Use of underwater digital holography to quantify oil droplet size distribution together with plankton and other particles in the vicinity of the BP oil spill in the Gulf of Mexico.

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Efforts are underway to model the transport and spread of the oil plume that has formed from the leaking MC252 BOP site. Dispersants have been used to emulsify a some portion of the oil in the plume. Presently there is no data on the size distribution of the oil droplets within the plume, but such information is critical to accurate modeling of plume development and transport. This size distribution determines the buoyancy and physical properties of the oil and how it will be transported within the fluid ocean environment.

We propose to modify and use our underwater digital holographic imaging camera (holocamera) to measure the oil droplet size distribution at several locations within the plume. We will mount the holocamera on a Remotely Operated Vehicle so that it can be maneuvered into key locations for mapping the oil droplet size distributions. The holocamera was developed to image plankton and particles ranging in size from a few microns to several centimeters. Our underwater holocamera captures a hologram of a precisely defined 300 ml volume of water, within which images of particles and plankton are extracted for identification, size and shape measurement, and counting. The holocamera was developed through MIT and WHOI Seagrant funding to Davis et al. in a joint project with Professors Jerome Milgram and George Barbasthasis at MIT and PhD students, Jose Dominguez-Caballera and Nicholas Loomis, and Seascan Inc., Falmouth, MA.

The holocamera consists of a camera and laser light source in underwater housings that are mounted on an aluminum frame such that there is a 60 cm image volume (Fig. 1)

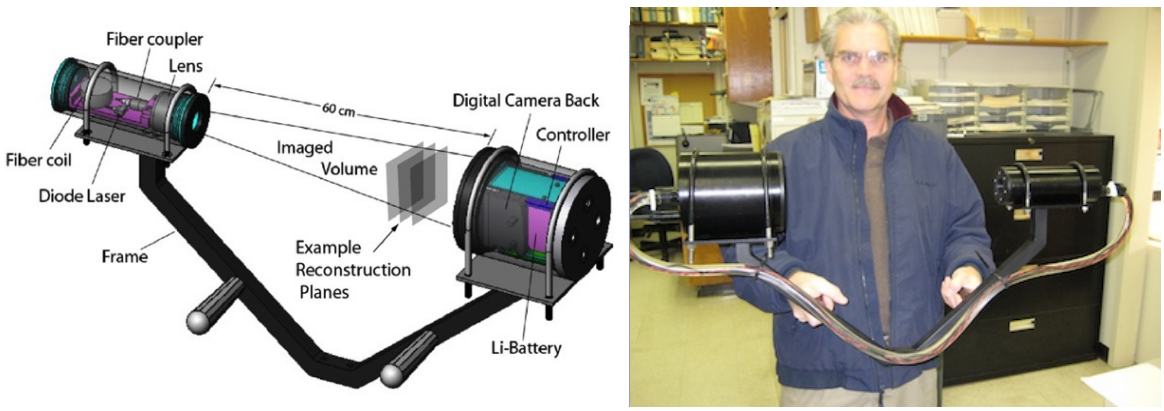

Figure 1. Holocamera drawing (left) and instrument held by Davis (right)

The holocamera works by using coherent light (from a 60 mW 658 nm fiber-coupled diode laser) that is partially collimated, yielding a spherical beam of light directed toward the digital camera back (Hasselblad CFV). A portion of the light reaches the camera undisturbed and is used as the *reference* beam, while some of the light is scattered as it contacts plankton and particles and is used as the *object* beam. The reference and object beams interact to form an interference pattern (a hologram) that is captured on the CCD of the digital camera back and recorded as a tiff image to a compact flash card in the back. Software developed at MIT is used to process the hologram in order to reconstruct images at specified distances within the imaged volume (Fig. 1). There is no lens on the camera and the size of the pixels in the reconstructed image is 3-9µm, depending on distance from the CCD. The axial resolution of the system (minimum resolvable distance between successive image planes, Fig. 1) is 200µm. We have used the underwater holocamera in a wide range of habitats, including Pacific and Indian Oceans (Hawaii and Maldives), the Southern Ocean and South Georgia, and coastal temperate waters off Cape Cod, MA. Example images of plankton and particles are shown in Fig 2.

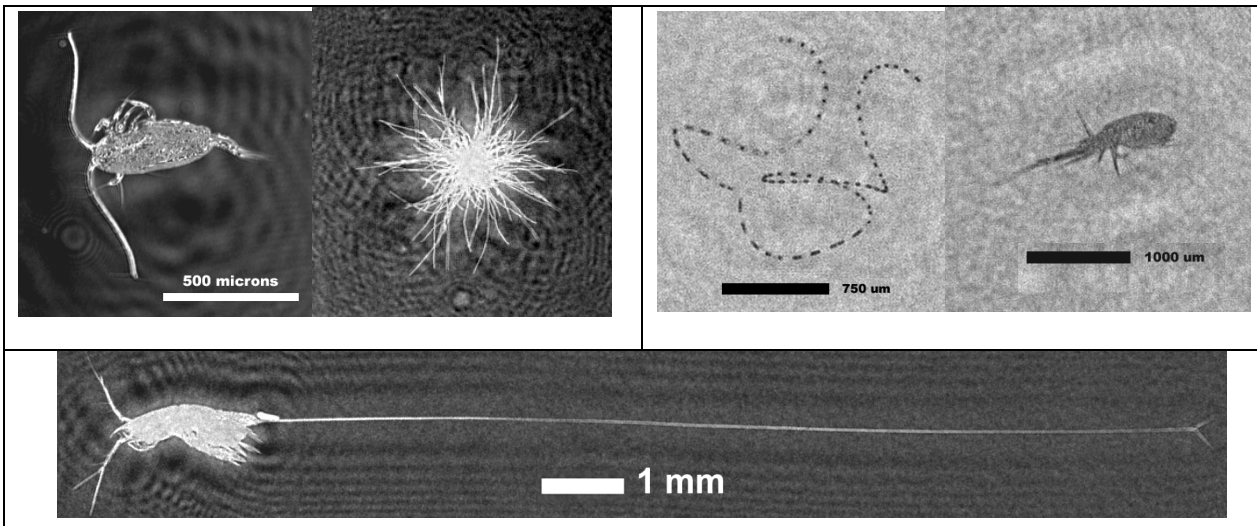

Fig. 2. Example images obtained from the underwater holocamera. (Top, left to right: copepod, *Trichodesmium*, diatom chain, copepod; Bottom: *Macrosetella gracilis*

Loomis has developed a new hardware/software solution for rapid processing of the hologram images. The new system utilizes state-of-the-art graphical processing units containing multiple CPUs that perform parallel processing tasks to quickly reconstruct images within the volume of the hologram. A joy-stick controller allows the user to move quickly through the hologram volume and select desired objects for identification, measurement, and counting.

We propose to participate in a 5 d cruise to site of the oil spill in the Gulf of Mexico to determine the size distribution of the oil droplets in the plume. This project will involve several steps. First, since the plume reaches down to the bottom at 1500m, we need our underwater holocamera to be able to sample to that depth. Currently our holocamera housings are rated to 1000m, and a new housing needs to be manufactured to 1500m by the WHOI machine shop. Once we have the new housing, we will travel to New Orleans to meet the ship. Presently, we have an "on/off" plug that is inserted into the camera housing to turn on the holocamera, which waits 5 minutes before automatically capturing a hologram every 3 seconds. We will need to modify the control software to allow time for the ROV to reach sampling depth before the holocamera turns itself on. We also will purchase a large compact flash card (32GB) to allowed extended sampling and 1000 holograms to be recorded on a single 1 hour deployment. We will mount the holocamera onto the front of the ROV and ballast it properly using syntactic foam. We will spend the 5 days of the cruise working with the ROV team to sample the oil plume. After each deployment we will download the holograms via a firewire card reader to our desktop GPU computer for processing. We will measure the size distribution of the oil droplets in the holograms. Since the geometry of the holograms captured by the holocamera is precisely known, the size of each oil droplet can be determined with high accuracy. We also will process identify and count plankton and particles observed in the holograms.

We require the following funding for this project.

Budget:

Personnel time (Davis 1 month and Loomis 0.5 month, includes cruise leave + overhead), $42K.
Travel $3K, round trip Davis and Loomis, Woods Hole/Cambridge, MA to New Orleans/local port. Air + hotel + ground transportation + meals + excess baggage fees (for equipment).
Holocamera housing design and fabrication $15K
Compact flash card $450. Syntactic foam $500.
Shop time 4 hours at $61/hr = $244
Miscellaneous supplies = $5000
Copying and communications = $500
Over the side insurance $5000
Total: $71,694