Powering nanotechnology with the world's smallest engine

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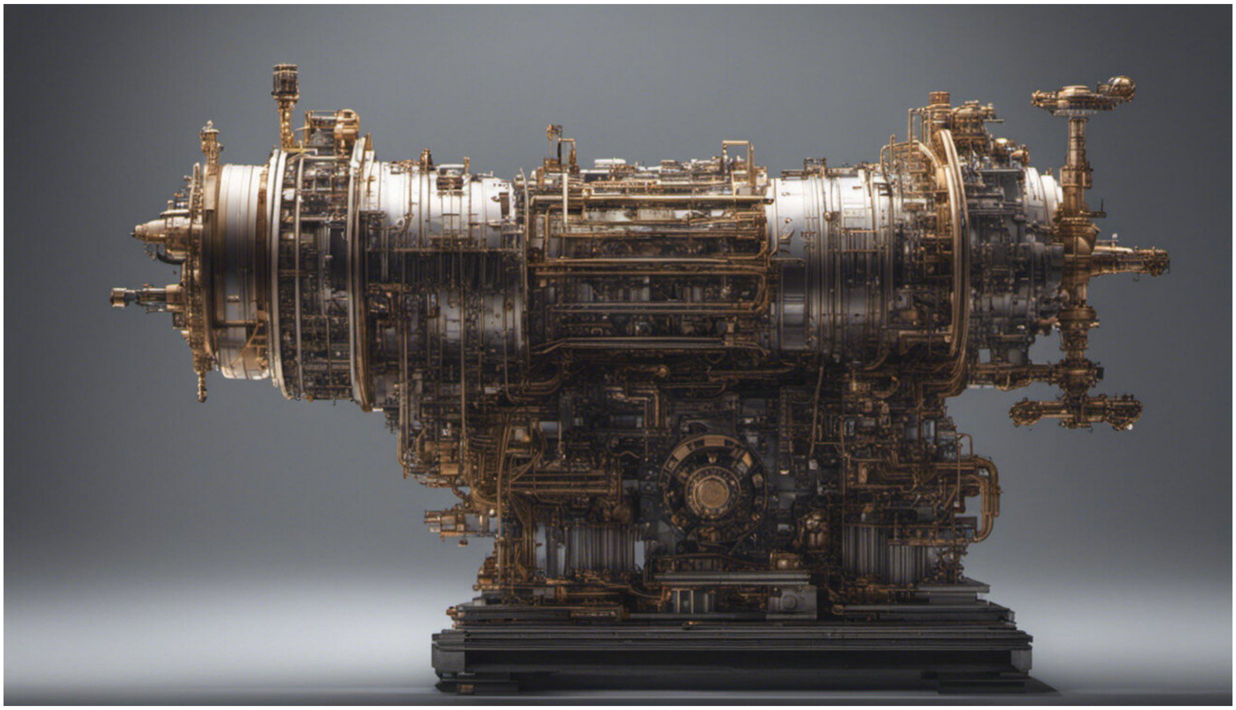
Credit: Pixabay from Pexels

In the minuscule world of nanotechnology, big steps are rare. But a recent development has the potential to massively improve our lives: an engine measuring 200 billionths of a metre, which could power tiny robots to fight diseases in living cells.

Life itself is proof of the extreme effectiveness of nanotechnology - the manipulation of matter on a molecular or atomic scale - in which DNA, proteins and enzymes can all be considered as machinery. In fact, researchers have managed to make micro-propellers using tiny strands of DNA. These strands can be stitched together so freely and precisely that the practise is known as "DNA origami". However, DNA origami lacks force and operational speed (it takes time measurable in seconds), reducing its robotic function.

But we have now produced nano-engines that can be operated with beams of light to work pistons, pumps and valves. Made from gold nanoparticles bound together by a heat-sensitive chemical, our machines are strong, fast and simple to operate, making them extremely practical for future applications.

One of the biggest problems when dealing with tiny technology is the need to create a strong force for an object at the nanoscale. If you think of a human moving in water, their movements are only slightly restricted and the water feels fluid. But imagine what would happen if that person shrunk to a size one hundred thousand times smaller than an ant. The water would feel incredibly viscous. In order to be able to move with ease at the nanoscale, a "nanoperson" would need to exert an enormous force for their size. The image of an ant, capable of lifting several times its own weight, comes to mind. Hence the name for our discovery: actuating nano-transducers – or ANTs.



Credit: AI-generated image (disclaimer)

The ANTs consist of gold nanoparticles bound by a thermo-sensitive material. At room temperature, the binding material is relaxed and can be filled with water, which push the nanoparticles apart. Heated up by just a few degrees using a laser, the material contracts to a thin shell, bringing the nanoparticles closer together and expelling the water. Then as it cools down again, the water rushes back in and repels the nanoparticles with enormous force. The ANTs act as a tiny but powerful spring, storing and releasing large amounts of elastic energy at great speed.

Key to the development of the ANTs was the use of laser light. By choosing the right colour of light for the right size of nanoparticles (in this case green light for gold nanoparticles) it is possible to heat them up very quickly. In darkness, because they are so small, the nanoparticles cool down very quickly as well. The ANTs then can operate within a microsecond. In the same way that light can heat up water to power steam engines, we can use light to build a piston for engines at the nanoscale.

Exploding ANTs

"It's like an explosion," explains Tao Ding from Cambridge's Cavendish Laboratory: "We have hundreds of gold balls flying apart in a millionth of a second when water molecules inflate the polymers around them."

Strong as an ANT. Credit: Steve Jurvetson, CC BY

One obvious application for this new advancement will be in the practise of microfluidics, which enable an entire chemical lab to exist on a chip. This allows the manufacturing of pharmaceuticals and the analysis of chemicals with very high precision. However, microfluidics have been limited by the need for bulky operating equipment such as pumps and valves which need to be connected physically with pipes to the chip.

The new ANTs can be used as tiny pumps and valves dispersed thought the microfluidic chip itself and operated by small beams of light without the need for any physical connection. Plus, the size of the ANTs (200-400nm) is similar to the size of the smallest spots into which we can focus light, which optimises the technology. Using ANTs would enable much more complex microfluidic designs in the next few years.

We are also looking over the same timescale at using ANTs to produce pistons and eventually engines on a nanoscale, by restricting the motion of the ANTs to a single direction. In the future, such motors could enable us to manufacture specific materials, and eventually even cars and houses, as well as providing the power for nano-engines to work nano-robots inside living cells. Small steps for ANTs could mean big leaps for humans.

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