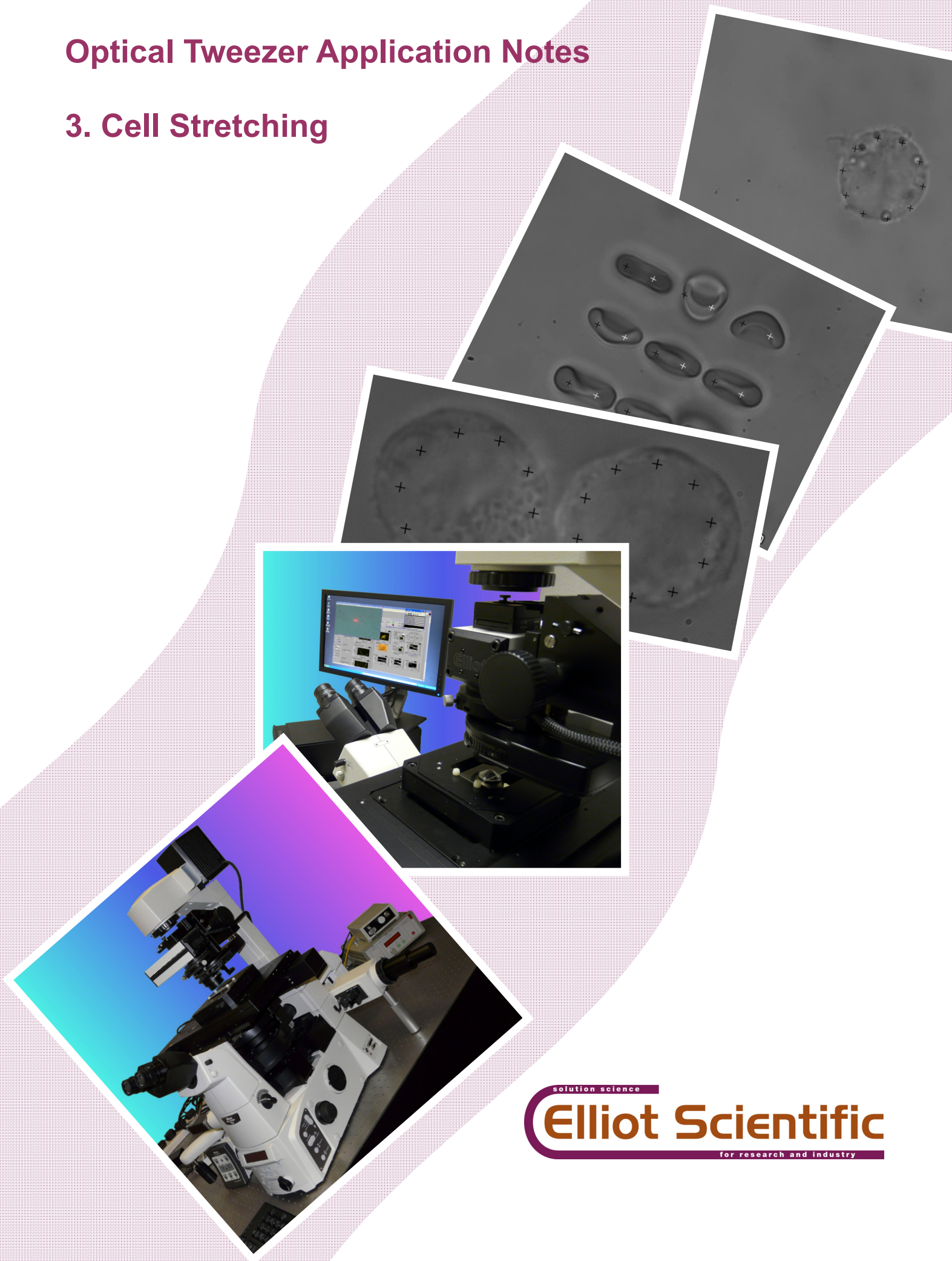
Optical Tweezer Application Notes

3. Cell Stretching



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ELLIOT SCIENTIFIC OPTICAL TWEEZERS APPLICATION NOTES

3. CELL STRETCHING

Important studies at the single-cell level have included the development of optical stretching of cells. The dual counter-propagating trap arrangement leads, in fact, to a bulging of a trapped deformable object of higher refractive index than its surroundings. This is a consequence of the change in photon momentum during passage from a medium of lower to higher refractive index—that is, as the light passes from the medium into the trapped object and re-emerges on the other side. In the case of a cell, the bulging and elliptical shape may be recorded and can be used to infer the state of the cytoskeleton. This is an internal polymer structure that can resist external optical forces.

Crucially, as well as the dual counter-propagating trap, optical stretching can also be performed with multiple-beam optical tweezers. Erythrocytes (red blood cells) and yeast cells are among the most common cell types studied with optical tweezers. In particular, erythrocytes have also been optically stretched both with and without the use of microspheres acting as “handles” on opposite ends of the cell, or by positioning the beam appropriately on a cell [1,2]. In this note, we explore the use of the Elliot tweezers system to perform stretching of red blood cells using non-specific binding of micro-particles to the cell.

Human erythrocytes were harvested and re-suspended in a solution of Phosphate Buffered Saline (PBS) and 0.1% Bovine Serum Albumen (added to reduce cell-cell and cell-glass adhesion). Non-specific binding of silica microspheres was achieved using the protocol outlined in [3]. A sterile microsphere solution was prepared by first suspending 2 μm diameter silica spheres in sterile PBS and then ‘washing’ the microspheres by three repeat cycles of: centrifugation to separate the microspheres from the solution, removal of the PBS and then re-suspension of the microspheres in fresh sterile PBS. The microsphere and erythrocyte solutions were mixed together and stored at 4 °C for two hours, after which the majority of cells were observed to have at least one bound microsphere. To ensure the cells retain their characteristic biconcave morphology, care should be taken to ensure the microsphere/cell solution is isotonic.

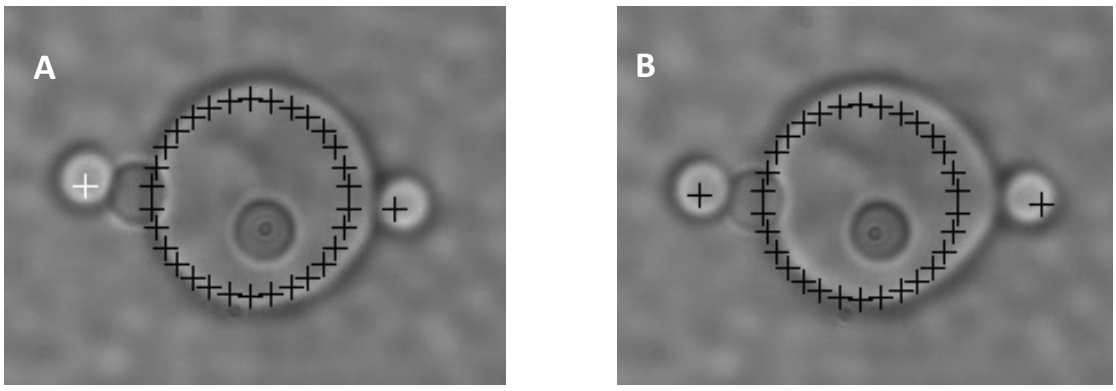

Figure 5: Stretching of a human erythrocyte, using non-specifically bound 2 μm silica microsphere ‘handles’. A circular array of 30 optical traps gently holds the cell upright, parallel to the camera plane. Two single traps tweeze the ‘handle’ spheres to stretch the cell. Total laser power (at objective back aperture) was 350 mW. The undeformed cell (shown in A) is 7.8 μm in diameter, the maximum stretching achieved (B) for this example was 0.6 μm - a diameter increase of 7.7%. Accompanying videos are available.

In figure 5 we see two stills from the accompanying video that shows an erythrocyte suspended between bound, trapped, micro-particles. A circular array of traps was used to orient the cell parallel to the imaging plane. The trap holding the left-most particle was held stationary, while the right-most trap was moved to increase the inter-trap distance thus stretching the cell. Clear deformation and a 7.7% diameter increase of the cell were observed, and can be seen in the accompanying videos:

- RBC Stretch - 1
- RBC Stretch - 2

[1] J. Bronkhorst, G. J. Streekstra, J. Grimbergen, E. J. Nijhof, J. J. Sixma, and G. J. Brakenhoff, “A new method to study shape recovery of red blood cells using multiple optical trapping,” Biophys. J. 69(5), 1666–1673 (1995);

[2] G. B. Liao, P. B. Bareil, Y. Sheng, and A. Chiou, “One-dimensional jumping optical tweezers for optical stretching of bi-concave human red blood cells,” Opt. Express 16(3), 1996–2004 (2008).

[3] S. Hénon, G. Lenormand, A. Richert, and F. Gallet, “A new determination of the shear modulus of the human erythrocyte membrane using optical tweezers”, Biophys. J. 76(2) 1145-1151 (1999).

This case study was performed at the University of St. Andrews using a standard Elliot Scientific E3500 AOD Optical Tweezers system.

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