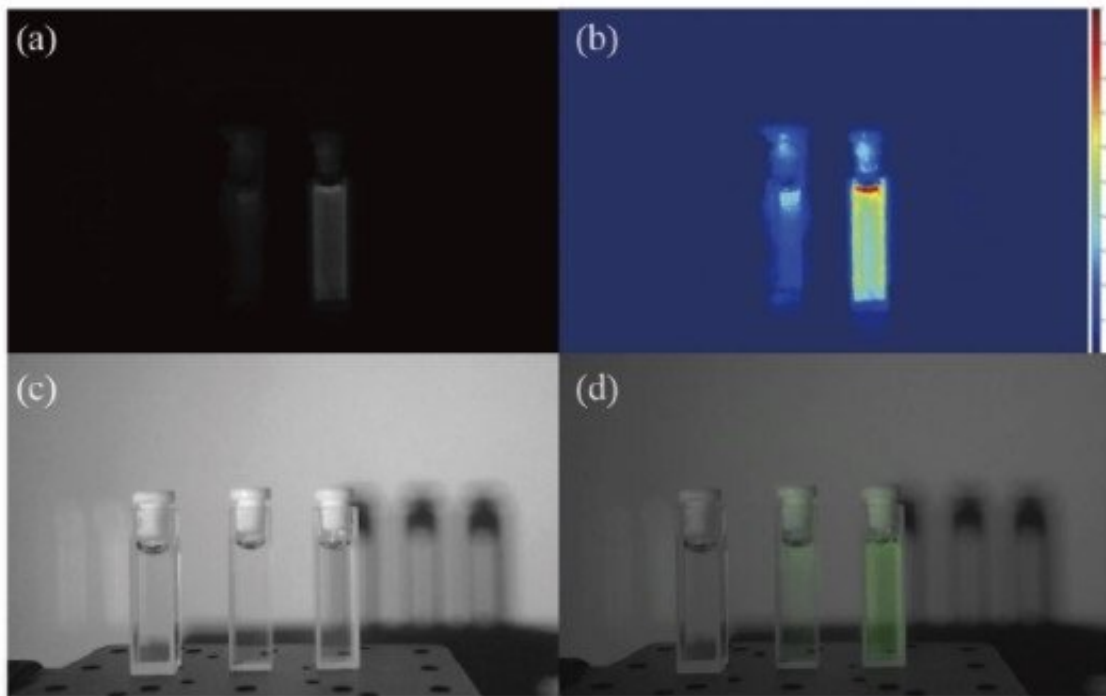


Bio-inspired endoscope provides 3-D visible and near-infrared images simultaneously

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Researchers developed a new bio-inspired medical endoscope that acquires visible light and near-infrared fluorescence images at the same time. They tested it by imaging three different concentrations of the fluorescent reagent indocyanine green. Images show (a) a near-infrared fluorescence image, (b) the intensity distribution of the near-infrared fluorescence image, (c) color image of the samples under visible illumination, and (d) a fusion image combining the color image and the near-infrared fluorescence image. Credit: Chenyoung Shi, Chinese Academy of Sciences

Researchers have developed a new bio-inspired medical endoscope that can acquire 3-D visible light and near-infrared fluorescence images at the same time. It features an optical design that combines the high-resolution 3-D imaging of human vision with the mantis shrimp's capability to simultaneously detect multiple wavelengths of light.

Endoscopes with 3-D imaging capability can help surgeons precisely locate diseased tissue. Adding fluorescence imaging can make cancerous tissue light up for easier removal or highlight critical parts of the anatomy that need to be avoided during surgery.

In The Optical Society (OSA) journal *Optics Express*, Chenyong Shi from the Chinese Academy of Sciences and colleagues describe and demonstrate the new multimodal endoscope. Although this is an early demonstration, the new endoscope is designed to directly replace existing [endoscopes](#) without requiring clinicians to learn how to use a new instrument.

"Existing fluorescence 3-D endoscopes require surgeons to switch working modes during operation to see the fluorescence images," said Shi. "Because our 3-D endoscope can acquire visible and fluorescent 3-D images simultaneously, it not only provides more [visual information](#) but can also greatly shorten the operation time and reduce risks during surgery."

Aiding robotic surgery

Although it could be used for any [endoscopic procedure](#), the researchers designed the new multimodal endoscope for robotic surgery systems. These systems help increase the precision and accuracy of minimally invasive procedures and can help surgeons perform complicated tasks in confined areas of the body. For robotic surgery, the enhanced visual information provided by the new endoscope could help a surgeon who

may be in a different room from the patient clearly distinguish various types of tissue in the surgical field.

"Although today's robotic surgical systems require the surgeon to be close by, robotic surgery based on this multimodal 3-D endoscope might one day allow surgeons to remotely perform procedures in faraway locations," said Shi. "This could help solve the problem of uneven distribution of medical resources and benefit people who live in areas with relatively poor medical conditions."

The new multimodal endoscope achieves high-resolution 3-D imaging using two optical systems to form a binocular design much like that of [human eyes](#). However, in this case, the [optical design](#) can accommodate both visible light like human eyes and the near-infrared wavelengths required for fluorescence imaging. This light is detected by a sensor inspired by the compound eyes of mantis shrimp, which not only detect multispectral information but also recognize polarized light. The sensor detects multiple parts of the electromagnetic spectrum by using pixels with different spectral and polarization responses.

To obtain high-quality 3-D images, the binocular optical system must have two optical systems with exactly the same parameters. "This places stringent requirements on the processing accuracy of optical components," said Shi. "We were able to accomplish this accuracy using precision optical processing and combined this with chip-based spectroscopy technology to make this multimodal 3-D endoscope possible."

Combining visible and fluorescence images

To test the new endoscope, the researchers analyzed its resolution, fluorescence imaging capability and ability to simultaneously obtain 3-D images with near-infrared and visible color information. The endoscope

performed well and achieved a resolution as high as 7 line pairs per millimeter with [visible light](#)— the same as the best 3-D endoscopes used today—and 4 line pairs per millimeter under near-infrared illumination.

They then used the endoscope to acquire visible color and near-infrared fluorescence images of three concentrations of indocyanine green. This near-infrared fluorescent label is approved by the FDA and used to label tumor tissues. Although the three samples could not be distinguished by the human eye, they could be clearly distinguished using the multimodal 3-D endoscope. The researchers also tested the endoscope's 3-D imaging performance by using it to image a toy with many crisscross parts. The endoscope was able to produce 3-D images that did not cause eye fatigue, even after a long period of viewing.

The researchers plan to use the 3-D endoscope to perform additional biological and clinical imaging. They also plan to incorporate more wavelengths and the ability to sense polarization to provide even more visual information.

More information: Chenyang Liu et al, Bio-inspired multimodal 3D endoscope for image-guided and robotic surgery, *Optics Express* (2020). [DOI: 10.1364/OE.410424](https://doi.org/10.1364/OE.410424)

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