**The world’s fastest rotating object**

*The blades in the turbine of a fighter jet aircraft can nearly spin one thousand times a second. But what is the highest rotation rate at which a mechanical object can revolve?*

Fighter jet aircrafts need to be fast. It therefore appears intuitive to boost the blades in the turbine of the jet to highest rotation rates. Following this approach, one will encounter an unpleasant surprise. At rotation rates around 1000 revolutions per second the blades start to disintegrate, and the turbine explodes. There, the maximum circumferential speed, i.e. the speed of a point at the tip of a blade, is about 1000 m/s. The speed of a point in the center of the turbine, however, is zero. This huge difference in speeds leads to an enormous stress in the material, which eventually results in the described explosion. The maximum circumferential speed of 1000 m/s seems to be a quite general material limit. In the same way, steel balls with a 0.5 mm diameter explode as they rotate more than 700 thousand times a second, which corresponds to a circumferential speed of about 1000 m/s.

Since the circumferential speed scales inversely with the size of a rotating object, the world’s fastest rotating object needs to be miniscule. And it cannot be attached to a normal motor which drives its rotation, as the motor itself would explode, too. If we are moving away from objects that can be easily seen by bare eye to objects that are a thousand times smaller than the diameter of a hair we have entered the nanoworld. In this world we find particles so tiny that they can be levitated and manipulated purely by light (see picture).

The particles we are using for our experiments are made from fused silica and have a diameter of 100 nm. We trap one of these nanoparticles in a strongly focused laser beam which functions as an optical tweezer [link to <https://en.wikipedia.org/wiki/Optical_tweezers>]. The optical tweezer does not only levitate the nanoparticle but can also be used as the motor to drive the particle into rotation. To turn this motor on, we set the polarization of the laser beam to circular [link to <https://en.wikipedia.org/wiki/Circular_polarization>]. In this polarization state the electrical field vector of the laser light rapidly revolves in a circle. The particle absorbs a bit of this circularly polarized laser light and is therefore driven into rotation. To achieve highest rotation rates, we need to mitigate friction from gas molecules which are bumping into the particle and are breaking its rotation. We therefore place the optically trapped and optically driven particle inside a high vacuum chamber [link to <https://en.wikipedia.org/wiki/Vacuum>]. This reduces the number of collisions between air molecules and particle by a factor of 100 million compared to ambient conditions. At this low gas pressure and with an optical power of about 200 mW (corresponding to about 100 standard laser pointers) we measure that the particle undergoes one billion revolutions per second, making it the world’s fastest rotating object. In very recent and unpublished measurements we recorded even higher rotation rates which correspond to circumferential speeds exceeding 1000 m/s.

Indeed, a rapidly rotating nanoparticle is a promising testbed for fundamental material stress tests. Material probes at the nanoscale can be manufactured without defects and therefore can probe the fundamental material stress limits. In contrast a macroscopic probe (e.g. a blade or a mm seized steel ball) cannot easily be manufactured without defects and would break due to a crack or a scratch and not due to atomic bonds of the material being ripped apart. Furthermore, it is possible that materials on the nanoscale behave differently than on the macroscale. In a glass ball with a diameter of 1 mm, one in ten million atoms is sitting at the surface of the ball. For a 100 nm ball this ratio increases by a factor of ten thousand to one in a thousand atoms at the surface. Therefore, it appears possible that surface effects start to change the properties of a material at the nanoscale. This means that studying the rotation rate at which our tiny particles explodes would bring new insights to material science.

On the other hand, quantum mechanical effects tend to show up at the nanoscale. If we were able to perfectly isolate our experiment from all kinds of possible friction forces (air molecules, electric fields,…), there would still be a force that breaks the rotation of the maximally freely rotating particle. This force arises from quantum fluctuations [link to <https://en.wikipedia.org/wiki/Quantum_fluctuation>] of the vacuum. In other words, the fluctuations of what one could call ‘nothing’ would break the rotation of the particle. Even though such a quantum experiment is very challenging to perform, it is a fascinating perspective for our tiny rotors.