



# A compact, low-power digital holographic imaging system for automated plankton taxonomical classification

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# Initial Project Goals

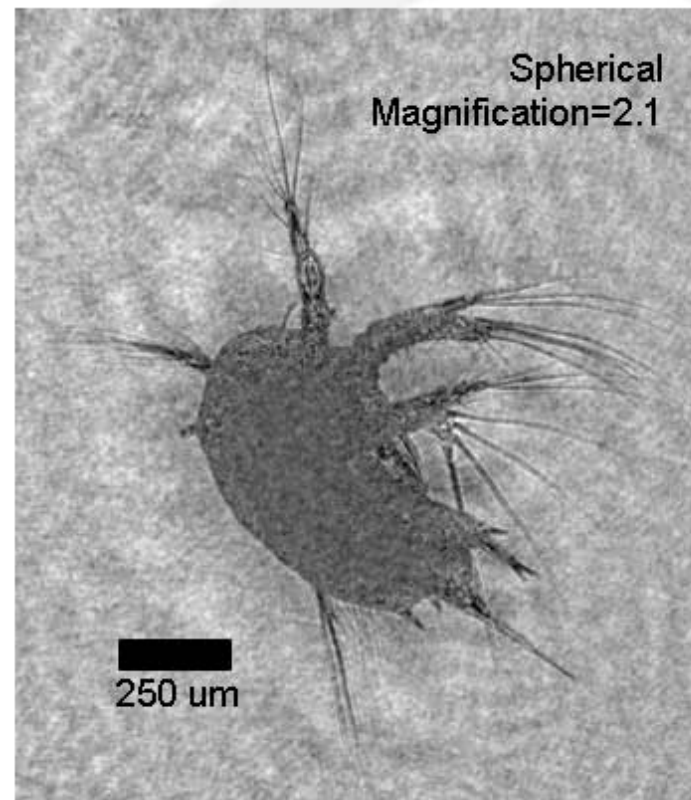
- Low power and compact: ideal for AUVs,  $<30$  W
- 2D images suitable for current automated algorithms
- High resolution,  $\sim 10$   $\mu\text{m}$
- Large sample volume,  $>100$  mL
- Non-invasive
- *In situ* measurements



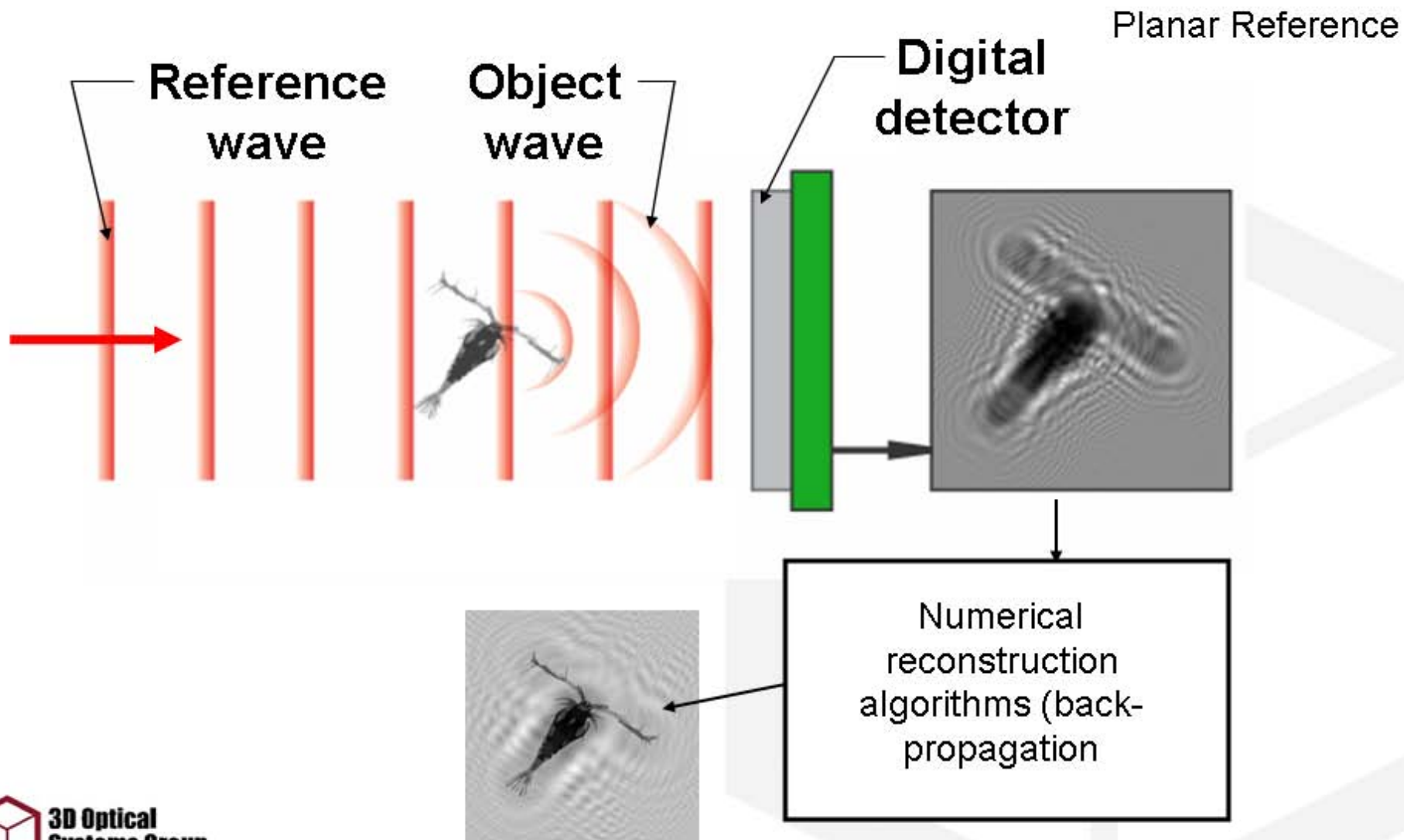
*Mock-up of digital holographic imager on a REMUS AUV*

# Digital Holographic Imaging

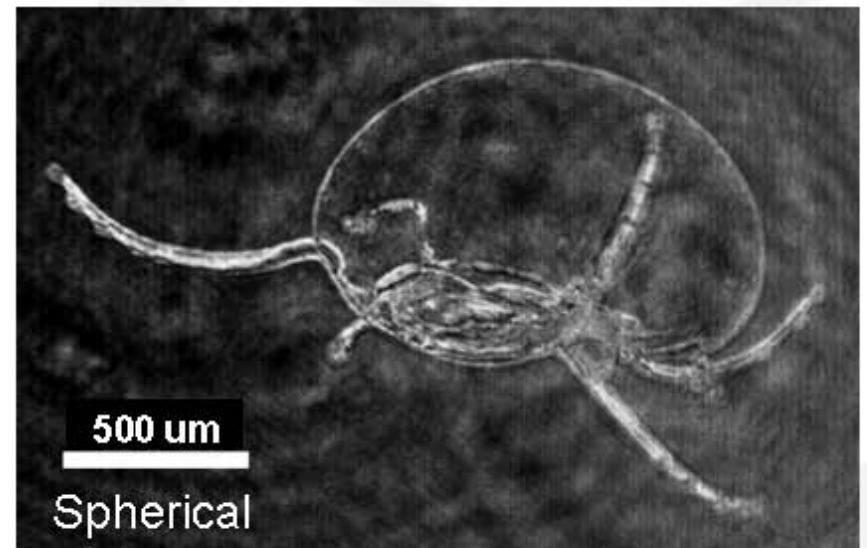
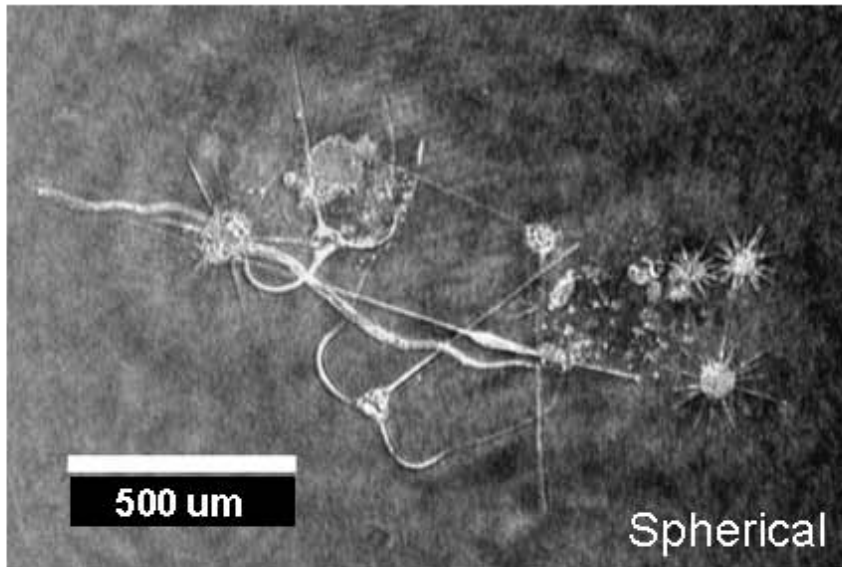
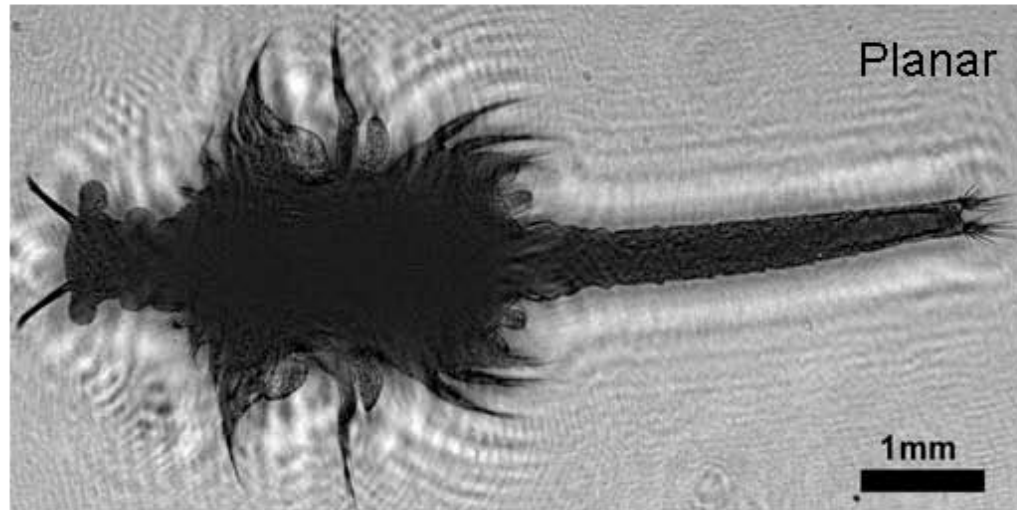
- 3D images for improved identification
- Population, orientation, morphology, 3D velocity, trajectory
- >500 mL volumes
- Flexible setups
- 9  $\mu\text{m}$  resolution



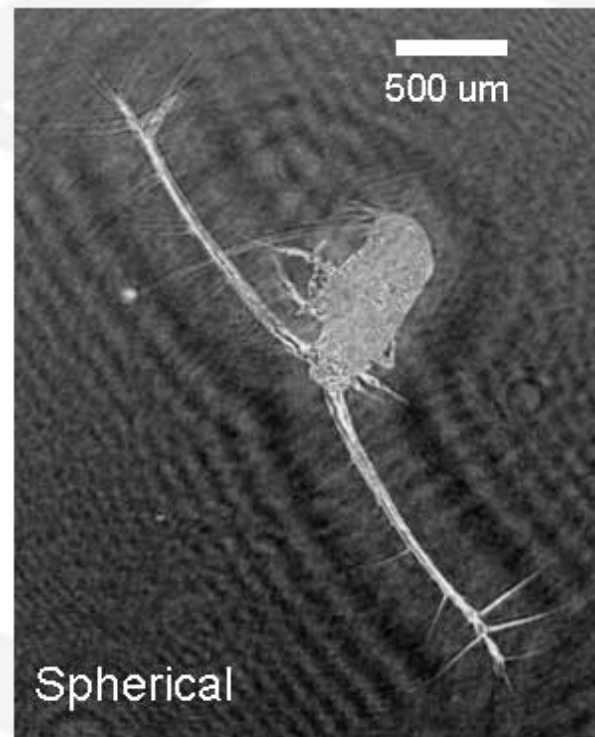
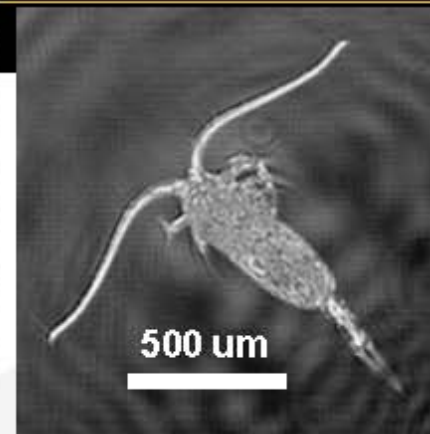
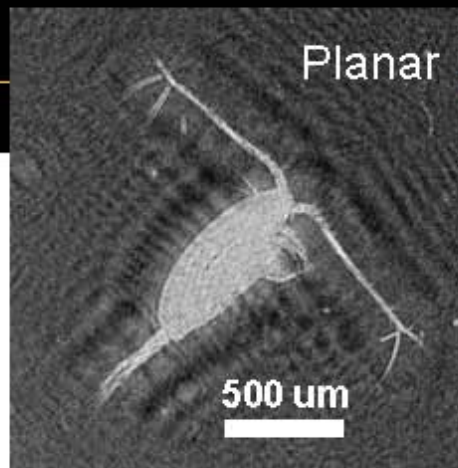
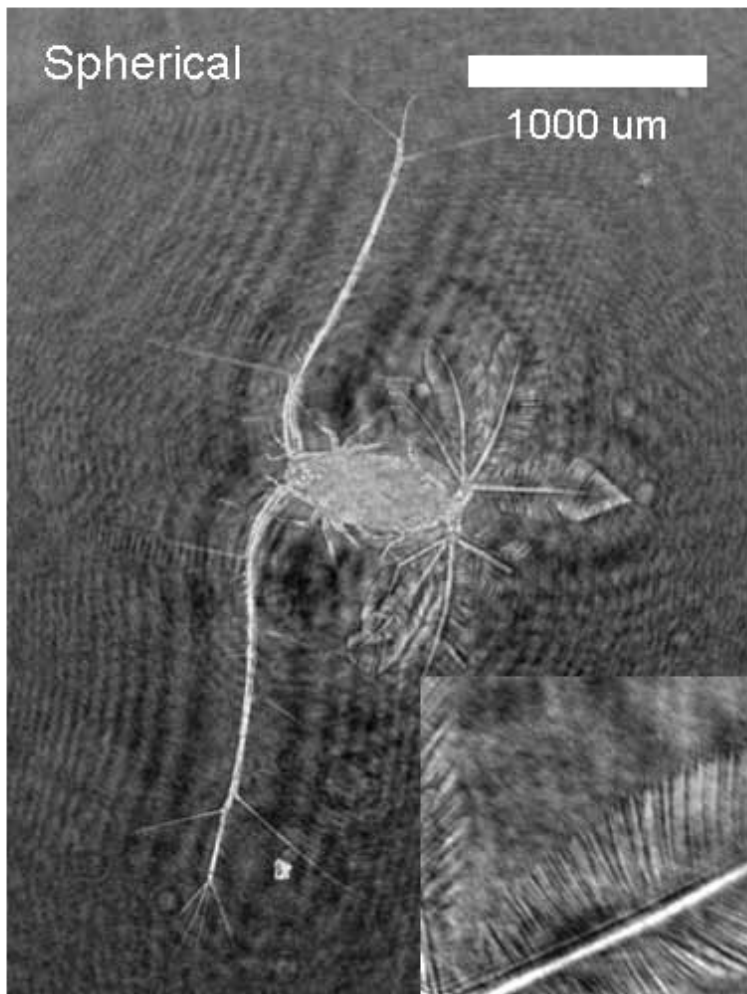
# Hologram Recording



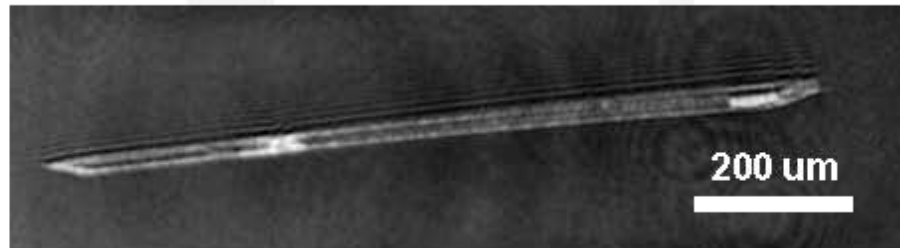
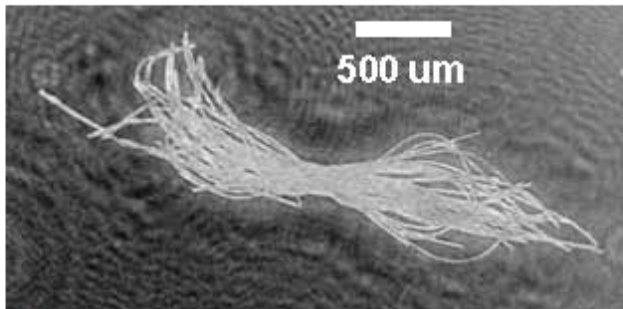
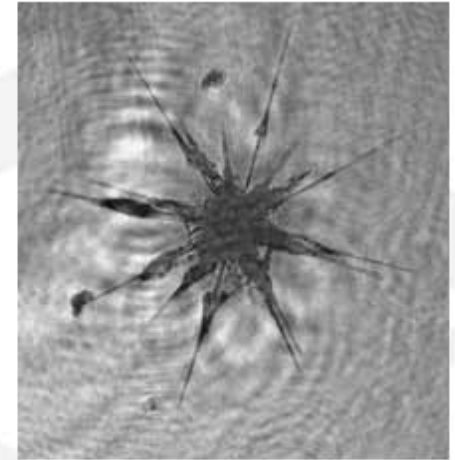
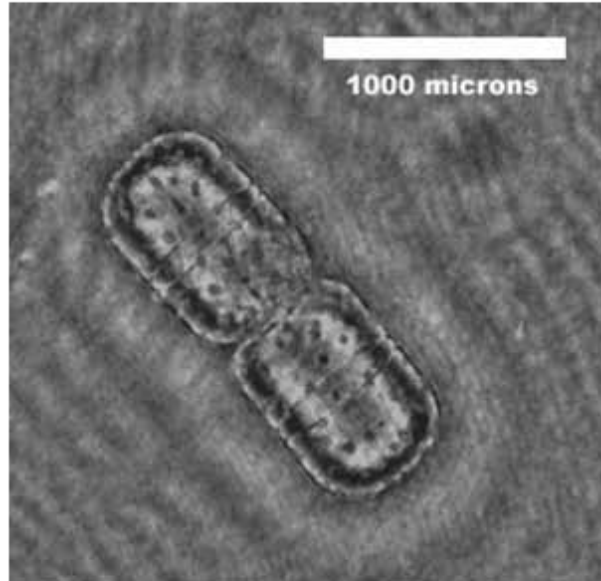
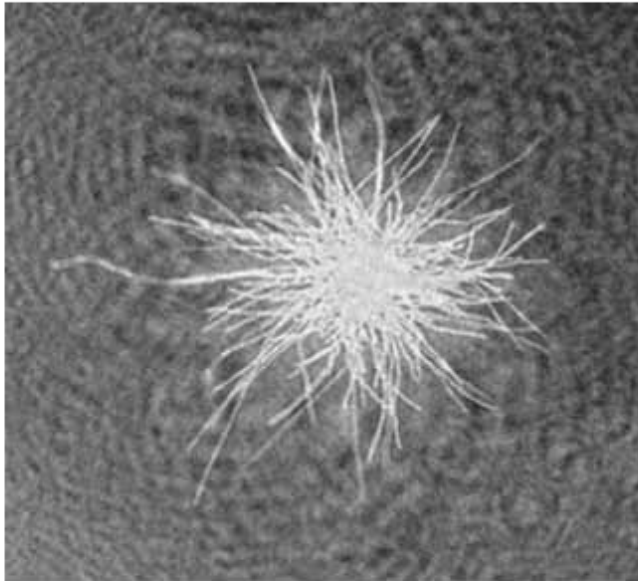
# Large Samples



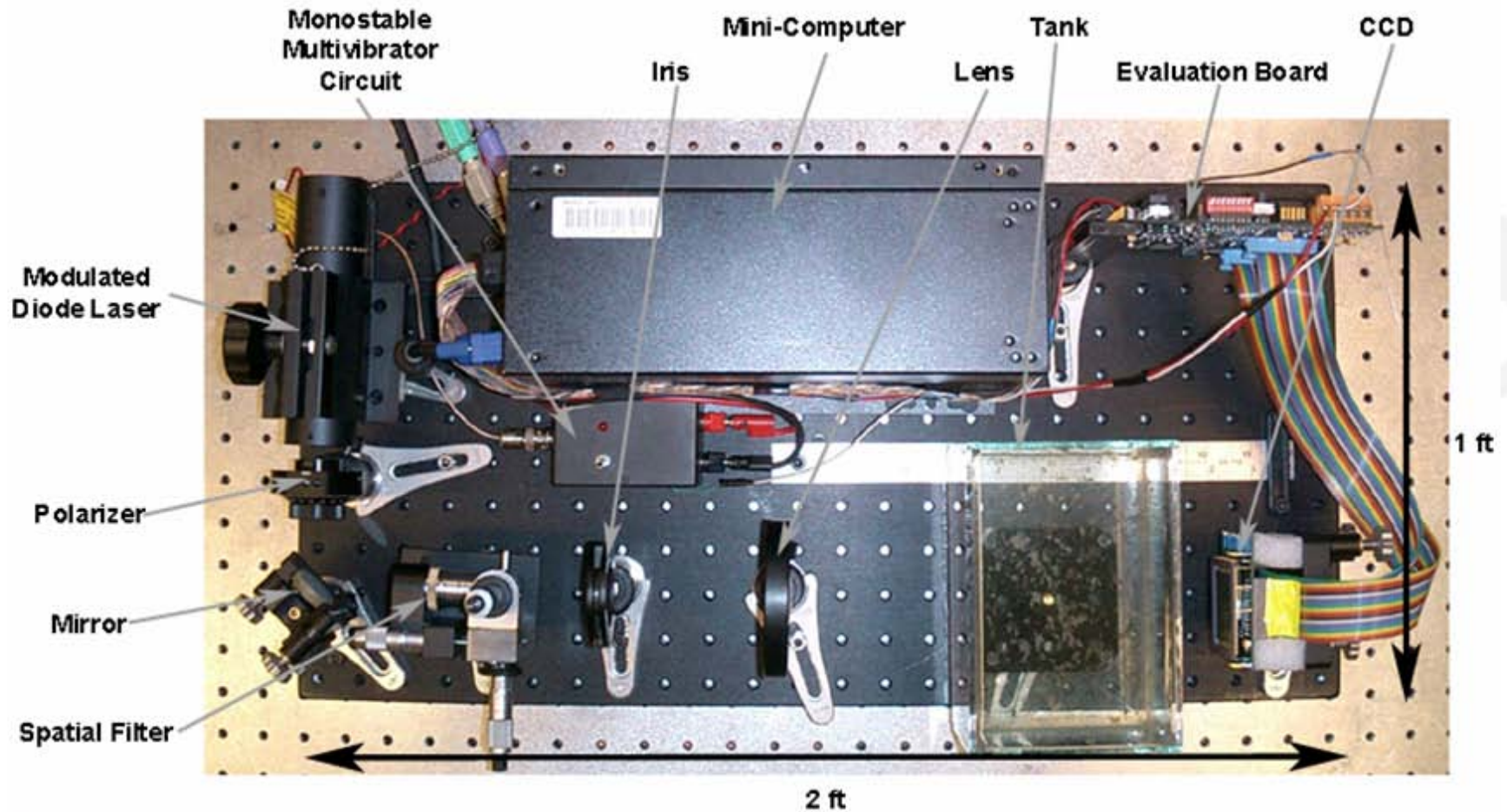
# Copepods



# Diatoms and *Trichodesmium*



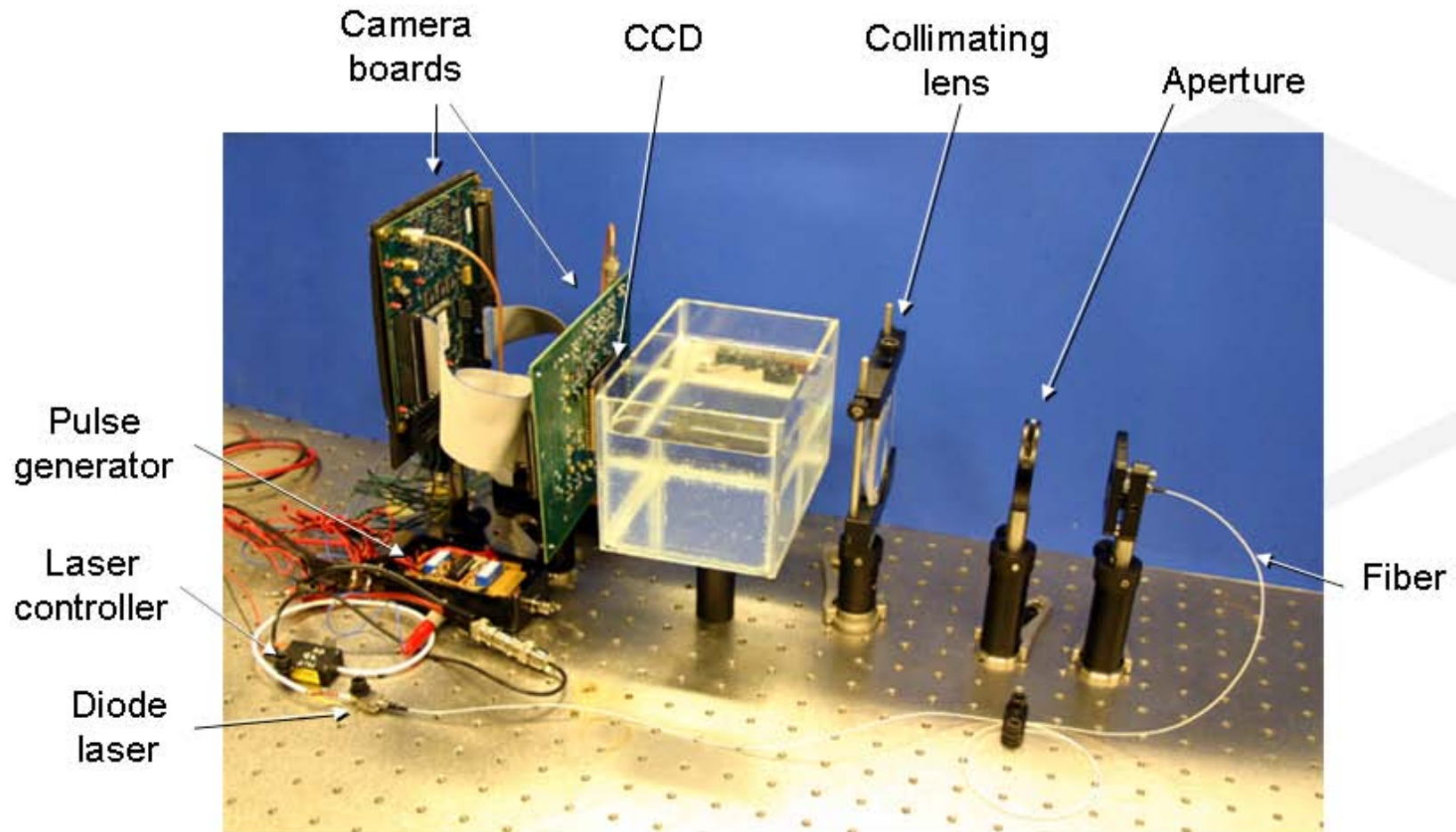
# Benchtop Prototype I



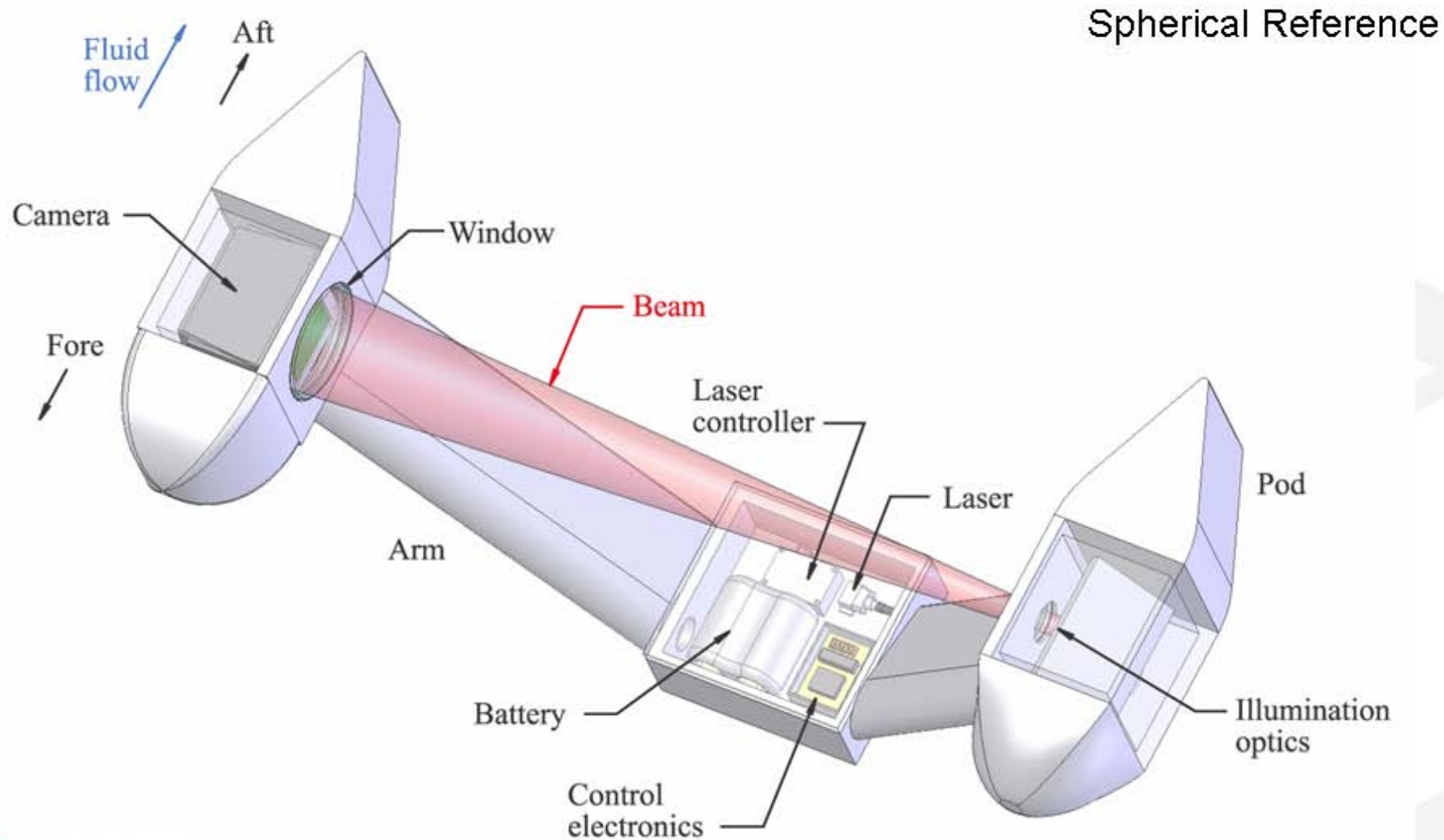


# Benchtop Prototype II

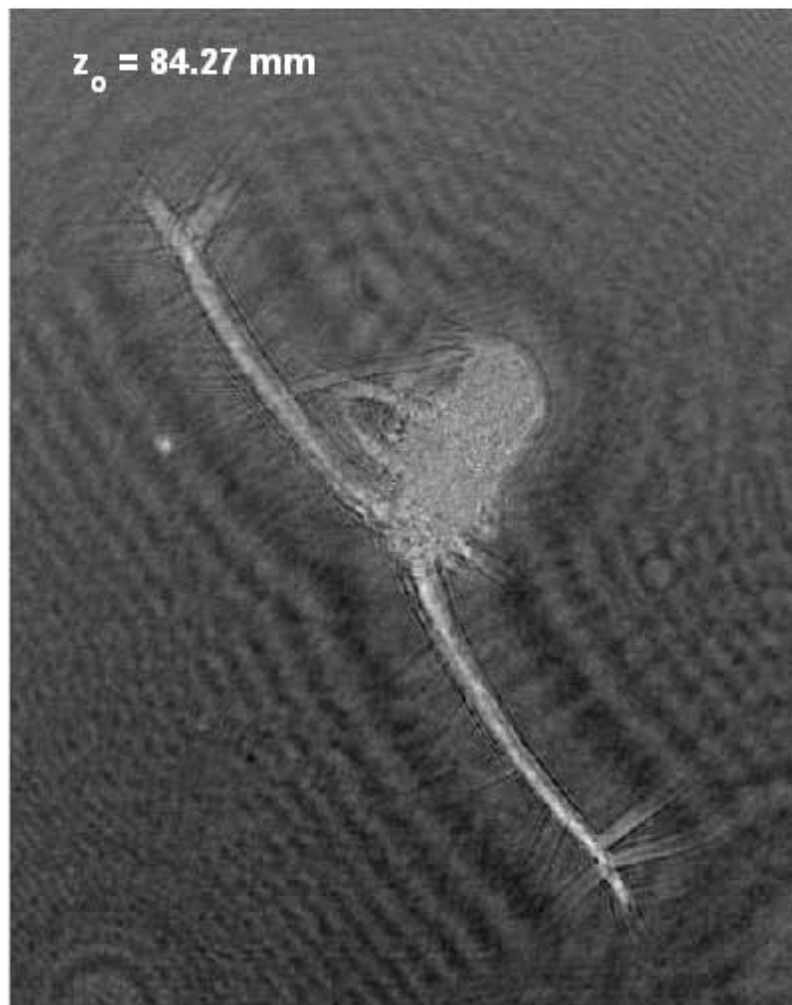
Planar Reference



# System overview



# Depth from Reconstructions

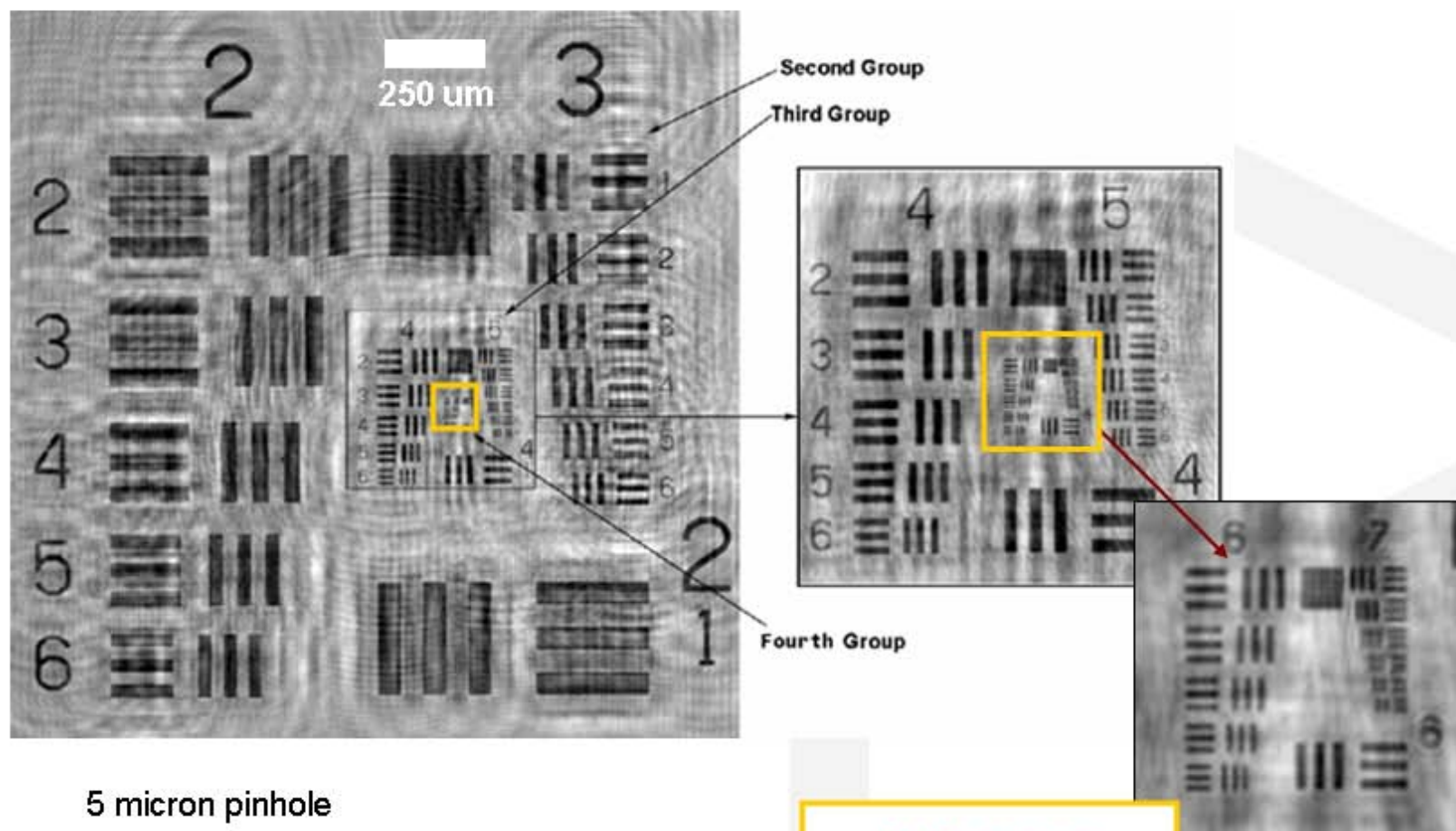


Spherical Reference

# Key Parameters

- Sample rate:  $\sim 0.75$  Hz\*
- Sample volume:  $> 500$  mL\* (30 L/min)
- Exposure time:  $\sim 1$   $\mu$ s (18 knots)
- 4096 x 4096 pixels detector (16 MPx)
- Axial resolution:  $\sim 200$   $\mu$ m
- Planar: resolve to pixel-sized details, 9  $\mu$ m
- Spherical: variable resolution, to 3  $\mu$ m

# Spherical: Resolution



5 micron pinhole

Spherical reference

**3.10 micron  
spacing (G7E3)**

- Multiple exposure digital holographic imaging: increase sample rate, volume, 3D velocities and trajectories
- Alternate optical setups
  - Spherical/Planar
  - Microscopy
  - Mach-Zehnder

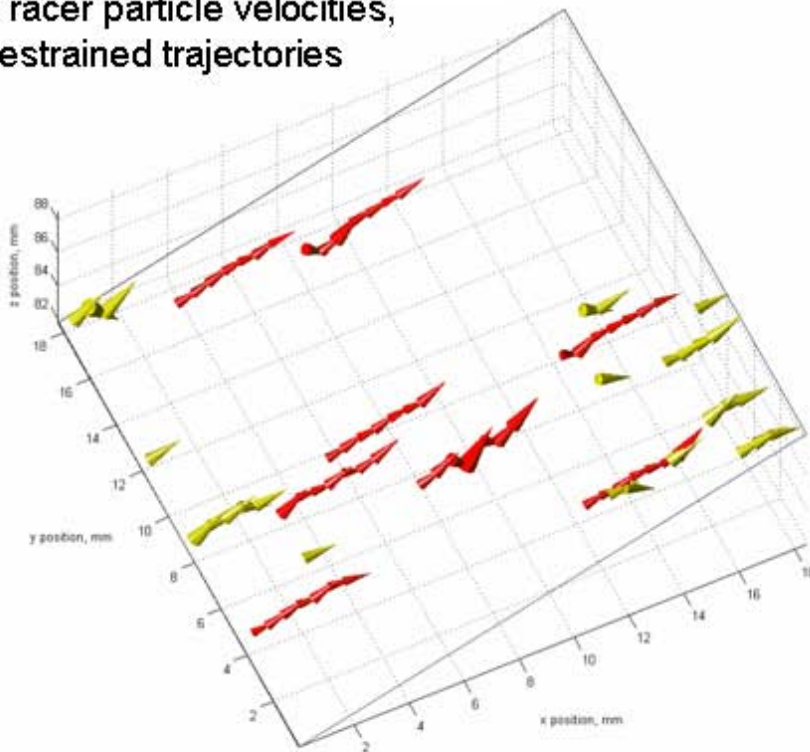


Spherical MEDHI

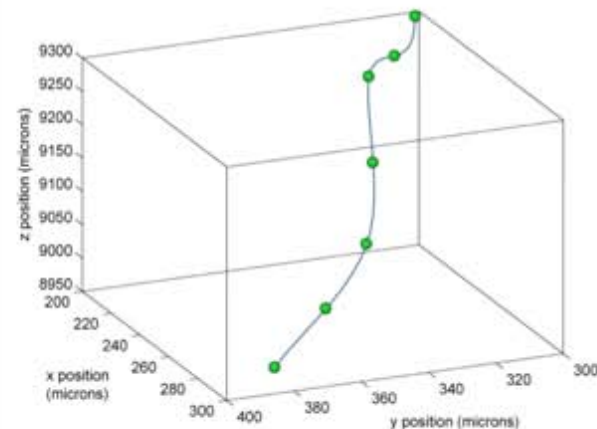
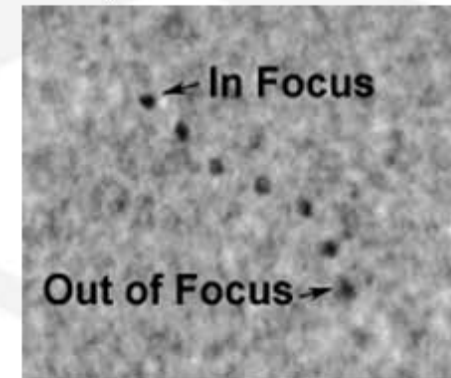
# 3D Trajectories

- Recorded using multiple exposure digital holography (MEDHI, unpublished)

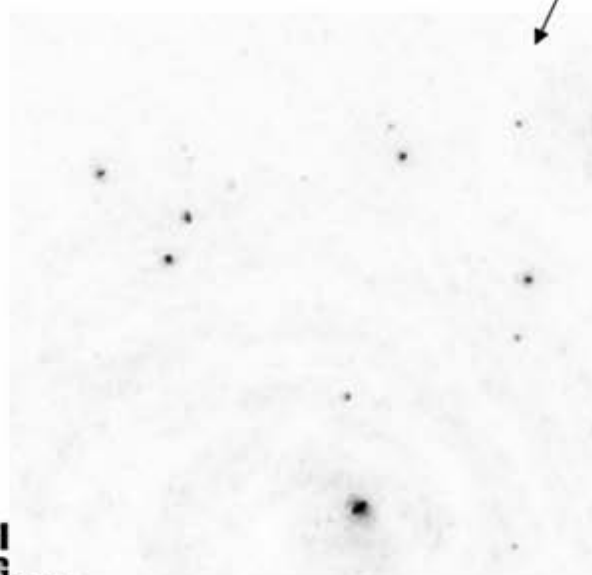
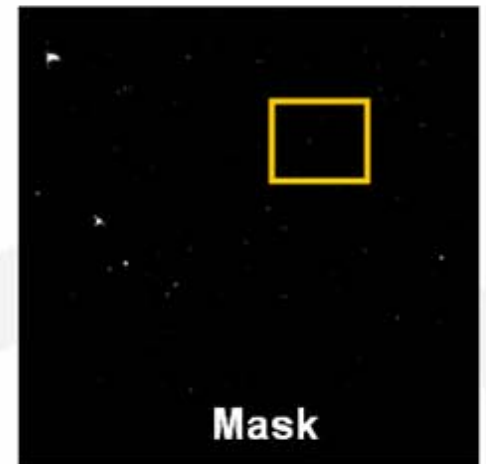
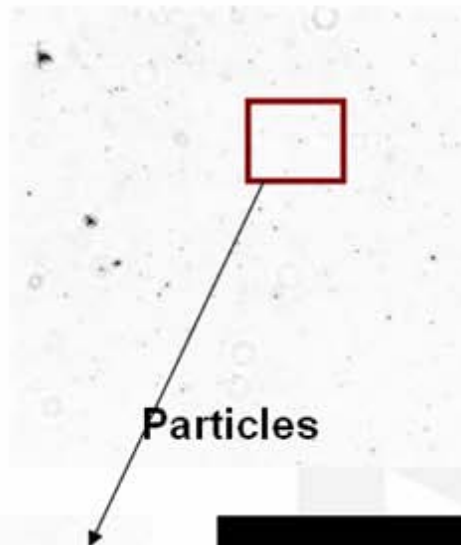
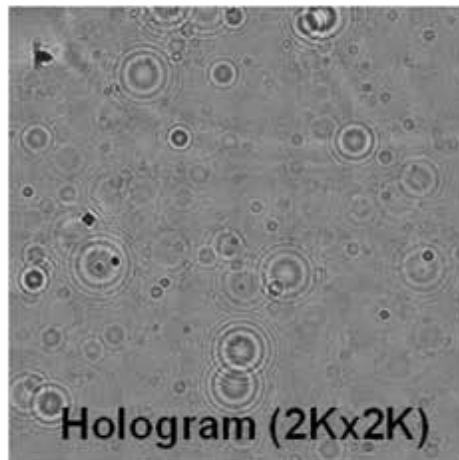
Tracer particle velocities,  
restrained trajectories



Algae swimming in  
small tank  
(microscopy)

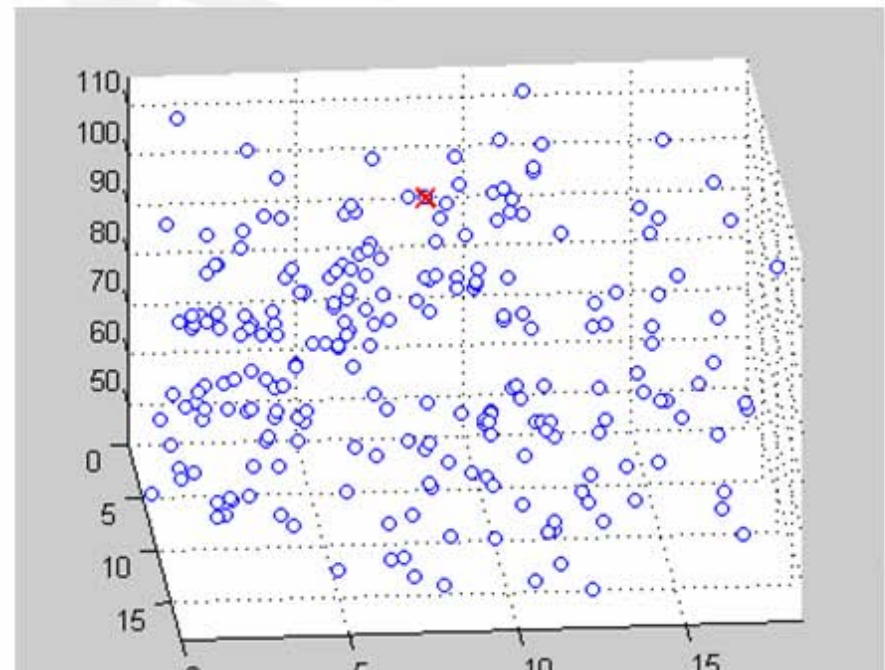
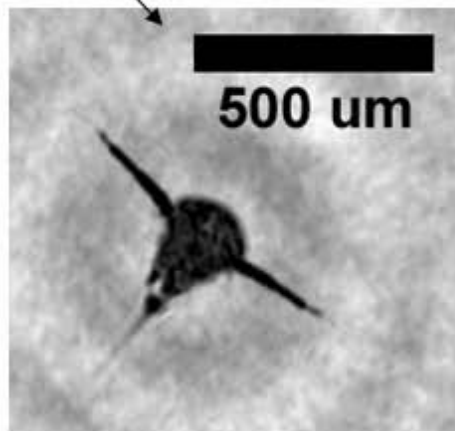
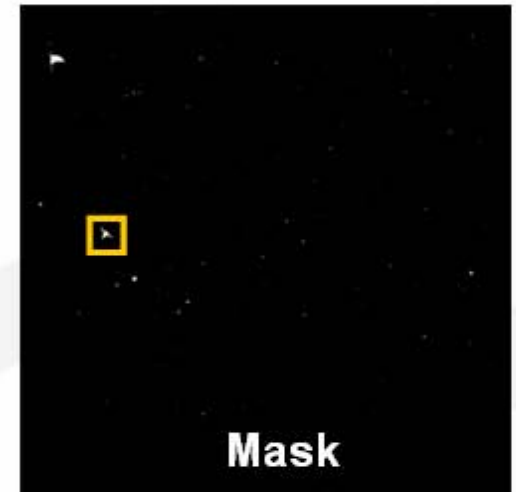
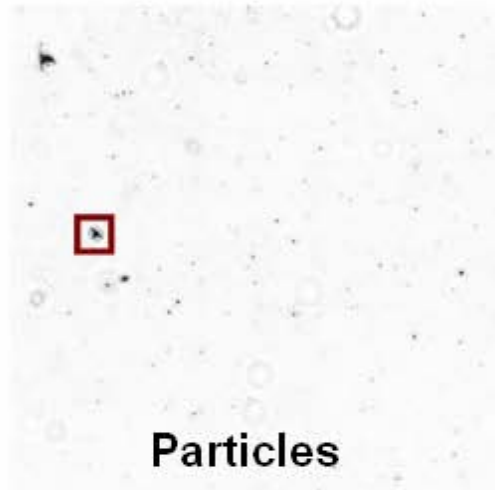
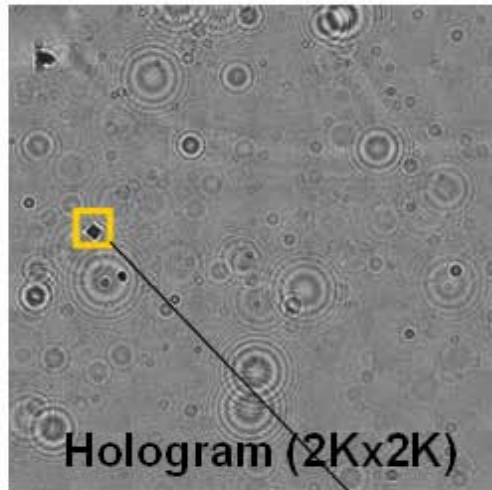


# Marine Particulates

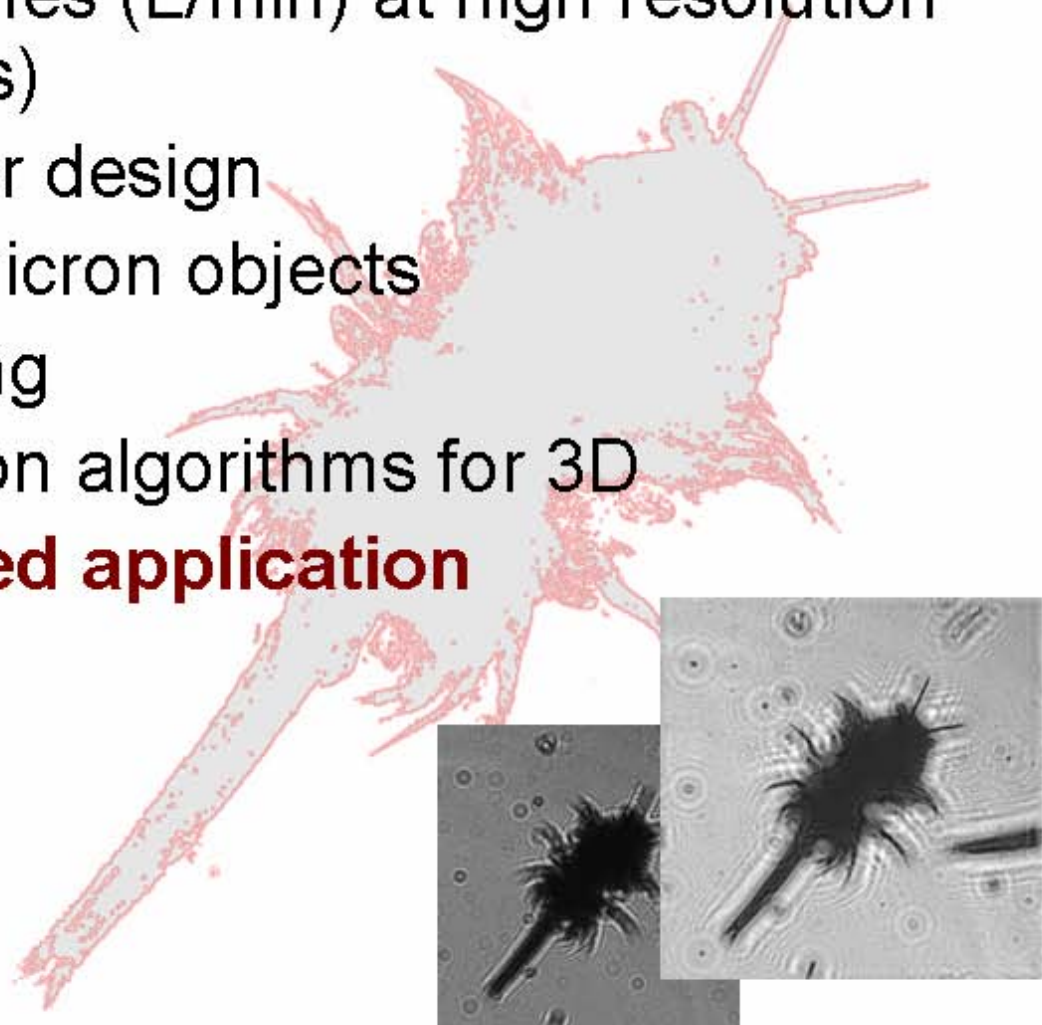




# Marine Particulates

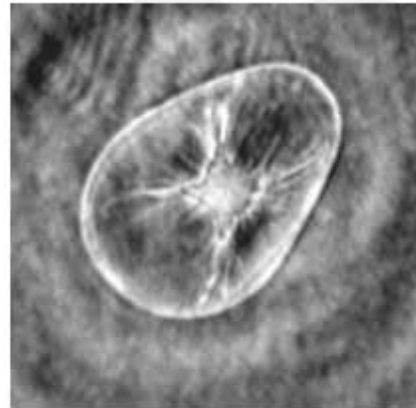


- Large sample volumes (L/min) at high resolution (order of 10 microns)
- Compact, low power design
- Planar: 250-5000 micron objects
- Real-time processing
- Modifying recognition algorithms for 3D
- **Ready for increased application**

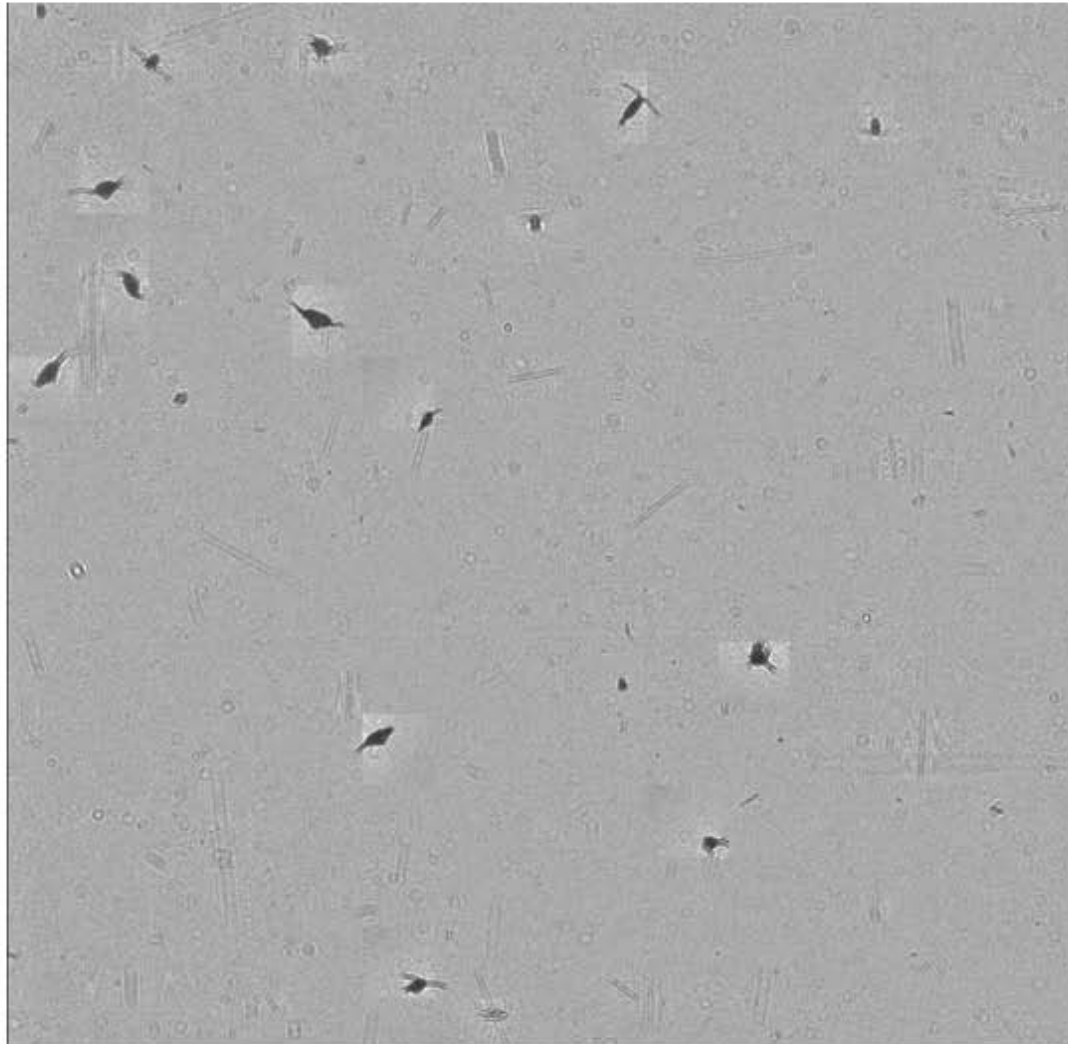


# Additional Information

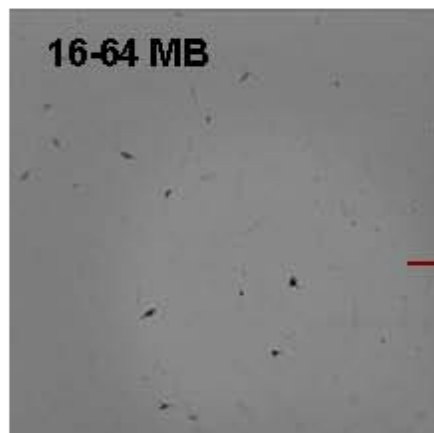
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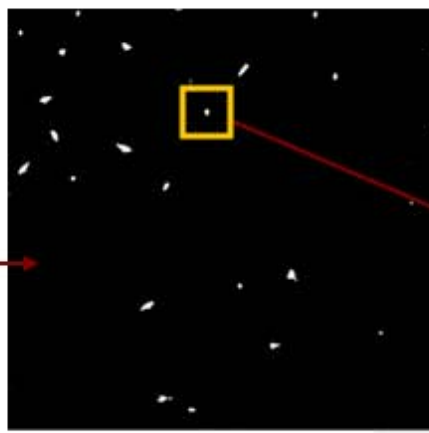
# Fast Automated Reconstructions



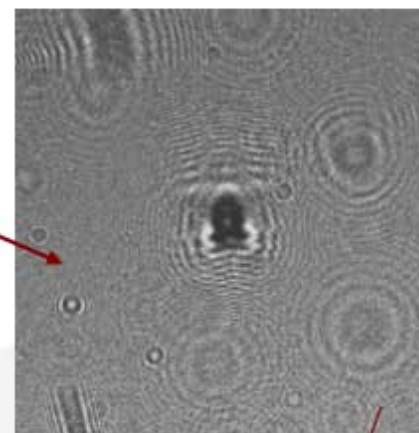
# Fast Automated Reconstructions



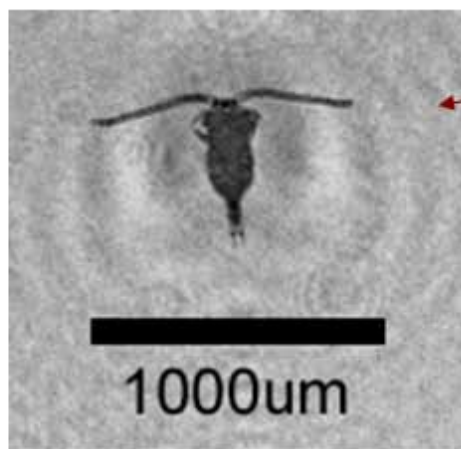
Hologram



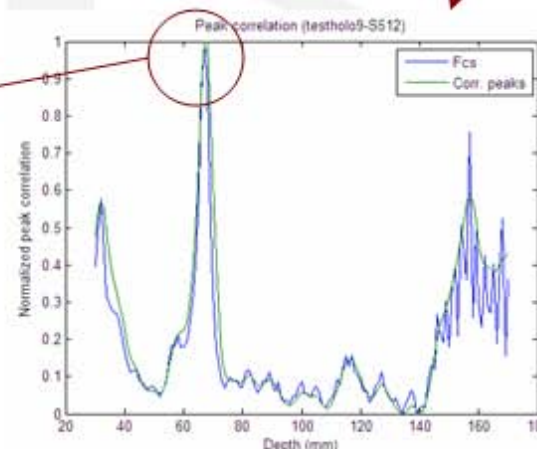
ROI extraction



ROI  
hologram



Reconstruction



Fast depth  
determination

*~2 s per ROI*

# Additional slide ideas

- Show that segmentation works with the holos and is simple, that twin doesn't significantly influence the outline, etc.
- Comparative PFF/spatial times
- More on MEDHI
- Undersample holos for faster processing