Holography and Oceanography

Lasers help elucidate an invisible world in the ocean

Nick Loomis never would have predicted he'd grow up to study marine science.

"I'm actually from Nebraska. We don't exactly have a lot of oceans out there," he said. "To be honest, I had never actually heard of plankton before I showed up at MIT."

Now a graduate student in the MIT/WHOI Joint Program in oceanography, Loomis is intimately acquainted with plankton, the ocean's microscopic plants and animals.

"The ocean is teeming with life," he said. "The problem is, most of the life in the ocean we can't see."

Straddling the fields of biology and engineering, Loomis has helped developed a new oceanographic instrument called the Holographic Plankton Observation Device, or HoloPOD. It takes advantage of lasers and three-dimensional holograms—similar to the rainbow-colored three-dimensional images commonly used on credit cards. He's using the HoloPOD to find out which plankton are where in the ocean, how they interact with their environment, where they're getting their food, and how they influence the food web around them.

He's especially interested in copepods, tiny crustaceans no larger than a pencil tip, which graze on marine plants and are eaten by bigger animals ranging up to whales. They are hard to study because they are so small that they can be seen only with magnification. But zooming in enough to see a copepod means you can examine only one tiny parcel of water at a time. Even in plankton-rich waters, there may be just a few tiny creatures per liter of water, so you could search lots of parcels without ever finding one.

"It turns out a great way to solve these two problems is by using holograms," Loomis said.

The HoloPOD uses laser light reflected off objects to reconstruct 3-D holograms of water samples. Then Loomis applies a computer program that digitally slices each 3-D image into thousands of two-dimensional black-and-white images, stacked like a deck of cards. The computer allows him to scan through the stack of images, looking at one thin slice of the water at a time, to find the plankton that were scattered throughout the sample.

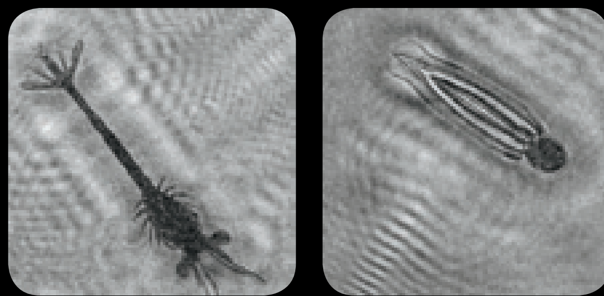
A marine voyeur

When Loomis first arrived at Woods Hole Oceanographic Institution in 2008 his Ph.D. advisor, biologist Cabell Davis, confessed to having some doubts about the young man from Nebraska.

"He didn't know about holography or what it was; in fact, he didn't know what a Fourier transform was at the time," recalled Davis, referring to a mathematical operation critical to understanding and using holograms. "I heard that, and I was a little bit worried—but I didn't need to worry at all, it turns out. He came in and within just a few months, he not only knew what Fourier analysis was, but understood all the wave equations for holography, how it worked, and got right into it. He knows the hardware, he knows the software, he knows the theory. He's one of the most brilliant minds I've known."

With the HoloPOD, Loomis said, "we end up capturing hundreds of holograms with beautiful detail. You can see the antennules, small hair structures, parasites that are living on the plankton, egg sacs on copepods. We're coming back with pictures and data of things that people have never seen before. And they're *beautiful*."

"We're able to find these plankton in their natural environment, doing what they do, without disturbing them," he said. "They have no idea that we're taking pictures of them, so we're able to sneak up and spy on their world. I guess you could say we're almost like a micro-paparazzi."



Cabell S. Davis, WHOI

Images captured by the HoloPOD of two kinds of plankton, a decapod (far left) and a larvacean (left).

Following the Deepwater Horizon disaster, Davis and Loomis found an unanticipated application for the HoloPOD. They adapted it to take images and measurements of marine objects about the same size as plankton—tiny oil droplets—to help ascertain where and how oil was being transported within the Gulf of Mexico (see Page 11).

Catch a copepod

Loomis has also had great success bringing his research to the public with a display at the MIT Museum. Visitors can sit before a tank of seawater and a screen showing a magnified view of small regions of the tank. They use a joystick to maneuver Loomis' instrument and direct it to make holograms of volumes of water in which they spot copepods.

"We wanted to be able to bring this microscopic world into the public's viewpoint," said Loomis. "So people are able to capture their own holograms, directly there in the museum, of real-life copepods, then navigate in three-dimensional space, scan through the volume, and see what animals are where."

When a museum visitor says it's like playing a video game, Loomis readily agrees.

"It *is* almost like a game, because you get copepods that come screaming across the screen, and you're trying to capture a hologram right when there is one flying past, or maybe you've got some copepod in a feeding pattern, and you're waiting for it to get to just the right spot," he said. "You're flying around in that hologram, and you're trying to find all these little things that are hidden in there. There's all this information that gets distributed throughout the hologram, but if you find just the right spot—boom!—it all comes into focus in an instant."

Despite his landlocked upbringing, Loomis now feels right at home in oceanography.

"I never imagined that I would be doing ocean science for a living," he said. "I swapped the waves of grain for waves of ocean, swapped cows for copepods. And here I am."

—Ari Daniel Shapiro

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Joint Program student Nick Loomis readies the lasers he uses to make holographic images of plankton.

Daniel Cojanu

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