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## ACTIVITIES IN ACOUSTICS AT LE MANS UNIVERSITY

Pierrick LOTTON<sup>1\*</sup>

Olivier DAZEL<sup>1</sup>

Michel BRUNEAU<sup>1</sup>

<sup>1</sup> Laboratoire d'Acoustique de l'Université du Mans (LAUM), UMR 6613, Institut d'Acoustique - Graduate School (IA-GS), CNRS, Le Mans Université, France

### ABSTRACT

Since the middle of the 20th century, acoustics departments have been established in universities and engineering schools throughout France. Similarly, since the founding of the University of Le Mans in 1965, several research departments have been created, with increasing focus on acoustic research and teaching. In this context, the Laboratoire d'Acoustique de l'Université du Mans (LAUM) was established in 1981 and has grown from 3 to 90 faculty and CNRS members (including 25 staff), with 80 research graduate and post-graduate students. The LAUM's research areas have also expanded to include Electroacoustics, Materials, Waveguides and Structures, fostering cutting-edge research and international collaboration. The university and CNRS provide extensive infrastructure, specialized equipment, and support services to facilitate research efforts. Bachelor and master's level courses in acoustics provide students with opportunities to pursue careers as high-level technicians or engineers in the private sector or to prepare for a Ph.D. in acoustics.

**Keywords:** *Acoustics, Research, History*

### 1. INTRODUCTION

In France, during the mid-20th century, certain universities and schools began to establish research departments and teaching modules dedicated to acoustics. This was done in response to the growing need for engineering and training activities that could meet both industrial and societal demands. Notably, Le Mans emerged as a hub for such initiatives, with the establishment of university courses in Humanities, Law, Economic Sciences, and Sciences (Mathematics, Physics, Chemistry, Computer Sciences,

Biology and Geology). Since the construction of the first premises on the current campus around 1965, research laboratories have been established every year.

Against this backdrop, the Laboratoire d'Acoustique de l'Université du Mans (LAUM) was created during the academic year 1980-81 under the aegis of the Faculty of Sciences and the Department of Sciences for Engineering of the CNRS. This was built upon the initial works on electrodynamic loudspeakers and their radiation that were carried out within the "Service de Physique" during the 1970s and 1980s.

### 2. THE FIRST YEARS (1981-95)

In the early years of the laboratory, several researchers and teacher-researchers from diverse backgrounds, including theoretical physics, graduate schools, and engineering schools, gradually joined the projects initiated by the first two teacher-researchers. This influx started with two returns from French cooperation abroad and an internal transfer to the CNRS, which was made possible by obtaining the status of UMR (Mixed Unit of Research) after four years of the laboratory's existence. The continued arrival of new researchers and teacher-researchers allowed the laboratory to grow its staff to 8 CNRS researchers, 15 teacher-researchers, 4 engineers/technicians, and 2 secretaries, totaling 40 members, including doctoral students, by 1995. This number has continued to grow since then (see below).

A postgraduate course in acoustics has been developed with the support of the laboratory and a community of external French laboratories. The program attracted students from « Grandes Ecoles », engineering schools, French and foreign universities, all of whom have diverse scientific backgrounds.

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*Corresponding author:* [pierrick.lotton@univ-lemans.fr](mailto:pierrick.lotton@univ-lemans.fr)

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The laboratory's research means, including materials and financing, were pooled in accordance with contracts, a practice that remains highly valued to this day. Similarly, the means attached to the postgraduate course were shared between associated laboratories.

During this period, the choice of research methods and topics required caution as the laboratory had to find its way in a national and international context already well advanced in many fields. Therefore, the laboratory developed analytical and experimental methods from the start, with numerical methods only becoming prominent after dedicated recruitments. In addition, the laboratory had to choose relatively original research topics, distinct from those widely studied at the time. Consequently, the laboratory focused on electroacoustics (transducers) and acoustic materials (particularly porous materials) initially, then waveguides (wind musical instruments and exhaust silencers) and room acoustics when new researchers arrived, and finally audio signal processing.

A policy of contracts has been in place since the beginning of the laboratory (industrial contracts on modeling and metrology of porous materials, silencers for the automobile industry, acoustic control of bonding, ...) allowing to support the more fundamental research. In parallel, academic collaborations in France and abroad have been progressively established. These collaborations include ongoing partnerships with universities such as Louvain, KTH Stockholm, EPFL Lausanne, Valencia, Athens, Sherbrooke, Harvard, MIT, Santiago (Chili), Sfax, Hokkaido, UST Hong Kong, Auckland and around thirty other establishments. The laboratory also collaborated with the Technical University of Prague during a time when the Iron Curtain was still in place, which complicated the process of crossing the border with scientific equipment...



**Figure 1.** An experimental room of the LAUM in the 80s

At the beginning of the laboratory, an anechoic room was built with funding from the regional council. It adjoined the existing physics building and was connected to the

available basements. Industrial contracts signed at the outset of the laboratory provided most of the equipment and operational costs. A whole apparatus of precision measurement, mainly analog, was acquired, and a system of connections between the rooms of experiments was set up to allow for shared use. Other infrastructures and means were established on the campus during this period, including the Acoustics department (independent of the LAUM) of the Centre de Transfert de Technologie du Mans (CTTM) created in 1992. It was equipped with a large anechoic room (1000 m<sup>3</sup>) coupled with a reverberation room. The engineering school (ENSIM) created in 1995 also had rooms for optical holography, vibrations, and microtechnologies integrated into the LAUM. Equipment dedicated to teaching was also established, including that of the Bac+2 course of study (DEUST "Vibration, Acoustics, Signal") created in 1990, which has trained over 500 technicians in acoustics in 20 years of existence and was highly valued by industrialists.

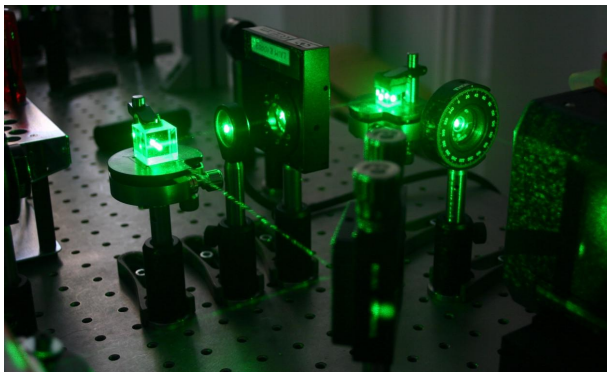


**Figure 2.** Anechoic room experiment

### 3. THE YEARS 1995 - 2023

Since the mid-1990s, the LAUM has experienced continuous growth in its staff, expanding from 40 to 170 members in 2023, including some colleagues based at Electronic engineering school ESEO in Angers. This growth has naturally led to the emergence of new research themes, owing to the evolution of research in general, as well as the diversity of recruitment. The laboratory has welcomed researchers and teacher-researchers with diverse backgrounds in acoustics, physics, mechanics, optics, thermics, micro-technologies, digital methods, applied mathematics, electromagnetism, electronics, and signal processing. Although the structure has remained largely on the model of three teams (Transducers, Materials, Guided Waves), the topics within these teams have gradually

become more diverse and enriched. Aeroacoustics, granular materials, vibro-acoustics, thermoacoustics, ultrasound, instrumentation and metrology, meta-materials, opto-acoustics, and other topics have been developed. These developments span a broad spectrum from the most fundamental studies to partnership research, while maintaining a balance between theoretical (analytical and numerical) and experimental studies.



**Figure 3.** Opto-acoustic experiment

To illustrate the above discussion on the research topics, let's now focus on a few of them. The four research topics chosen by the laboratory from the outset (electroacoustics, materials, guides, and rooms) shared a same physical phenomena: thermoviscous effects, and more specifically the phenomena that take place in the thermoviscous boundary layers. The advances achieved in these research topics are based on their revisited and dedicated analytical formulations, compared against the classical available formulations, even though these classical formulations covered most of the aspects of the phenomena involved. Then, on these analytical bases, the research topics were, on the one hand, extended (new materials, flow effects, transducer non-linearities, etc.) and, on the other hand, they introduced new concepts including i/ thermoacoustics (exploiting thermal boundary layers) which arose from US laboratories and was further developed substantially at LAUM in collaboration with the LMFA at ECL in Lyon, and ii/ acoustic "gyrometry" (exploiting viscous boundary layers), which arose from and was developed at LAUM. In addition to the analytical and experimental work required by these projects, numerical methods (finite elements) and construction of prototypes, including miniature prototypes (MEMS, from 1989-90), were developed at LAUM. It is obvious that these research orientations have been funded by state and private contracts because of the potential applications. Today,

these studies are being expanded in several directions: boundary effects of gas mixtures and phase changes, and dedicated numerical methods (finite elements) for each of the problems considered.

The LAUM has established numerous industrial collaborations, some of which have been long-term partnerships, including research contracts, patents, and industrial PhD thesis. Currently, the laboratory collaborates regularly with companies in the transportation sector (including automotive, aeronautics, rail, and space), as well as those in the building and audio industries. Furthermore, the LAUM's research activities are consistently supported by various research agencies such as ANR and Actions Marie Curie.

In 2015, the LAUM made a strategic decision to expand its international collaborations, particularly through the implementation of the "Acoustics Hub" program. This initiative was conceived by the laboratory and financed by the Pays de la Loire Region. The program enables foreign researchers to undertake regular research stays at the LAUM, ranging from several weeks to several months, thereby transforming the laboratory into a "hub" for researchers from all around the world to come together and collaborate.

The LAUM showcases its research through publication in leading international peer-reviewed journals, averaging around 100 publications per year in the fields of acoustics and physics. Thanks to the "Acoustics Hub", over 50% of these publications have involved collaborations with international colleagues, highlighting the laboratory's growing emphasis on international cooperation.

Simultaneously, the LAUM has expanded its training offerings over the last three decades. With the Bologna Process introducing a three-cycle higher education system, the DEUST program was transformed into a Bachelor of Acoustics, and a Master of Acoustics was created, with a "research" option corresponding to the former Postgraduate Course in Acoustics. This master has been further enriched by other options, such as the Master "Environmental Acoustics », the International Master of Electro-Acoustics (IMDEA), which was launched in 2011 and co-financed by a private foundation managed by the Institut de France, and the International Master "Wave Physics and Acoustics," which was opened in 2020. For these two international masters, all courses are taught in English. Currently, the Le Mans campus has approximately 500 students in acoustics at all levels (from Bac+1 to Bac+8) each year. In 2018, a University Research School called the "Institute of Acoustics - Graduate School" (IA-GS) was established. Modeled after the Anglo-Saxon

"graduate schools," it integrates the laboratory and the training of masters, engineers, and doctorates in acoustics into a single structure. One of its primary objectives is to develop research training by welcoming students into the laboratory at an early stage of their studies. This is especially true for the Master "Wave Physics and Acoustics," which substitutes research projects in the laboratory for part of the in-depth lectures.

The growth of the LAUM has also led to an expansion of its facilities. In the early 1990s, the ENSIM building and the physics building of the Faculty of Sciences were constructed. Currently, a new building is being built that will include additional experimental surfaces, new rooms dedicated to acoustics training, and a space for scientific dissemination/exhibition. Moreover, a new Techno-Campus "Acoustics and Matter" building is near completion, with delivery scheduled for September 2023. Its purpose is to house industrialists who wish to set up their businesses near the University's research laboratories. The building will include two of the LAUM's major facilities: the 3DVIB platform, which consists of three laser vibrometers mounted on a robotic arm for measuring complex vibration fields on large structures, and the MAINE FLOW multimodal aeroacoustic test bench for studying the interactions between acoustic materials and flows under conditions close to those encountered in an aircraft engine (Mach 0.6, 150 dB).



**Figure 4.** The test section of the "Maine Flow" aeroacoustic bench

The LAUM has always prioritized actions for the collective, both in its internal operations and in its relationships with partners. Several members have taken on collective responsibilities at the local level (such as leading Ensime, the Faculty of Sciences, and the University) and at the national level (through participation in the National Council of Universities and the National Committee of the CNRS). It is also heavily involved in the

French Acoustics Society (SFA), regularly organizing or co-organizing congresses (CFA 2000 and 2016), study days, and summer schools.

Since 2014, the LAUM has been working towards bringing together the various actors of acoustics in Le Mans under one banner. This effort has resulted in collaborations with the Institut Technologique Européen des Métiers de la Musique (ITEMM), the Superior School of Art and Sound Design of Le Mans, and the Centre de Transfert de Technologie du Mans (CTTM) for research, development, and training. It has also partnered with cultural organizations in Le Mans for "art and science" projects. In collaboration with the City of Le Mans, this consortium of acousticians has created an event for the general public called "Le Mans Sonore". This event, which combines science and culture, has now become an international biennial of sound. The third edition of this biennial will take place in January 2024, featuring unusual visits of the laboratory, exhibitions for the general public, and scientific workshops. Sound artists and designers are also invited to participate and highlight certain aspects of LAUM's research.



**Figure 5.** The future Acoustics building (in the background, the LAUM building of the Faculty of Sciences)

#### 4. KEYS TO THE FUTURE

It goes without saying that the lab is the fruit of communal endeavor of all the staff and of the input of generations of graduate and postgraduate students. During its 42 years of existence, it has been enriched by a friendly work environment and a continuous sharing of its life by everyone. It recently celebrated its 40th anniversary during a studious and friendly weekend; it's time to plan its 50th anniversary celebration in the same spirit!