

Reduction of back-reflection in high-resolution endoscopic imaging using an image bundle fiber

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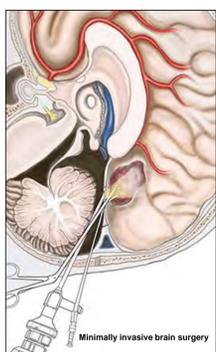
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Introduction :

The necessity for microendoscope

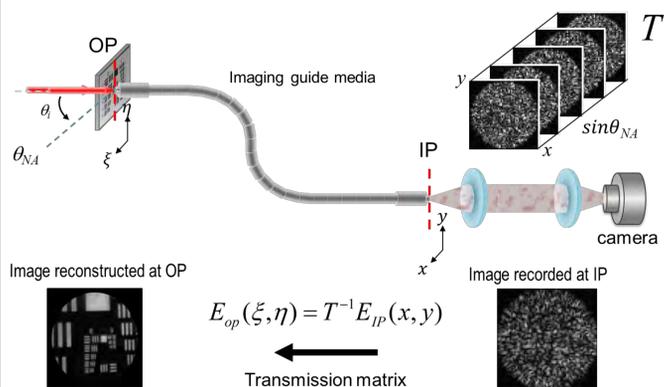


- It is possible to minimally invasive endoscopic imaging
- Microscopic level of spatial resolution

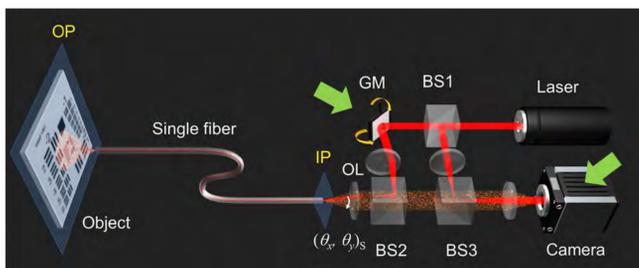
Previous work :

Lensless Single-Fiber Microendoscopy

Image reconstruction by transmission matrix

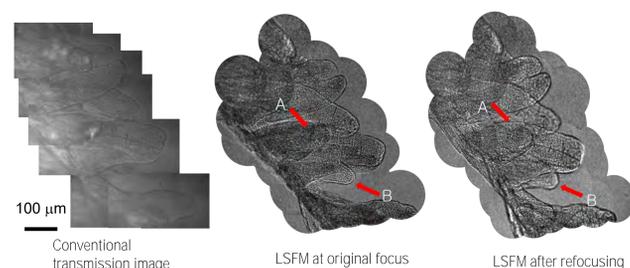


Lensless single-fiber microendoscopy



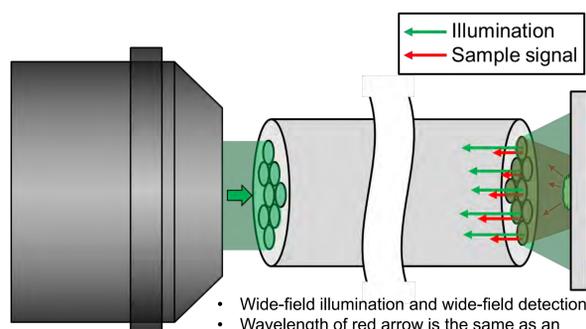
- Endoscope should work in reflection mode
- Twofold distortions need to be resolved
 - Distortion of illumination on the way in: IP → OP ← Speckle imaging
 - Image distortion on the way back: OP → IP ← Transmission matrix

Imaging villus in the rat intestine

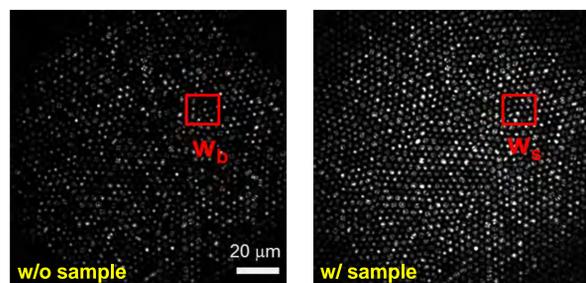


Y. Choi et al., Physical Review Letters **109**, 203901 (2012) (Selected as an editor's suggestion)

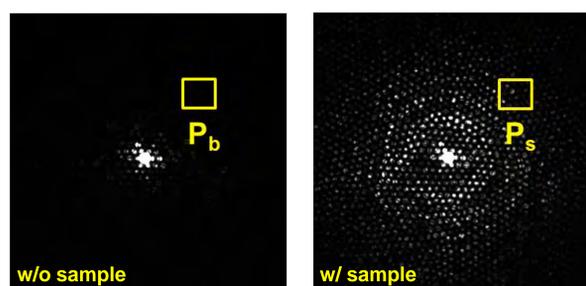
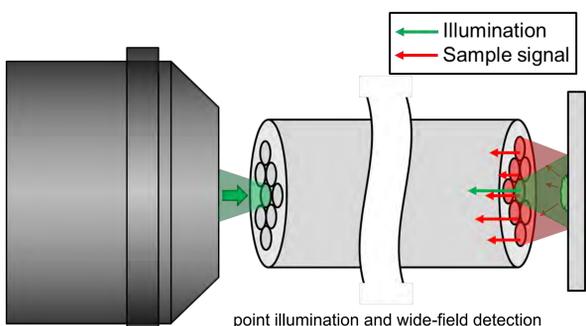
Reduction of back-reflection noise : point illumination and wide-field detection method



- Wide-field illumination and wide-field detection
- Wavelength of red arrow is the same as an illumination



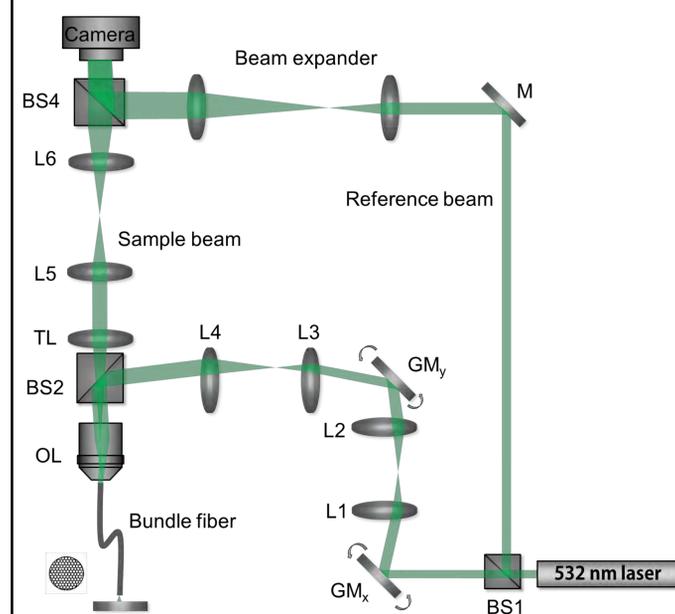
- Wide-field illumination and wide-field detection
- Signal to back-reflection ratio $\frac{W_s}{W_b} < 2$



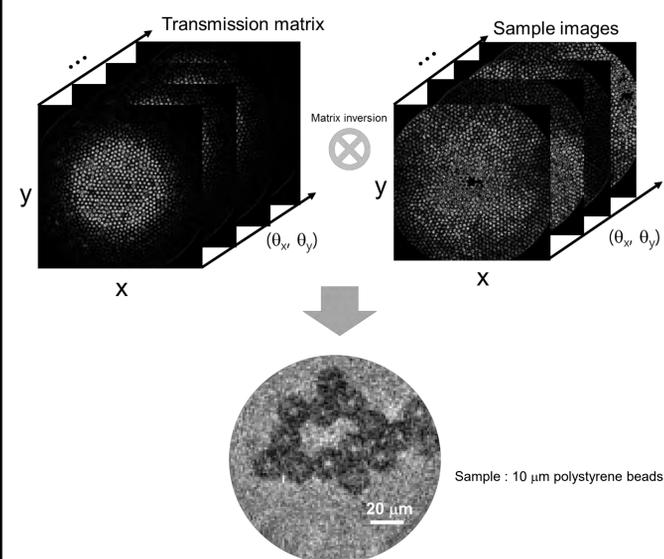
- Wide-field illumination and wide-field detection
- Signal to back reflection ratio $\frac{P_s}{P_b} > 10$

- 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

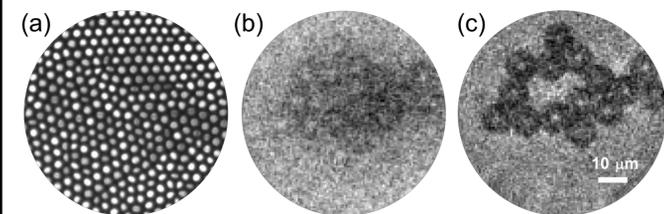
Experimental results



- Interferometric system for complex field measurement
- Image bundle fiber is used as an image guided medium
- 2-axis galvanometer mirror scan the focused beam for sample illumination



- Applying the transmission matrix method for reconstructing the sample image
- The back reflected component is easily excluded in image processing



- (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. The illumination method is wide-field
- (c) Point-illumination

Reference

- [1] 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)
- [2] Donggyu Kim, Jungho Moon, Moonseok Kim, Taeseok Daniel Yang, Jaisoon Kim, Euiheon Chung, and Wonshik Choi, "Toward a miniature endomicroscope : pixelation-free and diffraction-limited imaging through a fiber bundle", Opt.Lett. **39**, 1921-1924 (2014)
- [3] Sungsam Kang, Seungwon Jeong, Wonjun Choi, Hakseok Ko, Taeseok D. Yang, Jang Ho Joo, Jae-Seung Lee, Yong-Sik Lim, Q-Han Park and Wonshik Choi, "Imaging deep within a scattering medium using collective accumulation of single-scattered waves", Nat.Photon. **9**, 253-258 (2015)