# Experimental and numerical study of trapping of cells on a waveguide

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Cells are trapped by the evanescent field of a waveguide. Cell culture media and protein sera, in which the cells are submerged, significantly influence the trapping. Optical forces on the cell membrane are found with numerical simulations (FEM).

The evanescent field of a waveguide gives a gradient force that attracts a cell towards the surface and laterally holds the cell on top of the waveguide surface. The field also gives a radiation force that propels the cell along the waveguide (1). These optical trapping forces depend on the difference between the refractive indices of the cell and the medium, and are proportional to the available power in the evanescent field. The refractive index of red blood cells (1.38) is close to that of water (1.33), giving relatively weak forces. Thus, it is important to enhance the intensity in the evanescent field for efficient cell trapping. We have employed waveguides made of a high-refractive index material (Tantalum Pentoxide, *n*= 2.1@1070nm) for waveguide cell trapping (2). Waveguides of thickness 200 nm and width 2-10 µm are employed in the experiment.

In waveguide trapping, the cells are trapped close to the surface and propelled along the surface. Consequently, other surface forces (e.g. electrostatic forces) influence the propulsion of cells along the waveguide. Commonly used cell culture media like phosphate buffered saline solution (PBS), Sagman, Hepes and protein sera like human serum albumin, bovine sera albumin were found incompatible with waveguide trapping. The adhesive surface forces (in nN range) acting on the cells in these ion-rich media were believed to be stronger than the optical forces (in pN range). The cells were stuck to the waveguide surface and could not be propelled in these media and sera.

However, cells were successfully trapped and propelled in an isotonic sucrose medium (0.25 molar). Red and white blood cells were trapped and propelled on waveguides of width between 2-10 µm. A 6 µm wide waveguide propelled the cells with maximum velocity of around 6 µm/s (3). Cell propulsion is studied as a function of how long the blood has been stored, and it is found that geometric properties of the trapped cells depend on the storage time. This has not been demonstrated previously.

Numerical simulations of the optical forces were done with Comsol Multiphysics 3.5a. Optical forces on the cell membrane were determined using Maxwell's stress tensor. The simulation parameters were chosen to correspond with the experimental values. From the simulation it was found that the lower 600 nm of the cell (from the waveguide surface) contributes to the majority of the optical forces experienced by the cell. Thus, it is possible to simulate only the lower 600 nm of the cell, which significantly reduces the computational time and makes it possible to simulate the forces on larger cells.

A systematic experimental and numerical study of waveguide cell trapping is reported. Waveguides made of Tantalum Pentoxide are found suitable for cell trapping. Numerical simulations based on the finite element method are employed to understand the distribution of waveguide trapping forces on the cell membrane. Physical deformation of cells on waveguide surface can be used to sort healthy and malignant cells, and it depends on how long the cells have been stored.

## References

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