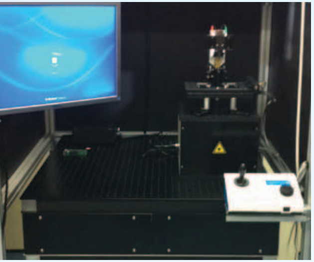

mathsinside

OPTICAL TWEEZERS

Engineering human organs with help from mathematics

cells | holographic optical tweezers | laser | phase | wavefront | microscope | lens equation | focal length



Top image: The optical tweezer system
bottom image: The internal optics

Imagine a future where scientists are able to engineer entire kidneys, hearts and lungs ready for transplant into human patients. These organs would be tailor-made from the patient's own **cells**, meaning the chance of their body rejecting the transplant is greatly reduced. The technique would also allow faulty organ parts to be swapped out and missing bits of bone caused by life's wear and tear to be filled back in.

Such procedures are still decades away, however the scientists of today, including those at the University of Nottingham, are working on the technology that might one day make them a reality. To build these structures the researchers need to trap individual cells (the building blocks of life which are often only a few millionths of a metre across) before adding them to a biological scaffold. One way to achieve that is to use **holographic optical tweezers**, which deploy a **laser** beam to isolate the cells, a bit like a tractor beam in sci-fi movies.

This idea was first thought up in the 1970s, but for complicated structures like organs, multiple traps are needed and so today the single laser is split into multiple beams using a 512 x 512 pixel LCD array called a spatial light modulator (SLM). This acts as a diffraction grating which changes the **phase** of the beams, meaning the **wavefront** differs at each pixel, creating a simple holographic pattern in three dimensions. Mathematics is used to calculate how to adjust the SLM. These points of differing intensity are then bounced off a mirror before being focused by passing through the lens of a **microscope**.

For individual cells to be trapped in the exact locations required, scientists also need to make sure they set up their equipment correctly so that the laser beams are focused in precisely the right way. To help them do this they use the **lens equation**:

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

where f is the **focal length**, u is the distance between the mirror and the microscope lens and v is the distance between the microscope lens and where the laser beam becomes focused (allowing the cell to be trapped).

At first this technique was used to trap things like bacteria and viruses, but now the technology is capable of manipulating cells commonly found in mammals. With 7000 people in the UK currently on the waiting list for an organ transplant, one day scientists may be able to use a similar technique to build entire organs without having to wait for a suitable donor to be found.

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

LMS Advancing Mathematics
London Mathematical Society

Institute of mathematics & its applications

selected
The Royal Society summer science exhibition 2013

mathsinside

Design: www.blitzbranding.co.uk