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On Time

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INDUSTRY

AT A REVOLUTIONARY RESEARCH INSTITUTE IN LAUSANNE, CUTTING-EDGE TECHNOLOGIES SUCH AS ULTRASHORT PULSE LASERS ARE PUSHING AT THE LIMITS OF WATCHMAKING.

By **ANDERS MODIG DAVIN**

The laboratory space looks like a normal university classroom, with grey floors and white walls and tables, but the École Polytechnique Fédérale de Lausanne (EPFL) in Switzerland is one of the world's top research and development institutions. It collaborates with numerous large and small watchmaking brands and specialises in the creation of new mechanisms featuring kinematic and technological innovation. "It has been linked with the watchmaking industry for as long as the university has existed," says its new president, Professor Anna Fontcuberta i Morral.

Historically, Patek Philippe, Audemars Piguet and Hublot have been among EPFL's collaborators and supporters. Together with EPFL, the R&D team at Audemars Piguet worked for eight years on the technology behind the Audemars Piguet Royal Oak Concept RD1, presented at the Salon International de la Haute Horlogerie in 2015. The work revolved around acoustic research, and focused on several aspects such as water resistance, volume, purity and harmony of sound.

However, it was Patek Philippe that took the link between the watch industry and research and development made by EPFL's scientists, researchers, post-docs and master students to new heights from 2012-2020. Its donation led to the creation of the Patek Philippe Chair, within the Instant-Lab (also called the Micromechanical and Horological Design Laboratory) led by Professor Simon Henein in a Neuchâtel building called Microcity. "We invent new fundamental bricks for society, we are not specifically targeting industry. We do research—it is not our primary role to solve problems for companies. And we are driven by intellectual issues, for instance how to make a mechanism insensitive to motion of its base. But we are not application driven," explains Professor Henein.

Five years after the non-conditional initial endowment by Patek Philippe, the laboratory—whose work also revolves around aerospace technologies, biomedical technology, satellites and optics—is still going strong, albeit run with federal money and industry collaborations. "Watchmaking is fascinating in terms of history; Newton, Galileo and Huygens are among the scientists who contributed to the science of timekeeping," says Henein, a curly-haired half-Swiss, half-Egyptian with round glasses and an intense gaze.

"You could say that mechanical watchmaking is a bit fake, as it would be easy to put a little motor inside a watch. But this constraint of remaining purely mechanical drives us towards interesting inventions that can also be applied elsewhere," says Henein. "I like the mechanical aspect of watches, that they are not electronic. There is no

THINKING AHEAD
Above: EPFL president Professor Anna Fontcuberta i Morral.

YUICHIRO CHINO/GETTY IMAGES. EPFL/ALAIN HERZOG.

magnet, no electrons running around. This constraint drives a lot of creativity. Just look at watches today, which have an accuracy of four to five seconds per day. This is objectively difficult—it is actually amazing. In some other industries a 1 percent deviation is considered precise. In watchmaking, we are talking about 10 parts per millions (0.001 percent) in a robust and portable object—this is really something. You learn a lot that can be applied elsewhere.”

BRIGHT SPARK
Below: Instant-Lab's Professor Simon Henein.

REVOLUTIONARY MOVEMENT

A major project at Instant-Lab is a watch movement without an escapement. “Most parts in a watch keep turning and gears are not easy to replace. So, for us, the obvious thing to do is to replace the oscillator itself, the balance, and hairspring. And in doing so possibly getting rid of the escapement,” says Henein. A watch without balance and anchor is, to say the least, a radical step. To have an escapement injecting bursts of energy into a movement has been a fundamental part of timekeeping since the 13th century.

“But the efficiency of a modern escapement is poor in terms of mechanics. Only 40 percent of the energy from the oscillator reaches the target, while 60 percent is lost, revealed by the annoying ticking sounds,” he says. Compare that with a bicycle, where 97 percent of the pedal power reaches the rear wheel. The annoying sound he talks about is the sound that watch collectors love. “The tick-tock has become the signature of time, but it is actually a bad sign—normally such ticking sounds in a bike or a car gearbox would mean trouble that would require fixing,” he says. “So, we developed Isospring, which made it possible to have mechanical timekeeping without ticking. We have invented a new oscillator that doesn't need an escapement. Instead, it has a periodic orbiting motion; it doesn't move back and forth. It is like the Earth moving around the sun. It is not stopping and going, it keeps going.”

So, how does it work? The principal idea came from reading 340-year-old texts by Isaac Newton, who was trying to understand gravity and why planets move around the sun in an elliptical manner. One of his hypotheses could be described as the planets being connected by a spring-like force to their star. This hypothesis would be proven wrong, as it would mean that all planets in our solar system would take the same time to revolve around the sun. But in the 2010s these historical texts served as an eye-opener. “For us as timekeepers, this is what we want: a system where the frequency is the same regardless of the amount of energy it receives. The goal was to make a physical object that emulates this situation.”

> “WE HAVE INVENTED A NEW OSCILLATOR THAT DOESN'T NEED AN ESCAPEMENT. INSTEAD, IT HAS A PERIODIC ORBITING MOTION.”

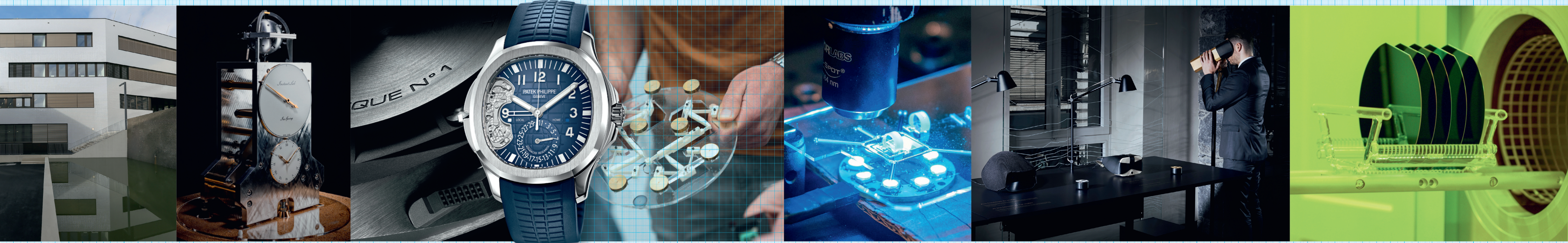
The result is a dense metal mass suspended by flexure blades, a frictionless technology widely used in aerospace. This allows the mass to move in a horizontal plane, while pulling it back towards a fixed centre, just like Newton's imaginary spring pulling the planet towards its star. Once set into motion, the mass will follow the heavenly elliptical orbits. “And this happens in a continuous motion, which means you can put a crank on it, just like pedals on a bike,” says Henein. “With the crank maintaining the oscillating mass in regular orbit you can simply put hands on the gear train, and you have a clock.”

With this extremely basic principle of a mass, a couple of blades and a crank, you can make a new kind of movement, free of escapement, with better precision, with at least 100 percent better energy transmission resulting in improved power reserve, and improved wear and tear since fewer parts are in contact with each other, thus reducing the problem of friction.

Henein points out that any material that can be used for springs can also be used for flexures. “Silicon is nice since you can machine it in a very precise way, but you could also use glass, titanium, steel, there are no given materials. Which means you could also decorate it the way they like to do in watchmaking. And since we don't have to use new materials or new technologies, this could have been invented 300 years ago.”

And it works. In the lab there is one clock with the mesmerising movement, and there is one similar installed in the Neuchâtel City Hall. Miniaturisation is well under way, but with strict non-disclosure agreements. But it is a challenge to convert the technology to fit into a wristwatch. It is not only about miniaturising, as you must make the movement insensitive to angles, to gravity and movement shakes. Thus far, the solution is to have two sub-oscillators with opposite rotating motions, where the movements would cancel each other. Professor Henein smiles: “It is such a beautiful, fundamental problem: how to make a mechanism insensitive to all motions of its base.”

PACE OF CHANGE
Below, from far left: the Microcity building; clock with Isospring movement; close-up of Audemars Piguet Royal Oak Concept RDI; Patek Philippe Advanced Research Aquanaut Travel Time Ref. 5650G; movement models; femtosecond laser; Vacheron Constantin virtual reality project; controlled environment in the CSEM Lab.



Existing oscillations made with blade solutions (such as those presented by Zenith and Frederique Constant) are, according to PhD student Loïc Benoît Tissot-Daguette, too high in frequency with their beating at 15 and 40Hz. “High frequency is good for increased precision, but when the frequency is too high, you come across new problems,” he explains, adding that his project uses buckled beams to reduce the frequency.

His goal is to be somewhere between 4 and 15Hz. “If you get it down to 4Hz, you could combine it with existing movements, which would be fantastic,” says Tissot-Daguette, “as you could raise the quality factor, have much longer power reserve and better accuracy from a single part, which creates no wear and tear and doesn't require oil.”

Professor Henein again stresses the broad spectrum of what goes on in the lab. “What we invent is scale-independent. And anything that touches precision you can target with flexures. It can be for optics in huge telescopes, large-size robotics or small watch movements. It could be used for any extremely high-accuracy instrument, for instance moving a mirror on a satellite or particle accelerator, or for machines that manufacture computer chips. It could be put to use underwater, in the desert, up in the atmosphere or beyond.”

EPFL/ALAIN HERZOG. EPFL/CATHERINE LEUTENEGGER. EPFL/JAMANI CAILLET. EPFL+ECAL LAB/DANIELA & TONATIUH. PANDADO STUDIO. AUDEMARS PIGUET. PATEK PHILIPPE. ANDERS MODIG DAVIN.

LASER SHARP

Also located in the Microcity building in Neuchâtel is the Galatea Lab, a research institute which is sponsored by the watch industry itself. “Instant-Lab is more about conceptual ideas, we are more about making—using a particular laser technology called femtosecond laser,” says Galatea Lab leader Professor Yves Bellouard.

As the professor and I don slippers, lab coats and oversized protective glasses, he explains that the technology, which can transform materials with lasers, was discovered three decades ago, and that it has been put to commercial use during the past decade. In the Galatea Lab, they are continually pushing the limits of what is possible. The protective gear allows us to enter a high-ceilinged space, chockablock with computers, lasers, optical lenses and gadgets, which would have a stylist on a science-fiction movie crying for joy.

FUTURE FACING
Above: Galatea Lab leader Professor Yves Bellouard.

“The thing with the femtosecond laser is that because of its speed and focus, we can modify materials inside its volume,” says Bellouard, pointing out that traditional lasers basically cut like a knife. “Thanks to our ultrashort pulses with super-high density of photons, we can actually bring energy inside without touching its surface, which can change its chemical structure and atomic arrangements."

Let us stop for a moment to think about how fast a femtosecond is: one quadrillionth, or one millionth of one billionth, of a second. But what does such an unfathomable number even mean? Consider that the speed of light is approximately 300,000km per second; thus light travels from the Moon to the Earth in approximately one second. One femtosecond is the time it takes for light to travel 0.0003 millimetres. Another comparison would be that a femtosecond is a million times faster than the fastest electronics going on inside computers.

In watchmaking, these altered materials could be used for new decorations and for giving craftsmen the possibility to create unique things.

FAST FORWARD
Below: CSEM CEO Alexandre Pauchard.

Several projects from the Microcity labs often make it to the commercial world in collaboration with CSEM, a leading Swiss technology innovation centre located in a neighbouring building. "Most Swiss watchmakers are shareholders of CSEM," says CEO Alexandre Pauchard. "We are famous for our strong R&D activities in functional surfaces, MEMS (microelectromechanical systems), in ultra-low power microelectronics, in photovoltaics and in batteries."

Vacheron Constantin is one of the brands that experimented together with the Galatea lab, using lasers to engrave sapphire crystals. And for the EPFL graduate course in innovation and entrepreneurship in engineering, the maison partnered with a team that worked on a prototype for a carbon-fibre case fitting over luxury watches during extreme sports.

Secrecy—or confidentiality—is a big part of what goes on at CSEM, but the portfolio of the organisation and its precursor, the Centre Electronique Horloger (CEH), speaks for itself: the world's first electronic quartz wristwatch (1967); the first silicon

thermo-compensated balance spring (2002)—a patent filed jointly by Rolex, Patek Philippe and the Swatch Group; some of the most precise and petite atomic clocks found in space; FlexTech-based oscillators and escapements, such as seen in Girard-Perregaux Constant Escapement (2013); Swatch Pager (2013); co-developing the Mirrored Force Resonance with the team from Armin Strom (2016), and the first solar-powered connected watch for Tissot (2020), with a second generation that arrived to market in 2023.

Pauchard sees no boundaries to further success. "I am confident the watch industry will grow in value and in volumes, and that the main Swiss players will continue to thrive through their focus on innovation, quality and desirability," he says.

In the near future, EPFL will commence a new Rolex-sponsored chair in tribology, the study of friction, wear and lubrication. And even though a lot of what goes on in Microcity is very specialised, Anna Fontcuberta i Morral believes it connects with the wider world: "We work together towards a common goal to benefit all, bridging the gap between academia and society, and engaging in meaningful dialogue about its needs, aspirations and concerns." ■

"WE GIVE THE CRAFTSMEN TOOLS TO DO THINGS THEY CANNOT DO NOW. THE ARTISANS WILL NOT BE REPLACED BY A COMPUTER."

"When you buy a watch you buy the dream, the craft and the uniqueness; not necessarily the function—here we can give the craftsmen tools to do things they cannot do now, while keeping the hand completely in control," says Bellouard. "The artisans will not be replaced by a computer. Medtech and information storage are other industry areas that are benefitting from femtosecond lasers."

MORE PRECISELY
Above, from left: BETA I, the world's first quartz watch, developed by CEH in 1967; Patek Philippe Calibre 324SQA made with Silinvar; atomic clock; Girard-Perregaux Constant Escapement, 2013.

CSEM. PATEK PHILIPPE. GIRARD-PERREGAUX.