To Fix This Engine, You'll Need a Quantum Mechanic

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This version of the article corrects an earlier version that stated the electric field was perpendicular to the ring.

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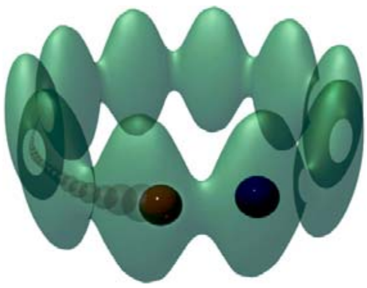

Crank it! If it could be built, this quantum-mechanical contraption consisting of two atoms in a ring of light would be the smallest electrical motor.

CREDIT: IVAN PONOMAREV

The first electric motor whirred to life nearly 2 centuries ago, and in recent decades scientists and engineers have worked to build ever-smaller ones. Now, a team of theoretical physicists has proposed a fully quantum-mechanical version of the classic spinning electric motor that consists of just two atoms trapped in a ring of light. Experimenters might be able to construct the thing now, the researchers say, even though they themselves don't have an intuitive explanation of exactly how it works.

An electric motor transforms the energy in an electric or magnetic field into mechanical work. Typically, a motor consists of a coil of wire turning like a flipping coin between permanent magnets. A current runs through the coil to produce a magnetic field that opposes the one from the permanent magnets. The coil then flips so its field will point in the same direction as the external one. But while it is moving, the current in the coil reverses so that the coil's field once again points the wrong way, making it turn again. The process repeats itself over and over, making the coil twirl rapidly and turning a shaft that is attached to it like the handle of a tennis racquet.

Now, Alexey Ponomarev, Peter Hänggi, and colleagues at the University of Augsburg, Germany, have devised the quantum-mechanical equivalent of such a motor. Their motor consists of bright spots of laser light that form a circle like so many pearls in a bracelet (see picture). The spots of laser light can trap two ultracold atoms: The first, called the carrier, is missing an electron and so is electrically charged; the second, called the starter, is uncharged. Instead of applying an oscillating current in a coil, the researchers envision applying an oscillating electric field parallel to the plane of the ring.

This will set the carrier into motion--but not in a simple way. Because it's a quantum particle, the carrier atom must be described by quantum waves that give the probability for finding it at one position or another. Applying an oscillating field alone will send waves of equal strength rippling around the ring in both directions, with the net result that, on average, the particle doesn't budge. To get it going, the physicists have to include the starter atom, which gives the carrier a shove whenever the two atoms happen to hop into the same light spot.

Even that is not quite enough. To make the motor turn over, the researchers find, the electric field has to oscillate in a pattern that would appear different if it were suddenly reversed--much as a song sounds different if you play it backward. Such oscillations set off quantum waves that flow predominantly either to the left or to the right, setting the motor in motion, the researchers report in a paper published online this week in *Physical Review Letters*.

Ironically, even though the calculations show that the starter atom is crucial, the theorists themselves don't have an easy, intuitive explanation of what exactly it does. "If I did, I would have put it in the paper," Hänggi says.

"Theoretically, it is very interesting; experimentally, there are some big questions as to whether it can be realized," says Sergej Flach, a physicist at the Max Planck Institute for the Physics of Complex Systems in Dresden, Germany. For example, he says, tracking just a single pair of atoms in a ring of light would be very difficult, so experimenters would probably have to configure many copies of the motor running in synchrony. Roland Ketzmerick, a theorist at the Technical University of Dresden, notes that that idea is related to long chainlike arrangements of light and atoms called quantum ratchets. "Of course, this [work] allows you to talk about motors," he says. "It's cute."

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