, Advanced Optical Disc. It was finally adopted by the DVD Forum and renamed HD DVD the next year, after being voted down twice by DVD Forum members who were also Blu-ray Disc Association members—a situation that drew preliminary investigations by the U.S. Department of Justice.

HD DVD had a head start in the high-definition video market, as Blu-ray Disc sales were slow to gain market share. The first Blu-ray Disc player was perceived as expensive and buggy, and there were few titles available.

The appearance of the Sony PlayStation 3, which contained a Blu-ray Disc player for primary storage, helped turn the tide. Sony also ran a more thorough and influential marketing campaign for the format. 2006 also saw the launch of AVCHD camcorders, whose recordings can be played back on many Blu-ray Disc players without re-encoding, but not on HD DVD players.

By January 2007, Blu-ray Discs had outsold HD DVDs, and during the first three quarters of 2007, BD outsold HD DVD by about two to one. At CES 2007, Warner proposed Total Hi Def—a hybrid disc containing Blu-ray on one side and HD DVD on the other, but it was never released.

In a June 28, 2007 press release, the Twentieth Century Fox cited Blu-ray Disc's adoption of the BD+ anticopying system as key to their decision to support the Blu-ray Disc format.

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, Walmart, and Circuit City and Canadian chains such as Future Shop dropping HD DVD in their stores. A then major European retailer, Woolworths, dropped HD DVD from its inventory. Netflix and Blockbuster—major DVD rental companies—said they would no longer carry HD DVD.

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 supported Blu-ray.

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. 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) sold in the U.S. had reached 28.5 million by the end of 2010.

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.[58] 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 that 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.

Ongoing development

Front of an experimental 200 GB rewritable Blu-ray Disc.

Although the Blu-ray Disc specification has been finalized, engineers continue to work on advancing the technology. By 2005, quad-layer (128 GB) discs had 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 had 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 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. This disc set of the TV series "Code Blue" featured 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 underway to create a 1 TB Blu-ray Disc as soon as 2013.

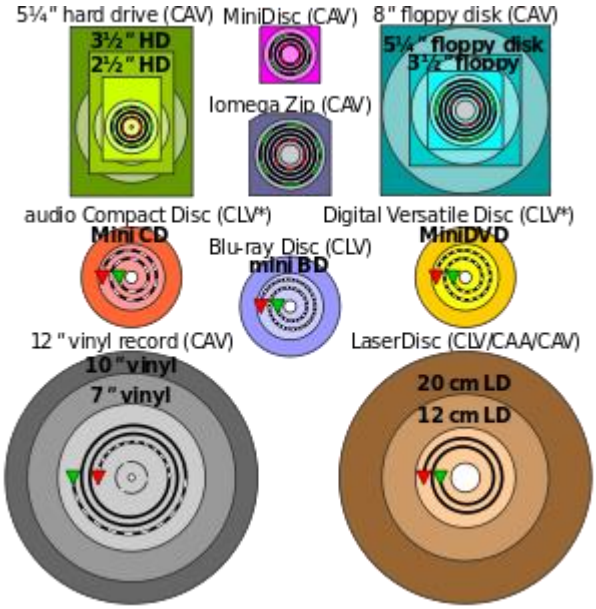
At CES 2009, Panasonic unveiled the DMP-B15, the first portable Blu-ray Disc player, and Sharp introduced the LC-BD60U and LC-BD80U series, the first LCD HDTVs with integrated Blu-ray Disc players. Sharp has also announced that they will sell HDTVs with integrated Blu-ray Disc recorders in the United States by the end of 2009. Set-top box recorders are not being sold in the U.S. due to fears of piracy. However, personal computers with Blu-ray recorder drives are available.

On January 1, 2010, Sony, in association with Panasonic, announced plans to increase the storage capacity on their Blu-ray Discs from 25 GB 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, although in 2010 Blu-ray.com reported that "it will likely happen sometime later this year."

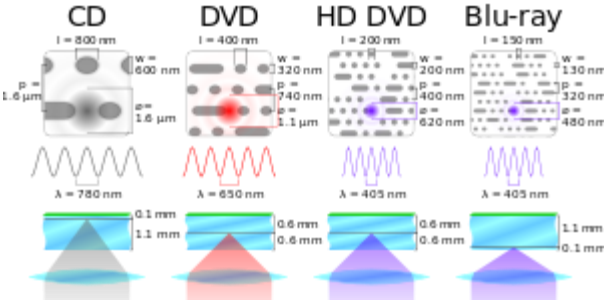
On July 20, 2010, the research team of Sony and Japanese Tohoku University announced the joint development of a blue-violet laser,which will help in creating Blu-ray discs with a capacity of 1 TB using only two layers (and potentially more than 1 TB with additional layering). By comparison, the first blue laser was invented in 1996, with the first prototype discs coming four years later.

On January 14, 2013, Blu-ray Disc Association president Andy Parsons stated that a task force created three months ago is studying an extension to the Blu-ray Disc specification that would add support for 4K Ultra HD video.

Physical media



Comparison of several forms of disk storage showing tracks (not-to-scale); green denotes start and red denotes end.
* Some CD-R(W) and DVD-R(W)/DVD+R(W) recorders operate in ZCLV, CAA or CAV modes.



Comparison of various optical storage media

Type	Diameter (cm)	Layers	Capacity	
			Bytes	GB
Standard disc size, single layer	12	1	25,025,314,816	25.0
Standard disc size, dual layer	12	2	50,050,629,632	50.1
Standard disc size, XL 3 layer	12	3	100,103,356,416	100.1
Standard disc size, XL 4 layer	12	4	128,001,769,472	128.0
Mini disc size, single layer	8	1	7,791,181,824	7.8
Mini disc size, dual layer	8	2	15,582,363,648	15.6

Laser and optics

While a DVD uses a 650 nm red laser, Blu-ray Disc uses a 405 nm "blue" laser diode. Note that even though the laser is called "blue", its color is actually in the violet range. The smaller beam focuses more precisely, thus enabling it to read information recorded in pits that are less than half the size of those on a DVD, and can consequently be spaced more closely,

resulting in a shorter track pitch, enabling a Blu-ray Disc to hold about five times the amount of information that can be stored on a DVD.

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

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. This allows a reduction of the pit size from 400 nm for DVD to 150 nm for Blu-ray Disc, and of the track pitch from 740 nm to 320 nm. See *Compact Disc* for information on optical discs' physical structure.

In addition to the optical improvements, Blu-ray Discs feature improvements in data encoding that further increase the amount of content that can be stored.

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 technology, called Hard Coat.

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

BD drive speeds

Drive speed	Data rate		~Write time (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
14×	504	63		

Blu-ray Disc recordable

Main article: Blu-ray Disc recordable

"Blu-ray Disc recordable" refers to two optical disc formats that can be recorded with an optical disc recorder. BD-Rs can be written to once, whereas BD-REs can be erased and re-recorded multiple times. The current practical maximum speed for Blu-ray Discs is about 12×. Higher speeds of rotation (10,000+ rpm) cause too much wobble for the discs to be written properly, as with the 20× and 52× maximum speeds, respectively, of standard DVDs and CDs.

Since September 2007, BD-RE is also available in the smaller 8 cm Mini Blu-ray Disc size.

On September 18, 2007, Pioneer and Mitsubishi codeveloped BD-R LTH ("Low to High" in groove recording), which features an organic dye recording layer that can be manufactured by modifying existing CD-R and DVD-R production equipment, significantly reducing manufacturing costs. In February 2008, Taiyo Yuden, Mitsubishi, and Maxell released the first BD-R LTH Discs, and in March 2008, Sony's PlayStation 3 gained official support for BD-R LTH Discs with the 2.20 firmware update. In May 2009 Verbatim/Mitsubishi announced the industry's first 6X BD-R LTH media, which allows recording a 25 GB disc in about 16 minutes.

Unlike the previous releases of 120 mm optical discs (i.e., CDs and standard DVDs), Blu-ray recorders hit the market almost simultaneously with Blu-ray's debut.

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

100 GB BDXL Triple layer disc made by Sharp

The BDXL format supports 100 GB and 128 GB write-once discs and 100 GB 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 2× and 4×, capable of 100/128 GB 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 2× and 4×, capable of 100 GB and usage of UDF2.5 as file system.

BDXL discs are not compatible with existing BD drives, though a firmware update may be available for some newer drives.

IH-BD

The IH-BD (Intra-Hybrid Blu-ray) format includes a 25 GB write-once layer (BD-R) and a 25 GB 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 the 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 the digital recording of High-definition television (HDTV) broadcast television. 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. These optical disc recording technologies 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 computer file system have been specified in *System Description Blu-ray Rewritable Disc Format part 2 File System Specifications version 1.0* (BDFS).[94]

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.

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). Windows Media Player does not come with the codecs required to play Blu-ray discs.

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 59.94 frames per second at a resolution of 1280×720 pixels.

Resolution	Frame rate	Aspect ratio
1920×1080	29.97-i	16:9
1920×1080	25-i	16:9
1920×1080	24-p	16:9
1920×1080	23.976-p	16:9
1440×1080	29.97-i	4:3

1440×1080	25-i	4:3
1440×1080	24-p	4:3
1440×1080[1]	23.976-p	4:3
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	29.97-i	4:3 or 16:9
720×576	25-i	4:3 or 16:9

For video, all players are required to support H.262/MPEG-2 Part 2, H.264/MPEG-4 Part 10: AVC, and SMPTE VC-1.[114] MPEG-2 is the compression standard used on regular DVDs, which allows backwards compatibility. MPEG-4 AVC was developed by MPEG, Sony, and VCEG. VC-1 is a compression standard that was mainly developed by Microsoft. BD-ROM titles with video must store video using one of the three mandatory formats; multiple formats on a single title are allowed.

The choice of formats 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 formats (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 format 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 formats 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 format 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 some of its bonus content. Today, Warner and other studios typically provide bonus content in the video format 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:[118]

LPCM (Lossless)	**Dolby Digital**	**Dolby Digital Plus**	**Dolby TrueHD (Lossless)**	**DTS Digital Surround**	**DTS-HD Master Audio (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).[96][123]
        - RREF (Realtime Recording and Editing Format): a subset of BDMV designed for realtime recording and editing applications.

Java software support

BD-J

At the 2005 JavaOne trade show, it was announced that Sun Microsystems' Java cross-platform software environment would be included in all Blu-ray Disc players as a mandatory part of the standard.[124] Java is used to implement interactive menus on Blu-ray Discs, as opposed to the method used on DVD-video discs. DVDs use pre-rendered MPEG segments and selectable subtitle pictures, which are considerably more primitive and rarely seamless. At the conference, Java creator James Gosling suggested that the inclusion of a Java virtual machine, as well as network connectivity in some BD devices, will allow updates to Blu-ray Discs via the Internet, adding content such as additional subtitle languages and promotional features not included on the disc at pressing time. This Java Version is called BD-J and is built on a profile of the Globally Executable MHP (GEM) standard; GEM is the worldwide version of the Multimedia Home Platform standard.

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 of the video-based player profiles (BD-Video) are required to have a full implementation of BD-J, with varying levels of hardware support.

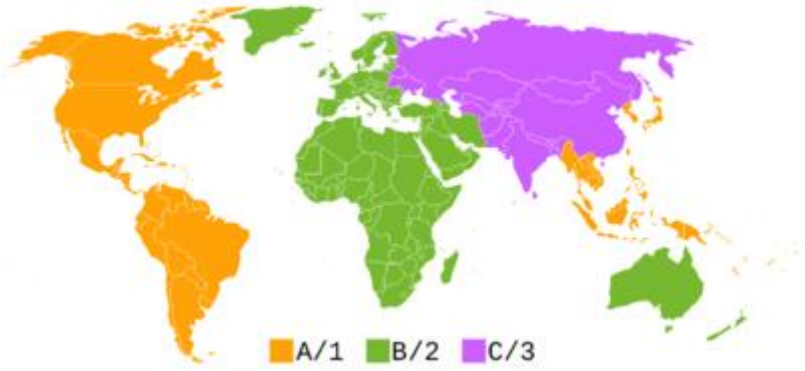
Feature	BD-Audio	BD-Video			
		Grace Period	*Bonus View*	*BD-Live*	*Blu-ray 3D*
	Profile 3.0	Profile 1.0	Profile 1.1	Profile 2.0	Profile 5.0
Built-in persistent memory	No	64 KB	64 KB	64 KB	64 KB?
Local storage capability	No	Optional	256 MB	1 GB	1 GB
Secondary video decoder (PiP)	No	Optional	Mandatory	Mandatory	Mandatory
Secondary audio decoder	No	Optional	Mandatory	Mandatory	Mandatory
Virtual file system	No	Optional	Mandatory	Mandatory	Mandatory
Internet connection capability	No	No	No	Mandatory	Mandatory

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 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 Disc standard:[137]

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 (Belarus, Russia and Ukraine only), 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.) to do effective price differentiation between regions. 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, Warner Bros., Paramount Pictures, Universal Studios, Sony Pictures and Walt Disney Pictures have released most of their titles region-free. MGM and Lions Gate Entertainment have released a mix of region-free and region-coded titles. 20th Century Fox have released most of their titles region-coded.

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

Region code	Area
A	Includes most North, Central and South American and Southeast Asian countries plus Taiwan, Japan, Hong Kong, Macau and Korea.
B	Includes most European countries, African and Southwest Asian countries plus Australia and New Zealand.
C	Includes the remaining central and south Asian countries, as well as 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.

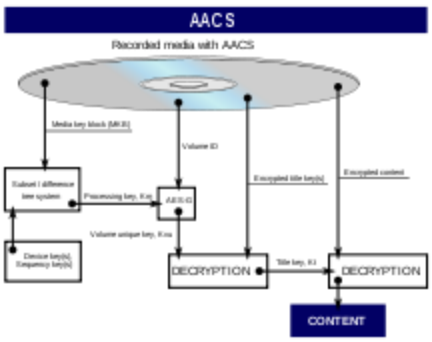
Digital rights management

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

High-bandwidth Digital Content Protection

Blu-ray equipment is required to implement the High-bandwidth Digital Content Protection (HDCP) system to encrypt the data sent by players to rendering devices through physical connections. This is aimed at preventing the copying of copyrighted content as it travels across cables. Through a protocol flag in the media stream called the Image Constraint Token (ICT), a Blu-ray Disc can enforce its reproduction in a lower resolution whenever a full HDCP-compliant link is not used. In order to ease the transition to high definition formats, the adoption of this protection method has been postponed until 2011.

Advanced Access Content System



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 the appearance of the format on devices in 2006, several successful attacks have been made on it. 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.[157][158] Other programs known to be capable of circumventing BD+ protection are DumpHD (versions 0.6 and above, along with some supporting software),[159] MakeMKV,[160] and two applications from DVDFab (Passkey and HD Decrypter[161]).

BD-ROM Mark

BD-ROM Mark is a small amount of cryptographic data that is stored separately from normal Blu-ray Disc data, aiming to prevent replication of the discs. The cryptographic data is needed to decrypt the copyrighted disc content protected by AACS.[162] A specially licensed piece of hardware is required to insert the ROM-Mark into the media during mastering. During replication, this ROM Mark is transferred together with the recorded data to the disc. In consequence, any copies of a disc made with a regular recorder will lack the ROM-Mark data, and will be unreadable on standard players.

AVCHD

AVCHD was originally developed as a high definition format for consumer tapeless camcorders. Derived from the Blu-ray Disc specification, AVCHD shares a similar random access directory structure, but is restricted to lower audio and video bitrates, simpler interactivity, and the use of AVC-video and Dolby AC-3 (or linear PCM) audio.

Being primarily an acquisition format, AVCHD playback is not universally supported by all devices that support Blu-Ray Disc playback. Nevertheless, many such devices are capable of playing AVCHD recordings from removable media, such as DVDs, SD/SDHC memory cards, "Memory Stick" cards, and hard disk drives.

AVCREC

AVCREC uses a BDAV container to record high definition content on conventional DVDs. Presently AVCREC is tightly integrated with the Japanese ISDB broadcast standard and is not marketed outside of Japan. AVCREC is used primarily in set-top digital video recorders and in this regard is comparable to HD REC.

Blu-ray 3D

The 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 December 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. They previously released support for 3D gaming on April 21, 2010 (followed by the availability of 3D movies). Since the version 3.70 software update in August 9, 2011, the PlayStation 3 can support DTS-HD Master Audio and DTS-HD High Resolution Audio while playing 3D Blu-ray. Dolby TrueHD is used on a small minority of Blu-ray 3D releases, and bitstreaming is supported by slim PlayStation 3 models only (fat PS3 models decode internally and send audio as LPCM). It can play 3D Blu-ray content at full 1080p.