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A Near-field Scanning Optical Microscope for Analysis of Magneto-optic Media

Fred F. Froehlich and Tom D. Milster

Optical Sciences Center
University of Arizona
Tucson, AZ 85721

602-621-8263

Abstract

The design of a near-field scanning optical microscope (NSOM) is described. Applications to the study of magneto-optic media and domain detection are discussed.

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The ability to achieve subwavelength optical resolution for microscopy through the use of a mechanically scanned near-field optical probe has recently been reported.[1] This technique provides a means of exceeding the far-field diffraction limit associated with the use of an objective lens in conventional optical microscopy, and is known as near-field scanning optical microscopy (NSOM). The near-field probe may be realized by forming a subwavelength-sized aperture in an opaque screen. Such a probe may be implemented in practice by tapering an optical fiber down to the desired diameter and coating its exterior (except for the very tip) with aluminum. The spatial resolution achieved is dependent on the aperture diameter and the tip-to-sample separation, and the resolution is approximately equal to the aperture diameter for separations less than one aperture radius.

NSOM is capable of providing imagery with polarization contrast and is, therefore, a potentially useful tool for the study and analysis of magneto-optic materials. NSOM also provides a means of performing very high-density MO data storage, and domains as small as 60 nm have been successfully written and detected.[2] High-resolution lithography on a submicron scale has also been demonstrated.[3]

Our NSOM instrument has been designed for the examination of MO thin film samples and is illustrated in Figure 1. The instrument consists of three optical subsystems: a conventional visual polarization microscope, a servo subsystem for maintaining the fiber probe position relative to the sample, and a characterization subsystem for obtaining the MO signal. The sample is mounted on a piezo-driven x-y flexure stage, and characterization is performed in transmission. The probe tip may be coarsely prealigned to sample features, such as domain structures, with the visual subsystem. The visual polarization microscope operates in reflection and consists of the lamp, polarizer, beamsplitter, objective, prism, analyzer, and eyepiece. The servo subsystem regulates the separation (typically less than 20 nm) of the tip and sample with a hybrid shear atomic force/optical technique. A small dither is applied to the fiber tip (parallel to the sample surface), and light from the HeNe laser is scattered from the tip and imaged to the pinhole. The dither produces a modulated signal on the PMT. Atomic forces between the tip and sample perturb the amplitude and phase of the dither, which can be detected and used as a feedback signal to regulate tip position. The characterization subsystem operates at blue wavelengths and generates an MO signal in transmission. Light from the Ar^+ laser is launched into the fiber probe with the aid of waveplates to produce any arbitrary state of incident polarization. The beamsplitter and prism are removed from the visual subsystem, and polarization-sensitive optics detect the signal light as the sample is scanned to create an image.

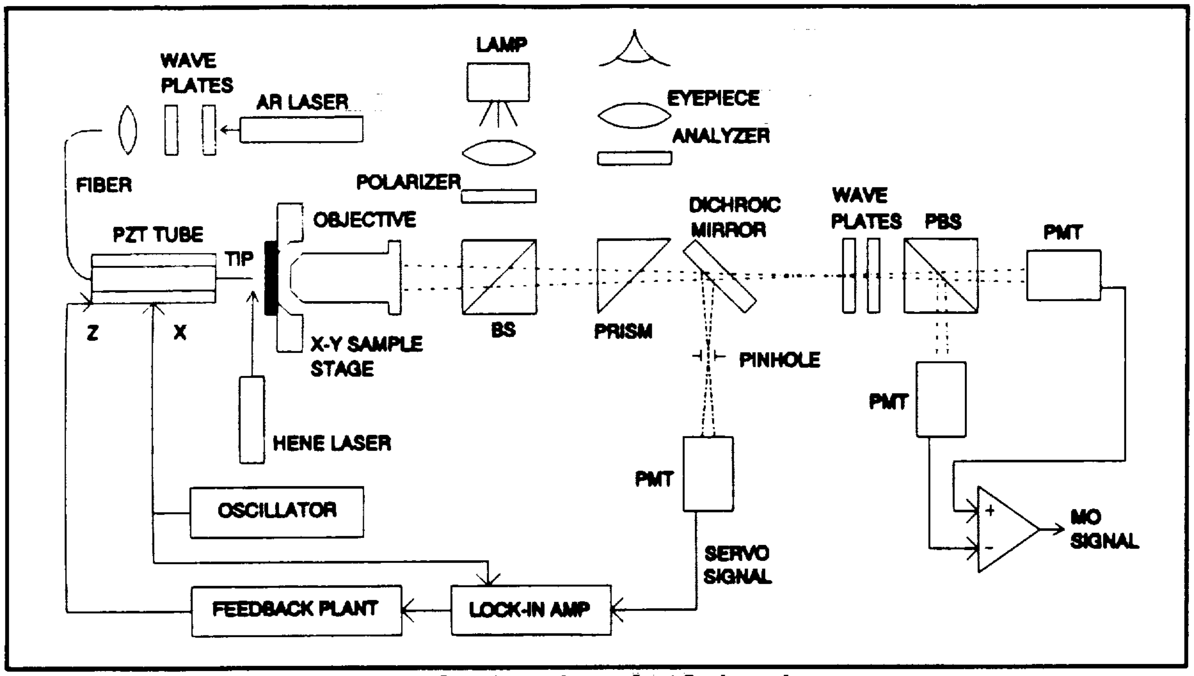

Figure 1. NSOM system layout for detection of MO domain structures.

A typical differential detection scheme is shown consisting of waveplates, a polarizing beamsplitter, two PMTs, and a difference amplifier, but other schemes are possible as well.

The samples used in this study are Co/Pt multilayers prepared by sputtering. The design is 13 bilayers of 3.5 Å Co and 8 Å Pt, yielding a total MO film thickness of 149.5 Å, on a Pyrex substrate. No cover layer is used because the probe tip must be in proximity to the MO layer surface to obtain the resolution afforded by the near-field interaction. Domains were prewritten on the samples by conventional far-field means using an Olympus polarization microscope fitted with a focused laser diode source and an electromagnet.

NSOM may be applied to a variety of studies of MO materials and data storage problems. The high spatial resolution of NSOM (down to 12 nm) can be utilized to study domain wall jaggedness. Depolarization effects due to disk grooves and surface roughness can be examined on a subwavelength scale. The interaction of the near-field probe and MO domain structures can be characterized with various detection schemes. Domain-sensitive methods such as differential detection with linearly polarized light, and edge-sensitive methods using split detectors and circularly polarized light are two techniques of particular interest.

References

1. E. Betzig and J. K. Trautman, "Near-field optics: microscopy, spectroscopy, and surface modification beyond the diffraction limit," Science, vol. 257, pp. 189-195, 10 July 1992, and references contained therein.
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3. F. Froehlich, T. Milster, and R. Uber, "High-resolution optical lithography with a near-field scanning subwavelength aperture," Proc. of the SPIE, vol. 1751, July 1992.

APPENDIX H