New 3-D printed microscope promising for medical diagnostics in developing countries

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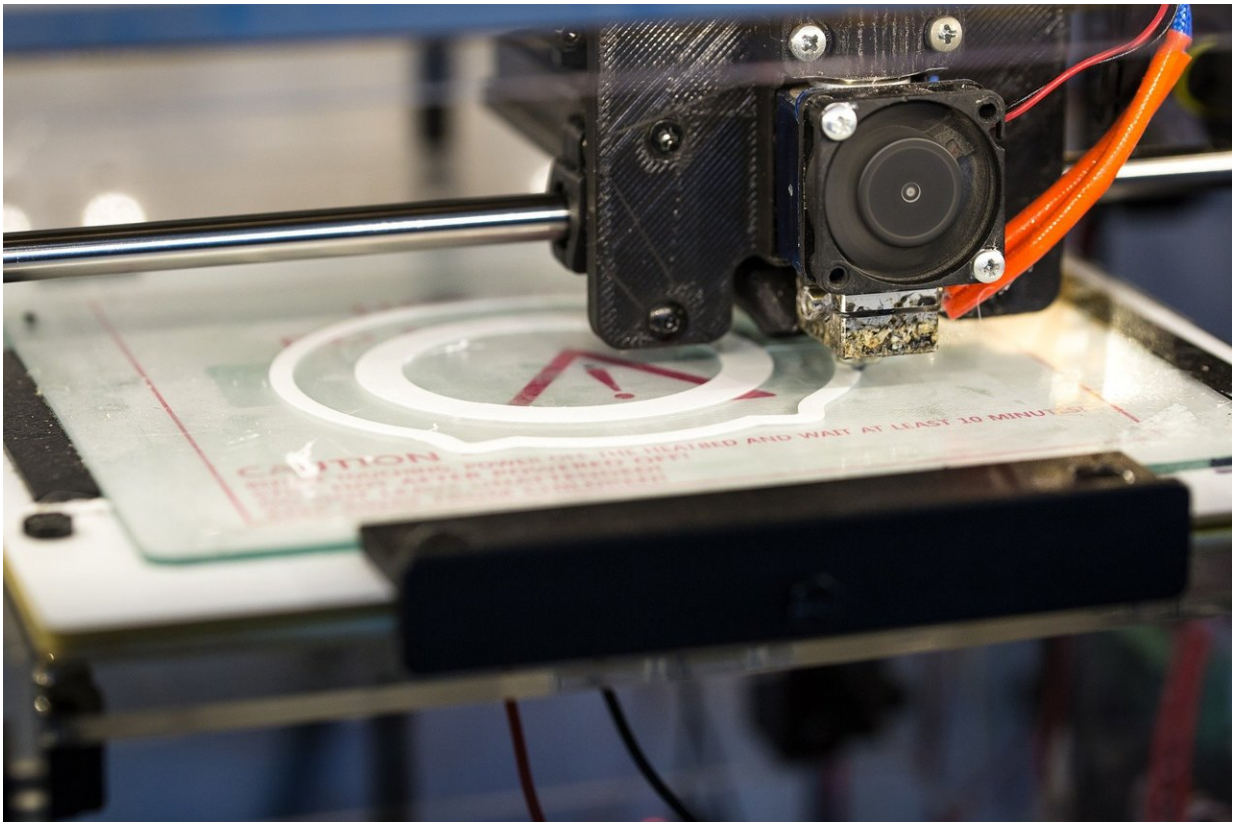

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Researchers have used 3-D printing to make an inexpensive and portable high-resolution microscope that is small and robust enough to use in the field or at the bedside. The high-resolution 3-D images provided by the

instrument could potentially be used to detect diabetes, sickle cell disease, malaria and other diseases.

"This new microscope doesn't require any special staining or labels and could help increase access to low-cost medical diagnostic testing," said research team leader Bahram Javidi from the University of Connecticut. "This would be especially beneficial in developing parts of the world where there is limited access to health care and few high-tech diagnostic facilities."

The researchers describe their new microscope, which is based on digital holographic microscopy, in The Optical Society (OSA) journal *Optics Letters*. The portable instrument produces 3-D images with twice the resolution of traditional digital holographic microscopy, which is typically performed on an optical table in a laboratory. In addition to biomedical applications, it could also be useful for research, manufacturing, defense and education.

"The entire system consists of 3-D printed parts and commonly found optical components, making it inexpensive and easy to replicate," said Javidi. "Alternative laser sources and image sensors would further reduce the cost, and we estimate a single unit could be reproduced for several hundred dollars. Mass production of the unit would also substantially reduce the cost."

From the lab to field ready

In traditional digital holographic microscopy, a digital camera records a hologram produced from interference between a reference light wave and light coming from the sample. A computer then converts this hologram into a 3-D image of the sample. Although this microscopy approach is useful for studying cells without any labels or dyes, it typically requires a complex optical setup and stable environment free of

vibrations and temperature fluctuations that can introduce noise in the measurements. For this reason, digital holographic microscopes are generally only found in laboratories.

The researchers were able to boost the resolution of digital holographic microscopy beyond what is possible with uniform illumination by combining it with a super-resolution technique known as structured illumination microscopy. They did this by generating a structured light pattern using a clear compact disc.

"3-D printing the microscope allowed us to precisely and permanently align the optical components necessary to provide the resolution improvement while also making the system very compact," said Javidi.

Testing the new microscope

The researchers evaluated the system performance by recording images of a resolution chart and then using an algorithm to reconstruct high-resolution images. This showed that the new microscopy system could resolve features as small as 0.775 microns, double the resolution of traditional systems. Using a light source with shorter wavelengths would improve the resolution even more.

Additional experiments showed that the system was stable enough to analyze fluctuations in biological cells over time, which need to be measured on the scale of a few tens of nanometers. The researchers then demonstrated the applicability of the device for biological imaging by acquiring a high-resolution image of a green algae.

"Our design provides a highly-stable system with high-resolution," said Javidi. "This is very important for examining subcellular structures and dynamics, which can have remarkably small details and fluctuations."

The researchers say that the current system is ready for practical use. They plan to use it for biomedical applications such as cell identification and disease diagnosis and will continue their collaboration with their international partners to investigate disease identification in remote areas with limited health care access. They are also working to further enhance the resolution and signal-to-noise ratio of the system without increasing the device's cost.

More information: Timothy O'Connor et al, Structured illumination in compact and field-portable 3D-printed shearing digital holographic microscopy for resolution enhancement, *Optics Letters* (2019). DOI: 10.1364/OL.44.002326

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