lensless microscopic imaging

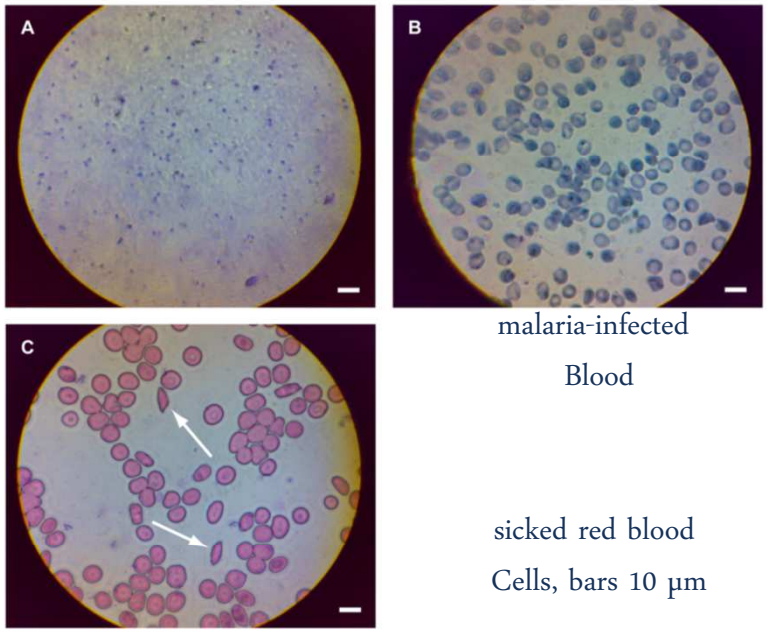
# Holographische Mikroskopie

# als linsenlose miniaturisierte bildgebende Sensoren

R. Riesenberg, IPHT Jena, J. Schreiber, Dresden

# Mobile Phone based Microscope for Health Application

## Motivation




malaria-infected Blood

sicked red blood Cells, bars 10 µm

OPEN ACCESS Freely available online

## Mobile Phone Based Clinical Microscopy for Global Health Applications

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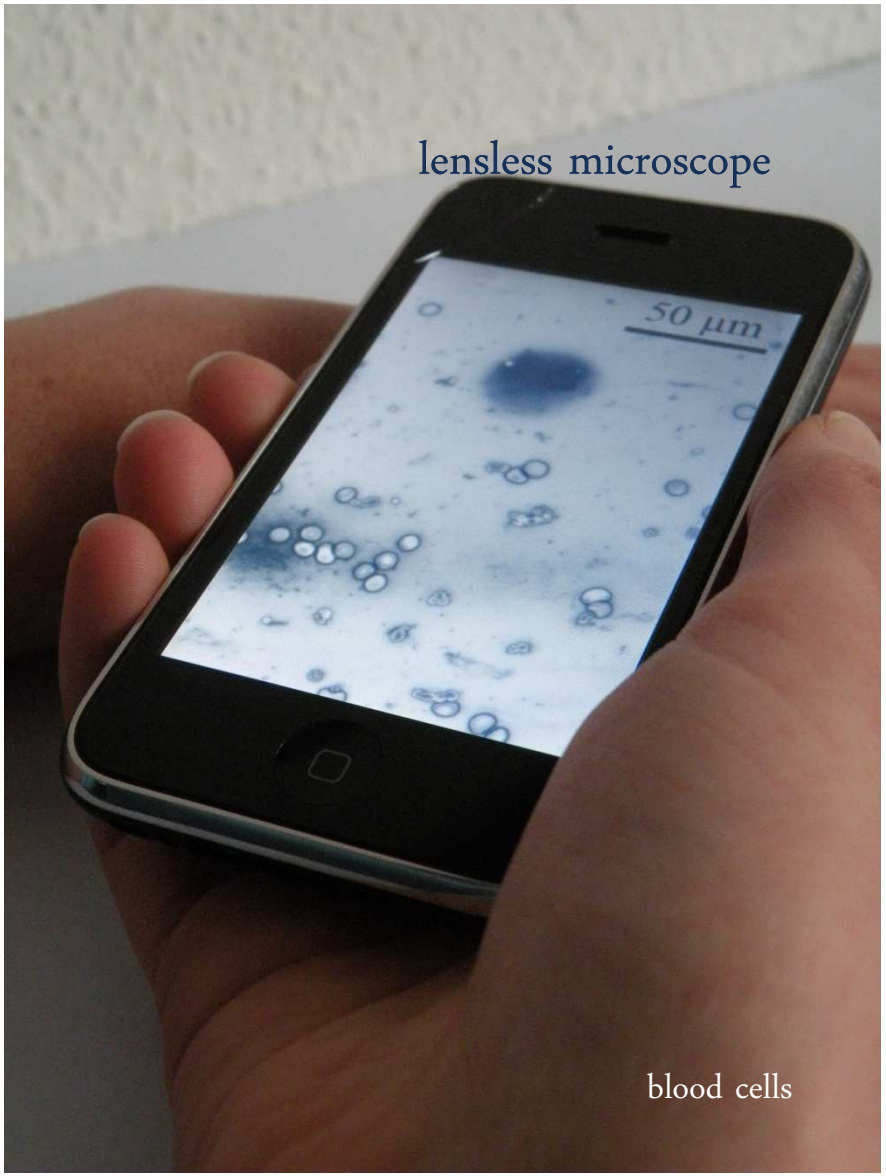
1 UCSF/UC Berkeley Bioengineering Graduate Group, 2 Department of Bioengineering, University of California Berkeley, Berkeley, California, United States of America, 3 Biophysics Graduate Group, University of California Berkeley, Berkeley California, United States of America, 4 Department of Pediatrics, University of California San

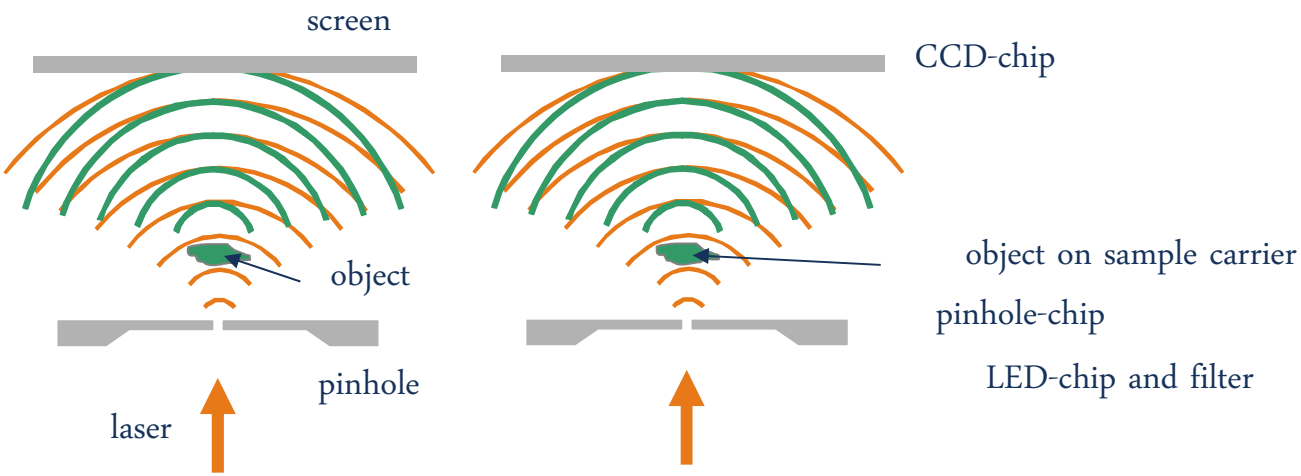
www.plosone.org, July 2009, Vol. 4, 7

# Motivation: Example blood cells imaging by




smartphone based

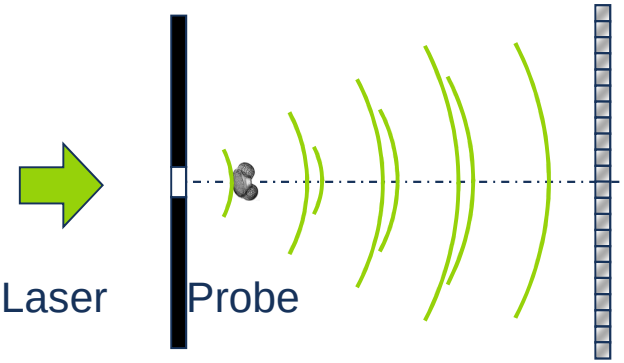
# Prinzip: Digital inline holographic microscope




D. Gabor, "A new microscopic principle," *Nature* 161, 777 (1948)

# Digitale holografische inline-Mikroskopie

The reference and scattered waves combine
to form an interference pattern at the screen.




$$\mathbf{I(r)} = |A_{ref} + A_{scat}|^2$$

$$= [A^*_{ref} A_{scat} + A_{ref} A^*_{scat} + A^*_{scat} A_{scat} + A^*_{ref} A_{ref}]$$

Linear in the scattered wave
(Holographic diffraction pattern).

Interference between
scattered waves
(Classical diffraction pattern)

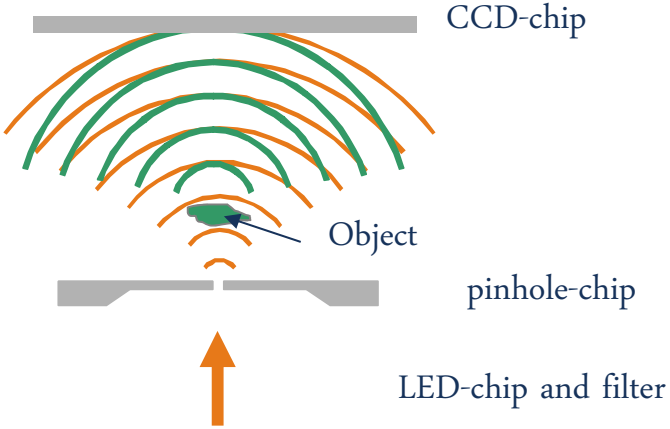
Unwanted nuisance!

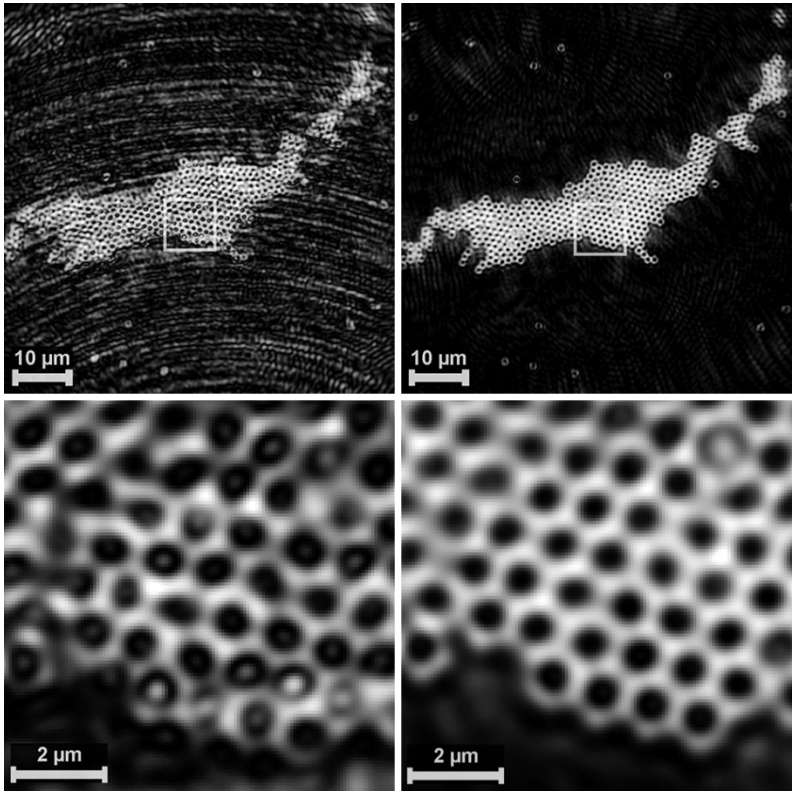
To get rid of the reference beam intensity,
the contrast hologram is formed

$$I_c(r) = I(r) - |A(r,t)|^2$$

Object reconstruction is then performed via the Kirchhoff-Helmholtz transform

# Illumination - reduced abbarations (speckle free)



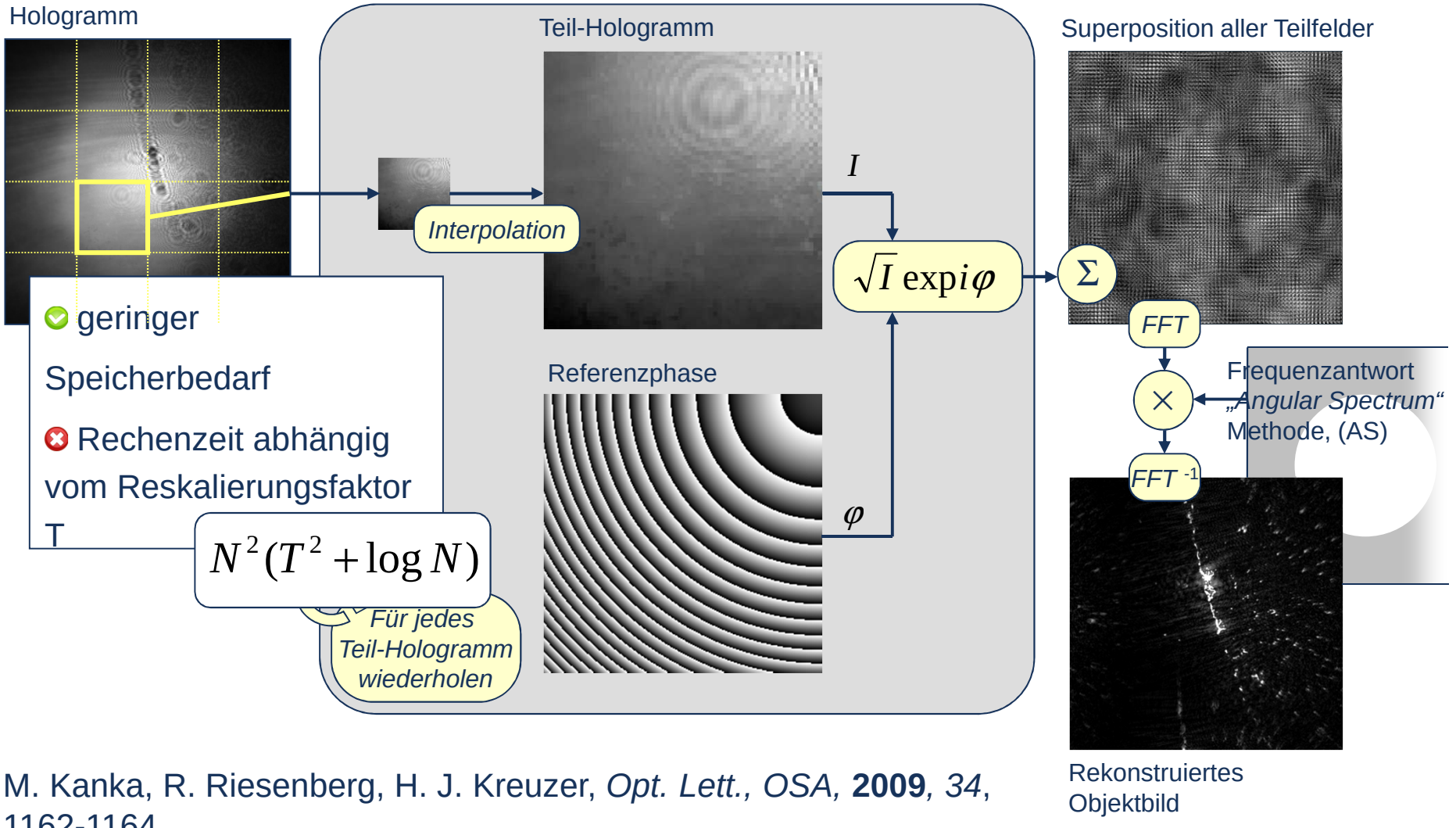

P. Petruck, R. Riesenberg, and R. Kowarschik,
Appl. Opt. 51, 2333-2340 (2012)

P. Petruck, R. Riesenberg, and R. Kowarschik,
Applied Physics B: 105, 339-348 (2012)

Full coherent illumination (coherence-length > $10^5$ µm) by a DPSS laser causes coherent noise.

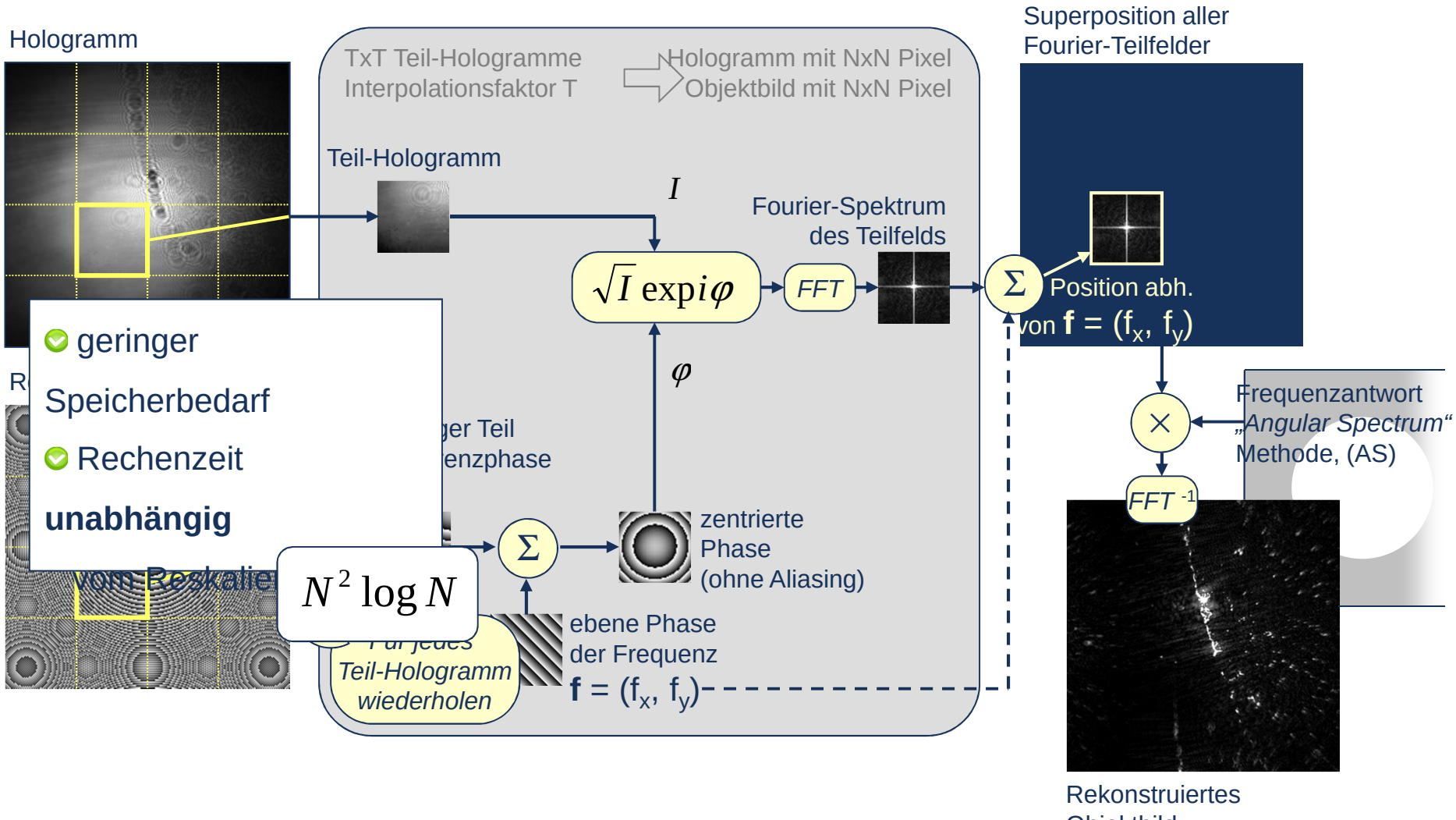
Right advanced imaging quality by micro-coherent illumination using a filtered LED with a coherence-length of 23 µm

# Rekonstruktion: Algorithmus „Kachel-Superposition“




M. Kanka, R. Riesenberg, H. J. Kreuzer, *Opt. Lett., OSA,* **2009**, *34*, 1162-1164

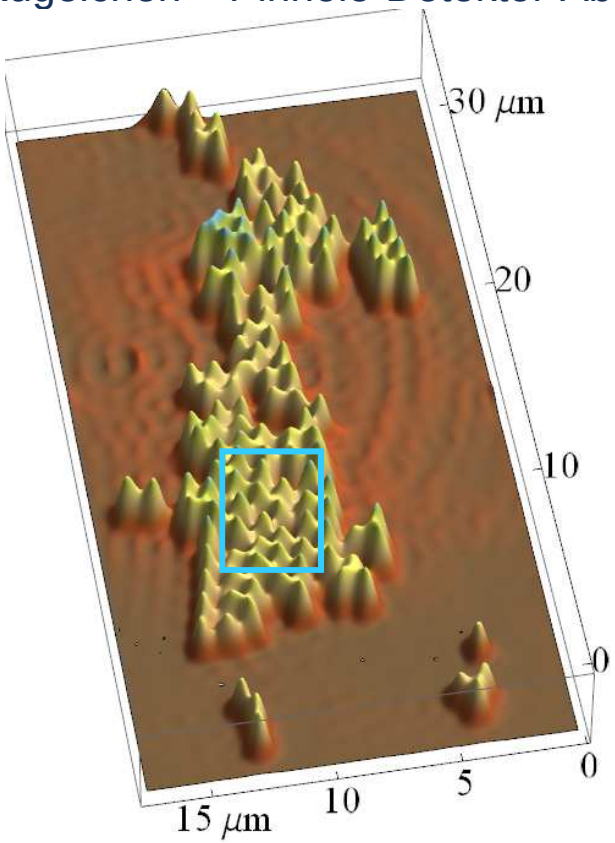
# Rekonstruktion: Beschleunigter Algorithmus

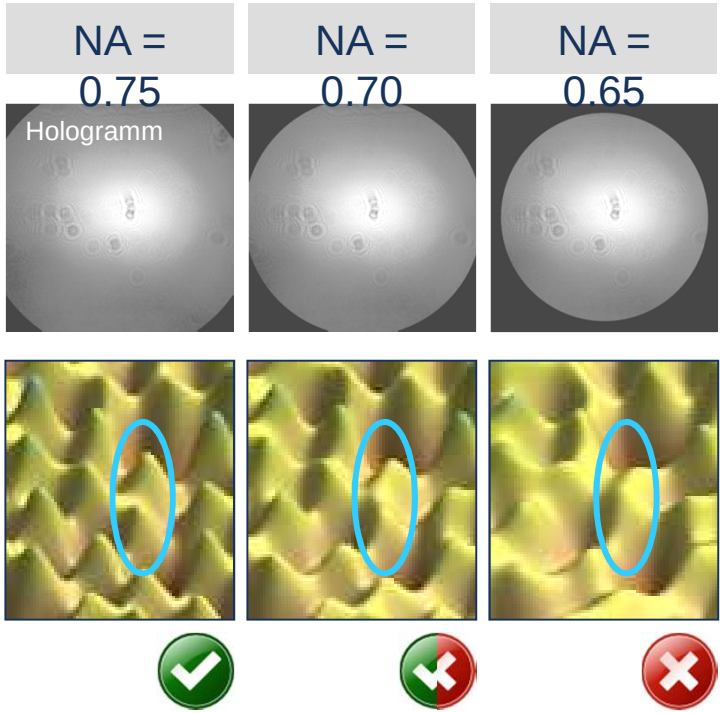



M. Kanka, A. Wuttig, C. Graulig, R. Riesenberg, *Opt. Lett., OSA,* **2010**, *35*, 217-219

# Rekonstruktion: Spatial resolution

## Probe: 1.06 µm PMMA-Kügelchen – Pinhole-Detektor-Abstand 4 mm

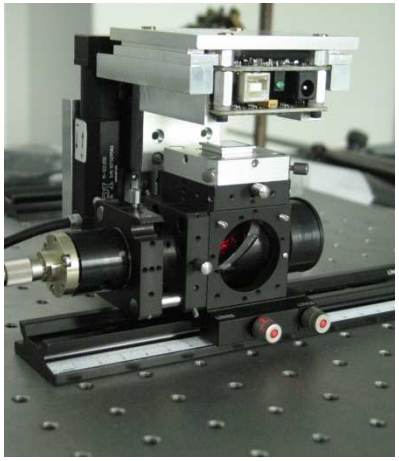



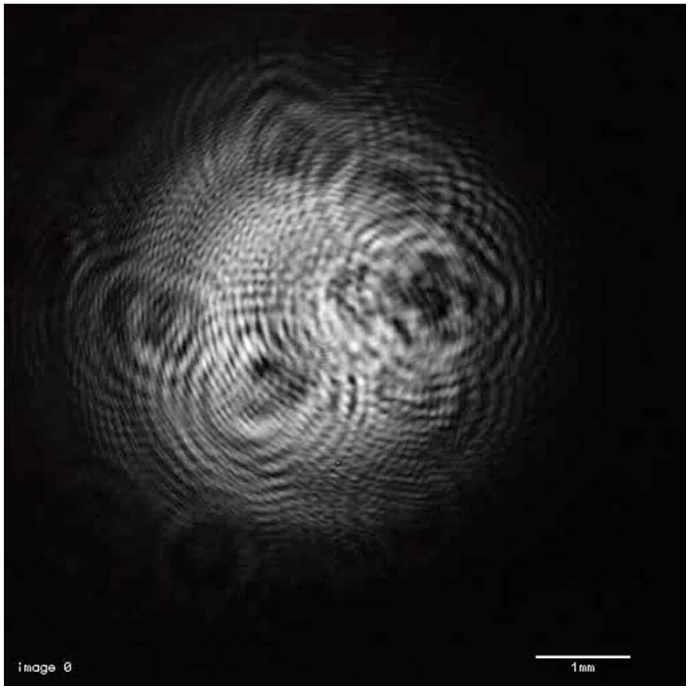

M. Kanka, R. Riesenberg, H. J. Kreuzer, Opt. Lett. 34, 1162 (2009)
M. Kanka, A. Wuttig, C. Graulig, R. Riesenberg, Opt. Lett. 35, 21 (2010)
M. Kanka, R. Riesenberg, P. Petruck, and Ch. Graulig, Opt. Lett. 36, 3651 (2011)

# Auflichtanordnung - Chipmikroskop

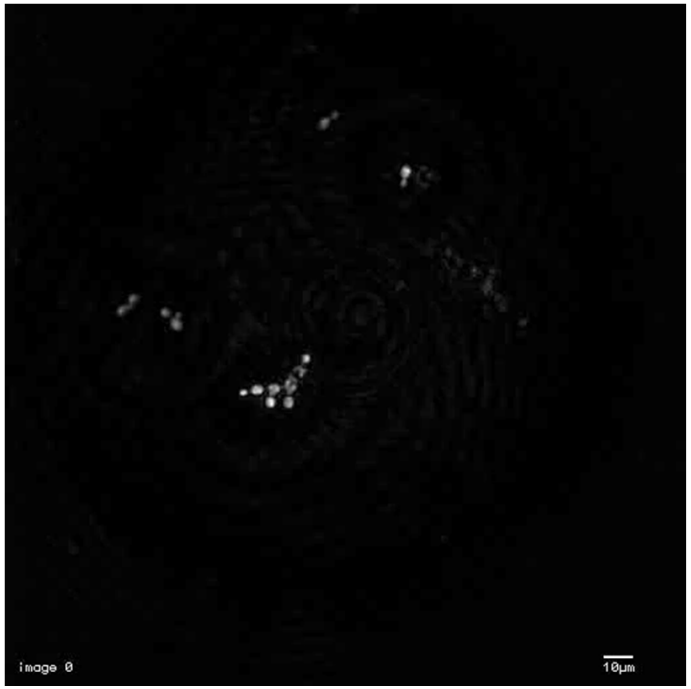
# Beispiel: Brewers yeast imaging



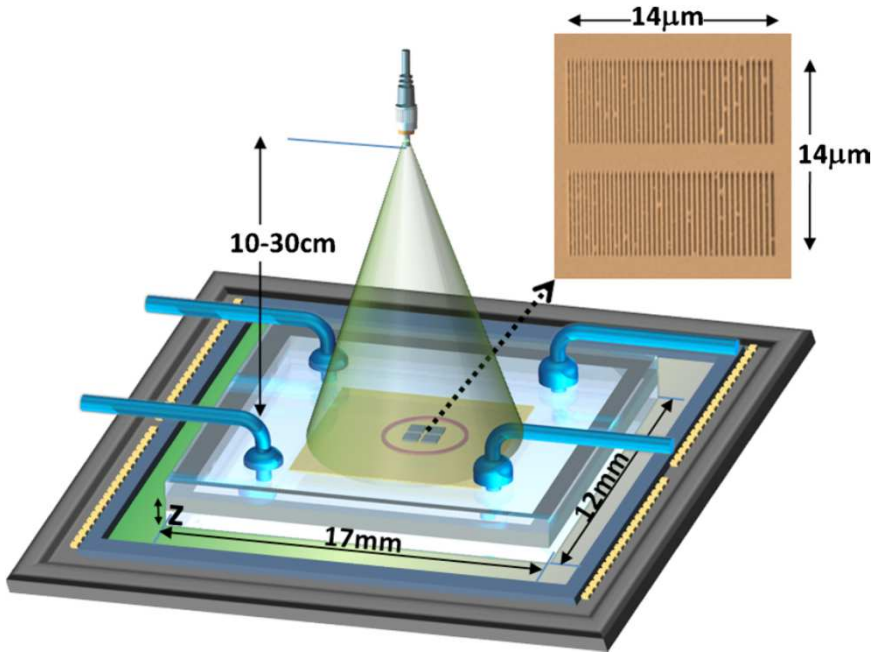
Hologram




Reconstruction brewer‘s yeast, resolution 1 µm



# Examples: Microfluidic Chip Microscopy, Lab-on-a-Chip



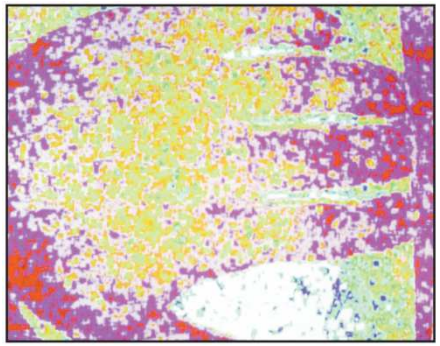

Lensfree sensing on a microfluidic chip using plasmonic nanoapertures

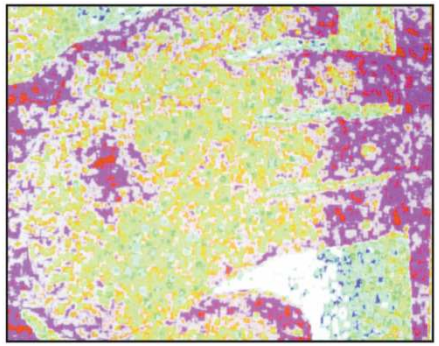
B. Khademhosseinieh, G. Biener, I. Sencan, T.-W. Su, A. F. Coskun, and A. Ozcan

Appl. Phys. Lett. **97**, 221107, 2010

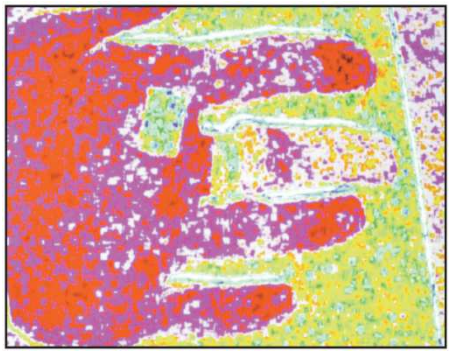
ipht jena
Applications

# Beispiele: Specklephotometrie in der Medizin

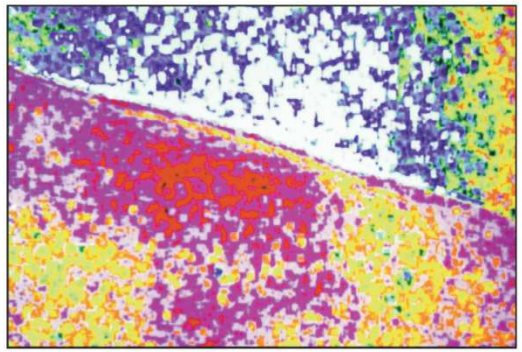




Laser Speckle Contrast Analysis (LASCA) images of the back of a hand, showing perfusion before and after gently rubbing a small area.



Reduction in perfusion caused by a rubber band

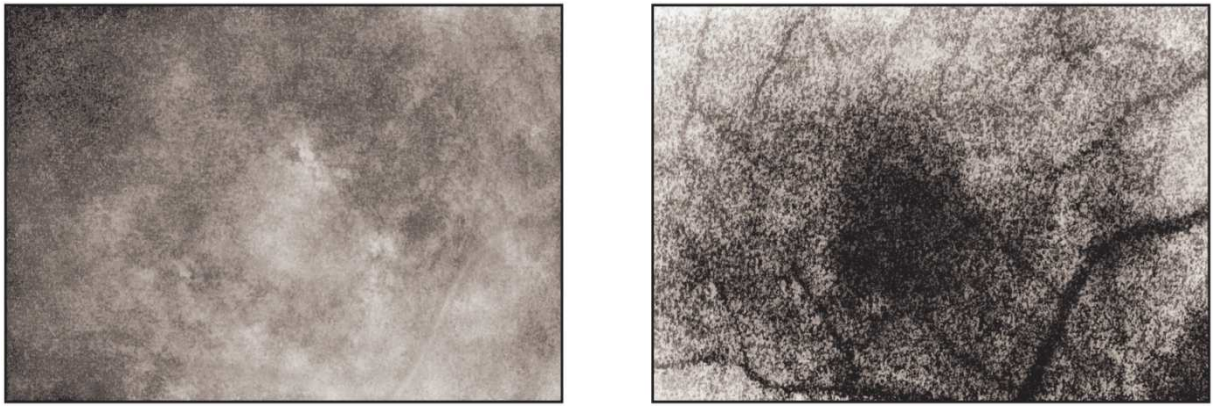


Part of a forearm, showing increased perfusion around a superficial hot-water burn

## Beispiele: Specklephotometrie und in der Medizin

Speckle contrast imaging for measuring blood flow

Speckle Contrast = $\sigma / \langle I \rangle \leq 1$, $\sigma$ – standard deviation



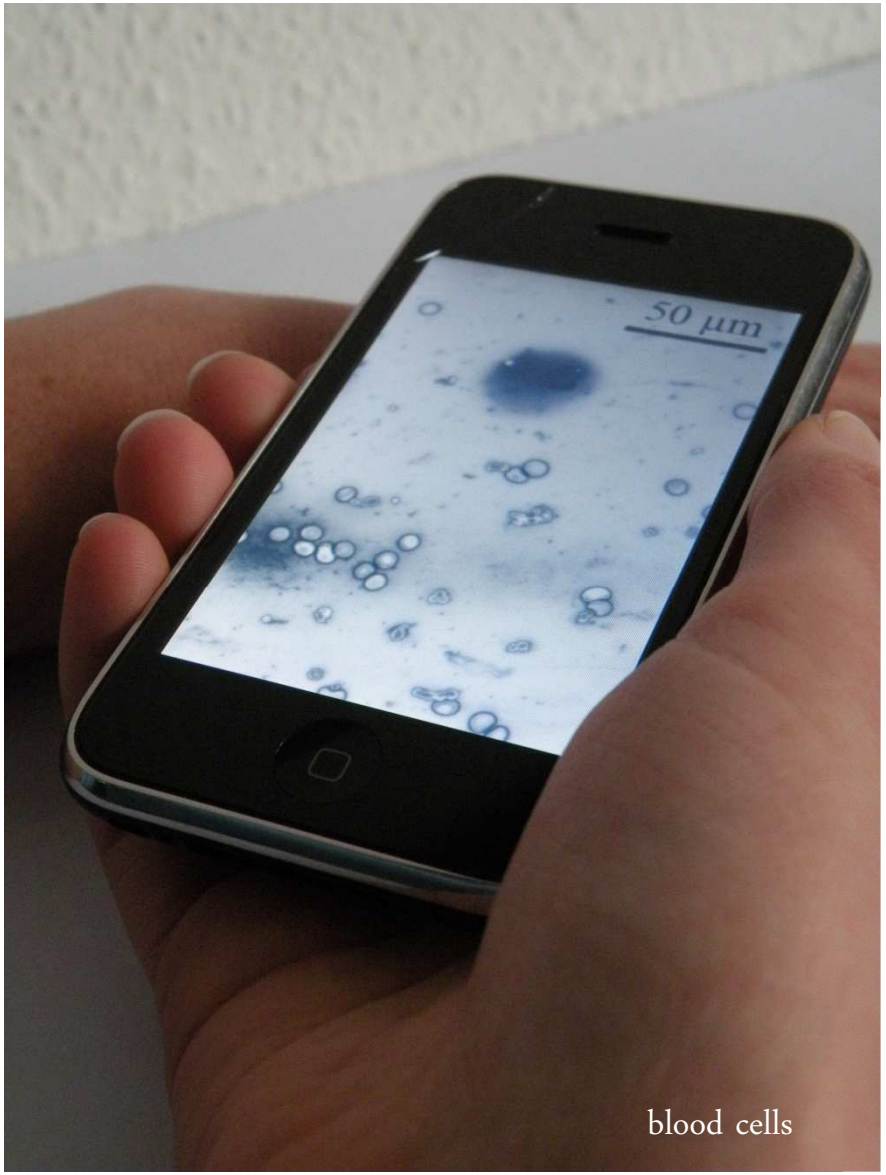
Single-exposure speckle photography – raw image of part of a retina (left), and its processed version (right).

a) "Health Eye" = Retina stimulator with monitoring unit

b) Ocular Microtremor Laser Speckle Metrology

c) Heart Pulse Variability monitoring (Speckle time dependence)

# Zusammenfassung: Smartphone based lensless microscope



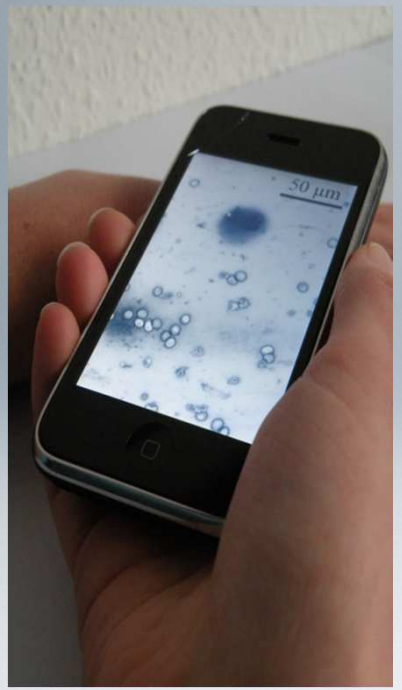
blood cells

numerical back propagation,
new reconstruction technique
(tile superposition)
for interference images

state-of-the-art lateral resolution
equals NA = 0.8,
less amount of memory and
processing time of seconds

halogen filament lamp or LED

- Linsenloses Chip-Mikroskop




„Kachel-Superpositionsprinzip“
state-of-the-art Auflösung,
800 nm

Speckle-frei mit LED

Auflichtanordnung

Auflösung … 100 nm

nature methods
Techniques for life scientists and chemists

**Imaging without lenses:..on-chip microscopy**

Alon Greenbaum[1,2], Wei Luo[1,2], Ting-Wei Su[1,2], Zoltán Göröcs[1,2], Liang Xue[1–3], Serhan O Isikman[1,2], Ahmet F Coskun[1,2], Onur Mudanyali[1,2] & Aydogan Ozcan[1,2,4,5]

2. Garcia-Sucerquia, J. *et al.* Digital in-line holographic microscopy. *Appl. Opt.* **45**, 836–850 (2006).
3. Kanka, M., Riesenberg, R. & Kreuzer, H.J. Reconstruction of high-resolution holographic microscopic images. *Opt. Lett.* **34**, 1162–1164 (2009).
4. Kanka, M., Riesenberg, R., Petruck, P. & Graulig, C. High resolution (NA=0.8) in lensless in-line holographic microscopy with glass sample carriers. *Opt. Lett.* **36**, 3651–3653 (2011).

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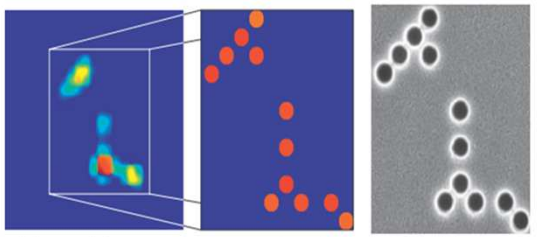
**…subwavelength coherent diffractive imaging**

A. Szameit[1,2†], Y. Shechtman[1†], E. Osherovich[3†], E. Bullkich[1], P. Sidorenko[1], H. [illegible]
E. B. Kley[2], S. Gazit[1], T. Cohen-Hyams[5], S. Shoham[4], M. Zibulevsky[3], I. Yavneh[3]
O. Cohen[1] and M. Segev[1*]



blurred image of nano-holes | reconstruction | SEM image