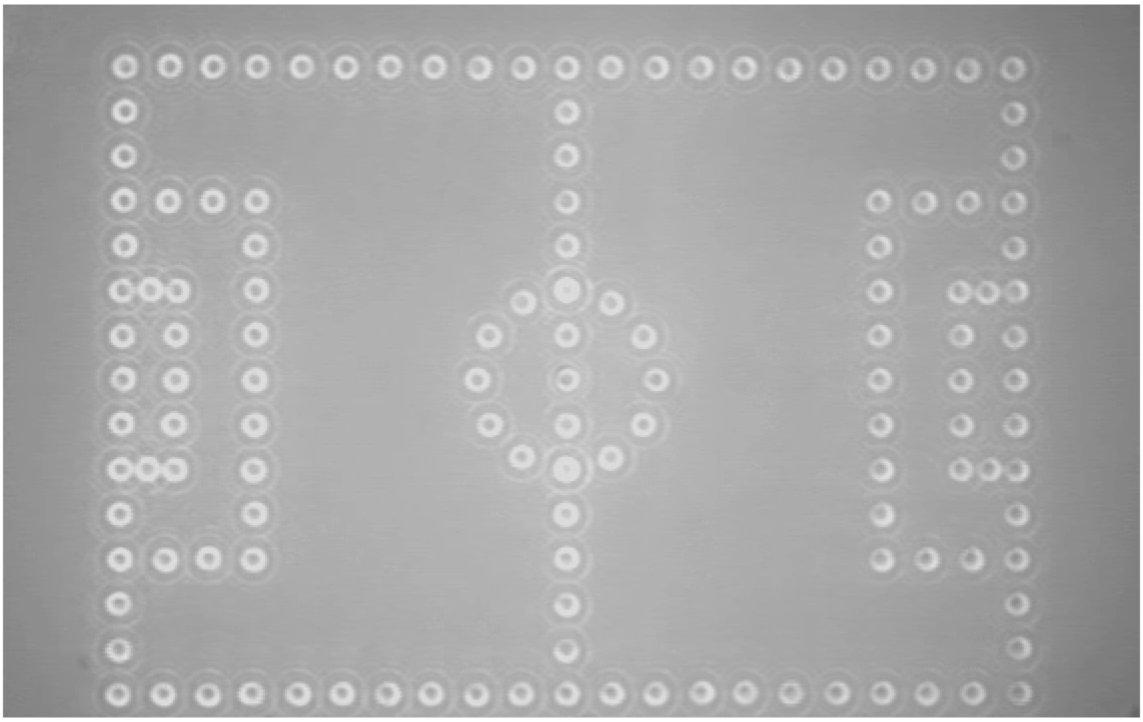
Acousto-optic deflector (AOD)

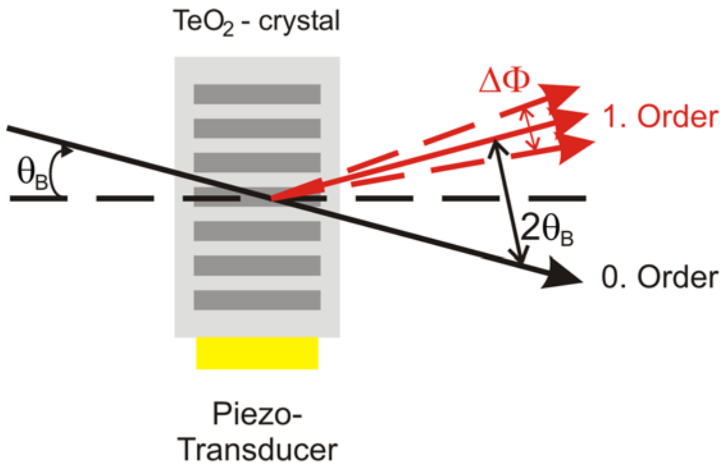


Picture 1: *Optical tweezers with trapped 1.6 µm silica particles, created with an AOD system. The dimensions of the field of view are about* $70\mu m \times 100\mu m$.

A system of two Acousto-optic deflectors (AODs) is a powerful tool, which enables us to create and control several (up to 100, see picture 1) independent optical tweezers only by deflecting one incoming laser beam. The created traps are not all illuminated at the same time, but the beam is deflected to one spot and then stepwise scans the whole pattern. This scanning thereby happens at a frequency of 50 kHz, which is fast enough to create quasi-static potentials for trapped objects, like colloidal particles or biological cells. With the custom-built driving electronics and software, single or even groups of traps can comfortably be controlled by the PC mouse or automatically by programs.

Functionality

The term "Acousto-optic deflector" indicates already, that the laser beam is deflected by sound waves created in the TeO_2 crystal inside the AOD by piezo-elements. Because the laser beam can of course be deflected in only one direction with one crystal, always a pair of AODs perpendicular to each other is mounted in our experiments.



Picture 2: *Functionality of an AOD: The laser beam is deflected by sound waves in the TeO_2– crystal inside the AOD. By slightly divergent sound waves, the direction of the deflected first order of the laser beam can vary in the range of $\Delta\Theta$, which makes a certain area in the sample plane accessible to the deflected laser beam.*

Picture 2 shows the principle of what is happening inside an AOD. The piezo-transducer creates sound waves of a certain wavelength Λ in the TeO_2 crystal. If this wavelength matches the Bragg-condition $\sin\Theta_B = \frac{\lambda}{2\Lambda}$, the first order of the incoming laser beam with wavelength λ is deflected with angle $2\Theta_B$. By creating slightly divergent sound waves it is possible to deflect the first order in a certain range of angles $\Delta\Theta$. The deflected beam is finally focussed into our sample through a microscope objective, so that $\Delta\Theta$ makes an area of about $160\mu m \times 160\mu m$ accessible for laser spots.

The whole intensity of the laser is, besides immense losses in the 0^{th} order, distributed over all created laser spots, so that the strength of a single optical trap is reduced with every additional spot. The single traps of a created pattern are scanned with a frequency of 50 kHz. Two succeeding spots are illuminated with a short delay between to eliminate a crossover of the different deflection frequencies. With all these losses about 20% of the incoming laser power can be used for the intended purpose of creating optical tweezers. However, in our experiments using a laser beam of about two Watts is sufficient to trap and even move more than 100 colloidal particles.

Applications

In principle, an AOD system is useful in every experiment that requires more than just one laser potential. For more advanced applications, every individual trap can be varied independently with time, so that it is possible to realise movements or changes of the intensities of single or groups of traps.

Examples for experiments in our group, which use an AOD system are Stochastic Resonance, Microfluidics, Ratched Cellular Automata, Giant Diffusion. A good demonstration of the possibilities and the versatility of a experimental setup using AODs can be seen in the movies of our colloidal soccer game.