FEMTO-ST 2018 ANNUAL REPORT

femto-st SCIENCES & TECHNOLOGIES

FEMTO-ST, a joint Research Institute from :

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Exploring Science and Innovation, from basic research to industries and spin-offs, from theory to experiments through high technology platforms, developing micro and nanotechnologies, increasing the density of functions and integrating intelligence for the engineering of components and systems with optimized performances, contributing to the future of a knowledge-based improved society.

I am very proud and very happy to introduce this 2018 Annual Report. Once again, this worldwide disseminated document is an important opportunity to keep our many partners updated with some of the latest scientific and technological achievements from the last year.

The FEMTO-ST institute is the largest public research laboratory in the Bourgogne-Franche-Comté region, located in eastern France, next to Switzerland and Germany. It comprises 7 scientific departments, gathering about 750 staff members (PhD students, postdoctoral fellows, technicians, engineers, administrative staff, researchers and professors). FEMTO-ST members are essentially employed by four different French public research and higher education institutions: the National Centre for Scientific Research (CNRS), the University of Franche-Comté, the National Engineering Institute of Mechanics and Microtechnology and the University of Technology Belfort-Montbéliard. The last three are now brought together under the common banner of a unique federal regional university, University Bourgogne-Franche-Comté (UBFC). Our activities obviously cover many different themes within the broad disciplines of engineering sciences, from fundamentals to applications. Each scientific department dedicates concentrated efforts to obtain world class scientific results in its own area. Beyond this internationally recognized focused expertise, we are also firmly dedicated to cross-disciplinary interactions whenever it appears relevant and with highly innovative scientific and technological breakthrough potentials.

The FEMTO-ST institute aspires to lead academically, but we also take seriously the impact in the society which is the main source of our financial support. We have tried to highlight this latter strategic and responsible ambition through a few examples of interactions with industrial partners, along with our contributions to the birth of spin-off companies, whose innovative activities are directly related to our scientific achievements and technological know-how.

I would like to thank all members of FEMTO-ST for their continued commitment, their passionate and professional contributions to our many scientific and technological successes. I wish the reader will enjoy going through this 2018 Annual Report. This document is also an invitation to join us, and share our enthusiasm in addressing new scientific challenges, discovering the unknown, and converting it into mastered knowledge and technologies for the future.

Laurent LARGER
Director of FEMTO-ST Institute
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EIPHI

THE FIRST UBFC GRADUATE SCHOOL,

COORDINATED BY FEMTO-ST, ICB AND IMB, WAS OFFICIALLY LAUNCHED IN SEPTEMBER 2018.

The University Bourgogne-Franche-Comté (UBFC) is a federal university created in 2015, whose objective is to gather at the academic level, under a unique and greatly strengthened international visibility, all higher education institutions within the Bourgogne-Franche-Comté Region. The creation of this new unified regional academic landscape is implemented through a coherent and joint restructuring of the regional research assets along three priority axes, among which the first axis is referred as "Advanced matter, Waves, and Smart systems". Within this federating initiative, FEMTO-ST (applied physics and engineering), ICB (physics and chemistry) and IMB (applied mathematics) counts as three major UBFC laboratories with high international recognition in their respective fields of research. They have jointly applied in mid-2017 to a highly selective national call of excellence, for the setting of an international Graduate School named EIPHI (e$^{i\Phi}$, Engineering and Innovation through Physical sciences High technologies and cross-dIsciplinary research). The proposals was successfully granted a M€ 14 program over 10 years.

The concept of EIPHI is to provide attractive international MSc and PhD programs of excellence, based on the scientific expertise available at FEMTO-ST, ICB, and IMB. EIPHI stands out from other French graduate schools by the fact that it aims to strongly focus on an interdisciplinary MSc and PhD teaching, training and research program targeted at high added value for the graduate students. The programs are focusing both on original and "niche" research areas (for which we are recognized as worldwide experts), as well as on their related innovative cutting edge technological solutions intended for the industry of the future. Important efforts in the program are pushed toward a synergy between theoretical skills and experimental ones. EIPHI will be strongly benefiting from several platforms and high technology facilities available in the laboratories, reaching many different high-tech application sectors (photonics, micro-robotics, energy and sustainable technologies, integrated sensors and complex smart systems, programmable matter and software integrity, RF & microwave metrology, clean room micro-nano-fabrication, advanced matter fabrication and characterization, etc.). Students are established in the labs from their 1st year of MSc, in close connection with the research teams. EIPHI Graduate School is also targeting strong links with high-tech industrial partners (at the local, national and international levels), thus claiming an important dedication toward economic and societal impacts through employability, innovation and start-up creation, exploiting and transferring the internationally renowned scientific expertise toward the industry.

The Graduate School is structured into 5 domains (Physics Maths & Applications, Energy, Computer Science, Smart Systems and Structures, Material Chemistry) proposing 9 Master programs: Physics, Photonics, and Nanotechnology (PPN); Photonics, mIcro-nano-technology, time-frequenCy metrology, and complex Systems (PICS); Mathematics for Physics (Math4Phys); Hydrogen, Energy, Energetic Efficiency (H2E); Software and System Engineering; Control for Green Mechatronics (GREEM); Mechanical Engineering (MEETING); Electrical Engineering, Components and Systems; Control and Durability of Materials; a 10th one, Internet of Things (IoT) is opening in September 2019. The PhD program covers the same scientific domains, and it is affiliated to two doctoral schools, SPIM and Carnot-Pasteur.

A BROAD RANGE OF MASTERED SCIENTIFIC EXPERTISE

FEMTO-ST IS STRUCTURED IN 7 SCIENTIFIC DEPARTMENTS IN WHICH RESEARCH TEAMS ARE WORKING.

WE ALSO ENCOURAGE PLURIDISCIPLINARY RESEARCH ACTIVITIES IN COLLABORATION BETWEEN DEPARTMENTS.

APPLIED MECHANICS

MATERIALS, SURFACES, PROCESS, STRUCTURES

MICROMECHANICS, MICROFABRICATION

FONCTIONALISATION, SMART STRUCTURES

SUSTAINABILITY, RELIABILITY, BIO-COMPATIBILITY

ROBOTICS AND AUTOMATION

MICRORobotics, MECHATRONICS

AUTOMATION

PROGNOSTIC & HEALTH MANAGEMENT (PHM)

INFORMATION SCIENCE

PARALLEL AND DISTRIBUTED COMPUTING

FORMAL METHODS FOR SOFTWARE ENGINEERING

HIGH PERFORMANCE COMPUTING

DISTRIBUTED SMART MICROSYSTEMS

ENERGY

HYDROGEN-ENERGY

ELECTROMAGNETIC CONVERTERS

THERMAL MACHINES

METROLOGY AND ENERGY MANAGEMENT

MICRO-NANOSCIENCES AND SYSTEMS

MICRO- OPTO- ELECTRO-MECHANICAL SYSTEMS

PHONONIC AND MICROSCOPY

NANOSCIENCES AND NANO-STRUCTURED MATERIALS

BIO-MICROSYSTEMS

OPTICS

NONLINEAR PHOTONIC

COMPLEX OPTOELECTRONIC SYSTEMS

NANO-PHOTONIC

TIME AND FREQUENCY

OSCILLATORS/ RESONATORS

TIME & FREQUENCY METROLOGY

MICROWAVE SYSTEMS AND SENSORS

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GRAND PRIX DE L'INSTITUT DE FRANCE FONDATION CHARLES DEFFOREY TO MINAROB TEAM

ROBOTICS AND AUTOMATION (AS2M)

The foundations hosted by Institut de France are all governed by the same philosophy of generosity, with very diverse concerns, ranging from promoting outstanding heritage (fondations-musées) to supporting innovative projects, distinguished or deserving people, or programmes with a social or humanitarian purpose.

The 2018 Grand Prix Scientique, awarded by the Charles Defforey Foundation and Institut de France, was dedicated to a French research team involved in "Mechanics, robotics and artificial intelligence".

The Biomedical Micro-Nanorobotics team from the AS2M department. Nicolas Andreff, Aude Bolopion, Redwan Dahmouche, Michaël Gauthier, Kanty Rabenorosoa, Patrick Rougeot and Brahim Tamadazte are the members (almost all below 45) of this team. The research developed in the team covers their 4 lines of investigation: contactless micromanipulation, intracorporeal dexterity, medical micromechatronics, and image-guided surgery.

On May 30th, under the famous Coupole (dome) of Institut de France, the 2018 "Grand Prix Scientifique de la Fondation Ch. Defforey-Institut de France" was received by Professor Nicolas Andreff, team head, from the hands of Jean-Paul Laumond from Académie des Sciences.

This award crowns an original positioning of the team at national and international levels, somewhere between medical robotics and microtechnologies. It also rewards the many collaborations with colleagues within FEMTO-ST Institute (all the AS2M department and, to name a few, B. Wacogne, C. Gorecki, S. Bargiel, M. Ouisse), with clinicians (CHRU Besançon, EFS Besançon, Uni. Genova, Pitié Salpétrière), with French research groups (ICube Strasbourg, ISIR Paris, INRIA Lagadic Rennes, TIMC Grenoble) and with international partners (UL Bruxelles, IIT Genova, LU Hanover, EPF Lausanne, U. Bern, SSSA Pisa, ETH Zürich).

References

http://www.institut-de-france.fr

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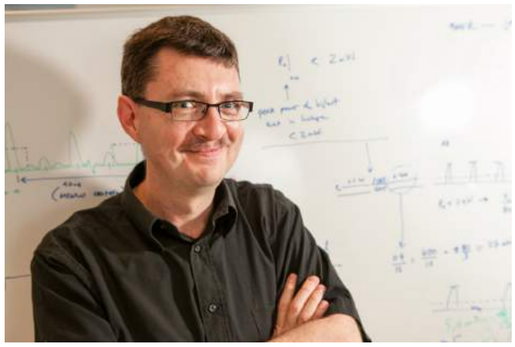
JOHN DUDLEY ELECTED FELLOW OF THE INSTITUTE OF PHYSICS

OPTICS

The Institute of Physics (IOP) is an international scientific society that works to advance physics education, research and applications. It has a worldwide membership of over 50,000, and supports a wide range of international activities to advance physics for the benefit of all.

During 2018, Professor John Dudley from the Department of Optics at FEMTO-ST Institute was elected a Fellow of the Institute of Physics (FInstP) in recognition of his scientific contributions and his commitment to education. Professor Dudley's elevation to the grade of Fellow was based particularly on consideration of his more than twenty-five year research career that has significantly contributed to the advancement of nonlinear optical physics, and his acclaimed contributions to the public understanding of science through his work driving the proclamation of the International Year and Day of Light in collaboration with UNESCO. Professor Dudley had previously been awarded the President's Medal of the IOP in 2016 for initiating the UNESCO International Year of Light that reached millions of people in over a hundred countries.



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VINCENT LAUDE,2018 OUTSTANDING APS REFEREE

MICRO-NANO SCIENCES AND SYSTEMS

The Outstanding Referee program was instituted in 2008 to recognize scientists who have been exceptionally helpful in assessing manuscripts for publication in the journals of the American Physical Society (APS). By means of the program, APS expresses its appreciation to all referees, whose efforts in peer review not only keep the standards of the journals at a high level, but in many cases also help authors to improve the quality and readability of their articles – even those that are not published by APS. The selection for this achievement is always difficult and APS expresses its appreciation to all referees that help make the Physical Review collection some of the most cited physics journals in the world.

The 2018 honorees come from 29 different countries, with large contingents from the U.S., Germany, the U.K., Canada, and France. Vincent Laude was one of the ten selected scientists from France, and the first honoree for the Bourgogne Franche-Comté region.

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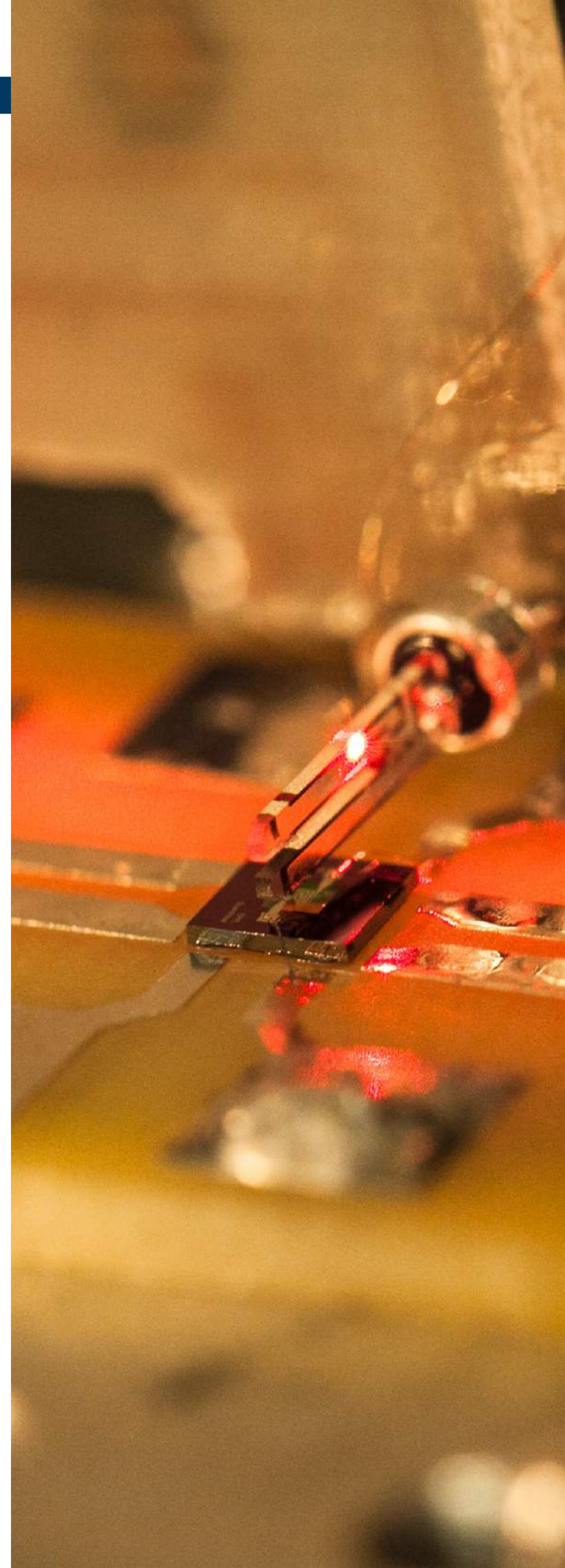

RENEWAL OF THE FRENCH-SWISS PARTNERSHIP WITH EPFL

ALL DEPARTMENTS

FEMTO-ST Institute and EPFL research activities show a lot of synergies and potential collaborations in various fields such as micromanufacturing, advanced optics, time&frequency, microsystems & micromechatronics. In order to identify, initiate and start innovative projects, both institutions have signed a French-Swiss academic Alliance named SMYLE Collegium: SMart sYstems for a better LifE in 2013.

In 2018, the alliance has been renewed for the next 4 years in order to strengthen their partnerships. Christophe Gorecki (France) and Pierre-André Farine (Switzerland), pioneers and historic presidents of the SMYLE Collegium handed the presidency over to Michaël Gauthier (France) and Yves Bellouard (Switzerland). FEMTO-ST Institute would like to thank the two funders of the SMYLE Collegium for their impressive support to promote French-Swiss collaborations.

The SMYLE Collegium is funding networking activities and concrete projects between both institutions linked with research activities, teaching activities and industrial transfer. The scientific collaborations have provided results in several fields such as (i) the development of High precision MEMS micro-clocks, (ii) new methods for advanced robotic micromanipulation dedicated to cell sorting, (iii) the study of integrated photonic micro nano-components on chip. The partnership deals also with the establishment of new, common educational contents between Switzerland and France. The first idea is to open the PhD or master courses of one side to students of the other side. The second idea is to build new courses or summer school based on French-Swiss complementarities. Moreover, the SYMLE Collegium is supporting networking activities between academic laboratories and industries.

The future challenges for the SMYLE Collegium is to initiate projects in new fields such information science, energy and mechanics. The annual budget is also going to be doubled in the next year thanks to Swiss-French INTERREG Program.

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https://www.femto-st.fr/en/Partnership/Institutional-and-academic-partners/international-collegium-smyle

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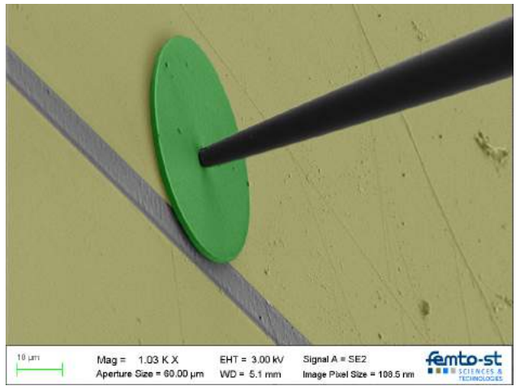
PHOTONIC MICROSYSTEM MADE BY DYNAMIC MICRO-ASSEMBLY

OPTICS & ROBOTICS AND AUTOMATION (AS2M)

The optics and AS2M departments of FEMTO-ST Institute propose disruptive photo-robotic strategies for dynamically assembling 3D hybrid photonic systems. In particular, low-loss 3D LiNbO3 fibered resonators -developped in the framework of A. Caspar's PhD thesis- have been presented in Cancun for the 19th International Symposium on Optomechatronic Technology, and the presentation has been awarded the « Innovation in Optomechatronic research » price.



Lithium niobate (LiNbO3) microresonators have attracted much interest over the last decade, due to the electro-optical, acousto-optic and non-linear properties of the material, that can be combined with thin resonances for applications as varied as integrated gyroscopes, spectrometers or dynamic filters. However, the integration of micrometer scale cavities with a waveguide is still a critical issue. A tapered fiber coupled with a microdisk is too fragile to be a commercial solution.

We propose a robust integrated resonator, with insertions losses lower than 3 dB, by retroactively assembling a pig-tailed low-loss microguide and a microdisk. Firstly, a low-loss microguide with spot-size-converters [3] is fabricated through standard techniques followed by local thinning by a circular precision saw. Then, the disks are produced through Focused Ion Beam milling. Finally, a micro-actuated needle grips the disk and places it accurately at the waveguide top while measuring the transmission response. The disk is fixed to the microguide with naphthalene rods. These developments open the way to a new generation of 3D hybrid photonic systems.

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OUR MICRO-HOUSE AMONG THE 20 BEST IMAGES OF THE YEAR FOR NATURE JOURNAL

ROBOTICS AND AUTOMATION (AS2M)
& MICRO-NANO SCIENCES AND SYSTEMS

Following an article published in the Journal of Vacuum Sciences and Technology (JVST A) in May 2018, the publisher, the American Institute of Physics (AIP), issued a press release entitled "the World's Smallest House". The press release was the trigger for a media rage around the world.

The image of the "smallest microhouse" has been considered by the scientific journal Nature, among the 20 best images of the year 2018 (1st rank) as a demonstration of "extreme downsizing, using nanoassembly tools — a focused ion beam, a gas-injection system and a tiny, manoeuvrable robot — to build this 20-micrometre-long house from silica."

We counted more than 350 articles, and all the articles were published in more than 65 countries. The micro house gave rise to 2 two other TV shows on the French television channel France 3 on June 21 at 7pm and June 22 at 1pm, an interview with AFP (the French Press Agency) with shots taken, 6 six radio shows, including one live appearance on local radio station France Bleu.

The micro house was broadcasted on the radio station RMC in the show "Bourdin Direct" at 6:55 am on August 07, relayed by the journalist Nina Godart. This same show was broadcasted again on August 12 at 1pm on BFM TV, a 24-hour news channel.

National Education Minister Frédérique Vidal also sent a congratulatory tweet in July.

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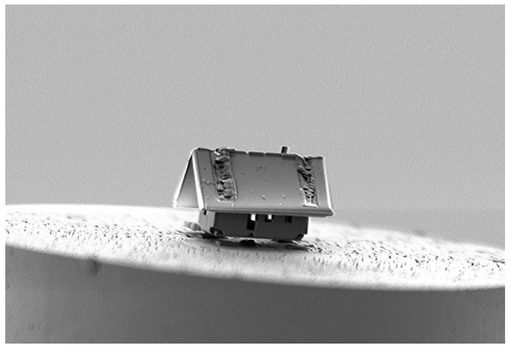

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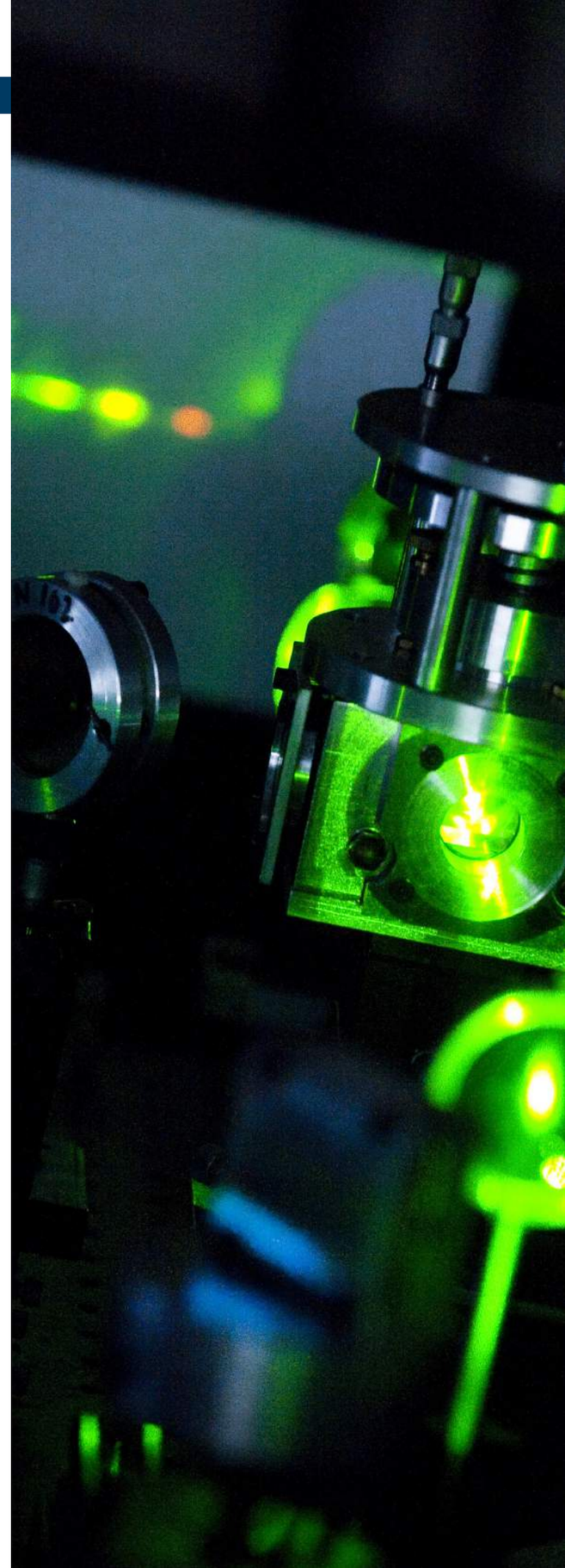

OUTSTANDING CONTRIBUTIONS TO THE OPEN DATA INITIATIVE

ROBOTICS AND AUTOMATION (AS2M) & APPLIED MECHANICS

The NASA Group Achievement Award is a prestigious NASA certificate awarded to any combination of government and/or non-government individuals for an outstanding group accomplishment contributing substantially to NASA's mission. Emmanuel Ramasso was part of the "multi-center Systems-Health & Operations Open-Data Team" (at NASA AMES center, directed by Dr. Kai Goebel) which received this award "For outstanding contributions to the open data initiative by conducting and posting experimental system fault and run-to-failure data sets with exceptional scientific value".

The team designed and conducted unique, difficult to produce, and eagerly sought run-to-failure experiments across diverse engineered systems. The data sets, posted on public repositories, have been downloaded thousands of times by industry researchers, educators, and students worldwide and used to advance research and shorten commercialization time for products in Systems Health Management and Predictive Analytics. The team's efforts directly support the Open-Data Initiative, the Open Government Initiative and the NASA Open Government Plan, encouraging data release as a driver for economic growth.

These data sets are being used for benchmarking algorithms and advancing the state-of-the-art in novel methods for systems health management. Several open "data challenge" competitions were carried out under the guidance of team members. The paper (Ramasso et al., 2014) summarized the impact of a single data set (simulated deterioration of a turbo-fan engine) on the research community, underlying that, just six years after posting, more than 70 peer reviewed journal and conference papers had been produced using the data. The team also developed and released research support tools to give the users objective and independent feedback on the utility of their specific solution, and posted metrics and several analytical tools as open source codes for educational or research purposes.

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PHOTOGRAMMETRIC AERIAL IMAGE PROCESSING FOR POLAR GLACIER MONITORING

TIME & FREQUENCY

Since 2007, a close collaboration between the geographers and hydrologists of the TheMA laboratory and the Time & Frequency department of FEMTO-ST Institute has focused on investigating a polar glacier as a detailed model of the impact of current climate changes on an Arctic region.

Among the technical developments involved in this collaboration, beyond automated digital cameras and subsurface Ground Penetrating RADAR bedrock mapping, using small Unmanned Aerial Vehicles to systemically collect high resolution aerial pictures provides the dataset needed to generate accurate – sub-decimeter resolution – Digital Elevation Models (DEM) by Structure from Motion (SfM) image processing. Thus, the glacier, well suited to interpolation of a few local measurements thanks to the smooth surface, is now considered as part of the full basin including slopes and moraine, both of which are hardly compatible to interpolations due to the rough topography.

As a complement to terrestrial LiDAR – more accurate but more expensive and hence challenging to deploy in a hostile environment, SfM is used to assess yearly snow cover and geomorphological evolutions, as well as changes over decades by georeferencing all models with respect to a common framework based on ground-control points. In this article, the geomorphological evolution of the moraine is assessed in the context of increased liquid precipitations and rising temperatures. Furthermore, the new bed followed by the sub-glacial river due to an ice plug provides insight into the morphological dynamics of areas of the moraine newly freed from ice following glacier retreat. This research activity keeps on being supported by a Bourgogne Franche-Comté regional grant over the 2018-2021 period since the tools developed in the framework of Arctic research are applicable in the framework of the Jura area morphological and snow cover monitoring investigations.

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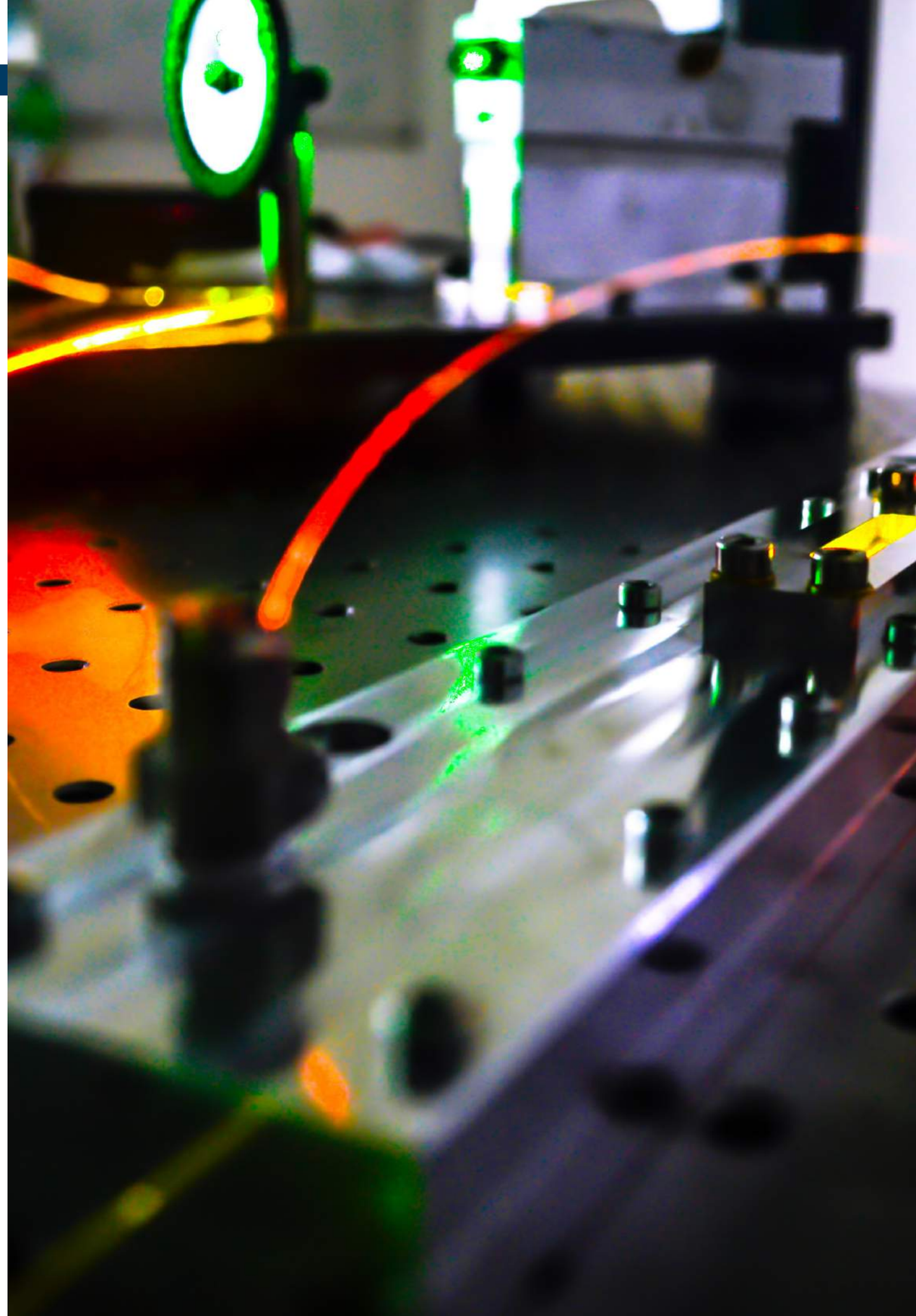

HIGHLIGHTS

A DISTRIBUTED SELF-ASSEMBLY PLANNING ALGORITHM FOR MODULAR ROBOTS PRESENTED AT AAMAS 2018

INFORMATION SCIENCE

In this work, we target modular robots composed of many homogeneous modules with limited computing resources that can change the way their modules are connected by releasing or docking some of them in order to create a given shape, thus creating intelligent objects. One of the most interesting capability of a system of modular robots is the ability of the modules to move towards a different position, that way changing the global shape or morphology of the whole. This is called self-assembly or even self-reconfiguration when the modules are always connected during the process.

Self-reconfiguration and self-assembly are hard problems for three reasons. First, the number of possible unique configurations for a modular robot is huge: $(c.w)^n$ where n is the number of modules, c the number of possible connections per module and w the ways of connecting the modules together. In one example studied in this article we have 61,780 modules, so there are $(12x12)^{61,780}$ possible unique configurations for our 12 neighbors modular robot considering isomorphic configurations.

Second, as modules can move or dock at the same time, the branching factor of the tree describing the configurations is $O(m^k)$ with m being the number of possible movements and k the number of modules free to move. Third, as a consequence of the previous reason, the exploration space of a reconfiguration between two situations is exponential in n which prevents it from finding a complete optimal planning.

In this paper, we presented a distributed algorithm assisted by a shape description to create close-packed structures and assemble any morphology. This algorithm is composed of simple rules given to all robots and according to our simulations, creates different shapes without any blocking position even for complex structures. We showed that this algorithm can have many simultaneous docking positions, can accelerate the creation of a model and uses only a linear number of messages.

AAMAS is a A* ranked conference, top 4% in the 2018 CORE ranking.

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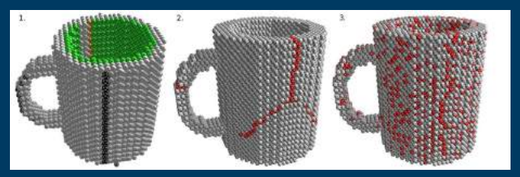

Importance of sequence planning shown on a Mug model made by 12,000 modules. Red modules represent modules that could not have been docked. 1. Using our algorithm, all modules have been docked. 2. Regularly filling each module neighborhood in sequence results in 231 positions that could not be filled 3. Choosing a stochastic order produces 3,691 blocked positions.

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SAIAD (SEGMENTATION OF KIDNEY TUMOURS IN CHILDREN USING DISTRIBUTED ARTIFICIAL INTELLIGENCE)

INFORMATION SCIENCE

Nephroblastoma (kidney tumour) is the abdominal tumour most frequently observed in children, representing 5 to 14% of malignant pediatric tumours. Its diagnosis is based on image processing.

Image segmentation is a hot topic in image processing research. Most of the time, segmentation is not fully automated, and a user is required to guide the process in order to obtain correct results. Yet, even with programs, it is a time-consuming process. In a medical context, segmentation can provide a lot of information to surgeons, however this task is time-consuming due to manual execution and that is the reason why it is rarely used.

The purpose of the SAIAD project is to define a platform based on different AI (artificial intelligence) tools dedicated to the segmentation of kidney tumours in children. We have integrated Deep learning tools, commonly used segmentation algorithms and also an original process based on Case-Based Reasoning (CBR) that can enhance region-growing segmentation. The main problem with region-growing methods is that a user needs to place the seeds in the image manually. Automated methods exist but they are not effective every time and they often give an over-segmentation. That is the raison why we have designed an adaptation phase which can modify the coordinates of seeds recovered during the retrieval phase without any human intervention. Our CBR system succeeded in performing the best segmentation for the kidney, even better than Deep learning methods. Our implementation of Deep learning revealed itself to be better than all the other methods for tumour segmentations. This work received the Best Student award in the International Conference on Case-Based Reasoning 2018.

Our efforts are now concentrated on the enhancement of the Deep learning tool and on the definition of a 3D fusion method of all the obtained segmentations in order to automatically create a 3D representation of the patient's abdomen.

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The SAIAD project is financed by the INTERREG France-Switzerland 2014-2020 program and is sustained by FEDER (520,223.28€), INTERREG Switzerland (132,900€) and Neuchatel canton (90,000€).

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SEVEN DEGREES OF FREEDOM PARALLEL MICROROBOT

ROBOTICS AND AUTOMATION (AS2M)

A new seven degrees of freedom (DoF) soft parallel microrobot was developed in the AS2M department. The proposed robot is the first parallel microrobot that integrates, within its structure, the gripping function simultaneously with six handling mobilities (three translations and three rotations). All the mobilities and the gripping are controlled by the movements of eight actuators located on the robot's base. This arrangement allows high manipulation dexterity with an extremely compact structure (~1cm^3 in volume and a mass of ~50 mg).

The structure of this microrobot was microfabricated thanks to the development of a new process. This method made possible the integration of a large variety of elastomers into silicon structures microfabricated in a clean room. The robot joints are thus made of an elastomer (PDMS) to be able to highly downscale the robot dimensions, eliminate the mechanical backlash and friction while providing large movement ranges especially in rotation (x20 higher than the literature). These properties allow the robot to reach high positioning precisions and high translation and rotation ranges inside confined spaces.

The applications of this 7-DoF micromanipulator are related to: (1) the manipulation and assembly of small components, especially in watchmaking and aerospace industries, (2) minimally invasive surgery, (3) the manipulation inside scanning electron microscopes (SEM) to assemble and characterize nano-objects (nanowires, nanotubes, photonic crystals, etc.).

The Micron d'Or prize was awarded to this work at MICRONORA 2018 (international microtechnology trade fair).

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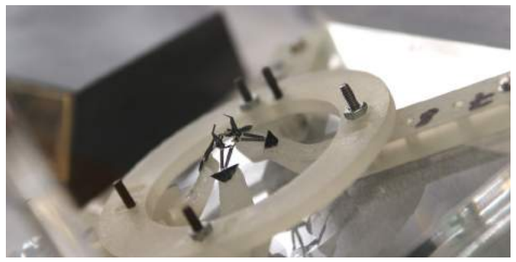

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µD² PROJECT – PRE-HARDENED AND PRECISE MICRO-COMPONENTS

APPLIED MECHANICS

After 3 years of collaborative work within the MiFHySTo micro-manufacturing platform, researchers from the µfab team of the Applied Mechanics Dept. and industrial partners developed a new strategy for precision Swiss turning of steel micro-components. It is now realistic to machine workpieces presenting submillimeter dimensions and micrometric precision directly in hardened steels. This approach was developed in the context of the regional smart strategy for innovation (RIS3) in Franche-Comté and supported by European FEDER and French BPI funds. It allows us not only to drastically reduce the deformations and the non-quality issues after final thermal treatment, but also to integer finishing operations such as rolling or burnishing in the same machine and set of operations.

The study was focused on the manufacturing of watch movement micro-components made in pre-hardened steels (hardness up to 50 HRC). Instrumented tests conducted in the laboratory permitted to characterize targeted micro-cutting operations such as micro-turning or micro gear shaping, and then the quality of produced workpieces through dedicated non-contact metrology procedures. Industrial tests conducted in industries and the laboratory were dedicated to machining strategies and production rate optimization, as well as to tool life analysis. The best configurations were then identified in terms of tools, coatings, trajectories, depths of cut, speeds and cutting fluids. Hundreds of micro-components have been produced with a tolerance of a few microns and surface roughness of quality class N6 (Ra < 0,8 µm) or even N5 (Ra < 0,4 µm) for some tests.

Current prospects target an extended tool life (thousands of workpieces with a set of tools) through a complete redesign of the cutting tools. In this objective, the local micro-geometry of the tool can be studied but also the type of materials used for substrate and coating and finally some innovative surface preparations on the tools.

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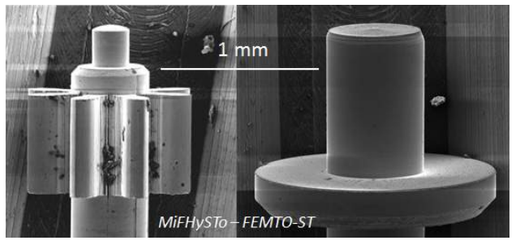

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INTEGRATING HYDROGEN ENERGY INTO MICROGRIDS

ENERGY

Microgrids are small power systems which typically include energy sources, storage units and loads, and can connect to the main grid or operate autonomously. Contrary to other storage technologies, hydrogen energy storage, combining an electrolyzer with tanks and a fuel cell, enables long term storage, which helps maximize the use of renewable sources with seasonal trends. Another advantage is the possibility to use the produced hydrogen for transportation applications, e.g., in fuel cell vehicles.

The SHARPAC team (Measurement systems, production, conversion, storage of thermal and electrical energy, fuel cell systems) and the FCLAB research federation (Fuel Cell Lab) are participating in three projects focused on this topic: DATAZERO (The French National Research Agency) aims to design data centers solely powered by renewable energy; HAEOLUS (Horizon 2020 Fuel Cells and Hydrogen-Joint Undertaking 2) focuses on the valorization of hydrogen produced from wind energy in remote areas; and RECIF (The French National Research Agency) intends to develop and implement microgrids for insular applications with an innovative coupling between electricity and cold generation.

With the development of local renewable electricity generation, microgrids may constitute a relevant building block of tomorrow's electricity grids. These projects contribute to tackling the challenges of integrating hydrogen energy storage in microgrids. They especially address the energy management, the system design and sizing, and diagnostics and prognostics of electrochemical devices.

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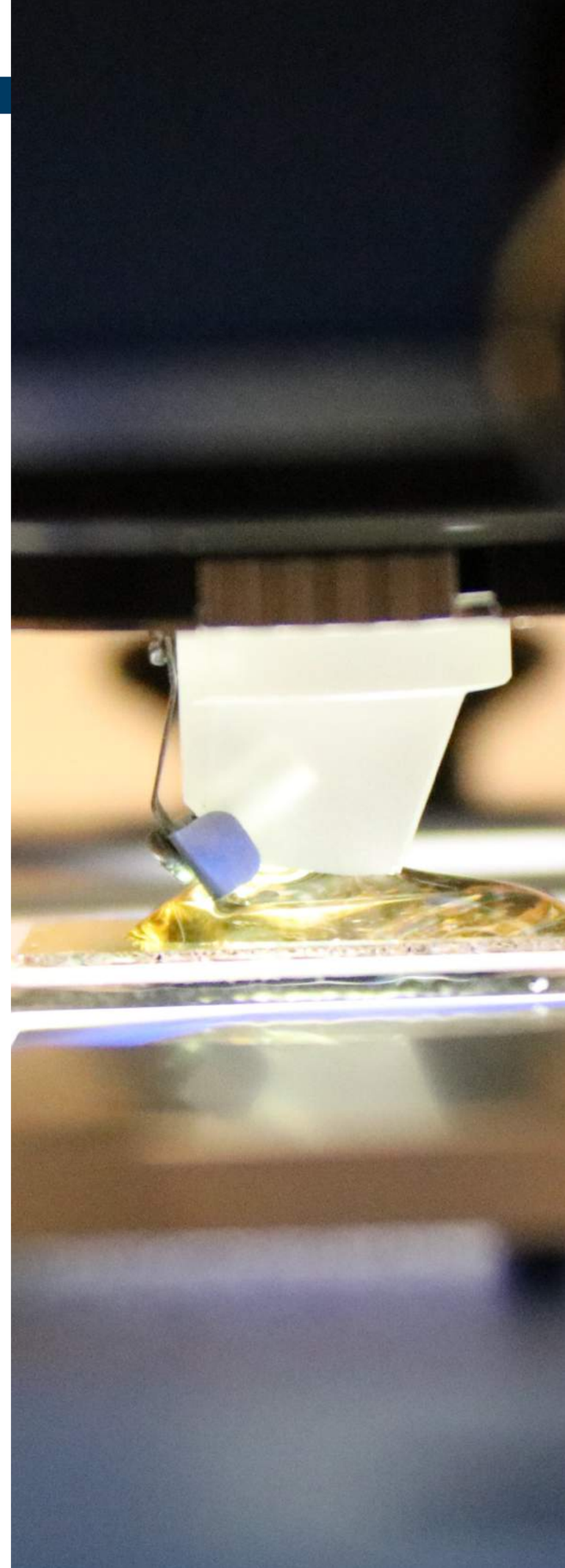

LIGHT-ASSISTED ON-SURFACE POLYMERISATION

MICRO-NANO SCIENCES AND SYSTEMS

On-surface polymerization of organic precursors provides new possibilities to form highly-stable and atomically-defined nanostructures with desired properties. This issue has been addressed by many research groups who performed on-surface reactions under ultra-high vacuum (UHV) conditions and on atomically clean single-crystal metal substrates. In this solvent-free environment, classical chemical reactions such as Ullmann type coupling, have successfully been used to create well-defined and covalently bound organic 1-D and 2-D structures with dimensions of about 100 nm. However, for the basic building blocks of molecular circuitry to interconnect active devices there is a need to fabricate isolated nanowires with a length larger than 1 µm. Other than length, the main limitations of structures fabricated to date for use in future nanoscale electronic and optical devices are (i) the use of metal substrates, (ii) the high number of defects in the formed covalent structures, and (iii) the side-products of some reactions that might remain on the substrate surface. This is why, in our work, we overcome these identified obstacles by using a side product-free 1-D polymerization on an alkali-halide surface. This new concept is driven by light-induced radical polymerization which has never been transferred onto the surface of bulk insulators so far. After the deposition of molecules on the KCl surface, the growth of the fibres is provoked by UV-light illumination. This process is only stopped by either surface defects. Highly-ordered and long nanofibres are formed due to the fact that the UV-induced radical polymerization is chain-like, that it is guided by molecule-substrate interaction, and that the reaction takes place in a diluted 2-D gas phase acting as a reservoir of the precursor molecules. Noncontact atomic force microscopy was used to evaluate the geometrical structure of the fibres formed on the KCl substrate and to test both their mechanical and thermal stability.

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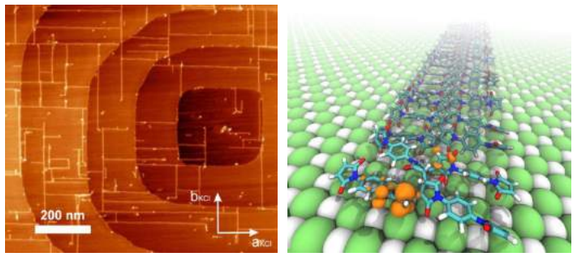

On the left, nc-AFM image recorded at room temperature showing nanowires obtained by UV-light illumination of molecules on a KCl surface. On the right, adsorption model of nanowires on a KCl surface.

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ARTIFICIAL INTELLIGENCE WITH LIGHT

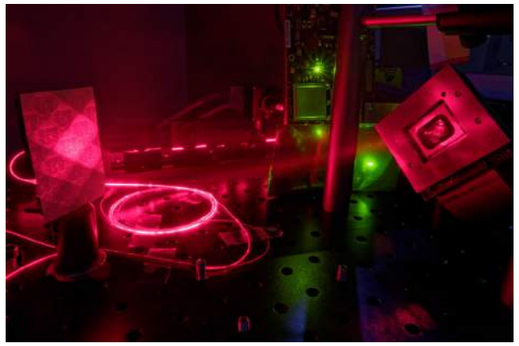
OPTICS

Neural Networks are at the heart of artificial intelligence and its many societal applications in medical diagnostics, automatic translation and autonomous vehicles. However, because neural networks require multiple parallel linkages between a large number of elements, their implementation using classical electronic hardware is energetically inefficient and scales poorly with network size.

To address this problem, research in optics department is pioneering the use of light as the medium to connect the nodes of highly-scalable complex photonic networks. Using inexpensive lasers and readily-available optical components, it becomes straightforward to couple together hundreds or even thousands of photonic elements to perform the complex computations of a neural network. In two publications during 2018, we performed research using proof-of-principle photonic networks.

Our double-delay network has demonstrated the existence of fundamental complex structures known as chimeras. In chimeras, two contrary network states coexist at once: chaotic dynamics and coherent motion. This work was published in the journal Chaos and covered by the AIP Scilight.

We also created spatio-temporal nonlinear photonic networks of so-far unreported size and scalability. Based on diffraction, the network consisted of 900 photonic elements and is scalable up to 30,000, which is sufficient for even the most demanding neural network applications. Based on micro-mechanical spatial modulators, we realized reinforcement learning and trained the photonic neural network to predict a chaotic signal. These results were published in Optica, and an image of the system's photonic learning layer was featured on the journal's cover image.



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WHEN PHOTON SPIN TALKS TO PLASMON ORBIT

OPTICS

In addition to its energy, light possesses polarization and spatial degrees of freedom, manifested by its linear momentum as well as spin and orbital angular momenta. Remarkably, spin and orbital momenta are not independent quantities; the spin (circular polarization) can tailor the spatial distribution and propagation direction of light (via the orbital angular momentum). This phenomenon, known as spin–orbit interaction (SOI), has recently attracted much interest for applications involving light manipulation. It offers new prospects in the development of a polarization-controlled tunability in plasmonics, thus unlocking the full potential of small scale optics.

The optics department recently introduced a new concept of an SOI that enables tunable unidirectional waveguiding in optical nanocircuits. Such a concept is based on the conversion of the spin angular momentum of a diffraction-limited incoming wave to the extrinsic orbital angular momentum of surface plasmons confined and conveyed in a 50-nm wide waveguide. Using this idea, they demonstrated the first dynamically controllable optical circuitry on the nanoscale.

This research group has also demonstrated the first optical SOI solely driven by the magnetic field of light. The optical magnetic field is often considered to be a negligible contributor to light-matter interaction. However, with the advent of nanophotonics, this hidden side of light has recently been revealed at the expense of the development of complex resonant optical nanostructures. Using SOI, the magnetic field of light has been revealed for the first time without any magnetic optical resonators. Because only the helicity of the magnetic optical field is involved, this magnetic effect is clearly visible even with simple dielectric nano-elements whose optical properties are governed by a pure electric dipole moment. Such a magnetic optical SOI thus offers the opportunity to consider the magnetic field of light as a new degree of freedom in the design of tunable integrated optical functionalities.

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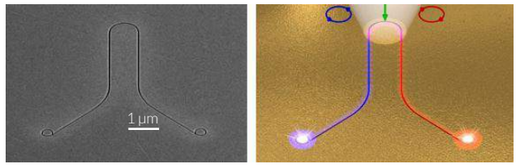

Left : Scanning electron micrograph of the first tunable optical nanocircuit

Right :Schematic diagram of the polarization-controlled tunable directional waveguiding in the nanocircuit.

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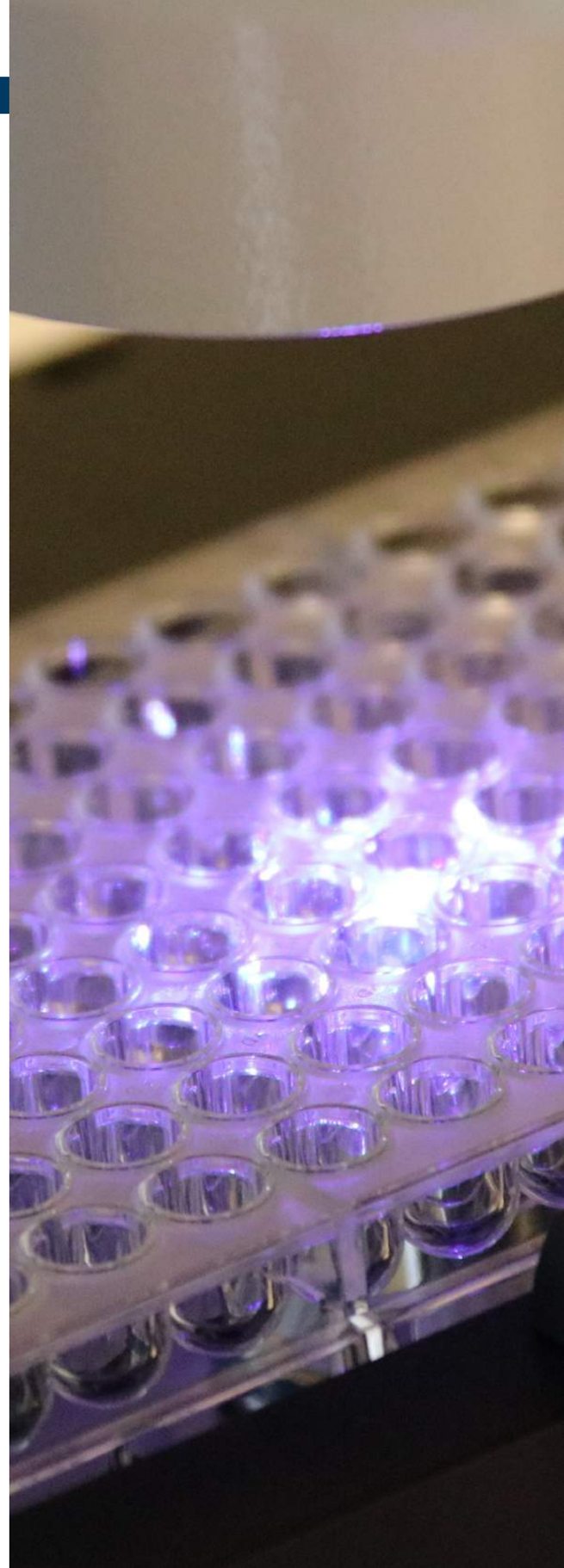

HIGHLIGHTS

ULTRAFAST LASER SCIENCE AND APPLICATIONS

OPTICS

The recognition of ultrafast lasers in the 2018 Nobel Prize for Physics has also placed the spotlight on a major area of research at FEMTO-ST Institute. In particular, the physics of ultrashort light pulses and their applications has developed into an important area of study, focusing both on fundamental areas of light-matter interactions as well as significant applied research and industry collaborations. Work in this area at FEMTO-ST Institute has attracted both national and international interest over the last ten years, and indeed we were greatly honoured in 2016 to be visited by Gerard Mourou, one of the 2018 Nobel Prize laureates.

During 2018, this field of research at Optics Department has seen two particular successes. One result that has attracted major attention were experiments using a new real-time measurement technique to completely characterize the birth of ultrashort pulses in a mode-locked fibre laser. This work was published in Nature Photonics during 2018 and was selected by the Optical Society of America as one of only 30 highlights from all areas of optics in their Optics in 2018 issue of Optics and Photonics News.

Another major success was the award of a new Horizon2020 European Project kW Flexiburst which is being coordinated by FEMTO-ST Institute. The consortium is led by François Courvoisier and comprizes 7 academic and industrial partners. The project aims to develop a high repetition rate burst laser emitting sub-picosecond pulses with average power exceeding 1 kW, and apply this to high speed micro-manufacturing. The project begins in 2019 and has received a total of 5.1 M€ funding over four years.

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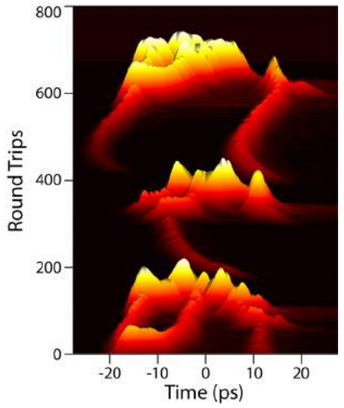

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ION TRAP FOR SINGLE-ION OPTICAL CLOCK

TIME & FREQUENCY

The Time and Frequency department has successfully demonstrated the trapping and cooling of single Yb^+ ions, within the MITICC project of compact single-ion optical clocks. Our prototype trap, made using a standard printed circuit board, allows stable trapping using a combination of RF and DC voltages, while lasers cool down the ion using the radiation pressure force (a technique also known as Doppler-cooling). We can deterministically load single-ions or multi-ion chains, where the charged particles, cooled down well below 10 mK, form a line along the trap nodal line (see picture). A new trapping chip is currently being fabricated at the MIMENTO cleanroom facility. Based on standard microfabrication techniques, it will have the advantages of better electrodes surface quality, smaller inter-electrodes gaps, and better ultra-high vacuum compatibility.

With this experimental success, FEMTO-ST Institute is now among the four French laboratories that master ion trapping and cooling, and among a European community of 32 ion trappers groups, structured within a European COST network. Laser cooling is at the heart of atomic, molecular and optical physics with both neutral and charged particles an even broader field with an impact both in theoretical and technical domains.

The new trap will be the heart of a compact single-ion optical clock, with potential applications in fundamental Time-and-Frequency metrology, relativistic geodesy, and fundamental physics. It will be connected to the growing network of European optical clocks through the REFIMEVE+ network, which interconnects metrology institutes and laboratories using stabilized optical fiber links.

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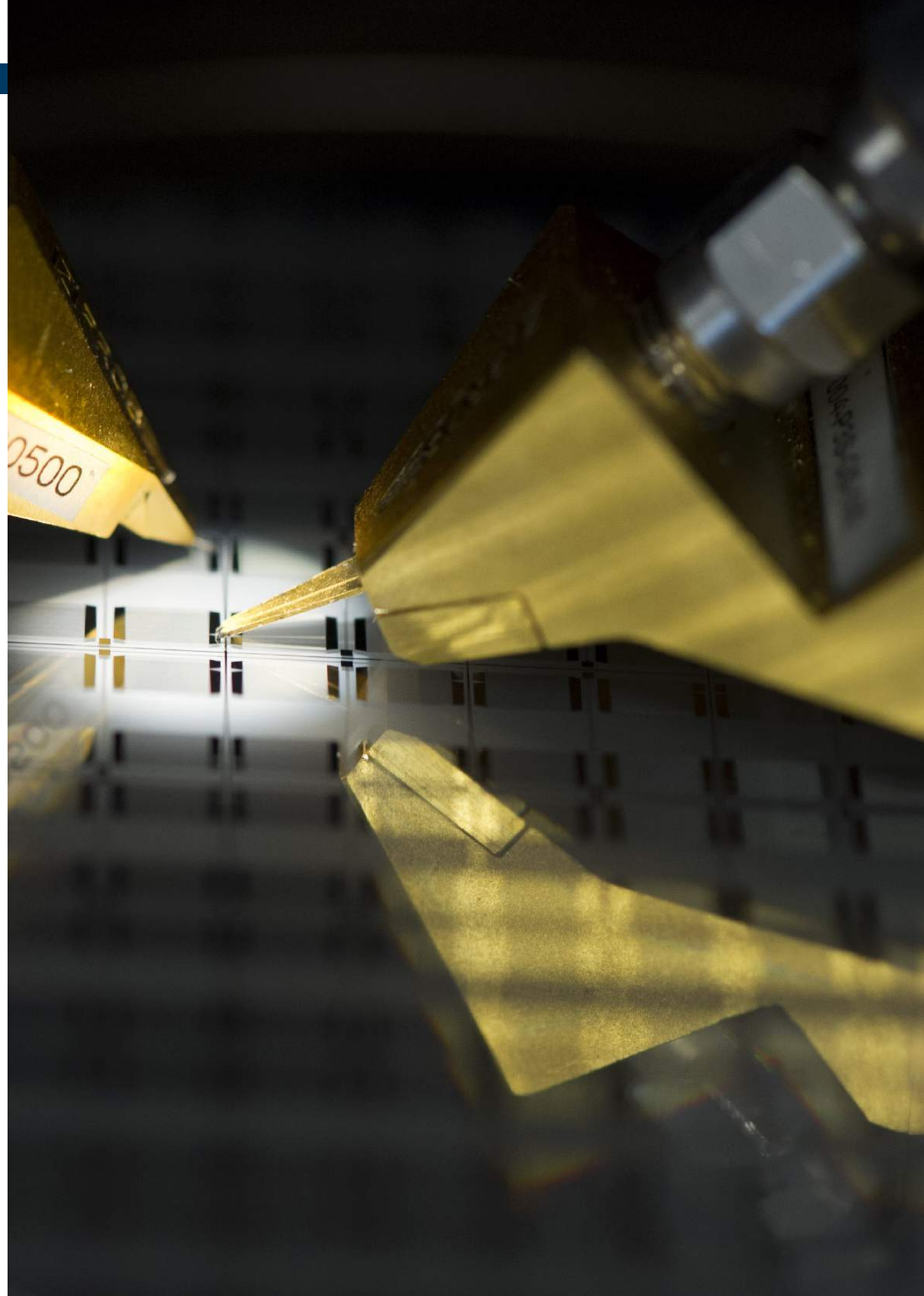

THESIS AWARDS

A. AGNE, METAL POWDER INDUSTRIES FEDERATION THESIS AWARD

APPLIED MECHANICS

The Metal Powder Industries Federation (MPIF) is a federation of six trade associations representing various aspects of powder metallurgy (PM), metal powders, and particulate materials. His mission is to advance the interests of the metal powder producing and consuming industries. Throughout its long history, the MPIF has been a champion of this innovative technology, providing our member companies with valuable services that help advance the art and science of powder metallurgy, while promoting technological benefits to prospective end users.

The Metal Powder Industries Federation holds international conferences in the spring of each year, providing a forum for exchanging information on the latest scientific and technical developments in the field of powder metallurgy. The MPIF conferences bring together scientists, engineers, and researchers from academia, industry, and government laboratories to share results, transfer technology, and discuss issues on related topics through a variety of formats, such as oral presentations, poster sessions, and panel discussions.

The MIMA Conference Grant and Prize Committee selected Mr. Aboubakry Agne, PhD Student of the University of Bourgogne - Franche-Comté, as one of the candidates to receive MIMA Conference Grants in 2018 to present his work on supercritical debinding. The award was to be used to help support the costs of attending MIM2018 held from March 5 – March 7, in Irvine, CA (USA).

The debinding or binder extraction of a component obtained by Metal Injection Moulding (MIM) can be performed in two steps, first by using solvent debinding in order to extract the organic part of the binder and then by thermal degradation of the rest of the binder. The debinding via a supercritical fluid is recently investigated to extract organic binders contained in components obtained by Metal Injection Moulding in order to reduce the debinding time. To understand the phenomena, the supercritical extraction was modelled and numerical simulations by finite-element were presented in order to predict binder distribution of all components obtained by Metal Injection Moulding1.

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M. LIBSIG, ASSOCIATION AÉRONAUTIQUE ET ASTRONAUTIQUE DE FRANCE THESIS AWARD

ENERGY

The Thesis Prize 2018 of the “Association aéronautique et Astronautique de France” has been awarded to Michel Libsig. His thesis, entitled "Flow Control for an alternative artillery projectile steering" has been developed with the French-German Institute of Saint-Louis (ISL) and FEMTO-ST Institute. Every year, this prize rewards a young researcher that has performed a thesis in the field of aeronautics and space.

Michel Libsig has proposed original solutions to perform supersonic projectile steering. Starting from an original idea, he has been able to test it on a free flight validation campaign after a whole study of the actuator design. The award jury particularly appreciated that he took advantage of the different complementary aerodynamic research tools, namely numerical simulations, wind tunnel tests (and the different associated measurement methodologies) and free flight tests, which results to a very original thesis.

This prize has be delivered to Michel Libsig, PhD Student of the University of Bourgogne - Franche-Comté, on October 28, 2018 in the Salon de l'Aéro-Club de France (private reception room of the French Aeronautics Club) in Paris by Christian Mari, emeritus member and president of the high scientific council of the 3AF (The French Aeronautic and Astronautic Association).

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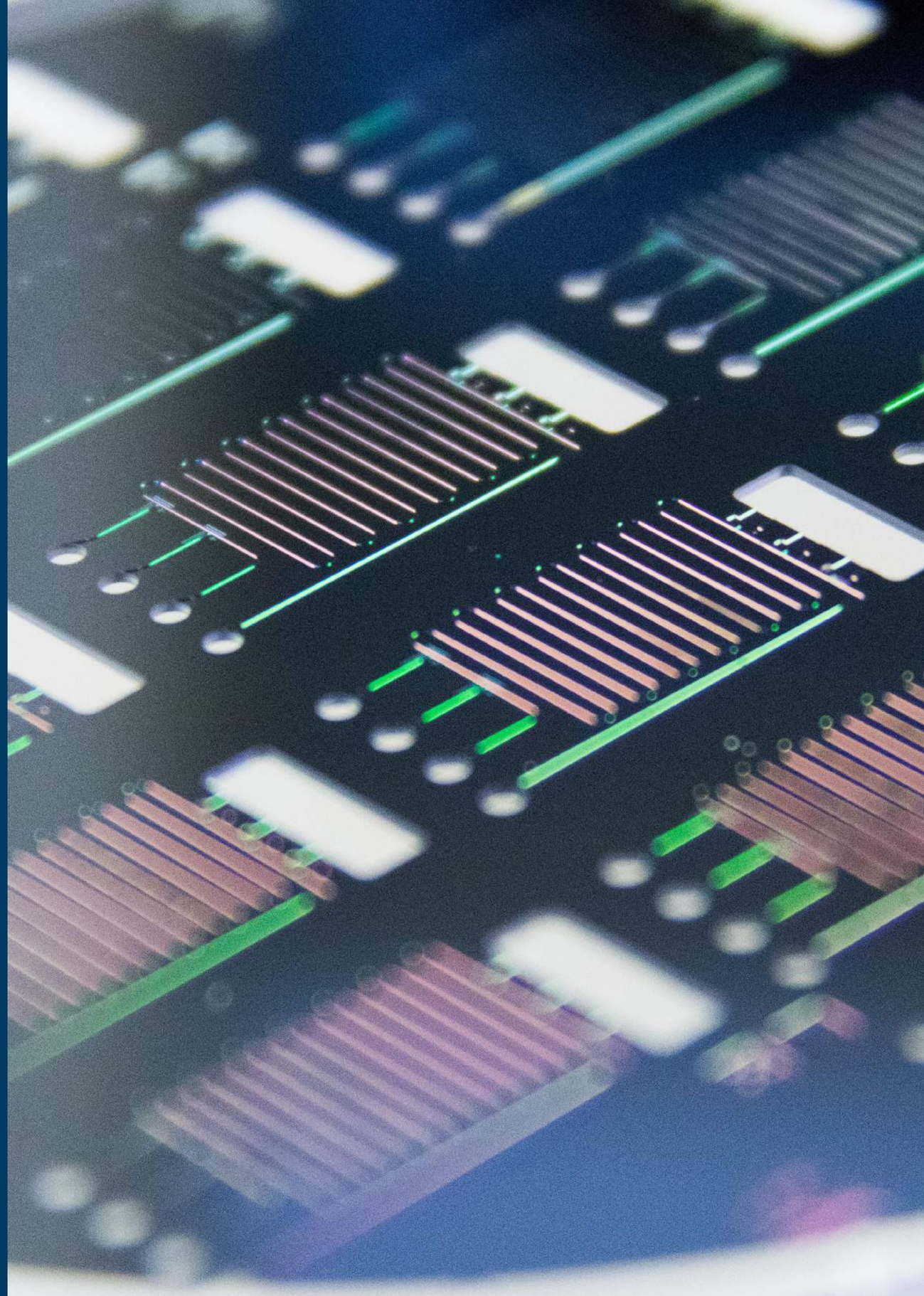

THESIS AWARDS

J-A. SEON, FRENCH ROBOTIC COMMUNITY (GDR ROBOTIQUE) THESIS AWARD

ROBOTICS AND AUTOMATION (AS2M)

For a human, grasping an object in human scale is common, but it is very hard in micro-nanoscale because of the lack of human grasping capabilities in small scales. In order to open the door of the micro-nanoscale to humans, AS2M department is studying robotic in-hand micromanipulation systems and methods in order to enable humans to grasp, move and rotate micro-nanocomponents with the same dexterity as the human hand in macroscale.

In microscale, robotic manipulations are usually limited to simple pick and place operations, and accurate rotational positioning of micro-objects is currently particularly difficult to obtain. Indeed, the dominant forces in microscale are different than in macro-scale: adhesion forces overcome gravitational and inertial forces. This physical originality generates a new scientific paradigm for robotic in-hand manipulation in which new methodologies dedicated to the microscale have to be developed (robotic hand design, finger planning and trajectory control).

Jean-Antoine Seon, PhD student of the University of Bourgogne - Franche-Comté receives the 2nd PhD price in robotics delivered by the French robotic community (GDR Robotique) for their contributions in this field in Novembre 2018,. He worked on the study of the impact of adhesion forces on optimal finger trajectories and developed of an original trajectory planner for in-hand dexterous micro-manipulation. The trajectories, currently limited to planar movement, have been tested and validated experimentally on micro-objects. The results show that optimal finger trajectories in micro-manipulation are significantly different than the trajectories in macro-manipulation where adhesion can be neglected.

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R. VIALA, "JEAN LESBATS" THESIS AWARD

APPLIED MECHANICS

The building of musical instruments is traditionally based on craftsmanship and rigorously selected natural materials. Stringed musical instrument makers acquire knowledge and skills through years of training and practice. Nowadays, the arrival of sophisticated manufacturing processes or low-cost human labour combined with the shortage and cost of woods has created a highly competitive environment for the production of new, handmade instruments.

Historically, the physics underlying the behaviour of musical instruments have been studied primarily using analytical or experimental methods. These approaches are useful in understanding global tendencies, but are not well adapted for detailed study of the impact of design modifications on the instruments' dynamic behaviour. Moreover, traditional approaches are generally limited by the irreversibility of structural modifications and the high cost of raw materials and construction time.

The virtual prototyping, whose use has widely increased in industrial domains, is a potential tool for instrument makers to modify their designs without spending time and precious resources in test builds. This enables screening analysis, design optimization, and uncertainty quantification for complex, dynamical systems.

Our study explores the potential of virtual prototyping in its application to stringed instrument making in the dynamical domain, and proposes decision support tools.

In the field of this project, both experimental and numerical means have been deployed to develop geometrically accurate numerical models of stringed instruments (violins and guitars), and evaluate the mechanical properties of the woods used in instruments making. One of the main results of this project is the ranking of the impact of design, presets, material and climatic conditions on the dynamical behavior of musical instruments. Especially, the prevalence of fine design choices over the overall variability of the tonewood has been highlighted.

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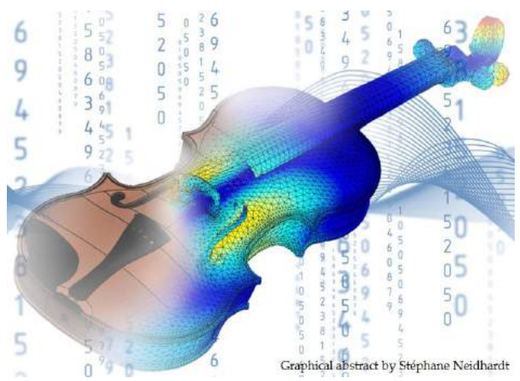

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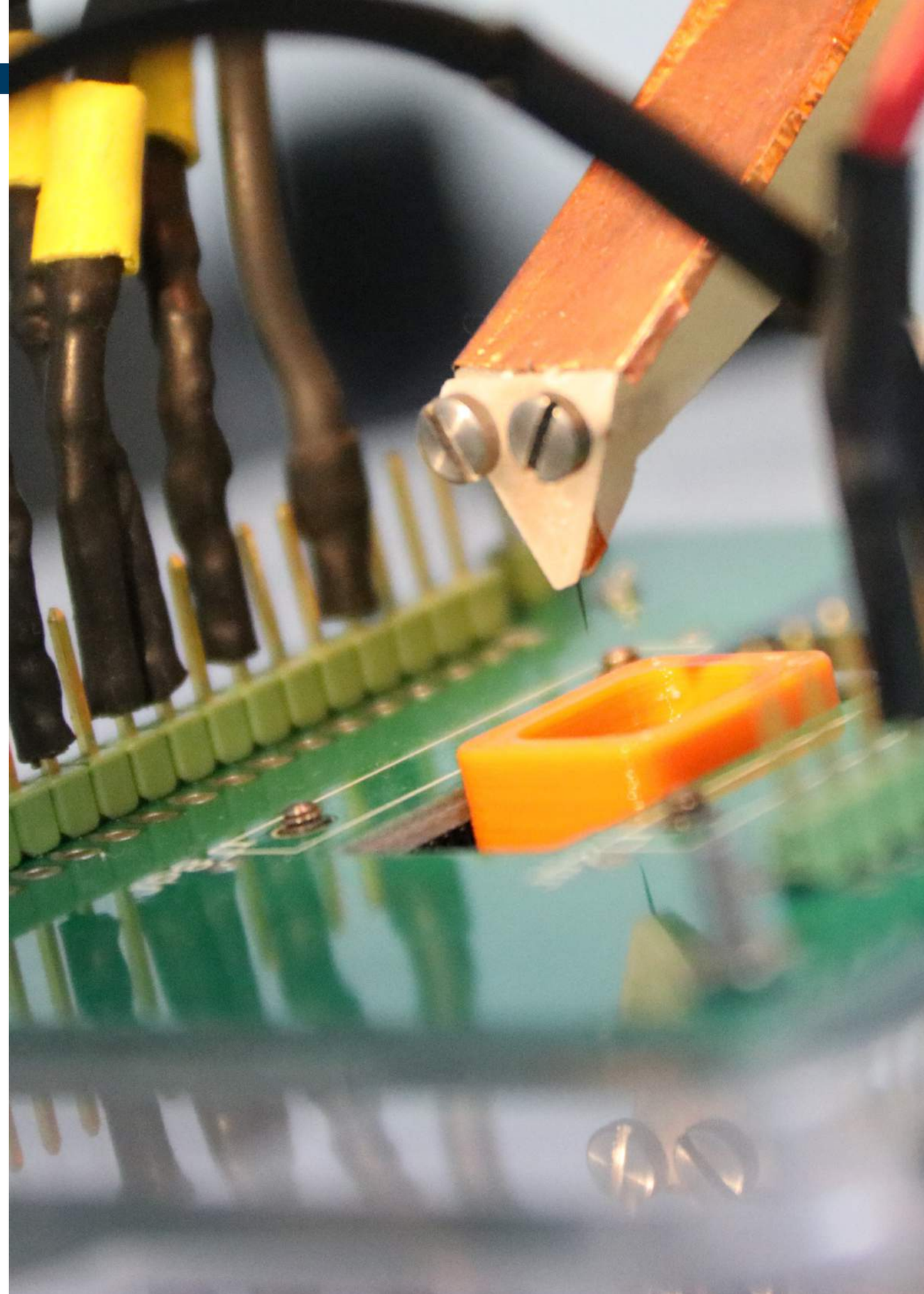

E. PAHON: YOUNG RESEARCH HYDROGEN EUROPE AWARD

ENERGY

Hydrogen Europe Research deserved an award to young scientists contributing to the three pillars of the European Hydrogen and Fuel Cells Joint Undertaking: transportation Systems, energy Systems and cross-cutting activities. Applicants must be young researchers, not older than 35 and must demonstrate their personal contribution to at least one FCH-JU project.

On 14 November 2018, Elodie Pahon in post-doctoral position in the SHARPAC research team (Hybrid & Fuel Cell systems, Electrical Machines) and a member of FCLAB, The Federation for Fuel Cell Research, won the HER Transport Pillar award for "her high-level works that aim developing the monitoring, diagnostic, prognosis and smart control approaches dedicated to improve the durability of fuel cells with no additional cost for the system."

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M.DELEHAYE: SINGLE ION OPTICAL CLOCK

TIME AND FREQUENCY

Marion Delehaye just joined the OHMS team (Oscillators, Clocks, Metrology and Systems) of the T-F Department as a CNRS (French National Center for Scientific Research) researcher. After predoctoral studies at the Ecole Normale Supérieure, she made her PhD at the Kastler Brossel Laboratory on ultra-cold Bose-Fermi mixtures. She joined FEMTO-ST Institute in 2016 as a post-doctoral researcher to work on a compact, single-ion optical clock, in a team led by Clément Lacroûte and contributed to the observation of the first trapped ultra-cold ions at FEMTO-ST Institute in May 2018. Her skills mainly concern experimental atomic physics and metrology, and include lasers, atomic cooling, ultra-high vacuums, time and frequency metrology and data analysis.

Her CNRS project is the realization of an ultra-stable superradiant laser, enforcing the OHMS tradition of innovative, ultra-stable oscillators at the best worldwide level. Optical atomic clocks now perform measurements at the 18th decimal. These outstanding performances pave the way towards numerous applications, from the search of dark matter of gravitational waves emitted by the early Universe, to the improvements of telecommunications procedures. However, optical clocks partly rely on ultra-stable Fabry-Perot cavities, the residual thermal noise of which limits the performances of the most stable clocks. To reduce this thermal noise, solutions such as the operation in a cryogenic environment have been set up, but they will not follow the long-term miniaturization of optical clocks. Another option consists in realizing an active optical clock. It is a laser in the so-called superradiant regime, where atoms are located inside the ultra-stable Fabry-Perot cavity. This releases the constraints on the stability of the cavity by several orders of magnitude and should lead to a striking improvement of the stability performances, while showing unrivaled miniaturization perspectives.

She will take advantage of the knowledge of FEMTO-ST Institute in various domains, starting with optics and TF metrology, and including MEMS components and mechanical simulation.

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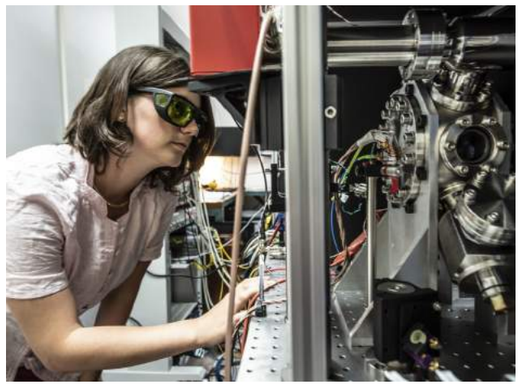
http://teams.femto-st.fr/equipe-ohms/



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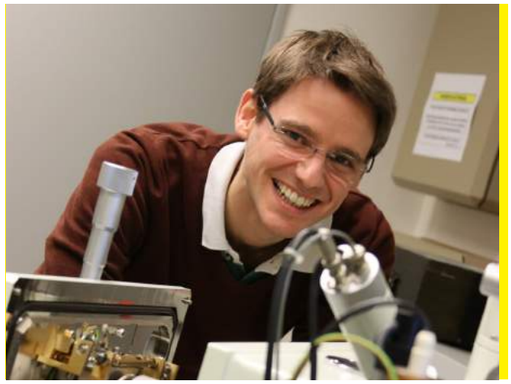
G.COLAS: MECHANO-CHEMISTRY FOR TRIBOLOGY

APPLIED MECHANICS

Guillaume Colas has recently joined the TFCS research group (Materials, Surfaces, Processes & Structure) of the Applied Mechanics Department as a CNRS researcher (French National Center for Scientific Research). After his predoctoral studies at both the Engineering Institute ENSMM and the University of Franche-Comté, he made his PhD at LaMCoS (Contacts and Structures Mechanics Laboratory), at INSA Lyon (National Institute of Applied Science), to work on the tribology of thin coatings for space application. After his PhD, in 2013, he kept working on space tribology at LaMCoS as a Postdoc. Then, in 2014, he joined the NMML (NanoMechanics and Materials Lab) research group in the MIE Department (Department of Mechanical and Industrial Engineering) of the University of Toronto, Canada to work on the nanotribology and nano-/micro-mechanics of various materials (thin coatings, 2D materials). In 2018, he joined FEMTO-ST Institute to work on the tribology in the blanking manufacturing process. Thus, he developed skills in the research areas of multiscale tribology, tribochemistry and multiscale mechanics.

His CNRS project concerns the robustness of tribological materials towards environmental variations, with an emphasis on the mechano-chemistry phenomena occurring in real interfaces. The project aims at (i) predicting the friction and wear behaviour of the materials based on their response to environmental changes through the creation of an experimentally based predictive model, and (ii) designing new tribological materials. The project will contribute to reduce the environmental, health, and industrial costs of friction and wear. Guillaume will conduct tribological work in multiple environments (from ultrahigh vacuum to atmospheric pressure, in dry and humid atmospheres) and micro-characterization of materials (mechanics and physics-chemistry). His project aims at tackling the biggest challenge in tribology: "the complexity of direct measurements and inseparability of various multiphysical mechanisms in real interfaces". To succeed, he will build on FEMTO-ST Institute's multidisciplinary research domains, starting with tribology and surface functionalization, micromechanics, data processing and microsystems.



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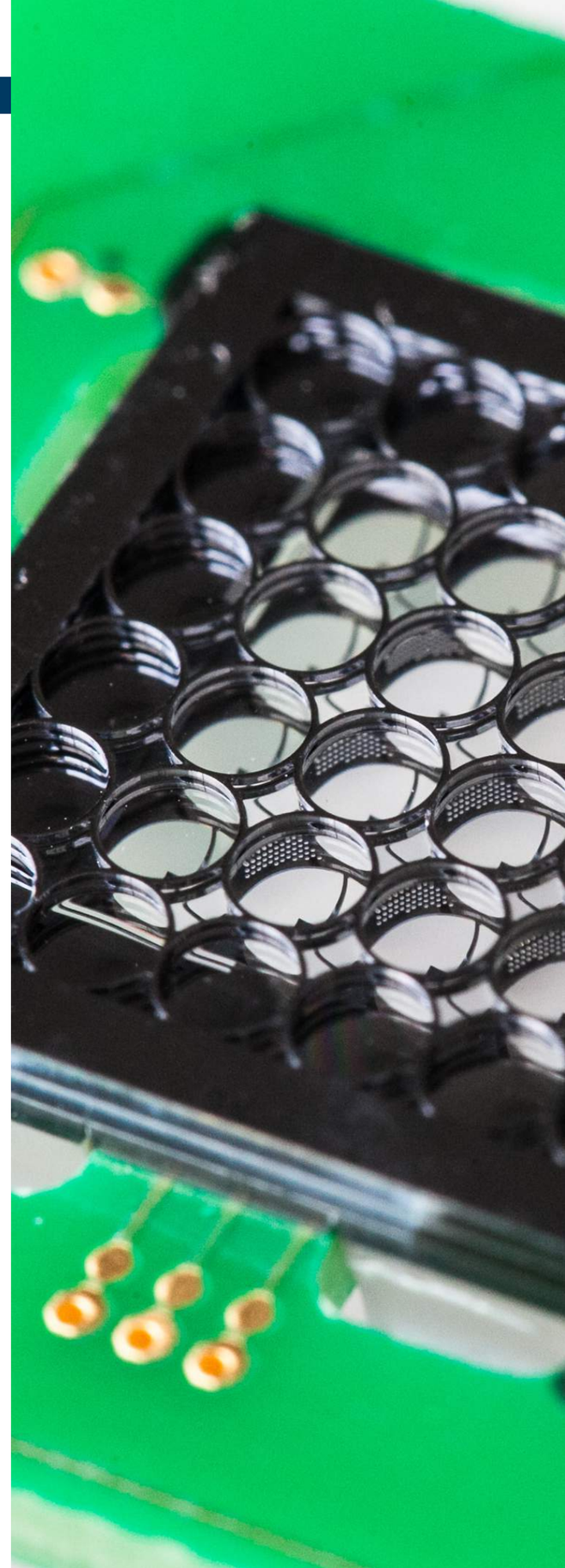


FOCUS ON MEMBERS AND TEAMS

NANOROBOTICS TEAM

ROBOTICS AND AUTOMATION (AS2M)

Micro and nano-scales are unbelievably concentrating scientific and technological challenges, but strongly lacks methods and experimental tools. In this scope, the nanorobotics team has been created one year ago to conduct ground-basis investigations through a robotics approach that is disruptive at these scales and that consists in the characterization, manipulation and assembly of single components. Our works notably target objects ranging from 10 nm to 10 µm and aims at achieving complex tasks, i.e. typically controlling the translations and rotations of objects, with high positioning accuracy (10 nm has recently been demonstrated).

To achieve this goal, team members notably investigate:

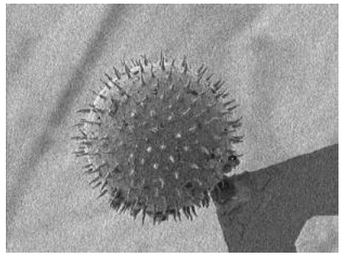
- innovative robotic designs notably based on soft, origami or polyarticulated robot architectures integrating smart materials based actuation and sensing

- original control and manipulation strategies including smart, adaptive and collaborative control approaches

- the demonstration of high performances tasks (dexterous, accurate, high dynamics...) especially in severe environments such as within a Scanning-Electron-Microscope.

The works investigated by the team have already demonstrated very nice achievements such as Dexterous, a new parallel microrobot, the fabrication and assembly of complex origami structures at the tip of optical fibers, and the succeed in the high accuracy dynamic assembly for integrated optics.

Works also highlight a high transverse and applicative potential for both scientific and industrial fields, through the mechanical characterization of plant fibers using robots (with the Applied Mechanics Department), the assembly of nanophotonic components and circuits (with the Optics Dept.), providing new ways for metrology through robotics (with the Applied Mechanics Dep.), as well as the investigation of new robotic principles or the dynamic solicitation of nanotubes (with the MN2S dep.).



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OMNI TEAM DEVELOPS ACTIVITIES IN TRANSPORT AND MOBILITY

INFORMATION SCIENCE

The OMNI team (mobile networks, distributed systems, verification and validation of software and embedded devices), initially mainly focused on programmable matter, has started a new research axis on transport and mobility. It includes 9 researchers including 5 UFC (University of Franche-Comté) researchers and 4 UTBM (Belfort-Montbéliard University of Technology) researchers who have integrated FEMTO-ST Institute in 2018. Their arrival thus reinforcing the skills of the axis in the internet of things and optimization and operational research in the areas of communications and logistics, and more widely of networks.

This new transport and mobility axis focuses on modeling, analysis, performance evaluation, simulation and the optimization of the flow of people, goods and/or data. The challenges of this research activity are related to the sizing, allocation, programming, parameterization and optimization of all resources used in transport, infrastructure and communications in a context of sustainable development. These issues are of a spatial and temporal nature, in relation with the quality of service and they depend on the mobile entities concerned.

Concretely, the team is involved in the optimized planning of vehicle routes for the distribution of goods and the location and sizing of warehouses to optimize the transport of goods in a supply chain. In the framemork of future smart cities, they work on the dynamic routing of people in a transport network, and the optimization of multi-path routing protocols in a network without infrastructure.

The applications are wide: from smart cities with new urban mobility, to the factory of the future, and alos includes communication systems and the internet of things. As an example, several collaboration projects are focused on new mobility models and global urban travel optimization algorithms, centered on communicating systems for mobility.

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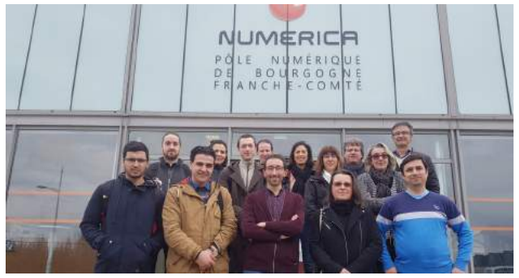

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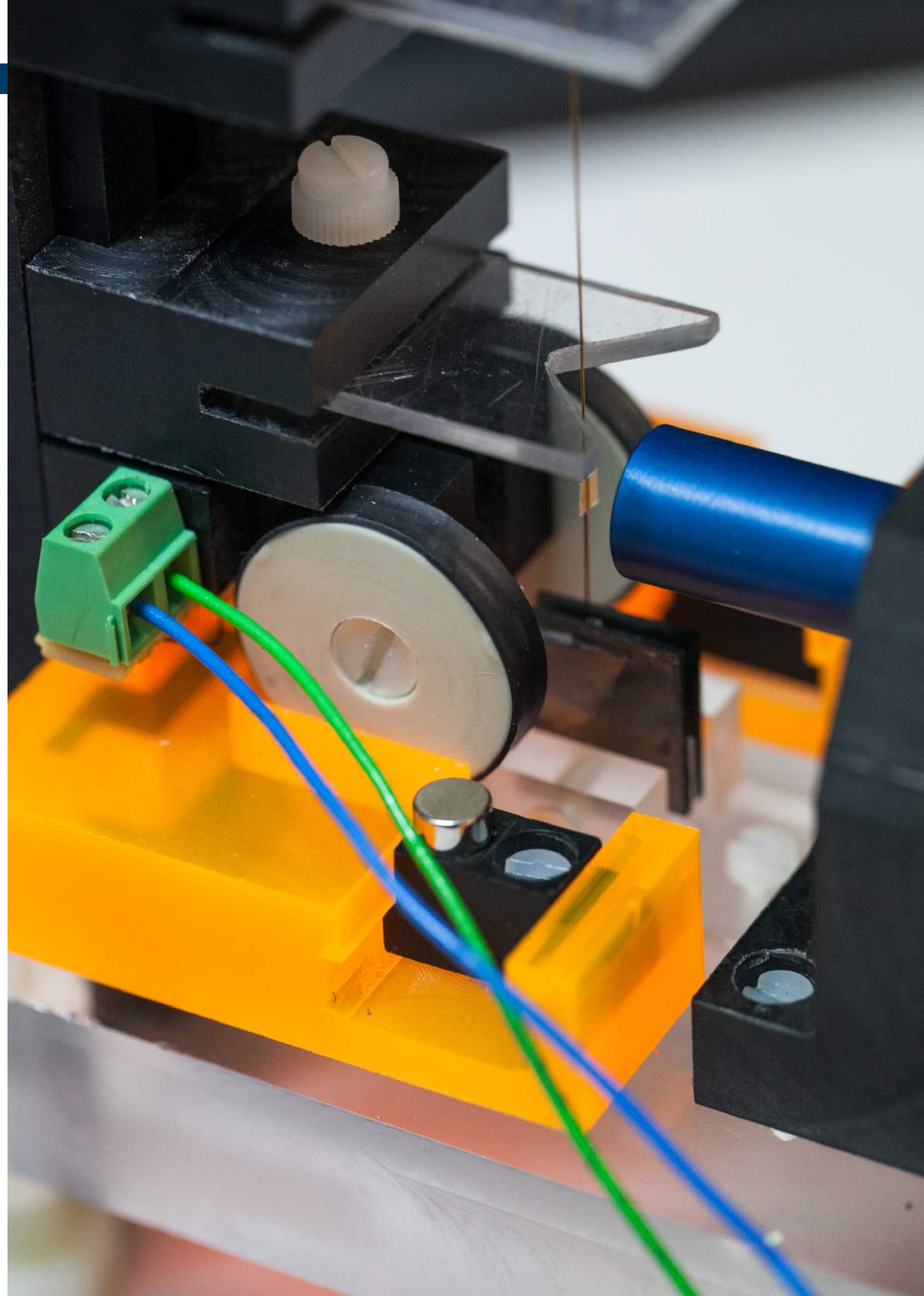

EVENTS ORGANISATION

SCANNING PROBE FRONTIERS IN MOLECULAR 2-D ARCHITECTURE WORLDS

MICRO-NANO SCIENCES AND SYSTEMS

The main scope of this symposium is about gathering the international community involved into the development and advancement of an atomic scale description of molecular assemblies through scanning probe microscopy (SPM) techniques. SPM are mostly used to describe structural properties of assemblies, but they are also used to probe more specific properties and to support strategies for building 2-D molecular systems with new functionalities. The property description with SPM may go from the simple structural imaging of a molecular island on a surface to a more accurate determination of the intermolecular energy within the units of this island, and possibly its growth mechanism. The emergence of SPM techniques that are coupled to a spectroscopic (FTIR, Raman, XPS, etc.) probe may reveal additional information related to electronic, electrical, magnetic or vibrational properties of assemblies at the atomic scale. The improved knowledge and understanding of intermolecular interactions obtained from SPM also contribute directly to the strategy for creating more specific molecular building blocks, for designing and producing well-defined assemblies, and for predicting the influence of new functionalities of modified molecular building blocks. This symposium strongly encourages the presentation of experimental and theoretical works that explore and contribute to extent the limits of SPM techniques.

This symposium was organized in June 2018 during the spring meeting of the e-mrs, hold in Strasbourg. Fréderic Chérioux (FEMTO-ST) was one of the four co-organizers of this symposium. One hundred persons, including all the international leaders of this field of research contributed. In addition, Fréderic Chérioux was guest-editor of a special issue of Chemical Communications was published, including the main contributions presented during the symposium.

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INTERNATIONAL CONFERENCE ON EMERGING AND RENEWABLE ENERGY: GENERATION AND AUTOMATION

ENERGY

UTBM (Belfort-Montbéliard University of Technology), UFC (the University of Franche-Comté) and UBFC (Burgundy-Franche-Comté) Universities, FEMTO-ST Laboratory and FCLAB (Fuel Cell Lab) research federation from France organized ICEREGA'18 (International Conference on Renewable Energy) in Sousse, Tunisia from the 28th to the 30th of October 2018. This event aims at gathering scientists and engineers from academia and industry to discuss the latest techniques in the broad field of renewable energy, energy management and transportation applications. ICEREGA'18 provides the opportunity for PhD students and young researchers from both academia and industry to meet and discuss with distinguished professors.

In ICEREGA'18, 123 submissions have been received from 23 countries. There were 67 accepted papers with an acceptance rate of about 54%. The contributions are from: Algeria, Tunisia, France, Lebanon, Portugal, Saudi Arabia, Spain, the United Arab Emirates, Egypt, Italy, Oman, Fiji, Iran and India. During the three days event, there were 11 oral presentation sessions besides two poster presentation sessions. Different prestigious journals such as: Renewable and Sustainable Energy Review, International Journal of Hydrogen Energy, Electricity, Energy Procedia etc have supported ICEREGA18 participants to publish their high-quality papers. In this ICEREGA'18, the keynote speakers are invited from three different continents with different professional scientific experience and backgrounds.

Three plenary speaks presented outstanding talks

- Dr. A. Al-Muhtaseb from Sultan Qaboos University, Oman has presented the speech "biofuel production from agricultural waste biomass available in arid areas".
- Prof. Dr. J. J. Suñol from University of Girona, Spain has introduced to the participants "materials for energy: soft magnetic, magnetocaloric, hydrogen storage".
- Dr. A. Rhif from University of Carthage, Tunisia highlighted the interested research topic "advanced control techniques for uav systems".

During the conference, a half-day social event has been assigned for visiting Marina El-Kantawi and the medina old city of Sousse.

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EUROPEAN OPTICAL SOCIETY BIENNIAL MEETING (EOSAM) 2018

OPTICS

The first topical meeting dedicated to tapered optical fibers for light manipulation at the nanoscale was organized during the annual meeting of EOS (European Optical society), held in Delft in the Netherlands from October 8 to 12. Jean-Charles Beugnot (FEMTO-ST Institute) and Sylvie Lebrun (Institut d'Optique) acted as co-chairs.

The focus of the topical meeting was to explore new trends and applications of tapered optical fibers with diameters close to or smaller than the optical wavelength. These micro/nanoscale waveguides are attractive for tight light confinement, generation of strong evanescent fields, dispersion design, or enhancement of surface effects.

New developments on in tapered optical fibers from fundamental physics to application devices were presented. Topics included the design, the simulation, and the fabrication of tapered optical fibers. Nonlinear optical effects and laser applications in tapered optical fibers were discussed, as well as tapered fibers embedded in different materials (polymers, metals, ...) for the realization of complex systems (plasmonic fiber, optomechanics at the nanoscale, etc.).

Four plenary speakers presented outstanding talks:

- Sile Nic Chormaic (OIST Graduate University, Japan) Ultrathin Optical Fibre Applications from Atomic Physics through Quantum Optics to Particle Manipulation,
- Yuliya Semenova (Dublin Institute of Technology, Ireland) Whispering Gallery Modes in Optical Fiber Micro-Resonators for Sensing Applicators.
- Julien Laurat (Université Pierre et Marie Curie, France) Quantum optics with nanoscale waveguides and arrays of cold atoms.
- Dario Pisignano (University of Pisa, Italy) Light transport and amplification in networks of electrospun nanofibers.

References

http://www.myeos.org/events/eosam2018_tom9

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EVENTS ORGANISATION

INTERNATIONAL CONFERENCE ON COGNITIVE COMPUTING HARDWARE

OPTICS

The fundamental task of artificial intelligence is to approximately recreate human intelligence in artificial systems. By its very definition, the field is therefore highly interdisciplinary. Ignoring philosophical considerations about intelligence, the challenge spans neuroscience, mathematics, and physics as well as engineering. Progress has strongly accelerated in each field, yet the individual communities remain distant from one another and do hardly interact.

The need for creative and interdisciplinary approaches is pressing. Current technology only enables artificial neural networks with a size comparable to the very simplest biological equivalents, a jellyfish for example. A system with a size even remotely comparable to the human brain would consume the power of an entire city, over a million times more than the brain itself. It is therefore clear that the current technology is highly inefficient, not scalable and cannot support far-reaching future evolution.

The conference, “Cognitive Computing: Merging Concepts with Hardware” places a decisive focus on bringing all the relevant communities together. Participants presented and discussed novel computation concepts particularly suited for hardware and unconventional hardware substrates, which in turn favor information processing. Overall, the theme was guided by brain-inspired, neuroscientific considerations.

This conference was initiated and co-organized by Daniel Brunner. It took place in the Castle of Herrenhausen, a heritage of the Kings of Hannover and award-winning conference center. Generous funding was provided by the Volkswagen foundation. Numerous invited speakers, each highly-recognized international leaders within the event’s diverse disciplines presented the field’s state of the art. Overall, 130 participants will meet for 3 full days and actively interacted in the single-track event.

References

http://www.cognitive-comp.org/

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NATIONAL WORKSHOP OF THE CNRS TECHNICIANS AND ENGINEERS IN ROBOTICS: ROBOTEX TECH DAYS

ROBOTICS AND AUTOMATION (AS2M)

The annual Robotex days event took place this year in Besançon, organized by FEMTO-ST institute in the framework of the national network of robotic platforms, called robotex. The goal of the network is to setup coherent infrastructures of technical equipment in order to:

-Promote scientific exchange and development of collaborative work between academic research teams, companies and end- users, and provide durable and reusable expertise and know–how,

-Give researchers high-level equipment with a facilitated access,

-Increase the visibility of the French robotics academic research and its international impact. It particularly concerns the strengthening of its European scientific leadership, and the increase of collaborative works with leading European countries as well as at an international level,

-Boost the competitiveness of French companies and open new markets based on robotic technologies.

The experimental platforms of the ROBOTEX national network mostly belong to joint CNRS-university laboratories with strong research and development activities in robotics, and having the necessary human resources to give access and provide optimal exploitation of the platforms. This national network links together most of the leading academic robotics research teams in France.

The objective of the annual Robotex tech’days is to merge the knowledge and know-how of engineers and technicians working in Robotex network. It concerns all the robotic topics such as mechanics, actuation, perception, automation and artificial intelligence. 50 people participate in the 2018 techdays in Besançon. Various sessions including 17 talks have been organized on humanoid robotics, micro-actuation, vision in robotics and robot calibration, mobile robotics, the future of robotic platforms. These two days were a great success on the scientific and technical level.

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NATIONAL WORKSHOP OF THE CNRS TECHNICIANS AND ENGINEERS IN ELECTRONICS

ALL DEPARTMENTS

The 18th edition of the National Workshop of the CNRS (the French National Center for Scientific Research) technicians and engineers in electronics has been organized by FEMTO-ST Institute in Besançon in 2018. Since 1999, this event is a unique opportunity to merge the expertise and know-how of technical staff in electronics working in several research laboratories in France. The workshop also proposes high-level courses in various fields of new electronic technologies and instrumentation. The content of the program is driven by the scientific committee of the CNRS national network of electronics engineers and technicians (réseau des électroniciens - RdE) which currently has 1031 members.

In 2018, the local arrangement committee (FEMTO-ST Institute members) proposed a new schedule including 4 plenary talks, 7 keynote talks (available live online), and 28 scientific and technical talks including 9 industrial presentations. The program also contained several practical courses done in FEMTO-ST Institute. About 100 technical staff participated in this workshop.

The workshop focused on analogic electronics. Even though, digital electronics has made lot of progress during the last few decades, analogic electronics is still a key technologies for instrumentations in which low signal and/or low noise are considered. In other words, in most of the electronic instruments analogic electronics makes the link between analog sensors and digital electronics. Consequently, improving the sensibility of high tech instruments such as highly sensitive light sensors requires an advanced knowledge in analog electronics.

Various application fields have been addressed such as the passive radar applied to target detection; electromagnetic compatibility for complex systems; the origin and the behavior of the phase noise and the front-end technologies in particle physics. The workshop was an opportunity to develop and share competences in analogic electronics between research laboratories at the national level.

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PLATFORM FOR THE MECHANICAL CHARACTERIZATION OF HUMAN OOCYTES

ROBOTICS AND AUTOMATION (AS2M)

Infertility issues concerns more and more people all over the world. To deal with this problem, Assisted Reproductive Technique (ART) centers propose several fertilization techniques like IVF (In Vitro Fertilization) or ICSI (Intra Cytoplasmic Sperm Injection). Nevertheless, the average success rate of ART remains low: 1 chance over 5 trials. The objective of our platform is to provide mechanical parameters on the elastic properties of human oocytes in order to sort and select the best candidates for ICSI fertilization. A recent work of Yanez indicates that it is possible to determine the maturity of oocytes knowing their mechanical properties. Thus, selecting an oocyte with nominal mechanical properties may increase the pregnancy success rate. Here, the mechanical behavior is measured like on a classical tensile test machine, but using a disposable magnetic indenter that is fully compatible with ART constraints and regulations. Whatever the mechanical oocyte behavior is, the position of the indenter is controlled to perform with high precision loading profiles determined by the physician. The forces applied to the oocyte are calibrated and are in the range of 0-300 nN. The platform was initially designed during a 2013-16 PhD work. An engineer is now in charge of designing a new platform that will be installed soon in the Besançon hospital ART center. Industrial partners have been found and a co-maturation is under preparation (SATT Sayens). At the end of the maturation process, we expect experimental data and to be able to correlate the mechanical properties with the oocyte's morphology and development. Wider range experiments are envisaged in a near future to confirm the link between mechanical properties and pregnancy potential of a given oocyte.

The platform is patented: WO2018FR50670

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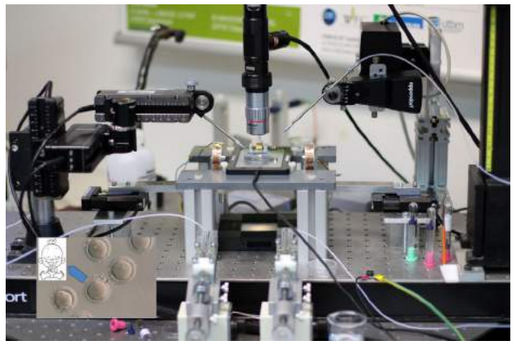

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INTENSE INDUSTRIAL TRANSFER IN MICROROBOTICS

ROBOTICS AND AUTOMATION (AS2M)

2018 saw three remarkable industrial transfer actions from the AS2M, department of FEMTO-ST Institute.

Sergio Lescano, former PhD student and "post-doc entrepreneur" at AS2M, is now turning his dream of starting Amarob, a global company in medical microrobotics into close reality. After the successful proof of concept of a microrobot for endoscopic laser surgery of the vocal folds within the FP7 µRALP project, the completion of a BPI (entrepreneurial investment bank) French Tech contract and the submission of three international patents, he was admitted, with 18 others out of 150 candidates, to the prestigious HEC Challenge+ programme, aiming at training technology developers into business developers. Last December, he took part, with 14 others, to the programme's final pitch contest. In parallel, his start-up project entered the DECA BFC incubator. May 2019 will see the birth of Amarob!

Vladimir Gauthier, just before defending his "docteur entrepreneur" work on December 18th, took part to the Chercheur-Entrepreneur (Researcher-Entrepreneur) contest, aiming also at selecting high-tech start-up projects. Last November, after winning the regional finals, he ranked 2nd out of 10 competitors at the national finals, pushing him firmly and surely forward on his way to transferring, their results in the field of high-speed single-cell handling, with potential applications in adoptive cell therapy.

Haouas, Dahmouche, Laurent and Piat, all within the AS2M department, were awarded the Micron d'Or prize (academic section) at MICRONORA 2018, the international industrial fair in microtechnologies, last September. They presented a novel, miniaturized parallel kinematics manipulator with an integrated gripper, an unprecedented compactness (~1cm3) and rotational range 20x larger than usual. A maturation project is under discussion with Sayens (SATT - a technology transfer company) to exploit the recently delivered international patent.

Noteworthily, Percipio Robotics, a spin-off company from FEMTO-ST, also received the Micron d'Or prize (industrial section) at MICRONORA 2018.

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METABSORBER, THE NEW NAME GIVEN TO SILENCE

MICRO-NANO SCIENCES AND SYSTEMS

The technological changes of today's society bring new challenges related to welfare, health, and more generally to individual and collective fulfilment. Noise pollution, a particularly salient issue, has been the subject of many studies, and its harmful effects on populations have been demonstrated time and again. Indeed, noise pollution can have devastating consequences on sleep and cardiovascular risks, but can also yield losses in terms of productivity of businesses and learning disabilities. The financial impact has been estimated as 57 billion euros a year for France, in terms of social cost. Thus, to protect ourselves against noise is much more than a simple need. It is rather a challenge for our society, considering the socio-economic impacts.

The project Metabsorber, born at the Femto-st Institute, enables to increase significantly acoustic comfort performance with new artificial materials called acoustic metamaterials. With Metabsorber, any material can be designed acoustically to perform better than classical foams in terms of sound absorption, without harmful effects to human health. It also takes advantage of the mechanical and thermal characteristics of the base material. More specifically, new kinds of acoustic materials will be developed:

- with low environmental impact or bio-sourced for instance,
- tough in terms of durability (recyclability),
- from local resources and with the smallest carbon footprints.

In this context, the project Metabsorber was rewarded by the Agence Economique Régionale (Regional Economic Agency) and received the "Trophée Eco-innovez 2018" prize. The start-up, set for creation in 2019, will be able to target a broad market spectrum from building to transportation applications, starting with a new concept: noise-absorbing furniture.

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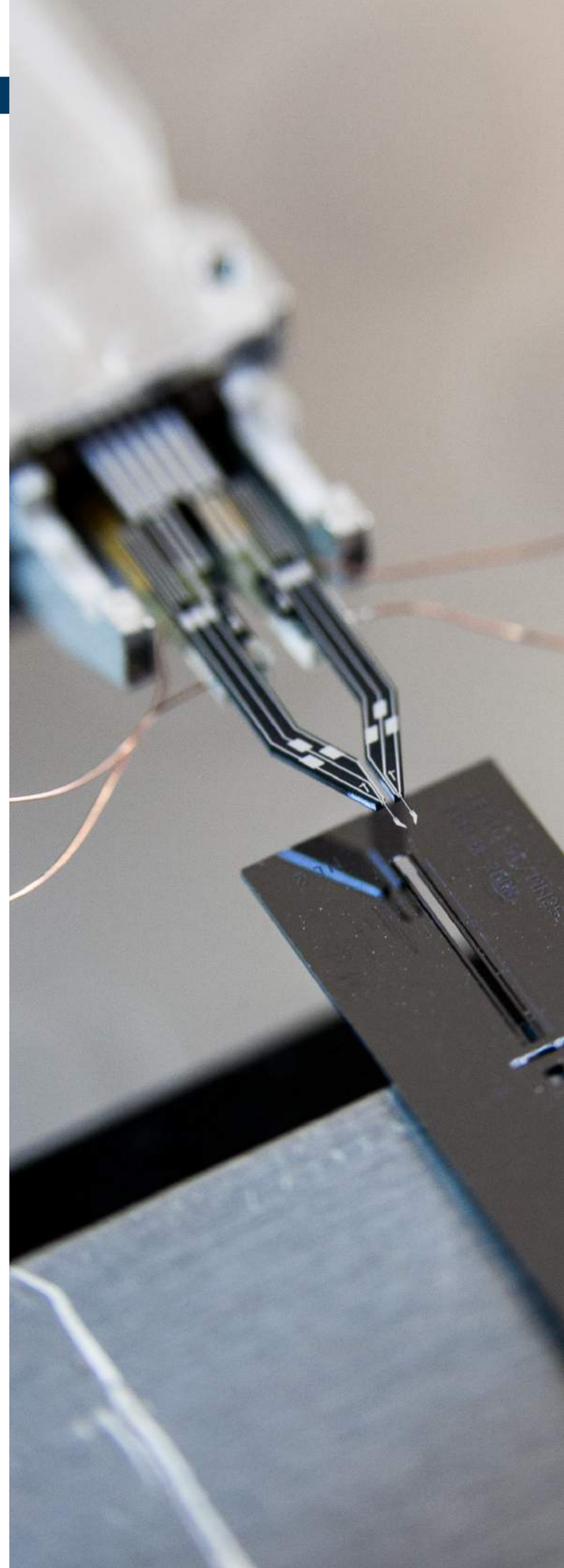

START UP NEWS

AFULUDINE: ECOLOGICAL LUBRICANT

APPLIED MECHANICS

The start-up born in Besançon AFULudine reached the first steps of the podium in Vienna, Austria on November 14, 2018 and received a trophy in the Product and Services category at the European Business Award for the Environment. It all began in 2016 when AFULudine, a start-up resulting from the collaboration between three Besançon researchers (X. Roizard, FEMTO-ST Institute and Fabrice Lallemand, Jean-Marie Melot, UTINAM Institute), presented its ecological alternative to traditional lubricants at the "Entreprises et Environnement" award given by the Ministry of Ecology and ADEME. AFULudine wins “the Grand Prix de l'innovation dans les technologies”, an award that earned it the distinction of representing France at the EBAE 2018-2019 (European Business Awards for the Environment). A reward for companies at the forefront of eco-innovation.

Despite the strong increase in the number of applications and the quality of the innovations pre-sented, AFULudine is on the first steps of the podium. The small start-up has become vice-champion of Europe in the Product and Services category.

Why such a reward for AFULudine?

Neutral towards the environment and users and completely biodegradable, the application of the ecological lubricant AFULudine avoids degreasing, a very water-intensive phase. This hydro-alcoholic solution with active molecules therefore makes it possible to drastically reduce water consumption and limit the treatment of discharged water. An innovation made in France, the result of two research institutes in Franche-Comté, dedicated to industry, but soon accessible to profes-sion-als and individuals with a range adapted to each need.

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www.afuludine.com

AUREA TECHNOLOGY: QUANTUM PHOTONICS

OPTICS

Based on a knowledge transfer strategy issued from FEMTO-ST Institute, Aurea Technology, a leading company in Quantum Photonics has been recently recognized as a major actor for the development of the French photonics. Aurea Technology has been invited at the French Photonics Perspectives meeting organized in 2018 by the Directorate General for Enterprise and Industry and the Ministry of Economy and Finance to present the perspectives of quantum photonics in industrial.

Beyond this recognition, AUREA technology and FEMTO-ST Institute has strengthened their interaction by signing a convention agreement with the University of Franche-Comté (UFC), the National Center for Scientific Research (CNRS), the Mechanical and Microengineering School (ENSMM) and the Belfort-Montbéliard Technological University (UTBM) to develop emerging applications based on quantum technologies. This structure has already enabled the involvement of AUREA Technology in a major European project called the MiMédi project which aims to optimize the production of innovative medicines and reduce their manufacturing costs to facilitate access to these new personalized treatments. This successful collaboration is an exemplary interaction of how applied research activities can lead to the developments of innovative high-tech applications.

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H2SYS : A HYDROGEN WIND BLOWING ON THE ENERGY LANDSCAPE

ENERGY

H2SYS is a start-up company, launched in September 2017, based on the twenty-year unique expertise in hydrogen-based systems of FEMTO-ST Institute/SHARPAC team (Measurement systems, production, conversion, storage of thermal and electrical energy, fuel cell systems) & FCLAB (Fuel Cell Lab).

H2SYS offers energy supply solutions for off-grid applications. The core business of H2SYS is the development of a new generation of hydrogen-based hybrid power gensets, for stationary and niche-transport applications. The target electric power range is starting from 1kW and can reach up to 20kW. The gensets, fully controlled through artificial intelligence algorithms, are environmentally-friendly and provides a real disruptive technology versus existing carbon-based fuel supplied gensets. Besides the delivery of many hydrogen systems and gensets during last year, H2SYS is also already involved in multilateral projects for micro combined heat/cold and power generation, using green hydrogen from water electrolysis as a key energy vector.

The first business year of the company has permitted to reach an impressive half-a-million euros turnover and has established H2SYS and its 9 employees and 5 scientific advisors, as one of the European technological leaders in hydrogen-energy systems.

References

http://www.h2sys.fr

VERSO-OPTIM : EFFICIENT OPTIMISATION SOFTWARES

ROBOTICS AND AUTOMATION (AS2M)

Founded in December 2017 by FEMTO-ST Institute members J. Coupey, J-M. Nicod and C. Varnier, and joined in 2018 by Stéphane Chrétien (Laboratoire de Mathématiques de Besançon and the National Physical Laboratory, London), the spin-off, VERSO Optim proposes efficient optimization softwares tailored to solve planification and optimization problems in industrial contexts.

Many companies from different fields (logistics, transport, supply-chain, manufacturing) face planification and optimization problems arising in their workflow. A widely-spread response is to use human expertise and "common sense" to get practical solutions. The resulting process is usually very time-consuming (hours), offers no flexibility and yields largely sub-optimal solutions. VERSO Optim proposes innovative softwares, implementing efficient and fast algorithms based on up-to-date research results from FEMTO-ST Institute. Thus, specific problems in real-life practical applications can be solved in a matter of seconds.

VERSO Optim has a specific expertise in the field of vehicle routing problems (VRP) encountered in logistics and mobility. Production-ready software has been tested on use-cases in that domain, resulting in a drastic reduction of planning time and an overall simplification of the workflow. Switching from human-based planification to an artificial intelligence enables industry to reduce planification time from a few hours to a few seconds. Solutions are also better, with gains related to reduced travel times, distances and gaz emissions usually beyond 20%. Other markets will be addressed in the next few years, including supply-chain and manufacturing. The company is already setting up partnerships with field players in France and abroad.

References

https://www.verso-optim.com

FEMTO-ST IN FIGURES

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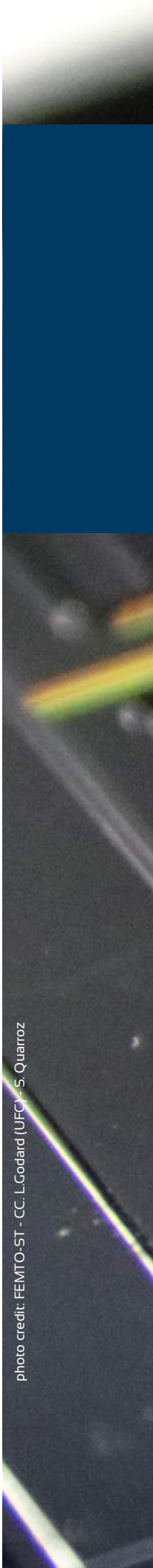

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