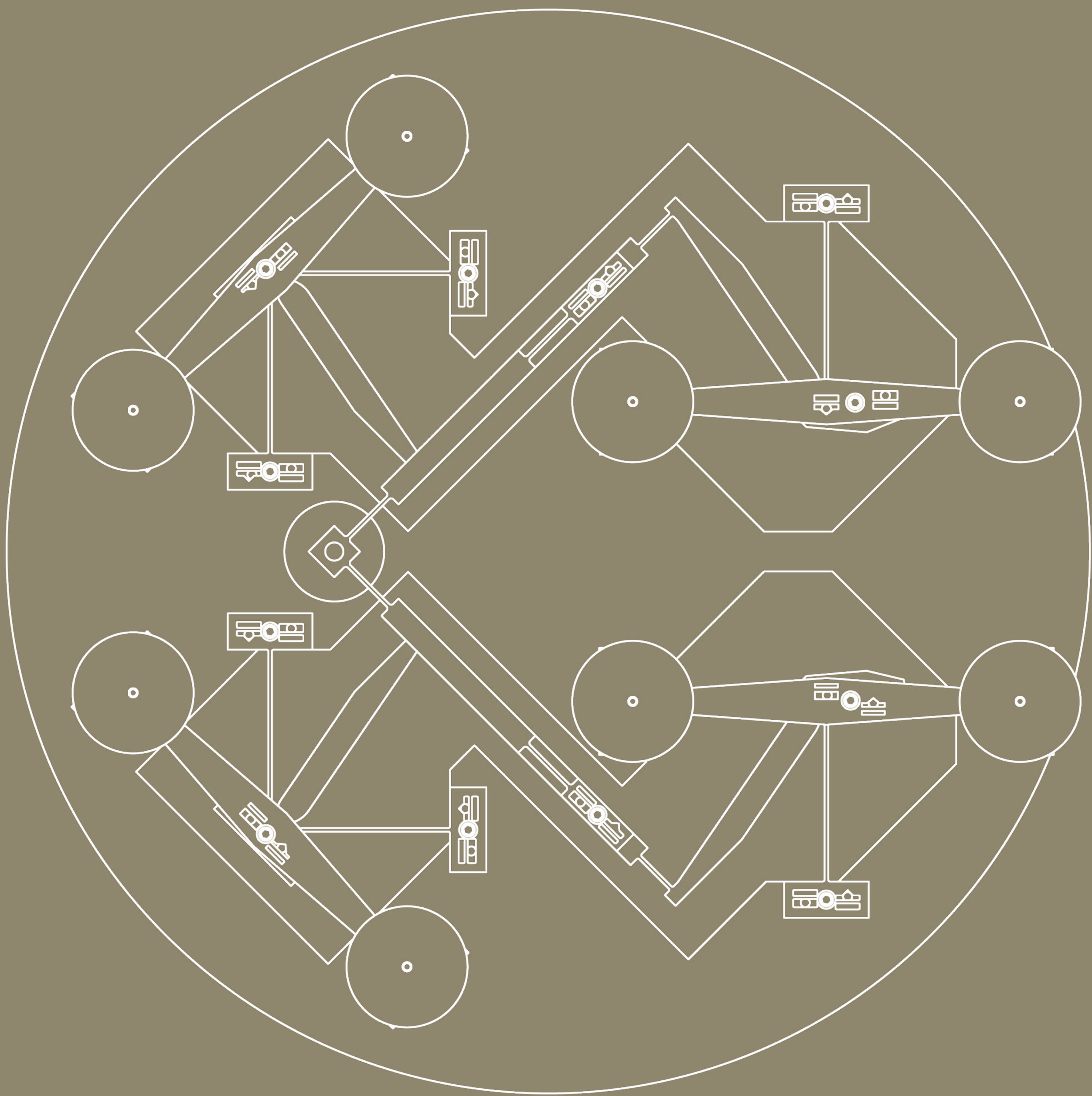
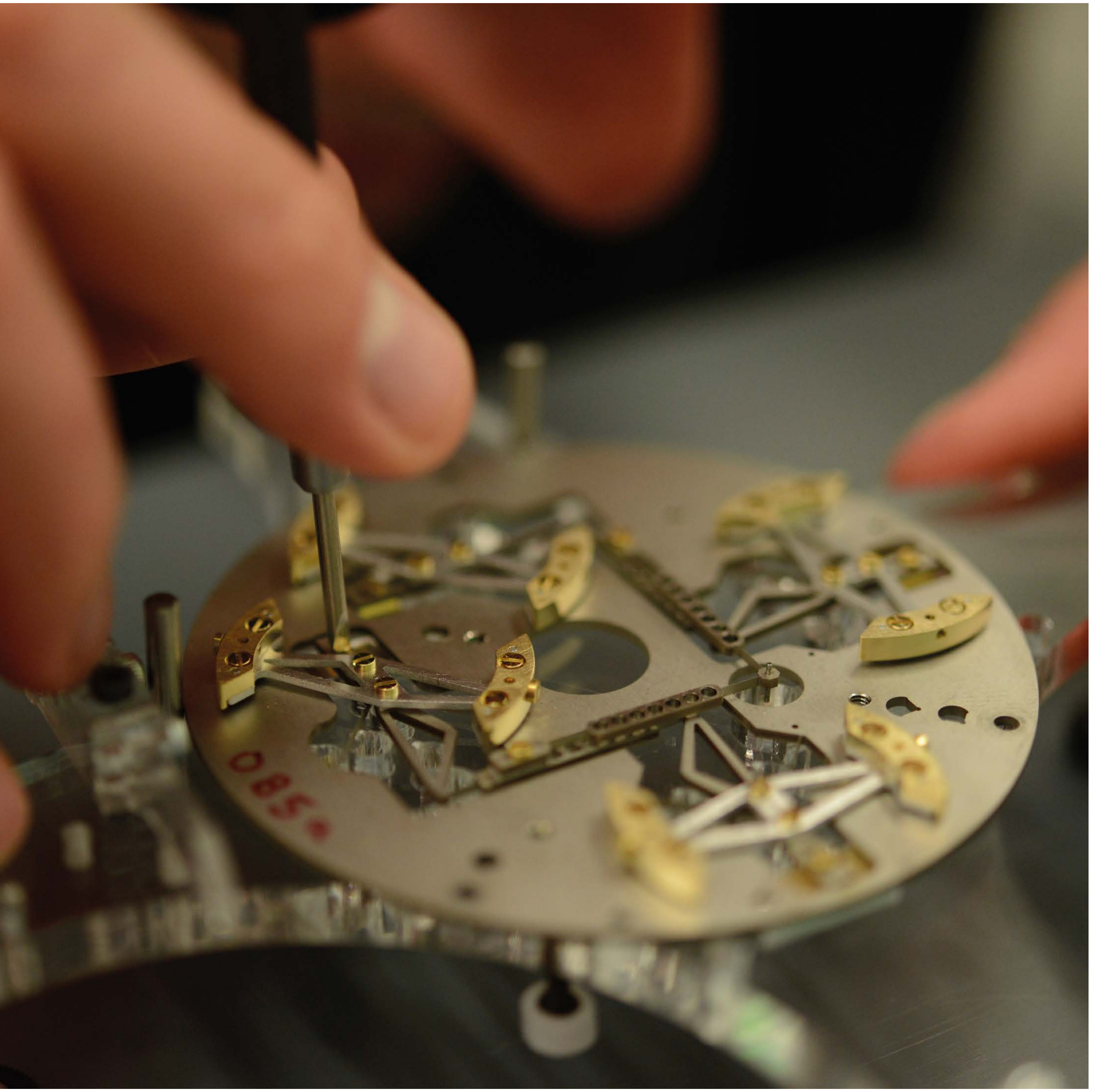
Patek Philippe Chair

Micromechanical and Horological Design Laboratory
INSTANT-LAB

Annual Report 2018





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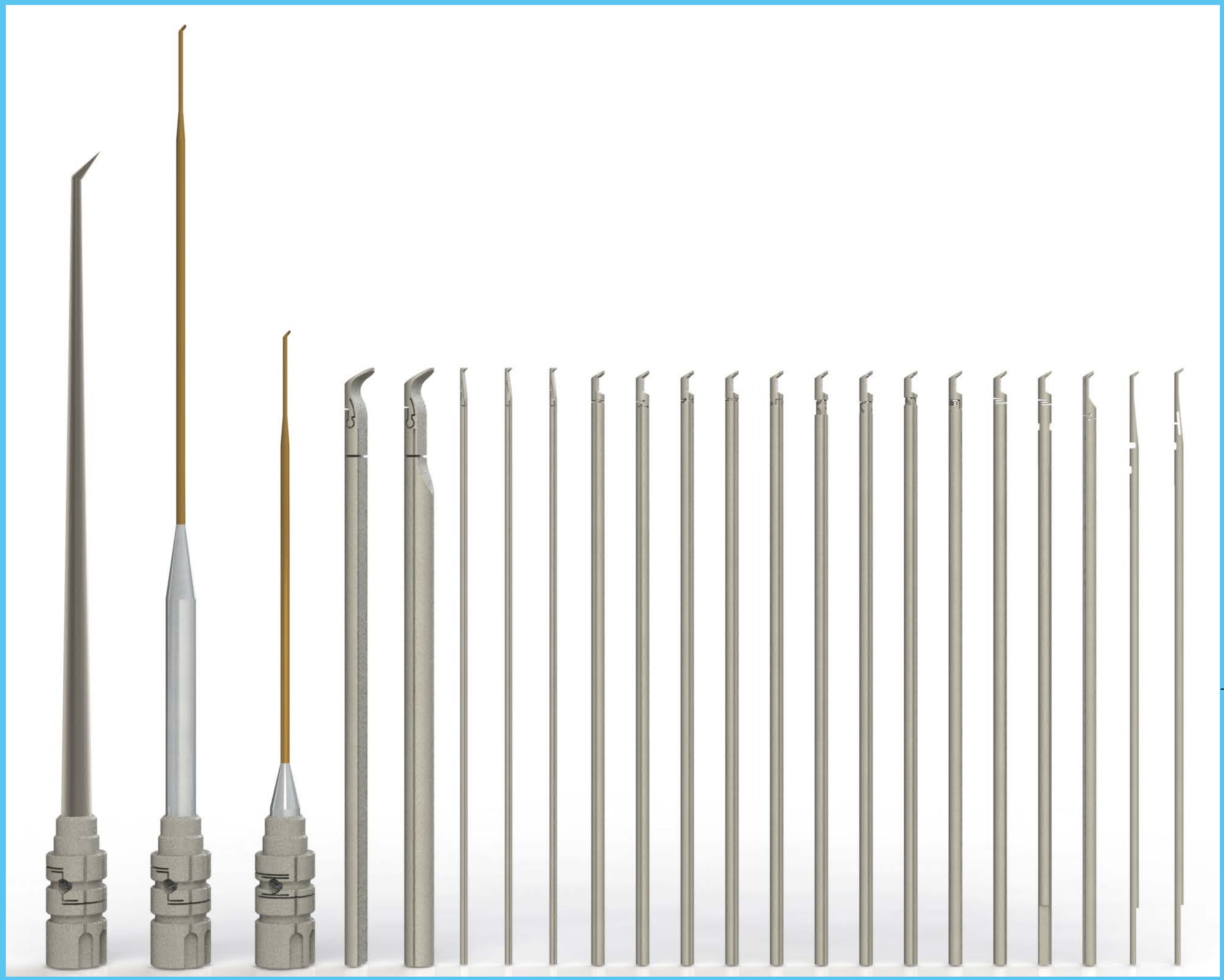


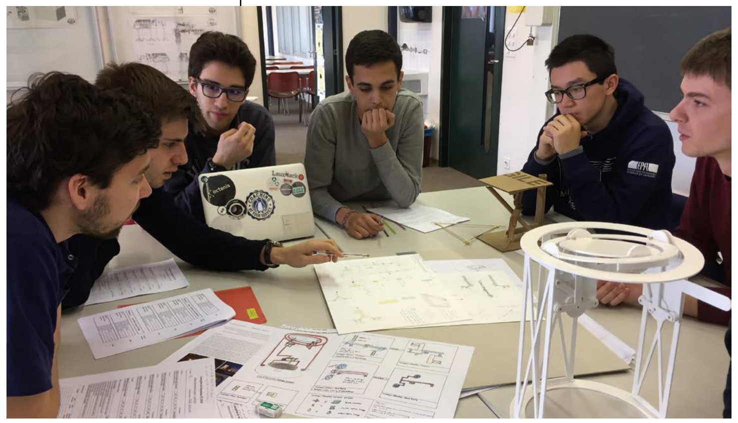
INTRODUCTION

In 2018, the Patek Philippe Chair in Micromechanical and Horological Design celebrated its sixth year. Named Instant-Lab, this laboratory has eighteen collaborators: Professor Henein, one administrative assistant, two senior scientists, three postdoctoral scholars, four Ph.D. students, five scientific assistants and two technicians. In addition, Instant-Lab has four external collaborators.

The laboratory specializes in creating new mechanisms featuring kinematic and technological innovation at the centimeter scale using a scientific approach inspired from mechanical design in fields such as classical horology, robotics and aerospace. Current projects apply to mechanical watchmaking and biomedical instrumentation, these fields being quite close, both technologically and in their industrial fabric. Beyond its academic mission to pursue excellence in fundamental research and teaching, the laboratory is also committed to establish ties with Swiss watchmaking culture and welcomes industrial collaboration with all Swiss watchmaking companies.

Surgical tools with integrated multidegree-of-freedom tip force sensors.

Two Instant-Lab Ph.D. students administering a Microengineering Bachelor exam.



TEAM

Director


Prof. Simon Henein

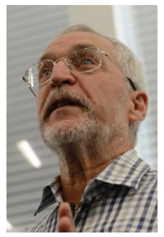

Joëlle Banjac
Administrative assistant

Senior Scientists


Dr Charles Baur


Dr Ilan Vardi

Visiting professor


Pierre Thomann

Post-Docs

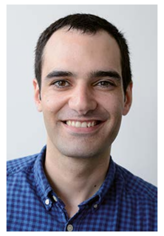

Dr Roland Bitterli


Dr Mohammad Kahrobaiyan


Dr Susanne Martin

Technicians

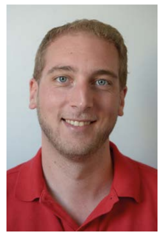

Romain Gillet

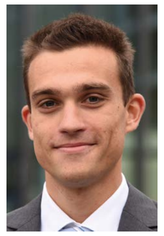

Arnaud Maurel

Scientific Assistants


Lisa Bonnefoy


Marine Clogenson

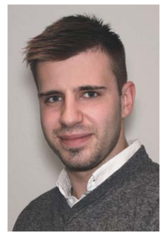

Tristan Derbanne

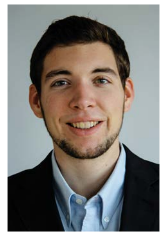

Thomas Fussinger


Hubert Schneegans

Ph.D. Students


Sebastian Fifanski


Michal Smreczak*

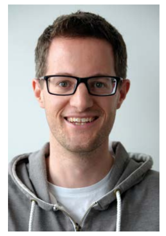

Etienne Thalmann


Mohamed Zanaty

* external

External collaborators


Joëlle Valterio

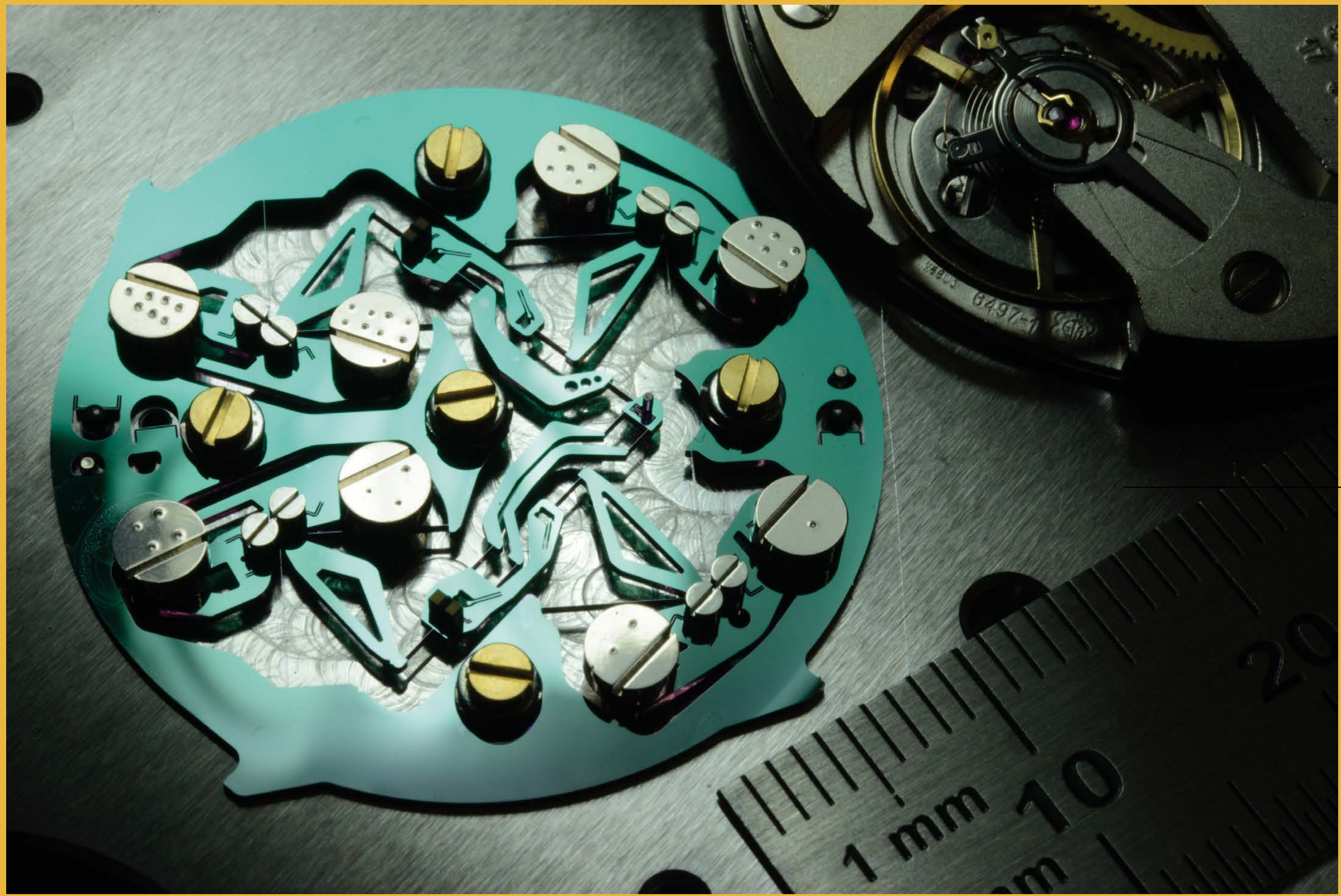

Billy Nussbaumer


Begonia Tora


Olivier Chappuis

*External

RESEARCH PROJECTS (part 1/3)



IsoSpring: continuous mechanical time

Mechanical timekeeping began in the Middle Ages with the invention of the escapement. After the introduction of oscillators in the 17th century, mechanical clocks and watches continued to rely on escapements. Despite numerous technical advances, today's escapements suffer from reduced mechanical efficiency. The IsoSpring project exploits ideas dating back to Isaac Newton to create a new time base which can be driven continuously, without the stop-and-go "ticking" of traditional mechanical clocks and watches. This solves the escapement problem by completely eliminating it: the mechanical watch can work without an escapement.

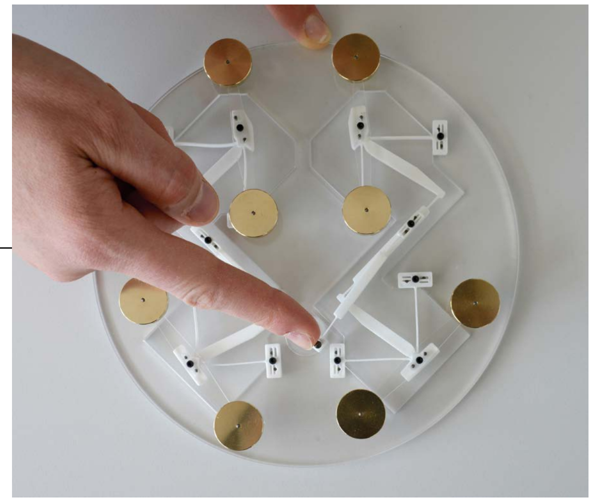
The result is a simplified mechanism having greatly increased efficiency and chronometric accuracy. This project is based on a new family of oscillators and maintaining mechanisms patented by the EPFL.

An industrial project was established in 2014 and successfully completed in 2017. This project was extended to a second phase, currently in its second year. This phase is focused on miniaturizing the IsoSpring concept to the watch scale. The key innovation is the use of a novel patented mechanism consisting of four balances whose rotations are converted to linear motion by classical Watt linkages. We named this oscillator Wattwins in order to highlight the historical inspiration of our mechanism. This new oscillator is insensitive to linear accelerations as required for wrist watches. Moreover, it is insensitive to rotational accelerations which is not always the case for classical mechanical watches. We have constructed physical demonstrators and our experimental measurements aim at validating the insensitivity to gravity.

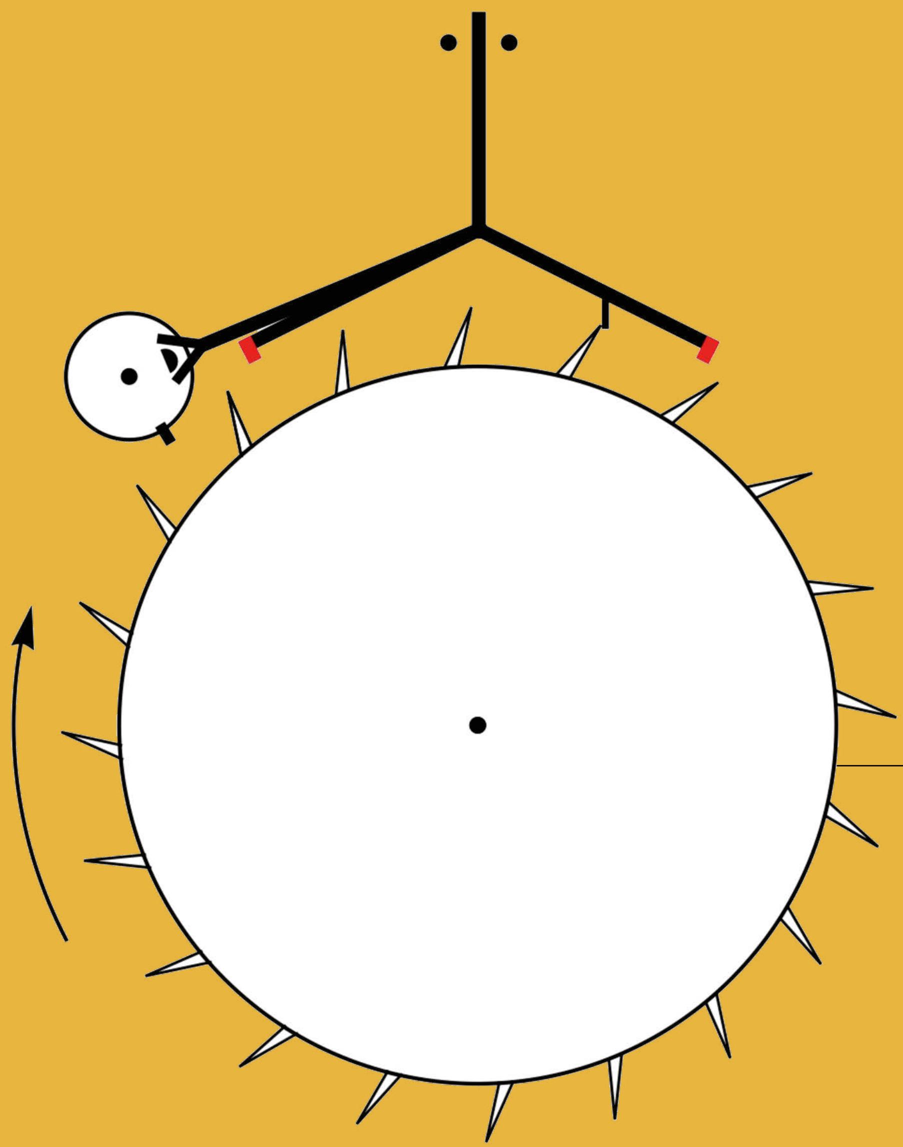
Wattwins oscillator manufactured in silicon.

Wattwins oscillator in silicon at watch scale.

Wattwins oscillator demonstrator.



RESEARCH PROJECTS (part 2/3)



Virtual impulse escapement concept

Instant-Lab introduced virtual impulse escapements in which a double beat escapement becomes a dead beat escapement when the balance wheel is at its operating amplitude. In this way, the advantages of dead beat escapements : direct impulse, greater freedom in choosing impulse position, are preserved, while the disadvantages : sensitivity to shock and difficult self-start, are minimized. The results of this project were published in the Bulletin de la Société Suisse de Chronométrie, the technical publication of Swiss watchmaking, in 2018.

Self-starting functionality of virtual impulse escapement concept.

High quality factor oscillators for wrist watches

Current mechanical wrist watches have an oscillator consisting of a balance wheel mounted on jewelled bearings and a hairspring. The use of flexure bearings instead of traditional pivots leads to a significant increase in quality factor, i.e., reduced energy loss. As a result, power reserve can be significantly increased and chronometric precision can be improved thanks to reduced oscillator perturbation. However, these new oscillators are sensitive to gravity and have isochronism defects. This project explores novel flexure-based pivots minimizing these issues. A paper based on this research appeared in the Journal of Mechanical Design in 2018.

Comparison of state-of-the-art flexure oscillator versus Instant-Lab mechanism.

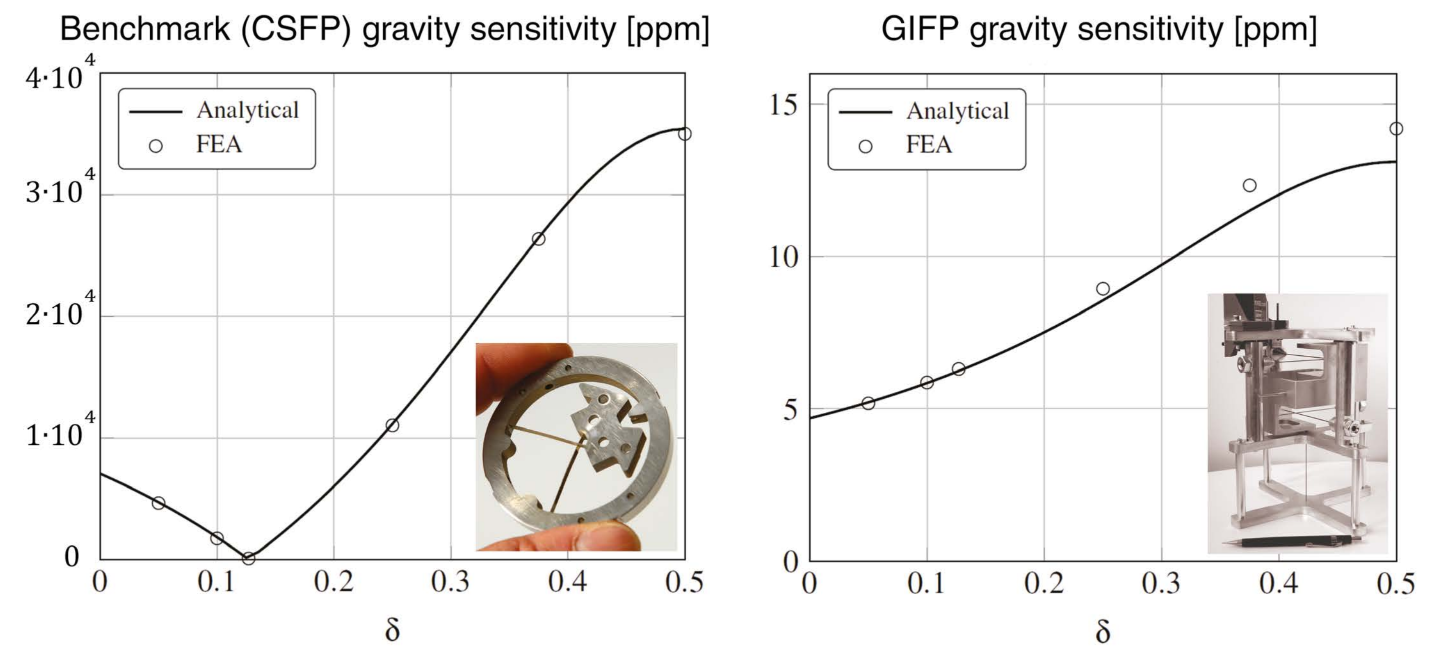


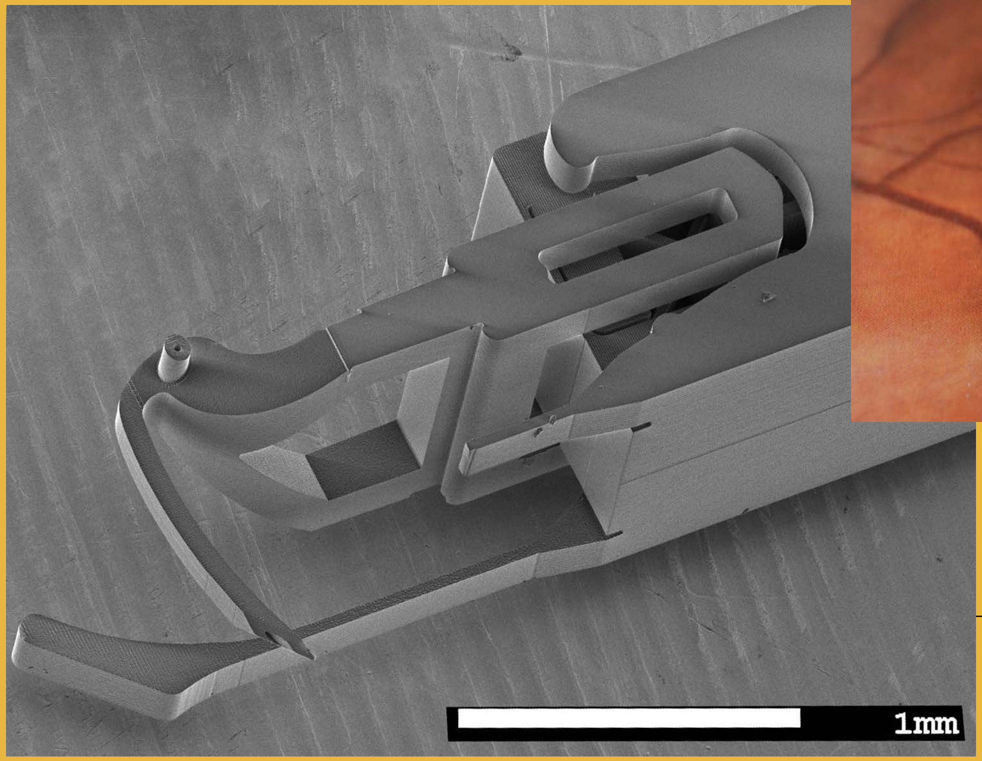
Fig. 1: CSFP (left) and GIFP (right) relative stiffness variation in parts per million versus geometric parameter δ for a normalized gravity load of 0.2 and a rotation of θ=0.1˚.

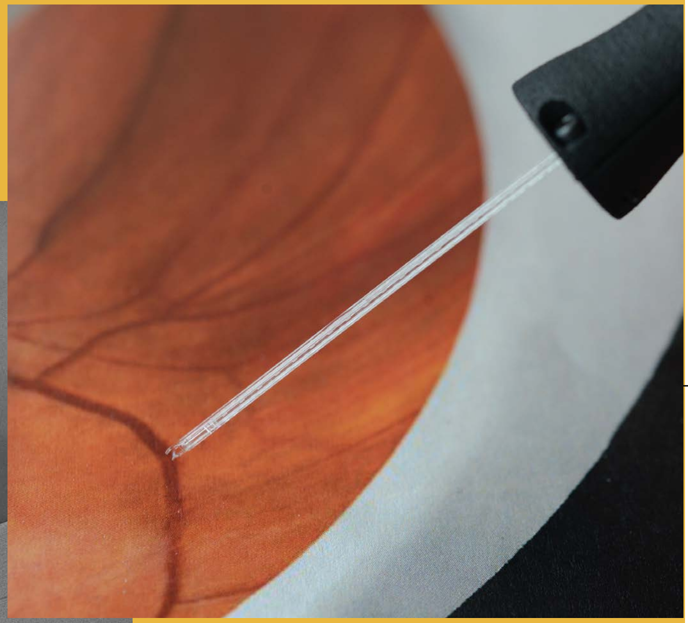
Programmable multistable energy storage mechanisms

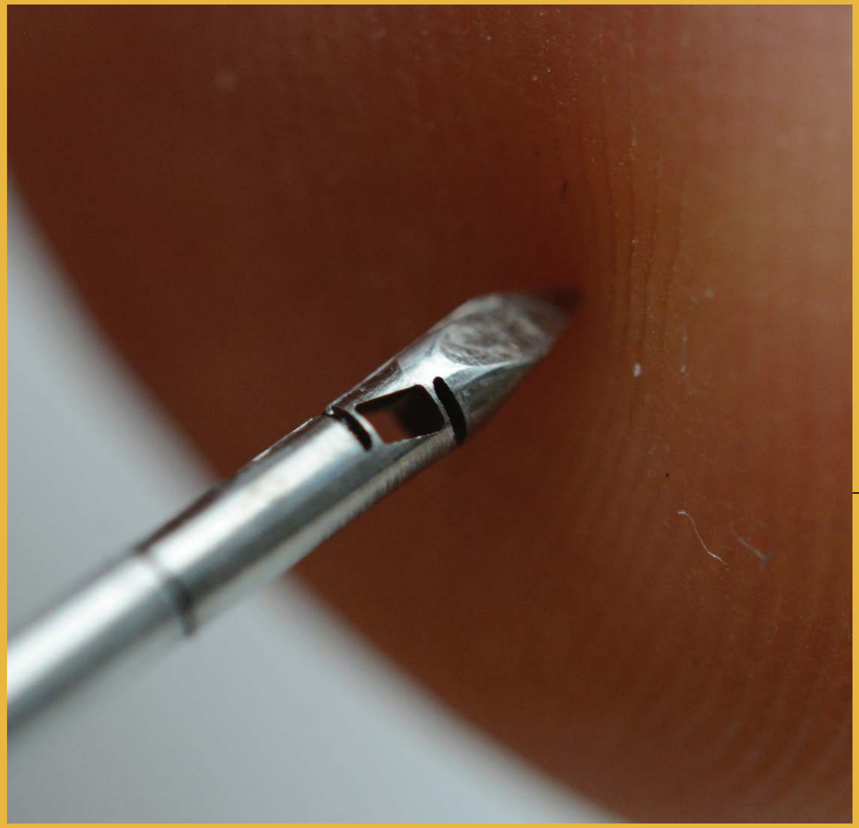
This project introduces the concept of programmable multistable mechanism in which the number and position of stable states of a multistable mechanism can be modified. A complete qualitative analysis of a generic multistable mechanism, the T-shaped mechanism, was established using analytical tools based on Euler-Bernoulli beam theory. These results were validated numerically using Finite Element Analysis and experimentally using physical models. Applications include new surgical tools and escapements. Two scientific papers based on this research were published in the Journal of Mechanical Design in 2018 and a further article will appear in 2019 in the Journal of Medical Devices.

Interactive intelligent robotics and 3D printing for surgery and interventional radiology (SPIRITS)

The SPIRITS (Simple Printed Interactive Robotics for Interventional Therapy and Surgery) project involves developing a robotic device for image-guided surgery and interventional radiology with a number of innovations, such as a tactile transducer, an intelligent needle, new 3D printing methods and new actuators and robots. This Interreg project is a collaboration between several leading institutions : INSA Strasbourg, Hochschule Furtwangen, University Hospital Mannheim, Fachhochschule Nordwestschweiz, EPFL. Instant-Lab is in charge of developing a needle with a flexure based selective stiffness and force sensing at the tool tip to better monitor and control needle placement.







RESEARCH PROJECTS (part 3/3)

Safe Puncture Optimized Tool (SPOT) for retinal vein cannulation (CTI project)

Retinal Vein Occlusion is a vascular disorder causing severe loss of vision. Retinal vein cannulation and injection of therapeutic agents in the affected vein is a promising treatment but the small size and fragility of retinal veins as well as the surgeon limited hand gesture precision and force perception makes this procedure too delicate for routine operations. The project aims at providing a compliant mechanical tool relying on a new programmable multistable mechanism to safely cannulate veins. This mechanism has the advantage that puncturing stroke and force can be predetermined which makes puncturing independent of surgeon manipulation. The feasibility of this project was demonstrated by a prototype made by femto-laser printing, one of the first buckled mechanisms made in glass. The focus is now on integrating microfluidics in the prototype. This project is funded by the Commission for Technology and Innovation CTI (Switzerland) with FemtoPrint SA as industrial partner, and run in collaboration with Pr. Th. Wolfensberger, Hôpital Ophtalmique Jules-Gonin, Lausanne. The results of this research will be published in the Journal of Medical Devices in 2019.

Programmable multistable mechanism for retinal vein cannulation.

Adjustable midsole intervention footwear for patients with medial compartment knee osteoarthritis (ADVANCER, SNSF project)

This project consists of a geometrically adjustable shoe orthotic to balance knee and hip loads which could otherwise lead to cartilage wear and tear, thus avoiding surgical intervention. Our proposed solutions are based on flexible elements combined with stiffness adaptable materials. This Swiss National Science Foundation project is a collaboration with CHUV (Centre Hospitalier Universitaire Vaudois). Different prototypes were realized. Tests with patients are under CHUV ethical commission evaluation. We are currently examining if the proposed device can be developed into a commercial product. One patent was filed.

Biopsy needle

Biopsy needle equipped with force sensor at its extremity allowing for precise navigation through corporal tissue via force sensing tip.

Biopsy needle tip force sensor.

Load cell with tunable stiffness dedicated to force sensing in nanoprobing applications

Contact detection and quantification between a probe and a sample is essential in nanoprobing applications. It is a must in automation and applications where a stable “probe/sample” contact has to be maintained during long lasting measurements. This project focus on a methodology of designing a flexure-based load cell that can be used with a microrobotic platform in nanoprobing applications. The innovative design (patent filed) will be capable of evaluating various ranges of forces depending on the application scale.

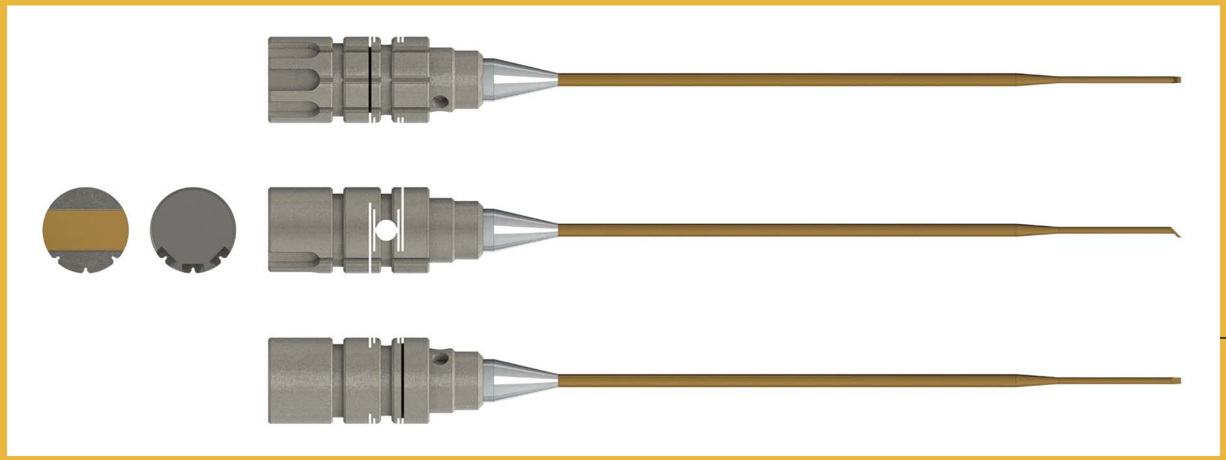
Building 4.0

The project Building 4.0 is conducted in collaboration with Granite Apps ltd. The project consists of navigating a building using beacon (Bluetooth low energy emitters) technology coupled with a dedicated application running on cell phone and taking benefit of the “stream” concept. The use case is Microcity building. The goal is to guide visitors to specific locations, to enhance security aspects and augment building content (e.g. display extended poster contend).

RESEARCH — Ph.D. THESES

Mohamed Zanaty, thesis title: *Programmable multistable mechanisms: Design, modeling, characterization and applications*.
Completed December 2018.

M. Zanaty, public thesis defense, December 14, 2018.



Sebastian Fifanski, preliminary thesis title: *Miniature flexure structures for contact force sensing in pointed tools*.
Expected completion September 2019.

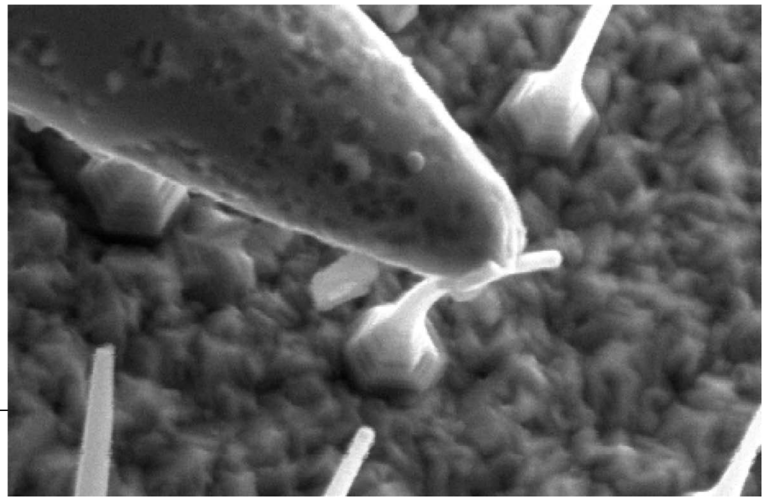
CAD design of a surgical tool integrating a triaxial force sensor.

Etienne Thalmann, preliminary thesis title: *Non-linear flexure based oscillators*.
Expected completion September 2021.

Video presenting the PhD program in Advanced Manufacturing https://www.youtube.com/watch?time_continue=2&v=wePUXjyUabo

Michal Smreczak, preliminary thesis title: *Load cell with tunable stiffness dedicated to force measurement at the nano-Newton range*.
Expected completion September 2021.

Probing of a carbon nanotube (courtesy of Imina Technologies SA).



PUBLICATIONS

Patents

I. Vardi, S. Henein, O. Mathez, T. Philippine, *Dard bi-fonctionnel, dispositif de verrouillage et de sécurisation pour pièce d'horlogerie, et échappement horloger*, EP1122617, September 2017.

M. Zanaty, S. Henein, *Système multistable programmable*, EP3266737A1, January 2018.

C. Baur, S. Henein, M. Zanaty, *Device for controlled puncturing of an object*, WO2018015488A1, January 2018.

M. Zanaty, S. Henein, *Programmable Constant Force Multistable Mechanisms*, ASME 2018 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Quebec (Canada), August 26-29, 2018.

Journal articles

I. Vardi , R. Bitterli, N. Ferrier, M. H. Kahrobaiyan, B. Nussbaumer, L. Rubbert, S. Henein, *Theory and design of spherical oscillator mechanisms*, Precision Engineering, 51 (2018), pp. 499-513.

S. Henein, I. Vardi, *Horloge neuchâteloise du XXIe siècle équipée de l'oscillateur IsoSpring*, Chronométrophilia, 82 (2018), pp. 107-113.

M. Zanaty, I. Vardi, S. Henein, *Programmable Multistable Mechanisms : Synthesis and Modeling*, Journal of Mechanical Design, 140 (2018), pp. 042301-01 to 042301-13.

M. Zanaty, S. Henein, *Experimental Characterization of a T-Shaped Programmable Multistable Mechanism*, Journal of Mechanical Design, 140 (2018), pp. 042301-01 to 042301-13.

I. Vardi, R. Bitterli, L. Convert, E. Thalmann, S. Henein, *Échappements à impulsion virtuelle*, Bulletin de la Société Suisse de Chronométrie, 85 (2018), pp. 25-32.

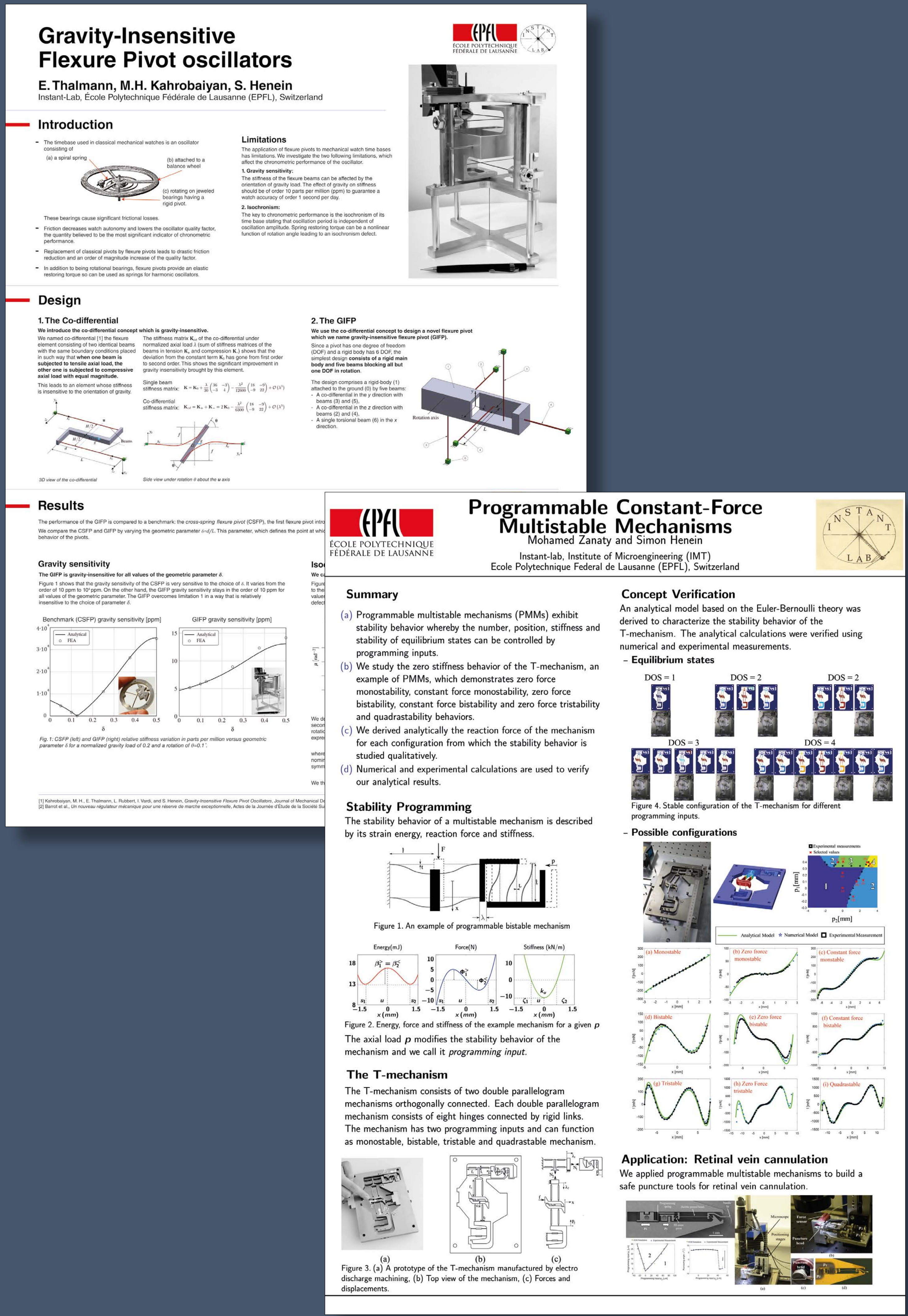
M. H. Kahrobaiyan, L. Rubbert, E. Thalmann, I. Vardi, S. Henein, *Gravity-Insensitive Flexure Pivot Oscillators*, Journal of Mechanical Design, 140 (2018), pp. 075002-1 to 075002-09.

C. Forestier-Kasapi, I. Vardi, *Le sens de la recherche*, Éditorial du Bulletin de la Société Suisse de Chronométrie, 86 (2018), p. 3.

M. Zanaty, T. Fussinger, A. Rogg, A. Lovera, D. Lambelet, I. Vardi, T. J. Wolfensberger, C. Baur, S. Henein, *Programmable Multistable Mechanisms for Safe Surgical Puncturing*, to appear, Journal of Medical Devices.

Conference proceedings

M. H. Kahrobaiyan, E. Thalmann, S. Henein, *Flexure-Pivot Oscillator Restoring Torque Nonlinearity and Isochronism Defect*, ASME 2018 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Quebec (Canada), August 26-29, 2018.



LECTURES, INVITED TALKS, POSTERS

C. Baur, T. Fussinger, *Slam session on Safe Puncture Optimized Tool for Retinal Vein Cannulation*, Swiss Medtech Day, Bern (Switzerland), June 06, 2018.

S. Fifanski, T. Fussinger, *Instruments for intraocular microsurgery*, Symposium in Medical Robotics Conference, London (United Kingdom), June 24th, 2018.

S. Henein, S. Martin, J. Valterio, *Improgineering keynote presentation*, Rencontres européennes autour de l'improvisation, Centre européen pour l'improvisation, Purget-Ville (France), September 7th, 2018.

C. Baur, *3D printing of glass structures for new surgical tools*, GDR Robotique, Strasbourg (France), October 16, 2018.

Ch. Baur, *Expert review committee LabEx*, ANR Agence National Recherche, Paris (France), December 05-07, 2018.

DISSEMINATION

Nomination

Ilan Vardi was nominated to the Scientific Committee of the Société Suisse de Chronométrie, the Swiss watchmaking industrial society, for 2018–2020. His activities include the organisation of the most important annual technical events in watchmaking, which gather engineers, scientists and watchmakers from around the world.

SSC, Journée d'Etude 2018, Auditorium Stravinsky, Montreux, Swtizerland.

External participation

Participation in "Nuit de la science", July 7-8, 2018,
Musée d'histoire des sciences, Geneva, Switzerland

Poster and demonstrators, "Nuit de la science", Geneva.

Media coverage

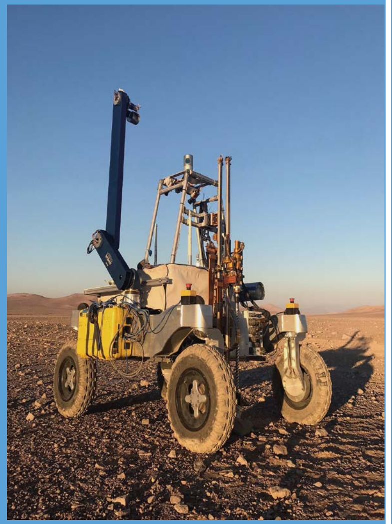
Instant-Lab group, IsoSpring: short film for the Jules Grossmann exhibit, Le Locle, Switzerland, Gasser Media, May 2018.

IsoSpring: short film for the Jules Grossmann exhibit, Le Locle, Switzerland.

"A technical perspective – The Flexure Revolution, Compliant Mechanisms applied to Watchmaking", X. Markl, *Monochrome Magazine*, December 12, 2017, including videoclip: "Isospring continuous mechanical time".

FEMTOprint SA presents Instant-Lab's Safe Puncture Optimised Tool (SPOT) for retinal vein cannulation as an example of advanced 3D subtractive manufacturing technique, A. Steimle, Laser Technik Journal, January, 2018.

Above documents available online
instantlab.epfl.ch/Media



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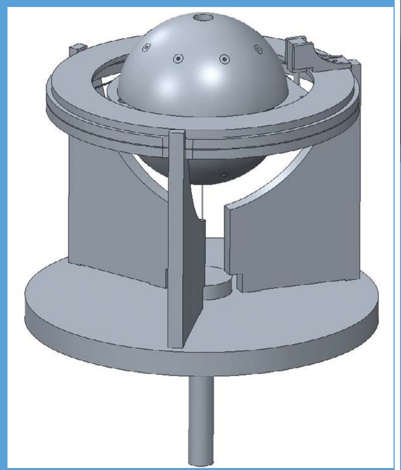

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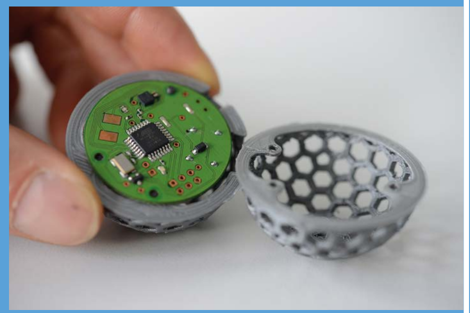

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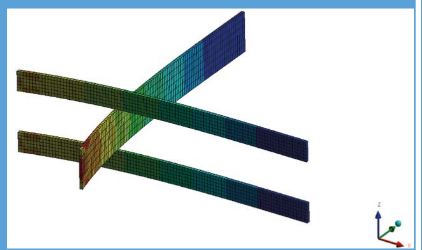

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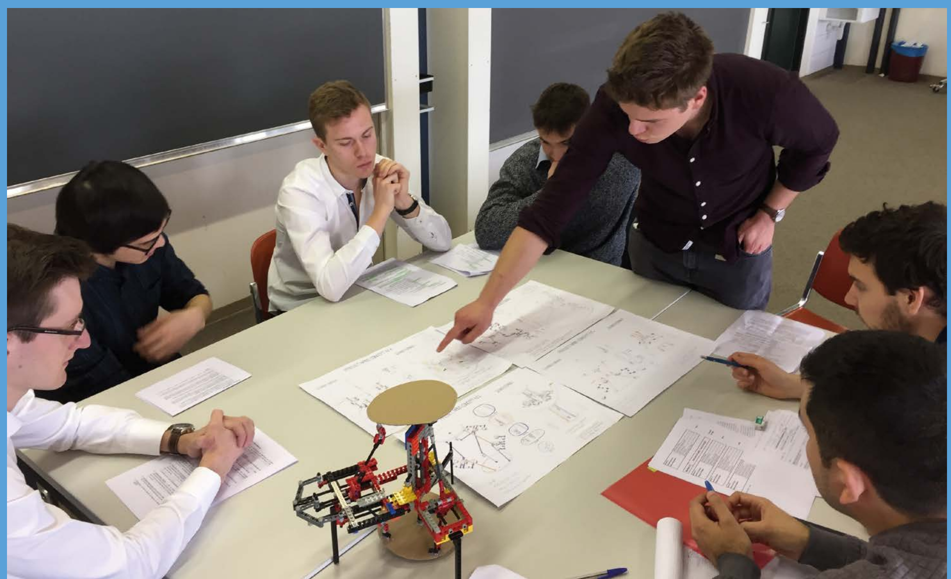

TEACHING

The laboratory is strongly involved in teaching. Focus is on training creative design and learning the analytical tools necessary to model, simulate and predict mechanism behaviour.

EPFL

Mechanism Design I & II
Lecturer: Prof. S. Henein and B. Nussbaumer; Section: Microengineering (137 students); Bachelor semesters 2 and 3; three hours per week.

Collective creation: improvised arts and engineering I & II
Lecturers: Prof. S. Henein, J. Valterio and guest lectures. 24 students; open to all sections; 24 students; Master semesters 1 and 2; three hours per week. Year-long course, EPFL Social and Human Sciences (SHS) program, developed in cooperation with the Centre d'art scénique contemporain (Arsenic), Lausanne.

Structural mechanics
Taught jointly by Dr Kahrobaiyan, Instant-Lab, and Dr Danick Briand, EPFL; Section: Microengineering; Bachelor semesters 2; four hours per week.

Elements of mechanical design I & II
Lecturers: Course under the responsibility of Prof. S. Henein and Prof. J. Schiffman taught by two external lecturers; Sections: Microengineering/Mechanical engineering (474 students); Bachelor semesters 1 and 2; three hours per week.

Visiting Professor

Pierre Thomann, Professor Emeritus, Université de Neuchâtel, November 2018 - May 2019.

Semester (S) and master (M) projects

a. Robotic arm with non-prehensile manipulation and wheel testbed design for a Mars planetary rover, Loïc Tissot-Daguette (M)
b. Vibrating rod for string musical instruments, Clément Dromart (S)
c. Foucault effect of the spherical IsoSpring, Patrick Flückiger (S)

Internships

d. Design of a sonorous tennis ball for blind players, Colin Berger
e. Finite element modelling of mechanical oscillators, Emmanuelle Brusq
f. Robotic tool holder for surgery, Loïc Tissot-Daguette

2018 Improgineering Jury : Isabelle Bouhet (comédienne et metteure en scène) | Danielle Chaperon (professeure à la faculté des lettres de l'Université de Lausanne et directrice du Centre d'études théâtrales) | Gisou van der Goot (doyenne de la faculté des sciences de la vie à l'EPFL) | Laure Kloetzer (professeure assistante en psychologie socioculturelle à l'Université de Neuchâtel) | Susanne Martin (Ph.D. des Universités de Northampton et Middlesex, danseuse, chorégraphe et artiste de performance) | Patrick de Rham (directeur de l'Arsenic) | Nicolas Weibel (directeur de Greene, Tweed & Co. (Suisse) SA – conception et fabrication de pièces haute-performance en composites – Ph.D. de l'EPFL en science et génie des matériaux).

PEDAGOGICAL ACTIVITIES

Practice

Professor Henein began the second edition of his course linking the engineering and humanities faculties of the EPFL : "Collective creation : improvised arts and engineering". This year-long course, which was launched in September 2017, is part of EPFL's Social and Human Sciences (SHS) program and was developed in cooperation with the Arsenic Theater (Centre d'art scénique contemporain) in Lausanne.

The course examines the creative process in engineering design and improvisation in the performing arts. Experts in a wide range of disciplines ranging from theater to mathematics present students how creativity is expressed in their field of expertise. Workshops explore improvisation through the theater, music, dance and performance arts. The 25 students taking the class will stage their final project on 15 May 2019 in a dress rehearsal and on 22 May 2019 in their final presentation before a board of examiners. Both events are open to the public.

Research

In September 2018, Insant-Lab launched a research project in collaboration with Professor Laure Kloetzer of the Institute of Psychology and Education at the University of Neuchâtel. The goal of this project entitled "Performing Arts as Pedagogical Tool in Higher Education" (ASCOPET) is to describe, analyze and evaluate the utilization of the performing arts in higher education.

The descriptive part of the project will consist of data collection : video recordings, interviews and student essays. The analysis will identify specific pedagogical approaches inherent in the respective teaching methodologies and compare them. Evaluation will be achieved by appraising the relative benefits of these pedagogical approaches and their relation to the state-of-the-art.

This project is the basis of publications on the subject authored by Professors Henein and Kloetzer and postdoctoral fellows Ramiro Tau and Susanne Martin.

CONCLUSION AND PERSPECTIVE

In 2014, Prof. Simon Henein announced the IsoSpring project to make the first mechanical watch without escapement. This led to patents and a large-scale industrial project which was successfully completed in 2017. This project was extended to a second phase focused on miniaturizing IsoSpring to the watch scale using the novel Wattwins concept.

Complementary to the IsoSpring concept, our new virtual escapement concept bridging the gap between double beat and dead beat escapements was published and we are continuing research on high quality factor oscillators.

Our laboratory is also committed to the dissemination and transmission of horological culture. Dr Ilan Vardi, senior scientist of our laboratory, was nominated to the Scientific Committee of the Société Suisse de Chronométrie.

Our medical research continued with the publication of our design and experimental results of a millimeter scale medical device featuring multistable flexure mechanisms realized in fused silica (glass). These features allow for safe puncturing of very delicate veins inside the human eye for the treatment of retinal vein occlusion.

This year marks the second edition of the new course bridging engineering and humanities. A new collaboration with the University of Neuchâtel studies the pedagogical processes associated to this novel teaching approach.

Perspectives

After the successful completion of the first phase of the IsoSpring project, the goal of the second phase is to have a functional watch with an IsoSpring time base by the end of 2019.

We are continuing our fundamental research complementary to our industrial projects.

Our teaching activities will expand with the participation in a new metrology course and the creation of a new course covering structural mechanics and mechanism design, as well as continuing our teaching in the Social and Human Sciences program.

Paul Scherrer Institute visit by Professor Henein's Microengineering Bachelor class.

M. Zanaty receiving his Ph.D. diploma from his thesis directors. Dr Zanaty has been awarded an Early Postdoc Mobility Fellowship form the Swiss National Science Foundation at the Harvard School of Engineering and Applied Sciences, Cambridge, USA.

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