Group

GROUP ACRONYM : AIMAN - FILMS

Name of the group : Acoustique Impulsionnelle & Magnéto-Acoustique Nonlinéaire - Fluides, Interfaces Liquides & Micro-Systèmes

Members: *P. Pernod (PR, Head group), O. Bou Matar (PR), A. Talbi (MCF-HDR), F. Zoueshtiagh (PR), M. Baudoin (PR), M. Goueygou (MCF), N. Tiercelin (CRCN-HDR), V. Aleshin (CRCN-HDR), S. Giordano (CRCN-HDR), Y. Dusch (MCF, 2014-), V. Preobrazhensky (Emeritus-PR), A. Merlen (Emeritus-PR)*

Responsible : Philippe PERNOD

Permanent staff (ETPR)	2013	2014	2015	2016	2017	2018 (*)
Professors and associate professors	3,5	3,5	3,5	3,5	3,5	3,5
CNRS scientists	3	3	3	3	3	3
Engineers and technicians (permanent)	0	0	0	0	0	0

Non-permanent staff (ETPR)	2013	2014	2015	2016	2017	2018 (*)
PhD students	12,58	15,26	13,51	12,42	9,25	4
Post Docs, ATER, long-term visitors	5,58	5,57	6	4,75	4,83	2,36

Publications, patents and thesis/HDR	2013	2014	2015	2016	2017	2018 (*)
Peer-reviewed articles	20	19	18	28	19	11
Books	1	0	0	1	0	0
Invited Speakers	0	1	1	2	2	0
Communications (internationals and proceedings)	8	7	17	6	14	0
Theses/HDR	1	6	7	2	5	2
Patents	(1 ; 9)	(0 ; 4)	(1 ; 2)	(0 ; 3)	(3 ; 1)	(0 ; 0)

(*) 2018 : until June 30.

Publication rate ETPR/Year : 3,2

Contractual activity 2013 et 2018

Europeans projects:

- FP7 Marie-Curie IRSES project PAS « Patterns and Surfaces » , 2012-2015, 505 k€
- FP7-AAT-2012-NDT project ALAMSA, 2012-2016, 3,1 M€ all partners, 325 k€
- LIFE SMART IN'AIR, 2018-2022, 2,3 M€ all partners, 195 k€

International grants:

- European Space Agency (**ESA**) : « Topical Team on ”Liquid interfaces subjected to oscillations” », 2011-2017, 140 k€
- CSC Chinese Government Scholarship PhD Grant, Yu DU, 2013-2015, 36 k€
- CSC Chinese Government Scholarship PhD Grant, Yuxin LIU, 36 k€
- CSC Chinese Government Scholarship PhD Grant, Xiaokun DING, 2013-2016, 36 k€
- NSF PhD Grant, Kevin WARD, 2013-2018, 100 k€

International projects with national financial support (ANR, CNRS, Ministry of foreign affairs):

- ANR “2DPS” with Singapore, 2017-2020, 250 k€ IEMN, 285 CINTRA, 535 k€ All partners, 114 k€
- CNRS Grant for the joint International franco-russian Laboratory LIA LICS, 2013-2018, 90 k€
- Metchnikov Grant Ministry of Foreign affairs / French Embassy in Russia, Invited researcher, Alexey KLIMOV, 2013, 3,5 k€
- Metchnikov Grant Ministry of Foreign affairs / French Embassy in Russia, Invited researcher, Pavel Shirkovskiy, 2014, 3,5 k€
- Vernadsky Grant Ministry of Foreign affairs / French Embassy in Russia, Joint PhD with Russia, Dmitry MAKALKIN, 2015-2018, 14 k€
- Vernadsky Grant Ministry of Foreign affairs / French Embassy in Russia Joint PhD with Russia, Sergey YANKIN, 2013-2015, 14 k€
- Vernadsky Grant Ministry of Foreign affairs / French Embassy in Russia, Joint PhD with Russia, Anastasia PAVLOVA, 2013, 14 k€

- PHC Hubert Curien Program Sakura (Japan), Ambassade de France à Tokyo : « Wetting dynamics in presence of particles », 2015-2016, 12 k€
- Grants in the framework of the joint International franco-chineese Laboratory LIA 2MCSI, 2013-2016, (3 projects), 24 k€

ANR :

- ANR Blanche "SMART-US" « Smart-UltraSons : détection/caractérisation/contrôle de sources de non linéarité ultrasonore », 2010-2014, 192 k€
- ANR blanche ANL-MEMS "Techniques d'imagerie acoustique non linéaire pour l'étude de la fiabilité des MEMS", 2010-2014, 430 k€ all partners, 224 k€
- ANR blanche PASNI "Imagerie passive par capteurs acoustiques répartis", 2012-2015, 450 k€ all partners, 223 k€
- ANR TDM Transport Durable et Mobilité "LIVE-CAMS" "Limitation de l'Impact des Véhicules sur l'Environnement par Contrôle Aérodynamique au moyen de Micro-jets Synthétiques", 2012-2015, 343 k€
- ANR blanche MIRAGES "Méta-matérIaux et cRistaux phononiques Actifs contrôlés par champs électriques et maGnétiquES", 2013-2015, 410 k€ all partners, 130 k€
- ANR blanche AWESOM "Laboratoire sur puce basé sur des technologies hybrides pour la manipulation et la caractérisation de fluides biologiques", 2012-2016, 530 k€ all partners, 199 k€
- ANR Astrid CAMELOTT « Capteurs et Actionneurs MEMS pour Le cOnTrôle réactif de décollement sur voleT», 2014-2017, 179 k€
- ANR "PANSCAN", "Passive Ambient Noise-based Structural monitoring through exploitation of Contact Acoustic Nonlinearity", 2018-2021, 180 k€

CNRS :

- PEPS INSIS project NONLIMETA, "Numerical laboratory for nonlinear acoustic metamaterials", 2015, 14 k€
- Transfer CNRS program, MELRAM "Mémoire Magnéto Electrique", 2018, 65 k€
- PhD Grant Yovan ORLIC, 2010-2014, 33 k€

CNES, ONERA:

- CNES project « Studies of interface dynamics at the interface of miscible and immiscible liquids under microgravity conditions", 2013-2018, 248 k€
- ONERA PhD Grant Cécile GHOUILA-HOURI, 2015-2018, 100 k€
- Carnot ONERA Contract INTACOO : « INnovaTive ACtuators and mOdels for flow cOntrol », 2014-2018, 70 k€

Local grants ("collectivités territoriales")

- 'CPER CIA/Flexible Electronics: "Mechanically reconfigurable 60 GHz antennas and phase shifters", 2013-2015, 95 k€
- CPER CIA/MESYA, "MELRAM "Mémoire magnéto-électrique et Composants ultra-faible consommation", 2014-2015, 65 k€
- CPER ELSAT2020 "Transport : Arrays of MEMS Micro-actuators and Micro-sensors for aerodynamic active flow control", 2017-2018, 230 k€
- STARTAIRR' Transfer program Région Hauts-de-France, MELRAM "Mémoire magnéto-électrique et Composants ultra-faible consommation", 2016-2017, 70 k€
- PhD Thesis grant Région Hauts-de-France, Théo MATHURIN, 2014-2017, 46 k€
- PhD Thesis grant Région Hauts-de-France, Gaetan DUFOUR, 2013-2016, 46 k€
- PhD Thesis grant Région Hauts-de-France, Antoine RIAUD, 2013-2016, 46 k€
- PhD Thesis grant Région Hauts-de-France, Manon BENEDITO, 2017-2020, 46 k€

— **I-Site ULNE:**

- I-Site ULNE action for industrial transfer, "Stack acoustical tweezers for micro-objects assembly", 2018-2019, 70 k€
- I-Site ULNE action for industrial transfer, "Development of an ultra-low energy magnetoelectric memory cell at the micron scale », 2018-2019, 70 k€
- I-Site ULNE action for joint international PhD with KU Leuven, "Interaction of ultrasonic waves with friction sensitive defects for nondestructive testing of materials", 2018-2021, 100 k€

— **SATT (Tech Transfer Acceleration Network):**

- Maturation project SATT NORD "MEMS Micropump", 2016-2018, 315 k€ including IP Group
- Maturation project SATT NORD "Acoustipince", 2016-2018, 315 k€ including IP Group
- Grant from Labex Ganex

— **Industrials grants:**

- Contract VALEO Systèmes Thermiques « Etude numérique et théorique de l'augmentation du rendement d'un échangeur thermique à l'aide de vibrations ultrasonores », 2014, 9,6 k€

- Contract Childerix Technologies : « Etude de faisabilité d'un dispositif ultrasonore » dans le cadre de la création d'une startup, 2015, 10 k€
- Contract CEA : « Etude d'applicabilité de la conjugaison de phase ultrasonore à la caractérisation d'un milieu », 2016, 25 k€
- Thales PhD Thesis, "Modelling and Evaluation of graphene foam thermoacoustic effect for effective sound generation in liquids", 2017-2020, 160 k€

Total contractual activity 2013-2017: 4 M€

Research Highlights 2013-2017 (max 10 lines)

• Writing and reading energies of a few attoJoules with operating times below 1ns were evaluated in our patented concept of MELRAM memory, and a magnetoelectric readout of the information was proposed **[Highlighted in Appl. Phys. Lett.]**
• We proposed a new phononic crystal design based on a disruptive technology for sensors and optomechanic applications and the implementation of phonons as information carriers in a chip **[highlighted in Electronic Letters Journal]**.
• We performed the first real-time mechanical characterization of DNA degradation under therapeutic X-rays and we successfully compared the results with theoretical modeling **[Highlighted in CNRS Scientific News]**.
• We designed the first miniaturized flat transparent acoustical tweezers which enable to grab and move selectively microparticles of sizes down to several microns **[Phys. Rev. Appl., Highlight from focus on fluids]**.
• We have shown that particles could dramatically alter the dynamics of an air-liquid interface in a closed environment and lead to the development of a hydrodynamic instability hitherto known as stable in the literature **[Phys. Rev. Lett. highlight]**.

Main Topics

I - General Objectives of the AIMAN-FILMS group :

The AIMAN-FILMS Group is focused on studies of **static, quasi-static and dynamic critical and supercritical phenomena in the multi-physic fields of functional electronics, acoustics and fluidics**. The activity extends **from fundamental research** on specific features of coupled nonlinear systems and instabilities, **to development of new concepts and disruptive solutions for applications and transfer**. Three major directions are defined:

1 - New paradigms for collecting, transmitting and processing of information (Multiferroic nanostructures & devices)
It consists of theoretical, experimental and technological studies of quasi-static and dynamic spin-reorientation phase transitions (SRT) in magnetic and stress-mediated multiferroic nanostructures and their application to the elaboration of new paradigms for information processing and in particular: ultra-low power nonvolatile random access memory MELRAM, as well as highly sensitive magnetic field sensors.

2 - Functional electronics and theragnostics (Critical State materials, bosonic micro-nano-structures & composites)
Here, we investigate theoretically, numerically and experimentally Critical State (CS) materials for the development of new controllable components for information processing and of theragnostic devices. This includes magneto-elastic materials with extraordinary nonlinear dynamics, quasi-phononic periodic structures (2D- structures with periodic magnetostrictive micro- and nano-inclusions), active media for supercritical parametric wave front reversal (wave phase conjugation WPC) of ultrasound for characterization of decompressed liquids and flows with microbubbles or nanoparticles, new nonlinear ultrasound imaging methods for defect detection, and polymer chains with multiple structural transitions.

3 - Functional micro-fluidics & interface dynamics
This topic is associated with the theoretical, numerical and experimental study of complex interactions between acoustic waves, micro-hydrodynamics and interfaces. This includes : precise manipulation of fluids and particles at small scales with and without acoustic waves (tweezers and stirrers), interfacial instabilities, and arrays of distributed microfluidic MEMS (with disruptive sensors and actuators) for reactive aerodynamic flow control.

During the 2013-2018 period, this activity was made within the framework of the Regional CPER Flagships "CIA/Fexible Electronics", "CIA/MEYSIA", "ELSAT 2020" and "Transport & Mobility Research Federation" (FR TTM, labelled by CNRS) and in accordance with the major scientific, technological and societal issues "Information and communication society", "Green and integrated smart transport", and "Life, Health and Well-being" in line with the European H2020 and the National Research Strategies (SNR). Since January 2017, the activity is also fully in line with the "Human-Friendly Digital World" and "Precision Human Health" Hubs of the PIA I-SITE ULNE project (University Lille Nord-Europe).

The group have settled a high level of international collaborations with in particular the creation of the franco-russian International Associated Laboratory on Critical and Supercritical Phenomena in Functional Electronics, Acoustic and Fluidics (LIA LICS), further strengthened by many other international collaborations with USA, Japan, China, Singapore, Canada, etc. Together with its partners, the group has developed pioneering approaches at the interface of nonlinear physics of coupled systems, physics of critical states and nanotechnologies, and favored the emergence of breakthrough solutions. New concepts, devices and systems have already emerged, leading to high impact factor publications and highlights, several prizes, and several patents with international extensions and transfer projects. The group which is

internationally considered as belonging to the leaders in the above mentioned field, obtained a good success in highly selective projects at international and national levels with regular collaborations involving companies.

II - Selected results of the AIMAN-FILMS group for each of the 3 major directions :

1.A - New concept of Nonvolatile MagnetoELectric Random Access Memory (MELRAM)

We have been studying various aspects of our patented magneto-electric memory that aims at reducing the energy cost by two orders of magnitude relatively to the state of the art [J. Phys. D: App. Phys. 2013, 46, 325002]. In particular, a macroscopic prototype of the memory cell was demonstrated using nanostructured magnetoelastic multilayers on single crystal 011 PMN-PT substrates [J. Appl. Phys. 2013, 113, 17C719]. Also, we have shown that besides writing the information, the magnetoelectric effect can be used as a readout method, also with an ultra-low energy consumption of a few attojoules per read bit. These results were highlighted by the editor of the Applied Physics Letters [App. Phys. Lett. 2017, 110, 222401].

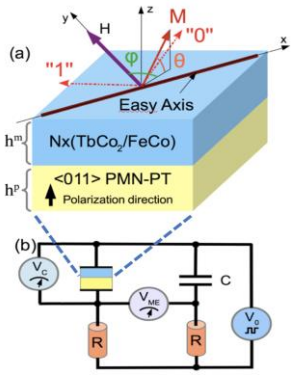

Fig.1.A Wheatstone bridge configuration for the magnetoelectric readout in the patented MELRAM.

1.B - Magnetoelectric control of magnetic domain wall motion

As an extension of the magnetoelectric memory, we have shown theoretically that magnetic domain walls can efficiently be controlled by an electric field in stress-mediated magnetoelectric structures [Appl. Phys. Lett. 2016, 108, 082401].

1.C - Surface Acoustic Wave (SAW) based magnetic field sensors

We have successfully demonstrated that thanks to the Spin Reorientation Transition, large variations of the effective elastic coefficients can be achieved in magnetoelastic multilayers upon application of an external magnetic field. This has been implemented in SAW delay lines on lithium niobate to devise highly sensitive magnetic field sensors that can operate in the sub nT range at room temperature and enable both DC and AC magnetic field measurement. We also have developed an accurate and fully coupled physical model to investigate the sensitivity of SAW devices using the magnetoelastic interaction with an external magnetic field. We have shown that the magnetic response of these devices is much more complex than often reported up to now and that a detailed understanding of the magnetic properties is essential to unravel and control the magnetoacoustic response [Appl. Phys. Lett. 2014, 104(11), 114101].

2.A - New phenomena of multi-phonon coupling and supercritical explosive instability of ultrasound in solids.

The concept of critical states materials includes structures in which explosive instabilities can be observed. The effect of giant amplification follows from the fundamentals of the three-phonon interaction and is theoretically far more efficient than other possible amplification mechanisms. We have found two systems in which the effect should be expected: Lamb waves and shear resonance in an anti-ferromagnetic crystal excited by magnetic field, and the gravity-capillary waves under acoustic pressure pumping.

2.B - Tunable and reconfigurable Quasi-Phononic crystalsOur original approach based on use of critical states near spin reorientation transitions and allowing extremal increase of controllability of the structures has been extended on 2D- structures with periodic magnetostrictive micro- and nano-inclusions (i.e. quasi-phononic crystals). We concentrated our studies on RF SAW and lamb wave phononic crystals and the experimental demonstration of the local resonance coupling mechanism in electro-acoustic devices. We have proposed a new design of cavity resonator based on 1D phononic crystal structure made of a corrugated AlN thin membrane where the central micro-strip line supports periodic gold disc shaped thin layer. The introduction of disc shape thin films on the grooved surface introduces nearly flat modes within the band-gap and consequently paves the way to implement advanced design of electroacoustic filters and high-performance cavity resonators. These results made the front-cover and were highlighted by the editor of Electronic Letters [Electron. Lett. 2018, 54(5), 301-303].

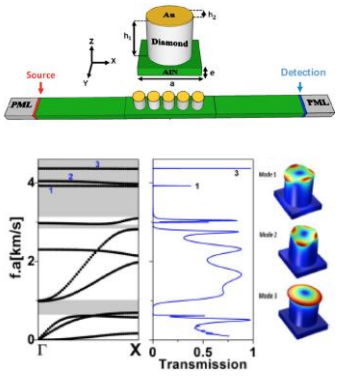

Fig.2.B 1D Phononic crystal structure with isolated acoustic disc-shape modes

2.C - Nonlinear imaging of heterogeneous media and defects and contact problems

We developed a high precision nonlinear ultrasound imaging method based on Coda Wave Interferometry (CWI) able to provide information on small changes in materials due to damage, temperature or shape variations accumulated in coda signals. The method is especially sensitive to damage since it uses nonlinear frequency mixing occurring in presence of internal contacts in a sample. Time-reversal focusing of acoustic energy allows to selectively “insonify” the sample thus constructing an image. This technique has been successfully used to estimate the efficiency of self-healing processes of novel composites and enhance material properties [FP-7 European project ALAMSA]. A modeling support tool describing the elastic wave propagation in materials containing frictional cracks/contacts and based on the original semi-analytical approach called Method of Memory Diagrams was created. In collaboration with researchers from KU Leuven, we created the software capable of visualizing all appropriate physical fields underlying nondestructive imaging techniques based on nonlinear ultrasound and thermal effects [Ultrasonics 2018, 82, 11-18]. In parallel, the advantages of application of

magneto-acoustic wave phase conjugation for ultrasonic diagnostics of bubbly liquids were demonstrated in the framework of the contract with CEA.

2.E- Chains with multiple structural transitions

The recent development of mechanical experiments on single molecules (nanomechanics of macromolecules) provided a deeper understanding of intermolecular and intramolecular forces (nanoscale elasticity), thereby introducing crucial additional information about the thermodynamics and kinetics of several molecular processes [Nat. Microsystems & Nanoengineering 2016, 2, 16062] [Phys. Rev. Lett. 2014, 113, 255501]. Single-molecule methods are based on laser optical tweezers (LOTs), magnetic tweezers (MTs) or atomic force microscope (AFM). Briefly, with such devices, we can measure the force-extension relation for a molecular chain under different conditions. We thoroughly analyzed the stretching of macromolecular chain, which can be typically performed at constant applied forces (extremely soft devices, Gibbs statistical ensemble), or at prescribed displacements (extremely hard devices, Helmholtz statistical ensemble). We generalized these concepts to analyze macromolecular chains where each domain exhibits a bistable (or multistable) behavior. In this case, we proved that the stretching of the chain produces the folding/unfolding of the domains, i.e. the switch between two (or more) well defined states. The theoretical analysis of such situations has been performed (we obtained the closed form expressions for the force-extension curves) and helps the interpretation of experiments.

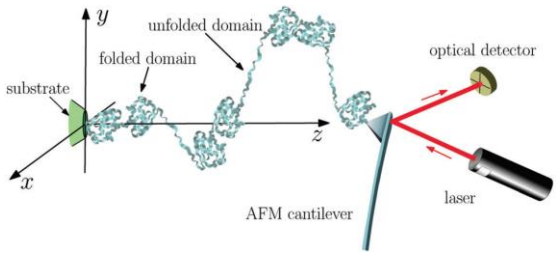

Fig.2.E. Extension of a macromolecules with two-state domains realized through the AFM force-spectroscopy

3.A - Faraday instabilities for fluid mixing and ultrasonic characterization of complex flows

We first performed experiments characterizing the influence of gravity and interfacial tension on the evolution of Faraday instability (complex flow instability at fluid interfaces) in immiscible, confined fluid layers. The influence of gravity was analyzed through a series of terrestrial and micro-gravity (CNES parabolic flight) experiments. For the first time, these experiments confirm the existence of a crossover frequency below and above which gravity plays opposing roles in the level of excitation needed for destabilizing the liquid interface [J. Fluid Mech. 2013, 729, 496-523]. Meanwhile we also developed a new non invasive ultrasonic characterization method of complex binary flows based on break of time reversal invariance providing simultaneously the spatial distributions of flow velocities and concentration distributions. The results obtained here are of interest for innovative spatial and medical applications (e.g. fuel mixers & BioMEMS microfluidic mixers, both with real time monitoring) and were part of an international collaboration (US-France-Japan-Russia) supported by FP7 Marie-Curie IRSES program “Patterns and Surfaces”.

3.B - Microscale acoustofluidics & micro-manipulation of fluids and particles

Microscale acoustofluidics opens tremendous perspectives for the manipulation of fluids, particles and cells at micrometric scales with the use of two nonlinear effects: the acoustic streaming and radiation pressure. In particular, we focused recently on the ability of some specific waves, called “acoustical vortices” to perform operations that are not accessible with any other class of waves. These acoustical vortices (also called Bessel beams) are some helical waves spinning around a phase singularity. These separate variable solutions of Helmoltz equation in cylindrical or spherical coordinates have some remarkable properties: (i) These nondiffracting waves focus the energy in 2D and in 3D but unlike focalized waves, they have a minimum at their center. This central minimum can be used to trap microparticles or cells with the used of the acoustic radiation pressure. (ii) These wave carry some angular momentum which can be transferred to the embedding fluid to create some controlled hydrodynamic vortices or to some particles to control their orientation.

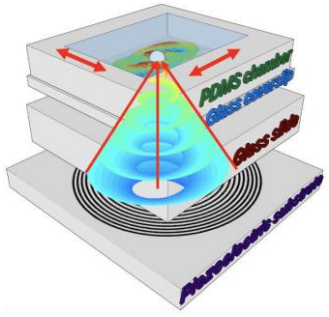

Fig.3.B. Principle of selective miniaturized acoustical tweezers based on focalized acoustical vortices and spiraing IDTs

We have shown that it is possible to synthesize these waves with only two spiralling metallic electrodes sputtered at the surface of a piezoelectric substrate [Phys. Rev. Appl. 2017, 7(2), 024007]. We then demonstrated the ability of this miniaturized simple flat system to trap and manipulate selectively some micrometric particles in a classic microfluidic environment. We also computed the streaming flow induced by these vortices and demonstrated that it is a combination of toroidal and poloidal flows, whose topology can be controlled by the topology of the acoustical vortex.

3.C – Distributed micro-actuators and micro-sensors for active flow control

Innovative state of the arts integrated micro-jet actuators and micro-sensors, based on Micro-System technology have been developed for aerodynamic reactive flow control. On the basis of our previously patented concept, large arrays of more than 80 highly miniaturized synthetic microjets were successfully tested and implemented on the rear end of a car model for flow control in order to reduce the drag. In parallel, we elaborated and patented 2 concepts of hot wire micro-sensors providing a sub-millimitric multiparameter parietal measurement (pressure, shear stress, and temperature). The sensors are fixing the state of the arts in the field and have been successfully calibrated in wind tunnels and used for the detection of separation on a motorized flap. This activity generated 3 patents (with 17 international extensions). The experiments were made in tight long term collaborations with the European aeronautic community and car constructors (ONERA, Dassault, MBDA, EADS, Rolls Royce, SNECMA, MTU, PSA, Renault, etc.) in the framework of many projects at international and national levels (European projects, ANR, etc.). Highly structured partnerships were settled with the local scientific community (fluid mechanicians, automaticians) with the creation of the CONTRAERO plateform integrating all means for a global solution for flow control, from technology (our micro-sensors and micro-actuators), to integration on airplane and car models for wind tunnels experiments, and engineering for integration on real vehicules. [Appl. Phys. Lett. 2017, 111(11), 113502], [Appl. Phys. Lett. 2016, 109(24), 241905].

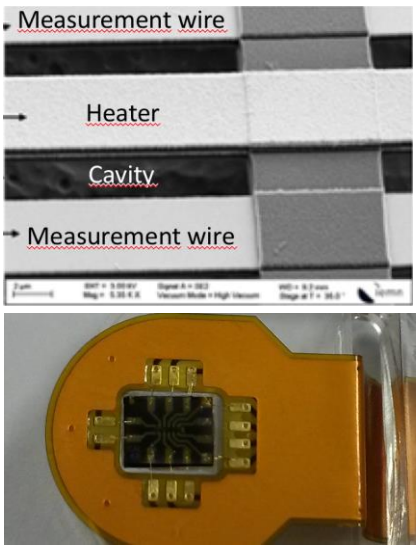

Fig.3.C. Detailed part on our MEMS wall shear stress patented sensor and its mounting on a flexible substrate for implementation on real structures (airplane wing, cars, etc.)

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Scientific strategy and projects

The group's strategy will remain centered on its core scientific positioning at the interface of **coupled nonlinear systems with controllable parameters** in multiphysics areas, physics of critical states and nanotechnologies, targeting the **development of new concepts and disruptive solutions** for applications and transfer in **functional electronics, acoustics and fluidics**. The work will be done in the framework of the strong international collaborative partnership of the group and the recent international, national and regional major directions and flagships described in the group's presentation. In addition to the quest for new fundamental concepts and breakthrough solutions, we also seek to: i) increase the TRL (Technology Readiness Level) of our patented prototypes owing to the maturation projects recently obtained, and promote their market opportunities through patent licensing and spin-off creations, ii) increase the reach of our concepts and solutions by further increase our involvement on collaborative projects with complementary groups of IEMN and local partners to address more complex systems [new flagships], iii) bring the outlets of our research closer to biological and clinical research taking the opportunity of the I-Site ULNE dynamics. Detailed projects in our 3 directions are :

1) New paradigms for collecting, transmitting and processing information: (i) the elaboration of a micrometric demonstrator of **MELRAM** with integration of the reading elements (magnetic tunnel junction MTJ or giant magneto-resistive structures GMR) **[CNRS & I-Site ULNE Pre-maturation projects]**, (ii) the elaboration of new concepts of **memristors and artificial synapses** for implementation of a neuromorphic architecture mimicking the brain, (iii) exploitation of our original approach based on use of **critical states near spin reorientation transitions** and allowing extremal increase of controllability of the structures for **highly sensitive SAW sensors** of magnetic field (at the pT precision) and extensions on **2D- structures (quasi-phononic and bosonic crystals)** with periodic magnetic micro- and nano-inclusions, (iv) study of New 'multiphysics' applications of the ***magnetoelastic multilayer structures*** with controlled properties e.g. in the field of **plasmonics [ANR-2DPS with the CINTRA UMI]**, or **TeraHertz** generation **[collab. with the TeraHz group @IEMN]**.

2) Functional electronics and theragnostics: (i) extensions of studies on quasi-phononic crystals to Bosonic crystals and Multi-boson instabilities. This includes the concepts and technologies of **new controllable components for information processing** based on **periodic bosonic structures** of different nature (phononic, magnonic, magneto-phononic, magneto-photonic), (ii) experimental observation of **explosive instability** and design of phononic crystals with a high-quality resonance in vicinity of the three phonon interaction zones for demonstrating the supercritical amplification for hyper-sensitive sensors and other microdevices, (iii) development of a novel approach for the design of **magnetic field sensors** based on the combination of surface acoustic wave devices and micro/nano structured magneto-elastic materials to realize NDT of ferromagnetic materials used in electric machines and measurements of bio-magnetic signals. Another critical state objects under consideration are the **chains with multiple structural transitions** simulating macromolecular chains in biophysics. The project includes: (i) the determination of the force-extension response of chains of bistable units, (ii) the study of the heterogeneous chains with bistable composing units, (iii) the study of dynamics of systems composed of bistable units that is motivated by the experiments on the force spectroscopy measurements. Our efforts in developing **novel nonlinear ultrasound theragnostics methods** will be focused on: (i) the development of **passive methods** that use ambient acoustic and vibration noise instead of active sources for detecting and imaging structural damage in transportation vehicules and infrastructures **[ANR PANSCAN project, 2018-2021]** in the perspective of on-board monitoring systems for aircrafts and vehicles. A **modeling support tool** that uses known physical mechanisms such as internal friction to simulate elastic and temperature fiends in damaged materials will be developed **[I-SITE joint project with KU Leuven]**, (ii) the elaboration of **magnetic microbubbles (MMB)** made of a gas enclosed in an albumin shell where magnetic nanoparticles have been attached, that will serve as injectable, **multimodal drug carriers, therapy and contrast agents** for cancer diagnosis and treatment. Their magnetic and acoustic properties makes them suitable for both ultrasound and MRI. Besides, to maximize their therapeutic efficiency, their trajectory inside the vasculature towards the target site can be controlled by a magnetic gradient and/or acoustic radiation pressure, using conventional medical imaging devices.

3) Functional micro-fluidics & Interface dynamics: we target to (i) add 4 functionalities to our recently developed **acoustical tweezers**, and meet the related technological and scientific challenges **[ISITE-ULNE** and **SATT NORD maturation projects]**: (a) 3D manipulation of particles, (b) control of particles orientation, (c) further miniaturization and frequency upgrading of the tweezers to trap and manipulate selectively particles of sizes down to a few hundred nanometers, (d) synthesis of hydrodynamic vortices of controlled topology, (ii) continue experimental and numerical evaluation of **Faraday instability** in confined geometries **[collab. Univ. of Florida, Japanese Space Agency, JNCASR (India)]** (iii) make a special focus on flow dynamics over particle laden substrates for innovative cleaning procedures of pathogens and spoilage in food processing lines (iv) increase of the TRL of our patented prototypes of **micro-sensors and micro-actuators** and demonstration of a reactive **aerodynamic flow control** (re-attachment) on a real vehicles and extend the research for the **control of low-frequency instationnarities in a turbulent flow [CPER Flagship ELSAT 2020]**.

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SWOT analysis

Strengths	Weaknesses
• New & specific scientific research directions, original topics at the State of the Arts with Pioneering results, high impact factor publications, highlights and prizes. • Multi-disciplinary, multiphysics and multi-scales research from Fundamental to Applied, covering theoretical, experimental, and technological activities • Strategy which includes intellectual property and subsequent technology Transfer. • High attractivity and high level of International collaborations with worldwide famous scientific Institutions in research and higher education (Creation and direction on French side of the International laboratory LIA LICS, principal investigators or partners of International & European projects, MOU and joint diplomas…). • Good success in highly selective projects (including I-Site ULNE calls) and close/stable collaborations with companies. • High involvement in research training and direction/co-direction of Bachelors and Masters degree programs.	• Absence of permanent supporting technical staff for backend/system electronics, instrumentation, and capitalization of technological expertise. • High involvement in teaching and academic organization with a low number of full time permanent researchers (weak ratio).
Opportunities	**Threats**
• Opportunities owing to the new dynamics generated by the I-Site ULNE project (won by Lille academic partners within the call from the Investment For The Future Program (PIA)) and by the Merging of the 3 Universities. This improves in particular the transversal synergies between health, science and engineering, in resonance with the group's strategy. • Future calls (H2020, PIA, CPER, ANR, …). • Research in good coherence with several recent local, national and international Flagships. • Recent maturation financial supports on several of our patented concepts and technologies opening doors to Industrial transfers and startup creations. • Involvement in the definition of the new Masters degree programs both at Centrale Lille ("Smart Systems and Smart Environments") and University of Lille ("RF systems & IoTs", "Telecommunications", "Mechanics & Fluid Mechanics"), and a potential Graduate School "Deep Tech" in the framework of the I-Site ULNE.	• Potential important increase of teaching activity of the group members in case of non-compensation of the recent retirement of one of our colleague, and the near future retirement of another one. • Constant growth of administrative duties at all scales with decrease of time dedicated to the core research activity.

Appendix 4 – Selection of research products and activities

(Please provide a selection of the unit or team/theme scientific production and activities)

EVALUATION CAMPAINGN 2018-2019

GROUP E

Name of the unit / the team / the theme: Acoustique Impulsionnelle & Magnéto-Acoustique Nonlinéaire - Fluides, Interfaces Liquides & Micro-Systèmes
Acronym: AIMAN FILMS
Head of the unit / Team leader / Theme leader for the current contract: Philippe PERNOD
Head of the unit / Team leader / Theme leader for the next contract: Philippe PERNOD

I - SCIENTIFIC OUTPUTS AND ACTIVITIES, ACADEMIC REPUTATION AND APPEAL

1- Articles

Scientific articles

Total number of RICL 2013-2018 = 115

79% of the RICL are in Web of Science Top 50%:

- Number of paper in Web of Science Top 25% = 64
- Number of paper in Web of Science 25%-50% = 27

1. **Nonlinear effective behavior of a dispersion of randomly oriented coated ellipsoids with arbitrary temporal dispersion**
   S. GIORDANO,
   International Journal of Engineering Science 98, 14-35 (2016). doi: 10.1016/j.ijengsci.2015.07.009 (IF = 4.261) - **WoS : 4.7%**

2. **Airways re-opening through catastrophic events in a hierarchical network**
   M. BAUDOIN, Y. SONG, P. MANNEVILLE, C.N. BAROUD,
   Proc. Natl. Acad. Sci., 110: 859-864 (2013) (IF = 9.809) - **WoS : 7.3%**

3. **Scaling Shift in Multicracked Fiber Bundles**
   F. MANCA, S. GIORDANO, P. L. PALLA, F. CLERI
   Phys. Rev. Lett. 113, 255501 (2014). *doi: 10.1103/PhysRevLett.113.255501.* (IF = 8.462) - **WoS : 7.6%**
   http://www.cnrs.fr/insis/recherche/actualites/2016/12/degradation-adn.htm)

4. **Inverse Saffman-Taylor Experiments with Particles Lead to Capillarity Driven Fingering Instabilities**
   BIHI, M. BAUDOIN, J.E. BUTLER, C. FAILLE, F. ZOUESHTIAGH,
   Phys. Rev. Lett. 117, 034501 (IF = 8.462) (2016), - **WoS : 7.6%**

5. **Cell detachment and label-free cell sorting using modulated surface acoustic waves (SAWs) in droplet-based microfluidics**
   BUSSONNIERE A., MIRON Y., BAUDOIN M., BOU MATAR O., GRANDBOIS M., CHARETTE P.G., RENAUDIN A.
   Lab Chip 14, 18 (2014) 3556-3563 *doi: 10.1039/C4LC00625A* (IF = 6.115) - **WoS : 7.6%**

6. **Magneto-electro-elastic effective properties of multilayered artificial multiferroics with arbitrary lamination direction**
   S. GIORDANO, M. GOUEYGOU, N. TIERCELIN, A. TALBI, P. PERNOD, AND V. PREOBRAZHENSKY
   International Journal of Engineering Science 78, 134-153 (2014). *doi: 10.1016/j.ijengsci.2014.02.011.*
   25 citations in the period 2013-2018 - (IF = 2.668) - **WoS : 8.4%**

7. **Capillary tube wetting induced by particles: towards armoured bubbles tailoring**
   ZOUESHTIAGH F., BAUDOIN M., GUÉRIN D.
   Soft Matter 10, 47 (2014) 9403-9412, *doi: 10.1039/C4SM01648C* (IF = 4.029) - **WoS : 11.5%** - **Journal issue front cover**

8. **Influence of viscosity on sessile droplet acoustic streaming: a numerical and experimental study**
   A. RIAUD, P. BRUNET, M. BAUDOIN, O. BOU MATAR, J.-L. THOMAS
   Fluid Mech. vol. 821, pp. 384-420, 2017. (IF = 2.821) - **WoS : 12.8%** - **Highlighted by Focus on Fluids and INSIS CNRS Department**

9. **the Faraday threshold in small cylinders and the sidewall non-ideality**
   W. BATSON, F. ZOUESHTIAGH, R. NARAYANAN
   J. Fluid Mech., 729, pp. 496-523. (IF = 2.821),2013 - **WoS : 12.8%**

10. **Selective manipulation of microscopic particles with Precursor Swirling Rayleigh waves**
    A. RIAUD, M. BAUDOIN, O. BOU MATAR, L. BECERRA, J-L. THOMAS
    Phys. Rev. Appl., vol. 7(2), pp. 024007, 2017.
    Highlighted by Physics central (Physics Buzz) (IF = 4.061) - **WoS : 15.2%**
    Supported by a SATT maturation project, I-Site maturation project and AWESOM ANR blanche project

11. **Selective manipulation of microscopic particles with Precursor Swirling Rayleigh waves**
    C. GHOUILA-HOURI, A. TALBI, R. VIARD, M. MOUTAOUEKKIL, O. ELMAZRIA, Q. GALLAS, E. GARNIER
    Appl. Phys. Lett. 111, 11 (2017) 113502, 4 pages (available online september 12, 2017 ; published september 11, 2017)
    doi: 10.1063/1.4995364 (IF = 3.411) - **WoS : 19%**

12. **High temperature gradient micro-sensor for wall shear stress and flow direction measurements**
    C. GHOUILA-HOURI, J. CLAUDEL, J.C. GERBEDOEN, Q. GALLAS, E. GARNIER, A. MERLEN, R. VIARD, A. TALBI, P. PERNOD,
    Appl. Phys. Lett. 109, 24 (2016) 241905, 4 pages (available online december 16, 2016 ; published december 12, 2016),
    doi: 10.1063/1.4972402 (IF = 3.411) - **WoS : 19%**
    Supported by CPER ELSAT 2020, ANR ASRID DGA, previously patented technologies.

13. **Magnetoelectric write and read operations in a stress-mediated multiferroic memory cell**
    A. KLIMOV, N. TIERCELIN, Y. DUSCH, S. GIORDANO, T. MATHURIN, P. PERNOD, V. PREOBRAZHENSKY, A. CHURBANOV, S. NIKITOV,
    Appl. Phys. Lett., 2017, 110, 222401 (IF = 3.411) - **WoS : 19%**
    http://scitation.aip.org/content/aip/journal/apl/110/22/10.1063/1.4983717, **APL Highlights:**
    https://publishing.aip.org/publishing/journal-highlights/magnetoelectric-memory-cell-increases-energy-efficiency-data-storage

14. **Stress-mediated magnetoelectric control of ferromagnetic domain wall position in multiferroic heterostructures**
    MATHURIN T., GIORDANO S., DUSCH Y., TIERCELIN N., PERNOD P., PREOBRAZHENSKY V.
    Appl. Phys. Lett. 108, 8 (2016) 082401 (IF = 3.411) - **WoS : 19%**

15. **Multilayer magnetostrictive structure based surface acoustic wave devices**
    H. ZHOU, A. TALBI, N. TIERCELIN & O. BOU MATAR
    Appl. Phys. Lett. 104(11), 114101 (2014) - *doi: 10.1063/1.4868530* (IF = 3.411) - WoS : 19%

16. **Two dimensional modeling of elastic wave propagation in solids containing cracks with rough surfaces and friction Part I: Theoretical background**
    V. ALESHIN, S. DELRUE, A. TRIFONOV, O. BOU MATAR, K. VAN DEN ABEELE,
    Ultrasonics vol. 82, pp. 11-18, 2018. (IF=2.327) - **WoS : 19.4%**

17. **Thermal effects in magnetoelectric memories with stress-mediated switching**
    S. GIORDANO, Y. DUSCH, N. TIERCELIN, P. PERNOD AND V. PREOBRAZHENSKY
    Journal of Physics D: Applied Physics 46, 325002 (2013). *doi: 10.1088/0022-3727/46/32/325002.*
    27 citations in the period 2013-2018 - (IF = 2.521) - **WoS : 22.1%**

18. **Method of memory diagrams for mechanical frictional contacts subject to arbitrary 2D loading**
    ALESHIN V., BOU MATAR O., VAN DEN ABEELE K.
    Int. J. Solids Struct. 60-61 (2015) 84-95, *doi: 10.1016/j.ijsolstr.2015.02.016* (IF = 2.081) - **WoS : 22.2%**

19. **Stress-mediated magnetoelectric memory effect with uni-axial TbCo2/FeCo multilayer on 011-cut PMN-PT ferroelectric relaxor**
    Y. DUSCH, N. TIERCELIN, A. KLIMOV, S. GIORDANO, V. PREOBRAZHENSKY, AND P. PERNOD
    J. Appl. Phys. **113**, 17C719 (2013) *doi: 10.1063/1.4795440* (IF = 2.068) - **WoS : 40.1%**

20. **Acoustic isolation of disc-shaped modes using periodic corrugated plate-based phononic crystal**
    M. MOUTAOUEKKIL, A. TALBI, E.H. EL BOUDOUTI, O. ELMAZRIA, B. DJAFARI-ROUHANI, P. PERNOD, O. BOU MATAR
    Electron. Lett. 54, 5 (2018) 301-303 *doi: 10.1049/el.2017.4029* "**Front-Cover** & **Highlight in "Electronics Letters"**(IF=1.155) - **WoS : 66.1%**

21. **Real-time mechanical characterization of DNA degradation under therapeutic X-rays and its theoretical modeling**
    G. PERRET, T. LACORNERIE, F. MANCA, S. GIORDANO, M. KUMEMURA, N. LAFITTE, L. JALABERT, M. C. TARHAN, E. F. LARTIGAU, F. CLERI, H. FUJITA, D. COLLARD
    Nature Microsystems & Nanoengineering 2, 16062 (2016). *doi: 10.1038/micronano.2016.62*
    New Nature journals series. **Highlight in the CNRS Scientific news** (5th december 2016)
    http://www.cnrs.fr/insis/recherche/actualites/2016/12/degradation-adn.htm

Scientific articles with last authorship *(Biology only)* / Review articles

Other articles (professional journals, etc.)

Mesure de la dégradation bio-mécanique d'une fibre d'ADN sous l'effet des rayons X thérapeutiques,
G. PERRET, T. LACORNERIE, F. MANCA, S; GIORDANO, M. KUMEMURA, N. LAFITTE, L. JALABERT, M.C. TARHAN, E.F. LARTIGAU, F. CLERI, H. FUJITA, D. COLLARD,
M S-Med. Sci. 33, 12 (2017) 1026-1029 doi: 10.1051/medsci/20173312003

Clinical articles

2- Books

Scientific book edition

Book chapters

1. **Strain Mediated Magneto-electric Memory, in "Nanomagnetic and Spintronic Devices for Energy Efficient Computing"**
N. TIERCELIN, Y. DUSCH, S. GIORDANO, A. KLIMOV, V. PREOBRAZHENSKY AND P. PERNOD,
co-edited by Prof. Bandyopadhyay & J. Atulasimha, ISBN 978-1-118-86926-0, John Wiley & Sons, Ltd (2016) chapter 8, 221-257 *doi: 10.1002/9781118869239.ch8*

2. **Tunable phononic crystals and metamaterials in Acoustic metamaterials and phononic crystals,**
O. BOU MATAR, J.O. VASSEUR, P.A. DEYMIER, DEYMIER P.A.
(Ed), ISBN 978-3-642-31231-1, e-ISBN 978-3-642-31232-8, Springer Berlin Heidelberg (2013) chapter 8, 253-280 *doi: 10.1007/978-3-642-31232-8_8*

3- Meetings

Meeting abstracts

1. **From non-linear magnetoacoustics and spin reorientation transition to magnetoelectric micro/nano-systems**
N. TIERCELIN, V. PREOBRAZHENSKY, O. BOU MATAR, A. TALBI, S. GIORDANO, Y. DUSCH, A. KLIMOV, T. MATHURIN, O. ELMAZRIA, M. HEHN, P. PERNOD,
[Invited] at SPIE San Diego August 2017 – in Proc. of SPIE Vol. 10357, 103571T-1

2. **Feshbach resonance and explosive instability of magnetoelastic waves**
V. PREOBRAZHENSKY, V. ALESHIN, P. PERNOD
Proceedings of 24th International Congress on Sound and Vibration, ICSV24, London, UK, july 23-27, 2017, paper 103, 8 pages, ISBN 978-1-906913-27-4, [Invited]
https://www.iiav.org/archives_icsv_last/2017_icsv24/content/papers/papers/full_paper_103_20170410120939111.pdf

3. **Large frequency tuning of a millimeter-wave antenna over dielectric liquid micro-channels**
G. DUFOUR, N. TIERCELIN, W. KHAN, P. PERNOD, P. COQUET AND J. PAPAPOLYMEROU
Proceedings of the IMS2015, 17-22 Mai 2015, Phoenix (USA) – pp1-4 DOI: *10.1109/MWSYM.2015.7167014*

4. **Manipulation of magnetic domain wall in magnetoelastic nanostripes,**
T. MATHURIN, S. GIORDANO, Y. DUSCH, N. TIERCELIN, P. PERNOD, V. PREOBRAZHENSKY
Actes du 23ème Congrès Français de Mécanique, CFM 2017, Lille, France, 28 août-1 septembre, 2017, Session S16 - Matériaux fonctionnels - couplages multiphysiques, 13 pages

5. **Investigation of magnetic field sensor based on ($TbCo_2$/FeCo)n/AlN/TiN/NCD composite membrane**
A. TALBI, M. MOUTAOUEKKIL, J.C. GERBEDOEN, Y. DUSCH, A. SOLTANI, V. PREOBRAZHENSKY, N. TIERCELIN, O. BOU MATAR, P. PERNOD, V. MORTET, O. ELMAZRIA, M. ELHOSNI
Proceedings of 2015 Joint IEEE International Symposium on Applications of Ferroelectric, International Symposium on Integrated Functionalities, and Piezoresponse Force Microscopy Workshop, ISAF/ISIF/PFM 2015, Singapore, Singapore, may 24-27, 2015, 218-221, e-ISBN 978-1-4799-9974-3, *doi: 10.1109/ISAF.2015.7172710*

6. **Wall shear stress and flow direction thermal MEMS sensor for separation detection and flow control applications**
C. GHOUILA-HOURI, J.C. GERBEDOEN, J. CLAUDEL, Q. GALLAS, E. GARNIER, A. MERLEN, R. VIARD, A. TALBI, P. PERNOD
30th Eurosensors Conference, EUROSENSORS XXX, Budapest, Hungary, september 4-7, 2016, paper TL.PHY-15-8170, Procedia Engineering **168** (2016) 774-777, *doi: 10.1016/j.proeng.2016.11.278*

7. **Multi-scale modeling for MEMS : from physical principles to engineering applications**
CLERI F., MANCA F., PALLA P.L., GIORDANO S.
11th Japan-France Workshop on Nanomaterials and 2nd WPI-Workshop on Materials Science, NanoMat 2015, Rennes, France, may 27-30, 2015, http://nanomat2015.sciencesconf.org/65474/document [INVITED].
8. **Narayanan Faraday Instability in Liquid-Air Electrostatically Oscillated Systems**
K.L. WARD, F. ZOUESHTIAGH, S. MATSUMOTO, R. AMERICAN,
SOCIETY OF GRAVITATIONAL RESEARCH, Washington DC, November 12 (2015)

9. **Ultrasonically induced dynamics of fluid interfaces in gravity and microgravity environments**
   A. BRYSEV, P. SHIRKOVSKIY, F. ZOUESHTIAGH, V. PREOBRAZHENSKY, P. PERNOD
   IEEE International Ultrasonic Symposium, Chicago, Illinois USA, September 3-6 (2014)

10. **Two Frequency Excitation of Single Mode Faraday Waves,**
    W. BATSON, F. ZOUESHTIAGH, R. Narayanan, IMA7, Vienna, June 2014

4- Meeting and congress organisation

1. Member of Local Scientific organizing committee and Session Chairman of the international conference Eurosensors 2017, Paris/France, 3-6/09/2017
2. Member of the international organizing committee of the International Congress on Functional Materials ICFM 2013, Partenit (280 Participants / 15 Countries)
3. Organization of an interdisciplinary Session « Flow control » Congrès Français de Mécanique 28/08-1/09/2017
4. Organization of the workshop « contrôle aérodynamique - Application aux transports terrestre » 20-05-2016 ; Stade Hainaut de Valenciennes
5. Member of the local organizing committee of the «49th International symposium of applied aerodynamics », Lille, 24-26/04/2014
6. Member of the organizing committee of the international summer school “Microfluidics’ 15”, Porquerolle, France, 21-26/06/2015
7. Member of the scientific committee and organization of a session at CFM Lille 2017

5- Electronic tools and products

Softwares / Databases / Tools for decision-making / Cohorts *(Biology only)* /Solver competition tools *(Science and technology only)*

6- Instruments and methodology

Prototypes

1. Prototype of a High flow rate chamber-less and valve-less reversible MEMS micropump
2. Prototypes of MEMS pressure and wall shear stress microsensors and MEMS synthetic microjet actuators for active flow control
3. Prototype of miniaturized flat transparent acoustical tweezers which enable to grab and move selectively microparticles of sizes down to several microns
4. Prototype of an active slippery surface controlled by surface acoustic waves.

Platforms and observatories

Contribution to the creation of the integrated Scientific Regional platform CONTRAERO. Unique in France, the platform gathers all the needs of aerodynamic control for transport, from the multi-physics development of micro-technological systems to the physics of flows: elaboration and characterization of actuators and sensors, model integration, modeling, advanced metrology wind tunnel tests and flow analysis methodologies

7- Other products

Artistic creations / Movie or theatre play creation / Movies

8- Editorial activities

Participation to journal editorial boards (books, collections)

- Associate Editor of the scientific international journal « Physics of Wave Phenomena »
  Allerton Press, Inc. / New York
- Associate Editor of the scientific international journal « Nanomaterials and Nanostructures»,
  Radiotechnika Ed. / Russia

9- Peer reviewing activities

Reviewing of journal articles

More than 100 reviews for :
Phys. Rev. Lett., Phys Rev. B, Journal of Applied Physics, Applied Physics Letters, European Physics Journal B, Mechanics of Materials, International Journal of Solids and Structures, Mechanics Research Communication, Smart Materials and Structures, Physica B, Proceedings of the Royal Society, Journal of Nanophotonics, Applied Physics A, Modern Physics Letter B, Surface Review and Letters, Advanced Materials, Nanoscale, AIP Advances, ACS Nano, Journal of Applied Physics, Journal

of Magnetism and Mag. Mat., Nanoscale, IEEE Trans. Microwave Th. and Tech, Acustica, Journal of the Acoustical Society of America, Journal of Nondestructive Evaluation, Physica B, Ultrasonics, J. Fluid Mech, New J. Phys. (and others).

Grant evaluation (public or charities)
About 6 ANR projects reviewed, 1 CEA enhanced Eurotalents, 2 DFG projects

Participation to lab site visit committees (Hceres etc.) / Participation to institutional committees and juries (CNRS, INSERM, etc.)

10- Academic research grants

Total amount of contracts 2013-2018 : 4 M€

European (ERC, H2020, etc.) and international (NSF, JSPS, NIH, World Bank, FAO, etc.) grants
- FP7 Marie-Curie IRSES project PAS « Patterns and Surfaces » , 2012-2015
- FP7-AAT-2012-NDT project ALAMSA, 2012-2016
- LIFE SMART IN'AIR, 2018-2022

National public grants (ANR, PHRC, FUI, INCA, etc.)
9 ANR projects (6 ANR projects as Principal Investigators), among which :
- ANR Blanche “SMART-US” « Smart-UltraSons : détection/caractérisation/contrôle de sources de non linéarité ultrasonore », 2010-2014, 192 k€
- ANR blanche ANL-MEMS “Techniques d’imagerie acoustique non linéaire pour l’étude de la fiabilité des MEMS”, 2010-2014, 430 k€ all partners, 224 k€
- ANR TDM Transport Durable et Mobilité “LIVE-CAMS” “Limitation de l’Impact des Véhicules sur l’Environnement par Contrôle Aérodynamique au moyen de Micro-jets Synthétiques”, 2012-2015, 343 k€
- ANR blanche AWESOM “Laboratoire sur puce basé sur des technologies hybrides pour la manipulation et la caractérisation de fluides biologiques”, 2012-2016, 530 k€ all partners, 199 k€
- ANR Astrid CAMELOTT « Capteurs et Actionneurs MEMS pour Le cOnTrôle réactif de décollement sur voleT», 2014-2017, 179 k€
- ANR “2DPS” with Singapore, 2017-2020, 250 k€ IEMN, 285 CINTRA, 535 k€ All partners, 114 k€
- Programme Hubert Curien (**PHC**) Sakura (Japon), Ambassade de France à Tokyo : « Wetting dynamics in presence of particles », 2015-2016

Local grants (“collectivités territoriales”)
- ‘CPER CIA/Flexible Electronics: “Mechanically reconfigurable 60 GHz antennas and phase shifters”, 2013-2015, 95 k€
- CPER CIA/MESYA, “MELRAM “Mémoire magnéto-électrique et Composants ultra-faible consommation”, 2014-2015, 65 k€
- CPER ELSAT2020 “Transport : Arrays of MEMS Micro-actuators and Micro-sensors for aerodynamic active flow control”, 2017-2018, 230 k€
- STARTAIRR’ Transfer program Région Hauts-de-France, MELRAM “Mémoire magnéto-électrique et Composants ultra-faible consommation”, 2016-2017, 70 k€

PIA (Labex, Equipex etc.) grants
- **I-Site ULNE:**
  - I-Site ULNE action for industrial transfer, “Stack acoustical tweezers for micro-objects assembly”, 2018-2019, 70 k€
  - I-Site ULNE action for industrial transfer, “Development of an ultra-low energy magnetoelectric memory cell at the micron scale », 2018-2019, 70 k€
  - I-Site ULNE action for joint international PhD with KU Leuven, “Interaction of ultrasonic waves with friction sensitive defects for nondestructive testing of materials”, 2018-2021, 100 k€

— **SATT (Tech Transfer Acceleration Network):**
- Maturation project SATT NORD "MEMS Micropump", 2016-2018, 315 k€ including IP Group
- Maturation project SATT NORD "Acoustipince", 2016-2018, 315 k€ including IP Group
- Grant from Labex Ganex
-

Grants from foundations and charities (ARC, FMR, FRM, etc.)

11- Visiting senior scientists and post-doc

Post-docs – ATER

a. Post-doctorants & IR :
   a. 16 different researchers
   b. Total ETP : 25,4 ETP during the period 2013-Mid 2018
   c. Typical financial supports : FP7 Marie-Curie IRSES, CNES projects, ANR projects, CPER projects, SATT maturation projects
   d. List :
   · Vasily Rudenko, postdoc, 2009-2012, ANR NAMAMIS
   · Pavel Shirkovskiy, postdoc, 2012-2015, ANR Smart-US
   · Fabio Manca, post-doc, 2013, "TWEEZ-RT", INSERM - Plan Cancer 2009-2013
   · Fabio Manca, post-doc, 2015, "MODCEL", SIRIC - ONCOLille 2014)
   · Sami Hage-Ali, postdoc, 2013-2014, CPER CIA / Flexible
   · Dmitry Zakharov, postdoc, 2014-2015, CPER CIA / Mesya (Energie)
   · Claire Théveneau, IR, 03/2016 - 03/2017, Project StartAIRR Région Hauts de France
   · Adrien Le Goff, postdoc, 01/2018 - 2020, Prematuration project CNRS
   · Mathias Dolci, postdoc, 06/2018 - 2020 - ANR 2DPS
   · Ralph Sindjui,postdoc, Juillet 2016-Juillet 2017, ANR ASTRID
   · Julien Claudel, postdoc, 09/2015-08/2017, ANR ASTRID
   · Jean-Claude Gerbedoen, Postdoc, 10/2012 -08/2015, ANR LiveCams
   · Jean-Claude Gerbedoen, IR, 09/2016-pres., SATT maturation project Acoustipince
   · Jamel Nebhen, Postdoc, 09/2017-08/2018, CPER ELSAT 2020
   · Sara Mhedhbi, Postdoc, 12/2017-11/2018, CPER ELSAT 2020
   · Maxime Seuleuthner, IR, 10/2017-12/2018, SATT Project Micropump
   · Astrid Linge, IR, 10/2017-12/2018, SATT Project Micropump
   · Nikolay Smagin 5/2/2013-15/04/2013 & 1/1-31/7/2014, FP7-AAT-2012-NDT project ALAMSA
   · Diwakar Seyyanur Venkatesan, 1/1/2012-30/6/2015, IRSES and CNES projects

b. ATER :
   a. 8 different researchers (6 with Centrale Lille and 2 for Univ. Lille)
   b. Total ETP : 4,5 ETP during the period 2013-Mid 2018 (an ATER accounts for 0,5 ETP for research)
   c. List :
   · Arnaud Stolz, 09/2012-08/2013, Centrale Lille
   · Abdallah Hamini, 09/2013-08/2014, Centrale Lille
   · Fabio-Manca 09/2014-08/2015, Centrale Lille
   · Jean-Claude Gerbedoen, 09/2015-08/2016, Centrale Lille
   · Bilel Hafsi 09/2016-04/2018, Centrale Lille
   · Abdellatif El Fellahi 09/2017-08/2018, Centrale Lille
   · Ilysse Bihi, 09/2014-08/2015, Univ. Lille
   · Stéphanie Signe Mamba, 09/2016-08/2017, Univ. Lille

Visiting senior scientists

a. 12 different researchers
b. Total ETP : more than 45 ETP during the period 2013-Mid 2018
c. Typical financial supports : LIA LICS budget (CNRS, Centrale Lille, Univ. Lille), FP7 Marie-Curie IRSES, CNES contracts
d. List :
   · Vladimir Preobrazhensky, Principal researcher / Co-Dir LIA LICS Wave Research Center, General Physics Institute, Russian academy of Science
   · Andreï Brysev, Chief of laboratory, Wave Research Center, General Physics Institute, Russian academy of Science
   · Leonid Krutyanskiy, Senior researcher, Wave Research Center, General Physics Institute, Russian academy of Science
   · Alexey Klimov, Assistant Professor, Moscow Technological University (MIREA), Russia

- Yuri Pylnov, Assistant Professor, Moscow Technological University (MIREA), Russia
- Alexander Sigov, Full Academician, President of Moscow Technological University (MIREA), Russia
- Mikhail Logunov, Professor, Ogarev Mordovia State University, Saransk
- Diwakar Seyyanur Venkatesan, Assistant Professor, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, India
- Ranga Narayanan, Professor, University of Florida, USA
- Jason Butler, Professor, University of Florida, USA
- Ichiro Ueno, Professor, Tokyo University of Science
- Evgeny Timofev, Professor, McGill University, Montreal, Quebec

12- Scientific recogniti

Prizes

2016 P. Pernod, Medal from UNESCO for « Contribution to the development of nanosciences and nanotechnologies »

Distinctions

2013 International Distinction for « Contribution to the development of sciences » from the Ministry of Education and Sciences of the autonomous Republic of Crimea

IUF members

Chair of learned and scientific societies

1. M. Baudoin, Membre du comité de pilotage du GDR Microfluidique
2. N. Tiercelin, Membre du bureau du GDR OXYFUN

Invitations to meetings and symposia (out of France)

1. [Invited] **Statistical mechanics of polymer chains in the Gibbs and Helmholtz ensembles,**
   S. GIORDANO,
   Workshop on DNA Mechanics and Dynamics, Leuven, Belgium, february 10, 2017

2. [Invited] **SAW-based vortical acoustofluidics,**
   M. BAUDOIN, A. RIAUD, J.-L. THOMAS, O. BOU MATAR,
   Acoustofluidics 2016, Opening keynote lecture, USWNET, 22-23 September 2016, Copenhagen (Denmark)

3. [Invited] **On-chip generation of acoustical vortices with swirling SAWs for single particle manipulation and vorticity control**
   M. BAUDOIN A. RIAUD, J.-L. THOMAS, O. BOU MATAR,
   171th ASA Meeting, 23-27 May 2016, Baltimore (USA)

4. [Invited] **SAW synthesis with inverse filter and IDTs arrays for microfluidic and biological applications**
   M. BAUDOIN, A. RIAUD, J.-L. THOMAS, A. BUSSONIÈRE, O. BOU MATAR,
   invited for an extended lecture (30 min), IEEE International Ultrasonic Symposium, 21-24 October 2015, Taipei (Taiwan)
   [B5] M. Baudoin, A. Riaud, J.-L. Thomas, O. Bou Matar, SAW-based vortical acoustofluidics, Acoustofluidics 2016, Opening keynote lecture, USWNET, 22-23 September 2016, Copenhagen (Denmark)

5. [Invited] **On-chip generation of acoustical vortices with swirling SAWs for single particle manipulation and vorticity control**
   M. BAUDOIN A. RIAUD, J.-L. THOMAS, O. BOU MATAR,
   171th ASA Meeting, 23-27 May 2016, Baltimore (USA)

6. [Invited] **Magnetoelectric random access memory (MELRAM)**
   TIERCELIN N., DUSCH Y., KLIMOV A., GIORDANO S., PREOBRAZHENSKY V., PERNOD P.
   International Conference on Functional Materials, ICFM 2013, Partenit, Crimea, Ukraine, september 29-october 5, 2013, paper EA-5O/2

7. [Invited] **Unequivocal Strain Mediated Magneto-electric Memory**
   TIERCELIN N., DUSCH Y., GIORDANO S., KLIMOV A., ZAKHAROV D., PREOBRAZHENSKY V., PERNOD P.,
   XXIII INTERNATIONAL MATERIALS RESEARCH CONGRESS 2014, Symposium 7C - Interfaces, Structure, and Domains in Ferroic and Multiferroic Material Systems abstract S7C-O013, 17 – 21 August, Cancún, Mexico

8. [Invited] **Magneto-electric Memory in Strain-mediated Multiferroic Nano- heterostructure N*($TbCo_2$/FeCo)-PMN-PT**
   A. KLIMOV, N. TIERCELIN, Y. DUSCH, V. PREOBRAZHENSKY, P. PERNOD, A. CHURBANOV, S. NIKITOV,

3rd Edition Nanotech Dubai International Conference and Exhibition, Nanotech Dubai 2016, Dubai, United Arab Emirates, december 5-7, 2016, 26-26

9. [Invited] **Strain-mediated multiferroic memory N*(TbCo$_2$/FeCo)-PMN-PT,**
PREOBRAZHENSKY V., KLIMOV A., TIERCELIN N., PERNOD P., DUSCH Y., GIORDANO S., CHURBANOV A., SIGOV A., NIKITOV S,
invited at Moscow International Symposium on Magnetism 1-5 July, 2017.

10. [Invited] **High field bipolar magnetic field sensors based on surface acoustic wave resonators**
V. POLEWCZYK, K. DUMESNIL, D. LACOUR, M. MOUTAOUEKKIL, H. MJADEH, N. TIERCELIN, S. PETIT-WATELOT, Y. DUSCH, O. ELMAZRIA, A. TALBI, O. BOU MATAR & M. HEHN,
Invited at SPIE San Diego August 2017.

11. [Invited] **From non-linear magnetoacoustics and spin reorientation transition to magnetoelectric micro/nano-systems,** N. TIERCELIN, V. PREOBRAZHENSKY, O. BOUMATAR, A. TALBI, S. GIORDANO, Y. DUSCH, A. KLIMOV, T. MATHURIN, O. ELMAZRIA, M. HEHN, P. PERNOD,
Invited at SPIE San Diego August 2017 – in Proc. of SPIE Vol. 10357, 103571T-1

12. [Invited] **LIA LICS Active nanostructures and MEMS for RF micro-transducer devices**
P. Pernod, V. Preobrazhensky, A. Talbi, N. Tiercelin, O. BouMatar, S. Giordano, Y. Dusch, A. Klimov, NMDC 2017, Singapore October 2017

Members' long-term visits abroad

II -INTERACTIONS WITH THE NON-ACADEMIC WORLD, IMPACTS ON ECONOMY, SOCIETY, CULTURE OR HEALTH.

1- Socio-economic interactions / Patents

Invention disclosures

Filed patents

1. MERLEN Alain, ZOUESHTIAGH Farzam, TALBI Abdelkrim, PERNOD Philippe, FRANKIEWICZ Christophe
"Procédé pour générer un écoulement de fluide"
   - FR3012443 (A1) 2015-05-01 [+]
   - CA2927425 (A1) 2015-04-30 [+]
   - WO2015059426 (A1) 2015-04-30 [+]
   - EP3060803 (A1) 2016-08-31 [+]
   - US2016258430 (A1) 2016-09-08 [+]
   - JP2016534284 (A) 2016-11-04 [+]

2. BAUDOIN Michaël, BOU MATAR-LACAZE Olivier, RIAUD Antoine, THOMAS Jean-Louis
"Acoustic tweezers"
   - WO2017157426 (A1) 2017-09-21 [+]
   - WO2017202747 (A1) 2017-11-30 [+]

Accepted patents

1. VIARD Romain, TALBI Abdelkrim, PERNOD Philippe, MERLEN Alain, PREOBRAZHENSKY Vladimir
"Capteur miniaturisé à élément chauffant et procédé de fabrication associé"
   - N° de brevet : FR2977886 (A1) 2013-01-18
   - WO2013008203 (A2) 2013-01-17 [+]
   - WO2013008203 (A3) 2013-03-07 [+]
   - CN103717526 (A) 2014-04-09 [+]
   - EP2731908 (A2) 2014-05-21 [+]
   - US2014157887 (A1) 2014-06-12 [+]
   - EP2731908 (B1) 2015-09-09 [+]
   - DK2731908 (T3) 2015-12-21 [+]
   - CN103717526 (B) 2016-08-17 [+]
   - US9476746 (B2) 2016-10-25 [+]
   - FR2977886 (B1) 2017-03-03 [+]

3. PERNOD Philippe, GIMENO-MONGE Leticia, TALBI Abdelkrim, MERLEN Alain, VIARD Romain, MORTET Vincent, SOLTANI Ali, PREOBRAZHENSKY Vladimir
"Capteur à fil chaud de taille submillimétrique et procédé de réalisation associé"
   - EP2561369 (A1) 2013-02-27 [+]
   - US2013125644 (A1) 2013-05-23 [+]
   - JP2013527436 (A) 2013-06-27 [+]
   - US8978462 (B2) 2015-03-17 [+]
   - EP2561369 (B1) 2015-04-01 [+]
   - DK2561369 (T3) 2015-07-06 [+]
   - JP5770828 (B2) 2015-08-26 [+]

4. TIERCELIN Nicolas, DUSCH Yannick, PERNOD Philippe, PREOBRAZHENSKY Vladimir
"Mémoire magnétoélectrique"
   - FR2961632 (B1) 2013-04-19 [+]
   - EP2583281 (A1) 2013-04-24 [+]
   - KR20130056276 (A) 2013-05-29 [+]
   - US2013163313 (A1) 2013-06-27 [+]
   - JP2013530535 (A) 2013-07-25 [+]
   - RU2013102286 (A) 2014-07-27 [+]
   - US8908422 (B2) 2014-12-09 [+]
   - JP5784114 (B2) 2015-09-24 [+]
   - RU2573207 (C2) 2016-01-20 [+]

5. BUSSONNIERE Adrien, BOU MATAR-LACAZE Olivier, BAUDOIN Michael, BRUNET Philippe
"Procédé pour favoriser le glissement d'au moins une goutte sur un support"
   - FR3044937 (A1) 2017-06-16 [+]
   - WO2017097769 (A1) 2017-06-15 [+]
   - FR3044937 (B1) 2018-01-12 [+]

Licenced patents

1- Socio-economic interactions

Industrial and R&D contracts

- Contract with CEA : « Etude d'applicabilité de la conjugaison de phase ultrasonore à la caractérisation d'un milieu diphasique avec nuage de bulles », 2016, 25 k€ Group
- Contract with Childerix Technologies : « Etude de faisabilité d'un dispositif ultrasonore dédié » dans le cadre d'un projet de création de startup, 2015, 10 k€ Group
- Contract with VALEO Systèmes Thermiques « Etude numérique et théorique de l'augmentation du rendement d'un échangeur thermique à l'aide de vibrations ultrasonores », 2014, 9,6 k€ Group

Cifre fellowships

- Thales PhD Thesis, "Modelling and Evaluation of graphene foam thermoacoustic effect for effective sound generation in liquids", 2017-2020, 160 k€ group

Creation of labs with private-public partnerships / Networks and mixed units *(Science and technology only)* / Start-ups / Clinical trials *(Biology only)*

2- Expertise

Consulting / Participation in expert committees (ANSES etc.) / Legal expertise

3- Expert and standardization reportsPublic outreach

Radio broadcasts, TV shows, magazines

Journal articles, interviews, book edition, videos, etc.

1. [Highlights] Magnetoelectric memory cell increases energy efficiency for data storage, A. Klimov, N. Tiercelin, Y. Dusch, S. Giordano, T. Mathurin, P. Pernod, V. Preobrazhensky, A. Churbanov and S. Nikitov, AIP Publishing in the News, Appl. Phys. Lett. 110, 222401, may 30, 2017, https://publishing.aip.org/publishing/journal-highlights/magnetoelectric-

memory-cell-increases-energy-efficiency-data-storage

2. [Highlights] Real-time mechanical characterization of DNA degradation under therapeutic X-rays and its theoretical modeling, Actualités scientifiques CNRS 5 décembre 2016, *http://www.cnrs.fr/insis/recherche/actualites/2016/12/degradation-adn.htm*

3. « Microsystèmes et Microfluidique », Semaine de la Recherche et de l'Innovation de la Région Hauts de France, Conférences Beyondlab Insights : Aux portes du futur / Prospective technologique, Lille, Nov. 2016

4. Forum sur l'Interaction Tactile et Gestuelle (FITG) 13-14 mai 2014, Tourcoing/ pleine images: Invité pour un oral et stand pour démonstration

5. Fête de la science (5-8 Octobre 2017), Stand Nano-Ecole, le thème de cette année « voyage » : Mouvement, territoire, migration. Technologies pour l'aéronautique « IEMN/ONERA »

Other popularization outputs / Debates on science and society

III - INVOLVEMENT IN TRAINING THROUGH RESEARCH

1- Educational outputs

Books / *E-learning, MOOCs, multimedia lessons, etc.*

2- For humanities only, published PhD theses

3- Quality of PhD student supervision

4- Students' follow up in association with doctoral schools

5- Participation to international training programs (e. g. Erasmus Mondus

6- PhD student participation to scientific animation and unit/team life

7- Participation of team members in setting up Master courses

- Involvement in the definition of the new Masters degree programs at Centrale Lille: "Smart Systems and Smart Environments"
- Involvement in the definition of the new Masters degree programs at University of Lille:
    - "RF systems & IoTs"
    - "Telecommunications"
    - "Mechanics & Fluid Mechanics"
- Present involvement in the creation of a Graduate School "Deep Tech" in the framework of the I-Site ULNE

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Group

GROUP ACRONYM : BioMEMS

Name of the group : BioMEMS

Members: ***4.4 ETPR,*** *Thomas DARGENT (Ass. PR), Jérôme FOLLET (Ass. PR), Vincent SENEZ (DR), Vincent THOMY (Ass. PR), Anthony TREIZEBRÉ (Ass. PR), Céline VIVIEN (Ass. PR), Alexis VLANDAS (CR).* ***Non-Permanent Staff: 7.7 ETPR*** *(18 PhD students + 5 Postdocs).*

Responsible : Vincent THOMY

Permanent staff (ETPR)	2013	2014	2015	2016	2017	2018 (*)
Professors and associate professors	1.9	1.9	1.9	2.4	2.4	2.4
CNRS scientists	2	2	2	2	2	2
Engineers and technicians (permanent)	0	0	0	0	0	0

Non-permanent staff (ETPR)	2013	2014	2015	2016	2017	2018 (*)
PhD students	3	5.5	7	6.5	7.5	3.5
Post Docs, ATER, long-term visitors	2	3	1	2	1	1

Publications, patents and thesis/HDR	2013	2014	2015	2016	2017	2018 (*)
Peer-reviewed articles	10	10	2	7	6	4
Books	1	1		1		
Invited Speakers	1		1			
Communications (internationals and proceedings)		1	4	4	1	
Theses/HDR		3/1	2/0		4/0	1/0
Patents				1	3	

Publication rate ETPR/Year : 1,5

(The group has an average of 4.2 ETPR by adopting the following rules: 0.5 for a Professor or Associate Professor (and 0.4 in case of 80% working time); 1 for a Researcher; a pro rata is applied according to the date of recruitment or departure.

Contractual activity 2013 et 2018

Europeans grants :

1. European INTERREG, PHOTOTEX, 2018-2021, 310 keuros
2. ERC Consolidator, NANOBUBBLE, 2015-2020, 255 keuros
3. FP7, SMARTWATER4EUROPE, 2013-2017, 100 keuros.

Industrials grants :

1. GDX project (Gènes Diffusion company), 2014-2017, 1 005 keuros
2. SATT Reflex 1, 2016-2018,287 keuros
3. SATT Reflex 2, 2018-2020, 330 keuros

Academic grants :

1. ANR-DFG - MolPro2BioSens, 2018-2021, 201 kEuros
2. INCA, GLYCOSTEM, 2015-2018, 146 keuros
3. CNRS PEPS, CRYPSTEM, 2016, 15 keuros,
4. CNRS PEPS, BIMIMOMETA, 2016, 15 keuros
5. ADEME – MEDISOV, 2014-2017, 80 kEuros
6. INSERM, GLIOMATRACK, 2012-2015, 150 keuros
7. PEPS: APPEL CONJOINT Université de Lille / CNRS 2016, 10 keuros
8. ANR P2N, REFLEX, 2011-2015, 170 keuros,
9. PEPS de Site Lille, 2014, 15 kEuros
10. Université de Lille, BQR Emergence, 2014, VMiFlu, 15 keuros
11. CNRS-INSIS-Cellule énergie, PEPS Energie, MiREISS, 2014, 15 keuros
12. Université de Lille, BQR Emergence, 2013, In-Vivo, 20 keuros
13. Region NpdC, NanoTraMI, 2012-2014, 52 kEuros
14. Région NpdC, InVIVO, 2012-2014, 200 keuros

Total contractual activity 2013-2017: 3 391 keuros

Research Highlights 2013-2017 (max 10 lines)