Acta Acustica 2025, **9**, 43

https://doi.org/10.1051/aacus/2025028

Available online at:
https://acta-acustica.edpsciences.org

Topical Issue – Development of European Acoustics in 20th Century

SCIENTIFIC ARTICLE OPEN ACCESS

History and activities of KU Leuven Laboratory of Acoustics

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Received 29 January 2025, Accepted 18 June 2025

Abstract – The Laboratory of Acoustics at KU Leuven was founded more than 50 years ago. Until today, various acoustics-related topics, ranging from physical acoustics through building and room acoustics up to environmental acoustics and noise-related health issues, have been investigated. In the second half of the 20th century, the laboratory was one of the main centres of expertise in acoustics in Belgium, contributing to consulting and establishing legislation in building and environmental acoustics. In the 1990s, it also consolidated expertise in the characterisation of porous materials and was one of the driving research groups in the field of photoacoustics. During the past 15 years, additional research directions have been taken thanks to interdisciplinary collaborations, including psychoacoustics, perception of sound, sound quality assessment, archaeo-acoustics, tackling acoustic issues in building retrofit, and characterisation of walls materials in the framework of sustainable development (recycled materials, biomaterials etc.) This paper first brings a brief historical overview of the past activities of the Laboratory of Acoustics (and Thermal Physics) (ATF), its involvement in national and international collaborations and its main recent scientific and educational activities.

Keywords. Physical acoustics, Building and room acoustics, Noise control, Psychoacoustics

1 Introduction

The Laboratory of Acoustics has its roots in the Faculty of Sciences of the Catholic University of Leuven (KU Leuven), one of the oldest universities in Europe, celebrating its 600th anniversary this year (2025). KU Leuven is also the oldest university in the Low Countries[1] and the world's oldest continuing catholic university.

This university was founded through the papal bull "Sapientie immarcessibilis", issued by Pope Martin V on 9th December 1425, following a request from the city of Leuven, with support from John IV, Duke of Brabant, and the local clergy. Initially, the University comprised four faculties: humanities, canon law, civil law, and medicine. In 1432, the Pope granted permission to include theology as a fifth faculty. The attraction of the University was undoubtedly enhanced by the presence of several brilliant thinkers, such as the humanist philosopher Desiderius Erasmus, anatomist Vesalius, cartographer Mercator, mathematician Gemma Frisius, pedagogy scholar Vives, physician Jozef Rega, chemist Jan Pieter Minckelers, philosopher Désiré-Joseph Mercier, physicist and mathematician Georges Lemaître [2].

2 Early history of the Laboratory of Acoustics

The Laboratory of Acoustics is embedded within the Department of Physics and Astronomy, which in turn makes part of the Faculty of Science of KU Leuven. From the 19th century onwards, original scientific research became an explicit task of the university [3]. The palaeontologist and zoologist Pierre-Joseph Van Beneden was a passionate scientist, who published studies on marine biology and parasitic worms, among other things. Van Beneden also made a significant contribution to the development of the Museum of Zoology. The chemist Louis Henry opened his chemistry laboratory in 1863,

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[1] The term "Low Countries" refers to a geographical area in northwestern Europe, mainly including the current countries of Belgium, the Netherlands, and Luxembourg. Historically, it also covered regions of France and Germany. This area is distinguished by its coastal lowlands and the Rhine–Meuse–Scheldt delta [1].

and under his impetus, practicals and personal scientific research became part of the training. Henry himself conducted research in organic chemistry. Jean-Baptiste Carnoy set up a cytology laboratory and also started a course in practical microscopy. His successor Frans Alfons Janssens is the discoverer of the crossing-over during meiosis. The geologist Charles-Louis de la Vallée-Poussin studied, among other things, the geomorphology of the Meuse valley, his son Charles-Jean de La Vallée Poussin did original research in mathematics, in particular in the field of integral and differential calculus and prime numbers. His Cours d'Analyse Infinitésimale (originally published in 1903 and 1906) is still used; the last reprint took place in 2003. De la Vallée-Poussin was also the promoter of one of the most important natural scientists of the University of Leuven: the cosmologist Georges Lemaître, founder of the Big Bang theory.

The Laboratory of Acoustics has its roots in the initiative of physics professor Augustin Van Itterbeek (1904–1968), who was leading the Laboratory of Low Temperatures and Technical Physics. The latter had been appointed in 1932 to organise a physics research laboratory for Dutch-speaking students as part of the university's Flemishization[2]. Van Itterbeek initiated a program "ingénieur-physicien" in 1936. Graduated engineers could receive additional training in scientific research. The program also opened paths for physicists themselves to industry. In that context, physics research was organised into groups around low temperatures, viscosity, acoustics and nuclear physics.

During World War II, KU Leuven faced immense challenges and destruction. Following the German invasion of Belgium on May 10, 1940, Leuven became a ghost town the university library was destroyed in a fire during a battle on May 16, 1940, and the university was forced to close. KU Leuven established the American College (located in Naamsestraat, Leuven) as a temporary library and sought support from other universities and organizations in Belgium and abroad to rebuild its collections. In this period also Oxford and Cambridge offered temporary accommodation for Leuven professors and other universities and individuals offering support.

Following Belgium's capitulation on 28 May, the university was reopened at the beginning of July. In the beginning of February 1943, the occupier requisitioned the first-year students to work in Germany. When an ultimatum was issued at the end of May and the university was threatened with closure, rector Van Waeyenbergh had hidden the enrolment lists in the cellars of the University Halls. During the night between 11 and 12 May 1944, Leuven was bombed by the British RAF. A few months later, the war ended, and Van Waeyenbergh was able to return the Rector's House. He remained rector until his retirement in 1962 [4].

Despite these hardships, Leuven University found ways to continue its mission, establishing a temporary library and seeking international support for rebuilding.

After the university was split in 1968, the Department of Physics was created with seven divisions, including the Acoustics and Thermal Conductivity ("Laboratorium voor Akoestiek en Warmtegeleiding (AW)") division, which was initially led by Prof. Odiel Van Paemel (1911–2006). The other pioneering laboratory members were Prof. Henri Myncke (1921–2001), Prof. André Cops, Paul Jacques and Willy Delvaux. The research part of the department relocated to newly built facilities on the Heverlee campus in March 1972 (Figs. 1–3).

The new acoustics laboratory building, which included an anechoic room, a reverberation room and sound transmission rooms, had already been occupied by then. The acoustic facilities (all built in a robust "box-in-box" approach), as well as setups for determination of thermal conductivity, were used for developing measurement methods and performing service measurements for companies.

Among the first environmental acoustics activities were traffic noise measurements (near the newly built E40 highway between Brussels and Liège and near Antwerp), and evaluations of noise disturbance (on the instructions of the Belgian Ministry of Public Health). This venture was undertaken with the help of newly hired members Piet Steenackers, Willy Bruyninckx (1949–2022) and Roger Gambart. In 1986, Prof. Jan Thoen joined the laboratory and became its director in 1988. The laboratory further developed its expertise in building acoustics, room acoustics and environmental acoustics, in particular in many studies and consulting on airport noise. In 1987, Prof. Jan Thoen also started research on photoacoustic and photothermal phenomena. Later on, the expertise (in collaboration with Prof. Jan Wouters and Prof. Astrid Van Wieringen from the audiology department) extended to perception acoustics. Around 2000, after a significant expansion of the lab building, the group of Prof. Gerrit Vermeir joined on the building-related acoustic topics. Throughout the years, several members of the laboratory have taken leading roles in different national and international societies related to acoustics. In particular, Prof. André Cops and Prof. Gerrit Vermeir have chaired the Belgian Acoustical Society (ABAV) and the Secretary-General of the International Institute of Noise Control Engineering (INCE). Henry Myncke was very active in the ICA (board member 1981–1984, president 1984–1990). In the early 1990s, Prof. Jan Thoen served as Secretary General of the Federation of Acoustical Societies of Europe (FASE). Prof. Monika Rychtarikova has chaired the Technical Committee of EAA Room and

[2] The "Flemishization" of KU Leuven refers to the university's transition from a bilingual institution, which primarily served the Dutch-speaking and French-speaking communities, to one that is primarily Dutch-language and fully integrated into the Flemish higher education system. This process involved splitting the university into two distinct institutions in 1968, with the Dutch-language university (KU Leuven) remaining in Leuven and the French-language university (Université catholique de Louvain) establishing a new campus in Wallonia.

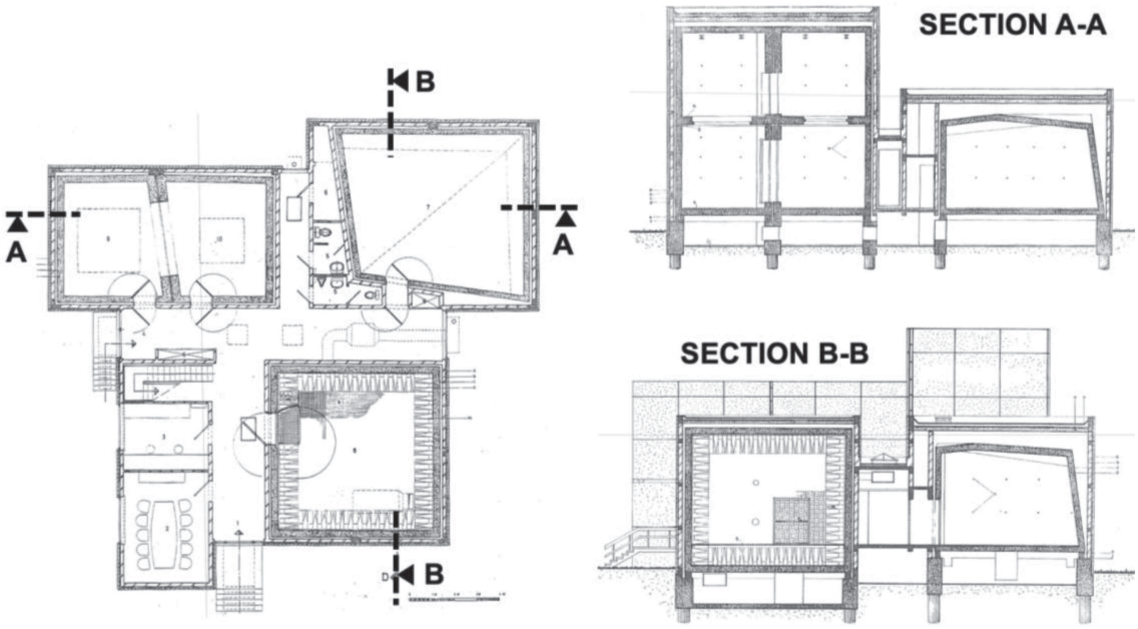

Figure 1. Ground plan cross-sections of the of the laboratory (1967).

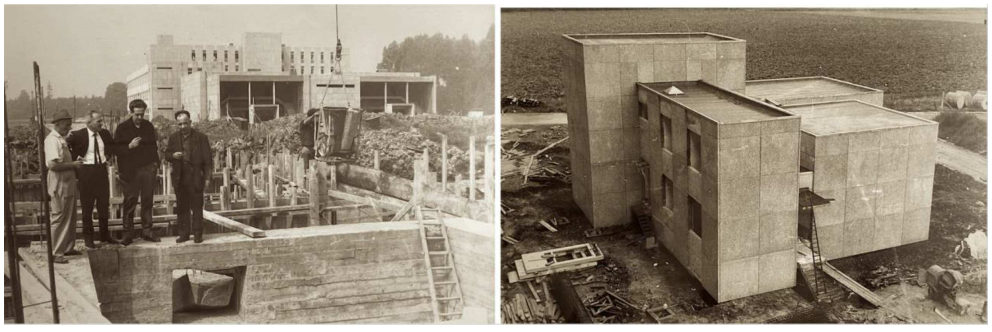

Figure 2. Photos from the process of building of the laboratory (1967). Prof. Henri Myncke (second from the left) and Paul Jacques (third from the left).

Building Acoustics (2011–2017) and has been a board member of ICA (2013–2017). The evolution of the different research, education, dissemination, and consulting activities is sketched in the following thematic overview.

3 Thematic overview

3.1 Environmental acoustics

Acoustics is one of the scientific disciplines that connects research in physics with society. Along with the industrial revolution, population density growth and the increase in motorised roads, railways and airborne traffic, concerns about the impact of noise on health have led to the need for expertise on efficient noise abatement. In view of this, from its early days, the laboratory has been very active in noise mapping, consultation for developing measures for mitigating noise problems and developing adequate legislation. Since the foundation of the laboratory, Belgian (Ministry of Public Health) and later on Flemish governmental administrations (subsequently the Administration of Spatial Planning and Environment – AROL, the Administration for Management of Environment, Nature, Land and Water – AMINAL [5] and the Department of Environment, Nature and Energy – LNE [6]) have been consulting its experts (Prof. Henri Myncke and Prof. André Cops, Willy Bruyninckx, Paul Jacques and Prof. Jan Thoen) for advice in general and compiling texts that currently still make part of the Flemish Regulation concerning the Environmental Permit (VLAREM [7]). Essential points of noise regulations, target $L_{A,eq}$ values ("richtwaarden") and limits and permits to install noise-producing facilities in Flanders, are determined by zones [8], and take into account the original sound $L_{A,95}$-levels. In this context, the laboratory executed and coordinated many studies on environmental noise impact for industrial partners and several pilot studies for the Flemish Government (e.g. PESO (1993) and EVA-PESO (1995) on evaluation methods for nature quiet areas; EMOLA (1997) on the determination of emission levels to the environment). From the beginning of the

Figure 3. View into the anechoic (left) and reverberant (right) room.

Figure 4. Example of calculated noise contours around Brussels Airport (left) and "Quiesst method" measurement set-up determining the sound absorption of noise barrier during a round robin test.

1990s, significant contributions were made to the determination and evaluation of aviation noise near the airport of Brussels for RLW (Regie der Luchtwegen) of the Belgian Government and for the Brussels Airport Authority, e.g. in 1989, 1990 and 2014: on noise from aeroplanes on the ground, from 1997 onwards: scientific support for noise control measures, from 1996 to 2014: calculation and evaluation of noise impact contours. The laboratory made a report on the environmental impact of Brussels Airport (MER-geluid Zaventem 2000) (Fig. 4).

Similar MER reports and noise contour evaluations were also executed (from 1997 to 2022) for three regional airports (Oostende, Antwerpen and Kortrijk-Wevelgem) in Flanders. Throughout the years, ATF also supplied support for noise control measures near the racetrack of Zolder, motocross circuits [9], and wind turbines [10]. Via partnership in the European projects ADRIENNE [11] and QUIESST [12, 13], the laboratory has also contributed to the development of European standards for measuring procedures CEN 1793-2 and CEN 1793-5 and 6 for the in situ determination of the absorption and isolation of noise barriers [14].

In the field of environmental acoustics, ATF, together with the Building Physics group at the KU Leuven Department of Civil Engineering, contributed a new approach to classifying soundscapes in the framework of the Belgian project DRUPSSUC [15, 16].

3.2 Building acoustics

Where in the early years' attention was focused on the use of the tube method, measurement techniques and in-situ measurements, the facilities of the newly installed laboratory opened many new avenues [17]. From 1969, there was the possibility of making use of transmission rooms, anechoic rooms, and reverberation rooms. Commissioned work and research clearly got off to a rapid start with reviewed published work. First, on a study on sound field diffusivity in the reverberation chamber [18], work on a sound reflection set-up in the anechoic chamber [19] and work on sound transmission [20].

The nature of the research topics, in particular the properties of building materials and constructions, was also very appropriate within the architectural engineering program of the Faculty of Engineering Sciences. This laid the foundations for a solid collaboration on studying noise transmission in buildings and using statistical energy analysis (SEA) [21], which triggered the start of frequent interfaculty master's and PhD work. Different parts of the laboratory infrastructure were used for dedicated goals.

The transmission chambers were intensively used for the standardised determination of the airborne sound insulation of walls, floors, and later roof constructions

and for the standardised impact noise testing of floor constructions. Time remained available for in-depth examination and experimental work into sound radiation measurement techniques (Fig. 5).

Attention was given to the then-new sound intensity measurement technique and research related to the standardisation. Also, the sound isolation quality of separation walls, sound propagation by flanking paths, and internal damping of walls and floors were highlighted. Recently, a new step was made in the measurement of acoustic sound isolation by using a laser Doppler vibrometer to measure the vibration of a wall of interest and extracting from the deflection shape the sound transmission and isolation spectrum. This method, which was consolidated in the framework of an EU RISE project PAPABUILD [23], has been validated with the classical microphone-based approach for intermediate frequencies. Its main strength is to yield reliable data in the low-frequency range, where the microphone-based method becomes unreliable due to the non-uniformity of the sound pressure level in the measurement rooms, caused by standing wave modes [22, 24]. An advanced computational approach of ribbed and stud frame assemblies [25] was successfully compared to laboratory experiments in the work of the team of Prof. Edwin Reynders, successor to Prof. Gerrit Vermeir, in the research on sound insulation. The laboratory also holds a concrete scale set-up used in the study of flanking transmission [26] and later converted into a holographic set-up.

3.3 Room acoustics

Research in room acoustic topics has been ongoing in the laboratory for many years, coordinated by Prof. Gerrit Vermeir. In the end of the 20th century, the group belonged to one of the European leaders in this field. In-house developed software EPIKUL was one of the leading ray-based software of those times [27–29]. The group was involved in many projects (both research-wise and consulting-wise), including several in very interesting locations, such as BOZAR concert hall (Brussels) [30]. Among a large number of smaller projects and so-called second opinion activities, some of the noteworthy are the Elzenveld chapel in Antwerp, AMUZ (Antwerpen), Scheepvaart Museum Amsterdam, several projects in Westmalle (Trappistencafé, abbey church, new brewery bottling plant).

The reverberation room has been intensively used within the laboratory facilities for standardized sound absorption testing. In the context of ISO standardisation, the laboratory participated in several round-robin tests. The determination of the sound power of various (ventilation) equipment for buildings was also addressed. In terms of research, the influence of edge effects of samples, the diffusivity of the sound field, and the validation of modeling scattering [31] were discussed throughout the history (Fig. 6).

In the anechoic room, important steps were taken in the measurement techniques concerning reflection, absorption, and diffusion of sound: burst tests [33], over impedance tests [34] to scanning tests [35]. In the reverberation room a numerous standardized sound absorption measurements, as well as research projects on developments on measurement techniques related to the sound reflections took place.

Recently, room acoustic research has increasingly focused on interdisciplinary collaborations, mainly with KU Leuven research groups in architecture and in audiology. Joint research with experts in architectural history [31, 35] has led to a recently approved ERC Pathfinder project between Oxford University (Prof. Küge) and KU Leuven (Prof. Rychtáriková and Prof. De Jonge). The infrastructure (anechoic room) is being extensively used for the preparation of anechoic recordings for high-level binaural auralisation and for listening test experiments free of background noise and reverberation.

3.4 Psychoacoustics and sound perception

In collaboration with the research group of Building Physics and Laboratory for Experimental Oto-, Rhino-, Laryngology (expORL), the laboratory has put its first steps into the field of psychoacoustics and research on perception of sound in the framework of an FWO-V project ("VIRTAK") on sound source localisation, the use of virtual acoustics for testing of speech intelligibility of hearing impaired people [37, 38] and echolocation [39, 40], by combining binaural impulse response simulations with listening tests with auralized sound. This research was further extended to auralized sound-based recognition of the textures of walls. The group also performed listening test-based assessments of wall sound isolation performance in the framework of finding an optimum single number quantity (SNQ) that takes into account the frequency dependence of human hearing. This research was complemented by a proposal for a Loudness calculation-based assessment method of the adequacy of SNQs for sound isolation, which was validated by listening test-based results.

3.5 Physical acoustics

Along with the measurement and evaluation of noise in the living environment, developing and characterising materials for optimum absorption, isolation, or scattering performance in applications has played an important part in the activities in ATF. In close collaboration with international partners at the universities of Le Mans, Hull, Trondheim, Nevers and others, ATF contributed to the development of dedicated measurement techniques for the key physical parameters that determine the acoustic absorption of porous materials, i.e. the tortuosity, the porosity, the flow resistivity, the thermal characteristic length and the viscous characteristic length [41], and for the macroscopic determination of the sound reflection. The main driving force behind this research was

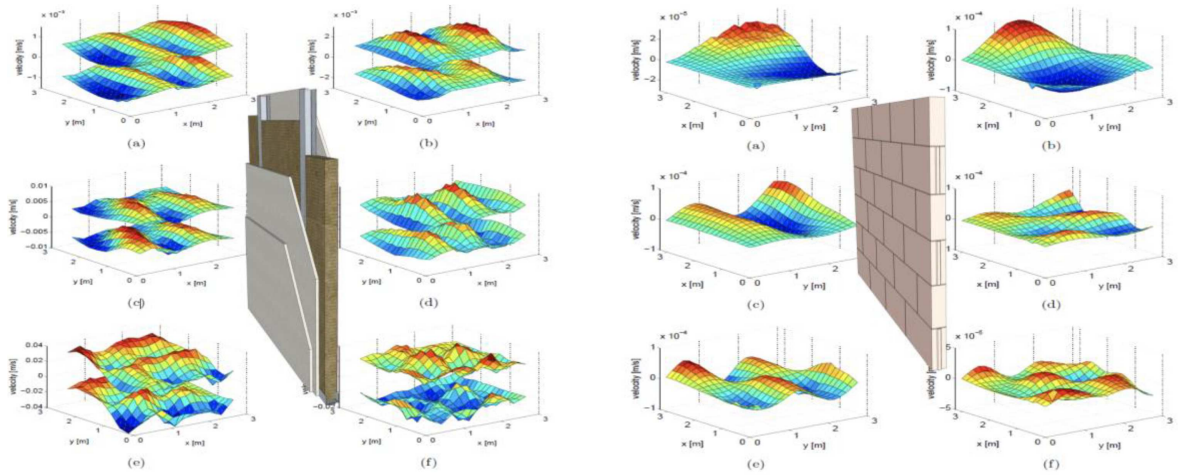

Figure 5. Example of modal behaviour of lightweight double wall (left) and masonry wall (right) as measured by Laser Doppler Vibrometry [22].

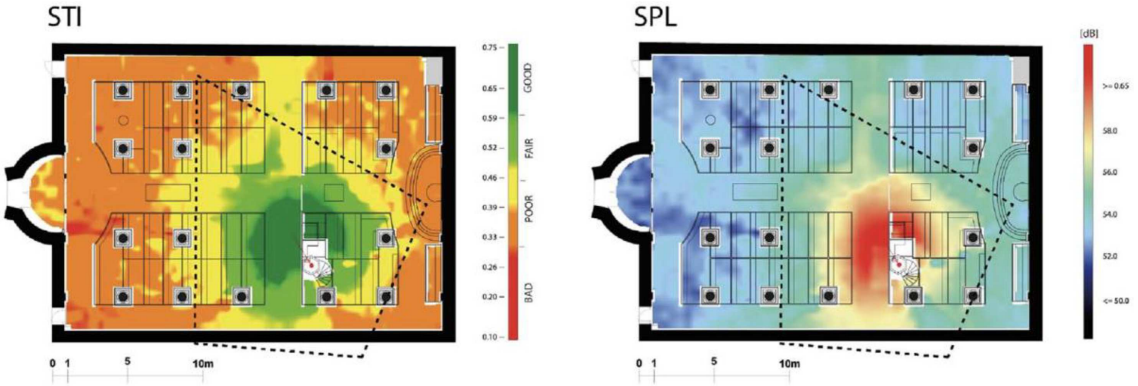

Figure 6. Results of room acoustic simulations (left: speech transmission index map, right: sound pressure level map) performed in the framework of an archaeoacoustic analysis of Wren's auditorium churches: case study of St Stephen Walbrook (1672–1679), London [31].

Prof. Walter Lauriks (1961–2010), in close collaboration with Prof. Jean-Francois Allard and two generations of acousticians from Université du Maine (LAUM), France.

Around 1987, a new research direction was opened by Prof. Jan Thoen in the emerging field of photoacoustics, which makes use of the phenomenon where intensity-modulated light absorbed by a gas, liquid or solid, through thermal expansion, results in density variations that, in turn correspond with sound or ultrasound. This phenomenon was first discovered by Alexander Graham Bell and his assistant Sumner Tainter, and along with the emergence of laser technology, made its way into material science after a publication [42] by Allan Rosencwaig and Allen Gersho in 1980. This approach allows to get combined information on optical absorption properties, thermal properties and mechanical properties of materials and became a unique tool thanks to the versatility of laser light in terms of allowing it to generate arbitrary spatial and temporal excitation patterns and remotely detect the resulting thermal expansion and acoustic waves. ATF contributed substantially to this research field and was an active player in European projects. In 1994–1995, Prof. Jan Thoen coordinated a large EU Human Capital and Mobility project on "Advanced materials characterisation by photoacoustic and photothermal phenomena". Initially, research efforts concentrated on thermal properties near phase transitions [43–45] but soon extended to depth profiling [44, 45] and acoustic wave generation and detection, in particular in applications of depth profiling [46–50] (EU project HARDPHOTOTEC, grant no. BRRT-CT-5032), non-destructive testing by laser ultrasonics [51–54] (EU-ITN project NDTonAIR) [55]. Recently, the first footsteps were made in the field of elastic characterisation of biological cells and tissue and photoacoustic imaging [56, 57], in the perspective of using this approach for biomedical applications.

A nice synergy between physics and arts was evidenced by the outcome of a collaboration between the laboratory and artist Aernoudt Jacobs, in the form of the artworks "Photophone" [58] and "Heliophone" [59], in the framework of an IWT CICI-grant (2013–2015).

The laboratory's multidisciplinary nature is well reflected in the ongoing EU-MSCA doctoral network,

Figure 7. Recently investigated materials for sound absorption in the framework of the EU-MSCA doctoral network ActaReBuild (top left: biomaterial mycelium, right composites based on recycled plastics, bottom left: impedance tube used for the characterization) [61].

Acoustic and Thermal Retrofit of Office Building Stock in EU (ActaReBuild)[3] [60], which joins efforts in sustainable development and thermal and acoustic characterisation of green and recycled materials, with special attention to the acoustic perceptive importance of innovative measures in building physic while training young researchers (Fig. 7).

4 Education

Since the Laboratory of Acoustics is embedded in a university, its mission is not only research but also education[4]. The members and collaborators of the laboratory have been involved in national and international pedagogical activities. To keep the length of this article within reasonable size, in the following, we list only the most important activities within Flanders and in international context.

4.1 Flanders

In Flanders, members of ATF have contributed to different courses[5] on acoustics listed below:

- Fundamentals of Acoustics (AC, WL, CG), Building Acoustics (GV, AD, ER), Measurement techniques and signal processing (BR) (`Hogere Cursus Akoestiek`, IENET).
- UIPUOUYAdvanced Acoustics (Master of Physics, KU Leuven: 1987–2021) (JT, WL).
- Environmental Acoustics (Master Environmental Studies, KU Leuven: 1987–2010) (JT, WL).
- Control technique: sound (Environmental coordinator, Syntra West (2020) (WB, CG).
- Waves and sound (`Bachelor Logopedy and Audiology`, KU Leuven).
- Introduction to the Physics of Speech and Hearing: Waves and Sound (`Bachelor Logopedy and Audiology`, KU Leuven) (CG, JW, MM).
- Noise control (Master of Bioscience Engineering: Human Health Engineering, `Master Building Engineering`, KU Leuven (GV, ER).
- Building acoustics (`Master Building Engineering`, KU Leuven) (GV, ER).
- Room acoustics and lighting (`Master Building Engineering`, KU Leuven) (GV, ER).
- Physics: additional topics: sound (`Bachelor Architectural Engineering`, KU Leuven) (2025) (CG).
- Comfort: acoustics (`Bachelor Architecture`, KU Leuven (MR).

4.2 International level

At the international level, the Laboratory of Acoustics has been a partner in several EU educational projects, networks and platforms [62], among which the most recent were Erasmus projects (Lifelong Learning Programme)

- Acoustics for Architects (ARAC platform) `https://arac-multibook.com/`, Programme: Leonardo da Vinci Transfer of Innovation. No. 2013-1-PL1-LEO05-37588. (2013–2015).

[3] Coordinator: Monika Rychtarikova.

[4] People involved: Andre Cops (AC), Armin Kohlrausch (AK), Arne Dijckmans (AD), Bert Roozen (BR), Christ Glorieux (CG), Danielle Fournier (DF), Gerrit Vermeir (GV), Edwin Reynders (ER), Monika Rychtarikova (MR), Myles Mac Laughlin (MML), Jan Thoen (JT), Jan Wouters (JW), Walter Lauriks (WL), Willy Bruyninckx (WB).

[5] AC: André Cops, WL: Walter Lauriks, CG: Christ Glorieux, GV: Gerrit Vermeir, AD: Arne Dijckmans, ER: Edwin Reynders, JT: Jan Thoen, WB: Willy Bruyninckx, MML: Myles Mc Laughlin, MR: Monika Rychtarikova, JW: Jan Wouters.

- Acoustics for Engineers (ACE) https://ace.acoucou.org/ Programme: ERASMUS+ Strategic Partnerships for vocational education and training. No. 2016-1-PL01-KA202-026719. (2016–2018).
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5 Dissemination

Collaborators of ATF have organised or co-organised a high number of national and international events, seminars or conferences. The most important are:

- Chair of Internoise 1981 Amsterdam (AC).
- Chair and proceedings editor of I-INCE 1993, Leuven, Belgium (AC, GV).
- Chair Forum Acusticum 1996, Antwerpen, Belgium (AC) [63].
- Chair 15th International Conference on Photoacoustic and Photothermal Phenomena (ICPPP19) 2009, Leuven, Belgium (CG) [64].
- Chair Gordon Conference on Photoacoustic and Photothermal Phenomena 2001 (JT, DF) [65].
- EAA summer school in Leuven 2019 (MR, AK).

6 Conclusion

During the 20th century, the KU Leuven Laboratory of Acoustics has been among the main acoustic laboratories in Europe, pushing forward advances in physical acoustics, building acoustics, room acoustics, and laying the ground for legislation in the domain of environmental acoustics. The laboratory is still fully equipped for the acoustic characterization of porous materials, layered and coated materials by dedicated techniques, and for performing absorption and isolation measurements of noise barriers (QUIESST method – EN1793).

At KU Leuven, the first research steps in acoustics were taken within the Physics department in the Faculty of Science, and the acoustic activities spread out over other departments of KU Leuven in its interdisciplinary dimension. The research fields connected with education, such as Physical acoustics, Building and Room acoustics, Psychoacoustics, Electroacoustics, etc, and currently have an established place at the university and EU context.

Currently, in addition to the acoustics research performed at the Department of Physics and Astronomy (CG), which is focused on advanced characterization techniques, in particular optical vibrometry from Hz (building acoustics) till MHz-GHz (guided waves in heterogeneous, stratified and biological matter), research and education in various subfields of acoustics can be found at KU Leuven, at several faculties and departments. Larger groups[6] are positioned at Mechanical Engineering (WD, ED), Electrical Engineering (TVW), Civil Engineering (ER), the Medical faculty (JW, AVW, JD), and the Faculty of Architecture (MR). KU Leuven also hosts the ALMIRA foundation, which deals with historical Soundscapes and Acoustics and has been disseminated broadly within and outside KU Leuven over the years. The collaboration within the university is evolving in its natural way through joint supervision and assessment of master's and PhD students, co-organisation of seminars, conferences or similar events. The fact that acoustics exists in various faculties helps to its visibility and sustainability. We hope to keep this trend by performing excellent research and delivering top education also during the coming decades[7].

Acknowledgments

We hereby sincerely thank our international partners and the numerous people who have spent time in our lab as technicians, scientific collaborators, visiting scholars, visiting fellows, Master's students or PhD students and contributed to the progress made and good atmosphere. Our recent research has received funding from the European Union's Horizon Europe research & innovation programme under the HORIZON-MSCA-2021-DN-01 grant agreement No. 101072598 – "ActaReBuild", and VEGA 2/0145/24. We are also grateful to KU Leuven, FWO-V, IWT, the Flemish government, the Belgian federal government and the European Commission for financial support for the research.

Conflicts of interest

The authors declare no conflict of interest in regards to this article.

Data availability statement

The data are available from the corresponding author on request.

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Cite this article as: Glorieux C. Cops A. Vermeir G. Thoen J. & Rychtáriková M. 2025. History and activities of KU Leuven Laboratory of Acoustics. Acta Acustica, **9**, 43. https://doi.org/10.1051/aacus/2025028.