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Vibrations

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Virtual Collaborations - Second Edition

The first edition of Virtual Collaborations featuring Jay Sheehan on Piezo Stack Pre-Load in Transducers was an outstanding success.

More than 60 participants from around the world listened to the presentation and then broke into small group discussions to talk about the application of this theory to their practical needs.

100% of the participants completing the evaluation indicated that they were very satisfied/ satisfied with the virtual collaborations.

The second **Virtual Collaboration** will be held on Thursday, 12 November 2020 at 10 am EST / 3 pm GMT

Register Now

> *"…my thanks for a presentation and format that exceeded my expectations for a virtual conference."*

Special Points of Interest

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Virtual Collaborations

November 12
10 am ET
3 pm BT

www.ultrasonics.org/VC

Multi-wavelength Probes and Blades:
Tuning / Gain / Balancing

To register go to:
Ultrasonics.org/VC

Jeff Vaitekunas will lead the second Virtual Collaborations with his presentation on Multi-Wavelength Probes and Blades: Tuning / Gain / Balancing.

Long blades, probes or waveguides are utilized in many ultrasonic technology applications, and particularly in medical surgical devices. Resonant devices may be any integer-number of wavelengths long. Often, longer devices exhibit parasitic vibration modes that lead to fatigue failure, audible noise, heat and other undesirable effects. This collaboration will address mechanisms for balancing undesirable transverse motion due to asymmetries and moving undesirable parasitic vibration modes to reduce energy coupling into undesirable modes of vibration.

> Small group discussions will give participants the opportunity to share ideas with their colleagues and peers about the information presented and specific applications.

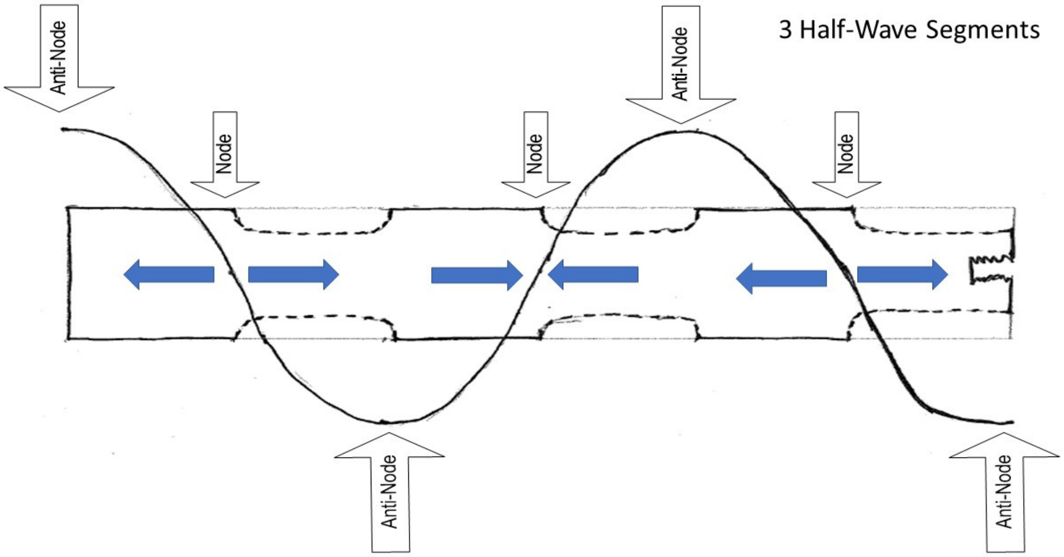
More comments (and a sneak peek at the next VC event)

"Making them frequent and maintaining them after the end of the pandemic. I am a new member and the Virtual Collaborations is allowing me to get involved. This first topic was a perfect start for me!"

"Jay Sheehan, thank you for the great presentation. The information about the minimum ratio between the bolt stretch and the amplitude of vibration was especially insightful for me."

"I really enjoyed the presentation and even though I have been designing transducers for a number of years, I have picked up new (and valuable) tips on transducer design."

Multi-Wavelength Gain and Tuning



Ultrasound Applications in the News

World's smallest ultrasound detector created

Researchers at Helmholtz Zentrum München and the Technical University of Munich (TUM) have developed the world's smallest ultrasound detector. It is based on miniaturized photonic circuits on top of a silicon chip. With a size 100 times smaller than an average human hair, the new detector can visualize features that are much smaller than previously possible, leading to what is known as super-resolution imaging.

Since the development of medical ultrasound imaging in the 1950s, the core detection technology of ultrasound waves has primarily focused on using piezoelectric detectors, which convert the pressure from ultrasound waves into electric voltage. The imaging resolution achieved with ultrasound depends on the size of the piezoelectric detector employed. Reducing this size leads to higher resolution and can offer smaller, densely packed one or two dimensional ultrasound arrays with improved ability to discriminate features in the imaged tissue or material. However, further reducing the size of piezoelectric detectors impairs their sensitivity dramatically, making them unusable for practical application.

Using computer chip technology to create an optical ultrasound detector

Silicon photonics technology is widely used to miniaturize optical components and densely pack them on the small surface of a silicon chip. While silicon does not exhibit any piezoelectricity, its ability to confine light in dimensions smaller than the optical wavelength has already been widely exploited for the development of miniaturized photonic circuits.

Researchers at Helmholtz Zentrum Munchen and TUM capitalized on the advantages of those miniaturized photonic circuits and built the world's smallest ultrasound detector: the silicon waveguide-etalon detector, or SWED. Instead of recording voltage from piezoelectric crystals, SWED monitors changes in light intensity propagating through the miniaturized photonic circuits.

"This is the first time that a detector smaller than the size of a blood cell is used to detect ultrasound using the silicon photonics technology," says Rami Shnaiderman, developer of SWED. "If a piezoelectric detector was miniaturized to the scale of SWED, it would be 100 million times less sensitive."

> The degree to which we were able to miniaturize… was breathtaking.

Super-resolution imaging

"The degree to which we were we able to miniaturize the new detector while retaining high sensitivity due to the use of silicon photonics was breathtaking," says Prof. Vasilis Ntziachristos, lead of the research team. The SWED size is about half a micron (=0,0005 millimeters). This size corresponds to an area that is at least 10,000 times smaller than the smallest piezoelectric detectors employed in clinical imaging applications. The SWED is also up to 200 times smaller than the ultrasound wavelength employed, which means that it can be used to visualize features that are smaller than one micrometer, leading to what is called super-resolution imaging.

Inexpensive and powerful

As the technology capitalizes on the robustness and easy manufacturability of the silicon platform, large numbers of detectors can be produced at a small fraction of the cost of piezoelectric detectors, making mass production feasible. This is important for developing a number of different detection applications based on ultrasound waves. "We will continue to optimize every parameter of this technology -- the sensitivity, the integration of SWED in large arrays, and its implementation in hand-held devices and endoscopes," adds Shnaiderman.

Future development and applications

"The detector was originally developed to propel the performance of optoacoustic imaging, which is a major focus of our research at Helmholtz Zentrum München and TUM. However, we now foresee applications in a broader field of sensing and imaging," says Ntziachristos.

While the researchers are primarily aiming for applications in clinical diagnostics and basic biomedical research, industrial applications may also benefit from the new technology. The increased imaging resolution may lead to studying ultra-fine details in tissues and materials. A first line of investigation involves super-resolution optoacoustic (photoacoustic) imaging of cells and micro-vasculature in tissues, but the SWED could be also used to study fundamental properties of ultrasonic waves and their interactions with matter on a scale that was not possible before.

SOURCE: Materials provided by **Helmholtz Zentrum München - German Research Center for Environmental Health**.

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Ultrasound Applications in the News, continued

An ultrasonic projector for medicine

A chip-based technology that generates sound profiles with high resolution and intensity could create new options for ultrasound therapy, which would become more effective and easier. A team of researchers led by Peer Fischer from the Max Planck Institute for Intelligent Systems and the University of Stuttgart has developed a projector that flexibly modulates three-dimensional ultrasound fields with comparatively little technical effort. Dynamic sound pressure profiles can thus be generated with higher resolution and sound pressure than the current technology allows. It should soon be easier to tailor ultrasound profiles to individual patients. New medical applications for ultrasound may even emerge.

Ultrasound is widely used as a diagnostic tool in both medicine and materials science. It can also be used therapeutically. In the US, for example, tumours of the uterus and prostate are treated with high-power ultrasound. The ultrasound destroys the cancer cells by specific heating of the diseased tissue. Researchers worldwide are using ultrasound to combat tumours and other pathological changes in the brain. "In order to avoid damaging healthy tissue, the sound pressure profile must be precisely shaped," explains Peer Fischer, Research Group Leader at the Max Planck Institute for Intelligent Systems and professor at the University of Stuttgart. Tailoring an intensive ultrasound field to diseased tissue is somewhat more difficult in the brain. This is because the skullcap distorts the sound wave. The Spatial Ultrasound Modulator (SUM) developed by researchers in Fischer's group should help to remedy this situation and make ultrasound treatment more effective and easier in other cases. It allows the three-dimensional shape of even very intense ultrasound waves to be varied with high resolution -- and with less technical effort than is currently required to modulate ultrasound profiles.

> We can use much more powerful ultrasonic transducers

High intensity sound pressure profiles with 10,000 pixels

Conventional methods vary sound fields with several individual sound sources, the waves of which can be superimposed and shifted against each other. However, because the individual sound sources cannot be miniaturized at will, the resolution of these sound pressure profiles is limited to 1000 pixels. The sound transmitters are then so small that the sound pressure is sufficient for diagnostic but not therapeutic purposes. With the new technology, the researchers first generate an ultrasonic wave and then modulate its sound pressure profile independently, essentially killing two birds with one stone. "In this way, we can use much more powerful ultrasonic transducers," explains postdoctoral fellow Kai Melde, who is part of the team that developed the SUM. "Thanks to a chip with 10,000 pixels that modulates the ultrasonic wave, we can generate a much finer-resolved profile."

"In order to modulate the sound pressure profile, we take advantage of the different acoustic properties of water and air," says Zhichao Ma, a post-doctoral fellow in Fischer's group, who was instrumental in developing the new SUM technology: "While an ultrasonic wave passes through a liquid unhindered, it is completely reflected by air bubbles." The research team from Stuttgart thus constructed a chip the size of a thumbnail on which they can produce hydrogen bubbles by electrolysis (i.e. the splitting of water into oxygen and hydrogen with electricity) on 10,000 electrodes in a thin water film. The electrodes each have an edge length of less than a tenth of a millimetre and can be controlled individually.

A picture show with ultrasound

If you send an ultrasonic wave through the chip with a transducer (a kind of miniature loudspeaker), it passes through the chip unhindered. But as soon as the sound wave hits the water with the hydrogen bubbles, it continues to travel only through the liquid. Like a mask, this creates a sound pressure profile with cut-outs at the points where the air bubbles are located. To form a different sound profile, the researchers first wipe the hydrogen bubbles away from the chip and generate gas bubbles in a new pattern.

The researchers demonstrated how precisely and variably the new projector for ultrasound works by writing the alphabet in a kind of picture show of sound pressure profiles. To make the letters visible, they caught micro-particles in the various sound pressure profiles. Depending on the sound pattern, the particles arranged themselves into the individual letters.

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Ultrasound Applications in the News, continued

Organoid models for drug testing

For similar images, the scientists collaborating with Peer Fischer, Kai Melde, and Zhichao Ma previously arranged micro-particles with sound pressure profiles, which they modelled using a slightly different technique. They used special plastic stencils to deform the pressure profile of an ultrasonic wave like a hologram and arrange small particles -- as well as biological cells in a liquid -- into a desired pattern. However, the plastic holograms only provided still images. For each new pattern, they had to make a different plastic template. Using the ultrasound projector, the Stuttgart team is able to generate a new sound profile in about 10 seconds. "With other chips, we could significantly increase the frame rate," says Kai Melde, who led the hologram development team.

The technique could be used not only for diagnostic and therapeutic purposes but also in biomedical laboratories. For example, to arrange cells into organoid models. "Such organoids enable useful tests of active pharmaceutical ingredients and could therefore at least partially replace animal experiments," says Fischer.

Materials provided by **Max-Planck-Gesellschaft**.

3D biometric authentication based on finger veins almost impossible to fool

Biometric authentication, which uses unique anatomical features such as fingerprints or facial features to verify a person's identity, is increasingly replacing traditional passwords for accessing everything from smartphones to law enforcement systems. A newly developed approach that uses 3D images of finger veins could greatly increase the security of this type of authentication.

"The 3D finger vein biometric authentication method we developed enables levels of specificity and anti-spoofing that were not possible before," said Jun Xia, from University at Buffalo, The State University of New York, research team leader. "Since no two people have exactly the same 3D vein pattern, faking a vein biometric authentication would require creating an exact 3D replica of a person's finger veins, which is basically not possible."

This new technique could used to enable better authentication techniques to protect personnel data and sensitive documents

In the Optical Society (OSA) journal *Applied Optics*, the researchers describe their new approach, which represents the first time that photoacoustic tomography has been used for 3D finger vein biometric authentication. Tests of the method on people showed that it can correctly accept or reject an identity 99 percent of the time.

"Due to the COVID-19 pandemic, many jobs and services are now performed remotely," said research team member Giovanni Milione, from NEC Laboratories America, Inc. "Because our technique detects invisible features in 3D, it could be used to enable better authentication techniques to protect personnel data and sensitive documents."

Adding depth information

Although other biometric authentication approaches based on finger veins have been developed, they are all based on 2D images. The additional depth from a 3D image increases security by making it more difficult to fake an identity and less likely that the technique will accept the wrong person or reject the right one.

To accomplish 3D biometric authentication using the veins in a person's fingers, the researchers turned to photoacoustic tomography, an imaging technique that combines light and sound. First, light from a laser is used to illuminate the finger. If the light hits a vein, it creates a sound much in the same way that a grill creates a "poof" sound when it is first lit. The system then detects that sound with an ultrasound detector and uses it to reconstruct a 3D image of the veins.

"It has been challenging to use photoacoustic tomography for 3D finger vein biometric authentication because of the bulky imaging system, small field of view and inconvenient positioning of the hand," said Xia. "We addressed these issues in the new system design through a better combination of light and acoustic beams and custom-made transducers to improve the imaging field of view."

Designing a practical system

To better integrate light illumination and acoustic detection, the researcher fabricated a new light- and acoustic-beam combiner. They also designed an imaging window

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Ultrasound Applications in the News, continued

that allows the hand to be naturally placed on the platform, similar to a full-size fingerprint scanner. Another critical development was a new matching algorithm, developed by Wenyao Xu from the Computer science and Engineering department that allows biometric identification and matching of features in 3D space.

The researchers tested their new system with 36 people by imaging their four left and four right fingers. The tests showed that the approach was not only feasible but also accurate, especially when multiple fingers were used.

"We envision this technique being used in critical facilities, such as banks and military bases, that require a high level of security," said Milione. "With further miniaturization 3D vein authentication could also be used in personal electronics or be combined with 2D fingerprints for two-factor authentication."

The researchers are now working to make the system even smaller and to reduce the imaging time to less than one second. They note that it should be possible to implement the photoacoustic system in smartphones since ultrasound systems have already been developed for use in smartphones. This could enable portable or wearable systems that perform biometric authentication in real time.

Source: Materials provided by The Optical Society

Detecting early-stage failure in electric power conversion devices

Power electronics regulate and modify electric power. They are in computers, power steering systems, solar cells, and many other technologies. Researchers are seeking to enhance power electronics by using silicon carbide semiconductors. However, wear-out failures such as cracks remain problematic. To help researchers improve future device designs, early damage detection in power electronics before complete failure is required.

The researchers are now working to make the system even smaller

In a study recently published in *IEEE Transactions on Power Electronics*, researchers from Osaka University monitored in real time the propagation of cracks in a silicon carbide Schottky diode during power cycling tests. The researchers used an analysis technique, known as acoustic emission, which has not been previously reported for this purpose.

During the power cycling test, the researchers mimicked repeatedly turning the device on and off, to monitor the resulting damage to the diode over time. Increasing acoustic emission corresponds to progressive damage to aluminum ribbons affixed to the silicon carbide Schottky diode. The researchers correlated the monitored acoustic emission signals to specific stages of device damage that eventually led to failure.

"A transducer converts acoustic emission signals during power cycling tests to an electrical output that can be measured," explains lead author ChanYang Choe. "We observed burst-type waveforms, which are consistent with fatigue cracking in the device."

The traditional method of checking whether a power device is damaged is to monitor anomalous increases in the forward voltage during power cycling tests. Using the traditional method, the researchers found that there was an abrupt increase in the forward voltage, but only when the device was near complete failure. In contrast, acoustic emission counts were much more sensitive. Instead of an all-or-none response, there were clear trends in the acoustic emission counts during power cycling tests.

"Unlike forward voltage plots, acoustic emission plots indicate all three stages of crack development," says senior author Chuantong Chen. "We detected crack initiation, crack propagation, and device failure, and confirmed our interpretations by microscopic imaging."

To date, there has been no sensitive early-warning method for detecting fatigue cracks that lead to complete failure in silicon carbide Schottky diodes. Acoustic emission monitoring, as reported here, is such a method. In the future, this development will help researchers determine why silicon carbide devices fail, and improve future designs in common and advanced technologies.

Source: Materials provided by **Osaka University**

From the President

Dominick DeAngelis

UIA President

These “troubling times” are still troubling to say the least, but we at the UIA are trying to stay relevant in this new “virtual” world order. Our first attempt at a “Virtual Collaborations” in September drew a huge crowd that even rivaled our annual symposium, so I think we are off to a really great start! The virtual chatrooms also gave attendees the opportunity to discuss the topic in an open forum with the look and feel of our famous “unconference sessions,” that are often the highlight of our yearly in-person gatherings; many even met new people too.

The success of our first virtual collaboration was no small feat by our board member and past UIA 2019 Toronto symposium chair, Jay Sheehan, since doing the first of anything is never an easy job. We plan to continue the Virtual Collaborations series in November, with our board member and past UIA president Jeff Vaitekunas, on the topic of “Multi-wavelength probes and blades: tuning / gain / balancing.” Jeff has a long history in designing medical transducers, but has the rare theoretical background to really understand the science involved when biology meets ultrasonics. Registration is now open, and I highly recommend that you help us keep this series going with your participation!

As for our annual symposium in 2021, we had to make the decision to plan a virtual event given the current state of COVID, but we hope to have the same program content that was planned for in-person at Warwick University. If the success of our first virtual collaboration is any measure, this virtual symposium will not disappoint!

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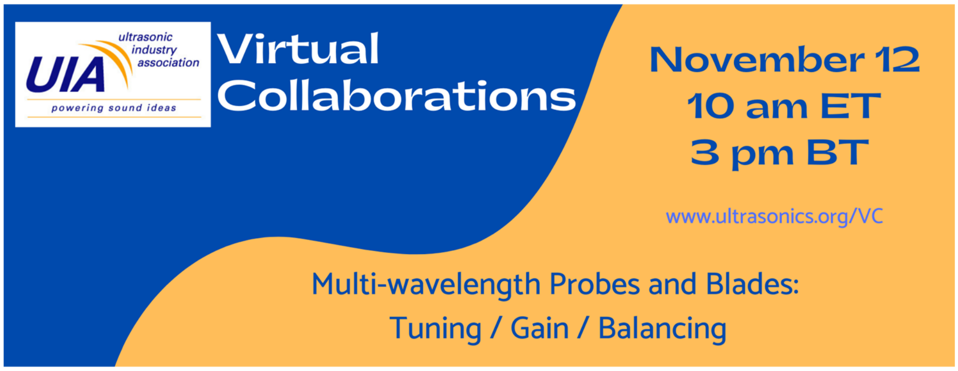
How can ultrasonics enhance the value of your business?

UIA is the international business forum for users, manufacturers, and researchers of ultrasonics. Our members use acoustic vibrations to improve materials, industrial processes, and medical technology. We call this *powering sound ideas.*

Let's work together to power your sound ideas. Contact a member consultant or company through our online Referral Network, learn about ultrasonics with our online primer, or meet industry leaders at our next symposium.

Important Dates



Virtual Collaborations

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Multi-wavelength Probes and Blades:
Tuning / Gain / Balancing

12 November 2020: Virtual Connections: Multi-Wavelength Probes and Blades: Tuning / Gain / Balancing

April 2021: Virtual UIA49 Symposium - Details coming soon!