Measuring elasticity of HeLa cells by laser trapping

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1. Research objective and experimental setup

The objective of our research is to develop the non-invasive method for measuring the elasticity of the biological cells. We developed the experimental setup shown at Fig.1. It consists of optical microscope and laser trapping system. In order to avoid cell damage the NIR laser was used as trapping and detection laser.

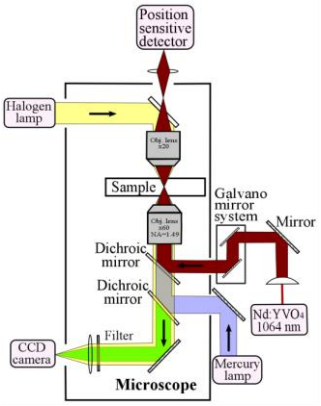

Figure 1 Experimental setup for laser trapping.

2. Indentation of biological cells by trapped polystyrene spheres

The fluorescent 500 nm polystyrene spheres (PS) were immersed in the medium with HeLa cells. A single polystyrene sphere was trapped and moved to the membrane of the cell, after the cell was indent, the polystyrene sphere was moved away from the cell and this process was repeated.

Figure 2 shows the schematic explanation of this process. The focused laser spot is marked by red gradient circle sphere with the maximum intensity in the center. The red arrow indicates the direction of the laser beam and red dashed light line corresponds to the input amplitude and trajectory of the laser steered by scanning galvo mirror system. The 0.5-μm polymer sphere (PS) is marked by white sphere. The dashed black line shows how the shape of HeLa cell membrane changes compare to the previous image.

For determining the elasticity of the cell, we need to find the value of the cell indentation. Figure 3 represents the comparison of the displacements of the polystyrene sphere while indenting and not indenting the cell. When the polystyrene bead touched the cell, the time delay occurs, from which the indentation value δ is obtained.

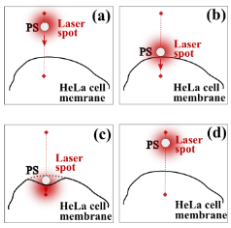

Figure 2 The Scheme of the process of the indentation of HeLa cell.

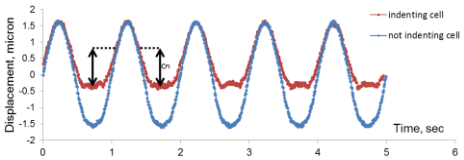

Figure 3 The displacement of trapped polystyrene sphere while indenting(red plot) and not indenting(blue plot) the cell

To determine cell elasticity, the variation on the Hertz model was used. This model describes a deformation of a large elastic body with a disc shaped contact area:

$$F = \frac{4ER^{1/2}\delta^{3/2}}{3(1-\nu^2)} \qquad (1)$$

where E is Young's modulus, ν is Poisson's ratio of the indented material, R is radius of the rigid indenter, δ is the resulting indentation and F is the applied force, which is the trapping force for 500nm polystyrene spheres.

From the equation (1) Young's module was obtained as 23.3 kPa. This value is appropriate for HeLa cells and comparable with cell elasticity [2]. Probing cell elasticity leads to determining cell functions.

3. Conclusions

We propose a technique for probing the cell elasticity by laser trapping system combined with optical microscopy. The cell elasticity for the HeLa cells was obtained. Ability to investigate the mechanical properties may lead to understanding cell functions and diseases, what opens new possibilities for novel treatments of biological cells.

References

[1] Johnson, KL. Contact mechanics. Cambridge: Cambridge University Press; 1985.
[2] Kuznetsova TG, Starodubtsteva MN, Yegorenkov NI, Chizhik SA, Zhdanov RI, Atomic force microscopy probing of cell elasticity, Micron 38: 824-833, 2007.