Ultrasound Imaging

IPUT® The Integrated Photonic Ultrasound Transducer

50 years innovation in Ultrasound

TNO colleague Jan Somer introduced the phased-array transducer to perform electronic sector scanning for ultrasonic diagnosis in 1968 [1]. Today, his disruptive invention is still used in many medical ultrasound imaging systems.

The IPUT® is a new disruptive TNO invention, in which light is used to strongly increase the performance of US detection.

TNO aims for a 100x increase in sensitivity compared to SOTA transducers.

[1] J. Somer, 'Electronic sector scanning for ultrasonic diagnosis, Ultrasonics, 6(3):153-9, 1968.

TNO's ultrasound team has a lasting experience in the modelling, design and manufacturing of highly innovative ultrasound systems for many application fields, including industrial process control sensors, non-destructive testing, semicon metrology and medical devices.

Ultrasound systems generate and receive acoustical waves in the 20 kHz – GHz range. The transducers used are often based on the piezoelectric effect. Piezoelectric transducers have existed for more than 100 years. Decades of engineering have lowered material costs and solved the processing issues of this brittle material.

Medical ultrasound imaging devices exist for over 60 years. Large improvements were made by TNO's invention of the phased-array transducer, which is still applied in almost every medical ultrasound imaging system.

During the last 60 years there has been a continuous drive to improve the quality of medical ultrasound images. Higher quality images will result in earlier, better and more precise diagnoses and therefore in increased patient health and lower health-care costs.

The measurement accuracy and image quality of ultrasonic equipment is directly linked to the efficiency and sensitivity of its transducers, and thus to the piezoelectric materials used. Although the topic of continued research, the improvement in practical piezoelectric material properties over the last 30 years has been rather slow.

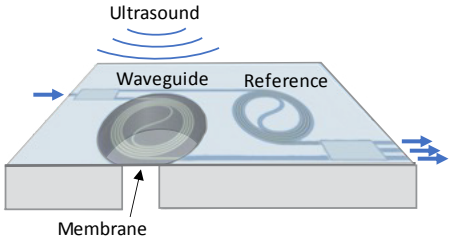
Thus, it is clear that **a disruptive innovation in ultrasound transducer technology is needed to achieve a substantial increase in medical ultrasound image resolution and quality**.

The Integrated Photonic Ultrasound Transducer

Optical interferometers, are used in many applications, e.g. for measuring low frequency displacement even up to subatomic level. In the last decades the field of "Integrated Photonics" aimed at miniaturizing such optical systems into optical chips.

About 15 years ago TNO in collaboration with TUDelft, invented, realized and tested the first Integrated Photonic Ultrasound Transducer (IPUT).

An IPUT uses a silicon oxide membrane in combination with a photonic waveguide to measure acoustic waves. An on-chip Mach Zehnder interferometer measures the membrane deflection, caused by the ultrasonic waves, with extreme sensitivity.



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Integrated Photonic Ultrasound Transducers

In an IPUT, the passing of an acoustic wave excites a deflection of a micromechanical membrane. The membrane displacement alters the refractive index and shape of the photonic waveguides on top of the membrane. The waveguides are designed in a Mach Zehnder configuration, providing a highly sensitive interferometric readout of the deflection of the membrane. Moreover, the Mach Zehnder configuration enables an extremely high dynamic range. An additional key advantage is the fact that the waveguides on the membranes can be cascaded, increasing the sensitivity of the sensor and allowing the filling of the full acoustic area of an array element with IPUT membranes whilst using a single optical read-out channel.

Next generation ultrasound imaging systems based on IPUTs

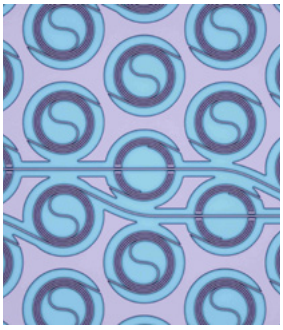
With the IPUT TNO aims for an ultrasound transducer with a 100x improvement of in sensitivity.

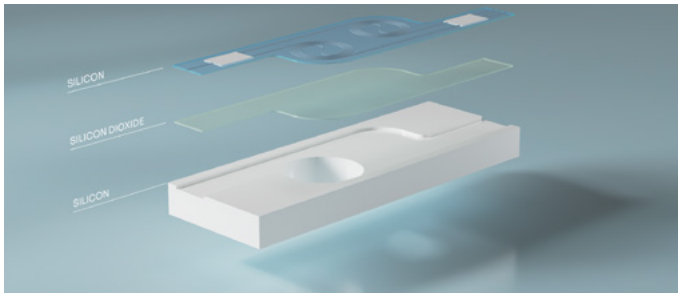
If the noise equivalent pressure (NEP) of an ultrasound transducer is reduced by a factor 100, and thus the SNR is improved 100x, this can be used in generic Medical Ultrasound systems for:

1. An increase of the ultrasound image resolution by up to a factor 4 in 2D imaging and up to a factor 8 in 3D imaging, at equal tissue penetration depth, by doubling the transducer's ultrasound frequency, or
2. An increase of the penetration depth by up to a factor 2 whilst keeping the ultrasound image resolution constant.

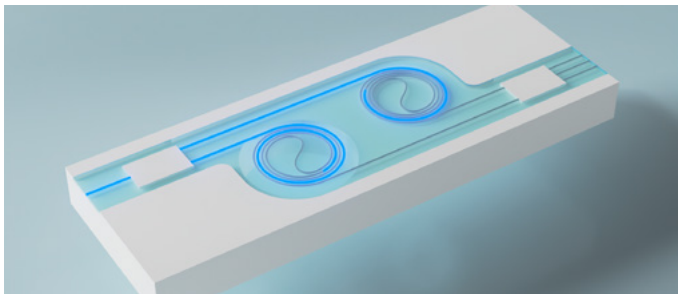
For photoacoustic imaging applications it has the following advantages:

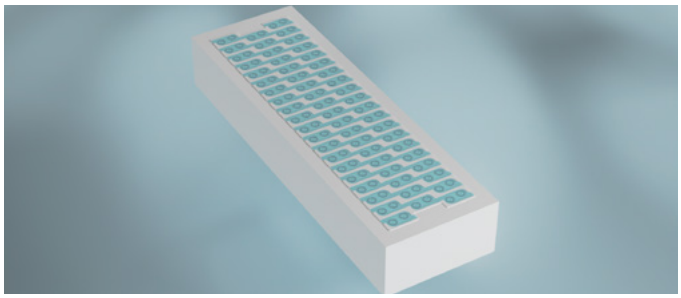
1. An increase of tissue penetration depth by multiple cm's.
2. A reduction of laser source power by a factor of up to 100.

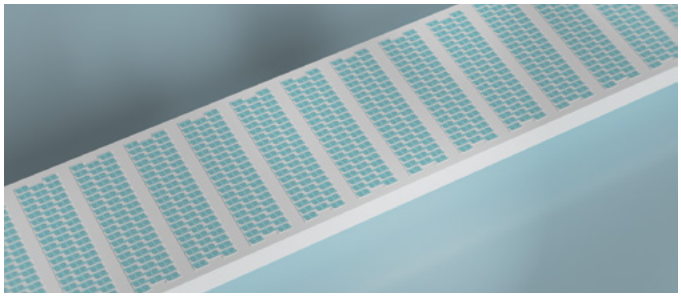


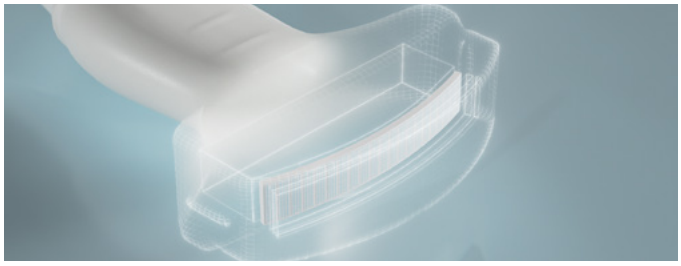


Construction layers of an IPUT


A single IPUT with one membrane


Cascaded IPUTs forming 1 acoustic element


Acoustic elements creating an ultrasound array



Please find more information on www.tno.nl/IPUT

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