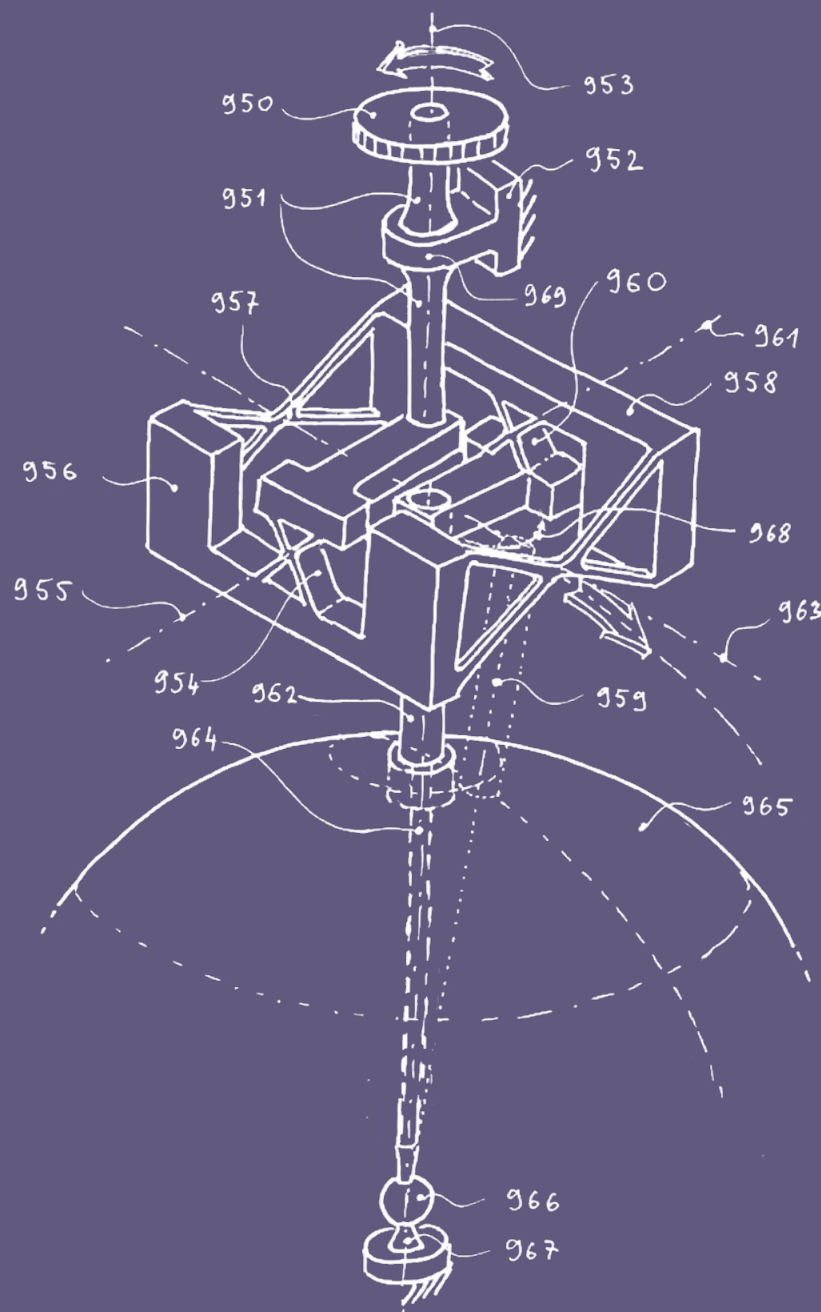


Patek Philippe Chair

Micromechanical and Horological Design Laboratory INSTANT-LAB

Annual Report 2014



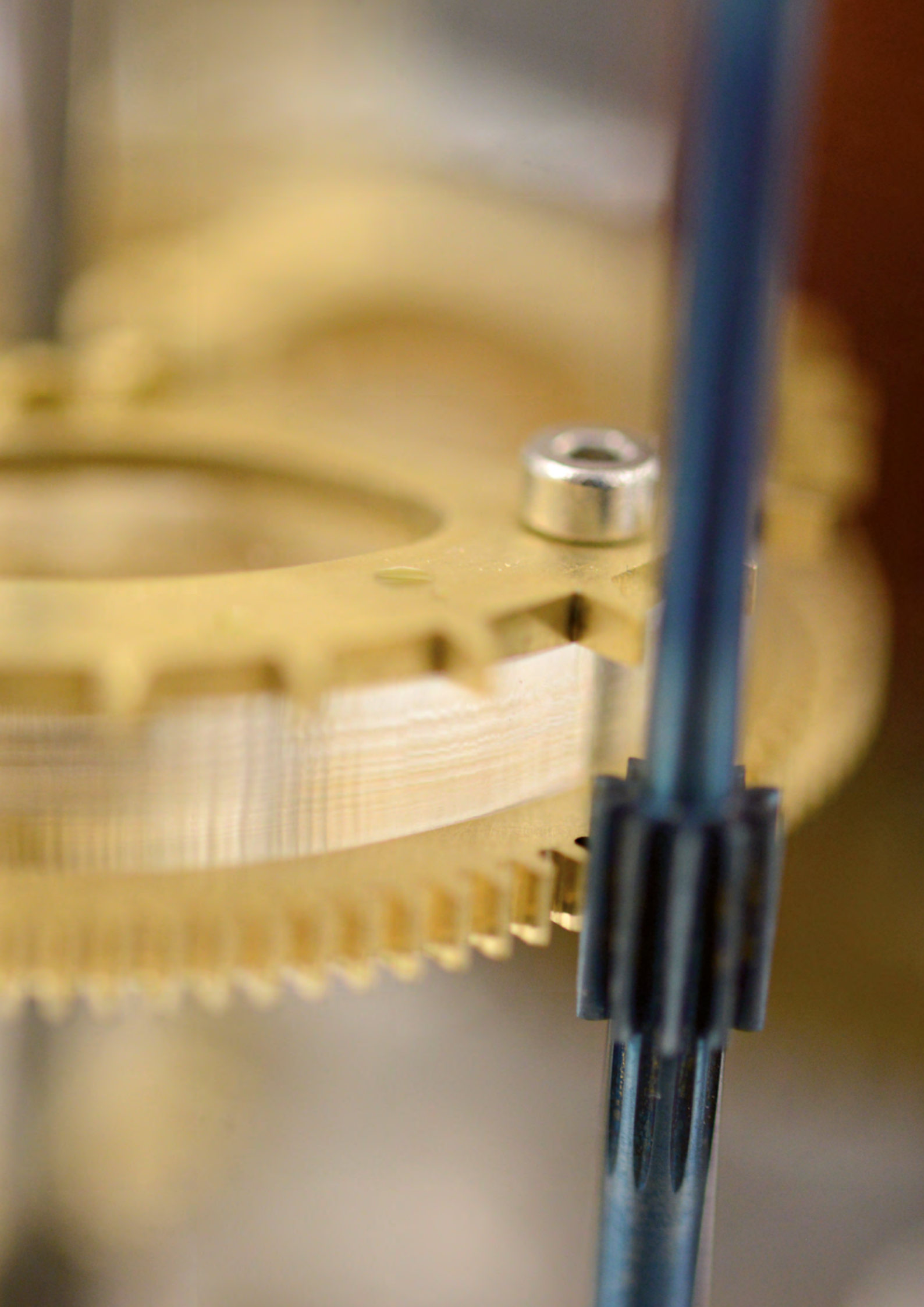


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Leçon inaugurale

Conception mécanique à l'échelle horlogère: invention, théorie et matérialisation



Simon Henein

RÉSUMÉ

«S'il ne faisait qu'imaginer, l'ingénieur serait seulement poète, si en plus il crée des machines, il devient inventeur. Mais pour être ingénieur, il faut aussi se donner les moyens de réaliser ses objectifs, et ceci en faisant appel à des connaissances souvent empiriques et en appliquant des principes

physiques ou mathématiques.» Cet extrait de la définition d'ingénieur tiré du *Dictionnaire culturel des sciences* (Seuil) nous replace dans la dimension synthétique et créative du métier. Dans ma leçon inaugurale, j'exposerai ma manière d'orchestrer le processus créatif individuel et collectif par des exemples de recherches en cours dans mon laboratoire. Ces dernières couvrent le domaine de la mécanique à l'échelle horlogère, assurant la continuité et le renouveau de cette discipline qui contribue historiquement au rayonnement de la Suisse. En nous appuyant sur les connaissances scientifiques actuelles et historiques, aussi bien théoriques qu'appliquées, nous développons le savoir et les méthodes de

conception portant sur des mécanismes aux fonctions et performances inédites. Ces mécanismes sont destinés à devenir des machines nouvelles au service de l'humain et de son environnement: gardes-temps, outils médicaux, robots, instruments scientifiques.

BIOGRAPHIE

Né en 1973, de nationalités suisse et égyptienne, Simon Henein effectue sa scolarité au Caire. Il obtient son diplôme d'ingénieur en microtechnique de l'EPFL en 1996, puis le titre de docteur ès sciences techniques de cette même institution en 2000. En 2001 il publie un livre intitulé *Conception des guidages flexibles* qui devient une référence dans le monde de la conception micromécanique. Il

s'engage ensuite professionnellement au Centre suisse d'électronique et microtechnique (CSEM) où il conçoit et développe des mécanismes dédiés à des applications robotiques, spatiales, astrophysique, biomédicales et horlogères, ainsi qu'à l'Institut Paul Scherrer où il développe des instruments pour le synchrotron suisse SLS. Depuis le 1^{er} novembre 2012, il est professeur associé en microtechnique à l'EPFL, où il dirige la Chaire Patek Philippe en conception micromécanique et horlogère. ☐

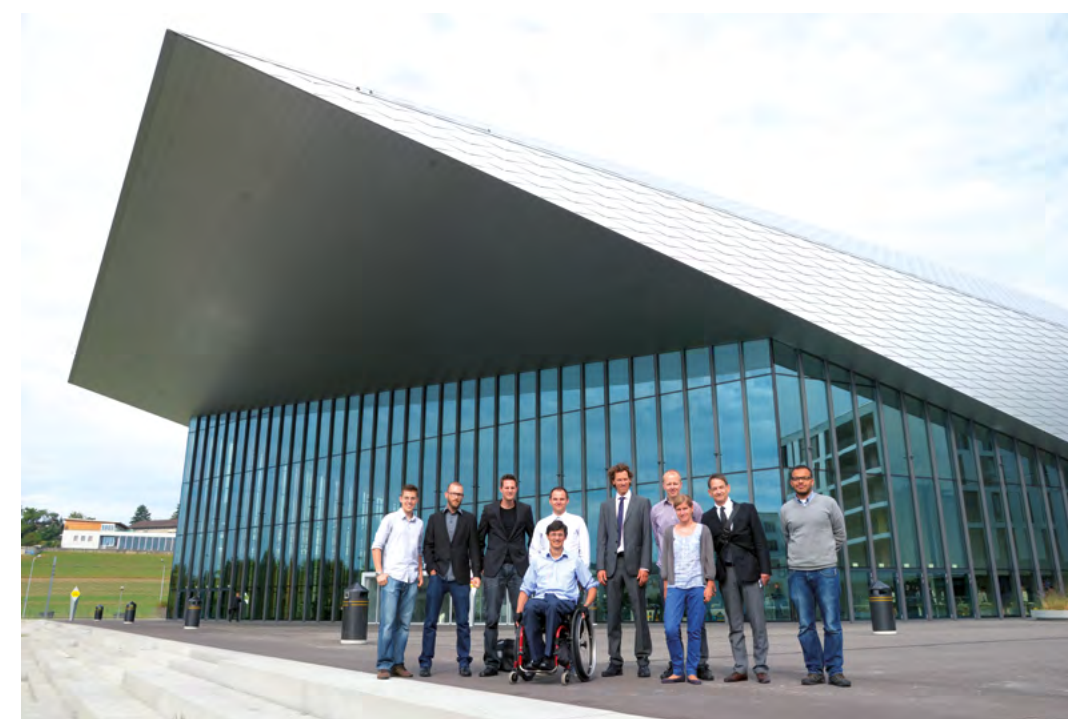
→ Leçon inaugurale du Prof. Simon Henein, jeudi 6 février 2014 à 17h15 dans l'auditoire SG1, inscriptions: inscription.epfl.ch/index.php?form=Simon_Henein

INTRODUCTION

Following the April 2012 announcement of a partnership between the 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. Instant-Lab currently consists of 16 senior scientists, postdoctoral scholars and graduate students.

The laboratory's specialty is the creation of new mechanisms featuring kinematic and technological innovation at the centimeter scale. The scientific approach is inspired from mechanical design in fields such as new and 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 strengthen ties with the Swiss watchmaking industry and therefore welcomes collaboration with all its industrial partners.

The present report gives an overview of the activities of Instant-Lab during 2014.



TEAM



Lab head



Professor 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 Kahrobayan

Technician



Romain Gillet

Scientific Assistants



Nicolas Ferrier



Marine Clogenson



Billy Nussbaumer



Tristan Derbanne

Trainee



José Rivera

Ph.D. Students



Johan Kruis*



Mohamed Zanaty



Sebastian Fifanski



Yannick Bastin*

(*hired by external companies)

INFRASTRUCTURE AND EQUIPMENT

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

Offices : 125 m²

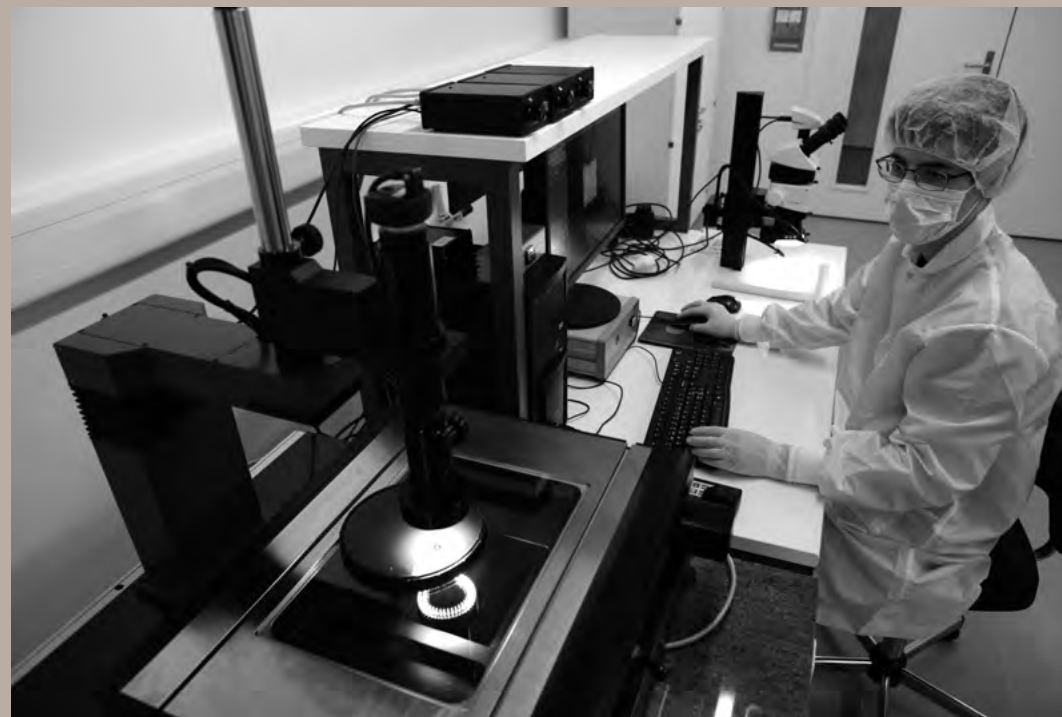
Laboratories: 170 m²

Grey room: 51 m²

The major equipment acquired during 2014 is the following :

- Video measuring system Marcel-Aubert OpenSYS 300 MZ with measuring and comparison software VideoCAD EVO
- Height gauge TESA MicroHite Plus M 600
- Binocular microscope, LEICA M80
- Performance controller cRIO-9030, 1.33 GHz, 4 slots, 70T FPGA
- Sourcemeter KEITHLEY 2460
- Measuring plate DIN876/00, dimension: 1000×630×150 mm
- Precision vibration isolation optical table TMC, dimension: 1200×1200 mm

The grey room is fully functional and the first micro-parts, some etched in Silicon and some other machined in Titanium by wire-electrodischarge machining have been manipulated, assembled and tested thanks to this facility.



RESEARCH PROJECTS

IsoSpring : watch without escapement

The biggest improvement in watch accuracy was due to the introduction of the balance-wheel and hair spring oscillator as a time base in the 17th century which was quickly adopted as the only time base for mechanical watches. Mechanical clocks and watches require an escapement and this mechanism can be an issue due to its inherent complexity and its relatively low efficiency. The present project exploits inventions made by the Instant-Lab team to solve the escapement problem by completely eliminating it. The goal is to design the first mechanical watch without escapement. The Instant-Lab team has also invented simplified escapements, which do not have the drawbacks of current watch escapements. The result would be simplified mechanisms with increased efficiency. These inventions are based on a new type of oscillator and maintaining mechanism both of which have been patented by Instant-Lab.

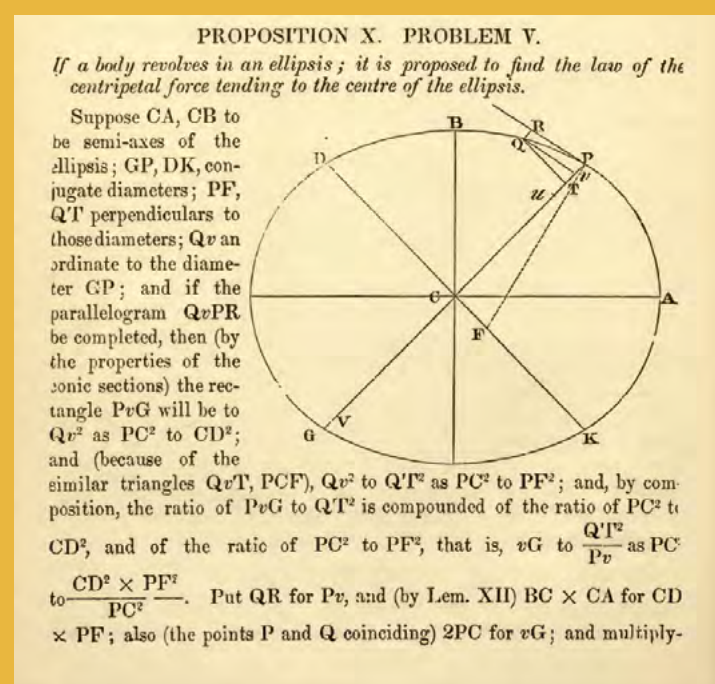
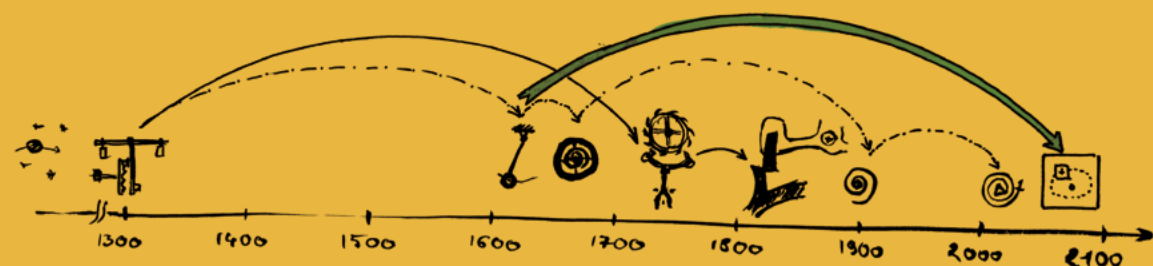
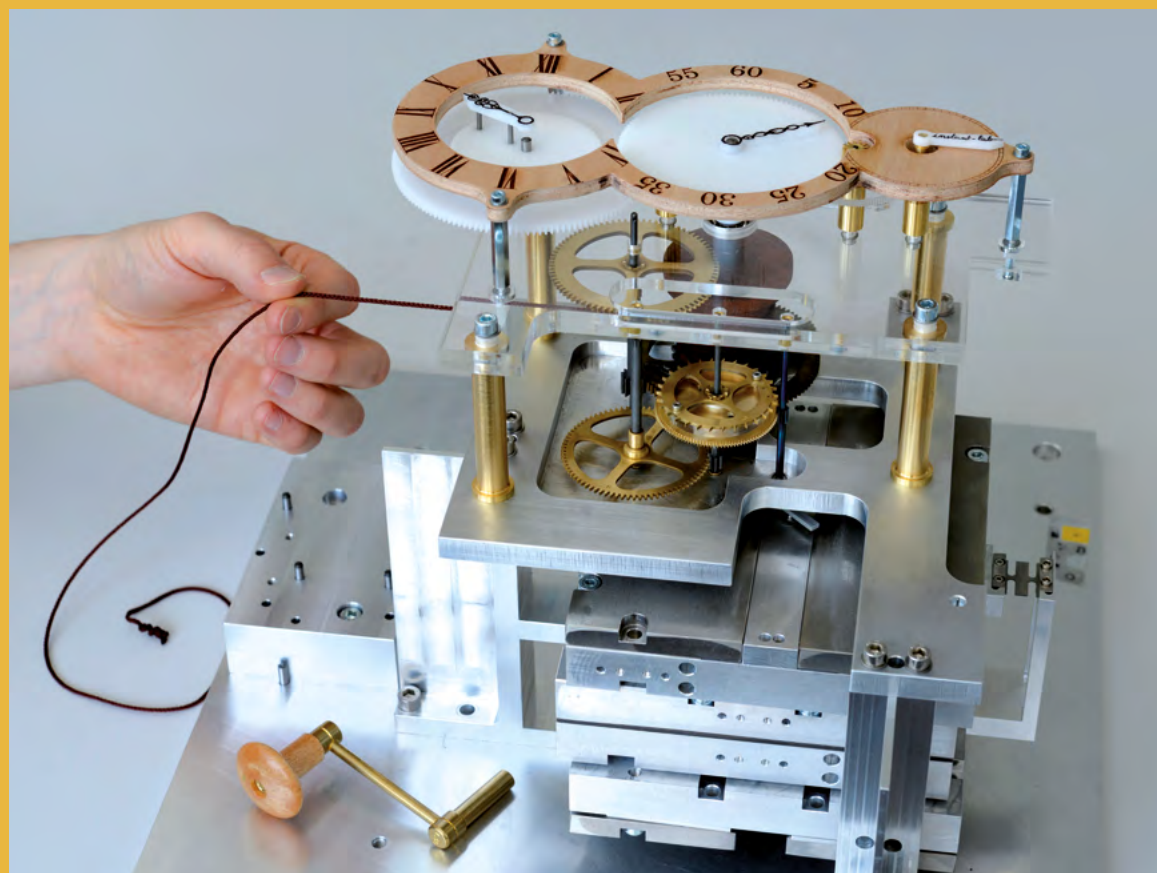
After a successful proof of concept achieved internally at Instant-Lab, a second phase funded by industrial partners was successfully launched in 2014.

First prototype of IsoSpring.

Isaac Newton, *Philosophiæ Naturalis Principia Mathematica*, 1686.

Framework agreement between EPFL and Audemars Piguet

On July 18, 2014, EPFL signed a framework agreement with the company Audemars Piguet. This agreement reflects the will to strengthen the existing relationship between the two institutions and to forge closer ties in their areas of common interest. This partnership will include a series of scientific research projects, carried out jointly by the two parties. The first project within this agreement is an important research project led by Instant-Lab.



RESEARCH PROJECTS

High quality factor oscillators for wrist watches

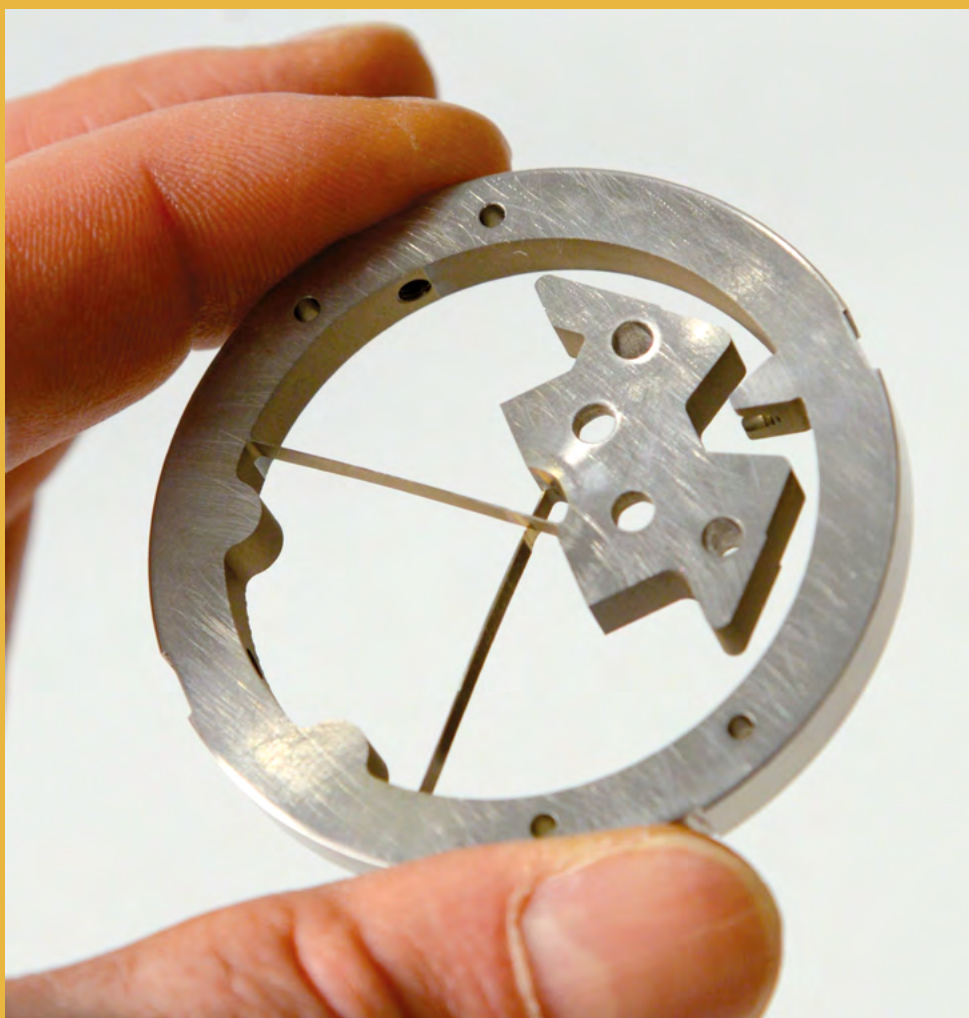
Current mechanical wrist watches have as time base an oscillator consisting of a balance wheel mounted on jewelled bearings and a hairspring. The use of flexure bearings instead of the traditional journal bearing leads to a high increase in quality factor, i.e., reduced damping and energy loss. As a result the power reserve can be significantly increased and chronometric precision can be improved due to reduced oscillator perturbation. This project aims at exploring fundamental and practical issues in the design of novel flexure-based high quality factor oscillators for watches

Cross-spring flexure pivot oscillator.

Multistable meso-scale springs

Flexure based mechanisms can be designed in order to produce strongly non-linear spring behavior. Combined with the use of advanced materials such as mono-crystalline silicon or other alloys or composites with their respective fabrication technologies, such springs 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 complete functional devices.

Elementary programmable stiffness mechanism.



RESEARCH PROJECTS

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

The goal of the project is to develop active surgical tools that fit microsurgery requirements (e.g. eye surgery, brain surgery, etc.) in terms of tool size, force range and required reliability. It will combine flexible structure technology provided by Instant-Lab together with in-house optical fiber based sensing technology of Sensoptic SA that has been successfully introduced into active tools in heart, ear, nose and throat surgery. Focus will be on flexible and sensing structure topology and design, extreme miniaturization, multiple DOF force and torque measurement as well as industrialization aspects such as sealing or in situ reliability of the sensing parts. To provide surgical instruments with force measurement capabilities at the tool tip will allow performing surgical gesture in precision and reliability that exceed those performed currently by an order of magnitude. Application of such sensors for manual watch-making tools is also foreseen.

This project is funded by Sensoptic SA and the Commission for Technology and Innovation CTI (Switzerland).

Force sensing hook for peeling of the epiretinal membrane in eye surgery.

Force feedback haptic interface for microsurgery

Virtual reality environments are thought to become to surgical field what flight simulators are to aviation training. Force feedback haptic interfaces allow users to instinctively interact with such environments. The objective of this project is to develop a 7-DOF interface comprising an active grasping motion on its manipulandum to simulate dissecting forceps.

Haptic interface developed in collaboration with Stanford University.

Steerable catheters for surgery

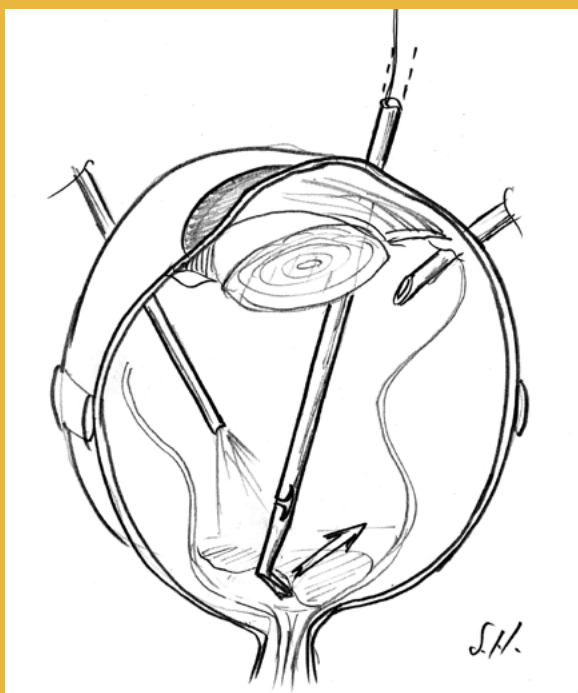
Steerable catheters improve manoeuvrability in minimally invasive surgery. The goal of this project is to develop novel flexure-based catheters.

Steerable catheters demonstrators.

Geometrically adjustable structure for orthopedic shoes

The project consists in a geometrically adjustable structure used in orthopedic shoes.

This project is being set up in collaboration with CHUV.



RESEARCH — PH.D. THESES



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

Dr O. Laesser and Pr. S. Henein.

J. Kruis, preliminary thesis title: *Novel design for assembly concepts for centimeter-scale 3D flexure-mechanisms.*
Expected completion January 2016.

Two body kinematic mount (courtesy of CSEM).

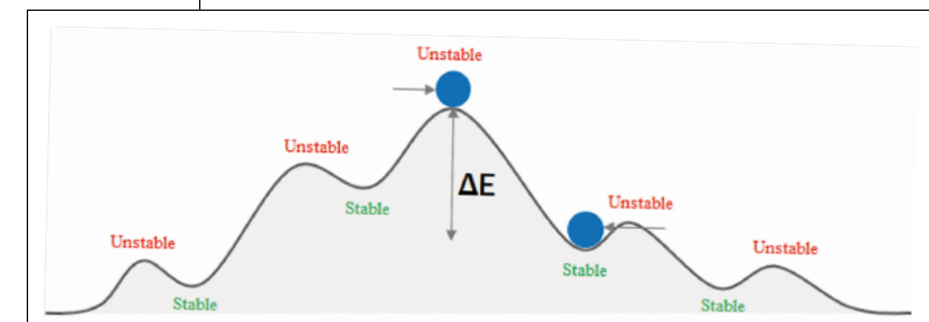
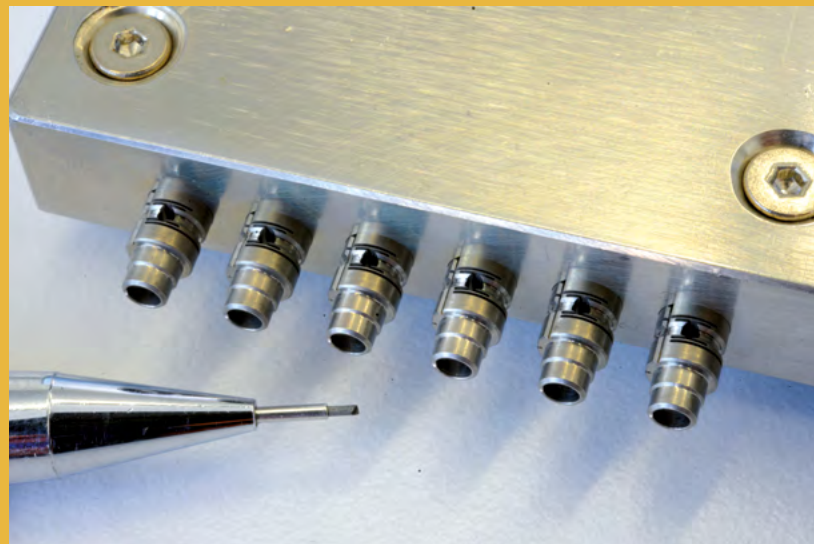
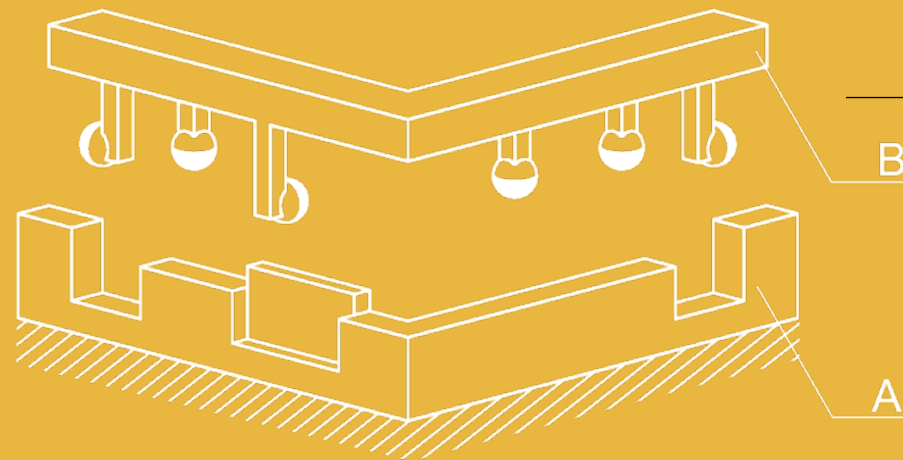
S. Fifanski, preliminary thesis title: *Miniature flexure structures for contact force sensing in pointed tools.*
Expected completion August 2017.

Flexure-based multi-degree of freedom load cells under testing.

Y. Bastin, preliminary thesis title: *Advanced watch escapements.*
Expected completion August 2017.

M. Zanaty, preliminary thesis title: *Programmable stiffness mechanisms.*
Expected completion August 2017.

Energy level in multistable mechanisms.



PUBLICATIONS

Patents

S. Henein, A. Bertholds and P. Llosas, *Optical measuring element having a single-piece structure*, US8659762B2, Holder: Sensoptic SA

S. Henein, I. Vardi and L. Rubbert, *xy isotropic harmonic oscillator and associated time base without escapement or with simplified escapement*, PCT/IB2015/050242, 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*, PCT/IB2015/050243, Holder: EPFL

S. Henein, C. Baur, *Adjustable prosthesis Insert*, PCT/IB2013/059841, Holder: EPFL

Conference proceedings

M. Clogenson and C. Baur, *Statistical shape model for robotic spine surgery*, in Winter Slicer Project Week 2014 (NA-MIC), Salt Lake City, Utah, USA, January 6-10, 2014.

M. Clogenson, J. M. Duff, M. Luethi, S. Kostrzewski and C. Baur, *The value of statistical shape models to spine surgery*, in Shape 2014: Symposium on Statistical Shape Models & Applications, Delémont, Suisse, June 11-13, 2014.

S. Henein, I. Vardi, L. Rubbert, R. Bitterli, N. Ferrier, S. Fifanski and D. Lengacher, *IsoSpring: vers la montre sans échappement* in Actes de la Journée d'Etude de la Société Suisse de Chronométrie, Lausanne, Suisse, September 17, 2014.

Journal articles

M. Clogenson, J. M. Duff, M. Luethi, M. Levivier, R. Meuli, C. Baur and S. Henein, *A statistical shape model of the human second cervical vertebra*, International Journal of Computer Assisted Radiology and Surgery, 2014.

L. Rubbert, S. Caro, J. Gangloff and P. Renaud, *Using singularities of parallel manipulators to enhance the rigid-body replacement design method of compliant mechanisms*, Journal of Mechanical Design, vol. 136, num. 5, p. 051010, 2014.

I. Vardi, *Le facteur de qualité en horlogerie mécanique*, Bulletin de la SSC 75, May 2014, pp. 57-65.

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 141, 2015, pp. 267-279.

Ph.D. Theses

O. Laesser; S. Henein and I. Vardi (Dir.), *Analyse, synthèse et création d'échappements horlogers par la théorie des engrenages*, Thèse N°6189, EPFL 2014.



DISSEMINATION

Invited talks

Inaugural lecture of Professor Simon Henein, *Mechanical design at the watch scale: invention, theory and materialization*; February 6, 2014, EPFL auditorium SG1.

16ème Journée d'Etude SSC, Lausanne, September 17, 2014, S. Henein, *IsoSpring: vers la montre sans échappement*.

Société d'astronomie du nord vaudois, Yverdon-les-Bains, March 14, 2014, I. Vardi, *L'astronomie à l'ancienne*.

Société neuchâteloise d'astronomie, Neuchâtel, October 24, 2014, I. Vardi, *L'astronomie à l'ancienne*.

FSRM, 1 Day Tutorial, Neuchâtel, S. Henein, January 24, 2014, *Conception des guidages flexibles*.

FSRM, 1 Day Tutorial, Neuchâtel, I. Vardi, December 1, 2014, *L'astronomie de la montre*.

Events

Microcity inauguration with the Council of State of Neuchâtel in corpore, May 8, 2014.

Microcity inauguration with local industry representatives, May 9, 2014.

Microcity open house day, May 10, 2014.

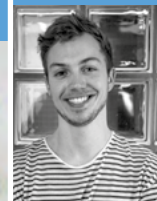
Microcity visit of President of the Swiss Confederation Didier Burkhalter with foreign ambassadors accredited in Switzerland, Senior Officials of the Swiss administration and representatives of Swiss parliament, May 15, 2014.

Microcity visit of the Swiss Federal Council in corpore, Council's traditional annual field-trip, September 8, 2014.





a



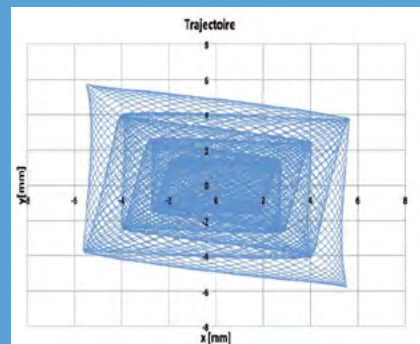
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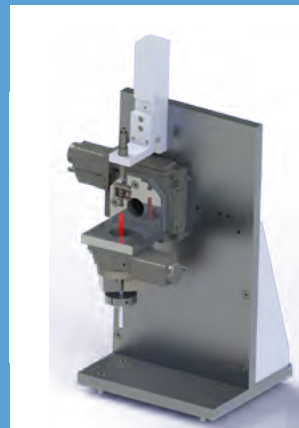
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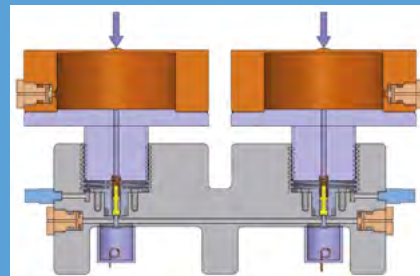
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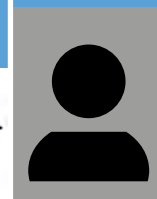
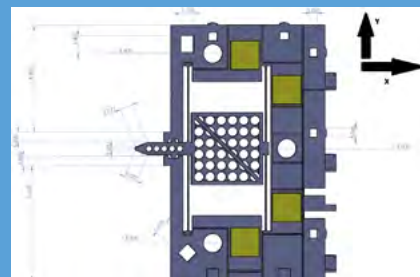
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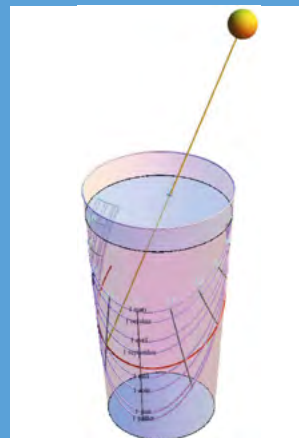
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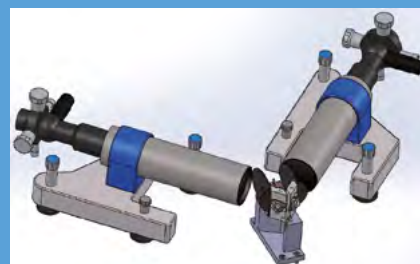
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TEACHING

The laboratory is strongly involved in teaching design. The focus is on training the creative process starting with the act of design and following up with the analytical method necessary to model, simulate and predict machine behavior.

EPFL

Mechanism Design I & II / Conception de mécanismes I & II (2014-2015)

Lecturer: Prof. S. Henein; Section: Microtechnique (92 students); Bachelor semesters 2 and 3. 3 periods per week.

Elements of mechanical design I & II / Construction mécanique I & II (2014-2015)

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 (2014)

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 and master projects at Instant-Lab

- Conception, réalisation et caractérisation d'un ressort isotrope à tige flexible, Déirdre Lenoir
- Evaluation du prototypage rapide par impression 3D pour des mécanismes flexibles, Nathan Guélat
- Watchmaking demonstrator, Romain Guénat
- Generic beacons interface, Cinthia Boissonnas
- Banc d'essai pour capteur de force à lame flexible, Michael Monney
- Mesure sur un prototype d'un nouvel oscillateur, Jorge Zarate
- Modélisation d'un cadran solaire conique, Althéa Araya
- Conception d'un insert à géométrie variable pour prothèse de genou, Maïka Guillemain
- Design of a characterisation setup for a MEMS capacitive sensor, Karim Benkara
- Design of a setup for characterisation of 6DOF MEMS alignment, Pascal Gentsch

Instant-Lab semester and master students.

Master projects abroad

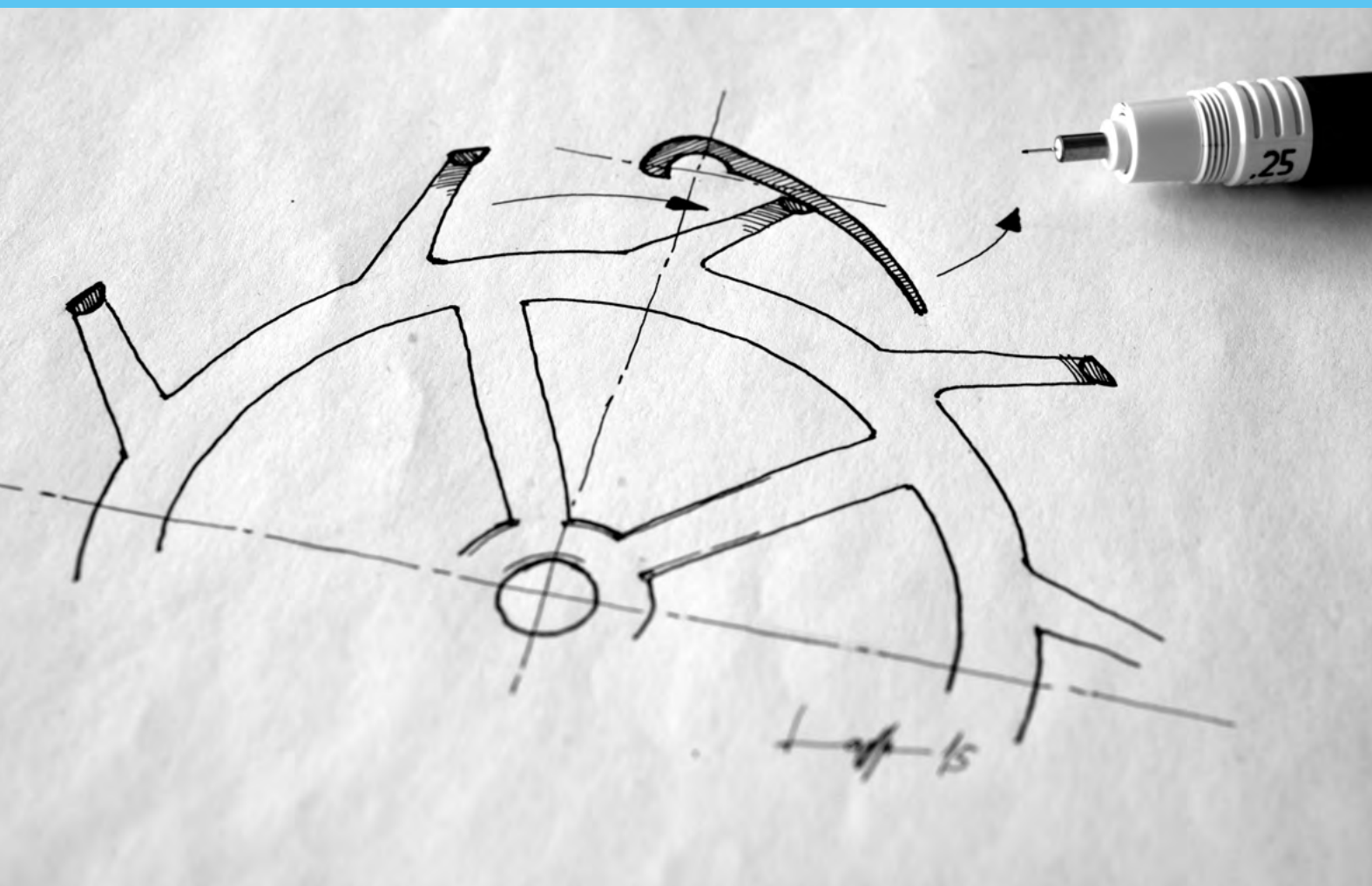
Master project monitoring in collaboration with Prof. K. Salisbury, Stanford University, The Salisbury Robotics Lab, February 2014.

Master project in collaboration with Prof. O. Khatib, Stanford University, Stanford Robotics, February 2014.

Master project in collaboration with Auris Surgical Robotics Inc., USA, February 2014.

Master project in collaboration with Intuitive Surgical Inc., USA, February 2014.

CONCLUSION AND PERSPECTIVE



In his inaugural lecture on February 6, 2014, Professor Simon Henein presented for the first time the concept of a mechanical watch without escapement as well as the proof of concept realized internally by Instant-Lab. This led to a number of patents and the rapid launch of the large scale IsoSpring industrial project. The presentation of the project at the SwissTech Convention Center in September 2014 received wide media attention.

The Instant-Lab was the first laboratory to start a project within the Audemars Piguet - EPFL framework agreement and received a CTI grant to pursue one of its key medtech projects.

Instant-Lab successfully completed its first Ph.D. and initiated two new Ph.D. projects.

The number of semester and master projects greatly increased over the previous year.

The Instant-Lab team was increased to 16 collaborators covering the full range of skills. Along with the completion of the equipping phase, the laboratory is now fully operational.

Perspective for 2015

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).

Establishment of more collaboration projects with industry.

Publication in academic journals of subjects patented in 2014 and Ph.D. results.

