Efficient nano motor cleverly harnesses light（图）

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Researchers at Lawrence Berkeley Labs and the University of California have made a new nanoscale motor that can drive a disc 4000 times bigger than itself. It is powered via the so-called "plasmonic effect" and could be used to manipulate ultra-small objects like DNA and for powering nanoelectromechanical machines (NEMS). At merely 100 nm across the motor looks like a tiny windmill, inspiring the researchers to dub it a "light mill".

Optical forces induced on a light mill motorScientists have long known that light can be used to move nano-objects thanks to the fact that photons have both linear and angular momentum. Transferring the linear momentum from photons to an object results in an optical force that can be exploited for trapping (for example, in "optical tweezers") and cooling. And the angular momentum carried by photons can induce a mechanical torque via light scattering or absorption.

Being able to generate large optical torques at the nanoscale could benefit a host of applications such as nanomechanical transducers in energy conversion, and also for manipulating and detecting tiny biological molecules. However, the main hindrance is that light–matter interactions are very weak because of the small optical constants of the dielectric materials used in such devices. This means that micron- or even millimetre-sized objects are required to generate a useful amount of torque.

Increasing interaction

In recent years researchers have discovered that they can increase the interactions between light and matter by taking advantage of the electrons that oscillate collectively at the surface of metals – called "surface plasmons". Light fields are enhanced when they are resonant with these plasmons – an effect that has already been successfully used in techniques like single-molecule detection and surface-plasmon enhanced Raman spectroscopy (SERS).

The Lawrence Berkeley team – led by Xiang Zhang – has now exploited this effect to make a nanoscale plasmonic motor directly driven by light. The motor is made from gold structures that comprise four small circuits whose resonant frequencies depend on the geometry and dielectric properties of the metal. The 100 nm sized device can rotate a silica disc that measures 2 µm across thanks to its strong interactions with light via the plasmonic effect.

By tuning the wavelength of the light used, the motor can be made to rotate in a certain direction or at certain speeds. For example, when illuminated with a 1 mW power light beam at a wavelength of 810 nm, the disc rotates in an anticlockwise direction at a rate of 0.3 Hz. When illuminated by the same power beam but at a wavelength of 1700 nm, the disc rotates clockwise at the same speed.

Simplifying the process

Since the torque results solely from the shape of the plasmonic structure itself (which was a metamaterial-type structure carefully designed by the Berkeley researchers) and its enhanced interaction with light, the device does not require light beams with a predefined angular momentum to work. This is in contrast to previous devices in which the illuminating beam's polarization had been adjusted for it to be able to rotate objects. Any simple light source, such as linearly polarized or unpolarized beam can thus be used to drive the new set-up.

The motor could be ideal for powering NEMS and for bio-applications, such as DNA winding and unwinding. It might also be useful for harvesting solar energy, after some modifications in design to optimize its performance for such an application – for example, making it more susceptible to a broader spectrum of light wavelengths. "Several motors can also be easily combined for larger power, like the cylinders in a car motor," team member Ming Liu told physicsworld.com.

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