is inserted between the diffusers and a conventional camera whose imaging plane is normal to the thin sheet is focused onto the sheet; the camera then detects the photons generated by the beads. Judkewitz *et al.* obtained results for plane-wave illumination, which was generated by displaying a constant-phase matrix on the spatial light modulator, thereby producing a very broad diffuse halo with a Rayleigh distribution. The TRUE method achieved a 30-μm-wide focal spot (the acoustic diffraction limit), whereas the TROVE method of Judkewitz *et al.* gave an optical focal spot that is about 5 μm wide. In this way, they demonstrated focusing of light in a scattering medium at a resolution limited only by the size of the optical speckle grain.

To further demonstrate the potential of their method, Judkewitz *et al.* perform an imaging experiment. Two 1-μm-diameter fluorescent beads are placed 15 μm apart between the strong diffusers (Fig. 1b). In the first experiment, the two beads are imaged from the right side and a typical speckle image is recorded (Fig. 1c), indicating the random and scattering nature of the diffuser located between the fluorescent beads and the camera. The researchers then use the TRUE and TROVE methods to scan the optical focus around the fluorescent beads, while collecting the fluorescent light exiting the system. Figure 1d clearly shows that the two beads cannot be resolved using TRUE[2], whereas TROVE[3] achieves very good imaging of the beads with a resolution of the order of 5 μm (Fig. 1e), which is again the size of a speckle grain.

This exciting demonstration proves that it is possible to image and focus deep within strongly scattering media. This has many potential implications for fundamental physics; for instance, it could allow one to capture the physics deep within exotic scattering media such as Lévy glasses or Anderson localized media. Moreover, these results show that the ability to image and focus deep inside living biological tissues is not far away.

Of course, many hurdles still need to be overcome before such amazing outcomes can be realized. For instance, for practical reasons, the work by Judkewitz *et al.* showed focusing and imaging between two strong diffusers. A demonstration of the approach within a thick scattering medium would greatly enhance its potential usefulness. Indeed, the amount of light collected would be much lower as a result of scattering deep inside the sample, which would reduce the sensitivity of the method. Furthermore, the technique currently takes two hours to image a 30 μm × 30 μm field of view, making it unsuitable for *in vivo* applications, as living tissues decorrelate on a timescale that is orders of magnitude shorter. The emergence of microelectromechanical-based ultrafast spatial light modulators and high-speed cameras should enable this type of experiment to be performed in less than a second.

Finally, and most importantly, this work shows that applying statistical approaches to optical experiments is incredibly useful for studying and using scattering media, as has very recently been demonstrated in a related publication[10]. ❐

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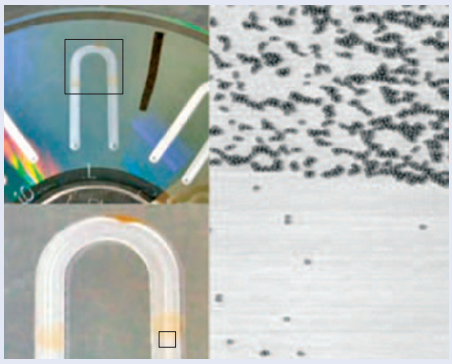
BIOIMAGING

Lab on a DVD

Scientists based in Europe have succeeded in converting a commercial DVD drive into a laser scanning microscope that can analyse blood and perform cellular imaging with one-micrometre resolution (*Lab Chip,* doi: 10.1039/C3LC41360H; 2013). Harisha Ramachandraiah and the team from KTH Royal Institute of Technology in Sweden and the companies, Plarion in the UK and Lingvitae in Norway, say that their 'lab-on-a-DVD' system offers affordable and convenient cellular diagnostic testing for diseases such as HIV.

The approach makes two important modifications to the DVD drive and standard DVD media. First, an extra photodiode is added to the drive to detect transmitted and forward-scattered light through the disk. Second, the DVD media is replaced with a disposable, multilayer, semi-transparent polymer disk that contains fluidic microchannels



in addition to the usual 0.74-μm-wide spiral track.

Before performing experiments, the inner surfaces of the fluidic channels are functionalized to allow surface attachment of the desired cells or particles. Samples of blood or another liquid of interest are then pumped into the channels and the DVD drive is switched on. The added photodiode records the amount of light from the drive's 658-nm semiconductor laser that is transmitted through the disk as it spins. The result is a two-dimensional image, which is saved to a computer hard drive for analysis. Cells or particles that have been successfully bound to the treated channels show up in the resulting images. To date, the team has tested their system by using it to image polymer beads of various sizes (1, 2.8 and 5 μm) suspended in a solution as well as $CD4^+$ cells in blood, which are an important marker for the HIV virus.

The researchers are now working on extending the system to handle larger sample volumes so that low-concentration species such as circulating tumour cells can be analysed in a fully integrated approach that automates the tasks of channel surface modification, washing and sample preparation.

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