

A dual-beam laser trap for detailed X-ray studies in biology

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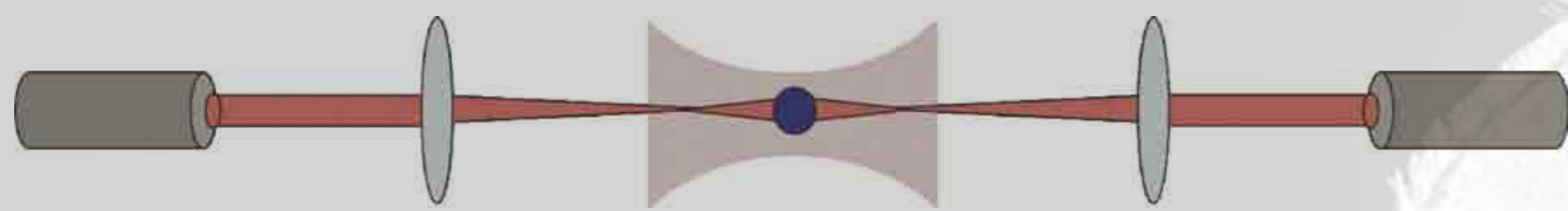
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Laser tweezers, utilising one or multiple beams, can be used to position and control small particles in three dimensions. As experimental research increasingly involves materials studied at the micron and submicron scale, laser tweezers provide an invaluable tool for the handling and manipulation of individual cells, polymers, and macromolecules such as DNA, globular and fibrous proteins.

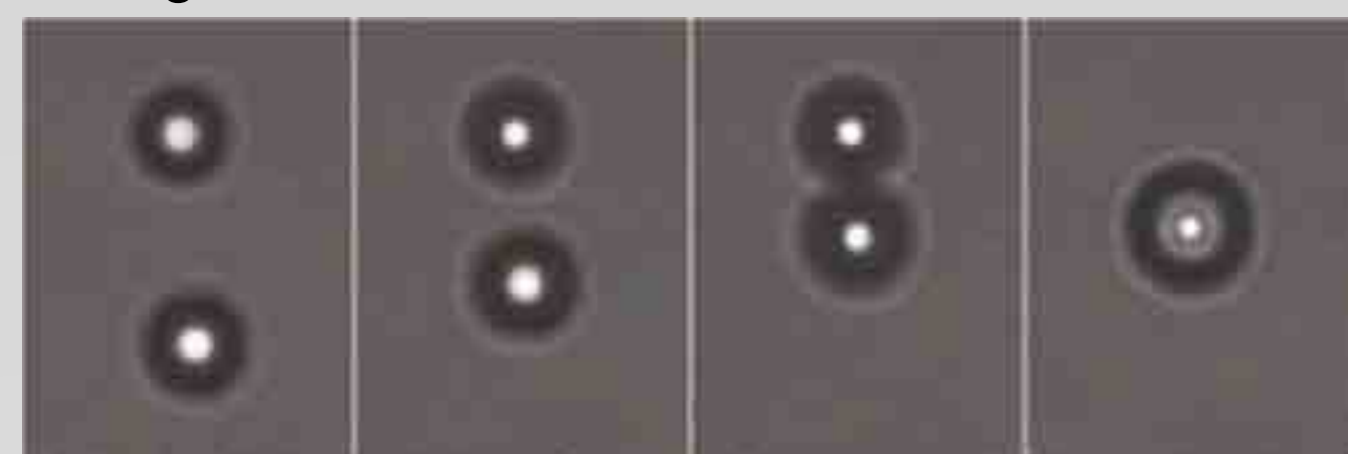
We have built a dual beam laser tweezers system as a novel sample environment for synchrotron X-ray studies.

HOT Laser trapping



When two laser beams are directed at each other and weakly focussed, an object near the central point experiences a balance of optical forces arising from the radiation pressure exerted by the opposing beams. Thus, microscopic particulates can be trapped and manipulated at distances of several centimetres from the nearest lens and several millimetres from the sample cell walls. Small angle X-ray scattering from particulates held in this way will therefore be free from any background scattering effects.

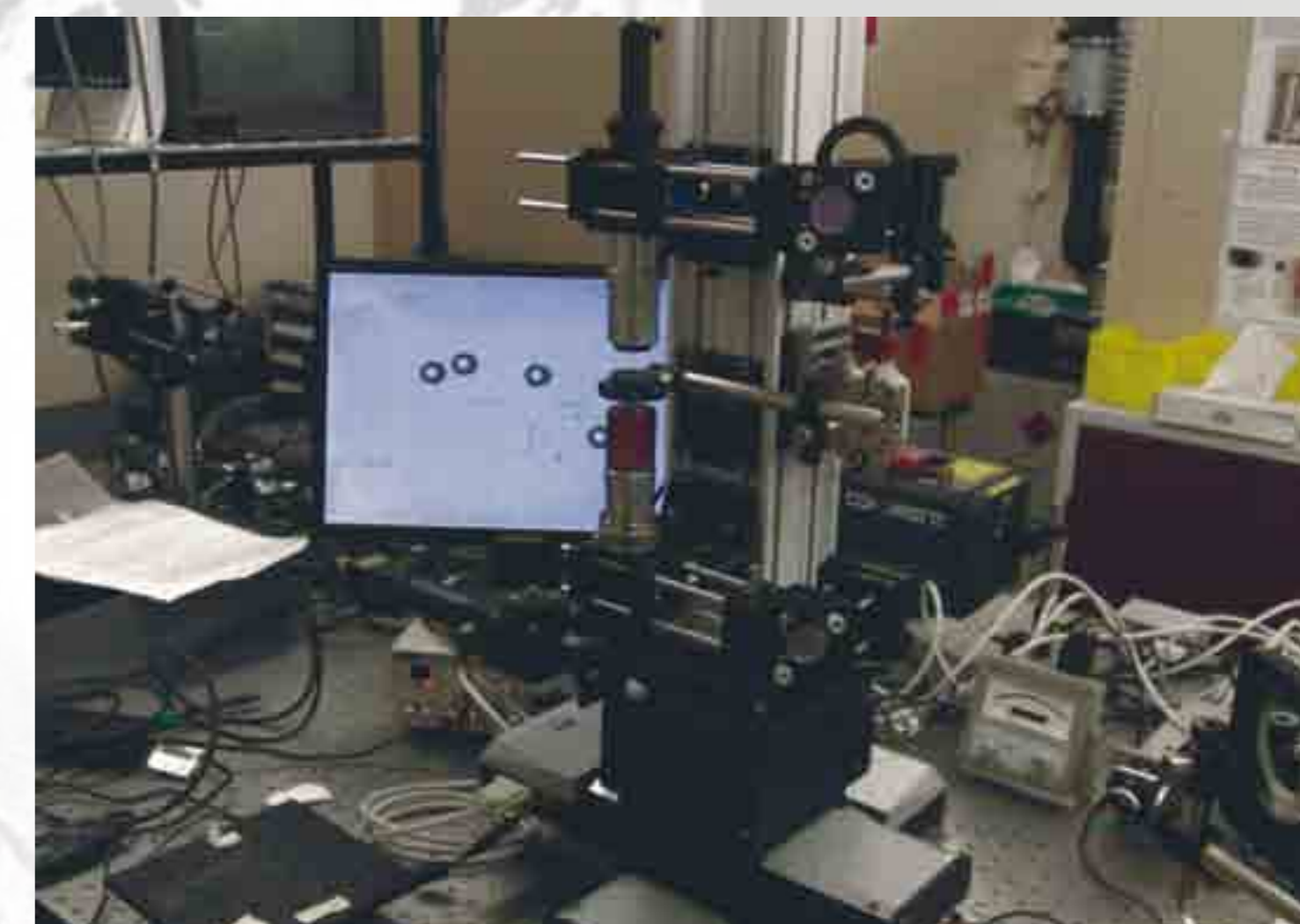
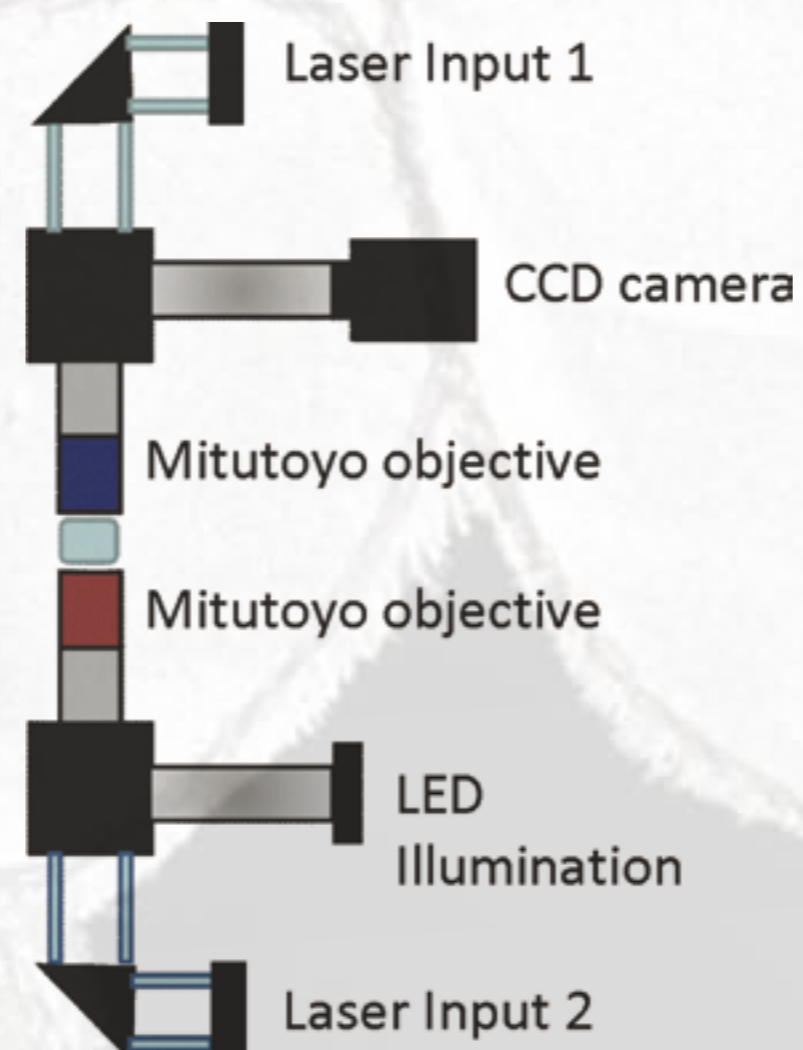
Spatial light modulators will create a holographic optical trap (HOT) system, giving three-dimensional control of multiple traps including rotation. This will allow us to use the traps as holders for several fragile samples at once, or create tools such as miniature stretching or mixing devices.



Multiple sample trapping: two particles brought together (grey), and a hexagonal multiple trap (green).



Our design and early results



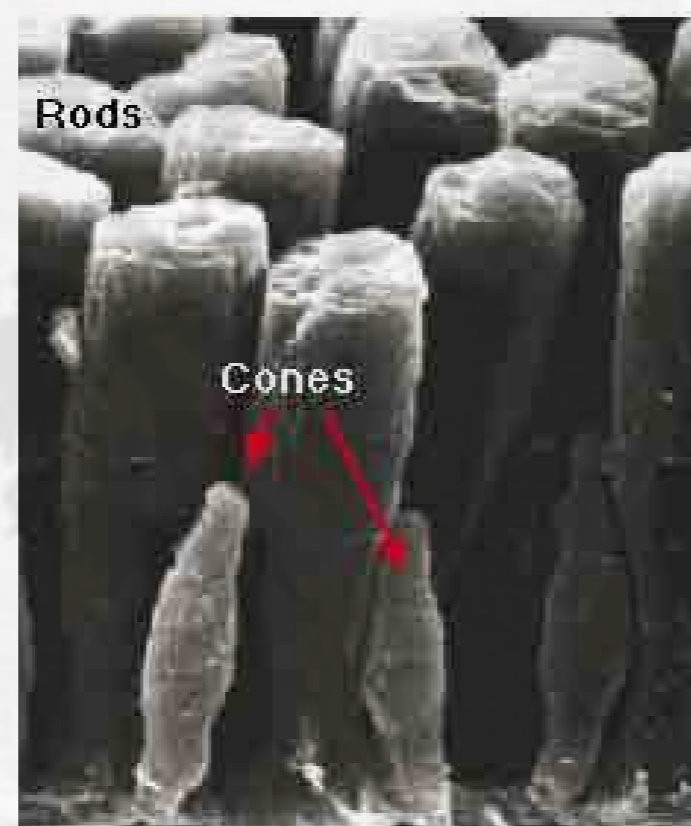
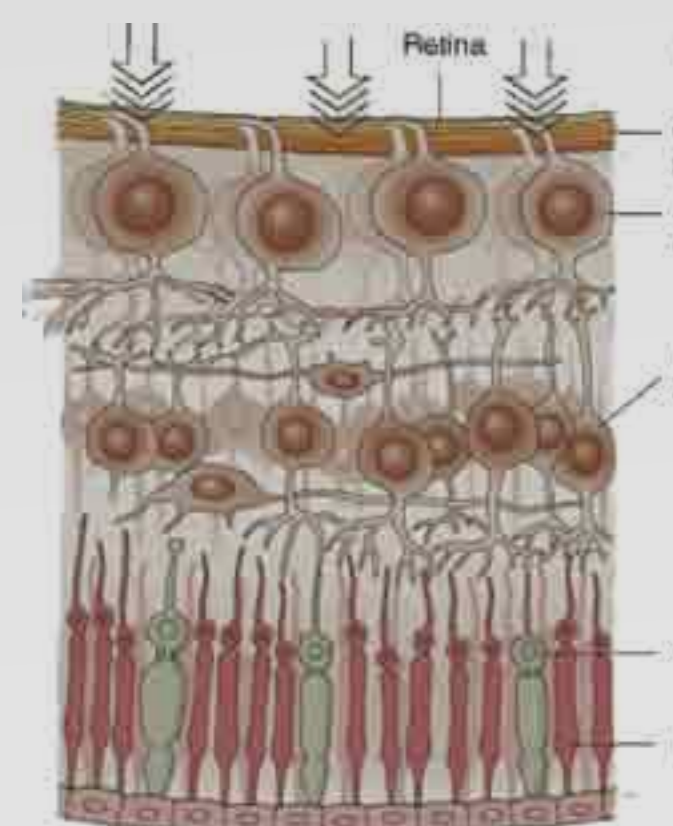
A schematic of the trap (left) and a photograph of the trap built in the Central Laser Facility. Polystyrene beads in the sample cell are visible on the computer screen.

We have built a vertical dual-beam single trap, with an infrared laser beam split into two beam paths. Two microscope objective lenses focus the beam to generate the trapping field, and also permit high magnification imaging of the sample.

The trap will form part of the microfocussing end station on beamline I22 at Diamond Light Source, where it will be used to hold biological objects such as single cells and macromolecules for X-ray scattering and imaging experiments. The X-ray beam will be approximately 0.001 x 0.003 mm in size, and will pass directly between the microscope objectives, hitting the trapped object without disrupting the trap itself.

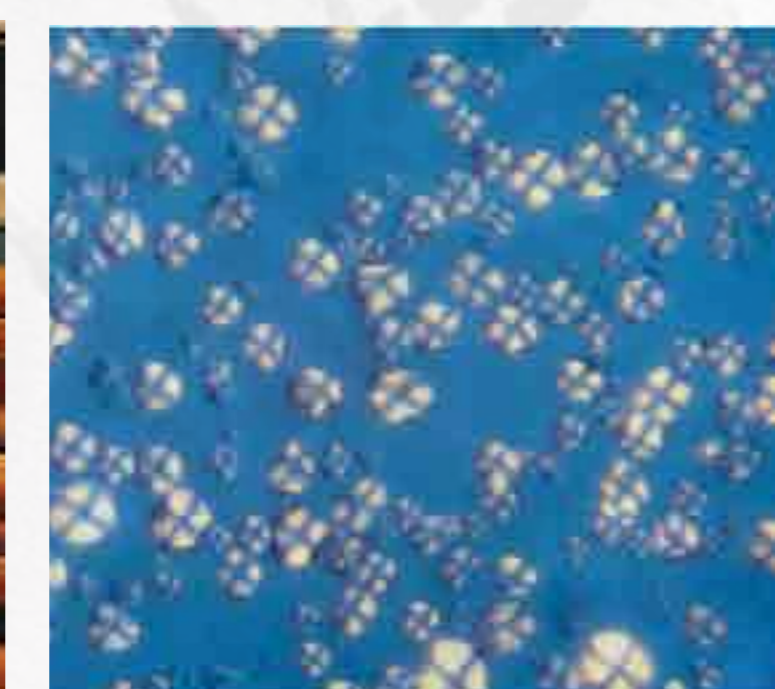
Synchrotron applications

Vertebrate vision

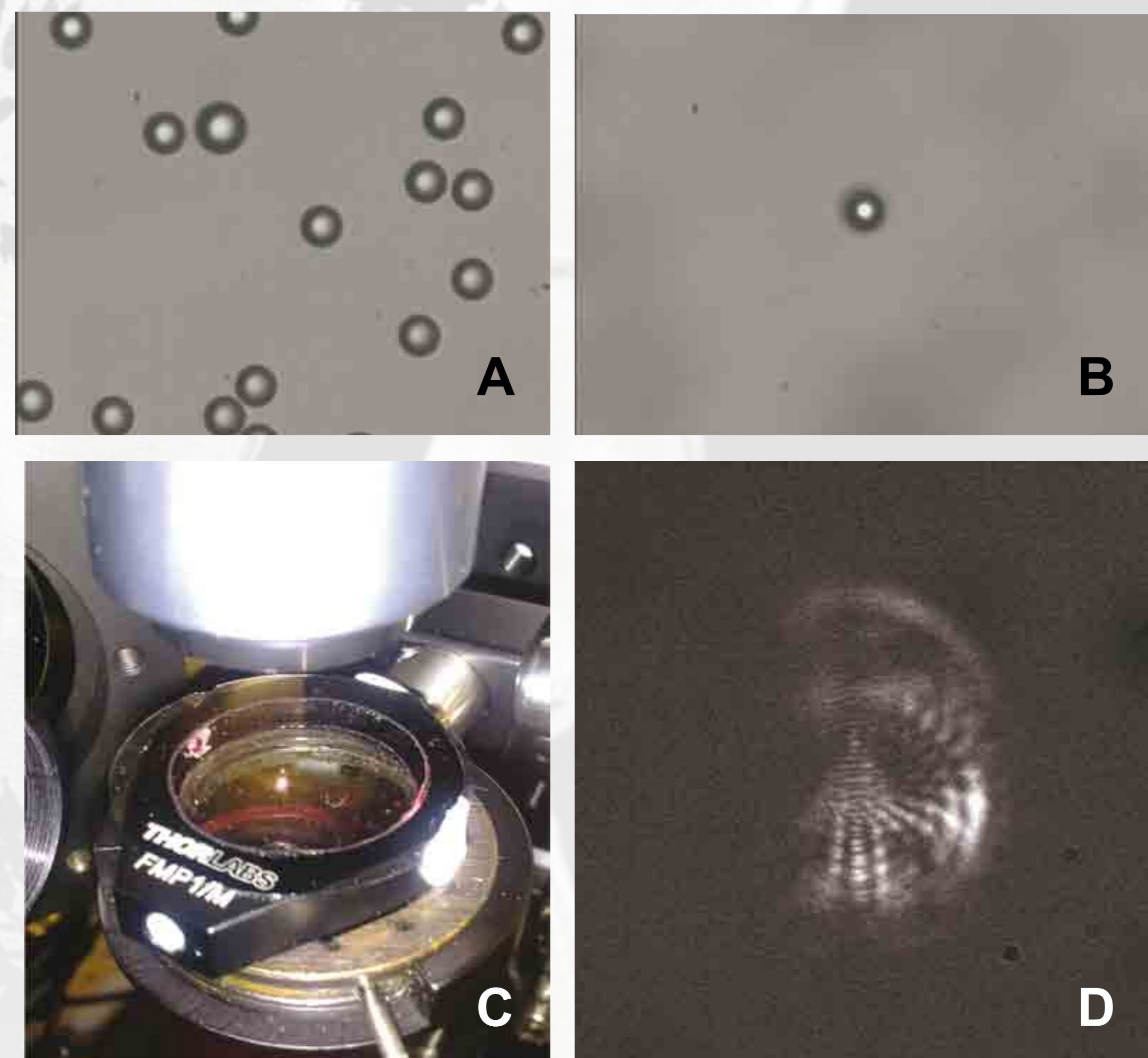


In the eye, two types of photoreceptor, rods and cones, mediate visual information. Integrating microbeam X-ray diffraction with the ability to manipulate individual photoreceptors into the correct scattering geometry will answer new questions of how rods and cones perform their different functional roles.

Prehistoric starch



Analysis of starch grains using optical microscopy has gained prominence in archaeology, due to their survival for up to 28,000 years. Attempts to 'age' starch artificially have shown that a fraction of the granules cannot be destroyed. This has implications for modern food technology and storage, as well as our understanding of the past. Laser trapping will now allow X-ray studies of single grains without a distorting mounting material.



Experimental results. (A) Polystyrene beads on the bottom of the sample cell. (B) A particle is selected, trapped and then vertically moved 3 mm to the centre of the cell. (C) The trapped particle illuminated from the side by a red visible laser following the path of the X-ray beam. (D) Scattering pattern generated when the laser hits the trapped particle.

For our preliminary experiment, we used a sample cell containing polystyrene beads 0.009 mm in diameter. Once the beads had settled on the bottom of the cell, we trapped one bead and lowered the cell, so the bead was 'levitated' in the centre of the cell. We used a low power red laser to illuminate the bead, to mimic the path of the X-ray beam. The bead was aligned to the laser and scattered red light to produce a characteristic Mie scattering pattern on the CCD camera.

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