

A battery-free, wireless underwater camera

by Jeremy Gray

Engineers at the Massachusetts Institute of Technology (MIT) have built a battery-free, wireless underwater camera that could assist scientists in exploring unknown regions of the ocean, monitoring pollution and surveying the effects of climate change.

Scientists estimate that more than 95% of Earth's oceans haven't been observed. That's a significant amount. We've explored the surface of Mars more than we've investigated Earth's oceans. Part of the reason for the lack of observation is the challenge of powering an underwater camera. Researchers have used vessels to recharge cameras or observed with a camera tethered to a ship to solve the issue. However, that's a limiting factor.

To overcome the issue, MIT researchers have developed a battery-free, wireless underwater camera that is roughly 100,000 times more energy-efficient than other undersea cameras. The new, autonomous camera records color photos, even in dark conditions, and can transmit data wirelessly through the ocean.

The camera is powered by sound. It converts the mechanical energy from sound waves traveling through water into electrical energy that powers the camera's imaging and communications equipment. After recording and encoding image data, the camera then uses sound waves to transmit the data to a receiver, which then reconstructs the image.

Without the need for an external power source, the camera can operate for weeks before it's retrieved, meaning that scientists can search extremely remote areas of the ocean and even search for new species that have so far gone undiscovered. The camera can also search for the effects of pollution or climate change or even be used for commercial aquaculture operations.

'One of the most exciting applications of this camera for me personally is in the context of climate monitoring. We are building climate models, but we are missing data from over 95 percent of the ocean. This technology could help us build more accurate climate models and better understand how climate change



impacts the underwater world,' says Fadel Adib, associate professor in the Department of Electrical Engineering and Computer Science and director of the Signal Kinetics group in the MIT Media Lab, and senior author of a new paper on the system.

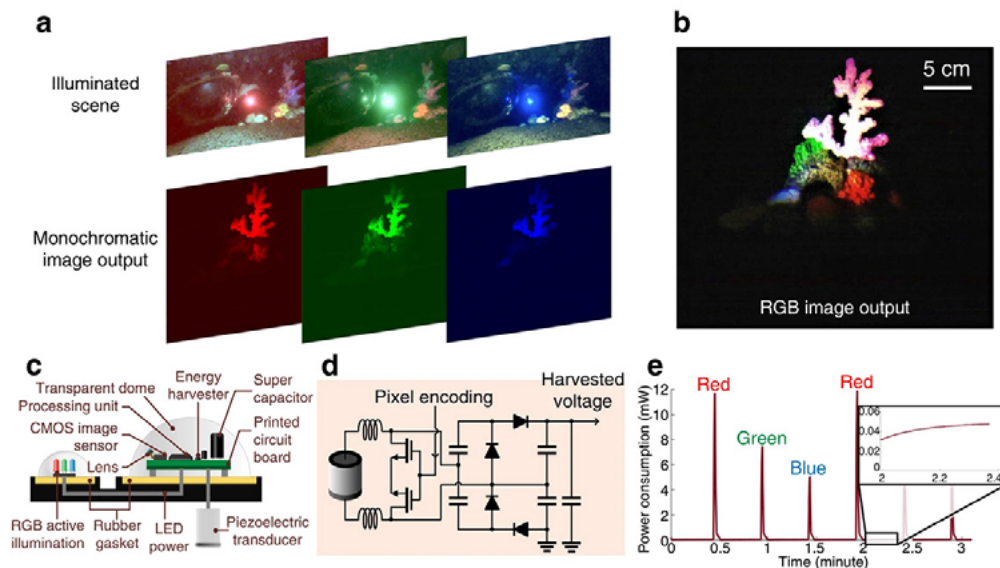
The camera is outlined in a new paper, 'Battery-free wireless imaging of underwater environments' written by Adib alongside Sayed Saad Afzal, Waleed Akbar, Osvy Rodriguez, Mario Doumet, Unsoo Ha, and Reza Ghaffarivardavagh. One of the most important parts of the new camera is its battery-free design. The researchers needed to develop a device that could harvest energy underwater

while consuming little power. As MIT outlines, 'The camera acquires energy using transducers made from piezoelectric materials that are placed around its exterior. Piezoelectric materials produce an electric signal when a mechanical force is applied to them. When a sound wave traveling through the water hits the transducers, they vibrate and convert that mechanical energy into electrical energy.' The sound waves can come from multiple sources, such as passing ships or marine life. The camera harvests and stores energy until it has enough power to take photos and communicate data.

To consume as little power as

Fig. 2: Active illumination in underwater backscatter imaging.

From: [Battery-free wireless imaging of underwater environments](#)



possible, the researchers used off-the-shelf, ultra-low-power imaging sensors. However, low-power sensors only capture grayscale images, and the low-light conditions require the use of a flash. The team solved both problems with red, green, and blue LEDs. When the camera captures an image, it shines a red LED light and then captures the shot. It then repeats the process with its green and blue LEDs. While the image appears black and white, when the image data is reconstructed later, a color image can be built. ‘When we were kids in art class, we were taught that we could make all colors using three basic colors. The same rules

follow for color images we see on our computers. We just need red, green, and blue — these three channels — to construct color images,’ Adib said.

‘To recover color images with a monochrome sensor, the camera alternates between activating three LEDs—red, green, and blue. (A) The top figures show the illuminated scene, while the bottom figures show the corresponding captured monochromatic images, which are transmitted to a remote receiver. (B) The figure shows the color image output synthesized by the receiver using multi-illumination pixels which are constructed by combining the monochromatic image output for

each of the three active illumination LEDs. (C) A side view of the camera prototype demonstrates a larger dome which houses the CMOS image sensor and a smaller dome which contains the RGB LEDs for active illumination. The structure is connected to a piezoelectric transducer. (D) The circuit schematic demonstrates how the imaging method operates at net-zero power by harvesting acoustic energy and communicating via backscatter modulation. (E) The plots show the power consumption over time. The power consumption peaks during active imaging and drops when the captured images are being backscattered.’

Once images are captured, they’re encoded as bits and sent to a receiver one bit at a time using a process called underwater backscatter. The receiver transmits sound waves through the water to the camera, and then the camera reflects them. The camera either reflects the wave or changes its mirror to absorb, such that it doesn’t reflect. A hydrophone next to the transmitter senses if the camera sent a signal or not. If there’s a signal, it’s a bit-1. If not? It’s a bit-0. The binary information is then used to reconstruct and post-process the image. There’s only a single switch, which requires significantly

less power than typical underwater communication systems.

The camera has been tested in several underwater environments. ‘The researchers tested the camera in several underwater environments. In one, they captured color images of plastic bottles floating in a New Hampshire pond. They were also able to take such high-quality photos of an African starfish that tiny tubercles along its arms were clearly visible. The device was also effective at repeatedly imaging the underwater plant *Aponogeton ulvaceus* in a dark environment over the course of a week to monitor its growth,’ wrote MIT.

The next step is to improve the camera’s range to be more practical in real-world settings. As of now, data has been transmitted successfully over 40 meters. The research has partly been supported by the Office of Naval Research, the Sloan Research Fellowship, the National Science Foundation, the MIT Media Lab, and the Doherty Chair in Ocean Utilization. To learn more, view the full research paper published at Nature Communications.

<https://www.nature.com/articles/s41467-022-33223-x>

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