The Abdus Salam
International Centre for Theoretical Physics
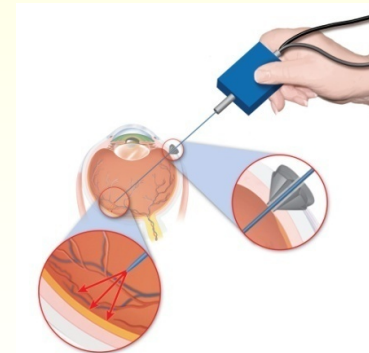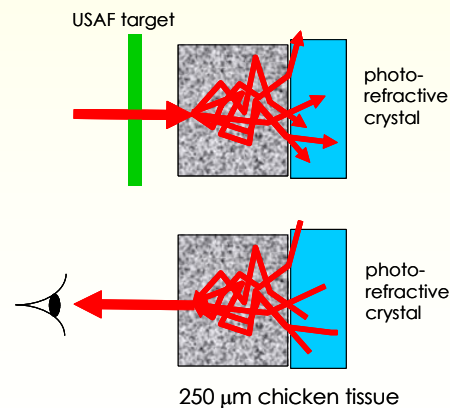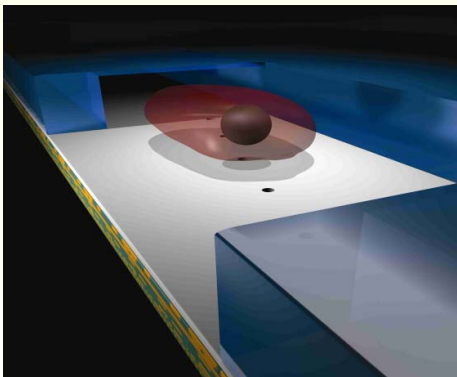
2037-19

Introduction to Optofluidics

1 - 5 June 2009

Optofluidic Microscope

C. Yang

California Institute of Technology
Pasadena
U.S.A.

Optofluidic Microscope

Changhuei Yang

(chyang@caltech.edu)

California Institute of Technology

Caltech Biophotonics Laboratory

Acknowledgment

My group:
Jigang Wu (microscope, probe)
Emily McDowell (turbidity suppression)
Xiquan Cui (microscope)
Lapman Lee (microscope)
Guoan Zhang (microscope)
Jian Ren (probe)
Sean Pang (microscope)
Yin Min Wang (microscope)
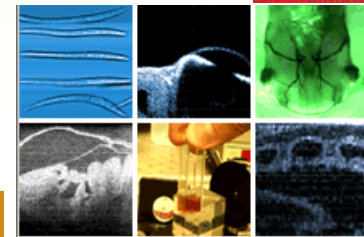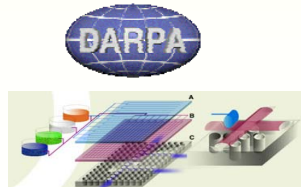Meng Cui (turbidity suppression)

Collaborators:
Demetri Psaltis (EPFL)
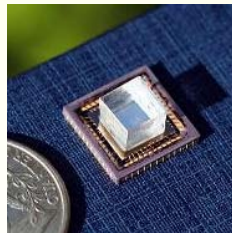Paul W. Sternberg (Caltech)
Snow Tseng (NTU, Taiwan)

Funding Sources:
DARPA Optofluidic Center,
NIH, NSF,
Coulter Foundation,
Caltech Grubstake Program,
Industrial Collaborators

Caltech Biophotonics Laboratory

# Redesigning the microscope

We abandon the conventional microscopy design and uses a novel aperture array for high resolution imaging

Images of C. elegans

50 μm

- compact microscope (fits on your fingertip)
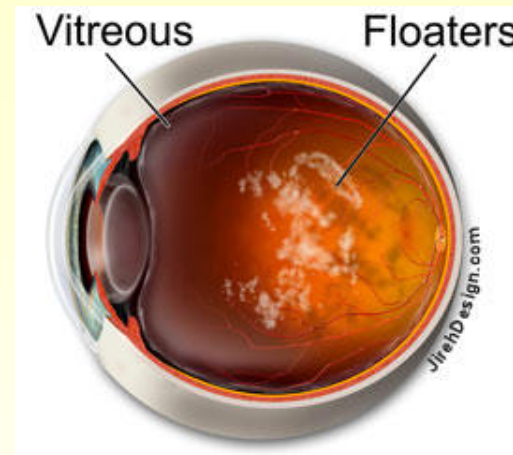- potentially cheap ($10's)

Xin Heng, David Erickson, Larry R. Baugh, Zahid Yaqoob, Paul W. Sternberg, Demetri Psaltis, and Changhuei Yang. 'Optofluidic microscopy: A Method for Implementing High Resolution Optical Microscope On A Chip,'Lab on a Chip 6, 1274 (2006).
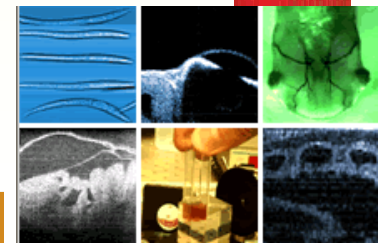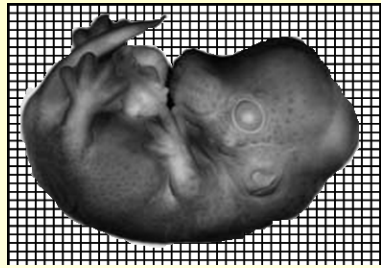
Caltech Biophotonics Laboratory
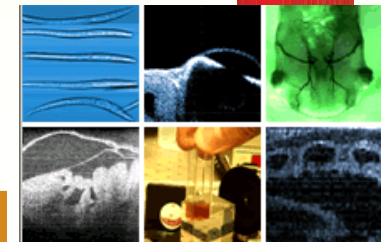
Floaters

Floaters in the field of view

The origin of floaters

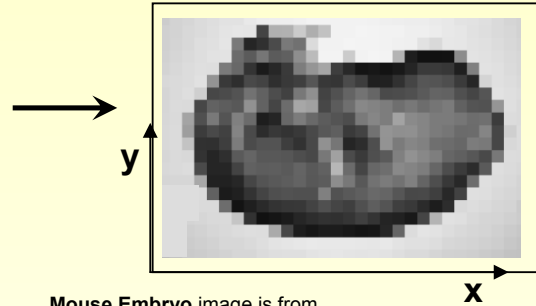# Operating principle

Poor resolution in both x and y !

Mouse Embryo image is from
http://www.uthscsa.edu/opa/issues/new33-33/images/mouse.jpg

(I) CCD chip

y

x

Opaque layer

Nanohole array
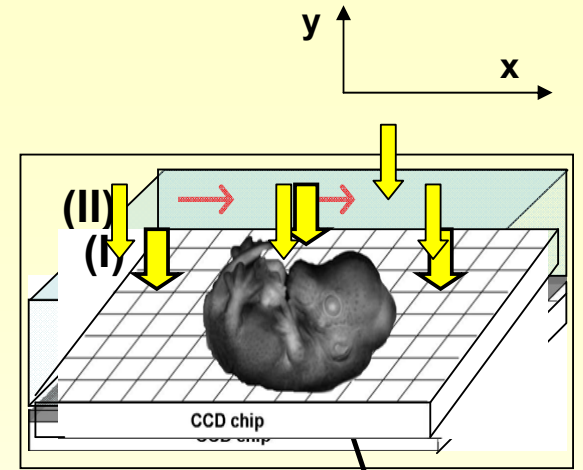
? What if sample is as small as a CCD pixel?

Flow direction

transmission
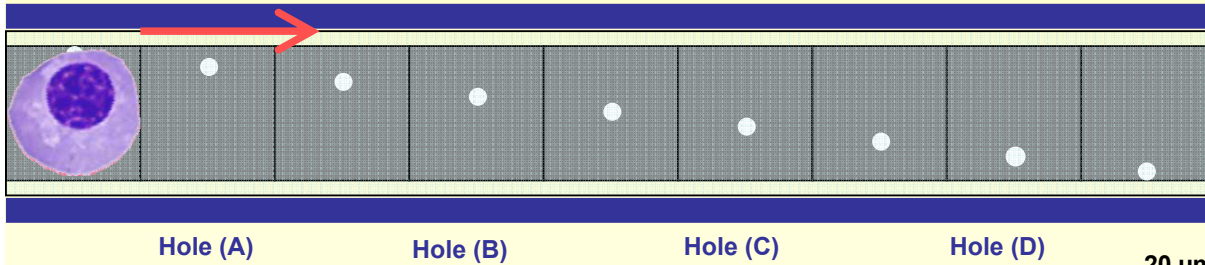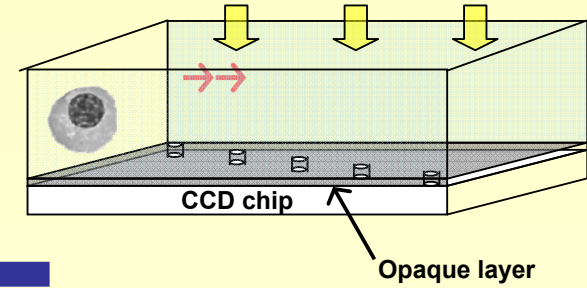
time

Improve resolution in only x direction
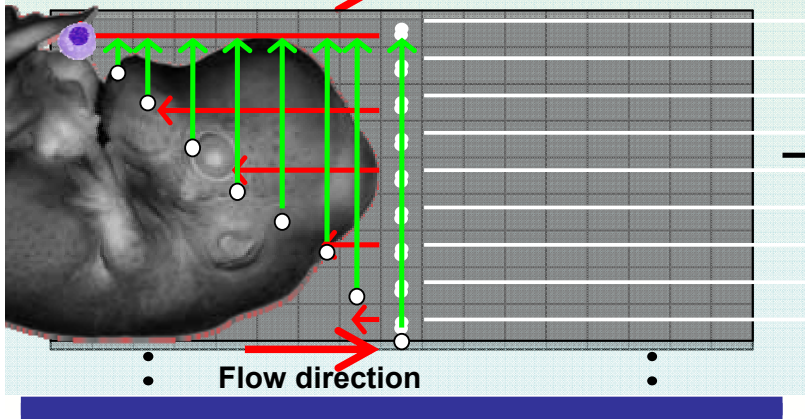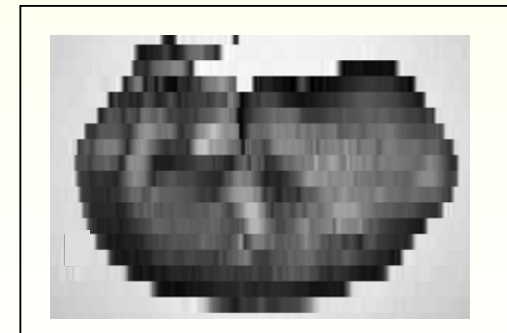
(II) Same CCD but with a column of nanoholes
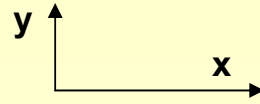
Nucleated blood cell image is from
http://www.wadsworth.org/chemheme/heme/glass/slide_011_nrbc.htm

Operating principle

Slanted nanohole 1D array
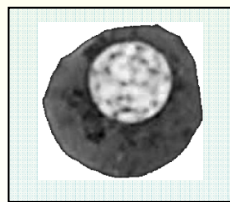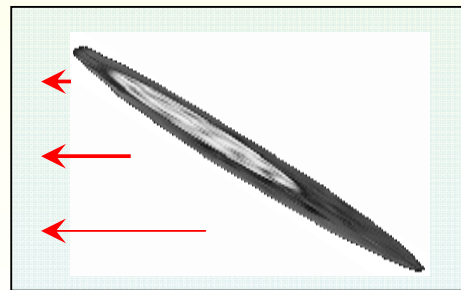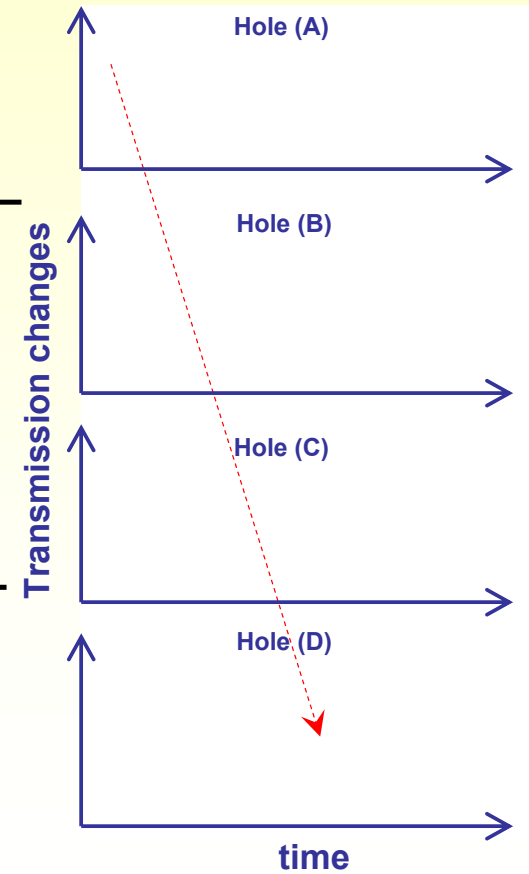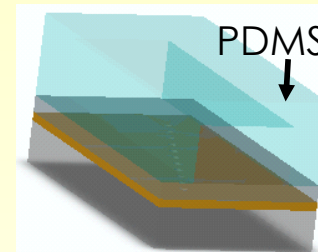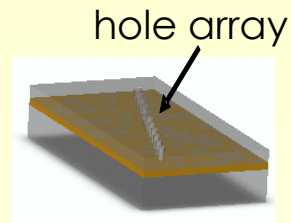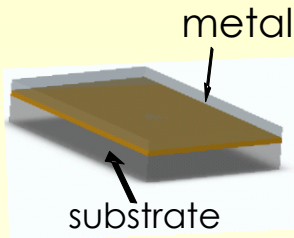Improve resolution in both x and y direction
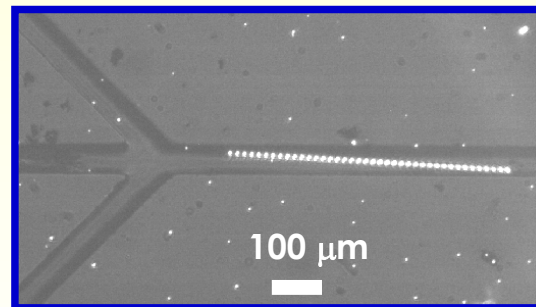
Final

Shift forward linearly

Nucleated blood cell image is from http://www.wadsworth.org/chemheme/heme/glass/slide_011_nrbc.htm

6

Fabricating the OFM

Fabrication Steps:
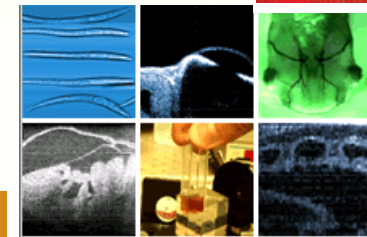

metal
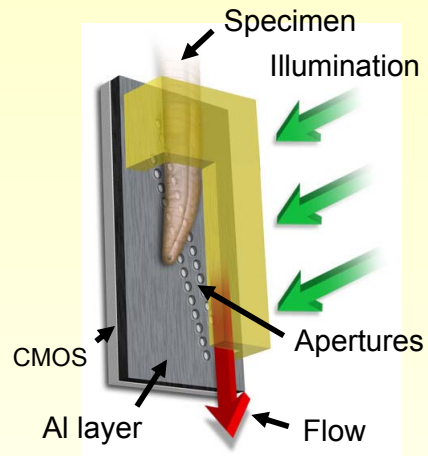
substrate

hole array

PDMS
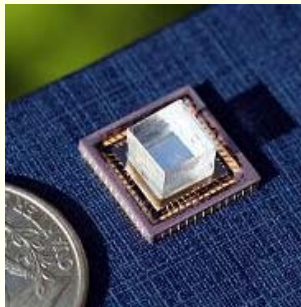
On-chip OFM

100 μm

Transmission microscope
image of the hole array

Xin Heng, David Erickson, Larry R. Baugh, Zahid Yaqoob, Paul W. Sternberg, Demetri Psaltis, and Changhuei
Yang. 'Optofluidic microscopy: A Method for Implementing High Resolution Optical Microscope On A Chip,'Lab
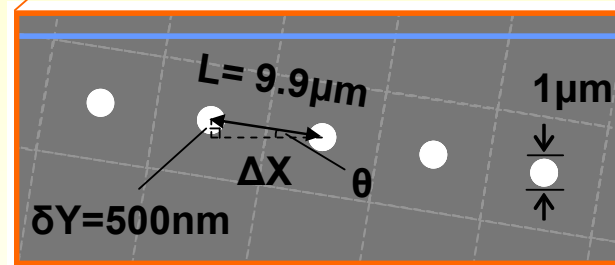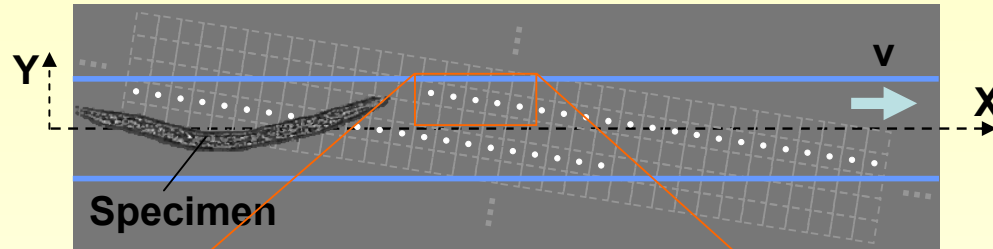on a Chip 6, 1274 (2006).
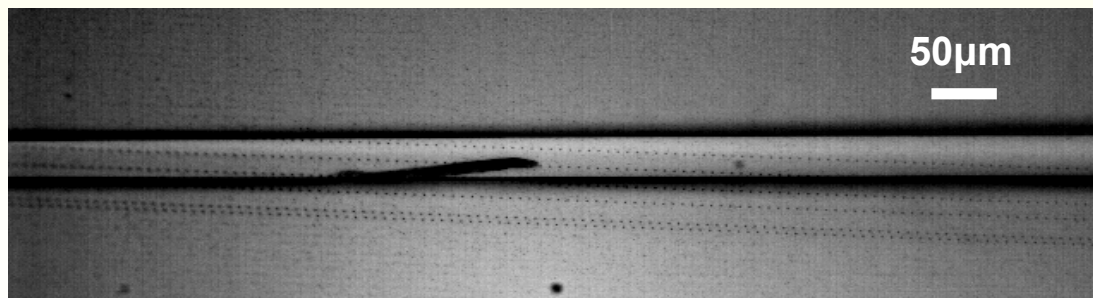
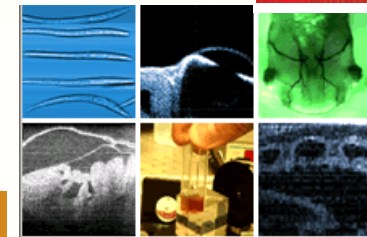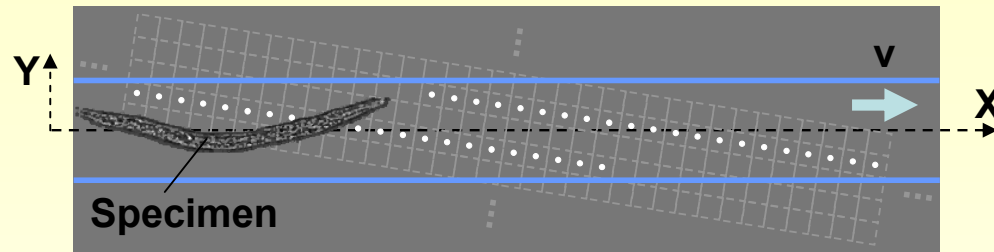*Caltech Biophotonics Laboratory*

Imaging Strategy

OFM imaging geometry

OFM aperture geometry

L = 9.9μm

1μm

ΔX

θ

δY=500nm

50μm

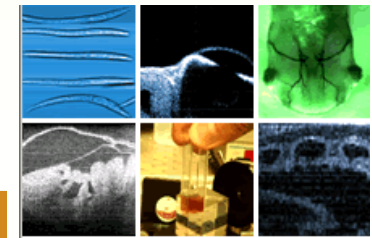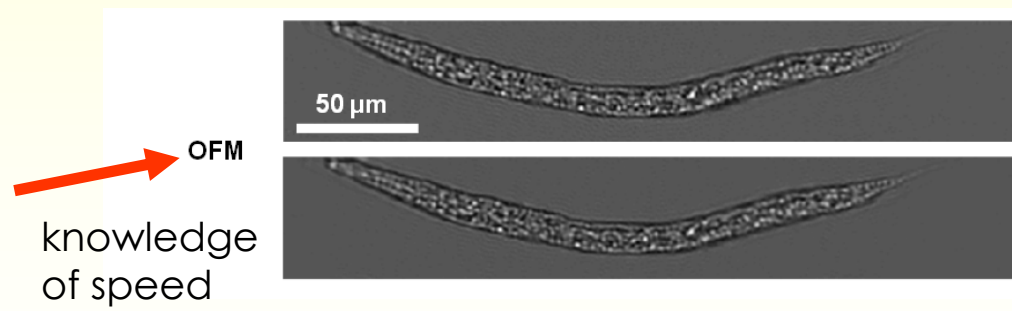C. elegans moving across the hole array

Caltech Biophotonics Laboratory

Imaging Strategy

speed
determination

line scans

knowledge
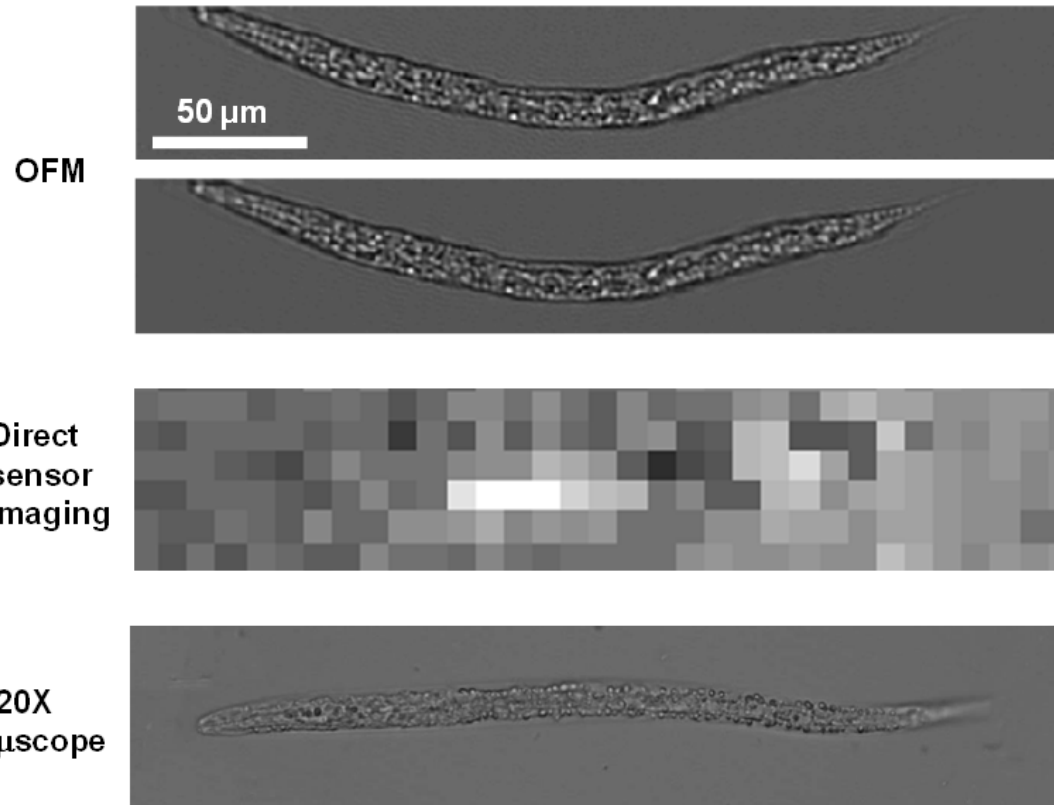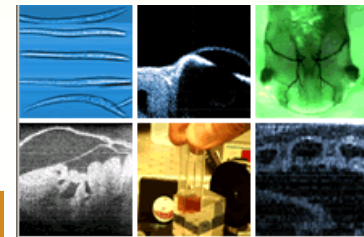of speed

OFM
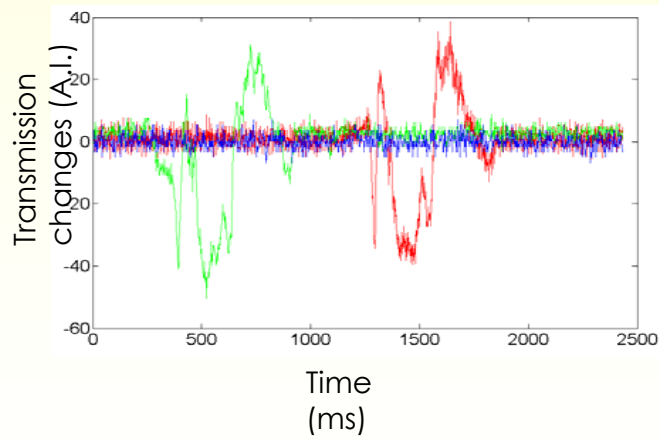
Imaging C. elegans

OFM prototype capabilities:
Each worm takes 2.5 sec to image
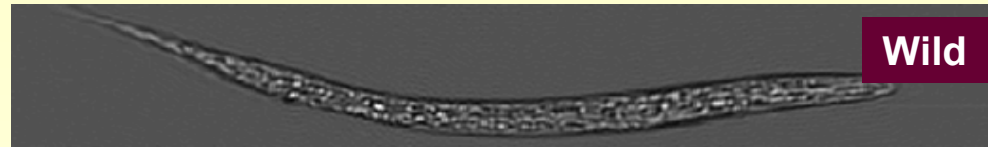Optimal worm processing rate: ~ 2 worms/sec

Caltech Biophotonics Laboratory
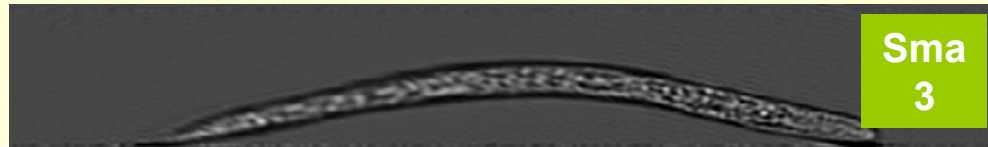
Automated Phenotype Characterization

Perform automated phenotype characterization

a) automated
c) computerized worm length and area measurement
d) drop and go

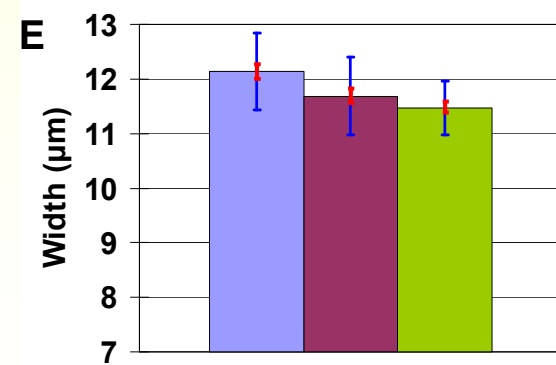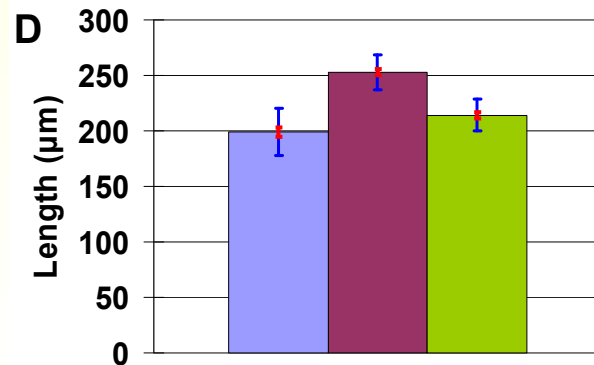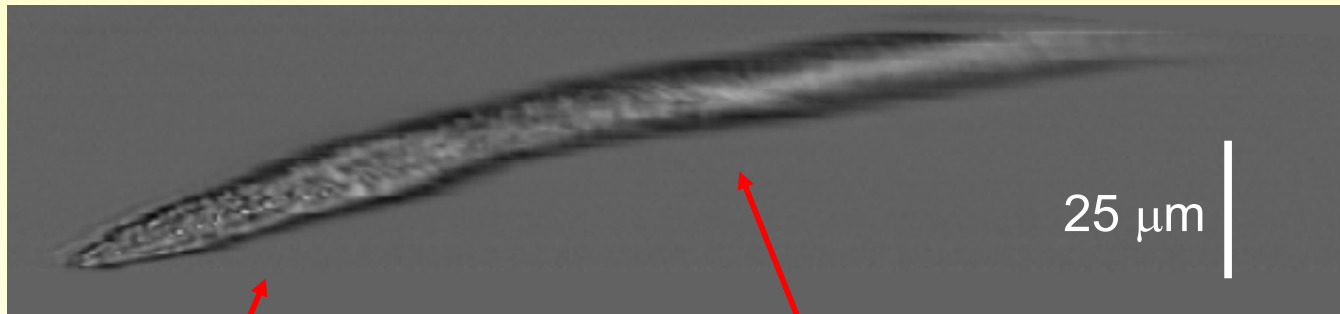A — Wild

B — Sma 3

C — Dpy 7

50um

D — Length (µm)

E — Width (µm)

X Cui, L Lee, X Heng, W Zhong, PW Sternberg, D Psaltis & C Yang, PNAS Vol 105, 10670 (2008)
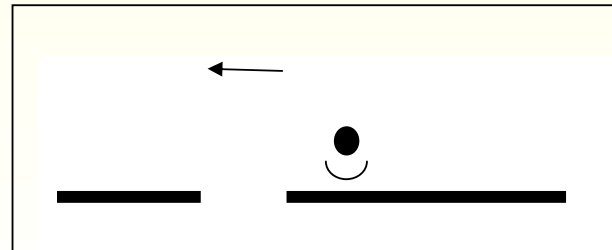
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Resolution Issues

25 μm

well resolved region that
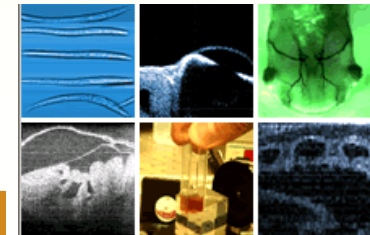was in close proximity to
the hole array

blurry region that was
not in proximity to the
hole array

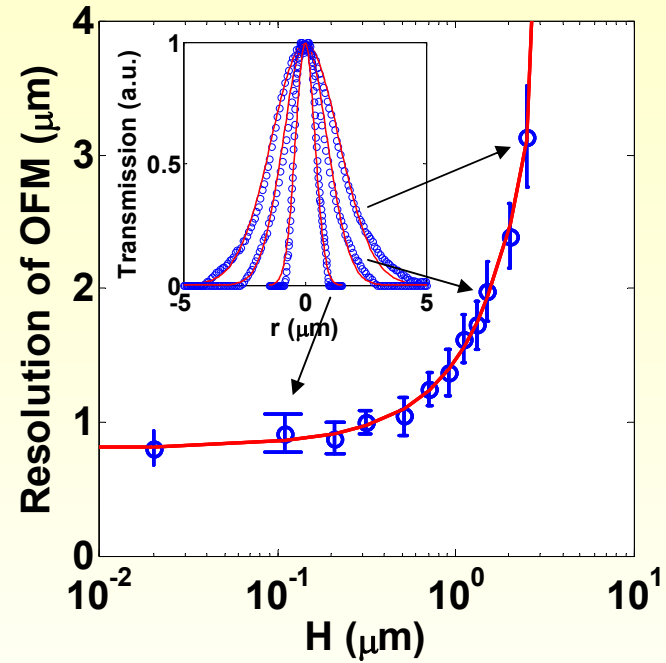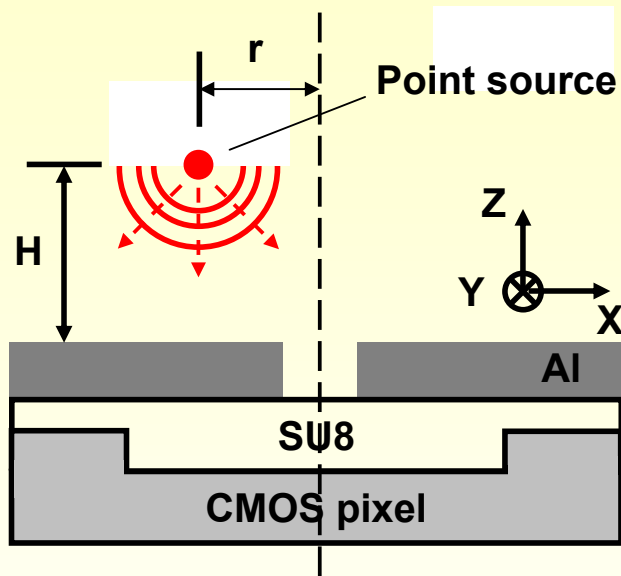**Proximity to hole array is
required for good resolution.**

X. Heng, X. Cui, D. W. Knapp, J. Wu, Z. Yaqoob, E. J. McDowell, D. Psaltis, and C. Yang, Optics Express, Vol. 14, No. 22, pp. 10410-10425, October 2006.
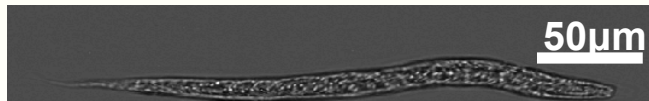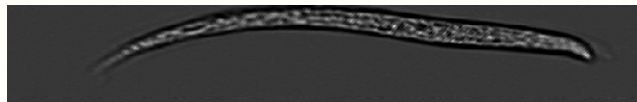
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Resolution Issues

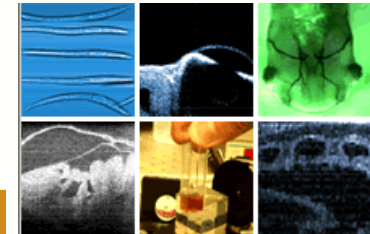**Prototype resolution = 0.9 microns (Sparrow's Criterion)**

15 micron tall channel

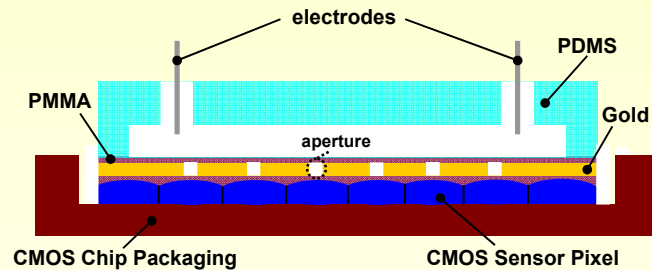25 micron tall channel

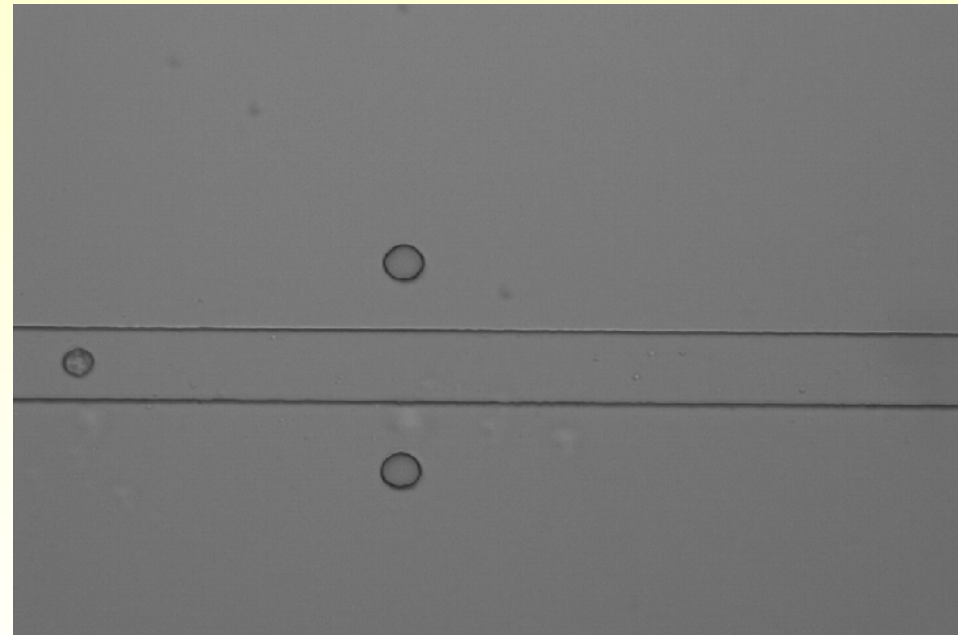**Shallow channels give better images**

Electrokinetic Drive based Optofluidic Microscope (EK-OFM)

electrodes

PDMS

PMMA

Gold

aperture

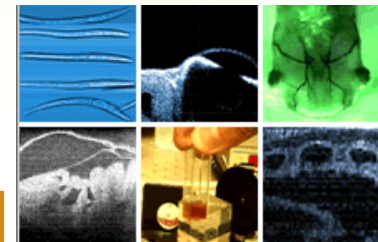CMOS Chip Packaging

CMOS Sensor Pixel

The flat velocity profile of EK flow reduces rotations of spherical/ellipsoidal cells in OFM.
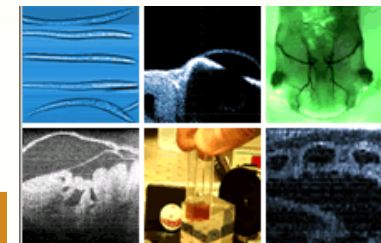

50 μm

X Cui, L Lee, X Heng, W Zhong, PW Sternberg, D Psaltis & C Yang, PNAS Vol 105, 10670 (2008)

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EK-OFM

OFM

| b | d | f | h | j |

10μm

conventional microscope

| b | d | f | h | k |

Chlamydomonas　　　　mulberry pollen spores　　　polystyrene microsphere

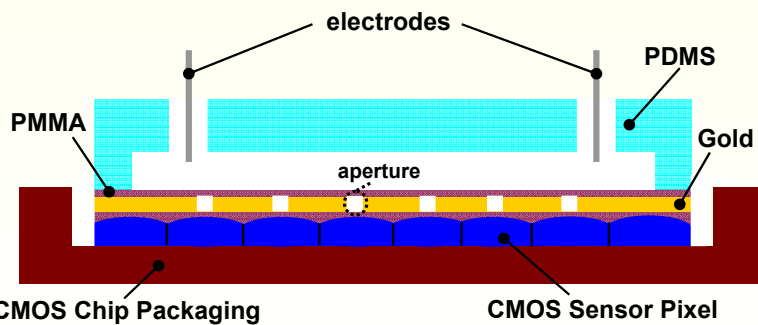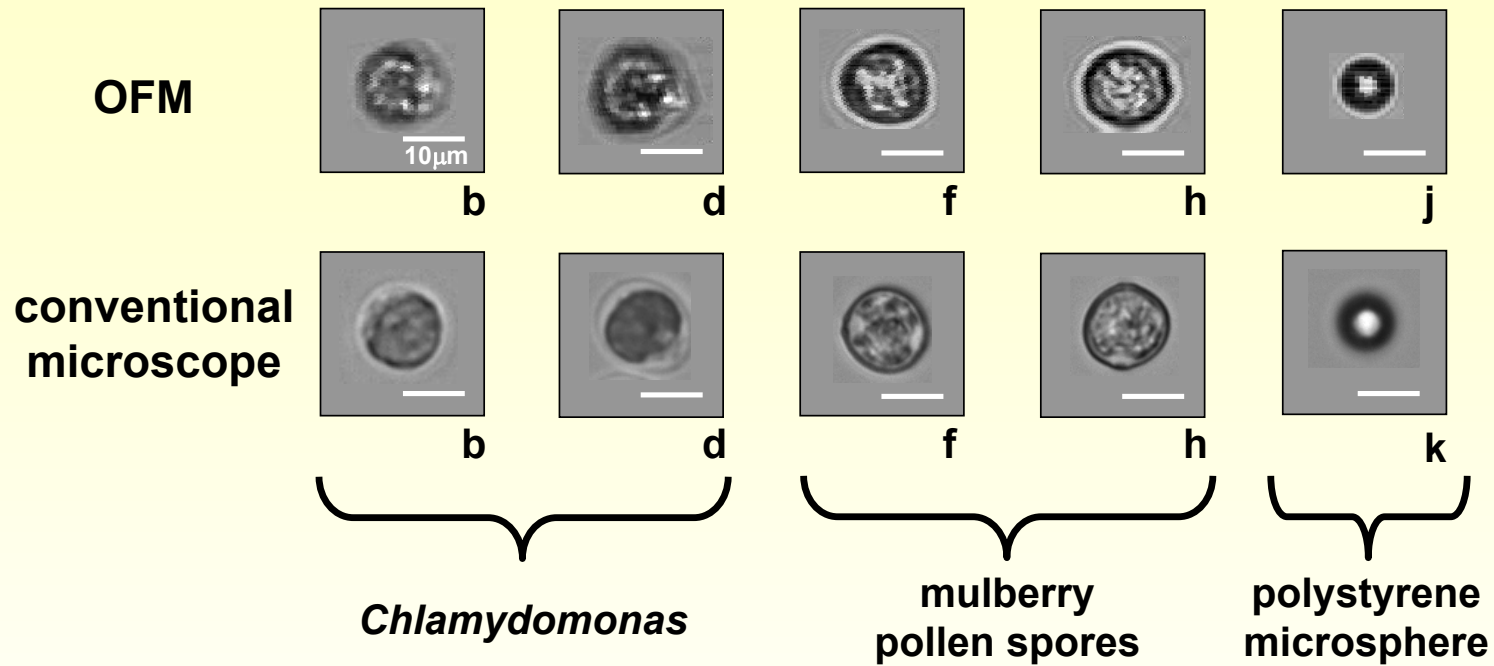electrodes　　PDMS

PMMA

Gold

aperture

CMOS Chip Packaging　　　CMOS Sensor Pixel

X Cui, L Lee, X Heng, W Zhong, PW Sternberg, D Psaltis & C Yang, PNAS Vol 105, 10670 (2008)
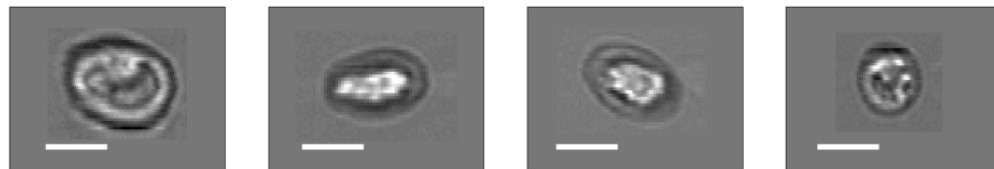
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Recent OFM images of Giardia

cyst (OFM)   cyst (traditional)
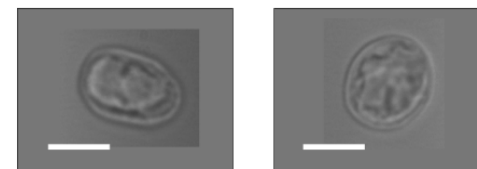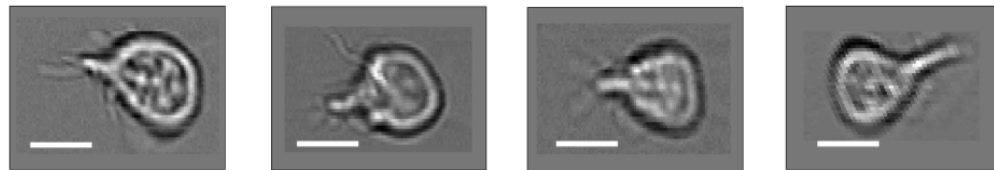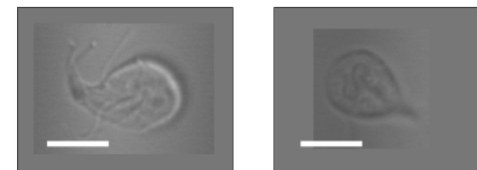

mature (OFM)   mature (traditional)

Bar = 10 microns