Aberration-corrected and label-free scanning endomicroscopy using GRIN lens

Changhyeong Yoon[1,2], Wonjun Choi[1,2], Munkyu Kang[1,2], and Wonshik Choi[1,2]

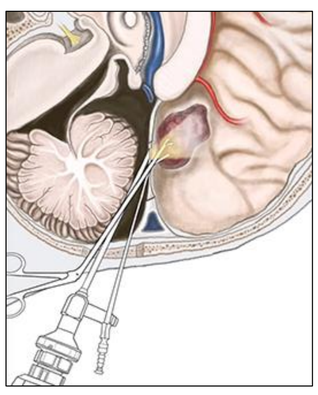
[1]Center for Molecular Spectroscopy and Dynamics, Institute for Basic Science (IBS), Seoul, Korea

[2]Department of Physics, Korea University , Seoul, Korea

Abstract: GRIN lenses are essential probe for miniature endoscope and deep tissue imaging. It can be made very thin and their length can be easily adjusted by combination of relay lenses, it is possible to perform minimally invasive imaging that minimized the damage to tissue during imaging. However, GRIN lenses have inherent aberration that makes it difficult to achieve high-resolution images. Therefore, researchers have been using the adaptive optics to correct the aberration using wavefront shaping devices. In this case, it is needed a fluorescent label for a guide star, and there is limitation to apply this method to human body due to toxicity of fluorescence.

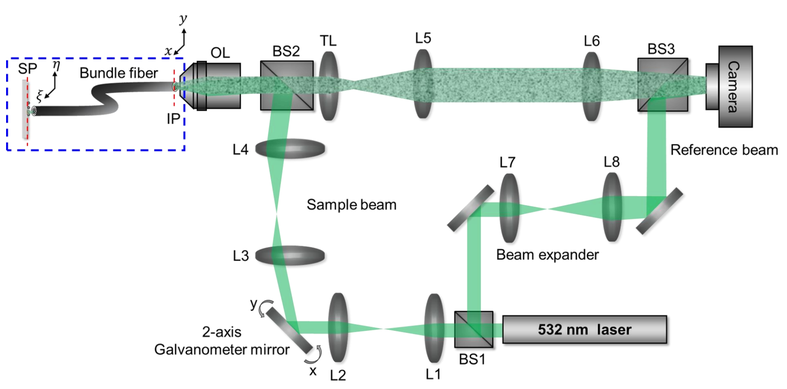
Here, we present a label-free GRIN lens-based scanning endomicroscopy. To correct both input and output aberrations we applied our recently developed aberration correction algorithm which can compensate two aberrations individually. We can also obtain the fixed aberration map of GRIN lens by measuring a resolution test chart which has no aberration. Compared with typical GRIN lens-based confocal imaging we achieved improved spatial resolution. Our aberration-corrected GRIN lens endomicroscopy is expected to facilitate label-free *in vivo* imaging application with improvement of the image qualities.

Introduction: The necessity for microendoscope

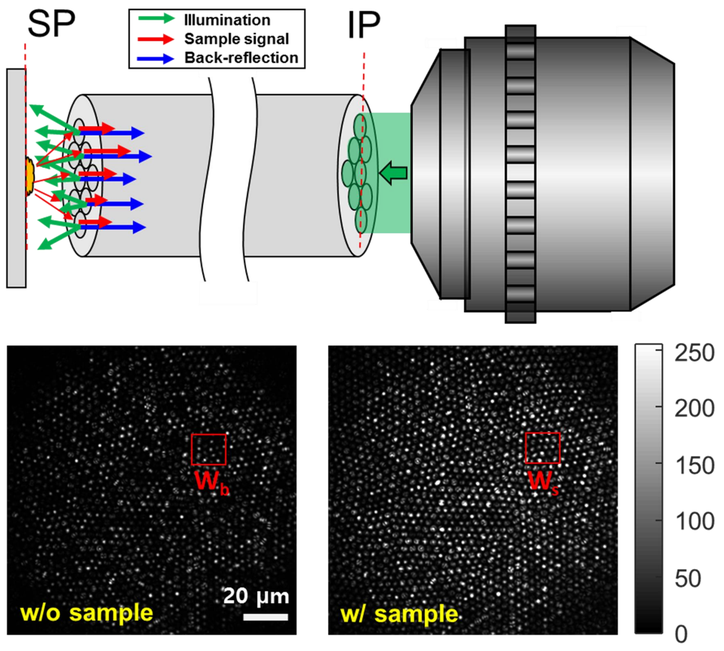


- It is possible to minimally invasive endoscopic imaging
- Microscopic level of spatial resolution

Previous work: Reflectance endoscopic imaging free from back-reflection noise

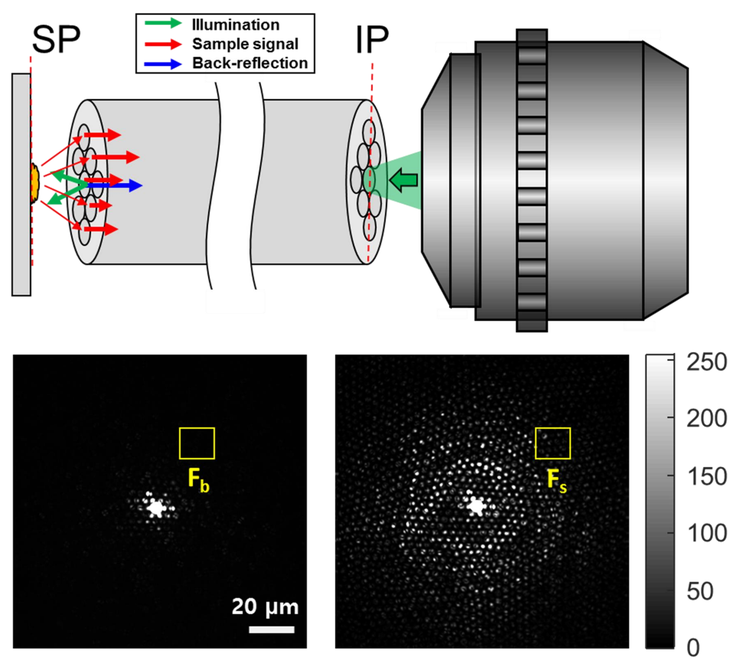


- Interferometric system for complex field measurement
- 2- axis galvanometer mirror scan the focused beam for sample illumination



- Signal to back-reflection ratio $\frac{W_s}{W_b} < 2$

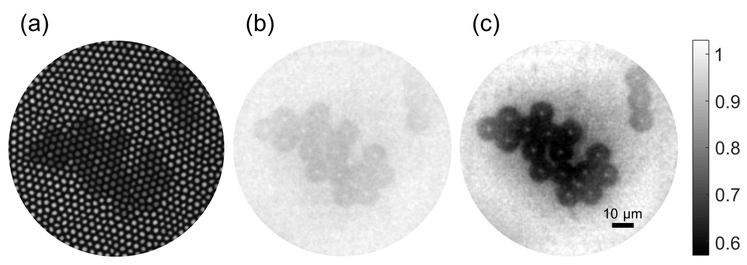
Single-core illumination and wide-field detection



- Single-core illumination and wide-field detection (SIWD)
- Signal to back reflection ratio $\frac{F_s}{F_b} > 10$

- The strong reflection from the surface of a probe spoils the image contrast
- Using an image bundle fiber, we can separate the illumination fiber and detection fiber

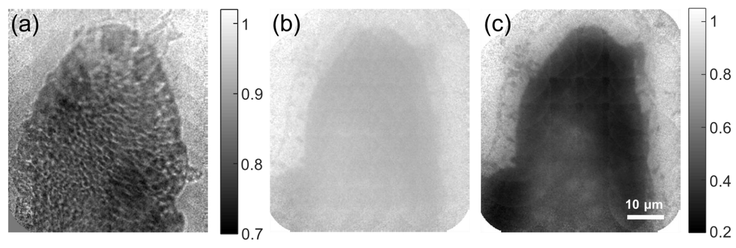
Results



(a) LED epi-illumination, the beads are on the surface of the fiber

(b) Reconstructed image, the beads are 100 μm from the distal end. (WIWD)

(c) With the SIWD method



Ex vivo imaging of a small villus of a rat intestine
(a) WIWD in oil (b) WIWD in air (c) SIWD in air
SNR of SIWD is 3.2 times better than the WIWD method

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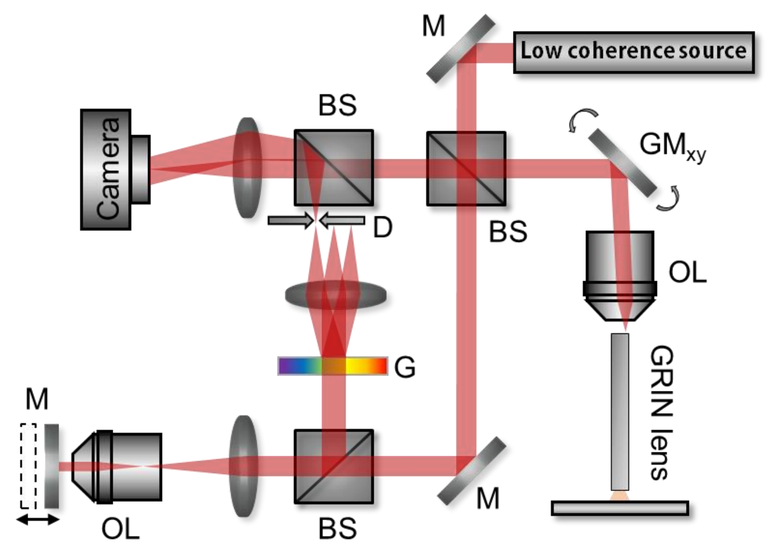
High-resolution endomicroscopy using GRIN lens

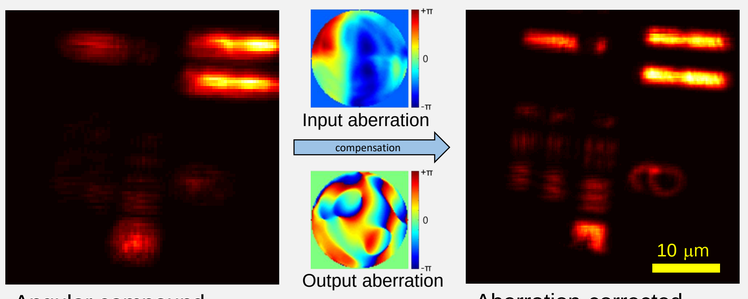
- The inherent aberration of GRIN lens degrades spatial resolution
- To obtain high-resolution imaging, the aberration has to be corrected
- The CLASS algorithm will be used to correct the aberration

Experimental Setup



- Off-axis interferometry for complex-field measurement
- High NA GRIN lens (0.8 NA)
- Low coherence laser for time-gated detection

Results



Angular compound intensity image

Aberration-corrected intensity image

- Using aberration-correction algorithm, we can obtain the clearer image through GRIN lens

Summary

- We explored endoscopic imaging using GRIN lens
- By using aberration-correction algorithm, we can compensate the aberration of the GRIN lens

Reference

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[3] Youngwoon Choi, Changhyeong Yoon, Moonseok Kim, Taeseok Daniel Yang, Christopher Fang-Yen, Ramacandra R. Dasari, Kyoung Jin Lee, and Wonshik Choi, "Scanner-Free and Wide-field Endomicroscopic imaging by Using a Single Multimode Optical Fiber", Phys.Rev.Lett. **109**, 203901 (2012)