# Three-dimensional shift multiplexed recording in coaxial holographic data storage with virtual varifocal lens

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## 1 Introduction

Holographic data storage (HDS) is one of attractive solutions for archiving huge number of data produced all over the world. A coaxial system in HDS has some advantages of simple setup, tolerance to vibrations, and so on. In a coaxial system, the two-dimensional (2D) shift multiplexing is achieved by lateral medium shifts corresponding to disk rotation. Also, the multi-layer recording with a kinoform varifocal lens has also been proposed, which is based on adding a defocus phase distribution to signal and reference patterns displayed on a spatial light modulator (SLM) [1]. In this paper, we propose the three-dimensional (3D) shift multiplexing combining these multiplexed schemes and the criteria to determine the appropriate recording condition. The proposed method confirms the feasibility of improving the recoring density in coaxial HDS.

## 2 3D shift multiplexing with virtual varifocal lens

The proposed 3D shift multiplexing technique is based on combining the 2D shift multiplexing and the multi-layer recording with a virtual varifocal lens as shown in Fig. 1. The proposed multiplexing can be realized without mechanical scanning of a medium due to focal plane shifts by an SLM. Generally, since independently evaluated selectivities (lateral and depth selectivity) are utilized to determine a recordable position with less crosstalk from adjacent holograms in each multiplexing scheme, only the positions which satisfy both condition should be estimated as appropriate positions. Although there might be appropriate conditions for recording besides above positions, it cannot be found from only independently evaluated selectivities. We propose evaluating the 3D shift selectivity which is defined as the intensity change of a reconstructed image depending on both lateral and depth position displacements. Due to the 3D shift selectivity, less-crosstalk positions which does not be found from only lateral and depth selectivity can be estimated as the white point shown in Fig. 2.

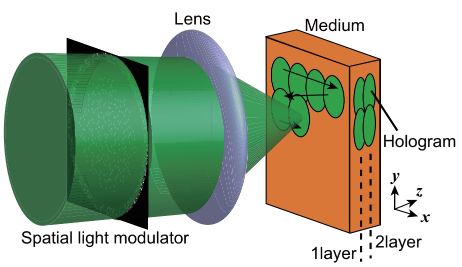


Fig. 1 Schematic of 3D multiplexed recording.

## 3 Experimental evaluation

The proposed method was experimentally evaluated by using a setup including a phase-only SLM with a pixel pitch of 3.74$\mu$m. The wavelength of a source was 532nm, and a photopolymer medium with a thickness of 400$\mu$m was used. After single recording, the 3D shift selectivity was evaluated by shifting a medium laterally and a focal plane with a interval of 1$\mu$m and 100$\mu$m, respectively. A first local minimum of the lateral direction and one of the depth direction were estimated as $d_{xy}$ = 6$\mu$m and $d_z$ = 1500$\mu$m, respectively. Additionally, the reconstructed intensity at the position of $d_{xy}$ = 3$\mu$m and $d_z$ = 600$\mu$m was also enough low. Then, two datapages were multiply recorded at the origin and above position. Although reconstructed images have some error, less-crosstalk is confirmed at the position estimated by the proposed method.

## 4 Conclusion

The 3D shift multiplexing combining the 2D shift multiplexing and the multi-layer recording with a virtual varifocal lens is proposed. The feasibility of improving the recording density was confirmed from experimentally estimated 3D shift selectivity.

## Reference

[1] T. Nobukawa, *et al.*, Opt. Lett. **40**, 5419 (2015).

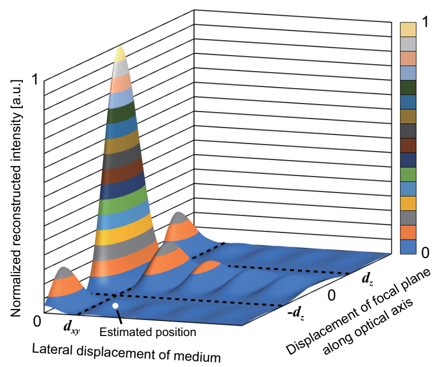


Fig. 2 Schematic of 3D shift selectivity.