NANOTECHNOLOGY

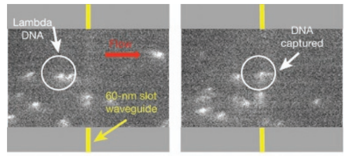
Setting a nanoparticle trap

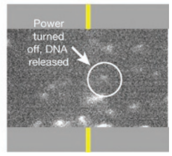
Researchers developed a hybrid microfluidic–optical trapping device to trap and transport very small nanoparticles and DNA molecules.

Like a tiny hand picking up an object, a tightly focused laser beam can trap and transport micrometer-sized particles, including cells. These aptly named optical tweezers have been applied to a number of interesting biological questions on the single-cell or even single-molecule levels. However, trapping nonmetallic particles with a diameter of less than a few hundred nanometers is very difficult, according to David Erickson of Cornell University. "The actual force is proportional to the volume of what you're trying to grab," he explains. "So if, for example, you can grab something that is 3 microns, if you want to grab something that's 10-fold smaller than that with the same force, you need to improve your approach 1,000-fold. In order to grab something 100 times smaller than that, you need something that's a million-fold better."

Hoping to tackle such a challenge, Erickson, whose expertise is in micro- and nanofluidics, began a collaboration with Michal Lipson, also at Cornell. Lipson's lab had previously developed a nanophotonic structure for guiding light called a "slot waveguide," which is a long nanoscale trough between two slabs of a material with a high refractive index (Almeida *et al.*, 2004). The slot waveguide concentrates optical energy down to a very narrow beam, much smaller than is possible using traditional, diffraction-limited optical traps. The researchers realized that by combining this nanophotonic structure with microfluidics, they could develop a powerful trap for capturing nanometer-sized particles.

Within a microfluidic channel, they flowed polystyrene nanoparticles as small as 75 nm over a 100-nm slot waveguide (positioned perpendicularly to the flow) and showed that the particles were optically trapped inside the waveguide (Yang *et al.*, 2009). The most interesting and useful property of the slot waveguide is that it concentrates optical energy down to a line, rather than at a point like a traditional optical trap. This has a couple of important advantages. "First, it means that the light pressure can be used to push trapped particles along the slot waveguide instead of just holding them at a point," says Erickson. "This is critical for being able to efficiently shuttle things around on the nanoscale." These line traps also have the potential to trap fully extended long biomolecules because the trapping force acts along every part of the molecule instead of just at a single point. The researchers performed proof-of-principle experiments in which they trapped a short piece of DNA under pH conditions in which DNA is known to be in an extended state.





A single fluorescently tagged 48-kb λ-DNA in a flow channel (top left) is optically trapped in a slot waveguide (top right), then released when the laser is turned off (bottom). Reprinted from *Nature*.

Besides the ability to trap smaller particles in addition to biomolecules, trapping within a slot waveguide also provides high stability, which could be useful for a number of single-molecule biophysical experiments. "One of the challenges with being able to do, for example, single-protein folding experiments is that you need to be able to hold something in place for a long time while you observe it," notes Erickson. "With these kinds of really strong optical traps, you might be able to pin something in free solution and look at it for much longer times than is possible now."

Another potential application is on-chip optical separations. "There's a number of ways of doing bioanalytical separations on a chip with microfluidics. . . the physics says that optical separation can be much more sensitive than these traditional techniques," says Erickson. "We can imagine being able to do much [higher-resolution] separations than one can do now."

Allison Doerr

RESEARCH PAPERS

Almeida, V.R. *et al.* Guiding and confining light in void nanostructure. *Opt. Lett.* **29**, 1209–1211 (2004).

Yang, A.H.J. *et al.* Optical manipulation of nanoparticles and biomolecules in sub-wavelength slot waveguides. *Nature* **457**, 71–75 (2009).