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A Complete Study of Differential Wax-wane Focus Servo Technique

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ABSTRACT

We present a thorough study of differential wax-wane focus servo technique including effects of aberration and cancellation of crosstalk.

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Summary

We concentrate on differential wax-wane focus servo technique[1] that is insensitive to many of the errors found in other schemes. Servo optics are illustrated in Figure 1. The beam reflected from optical disk is focused by the detector lens onto two detectors, detector 1 is slightly inside focus, and detector 2 is slightly beyond focus. The quad detector is offset from the center of the beam to give the FES algebra, where α is an electronic gain factor that can be any number larger than one.

We used scalar diffraction model to study its performance. We studied beam propagation in the optical system, the focus error signal, the detector alignment tolerance, the tracking error signal and crosstalk. The effect of aberration on the above parameters is modeled in detailed.

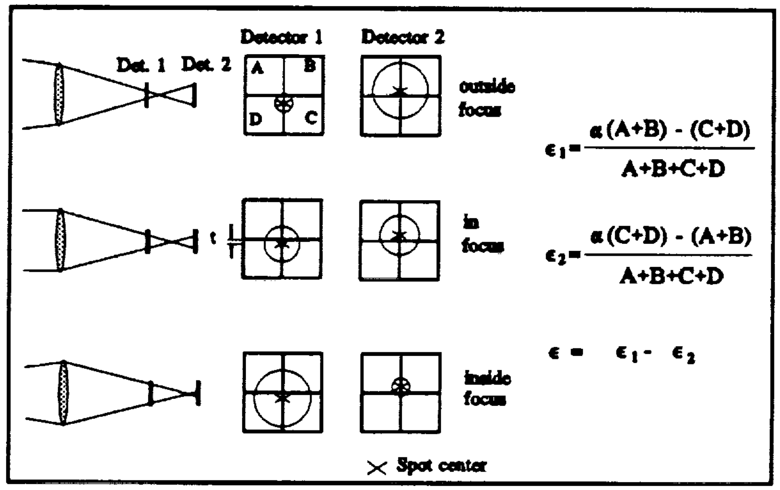

Figure 1 The differential wax-wane focus servo technique. α is an electronic gain factor.

The differential wax-wane technique has several advantages over a single wax-wane focus servo technique. The gain is two times higher, the lock-on-range is better defined, and the linearity is ten times better in terms of *RMS* deviation. It is also insensitive to track rotation and disk tilt.

One important performance parameter is sensitivity to *pattern noise*, which is a false focus error caused by small changes in the spatial distribution of optical power on the detectors. The most common type of pattern noise is due to diffraction from tracks. It is also referred as tracking crosstalk.

The effect of aberration varies depending on where the aberration is introduced and what kind of aberration it is. The focus offset in differential channel is the same as in a single channel. Crosstalk, change of gain, and nonlinearity are improved in the differential channel. $W_{222}(\perp)$ and $W_{131}(\perp)$ generate no focus offset and don't change the gain or linearity, but they change the amplitude and phase of track crosstalk significantly. $W_{131}(\parallel)$ has minimal effect on any parameter if it is disk aberration, but changes focus offset, gain, and crosstalk amplitude if it is source or detection-optics aberration. The most significant effect of $W_{222}(\parallel)$ and W_{040} is the focus offset.

The case of combined aberrations (in which we measured the aberrations on our optical system) generates a large focus offset that is a strong function of the electronic gain factor α. There is about 0.7 μm of track crosstalk in a single channel, and the amplitude and phase are different between the two individual channels. Thus, crosstalk is not canceled in differential channel. The crosstalk amplitude of individual channels differs by a factor of about 2, and the relative phase is also different. Total cancellation is not achieved in the differential FES. However, we found that, by rotating the detector, the phase of crosstalk can be adjusted so that the individual crosstalks are 90° out of phase with the tracking signal. T. crosstalk phase of detector 1 is then the same as detector 2. We can also change the electronic gain to compensate for the amplitude differences. By reducing the electronic gain of detector 1 by a factor of 2, the crosstalk amplitude become the same. The crosstalk in the differential channel is canceled very well. Theoretically, the crosstalk can be reduced to zero by fine tuning the electronic gain factor and rotating the quad detectors. The residual crosstalk is less than 0.1 μm. Figure 3 shows the measured crosstalk. Note that, by changing the electronic gain, the differential FES is $\epsilon = \epsilon_1/2 - \epsilon_2$.

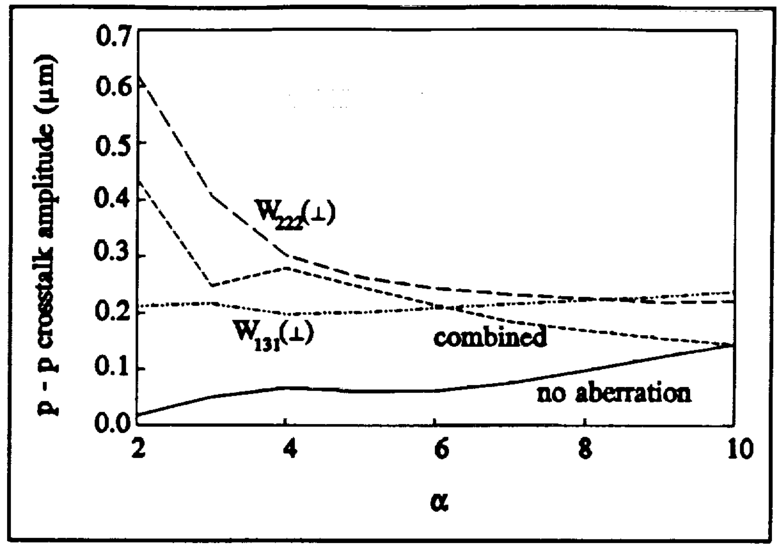

Figure 2 Crosstalk amplitude as a function of the electronic gain factor α when various aberrations are present in the optical system.

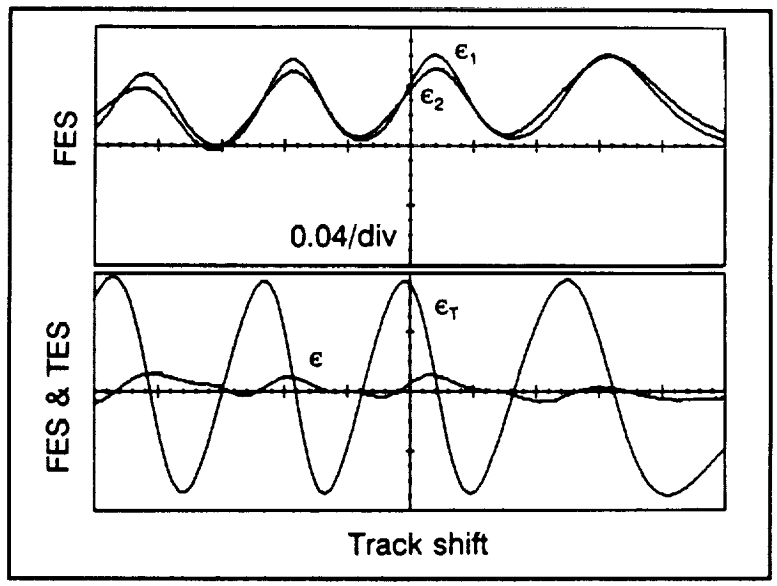

Figure 3 Measured FES crosstalk and TES as a function of track shift. $\epsilon = \epsilon_1/2 - \epsilon_2$.

Conclusion: We presented a complete study of the differential wax-wane focus servo technique including both scalar diffraction modeling and experimental measurements. The crosstalk was reduced from 0.7 μm in a single channel to less than 0.1 μm in the optimized differential channel. This gives the differential wax-wane technique a clear advantage over several techniques we compared.

Reference:

1. T. D. Milster, M. S. Wang, F. F. Froehlich, J. L. Kann, J. P. Treptau, and J. K. Erwin, "Differential Spot-Size Focus Servo," Proc. SPIE v. **1499** 348-353 (1991).

APPENDIX I

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