Effects of different NA Optics for +R and -R on DVDR Testing - Part I

By
Dr. Wlodek S. Mischke, Business Development Manager, DaTARIUS Group,
& Bob Dobbin, CTO DaTARIUS Group

Introduction

DVD+R and DVD-R have different optics specified. The most significant difference is the specification for Numerical Aperture (NA), and there are other differences, such as for Rim Intensity. Dr. Wlodek Mischke of DaTARIUS has undertaken studies both of the theoretical results that should be expected on measuring devices due to the specification differences, and whether experimental results match theory.

Presented here, in part 1 of 2 of the results of these studies is a description of NA, the specification differences, the basis of the theoretical modelling, the theoretical results, a preview of the experimental results, and a discussion of the effect of these results on the testing of DVDR discs.

NA

Numerical Aperture (NA) is a parameter used to define the focusing properties of an objective lens in an optical system. It is described by the formula $NA = n \cdot \sin \alpha$, where α is the angle between the outermost rays passing through the lens and the axis of the lens, and n is the refractive index of the medium in which the light is focused. NA determines the focal distance for the lens, the size (focused waist) of the focused spot, focal depth, tolerance for tilt, and tolerance for disc thickness.

Table 1

Property	***Proportionality factor***	***NA0.65 / NA0.60***
Focused Spot Size	λ / NA	0.92
Focus Depth	λ / NA^2	0.85
Tilt Margin	λ / NA^3	0.79
Disc Thickness Tolerance	λ / NA^4	0.73

Table 1 shows the relative differences in these parameters between NA of 0.60 and NA of 0.65.

One reason to use the higher NA is that the focused spot is smaller, so that smaller marks on the disc can be resolved, and more data can be stored on the disc. Other considerations include the fact that for blank media, the narrower spot diameter from the 0.65 NA optics, coupled with the lower rim intensities, should return a higher value for the push-pull signal during tracking, and should also facilitate recording of more refined pits with better jitter.
The tradeoffs are the more strict tolerances to manufacturing deviations which are the results of relations shown in the table 1.
An NA of 0.60 is specified for recording DVD-R, 0.65 NA is specified for recording DVD+R, 0.60 NA is specified for playback of DVD-ROM, and, by extension, the playback of recorded DVD-R and recorded DVD+R. Therefore it would appear that, to test discs according to spec, 0.60 NA should be used to test blank DVD-R and recorded DVD-R and DVD+R, and 0.65 NA should be used to test blank DVD+R. However, to further confuse matters, most (if not all) commercial DVD-R recorders currently use 0.65 NA for recording and reading, as do DVD+R recorders.
The purpose of this investigation, then, is to determine what differences can be expected between testing discs using 0.60 NA optics and 0.65 NA optics.

Theoretical Calculations

Several testing measurement parameters were calculated using a scalar diffraction modelling program. The three cases shown in Table 2 were modelled.

Table 2

Property	***Case 1***	***Case 2***	***Case 3***
Numerical Aperture of lens	0.65 ± 0.01	0.60 ± 0.01	0.60 ± 0.01
Entrance Aperture of the lens	3.6 mm	3.6 mm	3.6 mm
Wavelength of light	655 nm	650 nm	650 nm
Polarization of light	Circular	Circular	Circular
Rim Intensity – Radial	42% (35-50%)	> 40%	65% (60-70%)
Rim Intensity – Tangential	53% (45-60%)	> 50%	> 90%
Laser Power	0.7 mW	0.7 mW	0.7 mW

Other modelling parameters were held constant for the three cases. These parameters include such items as groove width, height, wall angles, track pitch, dye refractive index, thickness, etc. For details about the modelling parameters, please contact the author.
Common testing measurement parameters were calculated with the modelling software. For example, Figure 1 shows results from the PPb signal based on the theoretical assumptions.

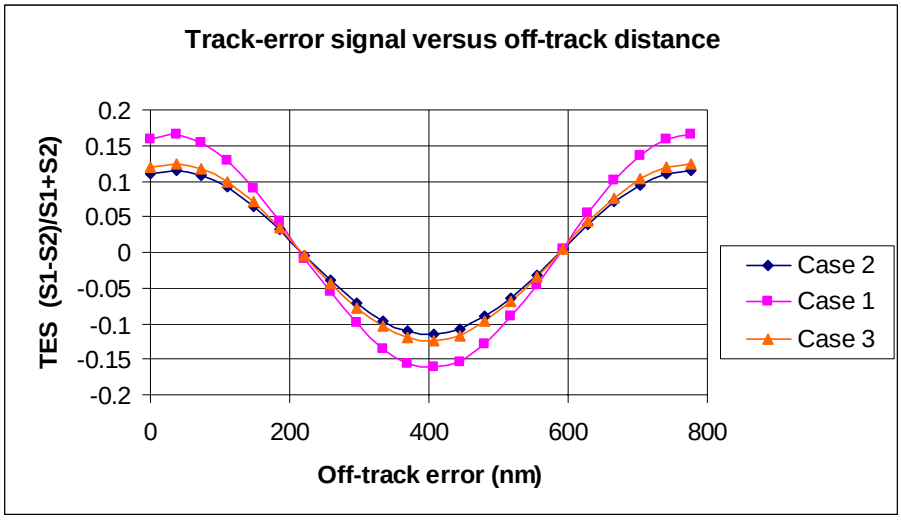

Fig.-1

The results of some of these calculations are summarized in Table 3. As we can see, HF parameters in general are well behaved between the two different NA cases, whereas Tracking signals have higher magnitudes in the case of 0.65 NA.

Table 3

Parameter	**Ratio P_{NA60} / P_{NA65}**
Reflectivity Land (Rl)	0.99
Reflectivity Groove (Rg)	0.99
Track Crossing Signal (TCS)	0.78
Push-Pull Before Recording (PPb)	0.69
Normalized Wobble Signal (NWO)	~1.0
Modulation (I14N)	0.95
Resolution (I3/I14)	0.73

The experimental results, which will be presented in Part II of this article, correlate very well with the above theoretical predictions. The major differences are related to the tracking signals. Note, of course, that sufficient attention must be paid to the fact that while in the theoretical calculations we can adjust as many or as few design criteria as we desire, in the experiments we must use pick-up Heads that are available, and have not only different focusing lenses, but also different optical head design and servo

mechanisms as well. These additional design and mechanical factors also influence the measured values.
The end result, however, is that both the theoretical calculations and the preliminary experimental results seem to indicate that there are some definite similarities and some definite differences between individual measurement parameters. It seems that almost all, however, can be mathematically arbitrarily calibrated to provide matching values independent of which NA optics are used to measure them.

Testing considerations

There are five considerations about testing DVDR which must be evaluated with the above data. The question which is necessary to investigate is "With which NA tester should DVDRs be tested?"
1) `Spec Compliance'. As mentioned above, the DVD-R specification requires 0.60 NA for testing both blank and recorded discs, while the DVD+R specification indicates 0.65 for blank and 0.60 for recorded discs.
2) 'Consumer Compliance.' This consideration refers to the migration that DVD-R and 'combi' drive manufacturers are making from 0.60 to 0.65 for all recordable discs. Manufacturers have always lost the argument that their discs are 'in spec' when facing a dissatisfied customer whose discs don't work in real-world situations.
3) Easy Signals. Some of the parameters measured on the discs, such as reflectivity, match very well between 0.60 and 0.65 measuring devices. Even without calibration, either NA tester can measure these parameters well, and there is no issue.
4) Correlateable Signals. Other tester parameters show differences between the two NAs. For the most part, these signals can be made to match each other through appropriate arbitrary mathematical calibration. For example, PP can be seen to be generally around 30% lower on 0.60 NA drives than on 0.65 NA drives, and can be calibrated fairly straightforwardly. Other parameters, such as HF Asymmetry, require more elaborate calibration. However, the very act of calibrating implies that the measurement values can be made close, but not exact, and that there are always outlier discs, which do not match the calibration assumptions.
5) Tester-Disc Playability. One last item is the fact that DVDR testers have to test good discs as well as bad ones. If a manufacturer produces a disc that fails in a consumer player, he needs more information than just the failure itself to be able to determine what he needs to fix in his process. One of the main failure modes concerns the tracking of blank DVDRs due to low PPb. Obviously there will be cases of blank discs with low PPb that can be played, and tested, in 0.65 NA drives, but cannot be played, or be tested, in 0.60 NA drives. It is also worth noting that for the latter case, playability is particularly critical with a drive with 0.60 NA using the single laser beam method of groove tracking (where PP is used). Ironically is the most usual type of drive used for DVDR approval.

Conclusion

There are obviously pros and cons for both the case of testing DVDR discs with 0.60 NA and with 0.65 NA testers. There are also the conflicts between Spec Compliance and Consumer Compliance, and between Spec Compliance and Tester-Disc Playability.
The good news is that it appears that either NA tester can yield usable results with proper and sufficient mathematical calibration. The only cautionary point being is that single beam 0.60NA drives can have difficulty tracking blank discs that can lead to erroneous results.
For now, the only conclusion, and the best recommendation, is that manufacturers ensure that their options are open by having the capability to test their DVDRs with both types of optics.
Detailed experimental results to follow in Part II.

** The author would like to acknowledge and thank Philips Optical Storage for discussion about the differences in signals and support in experimental data.*

DaTARIUS Corporate Information
DaTARIUS is a world-leading supplier of test equipment, not just proving but also improving optical media quality through comprehensive products and services embracing process optimization. Our Analyzers and Evaluators support all formats: pre-recorded, recordable, and rewritable, and our revolutionary DaTABANK technology is fully Blu-ray disc (BD) and HD-DVD enabled. Complementing these testers: optimization, including our MF DisCo temperature regulator; and inspection, with print label, disc orientation and ident code validation. We also

offer extensive training through our service and test centres worldwide. For the past 18 years DaTARIUS has been at the forefront of optical media technology with our commitment to the future of the industry and our customers.

For more information on the company and its products, visit www.DaTARIUS.com