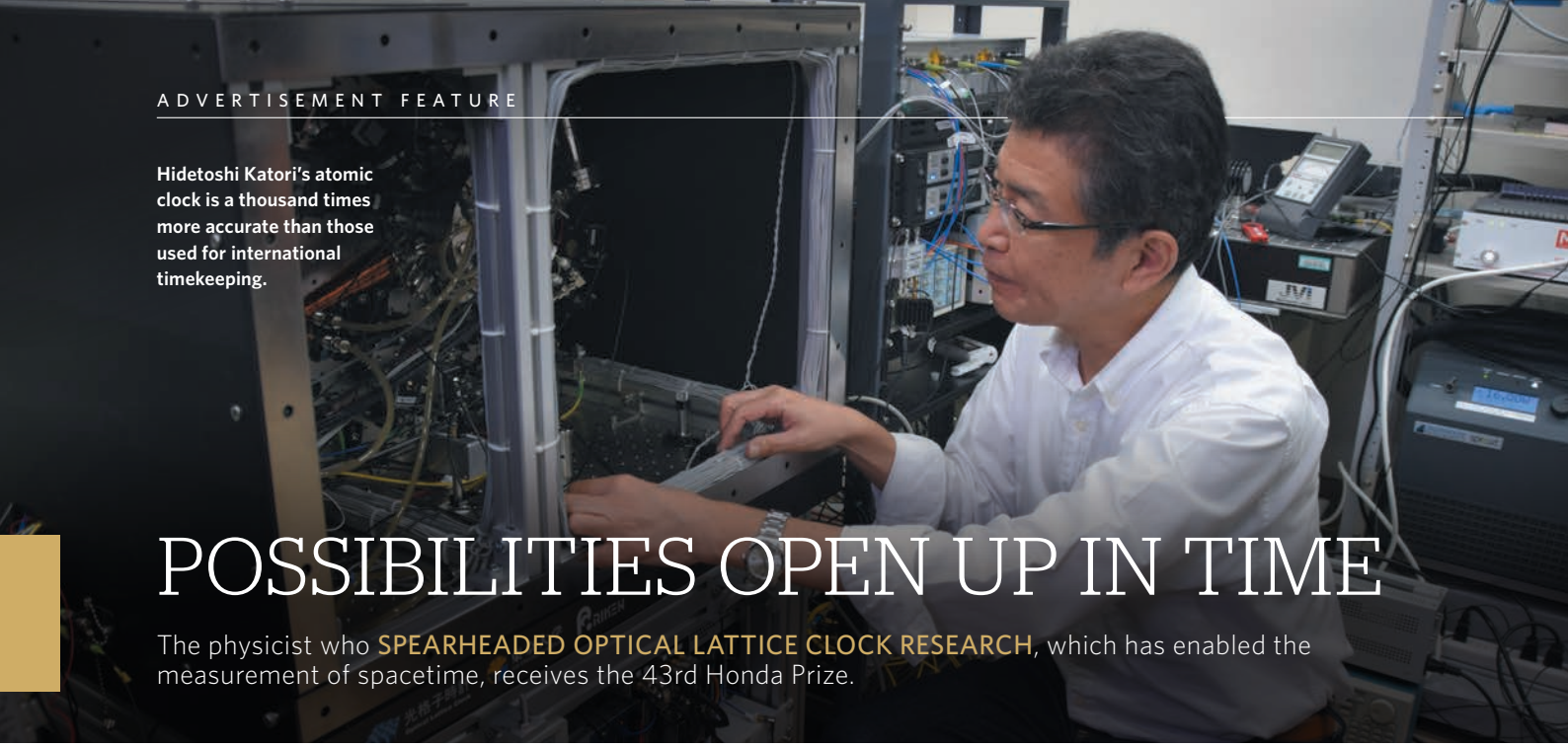

Hidetoshi Katori's atomic clock is a thousand times more accurate than those used for international timekeeping.

# POSSIBILITIES OPEN UP IN TIME

The physicist who SPEARHEADED OPTICAL LATTICE CLOCK RESEARCH, which has enabled the measurement of spacetime, receives the 43rd Honda Prize.

**In 2001, Japanese physicist Hidetoshi Katori** proposed a new type of atomic clock that only loses a second every 30 billion years, a period longer than the current age of the universe. The invention — called the optical lattice clock — is a thousand times more accurate than cesium atomic clocks used for international timekeeping and is a contender for redefining how long a second lasts. This year, Katori has been awarded the 43rd Honda Prize.

Atomic clocks use the oscillations of atoms as timekeeping 'pendulums' — which, like grandfather clocks, involve weights suspended from a pivot, the swing of which defines time. When irradiated with microwaves of certain frequencies, the atomic state changes from one energy state to another. In 1967, the second was defined as the equivalent of the time it takes for a cesium 133 atom to oscillate 9,192,631,770 times between the two energy states. Cesium atomic clocks define a second with a fractional uncertainty of $10^{-15}$, an accuracy that should remain constant for 30 million years.

What Katori proposed in the optical lattice clock was to measure the transition in energy states among a batch of neutral strontium atoms, laser-cooled and trapped into a lattice formed by laser beams. He found that the laser tuned to a certain wavelength would be able to confine atoms into separate wells without affecting the oscillations of atomic pendulums.

While this had the potential to enhance timekeeping precision by several orders of magnitude, Katori knew that the idea wasn't going to sink in immediately. "I was calculating until the day before my first international presentation to see whether such a wild idea could really be valid," he recalls. "Atomic clock research is also a very lengthy pursuit. It's not unusual to take five to ten years to obtain one study result, so it's not surprising that most others were cautious until we had something tangible to show." But slowly, research groups began paying attention. A breakthrough came in 2005, when Katori and his team demonstrated the first optical lattice clock, which was followed by similar work by research teams in the United States and France, and in 2015, by an optical lattice clock developed by Katori and his team capable of measuring to a fractional uncertainty of $10^{-18}$.

At this clock precision, physicists can observe Einstein's general theory of relativity — which states that gravity affects the flow of time. Time's speed, it suggests, is different depending on how close a clock is to Earth's gravitational centre. "Clocks with this level of precision create possibilities for innovative new sensing methods," notes Katori. This could be applied in contexts such as earthquake detection, by helping to detect incredibly tiny changes in the level of the Earth's crust as they occur.

An important step forward is to downsize the devices, so that they can be placed anywhere. In collaboration with Shimadzu Corporation, Katori and colleagues have reduced the size of optical lattice clocks from that of an entire laboratory room, to a 1,000 litre box. With this, he conducted an experiment at the Tokyo Skytree, showing in 2020 that clocks set on the observation deck at 450 metres ticked faster by 4/1,000,000,000 of a second per day than those placed at ground level. A smaller clock of 250L is currently in the works. "The goal is to eventually establish a network of clocks, which will allow us to create a sensing network for things like earthquakes," says Katori.

The real beauty of this research, however, is that future applications are currently unimaginable, says Katori. "The cesium atomic clock was invented in 1955. Eventually, it was not only used to define the second, but they were loaded onto satellites to bring us accurate real-time GPS tracking. Who would have imagined?"

Katori believes that optical lattice clocks will be similar. "It's difficult to imagine what this might look like, but it's exciting to think that we could be regular users of relativistic spacetime."

The Honda Foundation was established in 1977 with contributions from Soichiro Honda, founder of Honda Motor, and his brother Benjiro. The foundation established the Honda Prize in 1980 to honour scientists whose efforts advance ecotechnology, that works in harmony with complex human needs and the natural environment. Since then, the foundation has recognized the achievements of 42 individuals or groups. The 2022 ceremony took place on 17 November at the Imperial Hotel in Tokyo. ■

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