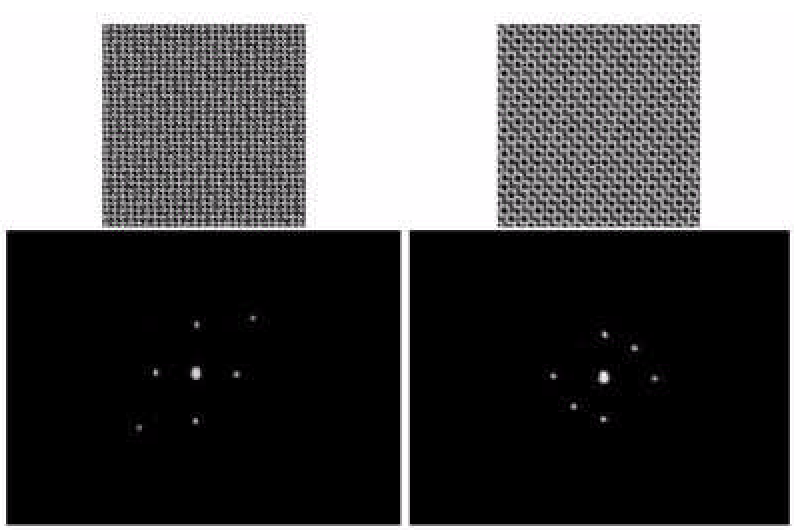
Optical Tweezers Array and Nimble Tweezers Probe Generated by Spatial-Light Modulator

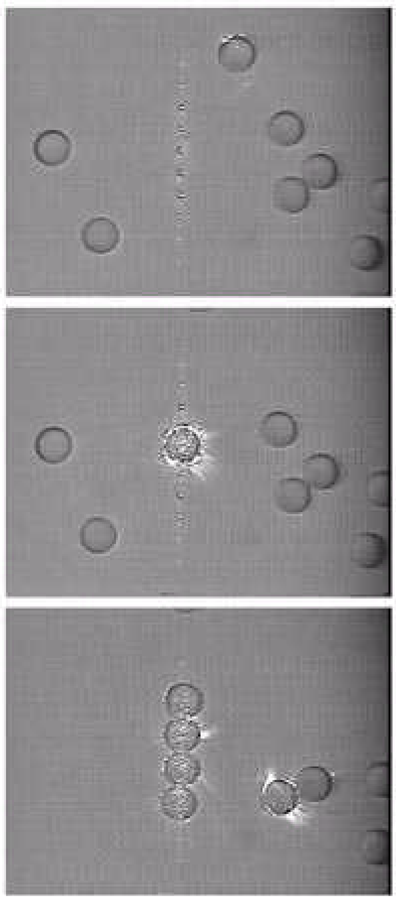
An optical tweezers is being developed at the NASA Glenn Research Center as a visible-light interface between ubiquitous laser technologies and the interrogation, visualization, manufacture, control, and energization of nanostructures such as silicon carbide (SiC) nanotubes. The tweezers uses one or more focused laser beams to hold micrometer-sized particles called tools (sometimes called tips in atomic-force-microscope terminology). A strongly focused laser beam has an associated light-pressure gradient that is strong enough to pull small particles to the focus, in spite of the oppositely directed scattering force; "optical tweezers" is the common term for this effect. The objective is to use the tools to create carefully shaped secondary traps to hold and assemble nanostructures that may contain from tens to hundreds of atoms. The interaction between a tool and the nanostructures is to be monitored optically as is done with scanning probe microscopes.

One of the initial efforts has been to create, shape, and control multiple tweezers beams. To this end, a programmable spatial-light modulator (SLM) has been used to modify the phase of a laser beam at up to 480 by 480 points. One program creates multiple, independently controllable tweezer beams whose shapes can be tailored by making the SLM an adaptive mirror in an interferometer (ref. 1). The beams leave the SLM at different angles, and an optical Fourier transform maps these beams to different positions in the focal plane of a microscope objective. The following figure shows two arrays of multiple beams created in this manner. The patterns displayed above the beam array control the intensity-to-phase transformation required in programming the SLM. Three of the seven beams displayed can be used as independently controllable beams.



Pattern-programmed movement of tweezers beams using SLM. Top: Images show *patterns displayed on SLM. Bottom: Patterns show resultant laser traps.*

The interferometer arrangement enables control of the intensity and phase profiles of the tweezers beams. Another device, called a nimble tweezers probe (ref. 2), was created at Glenn by adding a feature to the interferometer to render the polarizations of the two main interferometer beams orthogonal. The beams, then, do not interfere, but one beam is used to move particles individually to the multiple traps created by the other beam. The polarization is then rotated back to perform interferometric control of the filled traps. The next figure shows three different states of the tweezers traps. The traps are visible in the top frame but are unfilled. The center frame shows one trap containing a 9.6-µm sphere. The bottom frame shows four filled traps as well as a particle in a nimble tweezers trap to the right.



Generation of multiple traps and trapping of multiple particles. Top: Column of empty traps. Center: One particle trapped. Bottom: Four particles trapped (note guide particle in separate trap).

Work is in progress to calculate and measure forces and moments on generally shaped tools, to create an infrared version of the setup for biotechnology, to measure the second harmonic generated by the tool-nanostructure combinations for diagnostics, and to create a tweezers to operate under a vacuum.

References

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2. Jassemnejad, Baha: Nimble Optical Tweezer Beam for Tweezer-Array Manipulation and Interrogation. NASA Disclosure of Invention and New Technology, July 30, 2002.

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