Next Generation Disc Mastering with 375 and 405 nm Diode Lasers

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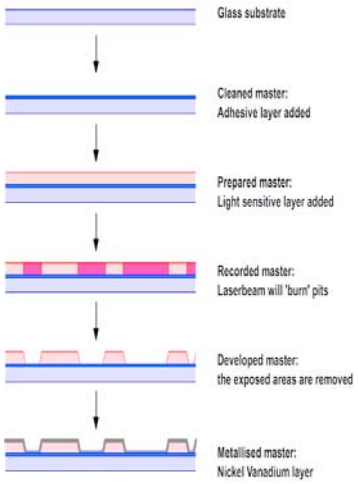
How to define HDTV

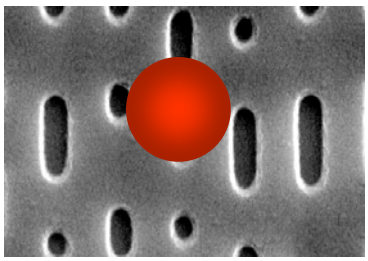
Today's modern high-class TVs usually feature a sticker "HDTV ready". So what is High-Definition TeleVision"? The term denotes the new format of a TV image with improved resolution (up to 1920 x 1080 pixels). To store movies with such resolution and a duration of 2 hours on an optical disc, the capacity of a common DVD is no longer sufficient. That's why film studios and disc manufacturers started production of next generation optical discs, called Blu-ray Disc and HD DVD. These formats increase the data capacity of the former DVD by a factor of 3 to 5 and the discs are read out by violet laser light (see table 1).

	CD	DVD	BD / HD DVD
Capacity (SL)	780 MB	4.7 GB	25 / 15 GB
Substrate	1.2 mm	2x 0.6 mm	1.5 + 0.1 mm 2 x 0.6 mm
Read-out wavelength	780 nm	650 nm	405 nm
Mastering wavelength	405 nm	405 nm	266 or 375 nm
Track pitch	1.2 micron	0.74 micron	0.32, 0.4 micron
Pit width	810 nm	400 nm	160 nm

Table 1



Picture 1: Steps of standard mastering process

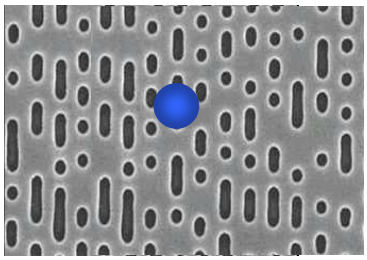


Picture 2: Red laser spot (650 nm) on DVD pits

Basics of disc manufacturing

How are such discs made? First of all, the content (e.g. a movie) needs to be converted from a computer file into a physical "shape" – a digitized pattern of pits (units of information) which encodes the movie images and sounds. Second, this shape is transferred into a so-called stamper, a casting mold which acts as the negative counterpart of the future pit structure on the disc. Third, hot liquid plastic (polycarbonate) is injected into the casting and molded. Such molded plastic shapes form the optical discs. A single substrate for CD and BD, two substrates bonded together for DVD and HD DVD. Subsequently, the plastic shape receives a partial Iin case of dual

layer) or fully reflective coating (e.g. Aluminum for total reflection) on top of the information layer. Finally, multiple layers are glued together to generate the standard thickness of 1.2 mm. In case of Blu-ray Discs, the substrate is covered with a 0.1 mm cover layer on which a protection coating is added.



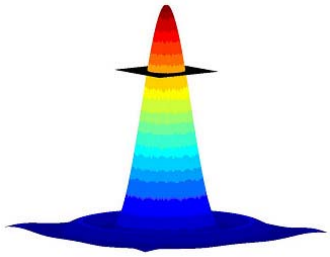
Picture 3: Violet laser spot (405 nm) on Blu-ray disc

What is Mastering?

Mastering comprises steps one and two explained above. At step one, a thin layer of photo resist is coated on an extremely flat glass substrate. A modulated focussed laser beam then exposes certain areas of the disc (picture 1) along a spiral track.
Next, the substrate is developed, thus removing all unexposed resist. Now the pit structure is present in the photoresis layer. In order to make the stamper using a galvanic process, a thin layer of Nickel is sputtered on the photo-resist. This forms the conductor on which the stamper is grown. (picture 1).

Mastering of next generation discs

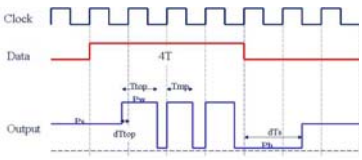
CD and DVD are read out by near-infra red (780 nm) or red (650 nm) laser light, respectively (table 1). When the laser beam is focused on the disc, the focus diameter is always larger than the width of the information pits (pictures 2 and 3). Adjacent tracks are read out as well (cross-talk), but this disturbing effect is corrected by sophisticated electronics. Mastering consequently requires a shorter laser wavelength with smaller focus than the read-out process in order to structure tiny pit dimensions or needs to make use of a high contrast process resulting in the same pit dimensions (PTM, Phase Transistion Mastering).



Picture 4: Threshold process of PTM

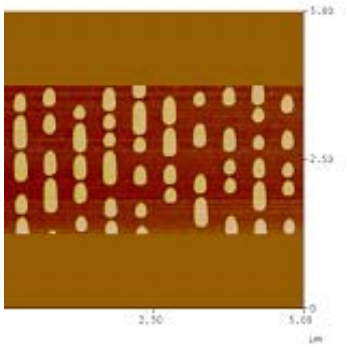
Which laser fits best

As Blu-ray and HD DVD are read out at 405 nm, the wavelength for mastering using the photo resist process needs to be in the UV range. However, not every UV laser lends itself for this task:



Picture 5: Waveshaping for PTM

- Excimer lasers do not provide suitable beam quality.
- Frequency-converted gas lasers (e.g. doubled Argon lasers) provide good beam quality, but have a low electrical to optical efficiency. Moreover, they require large space and are costly (the applicant has to purchase the high power laser plus second harmonic generation stage).
- Frequency-converted solid-state lasers (e.g. quadrupled Nd:YAG 266 nm) also provide good beam quality, but are also too expensive.
- Diode lasers at 375 nm provide a good beam profile and suitable power at moderate costs. In particular, no conversion stage is required.

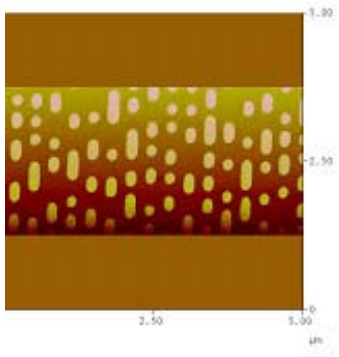


Picture 6a: tear shaped pits on PTM without waveshaping

Initially, 266 nm lasers or 257 nm lasers were used to master the first HD DVD or Blu-ray discs. The spot size of the 375 nm lasers is at the edge of what is required to perform mastering of HD DVD using the common photochemical process. This means a small process window and requires a very tight process and environment control.

When using the PTM (Phase Transistion Mastering) the situation changes dramatically.

Phase Transition Mastering
PTM is a method to generate smaller structures on a substrate using heat instead of light.
In conventional mastering, laser light induces / triggers a photo-chemical conversion process of an organic resist. Laser spot size and converted resist spot are approximately equal in size.
PTM, however, initiates a heat-triggered conversion of inorganic resist from the amorphous to the crystalline phase. Only the small center of the laser spot deposits enough energy to trigger this heat-related process (picture 4). Thus, the pit structure is smaller at PTM than in conventional mastering. This results in high contrast, allows recording of both HD DVD and BD with the 375nm or even the 405 nm wavelength laser.
In combination with PTM, 405 nm light becomes suitable for Blu-ray and HD DVD mastering. The market leader in mastering systems (picture 7), SINGULUS MASTERING joined forces with TOPTICA to tailor the 375 and 405 nm diode modules for this application.



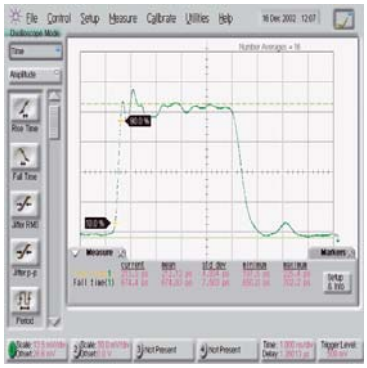
Picture 6b: correctly tear shaped pits on PTM with waveshaping

Picture 7: Modern DVD mastering systems from Singulus

However, this thermal effect also requires special measures in order to correct the different response to the laser energy (picture 6a and 6b). This, so-called “wave shaping”, has to be applied for the different behaviour of the thermal process. (picture 5). The iPulse 405 with multi level output has become the ultimate tool to do that.

Requirements of PTM disc mastering
Due to the steep threshold curve at PTM, laser stability parameters are even more crucial for Blu-ray and HD DVD than for standard mastering process:

- Lowest jitter value. The shortest Blu-ray pit length is 138 – 160 nm. Jitter can change length, start and end position of the pit.
- Beam quality. Specifying an M^2 value is no longer sufficient as this parameter comprises several causes of aberration (coma, defocus, astigmatism). Only a wavefront measurement determines whether a laser beam is suitable or not.
- Multi-power level imaging for pit shaping. By applying different laser power levels, the pit shape on the disc can be optimized for best read-out of the disc.
- Beam pointing stability. The distance between two adjacent tracks (“track pitch”) is 320 to 400 nm for Blu-ray resp. HD DVD. Even minute beam walk results in a worthless stamper.
- Power stability. Any power fluctuation immediately results in varying pit width due to the heat process of the PTM.



Picture 8: iPulse digital power modulation. Ultrafast rise and fall time in the nanosecond regime

Further advantageous characteristics are inherent to diode lasers:

- No vibrations are generated. Contrary to gas lasers with huge chillers or ventilation systems, diode lasers are cooled by Peltier elements. The absence of vibrations ensures good beam propagation along the photo resist.

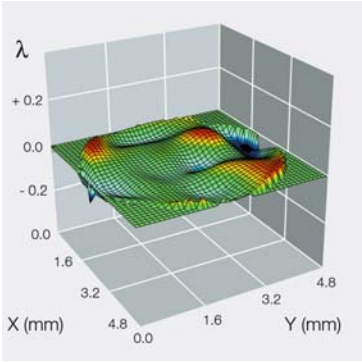
- No frequency conversion stage is required for 375 nm. There is no need to generate, and filter out, excessive IR power to compensate for low conversion efficiencies.
- Energy consumption. 375 nm and 405 nm diode modules require some Watts whereas DPSSL and gas lasers consume kiloWatts (external cooling, fundamental power > 200 mW)

The benefits of the iPulse
TOPTICA gained considerable experience in mastering with the previous violet laser system PVLS. Today the successor iPulse addresses the needs of Blu-ray and HD DVD mastering:

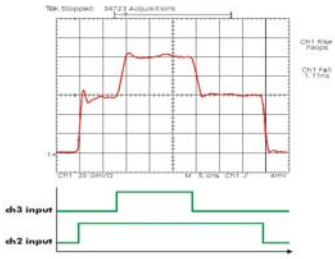
- Shortest pulse rise and fall times (approx. 1 ns, picture 8) and lowest pulse-to-pulse jitter (sub-ns range) prevent jitter on the replica disc.
- The wavefront error of iPulse 375 and iPulse 405 is less than 0.05 lambda (picture 9). Practically, this is a diffraction-limited beam.
- Multi-power level operation. The iPulse offers additional power levels (picture 10), which can be addressed by software command in the field.
- Superb beam pointing stability (drift < 10 µrad/°C). The integrated Peltier element ensures a temperature stability of <0.05 °C, resulting in a drift below 1 µrad.
- Best power stability (power drift < 0.5% over 48 hours, picture 11). Thus, pit width and subsequent read-out signal of the disc remain extremely constant.
- Typical power consumption of iPulse is only 12 Watts.

Additionally, an integrated external photo diode monitors long-term power drifts, or even aging effects of the laser diode itself. The laser diode's end of life can thus be predicted and exchange of laser module can be planned and arranged alongside with an intended service interval. As the diode exceeds lifetimes of 10.000 hours, such exchanges are literally seldom.

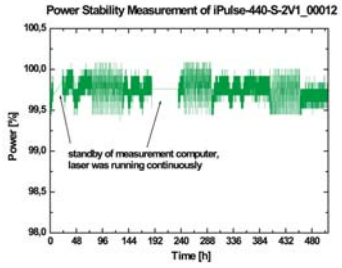
TOPTICA has a quasi exclusive partnership with the market leader SINGULUS and equipped both DVD and HD/BD mastering systems with its dedicated pulsed lasers.



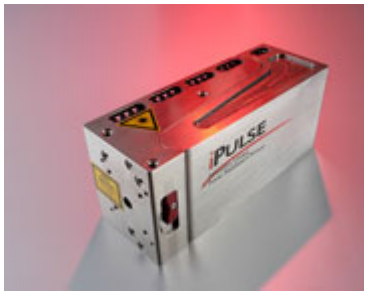
Picture 9: wavefront measurement of iPulse profile



Picture 10: multi-level power operation



Picture 11: iPulse power stability (480 hours)



Picture 12: iPulse laser system