# Acoustics and ultrasound

**Content and applications**

Denmark and Greater Copenhagen has proud traditions in audio research and has for many years been a global leader in this area of research. This leading position is reflected in breakthrough research into audio-visual technologies for the hard-of-hearing, room acoustic modelling and noise reduction in buildings and cities. Research has also led to the development of revolutionary new ultrasound technologies that can revolutionise diagnostics of a wide array of diseases, including cardiovascular conditions and cancer, with a far higher precision and speed than before. Also new portable ultrasound devices will enable practitioners and paramedics to benefit more directly from ultrasound technologies.

**Key environments and star researchers**

DTU Electrical Engineering at the Technical University of Denmark (DTU), is the key environment in Greater Copenhagen's audio research. Among the key research environments is the Center for Applied Hearing Research, where researchers carry out interdisciplinary, audiological basic research and investigate how the experience of hearing aid can be augmented. The centre is led by Torsten Dau. At the Center for Fast Ultrasound Imaging, researchers are developing innovative ultrasound and imaging systems that could potentially revolutionise diagnostics and therapies in the health care sector. The centre is led by Jørgen Arendt Jensen.

**Prospects for attracting investment**

DTU and the associated Danish ecosystem for sound technology has significant potential for attracting investment. Greater Copenhagen has a well-established ecosystem in audiology, and the know-how within this area is absolutely world-class. The novel ultrasonic technologies, developed at DTU, carry a considerable potential for improving diagnostics and reducing costs in the healthcare sector. Right from the beginning, research has been characterised by a big industrial involvement and several large international companies employ software for ultrasound solutions developed by DTU.

# Characteristics of the research area

Greater Copenhagen's stronghold within audio has deep historic roots. At the beginning of the 20th century, Valdemar Poulsen, an engineer, invented the arc generator and revolutionised wireless telegraphy and the development of the tape recorder. The first operational loudspeaker was invented in 1915 by a Dane, Peter L. Jensen. The Acoustical Laboratory at the College of Advanced Technology – what today is known as DTU - was established as early as 1941.

Audio research in Greater Copenhagen is absolutely world-class and is carried out in close collaboration with leading audio technology companies in the region, including Oticon, Widex and GN ReSound and BK Ultrasound, which develops revolutionary solutions for the health service.

DTU Electrical Engineering constitutes the centre of the region's research into audio technology. The research covers many different specialisations, such as acoustic technology, production and transmission of sound, noise control, advanced acoustic measuring technologies, modelling room acoustics and the effect of new construction materials on sound transmission. Greater Copenhagen also occupies a leading position in the field of audiology. Among other things, researchers at DTU Electrical Engineering investigate the development of better hearing aids using advanced signal processing and objective methods for measuring hearing.

Ultrasound research at DTU Electrical Engineering is one of the strongest environments in the world in the field. Over the years, researchers have developed the ultrasound solutions of the future for the health care sector, e.g. enabling imaging of cancer and analysis of the dynamics and speed of blood flow in 3D (for example in the heart) with far greater precision, speed and resolution than previously possible. Currently, this research underlies some of the world's most advanced ultrasound scanners from BK Ultrasound and Phillips, for example.

Researchers have also been engaged in developing new hand-held transducers that can be connected to smartphones or tablets, and which will make it possible for GPs or paramedics to make ultrasound scans quickly, cheap and with the option of transmitting information wirelessly and rapidly to hospitals, etc., via the internet.

Ultrasound technology has made it possible to make a better, cheaper diagnosis than previously possible for a whole range of health conditions. Research involves BK Ultrasound as well as other institutes and players, such as DTU Nanotech, the Alexandra Institute in Aarhus and researchers at Copenhagen University Hospital.

**International top quality niches**

The research done in Denmark on sound is world class. Top research covers the following environments:

ACT- Acoustic Technology - research in sound and vibration, including production and transmission of sound, noise control, transducer technologies, advanced measurement technology, room acoustics modelling and design, and the effects of new construction materials on sound transmission. Commercial applications include room acoustics and buildings, loudspeakers, concert sound and noise reduction in traffic and buildings. The area is headed by Prof. Finn Agerkvist.

CFU - Center for Fast Ultrasound Imaging - is DTU Electrical Engineering's centre for developing innovative new ultrasound technologies for the healthcare sector. The centre has been operating since 1998 and has developed new research tools and emerging technologies used by universities, companies and hospitals worldwide. CFU currently operates one of the largest projects being run by Innovation Fund Denmark aimed at developing the sustainable ultrasound scanners of the future. The centre is headed up by Jørgen Arendt Jensen.

**CAMM** - Center for Acoustical-Mechanic Micro Systems - is engaged in micro acoustics and the acoustic properties of materials at the micro level. Research at the Center is funded by Widex, GN ReSound and Oticon. This area is headed by Prof. Jakob Søndergaard Jensen.

**Hearing Systems,** comprising: 1) Oticon Centre of Excellence for Hearing and Speech Sciences, which is engaged in interdisciplinary, audiological basic research, including the treatment and diagnosis of hearing loss, and how the brain processes speech and music. The centre is headed up by Prof. Torsten Dau. 2) Center for Applied Hearing Research, which is characterised by a more application-oriented profile. The Centre is furthermore engaged in examining the perceptual implications of hearing loss, modelling how the brain processes and perceives sound, the use of modelling in hearing aids and measurements /testing of hearing aids.

**Bibliometric key figures**

The bibliometric indicators for research production and quality demonstrate that Greater Copenhagen is a clear leader in Europe with respect to research in acoustics and ultrasonics, cf. Table 1.

Over the past decade, researchers in the field have published 742 scientific articles in internationally recognised journals. This puts Greater Copenhagen into first place among the regions of comparison in terms of research output.

Greater Copenhagen is furthermore characterised by a strong specialisation, which means that sound research occupies a considerably greater proportion of the total research production in Greater Copenhagen, than is the case in the other relevant European regions of comparison.

Finally, Copenhagen take second place amongst the regions of comparison on quality of research, in terms of the percentage of publications figuring amongst the 10% most cited within the field of research globally.

**Key bibliometric indicators**

| | Specialisation | Output ranking (No. articles) | Highly cited article ranking (%). | Co-publication ranking (%) |
|---|---|---|---|---|
| Acoustics and Ultrasound | 1.72 | 1 (742) | 2 (18.7%) | 7 (3.8%) |

Period: 2005 -2015. Regions of comparison: Amsterdam, Berlin, Dublin, Geneva-Lausanne, Hamburg, Helsinki, Munich, Oslo and Stockholm/Uppsala.

Specialisation is an expression of the size of a field of research compared to all research production at University of Copenhagen, DTU and Copenhagen Business School compared with its size in the regions of comparison. A specialisation level 1 indicates that Greater Copenhagen is on level with the regions of comparison. Specialisation of >1 indicates that Greater Copenhagen is more specialised in the field of research than the regions of comparison.

Output ranking measures Greater Copenhagen's position in the field concerned among the regions of comparison in terms of article production (with the absolute numbers of articles in brackets).

Highly cited article ranking indicates Greater Copenhagen's ranking in the regions of comparison for the proportion of articles in the field of research in Copenhagen that are among the 10% most cited worldwide (percentage in brackets).

Finally, co-publication ranking indicates Greater Copenhagen's rank among the regions of comparison for the proportion of articles in the field published jointly with the business sector (percentage of overall article production in Greater Copenhagen in brackets).

# Key arguments for the research area prospects for attracting investments

Sound technology is an integral component in a wide range of solutions - from robot technology, via noise meters and sensors that can communicate with users, to digital teaching platforms. Sound also plays an important role as integrated technology in numerous solutions to the challenges facing society in the 21st century, for example in healthcare and welfare solutions or intelligent traffic and supply systems.

Greater Copenhagen has a clear strength in sound-related research. There is a considerable investment potential considering Denmark's strong sound-cluster, which includes well-established companies and start-ups working in audio and acoustics and hearing technology, together with its strong ecosystem. In 2014, the Danish Sound Innovation Network estimated that the 30 largest Danish sound companies had revenues amounting to more than DKK 30bn and that half of all the hearing aids in the world were made by Danish companies, such as Oticon, Widex and GN ReSound.

Greater Copenhagen is the undisputed global leader when it comes to developing audiology and hearing aids. The know-how accrued over many years and the world-leading research facilities available in this field are major assets for foreign companies engaged in innovation in hearing technologies.

Ultrasound research at DTU carries great potential with respect to revolutionising diagnostic methods in the health service, partly by way of much more precise, informative and cheaper methods for identifying and analysing such diseases as cancer and thrombosis, and as an aid in operations and analyses of biopsies. And also by way of developing new portable transducers connected to tablets that can accelerate the use of ultrasound diagnostics, for example in general practice or for paramedics in ambulances. All major ultrasound manufacturers (Phillips, GE, Siemens, Samsung, Sony and BK Medical, etc.) utilise simulation software developed by CFU.

**Star researchers and major scientific breakthroughs**

In the field of hearing aids, cutting edge research focuses on applying digital technology to improve hearing aids, including advanced algorithms and sensor technology. Researchers at DTU have worked closely with GN ReSound on developing ear-to-ear hearing aids that communicate wirelessly. This allows the left and right hearing aids to communicate with each other and automatically turn the volume up or down to give the clearest possible sound image in the hearing aid. These hearing aids can also be adjusted wirelessly using a smartphone.

Researchers at CAMM are studying how to optimise the complicated mechanical /acoustical connections in hearing aids. Researchers are also investigating how to improve the experience of hearing aids amongst other things by reducing acoustic feedback. Jakob Søndergaard Jensen is one of the lead researchers in this field. CAHR also study how to improve voice recognition using advanced signal processing, including the use of advanced algorithms that can filter out noise and feedback and improve the experience of using the hearing aids. Torsten Dau is one of the top researchers in the field.

CFU is an international leader in the field of ultrasonics and the centre's research has major medical/clinical significance. In contrast to traditional ultrasound scanners, health conditions in the body can be scanned and visualised from every direction in a single session, and with track changes over time (4D). This field of research has been awarded a total of DKK 250m in external funding, from research councils, Innovation Fund Denmark, private companies and foundations. CFU carries out translational research into advanced ultrasonics, including simulation, transducer technology, signal and image processing.
These technologies developed in collaboration with BK Ultrasound make it possible to investigate patients' anatomy and blood flow at very high resolution (down to the micrometre scale), speed (>1000 images /sec) and in 4D

- i.e. 3D imaging with data on changes over time.

For example, vortexes or differences in flow in blood vessels can be identified in real time. The technology significantly reduces the amount of time and resources spent in the clinic since ultrasound technology in many instances is cheaper and a better alternative than significantly more expensive MRI scanning.

CFU is also engaged in an Innovation Fund Denmark project aimed at developing the portable ultrasound scanners of the future, e.g. for use by nurses, doctors or paramedics, without the special training currently required to operate ultrasound scanners.

Nanotechnology and the use of advanced algorithms have improved the probe sensors used in ultrasonic systems, as these cut the number of calculations required and allow the probes to be portable, allowing for example general practitioners to be able to undertake preliminary investigations and transmit ultrasound images to hospitals or specialists. During operations, surgeons could use these scanners to investigate blood flow before suturing. Fundamentally novel ways of transmitting and processing ultrasonics are being developed to allow for data capture for subsequent processing by supercomputers.

**Large talent pool**

Every year, DTU trains about 20 engineers specialising in acoustics. In medicine and technology, around 30-40 graduates are trained every year, some specializing in ultrasound. DTU Electrical Engineering, Hearing Systems has about 22 PhD students and 11 postdocs. There are about 11 PhD students in Acoustic Technology. Since its establishment, CFU has trained 35 PhDs and currently has 10 PhD students.

**Unique research facilities**

At DTU, CHESS operates the Audiovisual Immersion Lab (AVIL) test facility, which makes it possible to test hearing technologies in a virtual sound environment. The laboratory features a sound-insulated, sound-dead room with 64 loudspeakers that can recreate audiovisual images, for example from restaurants, with background noise or crowded railway stations. The facility is funded partly by the Oticon Foundation, and partly by DTU's own resources for modernising research infrastructure. DTU also works closely with the DELTA GTS Institute in Hørsholm which has a whole range of test facilities for sound technologies.

CFU hosts one of the most powerful ultrasound scanners in the world, SARUS, developed in collaboration with BK Ultrasound and Prevas. This scanner can make 25,000bn calculations per second and can also be used to make 3D images of the entire heart's blood flow while also measuring flow speed and direction throughout the heart.

**Strong collaboration with leading international research environments**

The Oticon Centre of Excellence for Hearing and Speech Sciences has a large number of visiting audiology researchers. DTU also works with experts from universities including the Université Paris Descartes in France and University of California, Berkeley. CFU also has collaborations with Stanford University, Duke University, Lund University, Harriet Watts University and Institute Langevin in Paris.

**Extensive corporate collaborations**

There is a strong tradition of close collaboration between scientists and the corporate sector in the field of hearing aids (Widex, Oticon and GN ReSound), with the loudspeaker industry (e.g. B&O and Dynaudio) and in sound measurement and ultrasonics (Brüel and Kjær). Collaborations are characterised by a wide range of research and development projects and funding for major research efforts such as CHESS and CAMM.

CFU has a long-term, close collaboration with BK Medical and the simulation software for ultrasonic systems developed by the centre is used by all major ultrasound manufacturers.