コヒーレント結像型 SIM 実現を目指した
微細構造表面の FDTD 光学応答解析
Optical FDTD Analysis of Surface Microstructure for Coherent Structured Illumination Microscopy

○管一兆 [1)], 久米大将 [1)], 門屋祥太郎 [2)], 道畑正岐 [1)], 高橋哲 [2)],

○Yizhao Guan[1)], Masahiro Kume[1)], Shotaro Kadoya[2)], Masaki Michihata[1)], and Satoru Takahashi[2)]

東京大学 大学院工学系研究科 精密工学専攻 [1)], 東京大学 先端科学技術研究センター[2)]

Department of Precision Engineering, School of Engineering, The University of Tokyo[1)], Research Center for Advanced Science and Technology (RCAST), The University of Tokyo[2)]

E-mail: guan.y@nanolab.t.u-tokyo.ac.jp

The Structured Illumination Microscopy (SIM) uses standing-wave illumination to reach optical super-resolution. Two oblique incidences form the standing-wave. FDTD analysis is applied for observing the near-field response of microgroove under standing-wave illumination. The near-field phase shows depth dependency in this analysis.

1. Background

In previous research, the method to retrieve the phase information of light while reaching super-resoluiton by SIM has been developed.[1] Since the phase information has the potential to calculate the depth information, to study the phase dependency with depth under standing-wave illumination may provide a novel three dimensional SIM system. In this research, FDTD analysis is applied to understand the near-field response relationship with depth change as illustrated in figure 1.

2. Analysis

In FDTD analysis of a microgroove model, incident light, reflected light, and scattering light co-exist. The mixture jeopardizes the observation of phase and intensity. Therefore, the subtract method is applied to remove the incident light component. Two models are made, where one has the microgroove structure, and another is the air model. The simulation cell size is $5 \times 5 \times 5$ nm. Moreover, it should be noted that the polarization is critical in the case of diffraction-limited microgroove, and the S-polarization wave can not go into the microgroove to fetch the depth information. Therefore, P-polarization is used. One example of the P-polarized standing-wave is shown in figure 2. The amplitude distribution of E_x component is illustrated. It is confirmed that the electric field fills the microgroove. Finally, the near-field phase of E_x component is plotted along the near-field observer placed 20 nm above the surface while the modeled depth changes from 0 nm to 100 nm with the step of 10 nm. The relative phase shift is taken by setting a standard phase at 0 nm. It is observed that the relative phase shift in near-field above the microgroove decreases as the depth increases. It indicates that the phase delay caused by depth can be observed in the near-field in the case of standing-wave illumination

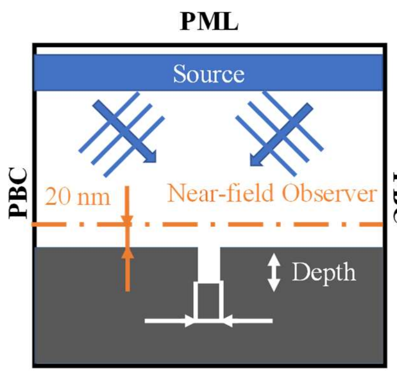

Figure 1. FDTD model for standing-wave illumination

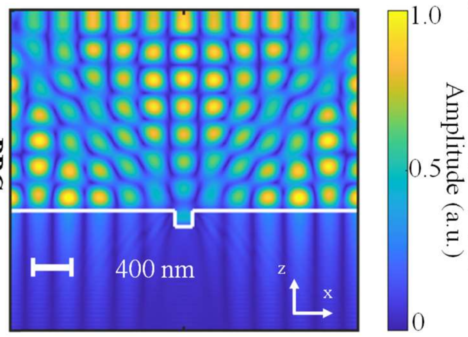

Figure 2. Typical amplitude distribution of E_x component in FDTD analysis

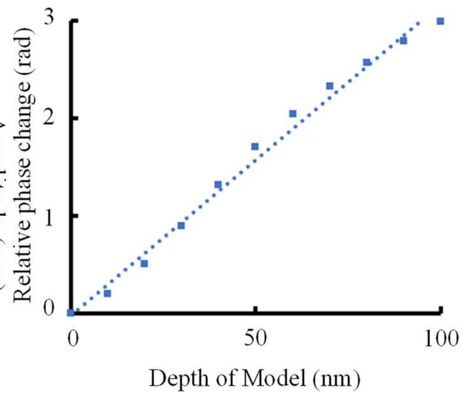

Figure 3. Near-field phase changes with depth

Reference

1. H. Kume, M. Michihata, K. Takamasu, S. Takahashi. Numerical analysis on high resolution optical measurement method with long working distance objective for in-line inspection of micro-structured surface,Precision Engineering,Volume 67,2021,Pages 232-247