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DYNAMIC TESTBED LABORATORY AND MICRO-OPTICS

T. Milster, K. Erwin, F. Froehlich, J. Kann, W. Li, W. Schlichting, R. Shetty, E. Walker and M. Wang

OBJECTIVES

Objectives of this research are as follows:

Understand the three classes of superresolution and their behavior in optical data storage systems;

Investigate new and improved components and techniques in the optical system for data detection and servo control;

Apply micro-optic components to the optical system to reduce size and weight;

Investigate techniques, such as near-field optical probes, for recording data densities beyond that possible with superresolution; and

Understand and find solutions for problems associated with dynamic testing, especially those that arise when evaluating blue-sensitive media.

PROGRESS

Our group has been very busy in several areas. In this progress report, we highlight some of the accomplishments of this quarter. In particular, we include an extended discussion of the superresolution work with the AMC testbed. We also discuss plans for our near-field optical microscope (NSOM) instrument and some theory that describes the NSOM transfer function. The MCD work is proceeding nicely, our static experiments are complete and a paper is ready for submission.

Theory

Our theoretical work this quarter consisted of continuing to develop a simple model for the NSOM work. We are completing a paper that will be submitted to *Optics Letters* on this subject.

Modeling

In the last several ODSC reports, we have described the effects of superresolution by using a shading band in the collection aperture. Our results indicated that both signal and noise are reduced with the shading band, producing no significant change in the carrier-to-noise ratio (CNR) except at high frequencies. However, the transfer function of the system is changed so that we may be able to take advantage of equalizing the frequency response of the system. A summary of our results has been accepted for presentation at the *ISOM* '93 meeting this summer. Appendix E is a copy of the extended abstract.

We are now studying a modification of the simple shading band described in previous ODSC reports. Our configuration is shown in Fig. 1. We shape the shading band into an "X" that is designed to pass the $\pm$ first diffracted orders at a specific frequency. In Fig. 1, the shading band is designed for around 4 MHz. The portion of the beam blocked by the shading band only contributes noise. The net effect is an increase in the CNR at this frequency. At lower frequencies, some degradation in signal is observed, but the CNR is improved due to the reduced noise. At higher frequencies, the signal is not affected, but the noise is reduced, again improving the CNR. An additional benefit of the X-band shading is that the transfer function of the system can be somewhat equalized. Our scalar diffraction model was used to determine the effect of X-band shading on the signal. The results are plotted in Fig. 2, which indicates a slight improvement in the transfer function with the shading band. In the *Dynamic Testing* section below we discuss our experimental results.

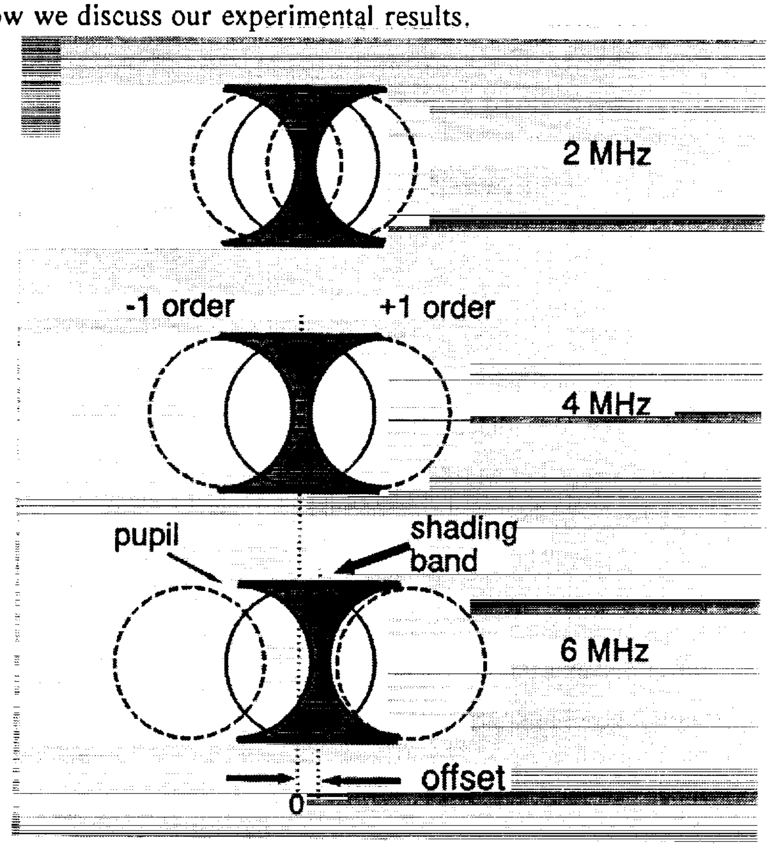


Figure 1. X-band shading. The exit pupil of the optical system used to read out data is shown with the $\pm$ first diffracted orders of the signal. The darkened portion of the picture corresponds to the shading band. This shading band is designed to pass most of the signal power at 4 MHz and block excess noise. At lower frequencies, the shading band blocks some of the signal, but the noise is reduced more, resulting in a net CNR increase. At high frequencies, the signal is not blocked, and the shading band only reduces noise. For our dynamic experiments, we tested the shading band at different offsets in the pupil.

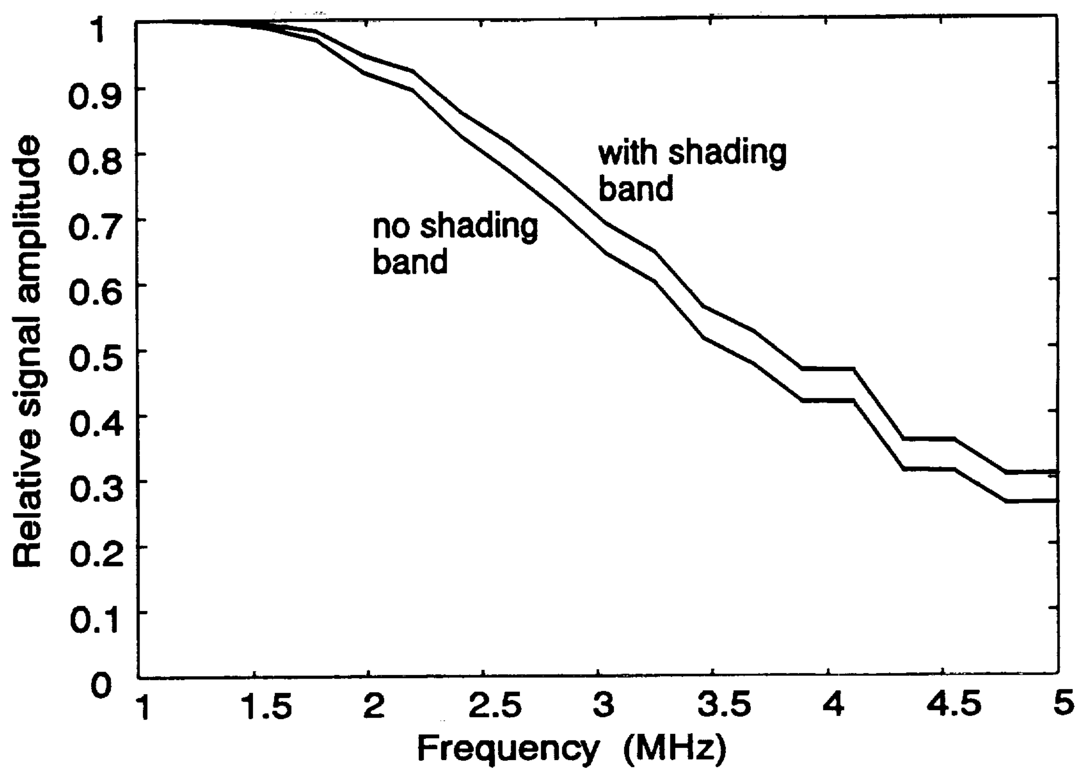
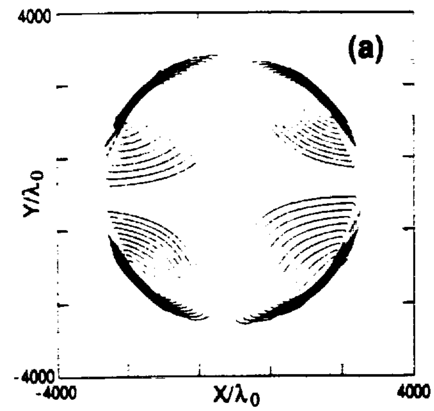


Figure 2. Diffraction model results with and without the X-band shading. A slight improvement in the transfer function is observed when X-band shading is used.

We presented a paper at OPTCON '92 titled "Figures of Merit for Laser Spot Quality," which describes the effects of aberrations on a simple gaussian laser beam that is passed through a diffracting aperture. An interesting observation of Ed Walker's modeling work is that caution should be used when implementing the full-width-at-half-maximum (FWHM) criterion for beam quality because it is very insensitive to aberration. A preprint of the paper appears as Appendix F of this report.

Static Experiments

We are continuing our research program in near-field scanning optical microscopy (NSOM). Fred Froehlich is constructing a sophisticated NSOM instrument to study the application of near-field technology to high-density optical storage. NSOM has been used to write and read MO domains as small as 60 nm (see E. Betzig et al., "Near-field magneto-optics and high density data storage," Appl. Phys. Lett. **61**(2), 1992). Our interest is to analytically model and experimentally characterize the detection of MO domain edges with a near-field tapered fiber-optic probe. WYKO instruments has provided an atomic force microscope (AFM) that we are adapting for NSOM use. Froehlich has submitted the abstract (Appendix G) that will be presented at the ISOM conference this summer.



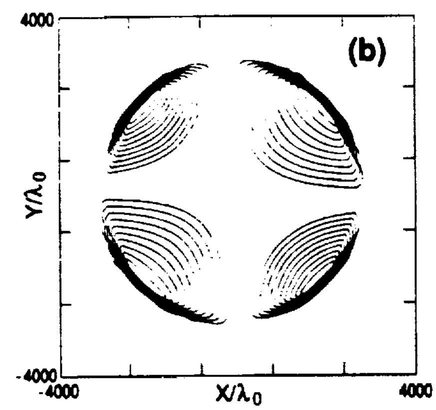


Figure 3. Contour plots of *Iy* for the quadrilayer structure, with the off-diagonal elements of the tensor restored: a) magnetization up; b) magnetization down.

Mark Wang is studying some aspects of superresolution by examining the amplitude and phase of the signal component reflected from MO media. Masud Mansuripur has predicted (Appl. Opt. 30(22), 3154, 1991) that high signal values exist in outer regions of the four quadrants in the pupil, as shown in Fig. 3. Besides trying to experimentally measure this effect, we will try to see the effects of moving the readout spot over a domain edge. The experimental aspects of this problem have proven difficult in the past, but we hope to improve the sensitivity by using a modification of a readout scheme that takes the difference signal optically (Milster and Yao, US Patent No. 4,823,220).

Dynamic Testing

We have configured the AMC testbed for optical equalization experiments, as reported in the December 15, 1992, ODSC report. Weiquan Li and Wang have been performing the tests. Our latest tests are with X-band shading. Figure 4 shows the results for a 3M disk at 3 MHz signal frequency. The graph is plotted versus offset of the shading band (see Fig. 1 for an explanation of offset). At 1.0 mm offset from the center, the CNR increases by about 3 dBm. Improvements in CNR also are observed at other frequencies. The reason that the maximum CNR does not occur in the center of the aperture is that the beam is not centered properly in the testbed. We will report more details on our experiments at the IAB meeting in April.

Wolfgang Schlitching has received an MO disk from Kodak that is optimized for MCD detection. He is evaluating the medium on the dynamic testbed. Since much more light gets back to the detectors with MCD, there are some modifications that need to be made to the electronics to handle the additional power. For example, the focus servo amplifiers saturate during writing and erasing, so their gains must be reduced. Without this adjustment, we can get about 41 dB CNR at low frequencies. More details will be presented at the IAB meeting.

In other dynamic testing news, Wang will be presenting his work on the differential wax-wane focus servo at ISOM '93. (A preprint of his abstract appears as Appendix H). We also are beginning work on the blue-laser head that will be used with the next set of superresolution experiments. These experiments use the air-bearing teststand.

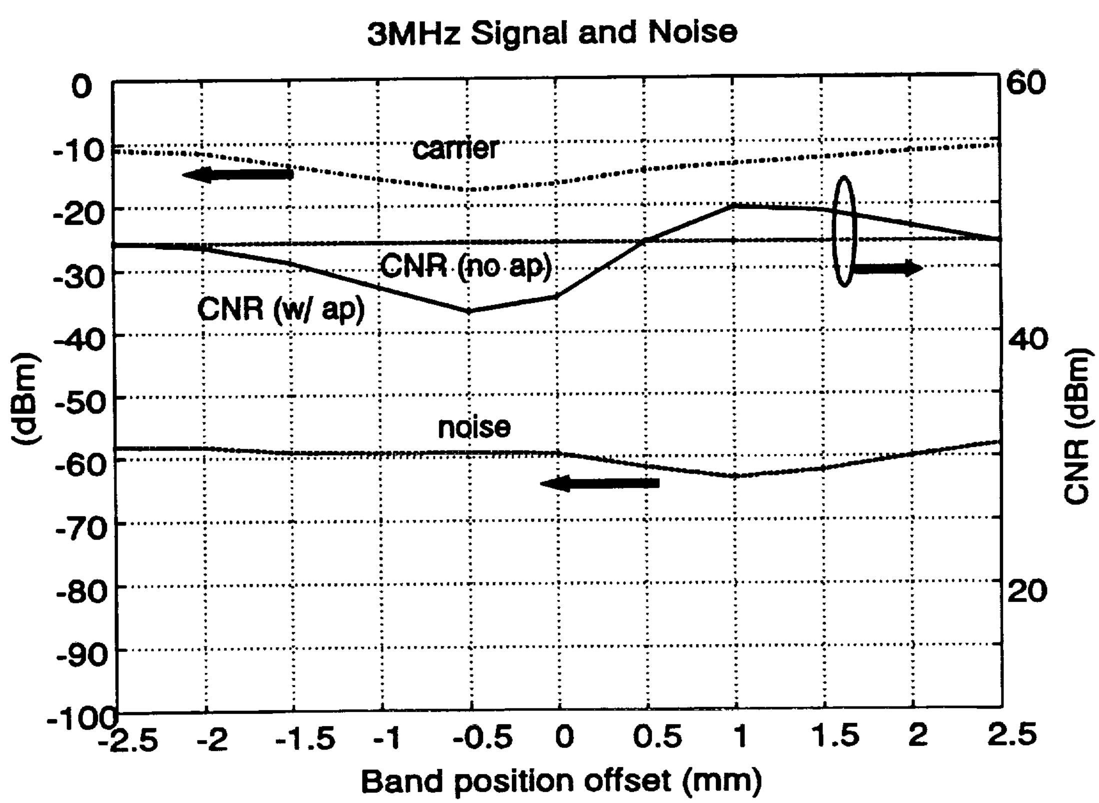


Figure 4. Carrier and noise properties versus X-band shading offset at 3 MHz signal frequency. Notice that the CNR is improved by 3 dB at an offset of 1.0 mm. The offset is necessary due to a slightly decentered beam in the exit pupil of the drive.