



Visitors at this year's Nuremberg Toy Fair were wide-eyed. The reason for their astonishment was a new toy locomotive that can raise and lower its pantograph just like a real train engine. Such fluid motion is made possible by a lightweight miniature piezoelectric motor. A revolutionary development, the device costs no more than a conventional electric motor but operates incomparably more precisely, and is also silent. "Our motors have neither rotors nor gears," says Dr. Björn Magnussen, CEO of Ellipectec Resonant Actuator AG in Dortmund, Germany, a company established in January 2001. "Since there's no need to reduce any rotor momentum during braking, they come to a stop 60 times faster than electric motors when they're switched off, and their braking distance is 2,000 times shorter."

But the miniature drive system from Ellipectec is ideal for far more than just model railways and the wiggling ears of animated bears, dolls and plastic puppies. The company expects the device to perform its preci-



Ellipectec's miniature motor looks like an aluminum key with steel springs and two power supply leads attached to it. Incorporated into a model train engine (top left), the piezoelectric drive ensures that the pantograph's movements are smooth.

Minuscule Motors

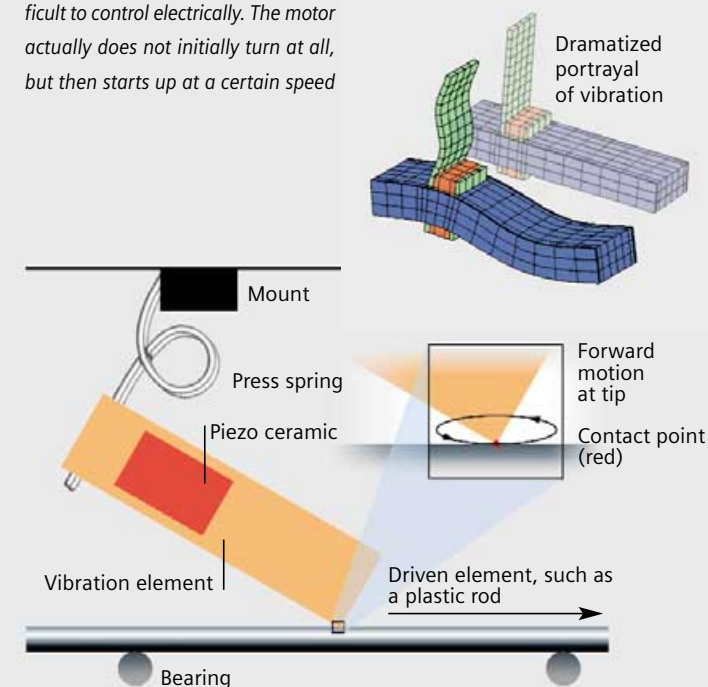
Björn Magnussen has managed it all. His miniature piezoelectric motors are precise, cost-effective, silent and light — and they have excellent prospects worldwide.

sion work in entirely different areas as well — in general, wherever small parts have to be moved with little effort. "That might include household appliances, cameras, printers, CD drives, medical and automotive applications — in short, virtually anything you can imagine," says Magnussen enthusiastically.

Piezoelectric motors are not entirely new; they've been used in microchip manufacturing for several years now. But their price of up to \$400 — and sometimes more than \$5,000 in the case of piezoelectric motors used for positioning systems in microscopes — has thus far prevented them from being

Fluid Motion Through Controlled Oscillations

The control system for the Ellipectec motor is impressively simple. A microcontroller and a single transistor are all that it takes to supply the piezo ceramic with voltage, which causes it to expand by less than one micrometer. If the drive current is absent, it contracts (piezo effect). Depending on the application, this cycle of alternating expansion and contraction of the piezo element occurs between 50,000 and 100,000 times per second. The rapid vibration is passed on to a key-shaped resonator, which causes it to oscillate with a movement resembling that of a struck tuning fork. The ingenious design causes the tip of the resonator to execute elliptical propulsive movements — thus the name of the company: *Ellip* as in "ellipse" and *tec* as in "technology." A spring attached to the motor presses its tip onto the element to be driven, ensuring movement. Bit by bit, the tip pushes or pulls an element such as a plastic rod, each time moving it between 0.5 and 2 micrometers. Although the rod is moved only a few micrometers with each push, the tremendously fast repetition results in speeds of up to 15 centimeters per second or more. In an electric motor, on the other hand, slow movements are difficult to control electrically. The motor actually does not initially turn at all, but then starts up at a certain speed



— hence the small, hardly visible jerky movements that result. The piezo motor, however, can move very slowly, evenly and silently. That's because its micrometer increments result in virtually smooth movements. It is worth noting that both the miniature motor itself and the machine that joins together two of the three motor's components (piezo ceramic and resonator frame) were developed completely in-house at Ellipectec, which currently has a staff of 12 employees. In the first stage of the motor's production, the centerpiece, which is a multilayered piezo ceramic from EPCOS measuring approximately half a centimeter in length, is automatically inserted into the two-centimeter-long aluminum resonator. The exact method for conducting this procedure remains a company secret. The steel springs and leads for the motor are still being attached to the device by hand. However, Ellipectec is looking to automate these processes as well in the future, partly as an in-house project.

applied extensively. Researchers from Siemens, EPCOS and Ellipectec were the first to achieve dramatic simplifications in the design, components and production process for the motors, thereby reducing the unit price to between two and four dollars. "At that price, we'll soon be taking a lot of market share from manufacturers of electric motors," says Magnussen.

Several years ago, during his tenure at Siemens Corporate Technology (CT) in Munich, Magnussen was already interested in piezo ceramics. He took part in an internal business-plan competition where he proposed the idea of using a new type of piezo technology worked out at CT as a basis for the development of a cost-effective motor suitable for mass production. He then won the opportunity to work with a team of researchers at the Siemens Technology-To-Business Center (TTB) in Berkeley, California. "For me, that was the big chance to follow up on my project idea and implement it," says Magnussen. The TTB helped put together a research team, covered personnel costs, and equipped a laboratory. "We also got extensive training and support in areas such as business development, patenting and starting a company," Magnussen recalls.

After staying in Berkeley for a year and a half, Magnussen, who is now 35, returned to Germany. He brought with him not only his first prototypes, but also five TTB staffers. All of this was so convincing that he received three million euros in venture capital to start a company; half of it coming from Cologne-based Intelligent Venture Capital GmbH and half from a technology investment association in Bonn — both in Germany. Siemens currently holds 24.9 percent of Ellipectec stock.

"We have a technological lead of at least two years — so no one is going to catch up with us quickly," says Magnussen. Production of the first batch of miniature motors got under way in June of this year at Ceramics GmbH in Redwitz, Germany, a wholly owned Siemens subsidiary. The lots are still small, but orders from the toy and automotive industries could rapidly catapult output into the millions.

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