FIELD-PORTABLE REFLECTION AND TRANSMISSION MICROSCOPE FOR TELEMEDICINE APPLICATIONS

Gabriel Biener[1,*], Alon Greenbaum[1], Serhan O. Isikman[1], Kelvin Lee[1], Derek Tseng[1], and Aydogan Ozcan[1,2,3,§]

[1] *Electrical Engineering Department, University of California Los Angeles, CA 90095, USA*
[2] *Bioengineering Department, University of California Los Angeles, CA 90095, USA*
[3] *California NanoSystems Institute, Los Angeles, CA 90095, USA*

ABSTRACT

A field-portable transmission and reflection microscope is presented. In this dual-mode microscope design, the reflection from the sample is collected using two cost-effective lenses onto a complementary metal–oxide–semiconductor (CMOS) chip while the transmission through the sample generates an inline hologram which is detected using a second CMOS sensor-chip located within the same platform. The acquired lensfree holograms are rapidly reconstructed using phase retrieval algorithms resulting in both the phase and the amplitude images of the specimen. To test the this device, we imaged blood smears and a histopathology slide corresponding to skin tissue. This field-portable dual-mode microscope, weighing only ~135 grams, might be useful for telemedicine applications in resource limited settings.

KEYWORDS: Microscopy, Holography, Telemedicine, Lensless Imaging, On-Chip Imaging, Global Health

INTRODUCTION

Employing compact and cost effective microscopes in remote and resource limited locations has recently attracted significant attention, resulting in several technical advances in this field. Along the same lines, here we demonstrate a *dual-mode* optical microscope that can provide both reflection and transmission images of specimens using a compact, light-weight (~135 grams) and cost-effective imaging architecture. In this field-portable microscope (Fig. 1) a light-emitting-diode (LED) uniformly illuminates the samples through a beam-splitter cube that is positioned above the object plane. This illumination is partially reflected by the sample and is imaged using two cost-effective lenses onto a complementary metal–oxide–semiconductor (CMOS) chip (see Fig. 1). The transmission portion of the same illumination passing through the sample forms a lensfree in-line hologram of the samples onto a second CMOS-chip that is positioned below the object-plane. These lensfree transmission holograms can be rapidly processed by iterative phase-recovery algorithms [1], where a 2D spatial mask that is generated using either, the reflection microscope image or the digital back-projection of the raw hologram is enforced at the

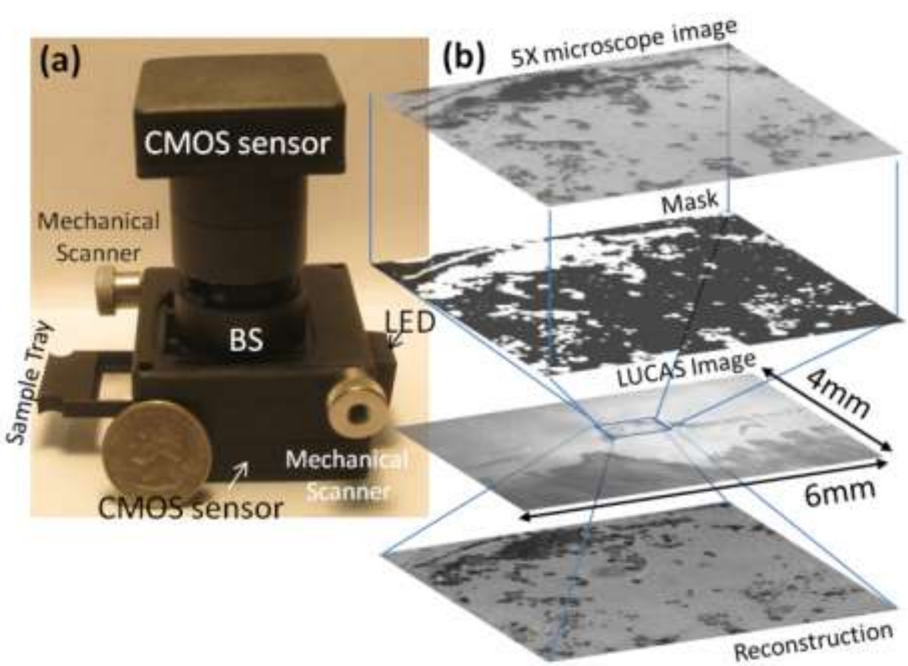

Figure 1: (a) Our dual-mode telemedicine microscope is shown. (b) Dual-mode imaging concept is summarized: Top CMOS sensor chip captures a 5X reflection microscope image of the specimen. This reflection mode image can also be further utilized as a digital mask for the reconstruction of the holographic transmission image of the sample.

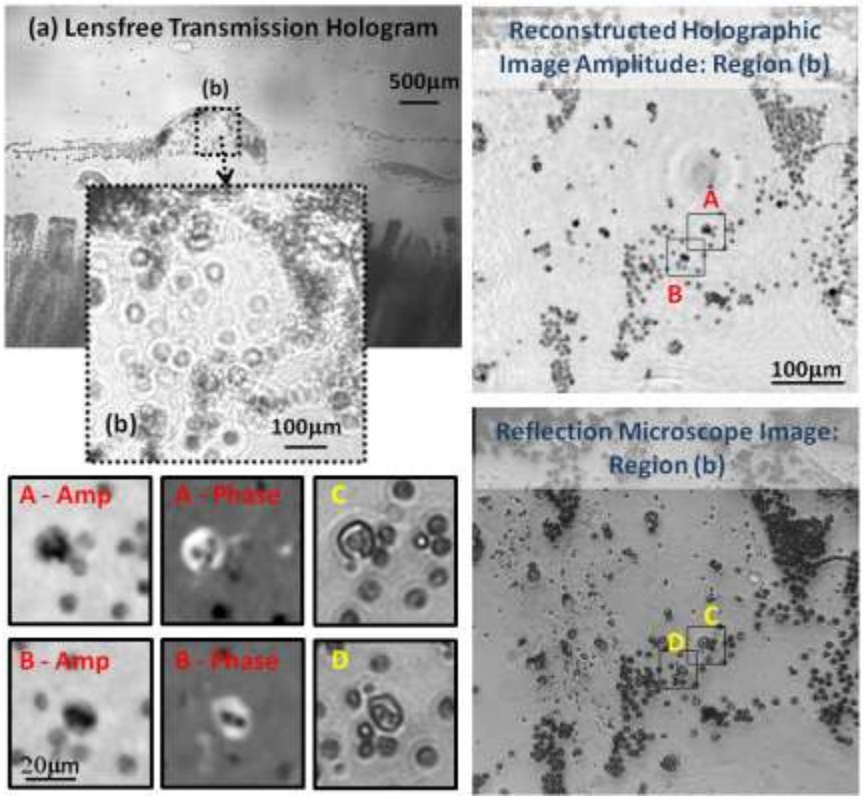

Figure 2: (a) Raw holographic image of a blood smear sample that is acquired using the bottom arm (transmission-mode) of the field-portable microscope shown in Fig. 1(a). (b) Cropped region from the raw holographic image shown in (a). Lensfree in-line transmission holograms of the cells are visible in this zoomed image. On the top right, the reconstructed image for this region of interest (b) is shown. At the bottom right, our reflection microscope image of the same region (b) is illustrated, providing a decent match to the transmission microscope images of the same regions. On the bottom left, several zoomed regions (A-D) taken from our transmission and reflection images are also provided, highlighting different contrast mechanisms present in the reconstructed phase and amplitude as well as the reflection microscope images

sample plane to create phase and amplitude transmission images of the objects.

The holographic transmission microscope contains additional contrast mechanisms compared to its reflection counterpart. This can especially be useful for imaging of weakly-scattering objects that cast their signatures mostly in phase images. By providing a better spatial mask, the reflection mode image of the sample can also improve the performance of the holographic image reconstruction at high object densities as outlined in Fig. 1.[1] Furthermore, our reflection mode microscope also enables imaging of optically-dense samples (such as tissue slides), where lensfree transmission imaging fails to provide good results [2].

RESULTS AND DISCUSSION

Our dual-mode microscope was tested using blood-smear samples as well as histopathology slides, the results of which are summarized in Figs. 1-3. In Figure 2(a) we show the raw lensfree hologram of a blood smear sample, where a zoomed region is also presented in 2(b). Reconstructed amplitude image of the corresponding zoomed region is also presented in Fig. 2, top-right image. Reflection mode image of the same region is also provided in Fig. 2, which agrees well with our lensfree transmission microscope image. Zoomed images of white and red blood cells are provided in Fig. 2 bottom-left images (A through D) as well.

In addition, Fig. 3 demonstrates the performance of our field-portable dual-mode microscope obtained for a histopathology slide corresponding to skin tissue (imaged through the reflection part of our telemedicine microscope). The same figure also shows the image that is obtained using a conventional reflection microscope (10X objective-lens; NA=0.25), which provides a decent match to our field-portable microscope. For such a connected tissue object, lensfree transmission microscopy would in general have reconstruction issues due to unavoidable distortion in the reference-beam, which emphasizes the usefulness of dual-mode architecture of our field-portable microscope for imaging of e.g., tissue slides.

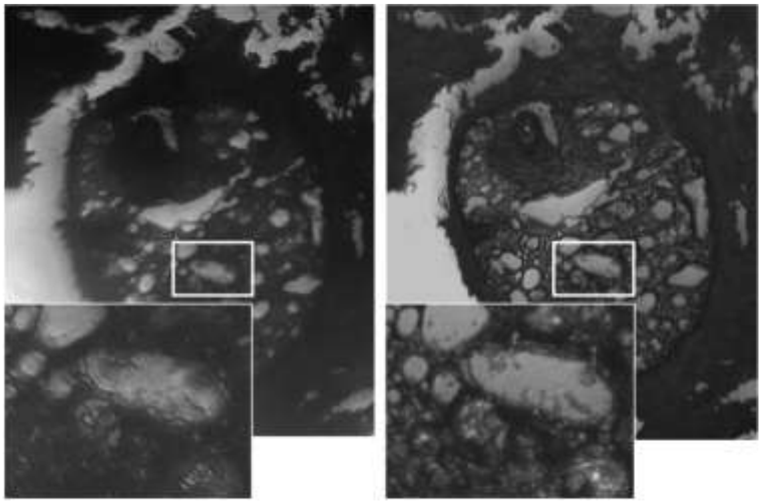

Figure 3: Comparison of our field-portable dual-mode microscope (Fig. 1a) against a conventional bench-top microscope (10X objective-lens; 0.25 NA) is provided for a histopathology slide (skin tissue) that is imaged in reflection mode.

CONCLUSION

Being rather compact and light-weight, this cost-effective dual-mode microscope might provide a useful toolset for telemedicine applications in resource-limited environments.

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CONTACT

[§] A. Ozcan, Phone: (+1) 310-825-0915; ozcan@ucla.edu ; http://innovate.ee.ucla.edu/

* G. Biener, Phone: +1-310-2062050; gbiener@ee.ucla.edu