VECTIS
The value of sharing innovation

# Opportunity to Acquire
# CMUT SOLUTION

**Technology Overview &**
**Asset Description**

From
## ATOA Scientific Technologies

**October 2022**

Content

Vectis, a UK-based industry leader in IP and technology transfer, has partnered with ATOA to help negotiate and implement a technology transfer agreement to foster the adoption of ATOA's CMUT technology

ATOA Scientific Technologies

VECTIS
The value of sharing innovation

ATOA

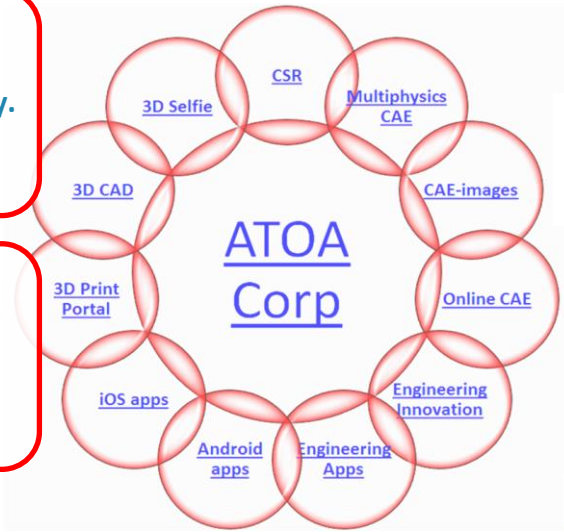
ATOA is a group of companies with a vision to proliferate engineering for all. ATOA stands for Atom to Application. ATOA currently offers, Multiphysics CAE services, Engineering Apps and 3D printing, through **ATOA Scientific Technologies PVT LTD**, ATOA Software Technologies and ATOA Smart Technologies, respectively. Our social mission is delivered through our ATOAST Jyothi Foundation.

**OUR Purpose**

**We want to be a Good, Great and Growth Company.**
**Good: Do Good for our Employees, Client and Humanity.**
**Great: Develop Great Technology.**
**Growth: Grow into a 5B$ Company by 2025.**

**Our Solution**

**Engineering Services, Multiphysics CAE, Online CAE**
**Engineering Innovation**
**Engineering Apps for Design on the Go**
**3D Printing for Next-Gen Products**




COMSOL certified consultant

NASSCOM® MEMBER

Consultants Review 25 Most Promising Project Management & Engineering Consultants 2015

The 10 Fastest Growing Consulting Companies 2016

CIO Review 20 MOST PROMISING Engineering Design & SERVICES PROVIDERS COMPANIES

# ATOA's MD: Raj CN Thiagarajan

## Academic Background

PhD @ Cranfield Univ. UK. Smart structures, Composite Fatigue characterization. Novel self sensing SHM of aircraft structures. IMechE Safety Award

MTech @ IITB : Aircraft structures specialization: Design, FEA of aircraft structures.
Thesis: Ultrasonic characterization of composites.

BE @ ACCET, Civil Structural Engineering, Group Project: Planning, design and analysis of T beam RCC bridge, Helicoidal staircase…

School @ GES, GHSS, Brahadambal HSS, Model HSS.

## Professional experience (30+)

Many Innovative Products, 92+ Patent Records, 75+ Publications

Founder Managing director @ ATOA Scientific Technologies Pvt LTD from Jan 2010 : Multiphysics CAE, Engineering apps, 3D printing, Engineering innovation.

Senior Technologist @ GE Global Research (10+): Multiphysics Engineered Multiwall sheet, Structural color, Nano foam, metamaterial, CAI.

Manager Engineering @ Tata Advanced Materials: FRP missile & transport containers, Bullet resistant composites.

Consultant To R&DE, DRDO: FRP Railway Sleeper. Concurrent engineering

Scientist @ R&DE, DRDO: Composite research centre.

Project Engineer @ IIT B: FRP hybrid Orthosis , Mechanical and NDE testing, Industrial consultancy support

ATOA

# Technical Project

**Innovative Product/ Technology Delivered:**
**Glazing, RF heater, Acoustic stethoscope, Solar, Metal cloak A pillar, Battery**

**Technical Publications:**
**26+ , Webinars and Keynotes**

**Patents (ATOASTIAN as Inventor):**
**21+ US Patents , 89 worldwide Patent records**

**Successful products in the market**

# Global Clients

Mercedes-Benz The best or nothing.
SIEMENS
RENAULT · NISSAN JOINT VENTURE COMPANY
ITC Limited
TATA
USQ AUSTRALIA
Unilever
intel
Schlumberger
AMARA RAJA Gotta be a better way
ANDRITZ
sabic
DUPONT The miracles of science
ए आर सी आई
Balfour Beatty
LARSEN & TOUBRO It's all about Imagineering
Petrofac
Perfint Intelligent Connected Reliable
Raychem RPG ENGINEERING GROWTH. PIONEERING EXCELLENCE
Mahindra Rise

Vectis

# Overview

Vectis is a premier full-suite IP licensing and consultancy boutique with a global reach that works with and for the technology leaders of tomorrow.

Our diverse and skilled team combines extensive experience in all facets of IP licensing, IP consulting, and tech transfer. Vectis believes in a level playing field for IP owners and implementers and is dedicated to finding collaborative and balanced licensing solutions which put innovation, and people at the centre, with the overall aim to accelerate the development of innovation for the benefit of all.

With unparalleled experience in designing, executing and managing global licensing programs, Vectis offers patent owners in most technology spaces the opportunity to reach their IP and technology licensing goals. Vectis is currently working on programs covering audio, video, communications, e-commerce, networking and ultrasound technologies.

Negotiated IP Deals in
**20+**
Countries

Experts in R/Frand matters in
**10+**
Jurisdictions

Negotiated IP Deals related to
**8+**
Technology Standards

IP Team that has closed
**3,000+**
Global IP Deals

Completed IP Projects with
**50+**
Global Technology Leaders

Vectis

# Solutions

## Tech Transfer

Vectis has a passion for new technologies and works alongside leading research institutions and universities to support them commercialize their latest innovations

## IP Consulting

Vectis helps innovation leaders to unleash the strategic value of their IP and drive business growth by designing holistic and business-driven IP solutions

## IP Licensing

Vectis is a pioneer in designing and managing innovative and efficient IP licensing platforms that build new synergetic approaches on how IP can be managed, mitigated, and rewarded

Vectis

# Clients






















Volkswagen

MEMS

# Micro Electro-Mechanical Systems

- MEMS are miniaturized structures, sensors, actuators, and microelectronics.
- Principles: Resistive, Capacitive, Inductive, Piezoelectric.
- Types: accelerometers, gyroscopes, pressure sensors, magnetic field sensors.
- A particular class of MEMS is devoted to the development of the Micromachined Ultrasonic Transducer (MUT).
- MUTs are usually distinguished in PMUTs (piezoelectric MUTs) and CMUTs (capacitive MUTs) depending on the actuation principle, piezoelectric or electrostatic.

Picture Source:
https://circuitdigest.com/tutorial/what-is-mems-various-mems-devices-and-applications

**MEMS devices are Multiphysics in nature, which is the core strength of ATOA**

CMUT

# Capacitive Micromachined Ultrasonic Transducer

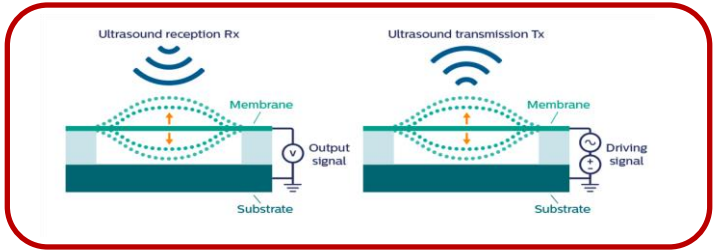
CMUTs are MEMS-based devices that can receive and transmit acoustic signals.

The fabrication of CMUTs relies on the fabrication processes of the ubiquitous integrated circuit (IC), thus resulting in highly cost-effective manufacturing.

As a breakthrough ultrasound technology, CMUTs convey numerous outstanding advantages such as large bandwidth (>100% in immersion), wider frequency range (from 500 kHz to 50 MHz), high resolution, low mechanical coupling between elements and capability of manipulating high-density arrays electrostatic

CMUTs and CMOS technologies help chip-size integration, accordingly allowing miniaturization for more sturdy designs

The CMUT has successfully achieved the measurement of sound speed, flow rate, viscosity, and acoustic impedance in the fluid environment




Picture Source: https://www.engineeringsolutions.philips.com/looking-expertise/mems-micro-devices/mems-micro-devices-applications/capacitive-micromachined-ultrasonic-transducers-cmut/

The fabrication technologies of CMUTs provides immense opportunities for the medical market; A typical CMUT product is an ultrasonic Tx Rx transducer for medical imaging

CMUT devices adopt common semiconductor materials that are commonly lead-free.

## CMUT is an epitome of MEMS and can make a difference to healthcare

CMUT

# Need of CMUT and a brief comparison with Conventional & PMUTs

The advent of **CMUTs** revolutionized medical imaging, clinical therapy, and NDT/NDE by mitigating the issues associated with **Conventional-Piezoelectric Transducer** and dominant **PMUTs**.

## Conventional-Piezoelectric Transducer

**Pros:**
- Proven technology

**Cons:**
- Labour intensive and expensive
- Difficult to manufacture
- No volume production
- Small bandwidth
- Reserved for professional use

## PMUT

**Pros:**
- Integration with electronics
- No bias voltage is needed
- Low-frequency range
- Flexible geometries
- Natural acoustic impedance matches with water

**Cons:**
- Labour intensive and expensive
- Difficult to manufacture, no volume production
- Small bandwidth
- Reserved for professional use

## CMUT

**Pros:**
- Wider frequency range, suited for high frequency
- Lack of self-heating, low power consumption
- Easy to be integrated with front-end electronics: CMUT-on-CMOS
- Low mechanical coupling, no crosstalk
- High resolution and low loss miniature device
- Easily attainable miniaturization, small form factor
- High volume production & cost-effective manufacturing
- Capability of implementing high-density arrays.

**Cons:**
- Relatively lower output acoustic pressure,
- Complex manufacturing process and mode of operation
- High bias voltage

**Sources:**


Capacitive_micromachined_ultrasound_transducers_for_intravascular_ultrasound_imaging

CMUT-and-PMUT-Rob-van-Schaijk-November-2018.pdf

Capacitive micromachined ultrasonic transducers | Philips Engineering Solutions

Flexible transparent CMUT arrays for photoacoustic tomography (optica.org)

CMUT

# Potential

**Technology:**
Ultrasonic sensors are established for low-interference monitoring and analysis of static and dynamic processes in industrial testing and automation technology.

**Trend:**
Innovations and developments in several market segments show trends towards automated systems, human-machine interaction, and multi-sensor fusion, which demand miniaturized ultrasonic sensor devices with a high level of integration and performance. CMUTs address these market requirements for the next-generation ultrasound systems based on MEMS structures utilized to generate and sense acoustic signals in the ultrasonic range.

**Applications:**
NDE, Medical Diagnostic (2D, 3D, 4D, Doppler), medical therapy (HIFU, ESWL), Sensing (Gas, Pressure, Velocity, underwater, fingerprint,) microscopy.

**Market Overview:**
Ultrasound Devices Market size is estimated to reach $9.1 billion by 2027, growing at a CAGR of 3.95% during the forecast period 2022-2027.
The boost in the acceptance of ultrasound devices for diagnostic imaging and treatment in conjunction with the increasing predominance of incessant and lifestyle-associated ailments is set to drive the Ultrasound Devices Market.

# State of the Art

## Exemplary references based on Standard 3 layer Stanford construction

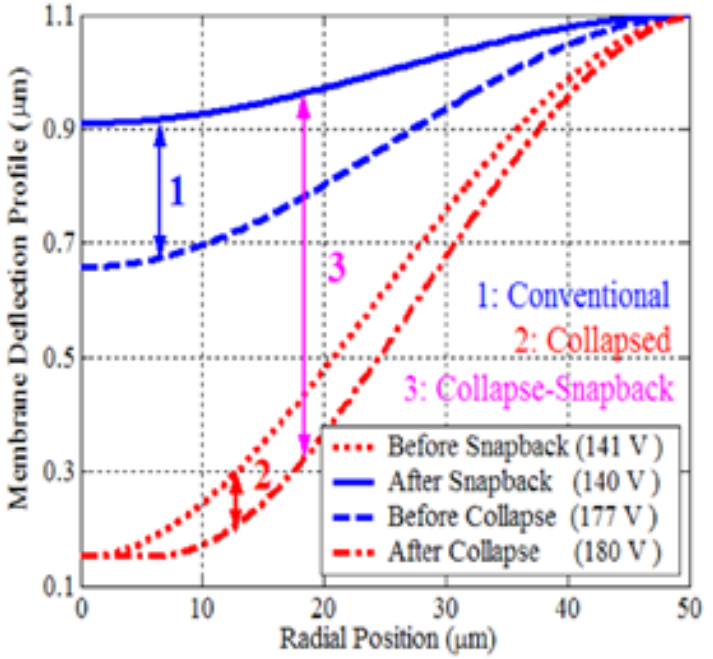
- Design and structure of the CMUT substrates, electrodes and membranes: US8483014, US7615834, US10598632, US2021/0260622.
- Multi electrodes and multi membranes CMUTs: US9925561, US8008835.
- Scalable arrays of CMUTs: US7493821.
- CMUT in permanent contact mode: US2013/0087867.

State of art has fundamental limitations dictated by the governing physics and does not provide adequate solution to the demanding needs of improving higher output sound pressure, higher sensitivity and lower bias/ operational voltage

# State of the Art

## CMUT Operating Modes

- CMUTs usually operate in either conventional mode, collapse mode or collapse-snapback mode.
- The diagram depicts the position of the bottom surface of the CMUT membrane from the substrate (vertical axis) vs the radial distance from the center of the membrane (horizontal axis).
- The arrows show the membrane motion in case of conventional mode (1), collapse mode (2) and collapse-snapback mode (3).




**Source:**

Source: http://stanford.edu/group/khuri-yakub/publications/05_Bayram_02.pdf

# State of the Art

## Limitations

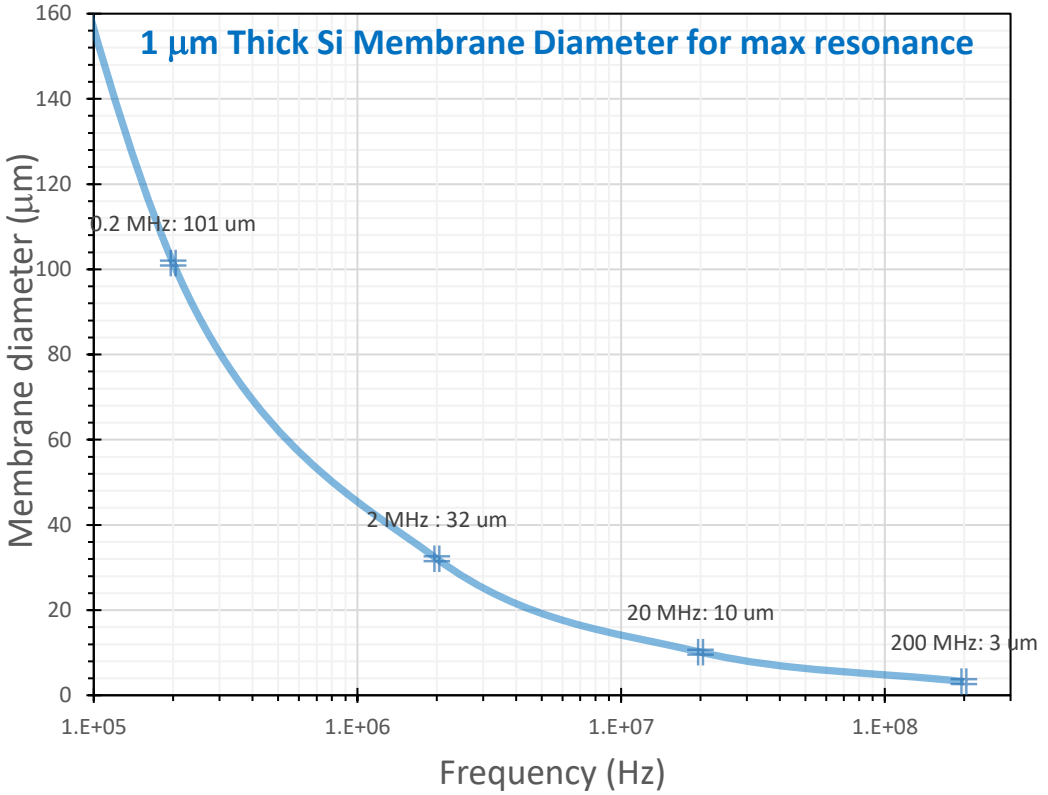
- Conventional mode limits the performance of CMUT, as it uses only 30% of maximum capability.
- Collapse mode reduces the sensitivity or sound power as only few part of membrane (50-80%) is used for sensing.
- Conventional, collapse and collapse-snapback modes provides nonlinear response for similar input signal, which is difficult for diagnosing or sensing.

# State of the Art

## Higher frequency range applications needs higher performances

- Ultrasound freq. range:
  - Medical range: 20kHz – 2 MHz.
  - NDE range: 2 MHz – 200 MHz.

- Typical membrane diameter range for 1 µm thick Si membrane: 101 µm (at 0.2 MHz) – 3 µm (at 200 MHz)
- As the frequency increases the resolution improves, but at the cost of a reduction of the membrane area available for generating ultrasound waves (that is proportional to the membrane diameter), and therefore with a reduction of the penetration performance.
- Applications at higher frequencies require more performing CMUT.



# ATOA CMUT Solution: a Step Beyond the State of the Art

## The CMUT cell

**The ATOA solution overcomes the disadvantages of the state of the art and provides significantly higher performance**

**ATOA fully simulates the CMUT cell performance through virtual product development**

# Virtual Product (VP) development: Introduction

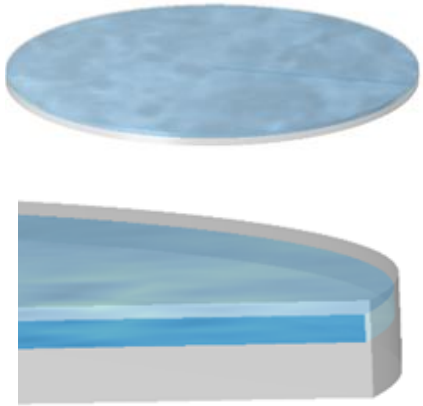
CMUT product development involves coupling of electrical, mechanical, acoustical and thermal physics to exploit the full potential and multiphysics optimization for highly efficient and cost-effective product development.
VP is industrial norm for CMUT.

COMSOL multiphysics models are used with appropriate governing equation, physics formulation, input parameters, boundary conditions, coupling of physics and FEM meshes

# Cell capacitor model

CMUTs transducer can work in transmit and reception mode, to produce and receive ultrasound, respectively

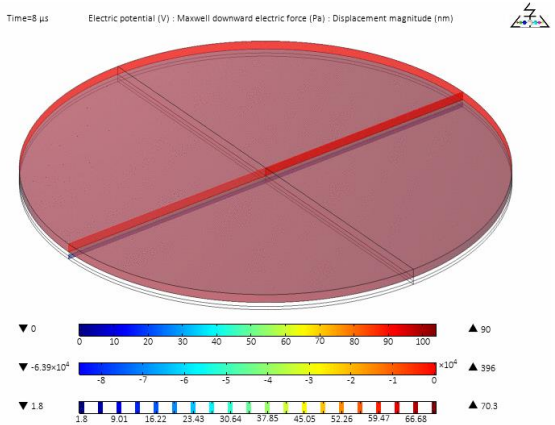
Typical capacitor cell full and quarter symmetry models:



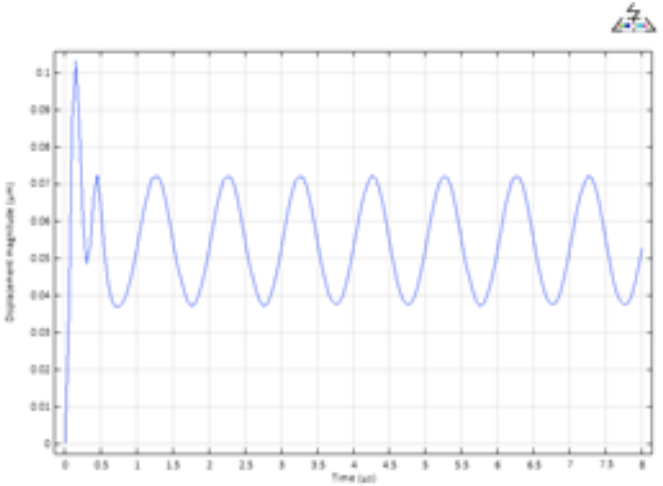
# Dynamic operation performance of DC bias plus AC signal

For Dynamic operation modelling Capacitor Cell's basic unit the DC static modelling method is extended to time domain transient analysis. Vdc + Vac signal is applied to one of the terminals for the transient analysis

Typical contour plots with electrical potential, Maxwell force and the dynamic Membrane performance due to DC bias plus AC signal:




Graphical representation of Membrane deflection due to DC bias plus AC signal on the time domain:



# ATOA CMUT Solution: The HIFU Use Case

**Exemplary Use Case**

**CMUT for High Intensity Focused Ultrasound (HIFU) medical therapy**

**ATOA fully simulates a HIFU device through virtual product development**

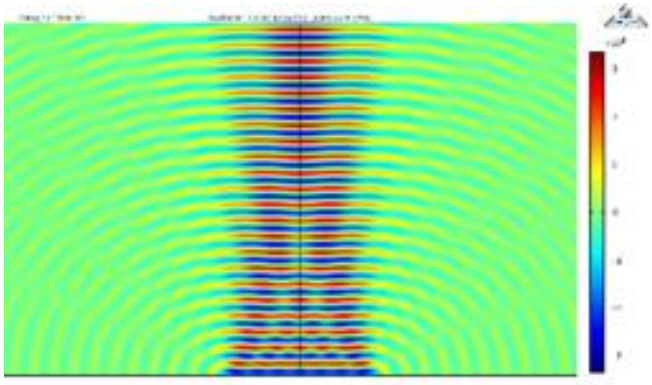
# High Intensity Focused Ultrasound application

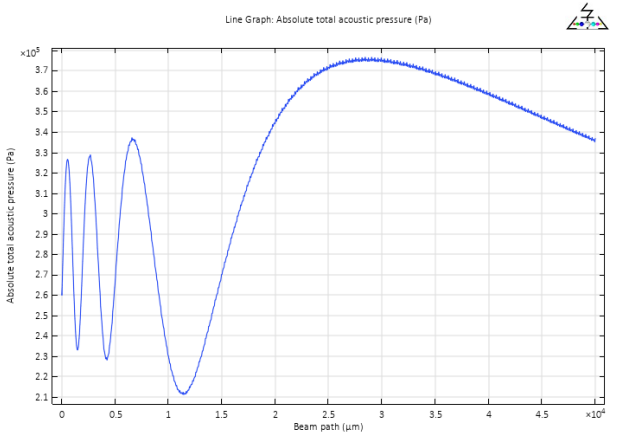
- A CMUT's emerging application is the HIFU for medical diagnosis and therapy.
- The key advantage of HIFU therapy is that the focused energy is sufficient for target treatment and not to killing the surrounding tissue.
- The number of arrays, size, thickness, frequency, geometric parameters, material properties and electrical configuration are used for effective design and analysis of the performance of CMUT arrays transducers for HIFU in tissue medium.

# Acoustic characteristics of transducer array

The acoustic performance of CMUT arrays transducer such as, the acoustic pressure distribution in tissue, variation of acoustic pressure along the transducer axis, and the far field angular beam directivity pattern are evaluated

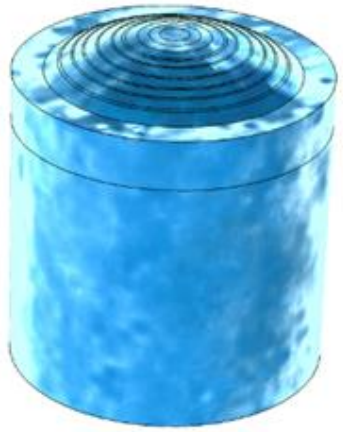
The acoustic pressure distribution from CMUT arrays transducer to the tissue medium:



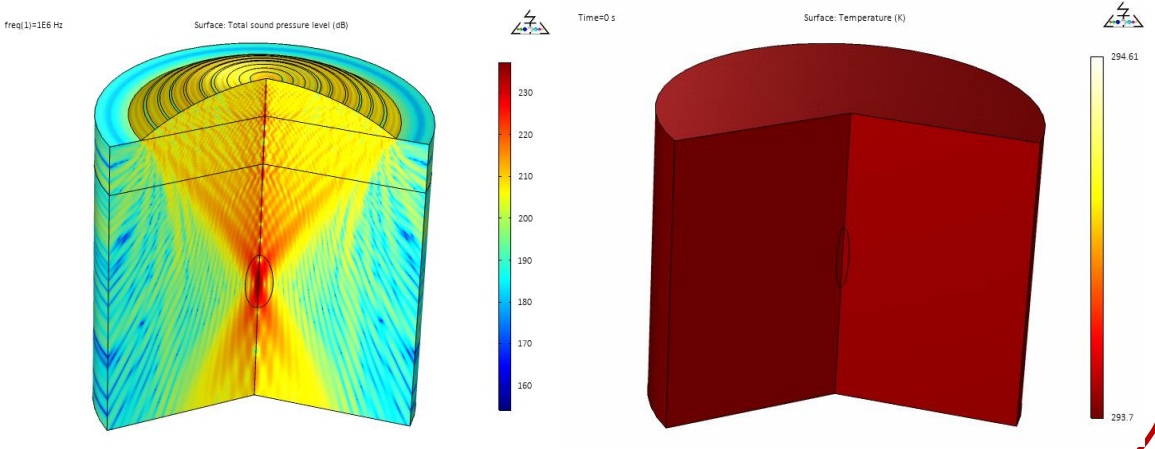


# HIFU therapy effectiveness

To design CMUT transducer for HIFU, a concentric curved membrane based device is modelled along with a tissue phantom. 3D CAD model and computing domain used for HIFU investigation:



A pulsed acoustic source is used to model the heating of the tissue phantom to study the effectiveness of HIFU therapy. Temperature distribution around tissue phantom due to focused treatment of 1 sec.:



# CMUT other use cases/modalities

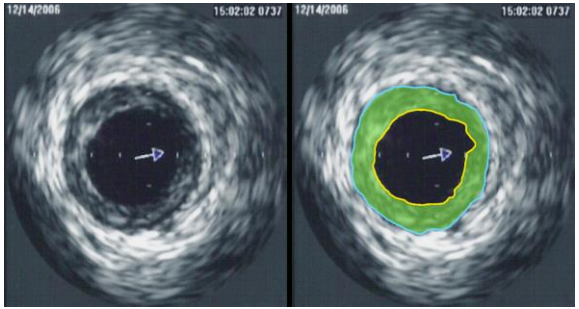
## Additional use cases for the simulated Single cell

**Single Cell simulated for HIFU therapy is applicable to any other use cases/modalities.**

**Some other exemplary use cases:**

- **Medical imaging (e.g. "IVUS" Intravascular ultrasound or intravascular echocardiography)**
- **Sensors (e.g. "VOC" Volatile Organic Compounds sensors)**

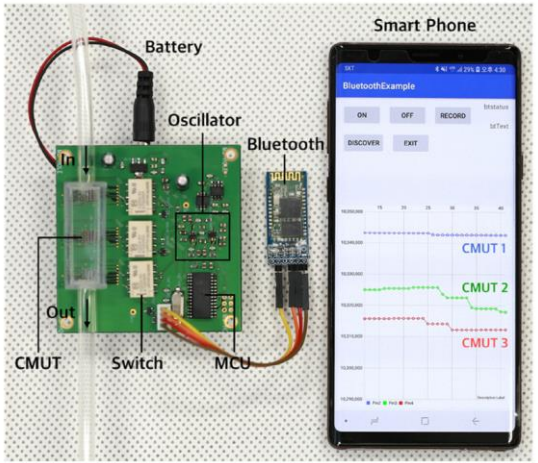
Intravascular ultrasound image of a coronary artery




**Source:**

Source: https://en.wikipedia.org/wiki/Intravascular_ultrasound#/media/File:IVUS_of_CAD.png

Portable VOC sensor system composed of multiple CMUT sensors




**Source:**

Source: Inug Yoon at al, A Capacitive Micromachined Ultrasonic Transducer-Based Resonant Sensor Array for Portable Volatile Organic Compound Detection with Wireless Systems, MDPI, 2019.

ATOA CMUT Development

# CMUT PROBE Architecture

## Single cell to probe

Single Cell simulated for HIFU therapy is applicable to any CMUT structure:

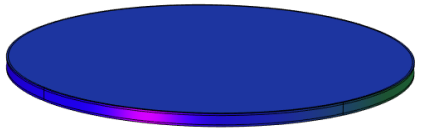
- 0D
- Single Cell – with movements for A scan, B Scan, M scan, C scan, D scan

- 1D
- Phased 1D array - sectional planer 2D image, no of cells ~128, 256

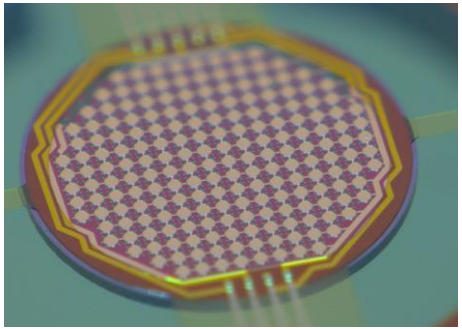
- 2D
- Phased 2D array - volume 3D image, Pixels can be addressed individually with the proper phase delay, state of art 100 cells x100 cell

- Single cell improvement benefits multitude of probes and application.

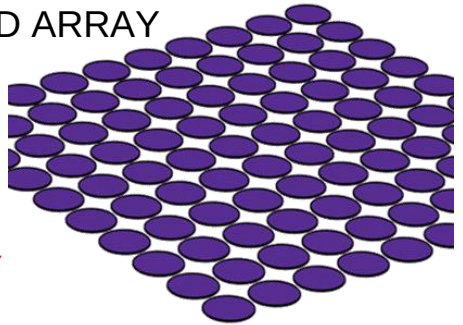
SINGLE CELL



1D ARRAY



2D ARRAY

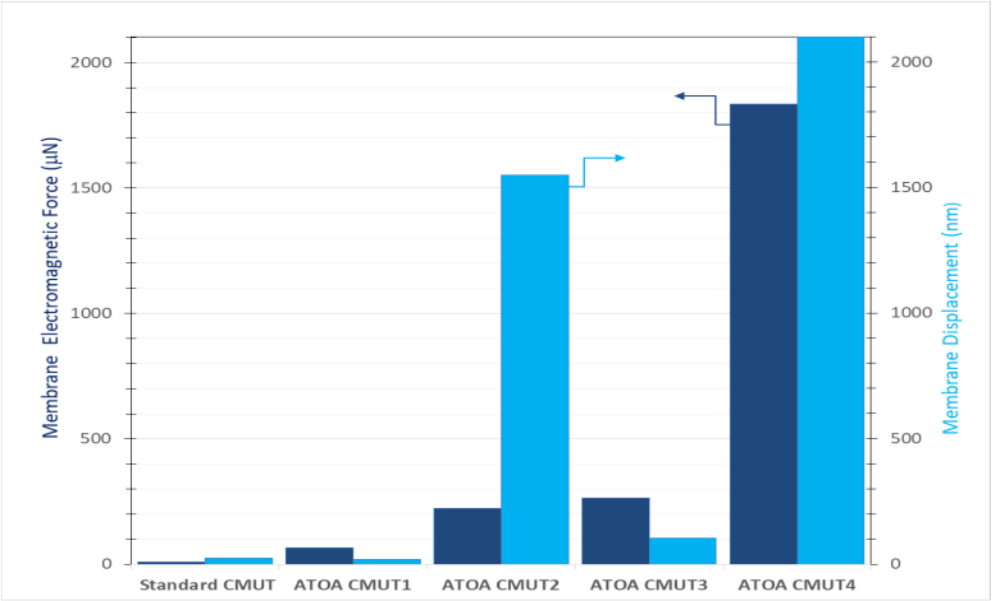


MULTITUDE OF PROBES

# ATOA solution improvements

- ATOA CMUT solution provides for a new and robust operational mode “the simple smooth mode” that overcomes the limitations of the state of the art.
- ATOA’s CMUT prototypes show exceptional performance by using a novel simple robust multilayer and multifunctional configuration.

- Electromagnetic Force improvement, max 19451%, ~ 200X
- Sound pressure improvement, max 8681%,~ 87X
- Low operational and bias voltage ~5-10V



Tech Transfer Proposal

# ATOA CMUT is a game changer for UT

## ATOA CMUT solution is ready for Technology Transfer/Licensing

- Patent applications already filed before Indian Patent Office and PCT, filing of International patent applications worldwide, in progress.
- Virtual prototype ready for further specific application/device design and development.
- Subject to an NDA, Vectis and ATOA are available to provide further information that can help the company to assess and evaluate ATOA Solution.

**Contact Vectis if your company is interested in acquiring or licensing ATOA CMUT technology**
**CMUT@vectis.com**