FREQUENCY-DEPENDENT FDTD ANALYSIS
OF LIGHT-BEAM SCATTERING FROM MO DISK MODELS
WITH LAND/GROOVE RECORDING STRUCTURE

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ABSTRACT

The present paper deals with the frequency-dependent FDTD analysis of the light-beam scattering from the land/groove recording MO disk model with an aluminum reflective layer. The numerical examples of main- and cross- polarized scattered fields and the phase difference between them are presented for the cases with and without adjacent recording marks. Assuming a differential type of signal detector, we examine the influences of the cross talk due to the adjacent recorded marks and the size of recording marks on the readout-signal characteristics. It is shown the calculated optimum depth of grooves agrees with the well-known result.

INTRODUCTION

The finite difference time domain (FDTD) method has been applied to the light beam scattering problems from random access memory (RAM) type of optical disks such as phase-change (PC) [1] and magneto-optical (MO) disks [2]. The magnet-optical recording medium becomes optically anisotopic by magnetization and in general its permittivity is defined as a tensor with complex off-diagonal components and the imaginary part of the off-diagonal components of MO medium mainly contributes to the Faraday and Kerr rotation [3]. The numerical simulations of light-beam diffraction from MO medium have been done under the assumption of real off-diagonal components, by the boundary-element method (BEM) [4] and the FDTD methods [2]. However, it has been pointed out that such assumption does not satisfy the energy conservation law and therefore the divergence of electromagnetic fields can always occur, even if a relatively large conductivity is introduced [2].

In the previous paper [5], we proposed a new FDTD formulation applicable to the MO medium and tried to simulate the plane wave reflection and transmission by the MO medium with opposite sign pure imaginary off-diagonal components. The results indicate that we never encounter such field divergence during the proposed FDTD calculation and we have a very good agreement between the results by the proposed FDTD formulation and the exact solutions.

As applications of the proposed FDTD formulation to more realistic model, the diffraction of light beam from two- and three-dimensional (2-D and 3-D) MO disk structures has been analyzed and the detected signal characteristics have been numerically simulated [6]. In those FDTD analyses, the reflective layers have been assumed to be a perfectly conducting medium. However, in general the real optical disk structures have metallic medium like aluminum (*Al*) or gold (*Au*) as a reflective layer. Appling the conventional FDTD method to such a metallic medium, we always encounter the divergence of the fields during its numerical calculations, because the permittivity of the metal becomes negative in the optical wavelength region where the metal behaves like a kind of dispersive medium. In order to avoid such a field divergence, we have tried to apply the frequency-dependent FDTD method to the reflection and transmission of a plane wave by a metallic layer and shown that we can have a very good agreement between the numerical results by the frequency-dependent FDTD method and the exact solutions [7].

In the present paper, we try to simulate the light-beam scattering from a magneto-optical disk model with a land/groove recording structure, which has been proposed as one of higher density recording version of the conventional MO disks. We also take the disk structure with an aluminum reflective layer (ALRL) into consideration in order to improve the conventional analysis for MO disk models under the assumption of perfectly conducting reflective layer (PCRL).

SIMULATION

The disk model considered here has a four-layered structure as shown in Fig.1. The indent Gaussian beam with the wavelength 660 [nm] and a linearly polarized electric field in the x direction parallel to the tracks is excited in the substrate region. The width of lands and grooves is 600 [nm] and the track pitch is 1300 nm. The width and height of the slopes between lands and grooves are assumed to be 50 [nm] and 70 [nm], respectively.

The complex index of refraction of the aluminum layer becomes n=0.980-j5.970 at the wavelength of the incident beam, and hence the corresponding values of the relative permittivity and conductivity are –34.68 and 307500 S/m. The direction of the magnetization of the recording layer is changed by recording and erasing the information. The upward magnetization corresponds to the non-recorded state (NRS) and the downward one to the recorded state (RS). In this analysis, we assume that the off-diagonal components of the permittivity tensor of the recording layer are opposite sign pure imaginary and the permittivity and conductivity of each layer are given in Table 1. The numerical aperture of an object lens is assumed to be 0.575. In our FDTD calculation the cell size is chosen as a rectangular with a side 5 nm. The computation region has 600cells in the y direction parallel to the radial direction and 250 cells in the z direction normal to the disk surface. In order to truncate the FDTD computation space, we use PML (perfect matched layer) absorbing boundary condition here.

The scattered electric field has two different kinds of polarized components because of the anisotropy of the MO recording layer. One is the main polarized component (MPC) whose electric field is polarized parallel to the incident light and the other is the cross polarized component (CPC) whose electric field is polarized normal to the incident electric field. In order to carry out the numerical simulation, we consider the four different patterns of the MO recording layer, i.e., the patterns A and B represent the RS states both without and with adjacent recorded marks and patterns C and D correspond to the NRS without and with adjacent recorded marks.

Fig. 2 shows the scattered field patterns of MPC and CPC for NRS and RS with and without adjacent recorded marks.

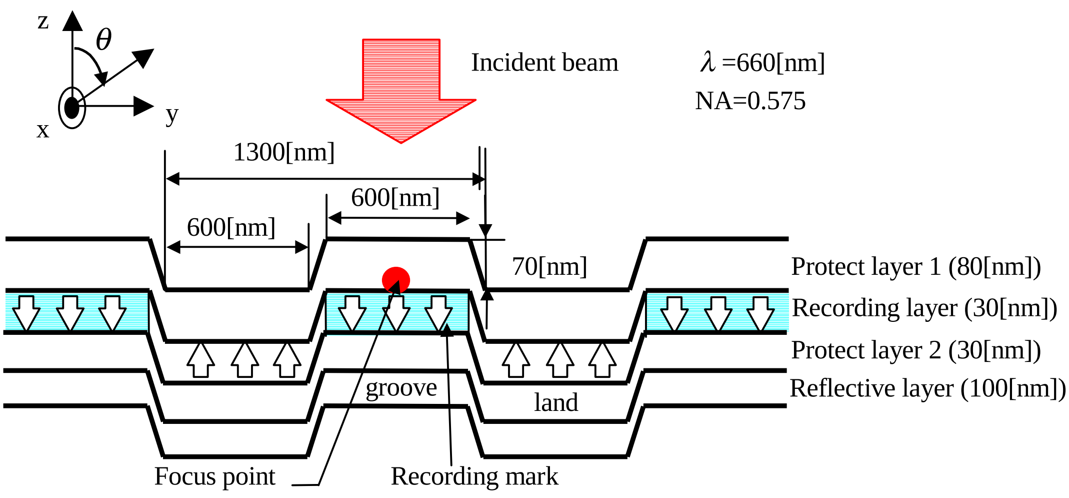
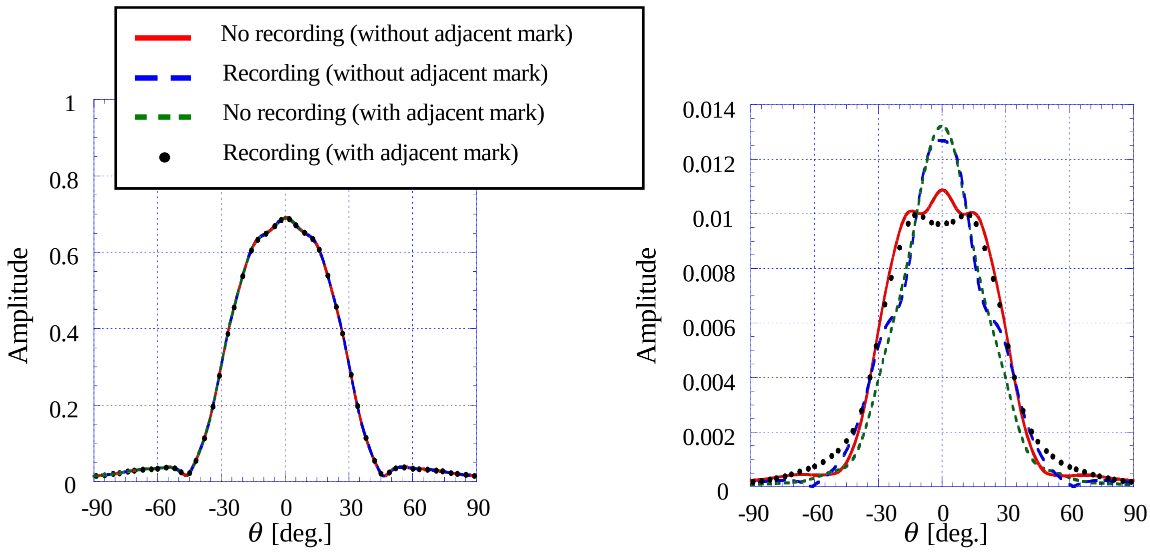


Fig.1 Land/Groove MO Disk Model.

Table.1 Constants of each layer.

	Permittivity		Conductivity
	ε	ε_{xy}	
Substrate	$2.5\varepsilon_0$	0.0	0.0
Protect Layer 1	$4.0\varepsilon_0$	0.0	0.0
Recording layer (Non-Rec.)	$2.0\varepsilon_0$	$0.1\varepsilon_0$	2700
Recording layer (Rec.)	$2.0\varepsilon_0$	$-0.1\varepsilon_0$	
Protect Layer 2	$4.0\varepsilon_0$	0.0	0.0
Reflective layer	n=0.980-j5.970		

From Fig. 2(a), we can observe the MPC becomes large in the vicinity of the optical axis and does not depend on the direction of magnetization and also on the existence of the adjacent recording marks. On the other hand, for both NRS and RS the CPC is clearly affected by the adjacent recording marks. The CPC in the vicinity of the optical axis is increased for the NRS and decreased for the RS by the existence of adjacent marks. It is shown that as long as the amplitude of CPC is concerned, we have certain amount of cross talk by the adjacent recording marks. In order to consider the polarized angle of the scattered fields, the phase difference between MPC and CPC is shown in Fig. 3 for the cases with and without adjacent recording marks. For the cases without adjacent marks, the phase difference for the NRS is 180° and that for the RS varies between 40° and -70° in the rage of the angles ±21°, which is determined from NA of the object lens. On the other hand, the phase difference for the NRS is increased by the existence of adjacent recording marks and its maximum and minimum become about 210° and 135°, and that for the RS is almost constant 0°. From this we can observe, the phase differences between NRS and RS are not so much changed by the existence of the adjacent recording marks. Therefore, the plane of polarization of the scattered fields rotates inversely by recording and erasing information whether or not there exist adjacent marks, and hence the cross talk due to adjacent tracks does not give so much influence to the performance of signal detection characteristics for the present model.



(a) main-polarized component.

(b) cross-polarized component.

Fig.2 Scattered far-field patterns.

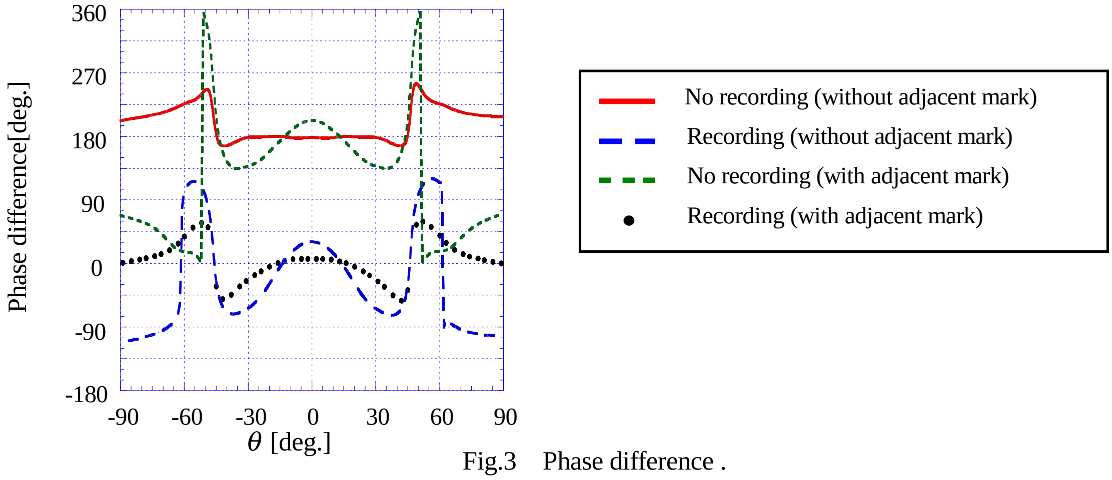


Fig.3 Phase difference .

For the limitation of space, the comparison of main- and cross-polarized scattered field between the modes with ALRL and PCRL cannot be shown here. However, the simulated result indicates that the polarized angle for the case of ALRL becomes greater than that for the case of PCRL. It is also indicated that the minimum cross talk is given at the groove depth 70 [nm], which agrees with the well-known result [9].

CONCLUSION

The present paper described the frequency-dependent FDTD analysis of the light-beam scattering from the land/groove recording MO disk model with an aluminum reflective layer. The main- and cross- polarized scattered fields and the phase difference between them were numerically calculated for the cases with and without adjacent recording marks. The influences of the cross talk due to the adjacent recorded marks on the readout-signal characteristics were also examined.

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