Patek Philippe Chair

Micromechanical and Horological Design Laboratory
INSTANT-LAB

Annual Report 2016
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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 2016, Instant-Lab has 19 collaborators: Professor Henein, an administrative assistant, 2 senior scientists, 2 postdoctoral scholars, 3 Ph.D. students, 8 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.
TEAM

**Director**
- Prof. Simon Henin

**Administrative assistant**
- Karine Frossard

**Senior Scientists**
- Dr Charles Baur
- Dr Ilan Vardi

**Post-Docs**
- Dr Roland Bitterli
- Dr Mohammad Kahrobaiyan

**Post-Docs**
- Laura Convert
- José Rivera

**Scientific Assistants**
- Marina Clogenson
- Billy Nussbaumer
- Nicolás Fernández
- Arno Rogg
- Cédric Hentsch
- Etienne Thalmann

**Technicians**
- Romain Gillet
- Arnaud Maurel

**Interns**
- Sebastian Fifanski
- Benoît Dubath

**Ph.D. Students**
- Johan Krüss
- Mohamed Zanaty

**Visiting Professors**
- Prof. Sonny Chan
  University of Calgary, CAN
- Prof. Pierre-Yves Donzé
  Osaka University Graduate School of Economics, JPN

*External*
INFRASTRUCTURE AND EQUIPMENT

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

Major equipment acquired in 2016:

- **Real-Time acquisition system PXIe-8135 RT**, Quad core i7-3610QE, 2.3 GHz, 4 Go RAM DDR3 with a PXIe-1082 chassis PXI Express 3U with 8 slots of 2 Gb/s bandwidth modules:
  - Module 1: PXIe-6814, eight 32-bit, 80 MHz counters/timers, 40 DIO @ 10 MHz, OCXO oscillator @ 10 MHz with 0.075 ppm stability
  - Module 2: PXI-7841R, FPGA LX30 Virtex-5, eight AI, +/-10 V @ 200 kS/s/channel, 8 AO, +/-10 V @ 1 MS/s/channel, 96 DIO @ 40 MHz, 96 counters/timers @ 40 MHz

- **Kistler 9207 tension-compression uniaxial force sensor**
  - Force ranges: -50 N to 50 N, -5 N to 5 N, -0.5 N to 0.5 N. Linearity: ±1 % FSO, sensitivity: -119.1 pC/N

- **Trotec Speedy 360 flexx laser cutting marking and engraving machine**
  - Work space: 813 x 508 mm, max. height: 280 mm, speed: 355 cm/s (CO2) and 200 cm/s (fiber), positioning precision: 5 um, repeatability: <±15 um, vacuum table, honeycomb cutting tabletop, aluminium slat cutting table
  - Aspiration system 2 x 330 m³/h ATMOS Duo
  - Materials: aluminium, stainless steel, brass, copper, precious metals
  - CO2: wood, MDF, Plexiglas, PC, ABS, PE, PES, PS

- **Linktronix PWS4323 single-channel programmable DC Power Supply**
  - 0-32 VDC output voltage, 0-3 A output current, 96 W.
  - ±0.03 % basic voltage output accuracy and ±0.05 % basic current accuracy
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 Instant-Lab.

In 2013 a successful proof of concept was achieved, leading to an industrial project in 2014. In 2016, variations of the original concept were realized as fully functional clocks. As an homage to the horological tradition of the region, the shape of the clocks is based on the famous Neuchâteloise clock design. Since December 2016, the City of Neuchâtel has exhibited the first prototype in its renovated City Hall.

Current research is focused on miniaturizing to the watch scale.
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.

Gravity insensitive flexure pivot (GIFP) demonstrator

Flexure based mechanisms can 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.

T-shaped multistable mechanism programmable to have 1 to 4 stable positions

Audemars Piguet research project

Instant-Lab and Audemars Piguet continued the project initiated in 2014.
RESEARCH PROJECTS

CTI Miniature flexure structures for multi-degree of freedom contact force sensing (VIVOFORCE)

The project developed active surgical tools fitting microsurgery requirements, e.g., eye and brain surgery. Combining 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 was 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. The project was completed within budget in November 2016 successfully satisfying the goals set by all partners.

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

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. 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 bistable mechanism to safely cannulate veins. The feasibility of this project was demonstrated by a prototype made by femto-laser printing, one of the first buckled mechanisms made in glass.

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

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 developed at Instant-Lab. This Swiss National Science Foundation project is a collaboration with CHUV (Centre Hospitalier Universitaire Vaudois).

STI Enable SOLE Project

The object of the SOLE project is to produce ADVANCER prototypes and to test them on CHUV patients. The project is funded by the EPFL STI (School of Engineering) Enable Initiative.

Spinal screw placement tool

This Instant-Lab project develops low cost passive alignment tools for spinal pedicle screw placement. The goal is to improve the surgeon’s ability to accurately insert a pedicle screw following a predetermined trajectory. This reduces the risk of plunging which can damage soft tissue, nerves, or the spinal cord.
RESEARCH — PH.D. THESES


3-body kinematic mount (left) and classical 2-body kinematic coupling (right)

Centimeter-scale 3-body kinematic mount for assembly repeatability measurements

Millimeter scale silicon 3-body kinematic mount for assembly repeatability measurements (courtesy of CSEM)


Hand held surgical tool equipped with 3 degree-of-freedom force sensor


Folded-Beam programmable bistable mechanism with blades under tension (no buckling)
PUBLICATIONS

Patents


S. Henein, L. Rubbert, M. Kahrobaiyan, Gravity-insensitive flexure pivots, CH 01255/16, September 2016


Conference proceedings


Journal articles


LECTURES, INVITED TALKS, POSTERS


HUG Genève, Colloque du département de chirurgie, January 11, 2016, lecture by C. Baur, Utilisation de lames flexibles et outils chirurgicaux : évolution ou révolution ?

Colloque EPFL Microcity, Neuchâtel, February 24, 2016, I. Vardi, Me and the Lamppost

Conférence publique FSRM, Neuchâtel, March 9, 2016, S. Henein, Les ressorts intimes du temps

EPFL, Lausanne, May 18, 2016, lecture by E. Thalmann, Two mechatronic systems

EPFL Microcity, Neuchâtel, May 19, 2016, lecture by S. Chan, Robotic Neurosurgery and Haptics for Surgical Rehearsal


CADFEM users conference, Lausanne, keynote address, September 13, 2016, I. Vardi, Nouveaux concepts en horlogerie traditionnelle

EPFL, Lausanne, September 15, 2016, S. Henein, Invention de l’horloge mécanique sans échappement : exemple de processus créatif collectif

EPFL Microcity, Neuchâtel, September 21, 2016, lecture by P.-Y. Donzé, La globalisation des systèmes de production dans l’industrie horlogère


MICRO16, IsoSpring poster presentation, Microcity, September 10, 2016
DISSEMINATION

Visits

Professors and Chiefs of Staff of Service de Chirurgie viscérale et transplantation, Hôpitaux Universitaires de Genève, visit, Microcity, March 4, 2016

University of San Francisco students, Microcity, May 25, 2016

Instant-Lab Zytlogge tour, Bern, August 30, 2016.

Newspaper articles

Une pendule révolutionnaire exposée, Nicolas Heiniger, L’Express, December 9, 2016

Une révolution copernicienne, Aline Botteron, Vivre la ville !, n° 40, December 14, 2016

Press conferences

L’horloge IsoSpring, au mécanisme révolutionnaire, mise en valeur à l’Hôtel de Ville, C. Gallard, City Councilor (Conseiller communal), S. Henein, I. Vardi, December 8, 2016

Above documents available online instantlab.epfl.ch/Media
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 behavior.

**EPFL**

**Mechanism Design I & II / Conception de mécanismes I & II (2016-2017)**
Lecturer: Prof. S. Henein; Section: Microtechnique (150 students); Bachelor semesters 2 and 3; three hours per week.

Watt balance for project-based learning (Spring semester)

**Elements of mechanical design I & II / Construction mécanique I & II (2016-2017)**
Lecturers: Course under the responsibility of Prof. S. Henein and Prof. J. Schiffman taught by two external lecturers; Sections: Microtechnique / Génie mécanique (500 students); Bachelor semesters 1 and 2; three hours per week.

**Industrial and applied robotics / Robotique industrielle et appliquée (2016)**
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. Force displacement transducer using flexible structure, Frédéric Junod (S)
b. Micro-torque test bench validation, Benoît Ellenrieder (S)
c. Rover-drill mechanical interface for autonomous Mars analog missions, Arno Rogg in collaboration with NASA Ames Research Center USA (M)
d. Développement d’une plateforme pour application mobile en utilisant la technologie Beacon, Anthony Prudhomme en collaboration avec EPF Montpellier (M)
e. Plug-in(s) to connect Atracsys optical trackers to third-party software, Charlotte Evequoz in collaboration with Atracsys Puidoux (M)
In 2014, Prof. Simon Henein announced the IsoSpring project to make the first mechanical watch without escape-ment. This led to patents and a large-scale industrial project. In the 2016, the laboratory succeeded in realizing a number of fully functional clock prototypes based on different embodiments of the IsoSpring concept. One of the prototypes was loaned to the Neuchâtel City Hall where it exhibited to the public. This led to significant media attention in Switzerland and beyond. In 2017, the laboratory is continuing work on this research project with a watch-scale prototype as its goal.

In November 2016, Instant-Lab successfully completed its first CTI project within budget and with promising results.

A second CTI project has been launched as well as an SNSF project, both in the medtech field.

The laboratory organized two visiting professorships resulting in a fruitful collaboration and a joint publication.

The Instant-Lab team continues to employ 18 collaborators covering a full range of skills.

**Perspective for 2017**

Two new Ph.D. projects will be launched in 2017 with very talented candidates and the possibility of a new industrial partnership.

Preparation of a second phase of existing industrial projects ending in 2017.

Publication in academic journals of 2015 and 2016 research, patents and Ph.D. work.