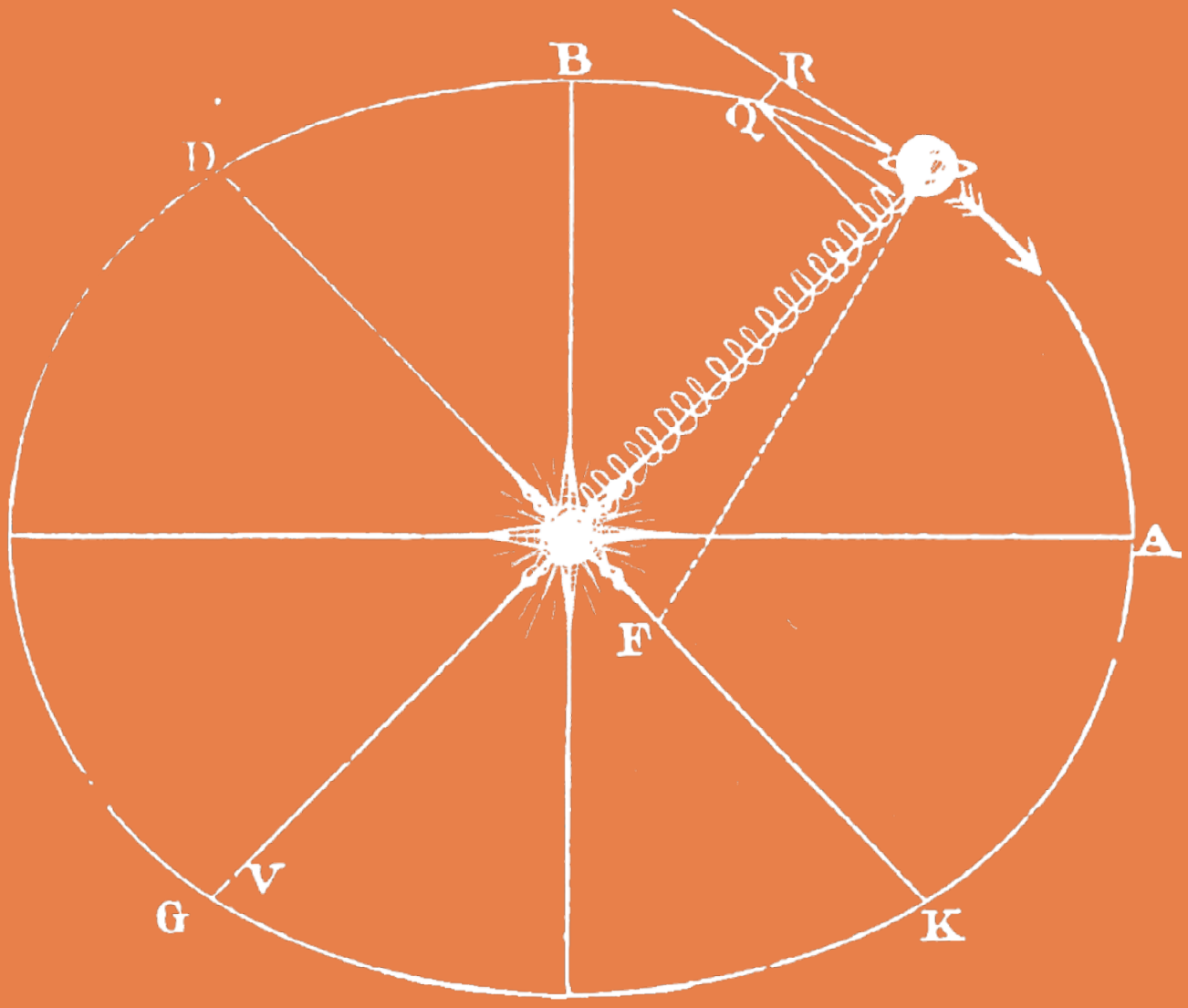
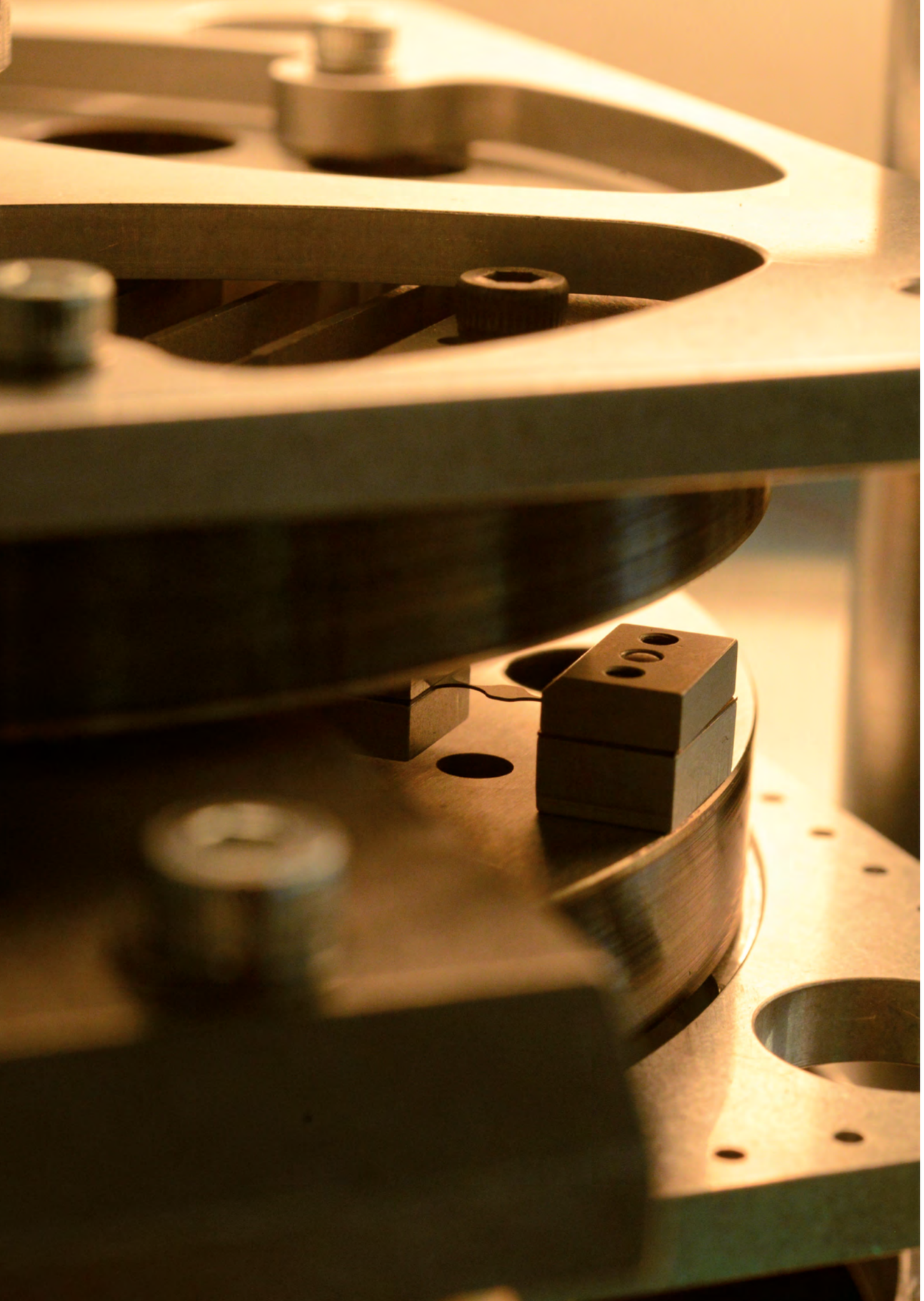
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Patek Philippe Chair

Micromechanical and Horological Design Laboratory
INSTANT-LAB

Annual Report 2015





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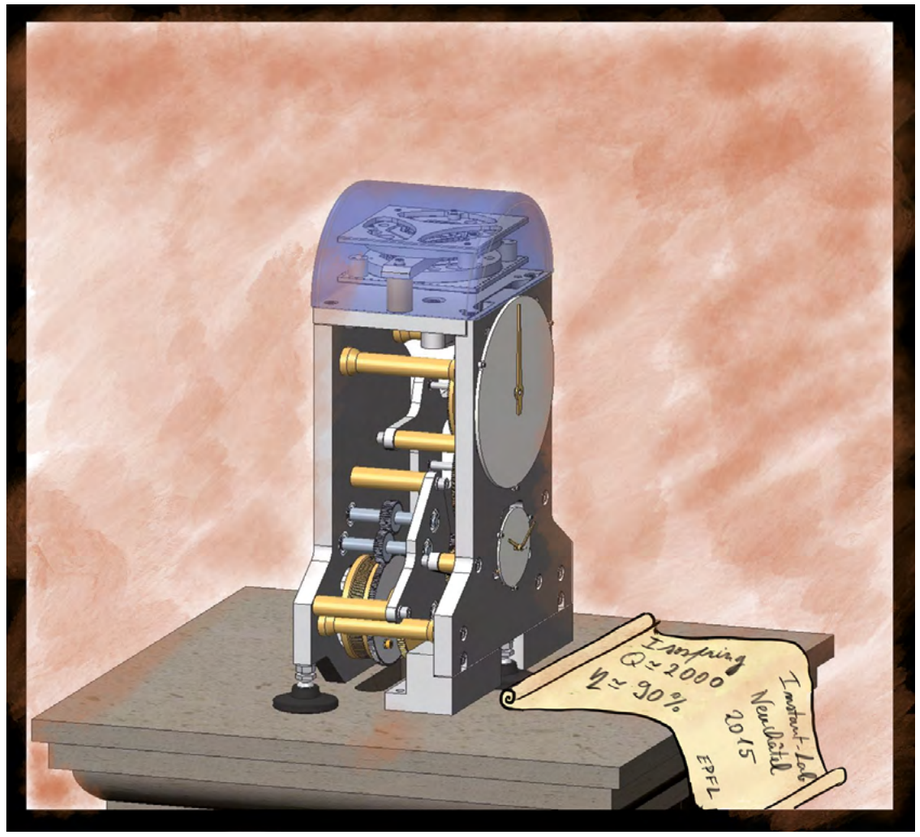
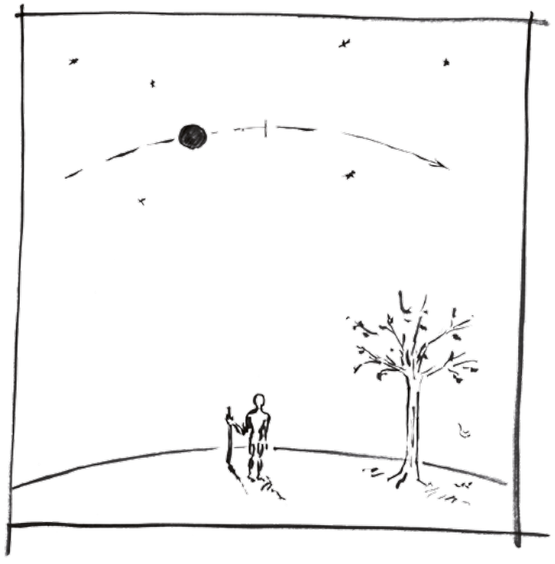
INTRODUCTION



Following the April 2012 announcement of a partnership between watchmaking manufacture Patek Philippe and the EPFL, the Patek Philippe Chair in Micromechanical and Horological Design was established on November 1, 2012, with the nomination of Professor Simon Henein. Instant-Lab, the name chosen for the new laboratory, is located in Microcity, the EPFL Microtechnology centre in Neuchâtel, Switzerland. As of 2015, Instant-Lab has 18 collaborators: Professor Henein, an administrative assistant, 2 senior scientists, 4 postdoctoral scholars, 4 Ph.D. students, 4 scientific assistants and 2 technicians.

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.

This report is an overview of Instant-Lab's third year, 2015, in which several of its fundamental ideas matured into significant research projects.



TEAM

Director

Prof. Simon Henein

Karine Frossard
Administrative assistant

Senior Scientists

Dr Charles Baur

Dr Ilan Vardi

Post-Docs

Dr Lennart Rubbert

Dr Roland Bitterli

Dr Olivier Laesser

Dr Mohammad Kahrobayian

Scientific Assistants

Nicolas Ferrier

Marine Clogenson

Billy Nussbaumer

José Rivera

Ph.D. Students

Johan Kruis*

Mohamed Zanaty

Sebastian Fifanski

Yannick Bastin*

Technicians

Romain Gillet

Arnaud Maurel

Interns

Antoine Pittion

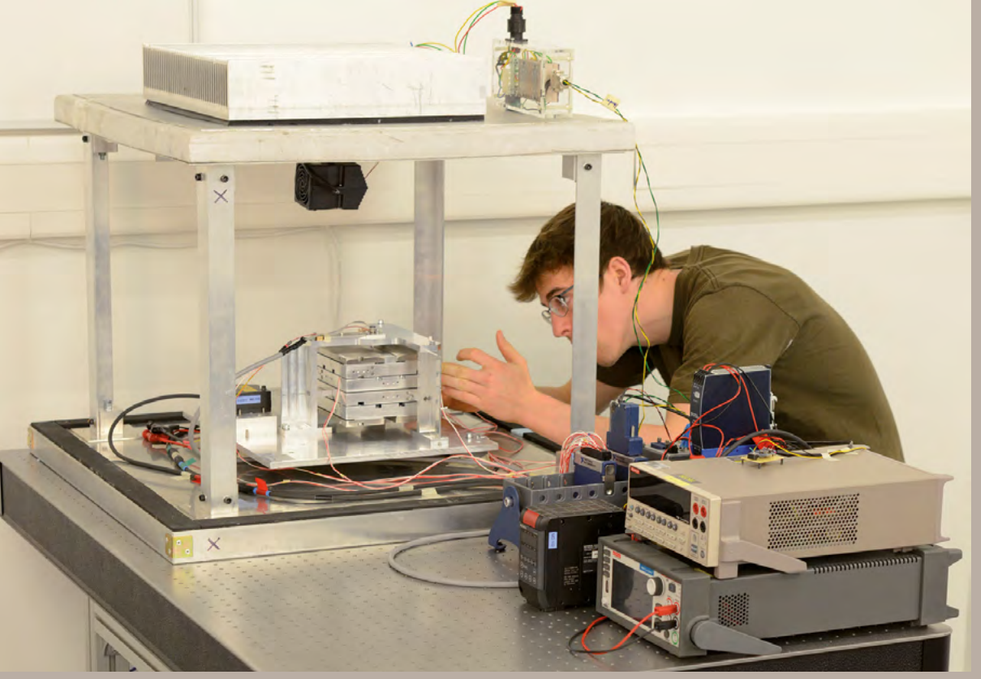
Jérémy Bastardie

Visiting Professors

Prof. Dannis Brouwer
Twente University, NL

Douglas Bateman
Fellow of the British Horological Institute, UK

*External



INFRASTRUCTURE AND EQUIPMENT

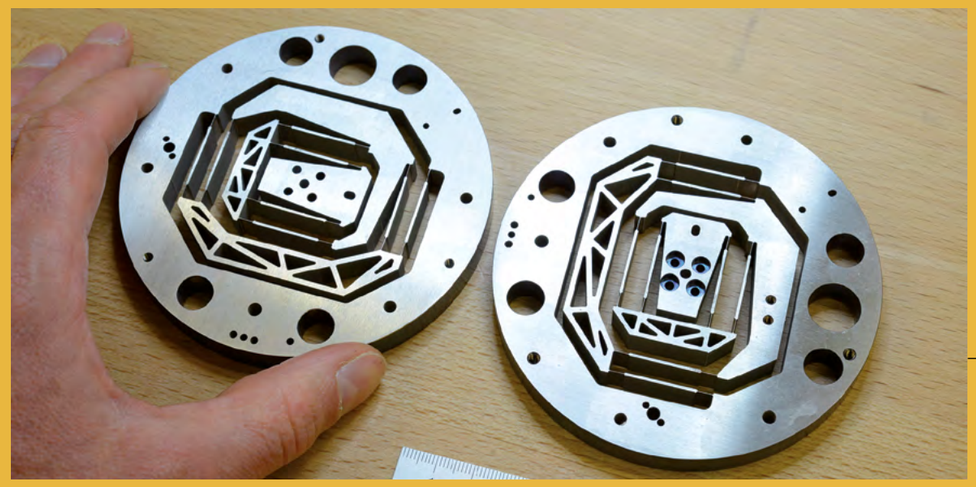
Instant-Lab was first located in the historic building rue Breguet 2, Neuchâtel, from November 1, 2012 until October 2013. On October 16, 2013, the laboratory relocated to the new Microcity building, rue de la Maladière 71b, Neuchâtel, with the following surface allocation:

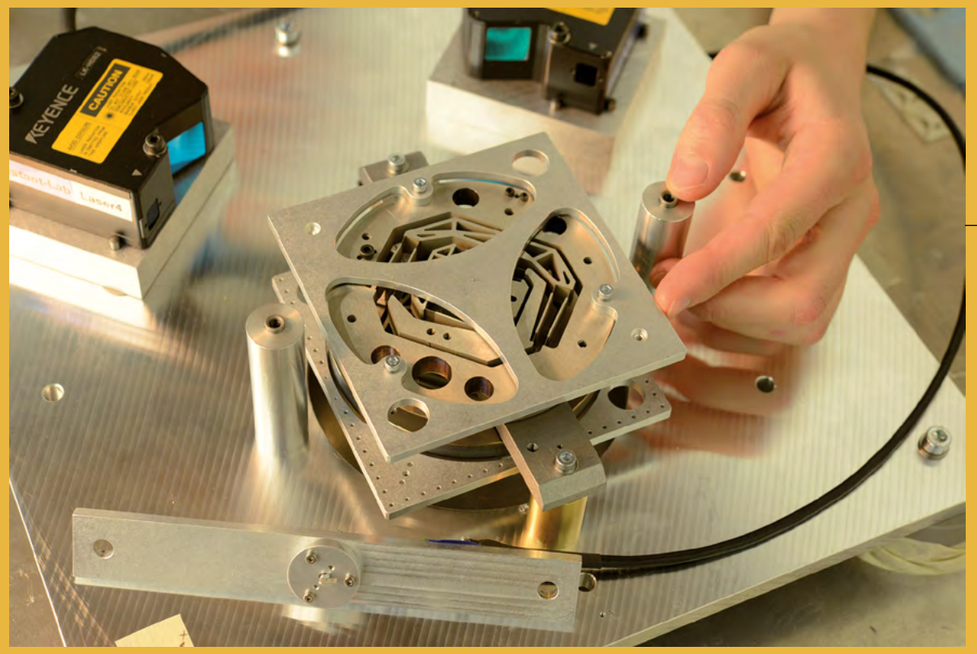
Offices: 136 m²
Laboratories: 171.5 m²
Grey room: 51 m²

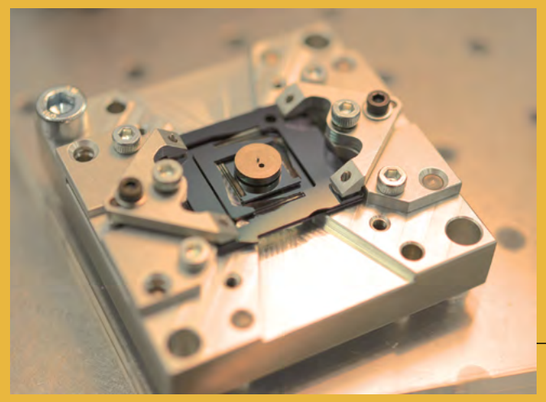
Major equipment acquired in 2015:

- National Instruments CompactRIO-9035 real-time acquisition system, 1.33 GHz, 8 slots, 70T FPGA
- Keyence laser single-axis displacement sensor LK-H082 and LK-H152 sensor head spot PNP LK-HA100 controller and LK-HA100 head extension
- Videal NX4-S3 high speed camera 1024 x 1024 image resolution at 3000 fps
- TESA ClinoBEVEL electronic inclinometer ±45° range, 0.02 mm/m precision
- Kistler 9207 uniaxial force sensor, ±50 N range
- ATI Nano17 6DOF sensor
- LulzBot TAZ 5 3D printer

RESEARCH PROJECTS







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 complex escapements. Despite numerous technical advances, today's escapements still 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 Instant-Lab.

In 2013 a successful proof of concept was achieved internally leading to an industrial project in 2014. Current research is focused on miniaturization of the original prototypes to the watch scale.

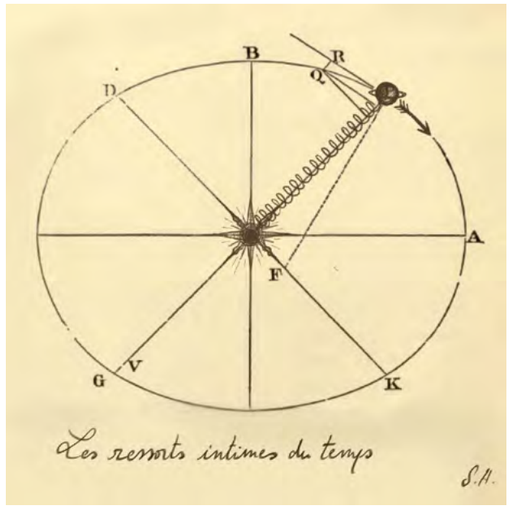
Planar IsoSpring oscillator springs.

Planar IsoSpring prototype.

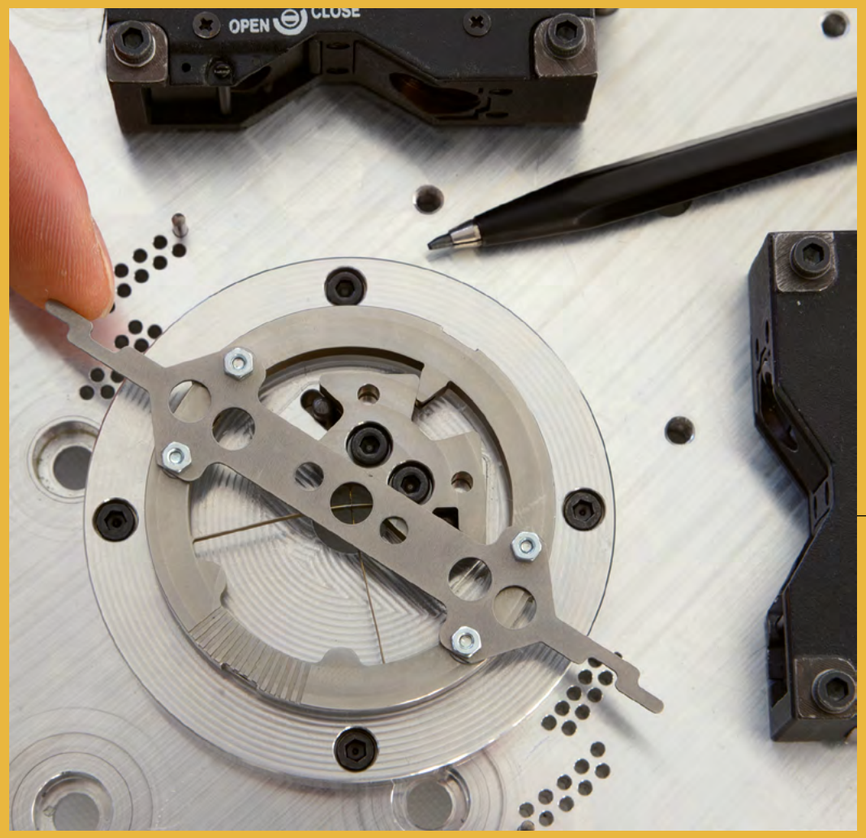
Spherical IsoSpring prototype.

Miniaturized IsoSpring prototype.

IsoSpring principle, adapted from Isaac Newton, *Principia Mathematica*, 1686.



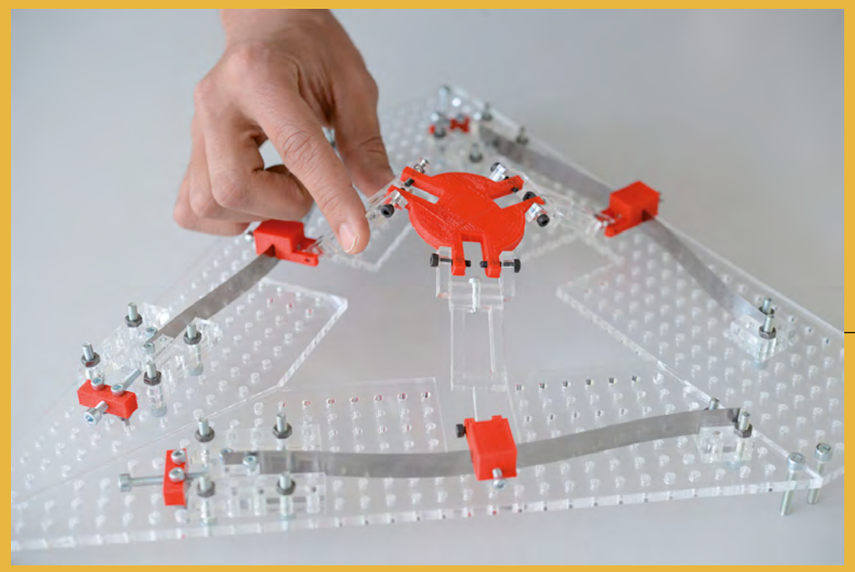
RESEARCH PROJECTS



High quality factor oscillators for wrist watches

Current mechanical wrist watches have as time base 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 damping and 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.

Cross-spring flexure pivot oscillator on test bench.



Programmable multistable energy storage mechanisms

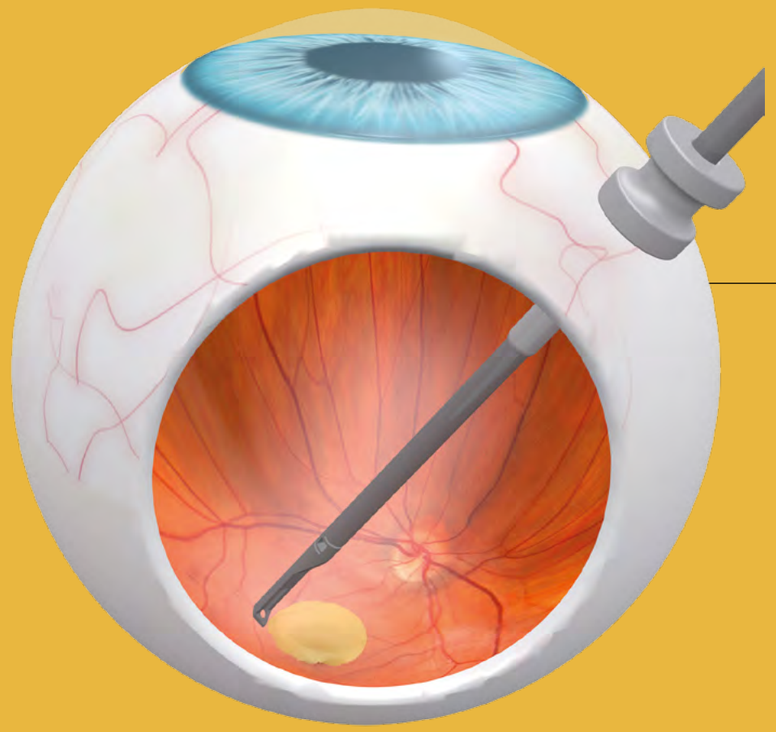
Flexure based mechanisms can be designed in order to produce strongly non-linear spring behavior. Machined in Silicon or innovative spring alloys, they enable completely new functionalities at the centimeter scale. This project aims at exploring the fundamental principles of elastic energy storage mechanisms, their production methods and their integration into functional devices.

Multi-degree-of-freedom multistable mechanism.

Instant-Lab – Audemars Piguet collaboration

On July 18, 2014, EPFL signed a framework agreement with watch manufacture Audemars Piguet. This agreement strengthens the existing relationship between the two partners by forging common research and development goals. The first collaboration within this agreement is a significant research project with Instant-Lab.

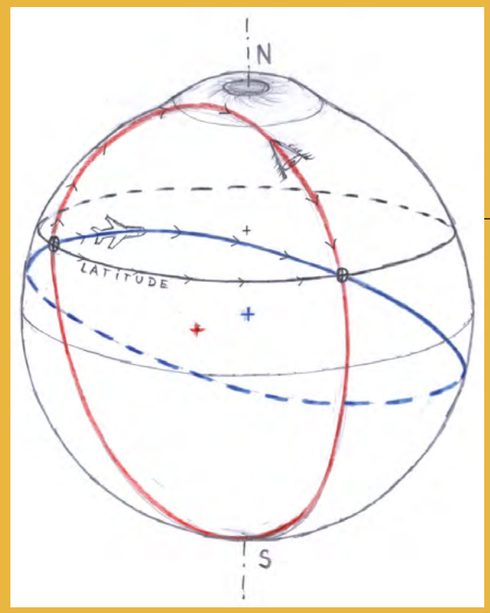
RESEARCH PROJECTS



Force sensitive hook for peeling the epiretinal membrane.

Miniature flexure structures for multi-degree of freedom contact force sensing

This project develops active surgical tools fitting microsurgery requirements, e.g., eye and brain surgery. It combines flexible structure technology provided by Instant-Lab together with Sensoptic SA's in-house optical fiber based sensing technology which has been successfully used in heart, ear, nose and throat surgery. Providing surgical instruments that are force sensitive at the tool tip allows precise and reliable surgical gestures far exceeding current practice. Watchmaking applications are also foreseen.
This project is funded by Sensoptic SA and the Commission for Technology and Innovation CTI (Switzerland) and run in collaboration with Pr. Th. Wolfensberger, Hôpital Ophtalmique Jules-Gonin, Lausanne.



Ballistic vs great circle eye movement trajectories.

Geometry of eye movement dynamics

This project developed a mathematical model of eye movement dynamics to derive analytical expressions for naturally occuring ballistic eye movements. The project is currently focused on applications of the theoretical results.

Force feedback haptic interface for microsurgery

Virtual reality has the potential to introduce simulation to surgery analogous to flight simulators in aviation. Force feedback haptic interfaces allow users to intuitively interact in virtual reality environments. The goal of this project is to develop a 7-DOF interface including active grasping motion on its manipulandum to simulate dissection forceps.

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

The project consists of a geometrically adjustable structure used in orthopedic shoes.
This Swiss National Science Foundation project is a collaboration with CHUV (Hôpital Orthopédique de la Suisse Romande).

RESEARCH — PH.D. THESES

O. Laesser, thesis title: *Analyse, synthèse et création d'échappements horlogers par la théorie des engrenages*.
Completed October 2014.

J. Kruis, thesis title: *Design and analysis of two-body and three-body kinematic mounts for high repeatability assembly*.
Expected completion July 2016.

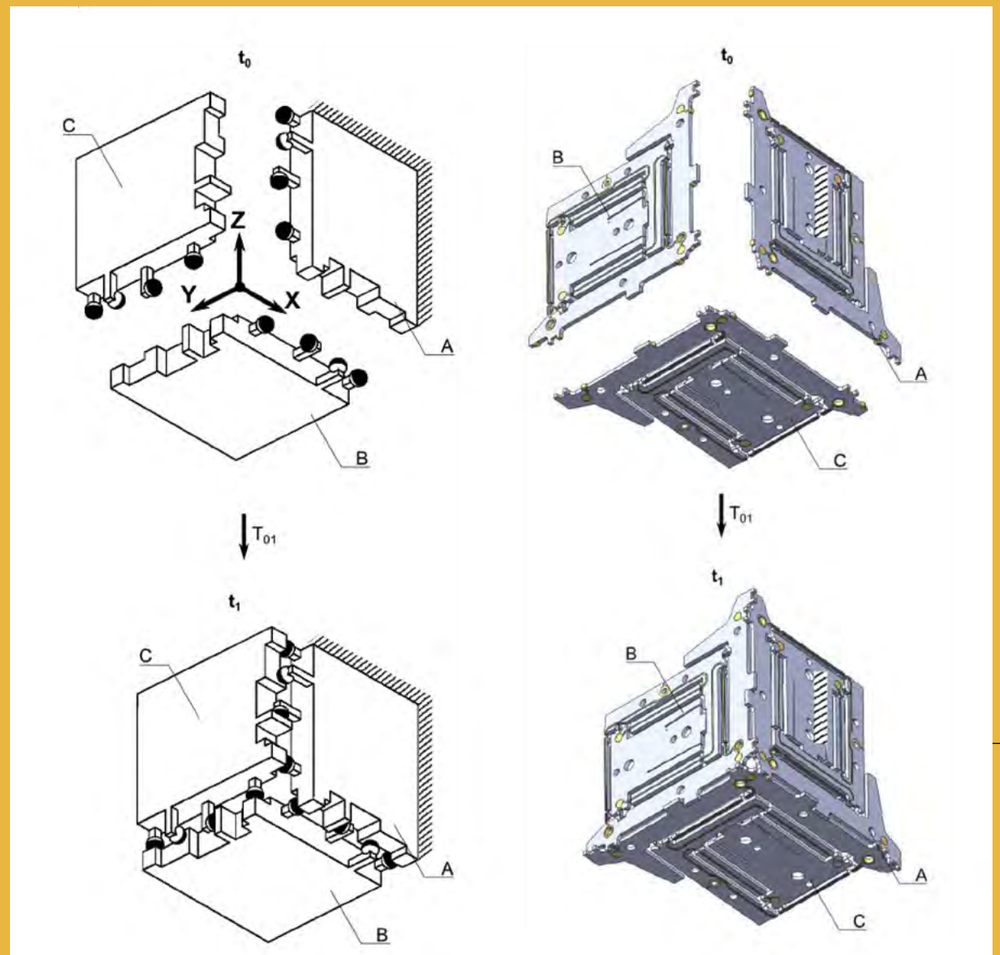
Three-body kinematic mount used for Silicon part assembly (courtesy of CSEM).

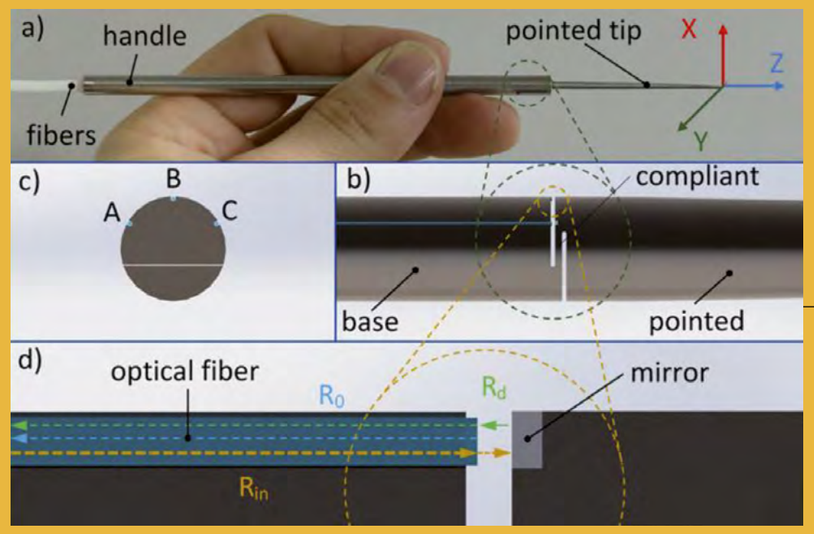
S. Fifanski, preliminary thesis title: *Miniature flexure structures for contact force sensing in pointed tools*.
Expected completion August 2018.

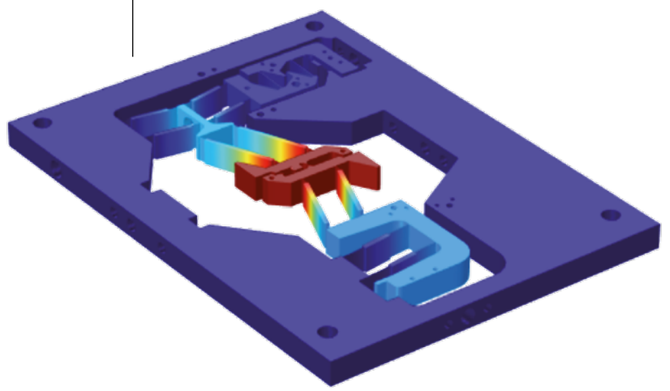
a. Force sensing instrument | b. Flexure body | c. Cross section with fiber locations | d. Fabry-Pérot cavity.

M. Zanaty, preliminary thesis title: *Programmable stiffness mechanisms*.
Expected completion August 2018.

T-shaped multistable mechanism.







PUBLICATIONS

Patents

S. Henein, I. Kjelberg, *Timepiece oscillator*, US 9207641 B2, Holder : CSEM SA

S. Henein, I. Vardi and L. Rubbert, *XY isotropic harmonic oscillator and associated time base without escapement or with simplified escapement*, WO 2015104692 A2, Holder : EPFL

S. Henein, I. Vardi and L. Rubbert, *General 2 degree of freedom isotropic harmonic oscillator and associated time base without escapement or with simplified escapement*, WO 2015104693 A2, Holder : EPFL

I. Vardi, *Oscillateur mécanique à diapason pour mouvement horloger*, WO 2015169708 A2, Holder : Asgalium Unitec SA

N. Dehon, I. Vardi, *Système oscillant pour mouvement horloger à échappement à ancre*, WO 2015197411 A1, Holder : ASRH

C. Baur, A. Chebira, E. Grenet, E. Franzi, D. Hasler, *Positioning system using a constellation of light sources*, Holder: CSEM

C. Baur, A. Chebira, E. Grenet, E. Franzi, D. Hasler, *6D positioning system using shadow sensor*, US14597434, Holder : EPFL

Conference proceedings

S. Henein, I. Vardi, *The geometry of eye movement dynamics*, in Abstracts of the 18th European Conference on Eye Movements, Vienna, Austria, August 16-21, 2015

O. Laesser, S. Henein, *Analyse, synthèse et création d'échappements horlogers par la théorie des engrenages*, Actes de la Journée d'Etude de la SSC, Lausanne, September 16, 2015

Journal articles

T. Fujita, J. E. Shin, M. Cunnane, K. Fujita, S. Henein, D. Psaltis, K. Stankovic, *Surgical anatomy of the human round window region : implication for cochlear endoscopy through the external auditory canal*, Journal of Translational Medicine, 2015

M. Clogenson, J. M. Duff, M. Luethi, M. Levivier, R. Meuli, C. Baur, S. Henein, *A statistical shape model of the human second cervical vertebra*, International Journal of Computer Assisted Radiology and Surgery, Vol. 10, pp. 1097-1107, 2015

A. Homsy, E. Laux, L. Jeandupeux, J. Charmet, R. Bitterli, C. Botta, Y. Rebetez, O. Banakh, H. Keppner, *Solid on liquid deposition, a review of technological solutions*, Microelectronic Engineering, Vol. 141, pp. 267-279, 2015

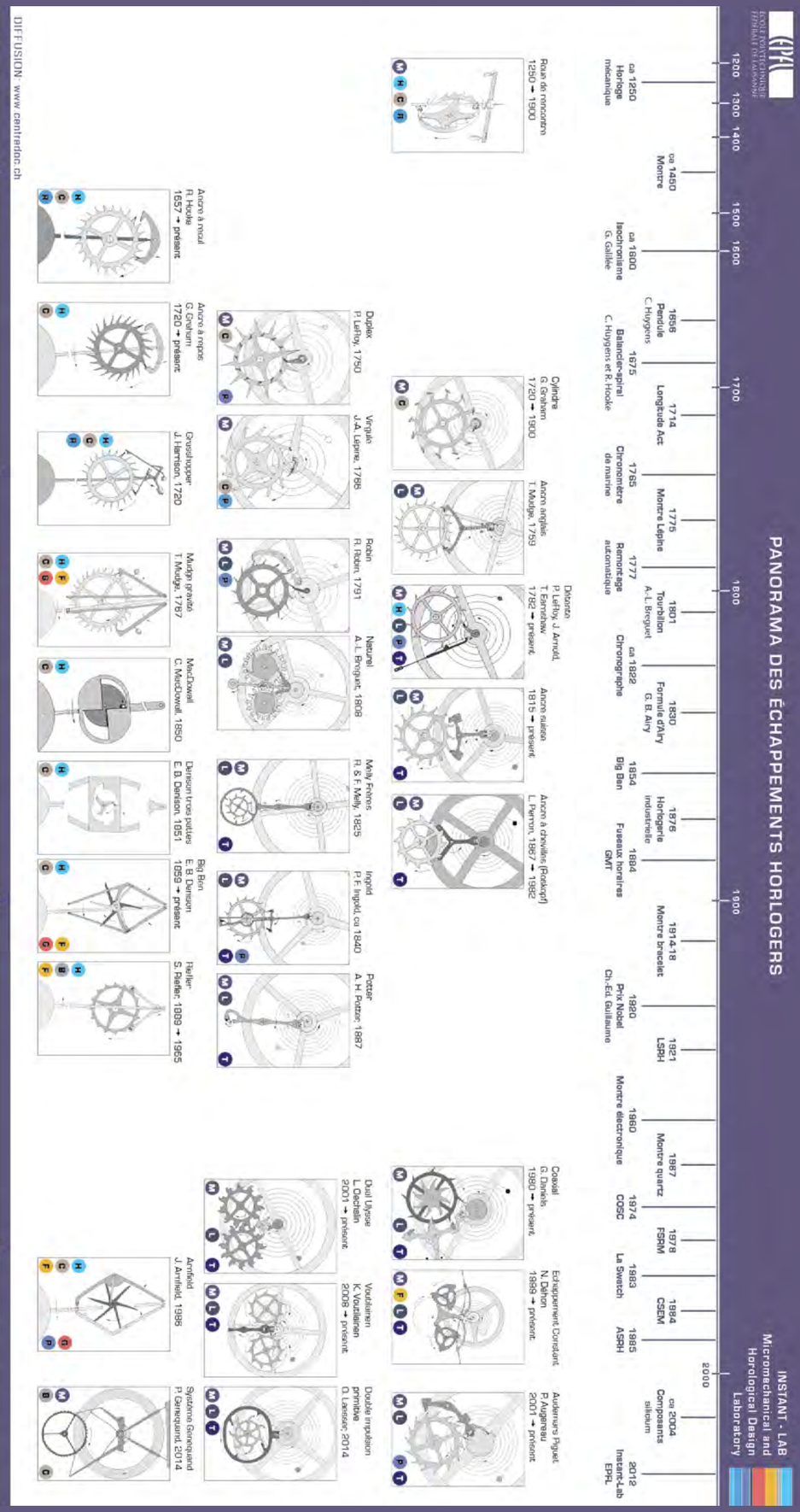
L. Rubbert, R. Bitterli, N. Ferrier, S. Fifanski, I. Vardi, S. Henein, *Isotropic springs based on parallel flexure stages*, Precision Engineering, Vol. 43, pp. 132-145, 2015

I. Vardi, *Mathematics, the language of watchmaking*, Watch Around, Vol. 20, pp. 90-94, 2015

S. Henein, I. Vardi, *The Geometry of Eye Movement Dynamics*, Journal of Eye Movement Research, Vol. 8, p. 65, 2015

Poster

R. Bitterli, S. Henein, O. Laesser, B. Nussbaumer, B. Tora, I. Vardi, *Panorama des échappements horlogers*, 2015



DISSEMINATION

Lectures and invited talks

Eye Movement Dynamics, Microcity, Neuchâtel, January 9, 2015, I. Vardi

FSRM, 1 Day Tutorial, Neuchâtel, S. Henein, February 5, June 12, 2015, *Conception des guidages flexibles*

Support for Innovation and KTT in Medical Technology, Swiss Institute for Computer Assisted Surgery (SICAS), Courroux, April 20, 2015, C. Baur, *Development of innovative surgical tools*

EPFL MicroNanoFabrication Annual Review Meeting, Rolex Learning Center, Lausanne, May 5, 2015, S. Henein, *Mechanical design at the watch scale*

EPFL IMT Colloquium, Microcity, Neuchâtel, June 2, 2014, Prof. D. Brouwer, *Flexure-based precision mechanisms*

European Conference on Eye Movements, Vienna, August 16-21, 2015, I. Vardi, *The geometry of eye movement dynamics*

17ème Journée d'Etude SSC, Lausanne, September 16, 2015, O. Laesser, *Analyse, synthèse et création d'échappements horlogers par la théorie des engrenages*

EPFL IMT Colloquium, Microcity, September 17, 2015, D. Bateman, *Oscillator and Escapement - an alternative view*

Rallye Patek Philippe, Microcity, Neuchâtel, September 17, 2015, S. Henein, *IsoSpring: vers la montre sans échappement*

Journées Culture et Jeunesse de l'Institut Neuchâtelois, Microcity, Neuchâtel, September 25, 2015, S. Henein, *Aux sources de l'invention*

Jaeger-LeCoultre event, Basel, October 1, 2015, I. Vardi, *Hommage an die Astronomie*

Colloque pour les enseignants du secondaire, EPFL, Lausanne, November 11, 2015, I. Vardi, *Redécouvrons l'horlogerie*

Jaeger-LeCoultre event, Château Le Rosey, Bursins, November 12, 2015, I. Vardi, *L'orientation de la montre*

Events

Rallye Patek Philippe, Microcity, Neuchâtel, September 17, 2015


INSTITUT NEUCHÂTELOIS

Des lycéens à la découverte de l'infiniment petit

Les lycéens ont visité l'Instant Lab de l'EPFL à Microcity, où ils ont pu découvrir un oscillateur horloger révolutionnaire.
lucas vuitel

...ées, dans ce laboratoire, elles flottent partout. On en attrape une ou deux, et parfois on se dit que ça vaut la peine de ... de déposer un brevet...»

Ohne Spiel, Stick-Slip, Reibung oder Verschleiss

>> Standardisierte Elemente können für den Konstrukteur oft von Nutzen sein. Doch sie bringen auch Nachteile mit sich wie etwa Abnutzung. Insbesondere bei Hochpräzisionsanforderungen kann es daher Sinn machen, alternativ monolithische Konstruktionen mit nachgiebigen Gelenken ins Auge zu fassen. Der folgende Artikel basiert auf einem entsprechenden Vortrag von Prof. Simon Henein bei der Schweizerischen Stiftung für mikrotechnische Forschung (FSRM) in Neuchâtel.

Die Kinematik klassischer mechanischer Systeme besteht meist aus Standardelementen wie Stäben, Drehgelenken, Hebeln, Lagern, linearen Führungen, Zahnrädern usw. Für den Konstrukteur hat dies den Vorteil, dass er auf einen standardisierten Baukasten zugreifen kann, mit dessen Hilfe die meisten Einsatzfälle ohne grössere Probleme gelöst werden können. Nachteil solcher Elemente ist jedoch die Tatsache, dass ihre Schnittstellen zugleich auch Schwachstellen sind. Hier treten unerwünschte Phänomene wie Lagerspiel, Reibung und Ermüdung auf

Bild Henein

Der «Delta Cube» ist ein paralleler Roboter mit drei Freiheitsgraden für Aufgaben im Bereich der Positionierung beim Mikro-Funkenerodieren.

MEDIA PRESENCE

Newspaper articles

Ohne Spiel, Stick-Slip, Reibung oder Verschleiss,
Klaus Vollrath, Schweizer Maschinenmarkt n° 19, September 2015

Des lycéens à la découverte de l'infiniment petit,
Françoise Kuenzi, L'Express-L'Impartial, September 26, 2015

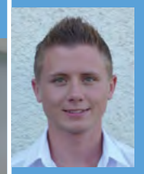
Guidages flexibles,
Edouard Huguelet, La Revue Polytechnique, n° 1805, June 22, 2015

Above documents available online
instantlab.epfl.ch/Media

AWARDS

Prix Omega étudiants obtained by Loïc Bovay for his Master project : *Design of a new surgical instrument for robotic application*

a



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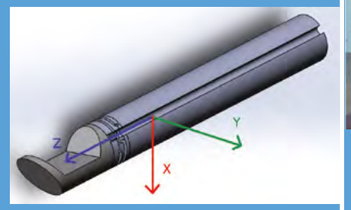

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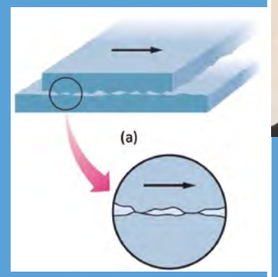

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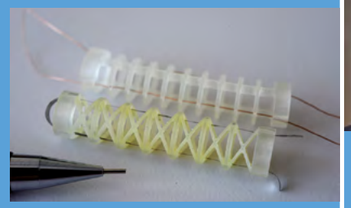

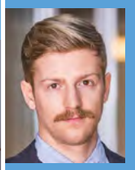

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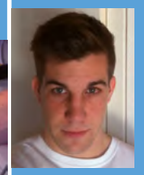

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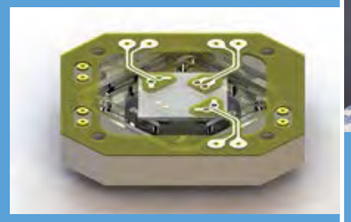

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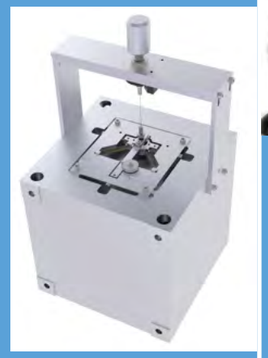


j

TEACHING

The laboratory is strongly involved in teaching. Focus is on training the creative process starting with the act of design followed by teaching the analytical tools necessary to model, simulate and predict machine behavior.

EPFL

Mechanism Design I & II / Conception de mécanismes I & II (2015-2016)
Lecturer: Prof. S. Henein; Section: Microtechnique (125 students); Bachelor semesters 2 and 3; 3 periods per week.

Elements of mechanical design I & II / Construction mécanique I & II (2015-2016)
Lecturers: Course under the responsibility of Prof. S. Henein & Prof. J. Schiffman and taught by two external lecturers; Sections: Microtechnique/Génie mécanique (500 students); Bachelor semesters 1 and 2; 3 periods per week.

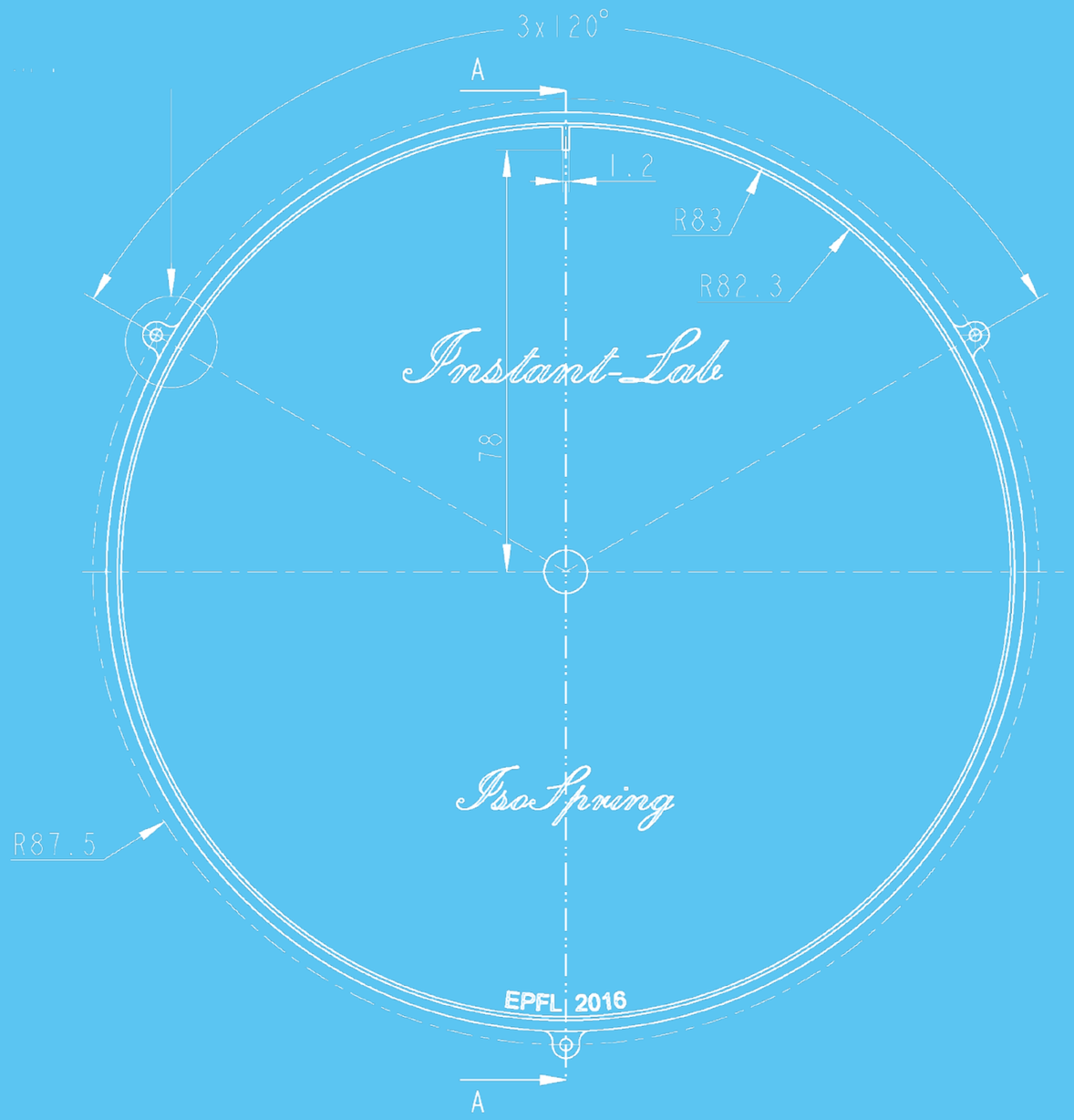
Industrial and applied robotics / Robotique industrielle et appliquée (2015)
Contributions to the course by Prof. S. Henein and Dr C. Baur; Flexure mechanisms Design of mechanisms for vacuum application; Medical robotics; Section: Microtechnique (60 students); Master semester 2.

Semester (S) and master (M) projects

a. Broche vibrante pour violoncelles, altos et violons, Camille Boymond (S)
b. Mesure de l'amplitude d'un oscillateur par vision, Jonathan Lutz (S)
c. Outil pour Mibot avec mesure de force, Nicolas Mayenzet (S)
d. Curette (outillage chirurgical), Rafael Tobler (S)
e. Transducteur de force/déplacement utilisant des structures flexibles, Mathieu Aberle (S)
f. Microwatch, Mahdi Tamizafar (S)
g. Flexure based minimal invasive surgery tools, Arno Rogg (S)
h. Low cost surgical tool for pedicle screw placement, Simon Métrailler (S)
i. Design of a new surgical instrument for robotic application, Loïc Bovay (M)
j. Capteur de micro couple pour caractérisation de paliers horlogers, Jonas Graf (M)
k. Conception, modélisation, réalisation et évaluation d'un support de cellule pour horloge atomique miniature (CSEM), Ludovic Zulliger (M)

Master project in collaboration with INSA Strasbourg

l. Structures flexibles en contexte chirurgical, José Rivera (M)



CONCLUSION AND PERSPECTIVE

On February 6, 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. In 2015 the laboratory continued work on this research project with a watch-scale demonstrator as its goal.

In August 2015, Instant-Lab successfully passed its CTI grant midterm review allowing it to pursue one of its key medtech projects.

The laboratory set up two visiting professorships resulting in fruitful collaboration and very successful invited addresses organised by Instant-Lab.

The number of semester and master projects continued to increase over the previous years.

The Instant-Lab team was increased to 18 collaborators covering a full range of skills. The laboratory is now fully operational.

Perspective for 2016

Fundraising via FNS (Swiss National Science Foundation) and CTI (Commission for Technology and Innovation) for the development of fundamental and applied research projects (typically one to two Ph.D. students for each project).

Preparing second phases of existing industrial projects.

Publication in academic journals of 2014 and 2015 patents and Ph.D. results.

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