Digital Holographic Microscopy for 200 € Using Open-Source Hard- and Software

Tobias Beckmann, Markus Fratz, Annelie Schiller, Alexander Bertz and Daniel Carl

Fraunhofer Institute for Physical Measurement Techniques IPM, Heidenhofstraße 8, 79110 Freiburg, Germany

Introduction

Digital Holography is a group of techniques that numerically derive data from digitized interferograms. Applications range from the fast measurement of macroscopic objects with sub-micron resolution [1] to the quantitative measurement of living cells [2]. We present a transmission microscope suitable for phase imaging of transparent samples with component costs of less than 200 € (not including screen), based on the Raspberry Pi computer.
All source code is published under the GNU public license (GPL), as well as the 3D models needed to build and use the setup.

Hardware

Commerical Components

- Raspberry Pi 3: computation and user interface
- Raspberry Pi camera v2
- Achromatic 4x objective (most expensive part)
- Cheap lens, mirror, beamsplitter
- Diode laser module: 635 nm, 5 V (USB-powered)

3D Printed Mounts

- Plastic mounts on 6 mm steel rods
- Mounts clipped to rods (Fig. 2)
- OpenSCAD, modifiable design

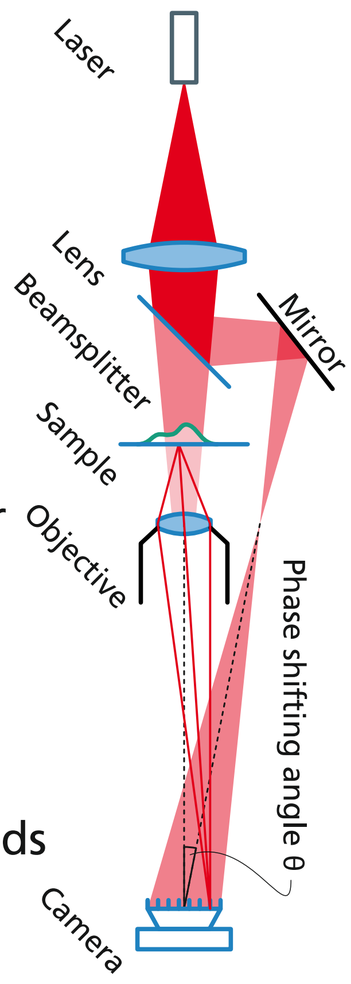

Figure 1: Sketch of the optical setup

Optical Design

- Spatial phase shifting [3]
- Small pixels: large angle $\theta \approx 7°$
- No beam combiner, reference beam passes next to objective
- Single lens as condensor and source of reference focus

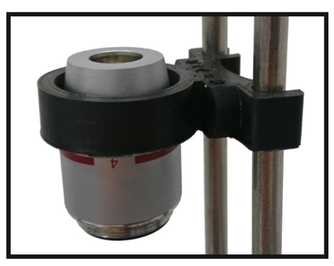

Figure 2: Objective lens in clip mount

Software

- Fully open-source, using Python
- No dependencies outside the Raspbian operating system (available pre-installed)
- Focus on short, readable code: 400 lines for UI creating Fig. 4 b-d

Figure 3: Touchscreen interface

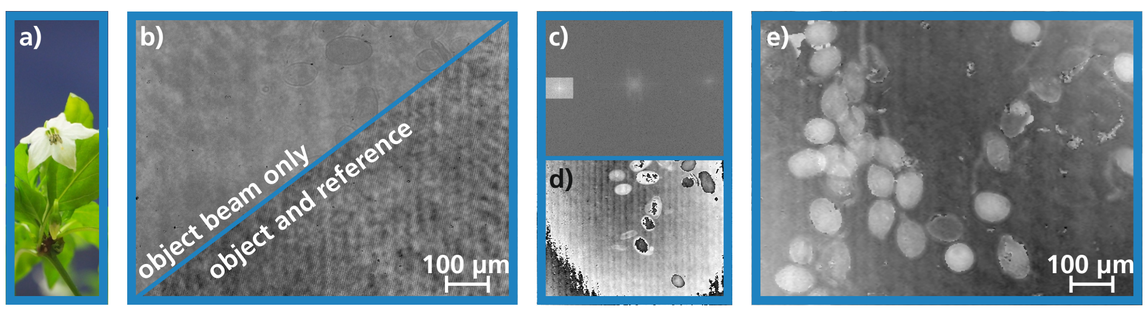

Figure 4: a) Capsicum plant on the author's desk; b) Raw image – pollen are nearly invisible; c) FFT, showing diffraction orders; user-selected region highlighted; d) Phase image; e) Unwrapped phase – pollen are clearly visible

Results

Low-cost transmission setup suitable for phase bioimaging

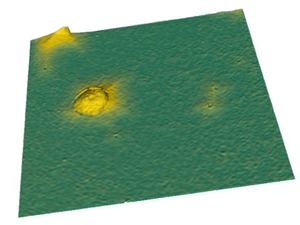

Figure 5: 3D plot of pollen phase map

Speed

- Live image (Fig. 4b) at 30 fps
- FFT image (3280 × 2464 px², 4c): 1.5 s
- Phase image (1640 × 1232 px², 4d): 4.2 s

Ease of Use

- Readily available components
- Two points of adjustment:
  Sample z-position for focussing
  Tilt of reference mirror to illuminate camera
- In use at Freiburg school (ages 15-18)

Acknowledgements

Financial support by the Federal Ministry of Education and Research BMBF (FKZ 13N14078, *HolMOS*) is gratefully acknowledged.

References

[1] T. Seyler et al., Appl. Sci. 8, 1042 (2018)
[2] P. Marquet et al., Opt. Lett. 30, 468-470 (2005)
[3] M. Takeda et al., JOSA 72, 156 (1982)

Author contact: tobias.beckmann@ipm.fraunhofer.de
Raspberry Pi code: https://github.com/holmos-ipm/holmos-rpi
3D printable parts: https://github.com/holmos-ipm/holmos-hardware

git: code + hardware

Build your own and let us know about it!