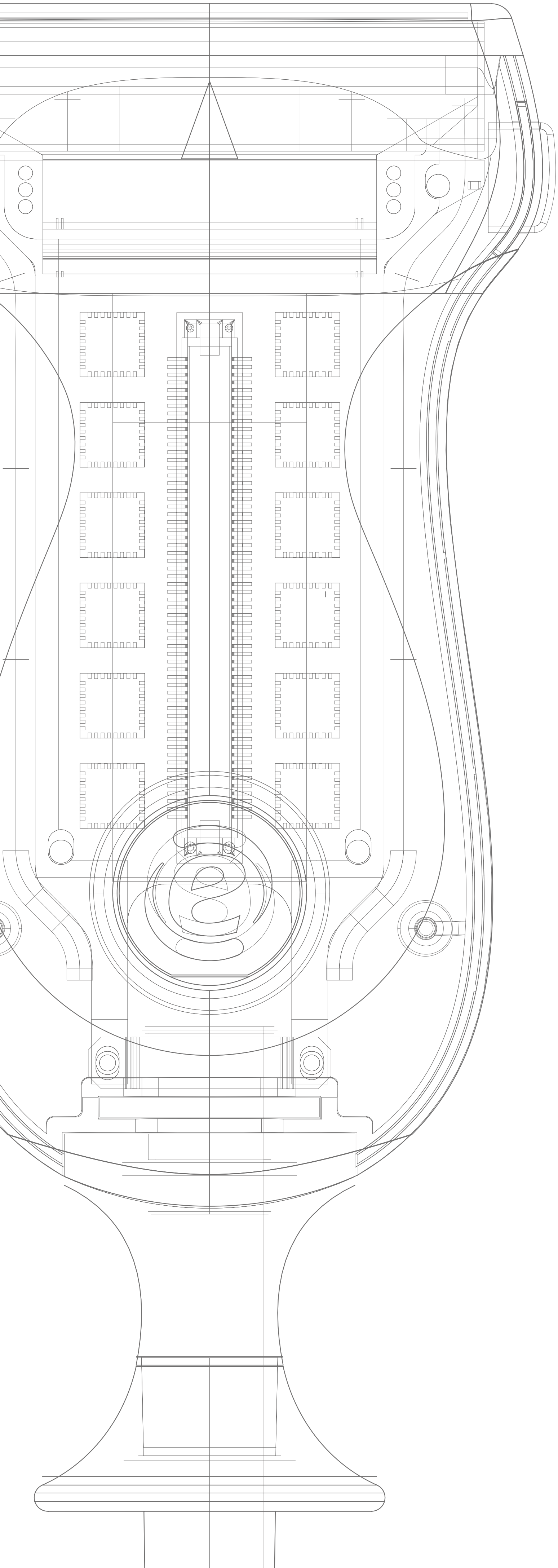

White Paper

iQProbes

Technical Perspectives on Broadband Ultrasound Transducers: Improvements in Diagnostic Imaging Resolution and Penetration

esaote
Creativity in Healthcare

"Imaging resolution and penetration homogeneity breakthroughs have resulted from the new iQProbe technology"

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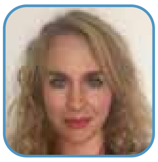
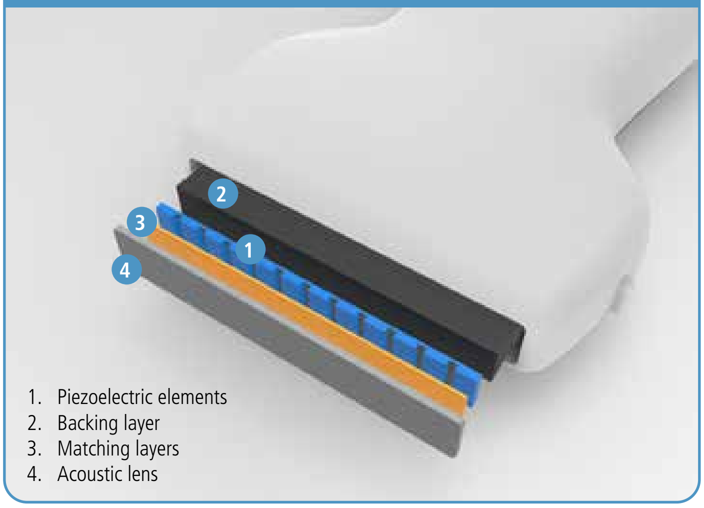


Esaote Ultrasound Probes Technologies

Ultrasound probes are comprised of a transducer, housing, cable, and system connector. Esaote probe design optimizes each of these components to ensure best-in-class clinical performance, ergonomics, and reliability. The core of the probe is the ultrasound transducer which has four main parts[1] (Figure 1):

1. Piezoceramic material that converts electrical energy to acoustic energy and vice versa. Thus, the transducer can both generate and detect ultrasound – the engine of the ultrasound probe.
2. Backing material bonded to the backside of the piezoelectric that both dampens the piezoceramic ringing to create wide bandwidth and attenuates unwanted ultrasound traveling in the direction opposite to the patient.
3. Matching layers bonded to the front face of the piezoceramic that dramatically improve ultrasound transfer into the patient and unlocking transducer energy conversion efficiency for even higher bandwidth.
4. Acoustic lens that focuses the ultrasound beam in the plane perpendicular to the electronic focusing plane.

Figure 1 - Typical medical ultrasound transducer comprised of an array of small piezoelectric elements attached to three other structures: matching layers, backing layer, and acoustic lens.



Transducer design, materials, and manufacturing processes play a crucial role in the development of high-performance probes that must provide accurate and reliable images.

The latest trend is replacing conventional lead zirconate titanate (PZT) piezoceramics with Single Crystal materials (Figure 2). Single Crystal has much higher electro-mechanical coupling combined with low loss, which translates to technical improvements such as extremely wide bandwidth, improved signal-to-noise ratio, and reduced heating compared to PZT[2],[3] (Figure 3). These technical characteristics enable significantly superior image quality (IQ) resulting in better and more repeatable diagnostic accuracy, while also minimizing the problems of imaging "difficult" patients due to improved penetration and greater sensitivity[2],[3]. In fact, ultrasound probes using Single Crystal improve IQ in every way including better contrast resolution, fine spatial resolution, and improved image uniformity from near to far field, leading to higher diagnostic confidence (Figure 4).

Figure 2 - The piezoceramic material (PZT or Single Crystal) must first be "poled" by exposure to an electric field. PZT piezoceramic consists of a dense polycrystalline structure with random orientation of dipoles before poling, while Single Crystal ceramic is grown in monocrystalline form. Poling aligns many – but not all – of the PZT domain dipoles, while aligning the entire Single Crystal domain. As a result, Single Crystal has much improved electro-mechanical properties compared to PZT, leading to better IQ.

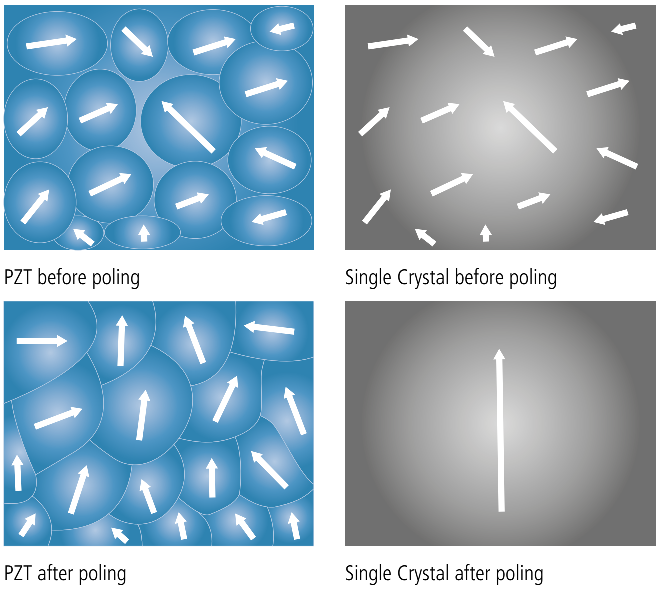


Figure 3 - Single Crystal (SC) provides up to 20-25% wider bandwidth and greater sensitivity compared to PZT. As a result, Doppler and tissue harmonic imaging performance is enhanced.[2]-[4]

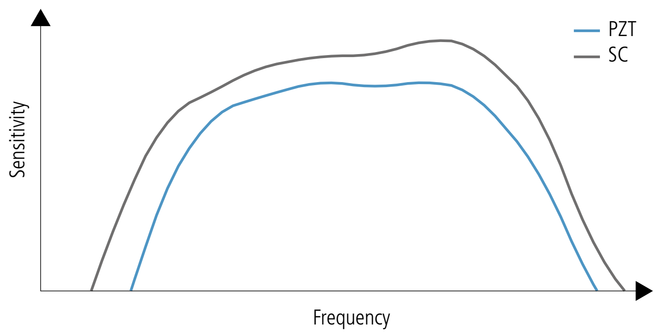


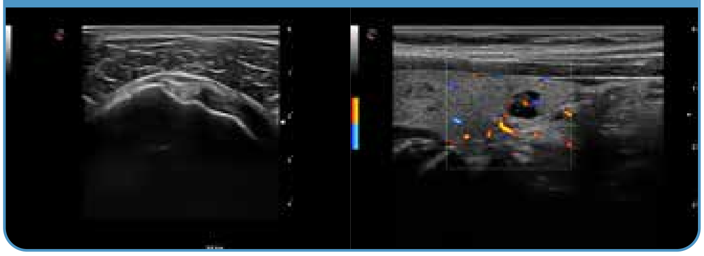
Figure 4 - Enhanced spatial and contrast resolution on parasternal long axis, interventricular septum and posterior wall and increased mitral valve definition with Single Crystal (left) compared to PZT (right).

Innovative piezoceramic materials are not sufficient alone to enable IQ breakthroughs. Ultrasound probe performance also depends on progressive designs of the matching and backing layers (Figure 5). Multiple adaptive matching layers are used between the high acoustic impedance transducer piezoceramic and the low impedance of the patient's body, to gradually transform this large difference and enable efficient ultrasound transmission, yielding a significant boost in sensitivity and bandwidth. Using Single Crystal enables new levels of IQ, but to unlock this potential required Esaote to develop new matching layers and to create an innovative new backing technology. These iQProbe technical advances have led to deeper imaging penetration, overall increased image sensitivity, and enhanced spatial resolution – in all imaging modes.

Finally, optimized acoustic lens materials were developed with low acoustic absorption and balanced acoustic impedance close to that of human tissues, while maintaining high mechanical strength for reliability in repeated clinical scanning. Current trends in aggressive reprocessing (cleaning, disinfection and sterilization) required an additional special insulation layer to protect against the wide range of chemical agents used in clinics, and guarantee probe robustness and longer life.

Another iQProbe innovation is a new proprietary thermal drain architecture inside the probe handle, which very effectively limits the temperature of probe patient applied surfaces. This further improves clinical scanning efficacy by allowing higher imaging frame rates and increased system transmit power applied to the ultrasound probe.

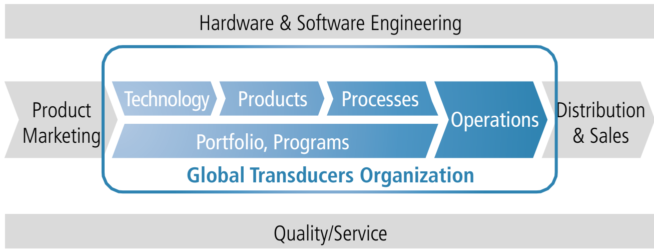
Figure 5 - High resolution ultrasound imaging of the shoulder and thyroid



Esaote R&D Center-of-Excellence for Ultrasound Probes

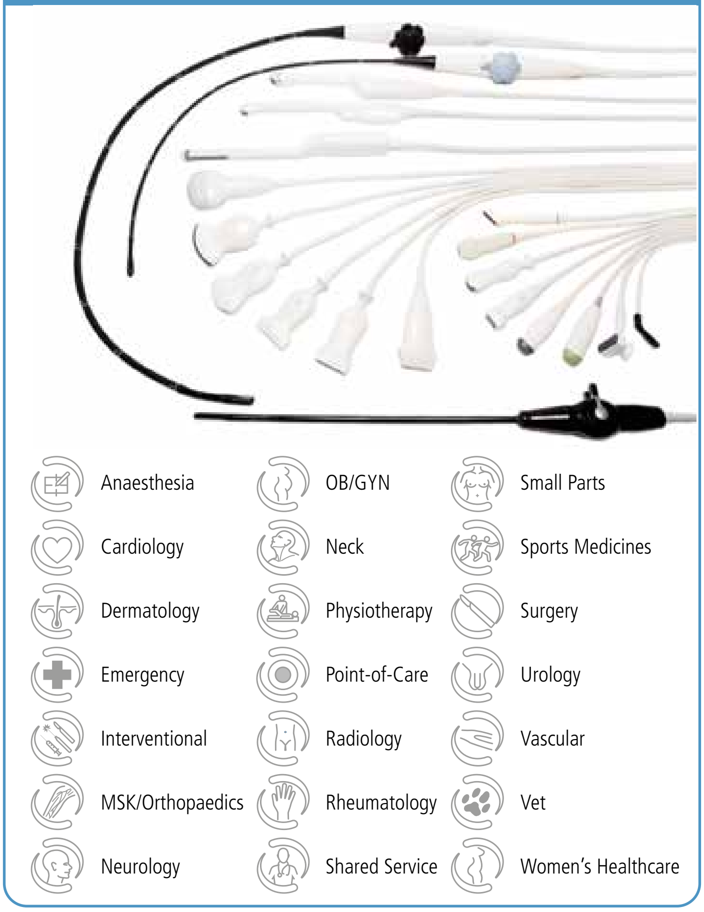
Esaote has more than 30 years of experience as a leader in ultrasound products, and continues to invest in technological research to ensure Esaote products and customers remain at the front of a continuously evolving and high competitive market. New investments in the Ultrasound Probes R&D Center-of-Excellence (Florence, IT) and manufacturing facilities (Italy and Netherlands) demonstrate Esaote's commitment to continuously improve ultrasound products for our customers (Figure 6).

Figure 6 - The Global Transducer Business Operations Department is structured into five main functions (Program Management, Portfolio Management, Product Development, Process Development, and Manufacturing) interacting with other departments of the company, from Marketing to Distribution and Sales, through Hardware and Software Engineers and Quality and Service.



Esaote offers a complete and versatile portfolio of ultrasound probes (Figure 7) and dedicated kits, with each probe adapted to multiple clinical applications according to exam type, scan depth, and patient characteristics. We provide conventional probes, i.e. linear, convex, and phased arrays, as well as specialized probes, such as intraoperative and trans-esophageal probes. Our mission is to embed advanced technologies in ultrasound probes for high IQ, easy ergonomics (handy and highly manoeuvrable probes), and improved manufacturability.

Figure 7 - Esaote offers a variety of ultrasound probes dedicated to a wide range of clinical applications



References

[1] T. L. Szabo and P. A. Lewin, **Ultrasound Transducer Selection in Clinical Imaging Practice**, J. Ultrasound Med., 2013.

[2] X. Ming Lu and T. L. Proulx, **Single crystals vs. pzt ceramics for medical ultrasound applications**, IEEE Ultrasonics Symposium, 2005.

[3] Jie Chen and R. Panda, **Review: commercialization of piezoelectric single crystals for medical imaging applications**, IEEE Ultrasonics Symposium, 2005.

[4] T. R. Gururaja, R. K. Panda, J. Chen, and H. Beck, **Single crystal transducers for medical imaging applications**, IEEE Ultrasonics Symposium, 1999.

Clinical use

2nd trimester of pregnancy - fetal femur

3rd trimester of pregnancy - fetal abdomen - autoOB measures

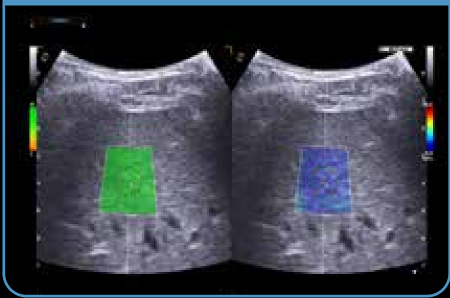
3rd trimester of pregnancy - umbilical artery

3rd trimester of pregnancy - circle of Willis - microV

Bladder with 2 mm calcification

Kidney cyst

Liver angioma



Liver stiffness assessment - QElaXto 2D

Liver focal lesion - CnTI™

Liver focal lesion - microV

Steatosis liver and kidney

Abdominal aorta - CFM color Doppler

Five chambers echocardiography - CFM color Doppler

Transcranial Doppler - microV

Transcranial Doppler - CFM color Doppler

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CnTI™: The use of of Contrast Agents in the USA is limited by FDA to the left ventricule opacification and to characterization of focal liver lesions. Technology and features are system/configuration dependent. Specifications subject to change without notice. Information might refer to products or modalities not yet approved in all countries. Product images are for illustrative purposes only. For further details, please contact your Esaote sales representative.