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研 究 主 論 文 抄 録

論文題目：Design and Theoretical Study of High-Density Optical and All-Optical Magnetic Storage Systems
（高密度光および全光磁気ストレージシステムの設計と理論研究）

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主論文要旨

This thesis presents design and analysis for some systems in high-density optical storage and all-optical magnetic storage from a theoretical perspective. The scalar diffraction theory is used for far-field diffraction and the vector diffraction theory is applied for near-field diffraction. To obtain high recording density for optical data storage and high resolution for microscopy or to reduce the complexity of conventional optical storage systems, some new methods are developed and new optical storage systems are designed.

The Multiple reflection effect inside a solid immersion lens (SIL) and SIL's dispersion effect with wavelength are analyzed. The effective reflection and transmission coefficients of the SIL are derived for the converging spherical wave illumination. Simulation results in reflection- and transmission-mode microscopy as well as single-photon emitter are quite consistent with the measured values for resolution and collection efficiency. Based on this, two types of the refractive index configuration with a SIL are designed, one is preferable for the transmission-mode microscopy and the other is useful for the reflection-mode microscopy. It is found that the structure parameters of SIL and the width of the air gap in optical data storage needs to be accurately controlled for achieving high-density recording.

Several types of filters are designed and their functions in optical data storage are analyzed. Results show that two-zone binary amplitude and phase filters can increase the resolution and depth of focus for a low-NA SIL system, but they can not increase the recording density for a high-NA SIL system. Three-zone binary amplitude and phase filters can increase recording density and, at the same time, improve focal depth of SIL optical storage systems with a high NA. The feature of the three-zone phase filter is better than that of the three-zone amplitude filter in optical efficiency and resolution, but its capability in sidelobe suppression is lower. To overcome the disadvantages of two-zone and three-zone binary filters, a special continuous phase filter is designed for

the SIL optical storage and microscopy. The outstanding feature of this continuous phase filter is that it can markedly increase the intensity of spot and the focal depth of SIL systems. At same time, the sidelobe intensity is suppressed well while the spot size is kept almost as same as that without the filter.

The focusing characters of higher-order radially polarized modes are compared with the conventional (lowest-order) radially polarized mode and it is found that two higher-order radially polarized modes with double-ring and triple-ring shapes can be applied to optical data storage. The numerical results show the double-ring-shaped radially polarized beam is very useful to the real high-density optical data storage because of its good features in improving recording density and increasing focal depth. A nanometer-scale composite structure consisting of a negative index film and a polymer film is used to excite surface plasmas so that the transmission light from SIL is enhanced.

Three nonspherical solid immersion elements are designed for high-density optical storage. The first is a multiphase Fresnel zone plate, the second is a plano-convex solid immersion mirror (PC-SIM), and the third is a plano-ellipsoidal solid immersion mirror (PE-SIM). Their common feature is that only such an element can replace two elements of objective and SIL used in the conventional near-field SIL system. Compared with SILs, the PC-SIM and PE-SIM can effectively control the spreading of spot size with the distance from the interface. Their convex surface can also reduce the risk of SIM touching the surface of the recording medium. In addition, the plano-ellipsoidal solid immersion mirror designed is illuminated directly by a point source of diode laser rather than by a collimated beam.

High-NA technology is used also to realize high-density all-optical ultrafast magnetic storage. The results show that the size of magnetization domain is largely reduced when incident beam is focused by a high-NA system. Moreover, the magnetization direction in the magneto-optic film is basically pointed along the direction of optical axis, which may be very useful to achieving high-density all-optical magnetic storage.

Several characteristic parameters are used to describe the point spread function. A three-zone binary amplitude filter with 3-D superresolving effect is designed by the analytical and optimizing methods, respectively. The analytical expressions allow a thorough analysis for the transverse, axial and 3-D superresolutions produced by the three-zone amplitude filters.