3D imaging of macroscopic objects hidden behind scattering media using time-gated aperture synthesis

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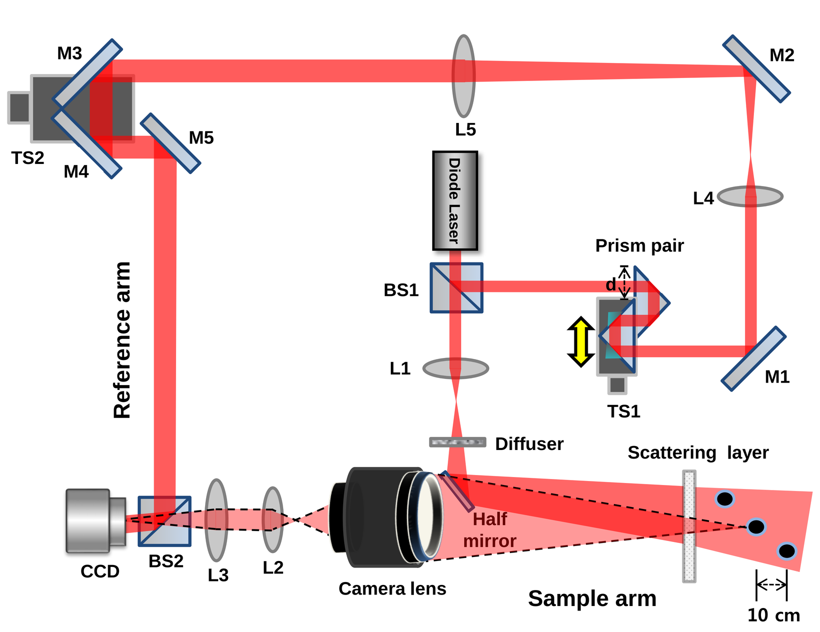
Introduction : Constraints on 3D imaging by scattering medium

- Depth information is distorted by scattering medium
- A need of more advanced macroscopic imaging method

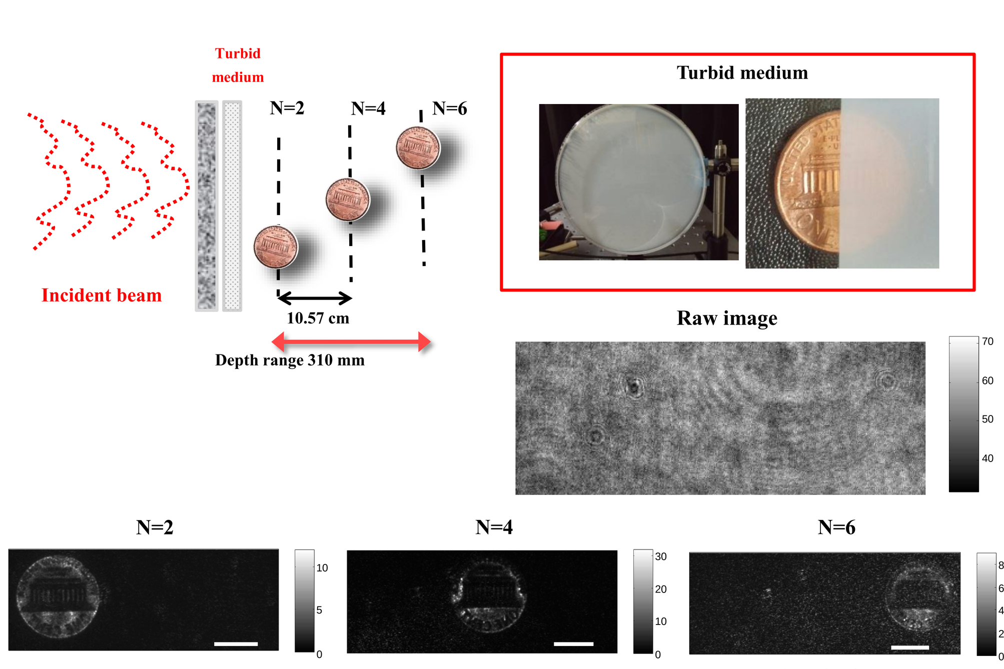
Previous work : Depth-selective imaging in turbid environment

Low-coherence and Wide-field interferometry



- Short-range scan using time-domain OCT
- Prism pair for small-stroke long-range scanning
- Compounding 100 different illumination speckle patterns to get clean object image

Imaging behind the turbid medium

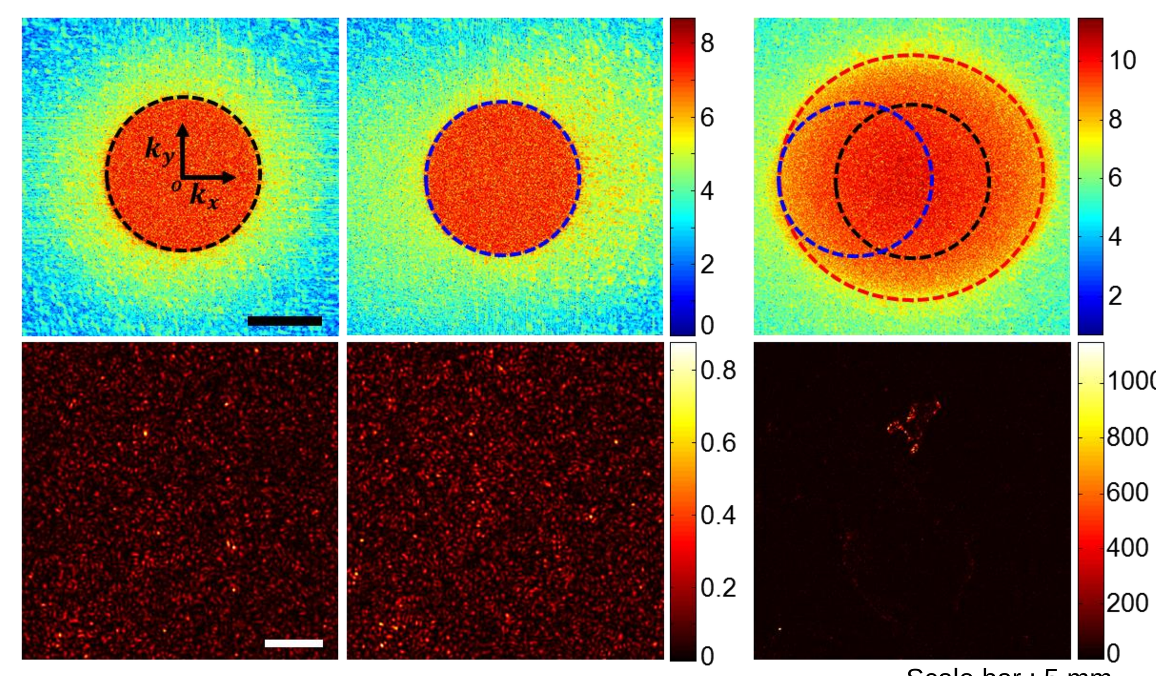


Scale bar :10 mm

S.Woo et al., Optics Communications, **372** (2012)

Enhancing signal to noise ratio (SNR): Synthetic aperture imaging

Synthetic aperture method



Scale bar : 5 mm

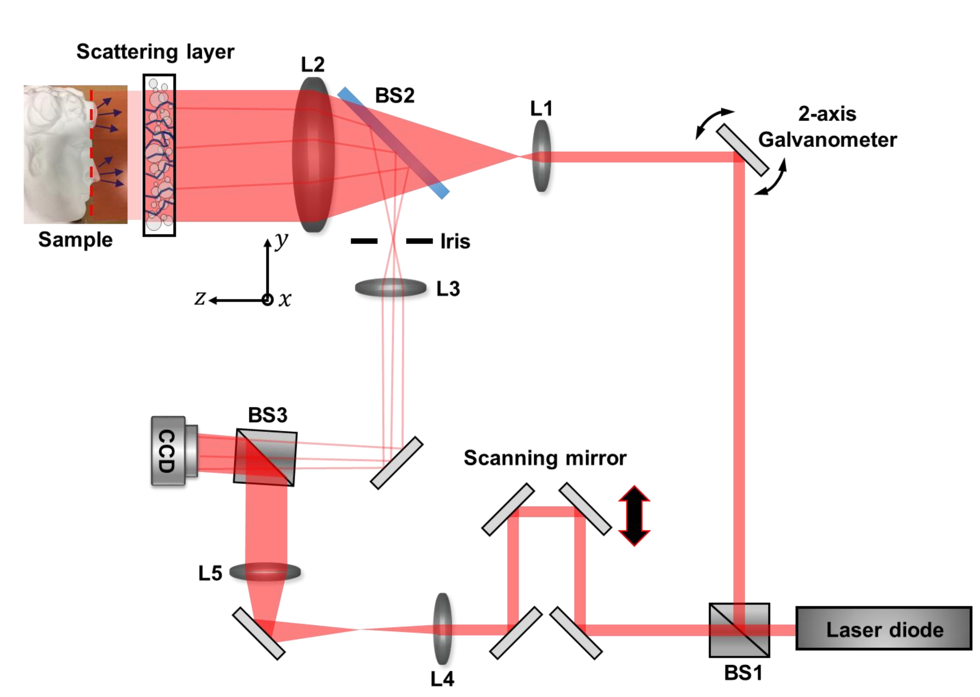
- The angular spectrum of each image was shifted by the wave vector of the illumination (Blue circle)
- The spectral bandwidth for imaging was enlarged by the amount of angular coverage of the scanning angle

	Incoherent image	Synthetic aperture image
Signal	$N_m \times I_s$	$(N_m \times E_s)^2 = N_m{}^2 \times I_s$
Nosie	$\sqrt{N_m} \times I_m$	$(\sqrt{N_m} \times E_m)^2 = N_m \times I_m$
SNR	$\sqrt{N_m} \times (I_s/I_m)$	$N_m \times (I_s/I_m)$

❖**The SNR of synthetic aperture image is $\sqrt{N}$ times better than incoherent image**

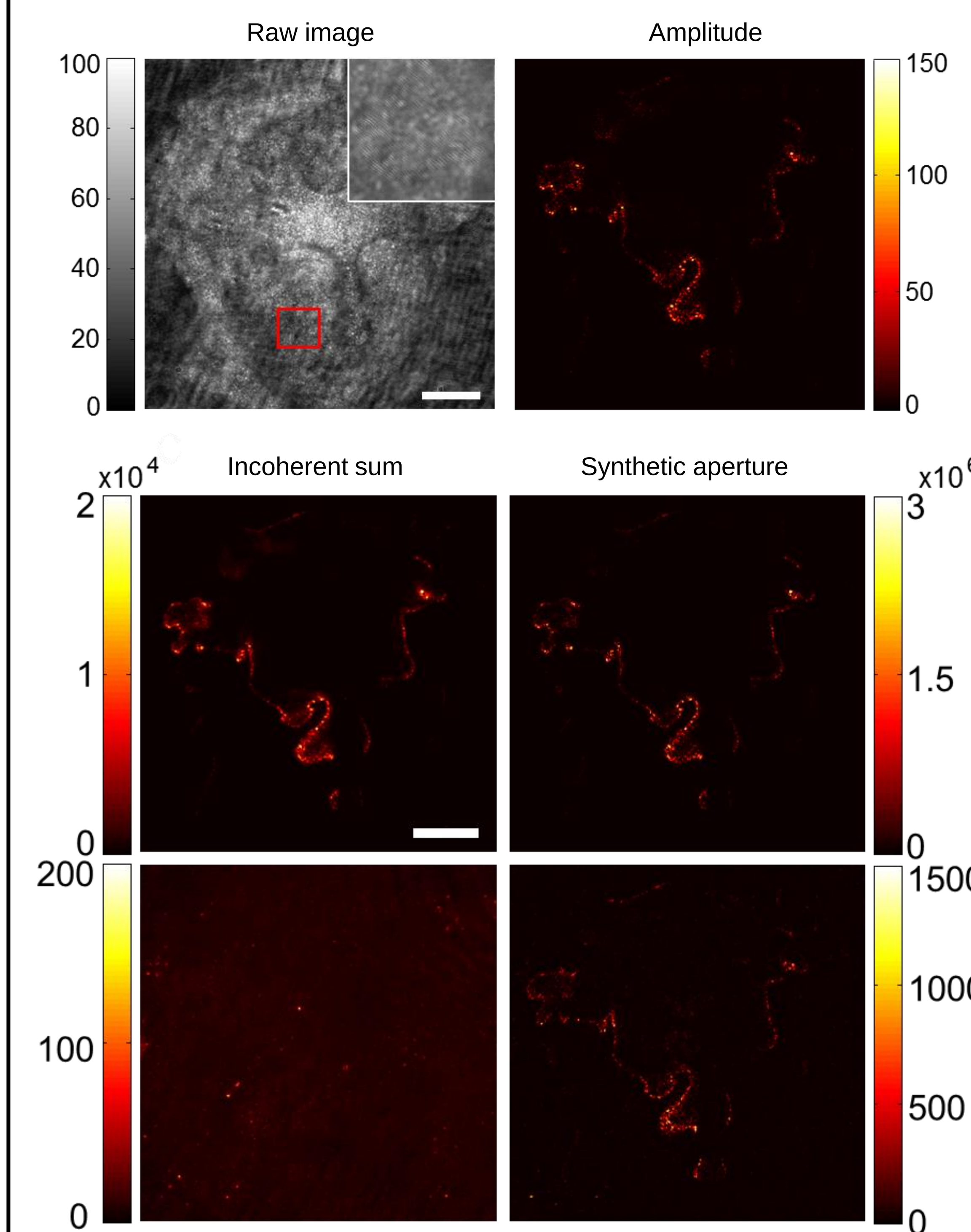
Experimental results

Experimental setup



- Mach-Zehnder interferometry to measure complex field image
- 200 different incidence angles scan at each depth using 2-axis galvanometer mirror
- Depth resolution depends on coherence length

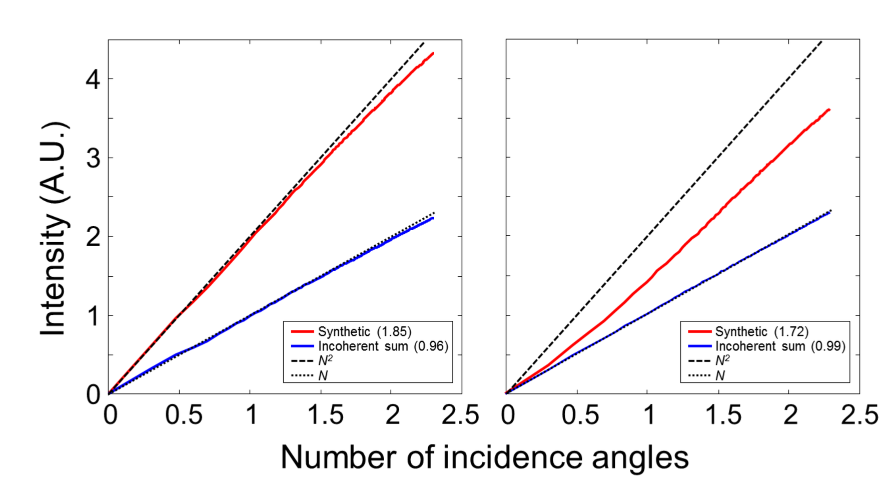
Complex field image



Scale bar : 5 mm

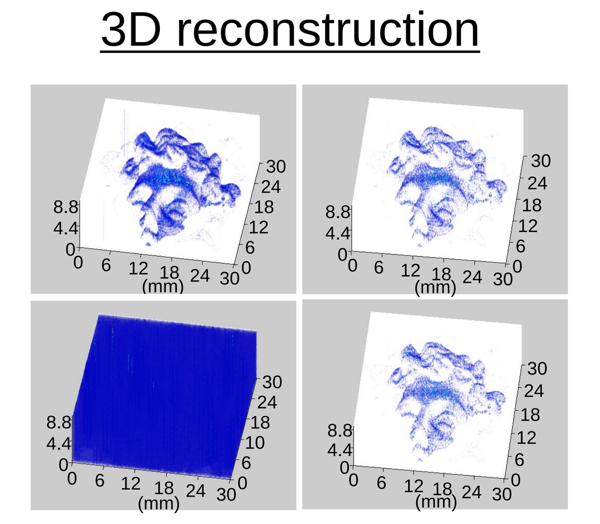
- Interference pattern was only found within a very limited region due to the short coherence length of the laser
- After the Hilbert transform, a band-shaped amplitude distribution was observed which have same depth
- Only the aperture synthesis could resolve the target structure in which the scattering layer was positioned

Signal growth (log scale)



- Signal intensity of incoherent sum grew almost linearly in proportion to N
- Intensity of single-scattered waves increases by N^2 in the aperture synthesis

3D reconstruction



S.Woo *et al.*, Opt.Exp. under review

Reference

[1] Sungsoo Woo, Sungsam Kang, Changhyeong Yoon, Hakseok Ko, Wonshik Choi, "Depth-selective imaging of macroscopic objects hidden behind a scattering layer using low-coherence and wide-field interferometry", Opt.Commun. **372** (2016), 210-214

[2] Youngwoon Choi, Moonseok Kimg, Changhyeong Yoon, Taeseok Daniel Yang, KyoungJin Lee, and Wonshik Choi, "Synthetic aperture microscopy for high resolution imaging through a turbid medium", Opt.Lett. **36**, Issue 21, (2011), 4263-4265

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