The newsletter of
The Acoustical Society of America

ECHOES

Volume 22, Number 3
Summer 2012

Acoustic Diode: One-way street for sound waves

Bin Liang, Xiasheng Guo, Juan Tu, Dong Zhang, and Jianchun Cheng

As we all know, most of the roads allow the cars to travel in both directions. But it is necessary to control the traffic under certain circumstances, e.g., in some congested streets, by directing the vehicles to move in only one direction. Usually, waves can propagate just as easily in both directions along a given path, while scientists can also design some "one-way streets" to control them in a similar manner. The most famous example is the electric diode used to restrict current flow in one particular direction, which is termed as "rectification". Similar devices also exist for light and heat transmission.

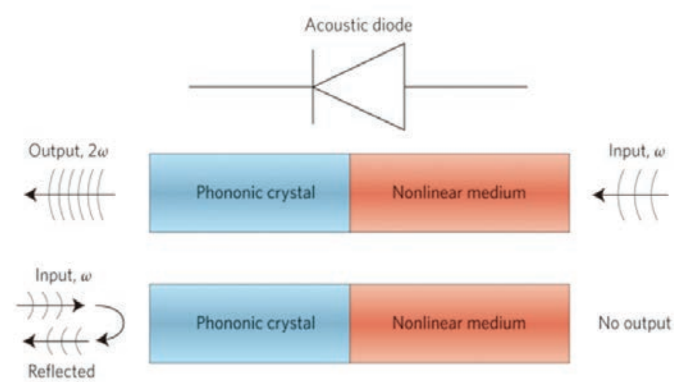

Figure 1 Schematic diagram of the acoustic diode sample.

Considering the worldwide revolutions led by the emergence of electric diode, it should be intriguing to make such one-way devices for acoustic waves, which have much longer research history than electricity and apply almost everywhere in our daily life. However, there exists no analogous method to "rectifying" sounds because of the way sound moves in a medium. Actually, in acoustics there is a classical "reciprocal theorem" which states that the transmission in any linear acoustic system is symmetric. In other words, for a speaker and a listener, the listening effect will not be affected if they swap their locations, as traditionally perceived. Hence the rectification of acoustic waves have always remained a challenge, until an "acoustic diode" was recently proposed theoretically and realized experimentally.

The basic model of an acoustic diode consists of two segments. The first is a special acoustic medium with strong acoustic "nonlinearity". This nonlinear medium is used for breaking through the bounds of reciprocal theorem which stands for any linear system. In such a medium, the sound enters at a particular frequency (pulsations per second) and will be partially converted into a second wave of twice (or another integer multiple of) the original frequency. This is in direct analogy of the creation of overtones in musical instruments. In the experiment, a layer of ultrasound contrast agent microbubble suspension, which has particularly strong acoustic nonlinearity and is widely used in ultrasound radiography to enhance the imaging quality of ultrasonic diagnostics, was used to produce the nonlinear medium sample. The other essential part in acoustic diode is a "phononic crystal", a periodic structure made from alternating layers of two different kinds of media. In the experimental realization, they are chosen as water and glass for the convenience of fabrication. The phononic crystal acts as an effective acoustic filter, because its "bandgap" prevents acoustic waves with frequencies within this bandgap from being transmitted through the structure. The frequency range of the bandgap can be altered by adjusting the elastic constant, mass density and layer thickness of the media I and II. The schematic diagram of an acoustic diode is illustrated in Fig. 1.

Similar to the case of an electric diode, one can define the positive and the negative directions for an acoustic diode. In general, the positive direction refers to the propagating direction of an acoustic wave incident from the side of the nonlinear medium, and the opposite direction is defined as the negative direction. And the phononic crystal in the acoustic diode is tuned to yield a bandgap at the frequency of the incident wave but allow the waves of doubled frequency to pass. The acoustic diode then works as follows (See Fig. 1). An acoustic wave coming in the positive direction has to hit and then go through the nonlinear material first, which creates the overtones.

continued on page 3

We hear that . . .

• Acoustical Society member **Jody Kreiman**, professor in residence of head and neck surgery at the David Geffen School of Medicine at UCLA and co-director of the UCLA Voice Perception Laboratory, won the PROSE Award in the language and linguistics category for her book, *Foundations of Voice Studies*, which she co-authored with Diana Sidtis of New York University. The text offers an interdisciplinary approach to explaining voice production and perception.

Stephen Dance (left) receives the Mentoring Award from Matthew Guild (photo by Charles Schmid)

• **Stephen Dance**, London South Bank University, received the Mentoring Award from the ASA Student Council at Acoustics 2012 Hong Kong.

• The **Brain Prize 2012** was jointly awarded to **Christine Petit** (France) and **Karen Steel** (UK) for their "unique world-leading contributions to our understanding of the genetic regulation of the development and functioning of the ear, and for elucidateing the causes of many of the hundreds of inherited forms of deafness." The €1 million prize is awarded by Grete Lundbeck European Brain Research Foundation. The two awardees are at the forefront of efforts to understand the molecular mechanisms of the specialized hair cells in the inner ear, whose extraordinary sensitivity to mechanical stimulation underpins the senses of hearing and balance.

• **ASA School 2012** is a new ASA event where graduate students and early career acousticians in all areas of acoustics can learn about and discuss a wide variety of topics related to the interdisciplinary acoustical theme *Living in the Acoustic Environment*. The school will be held Oct. 20-21, immediately before the ASA meeting in Kansas City. The application form and preliminary program is available online at www.AcousticalSociety.org. Applications are due by 1 August 2012.

• On August 22, 2012, a Public Outreach Workshop on Community Noise http://www.speechprivacy.org/PDFs/CommunityNoise2012.pdf) will be held at the Marriott Marquis in Times Square, New York City as part of Internoise 2012 (see http://internoise2012.com/).

• AAAS has established a Web site at http://election2008.aaas.org/2012 that offers a detailed look at the presidential candidates and their **positions on science and technology-related issues**. The site will focus on five areas: competitiveness and innovation; science, technology; engineering and matematics education and the workforce; climate and energy; health and medical research; and national security.

• "**The way we were**": 97 photos from the early days at BBN are posted online at http://www.acentech.com/images/company/acentech-bbn-early-days.pdf.

ECHOES ECHOES

Newsletter of the Acoustical Society of America

Provided as a benefit of membership to ASA members

The Acoustical Society of America was organized in 1929 to increase and diffuse the knowledge of acoustics and to promote its practical applications.

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Letter From the Editor
Science in India

I made my first visit to India in 1988 when I was invited to a symposium in Bangalore honroing the 100th anniversary of the birth of C.V. Raman. I spoke about Raman's contributions to acoustics, which included research on violins and Indian drums. My trip, which included visits to several universities and laboratories was an eye opener, as have been subsequent visits to Indian universities and research centers.

I was fascinated by the 24 February issue of *Science* which features Science in India. Earlier this year, Prime Minister Manmohan Singh pledged to hike R&D expenditures from $3 billion last year to $8 billion in 2017. At the same time the government intends to create incentives for the private sector to increase its spending on science and technology.

Elsewhere we read that India's peer-reviewed publications more than doubled from 2000 to 2010 and citation impact improved from 40% to nearly 60% of the world average. Indian scientists are well aware of the need for research that raises the standard of living in the world's largest democracy, home to 1.2 billion people.

Acoustics is alive and well in India. Many papers at ASA meetings have Indian authors. Acoustics research is carried out at the National Physical Laboratory in New Delhi as well as several other universities and laboratories. Madras (Chennai) was home to the first ASA chapter outside North America.

Thomas Rossing
Stanford University

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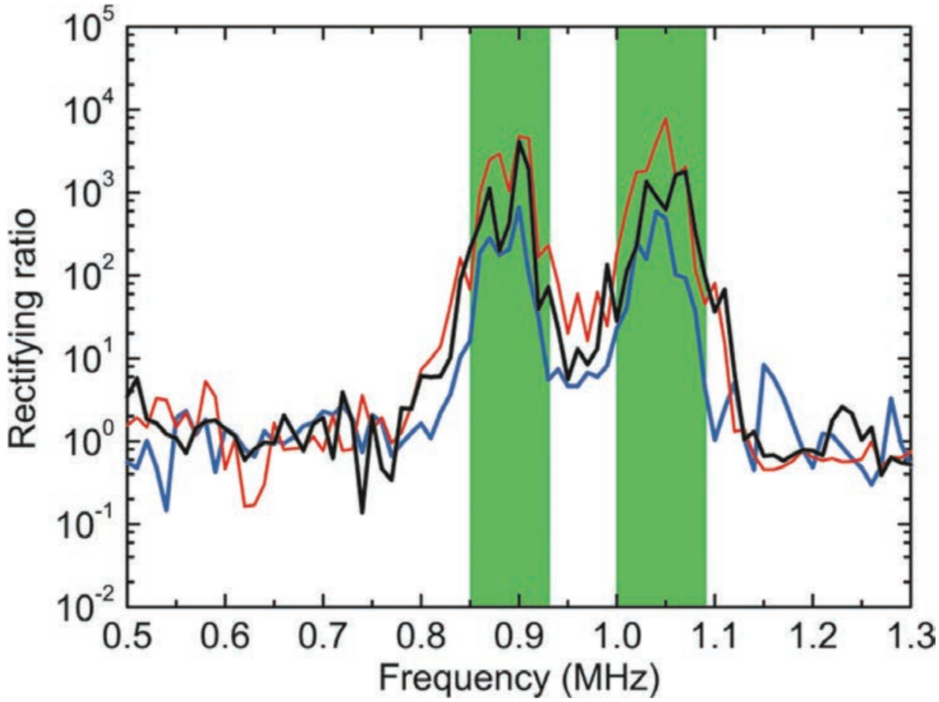

Figure 2 Comparison of the rectifying ratios for the acoustic diodes formed with three different nonlinear media samples. Results for nonlinear media samples produced using SonoVue® microbubble suspensions with volume concentrations of ~0.025% (blue line), 0.05% (red line) or 0.1% (black line), respectively.

Although the wave with the original frequency lies within the bandgap of the phononic crystal and will be blocked, the generated wave with doubled frequency will pass freely through the structure. However, an acoustic wave arriving from the other side will be totally reflected because only the original frequency is present, and this lies within the bandgap of the superlattice. In this case, the system works as an acoustic insulator.

In the experiment, a significant rectifying effect was observed within two frequency ranges that agreed well with theoretical predictions. Figure 2 plots the measured rectifying ratio for the acoustic diode prototype fabricated in the experiment. The rectifying ratio is defined, for a quantitative evaluation of the rectifying performance of an acoustic diode, as the ratio between the acoustic transmissions along the positive and negative directions. The green regions denote the calculated frequency ranges where the acoustic rectification is expected to occur. The performance of the acoustic diode prototype was confirmed by the remarkably high value of the measured rectifying ratios. At an appropriate ultrasound contrast agent microbubble concentration, the highest magnitude of the rectifying ratio approximates 10^4 with the incident wave driven at a source frequency of 1.06 MHz (1MHz=106Hz). This means the energy of the acoustic wave propagating along the positive direction is almost ten thousand times larger than that along the negative direction. The one-way propagation of acoustic waves in an acoustic diode then turned out to be very efficient.

With the first experimental realization of an acoustic diode, acoustic waves should no longer be considered to always travel easily in both directions in a given path as perceived traditionally. Although the acoustic diode is more like a conceptual prototype in the current stage, whose transmission efficacy and stability are considerably low, its development will inspire the interests and investigations in the more practical and efficient acoustic diodes in the future. This should have substantial significance for various practical situations where the acoustic waves need to be specially controlled, for example, the significant medical application of ultrasound. Most of the information and figures in this article are from Nature Mater. **9**, 989-992 (2010) and Nature Mater. **9**, 962-963 (2010).

The authors are with the Institute of Acoustics, Department of Physics, Nanjing University, Nanjing, 210093, China. This article is based on the Keynote Lecture presented 15 May at Acoustics 2012 Hong Kong.

Echoes from Hong Kong

Opening session of Acoustics 2012 Hong Kong: K.C. Lam (Technical Program Co-Chair, HKIOA), Whitlow Au (Co-Chair, ASA), Jing Tian (Co-Chair, ASC), Edward Yau (Secretary of the Environment, Hong Kong), Tom Ho (General Chair), Maurice Yeung (Co-Chair, HKIOA), Jungyul Na (Co-Chair, WESPAC) Mardi Hastings (ASA President)

Beranek receives Honorary Membership in Acoustical Society of China

At Acoustics 2012 Leo L. Beranek received Honorary Membership in the Acoustical Society of China. Leo, who has distinguished himself in so many ways in acoustics, was a fellow classmate of Dah-You Maa at Harvard, where they both studied with Frederick Hunt at the Cruft Laboratory. Leo continued working in Cambridge, first at Harvard, then becoming a professor at MIT and as a partner in the firm of Bolt, Beranek, and Newman (BBN). He served as president of ASA, and has won many awards from ASA and other scientific societies around the world. He is the first Honorary Member of the Acoustical Society of China.

Echoes from Hong Kong

Maa Dah-You named Honorary Fellow

Maa Dah-you was awarded Honorary Fellowship in the Acoustical Society of America at Acoustics 2012 Hong Kong. He has enjoyed a long and distinguished career in acoustics as well as in physics, electronics, electrical engineering, and in education. He is the author of 20 books and numerous scientific papers. He was elected to the Chinese National Academy of Sciences and received the Gold Medal of the Fraunhofer Society of Germany. As an ASA Honorary Fellow, he joins a long line of distinguished acousticians, beginning with Thomas A. Edison in 1929.

William Kuperman, winner of Gold Medal, with Mardi Hastings, president.

Pat Kuhl gives keynote lecture on language learning and the developing brain.

Best Student Paper Awards
Acoustics 2012 Hong Kong

Acoustical Oceanography/Underwater Acoustics
Huikwan Kim, University of Rhode Island
Menglu Xia, Zhejiang University

Animal Bioacoustics
First: Laura Kloepper, Hawaii Institute of Marine Biology
Second: Erika E. Alexander, Brown University

Architectural Acoustics
First: Jia Luo, Tsinghua University
Second: Ingo Witew, RWTH Aachen University

Engineering Acoustics
First: Matthew Guild, University of Texas at Austin
Second: Steven Dion, Université de Sherbrooke

Musical Acoustics
Brian Monson, National Center for Voice and Speech
Second: Brandon August, Rollins College

Speech Communication
First Place: Harim Kwon, University of Michigan
Second Place: Robert Risley, Rush University

Structural Acoustics and Vibration
First Place: André Verstappen, University of Canterbury
Second Place: Ye Wang, Harbin Engineering University

Best Paper by a Young Investigator
Noise
Jochen Steffens, Duesseldorf University

Signal Processing in Acoustics
Henglizi Zhang, Nanjing University

Echoes from Hong Kong

"Bioluminescence and the Dream World," a concert and puppet show with electroacoustic music by Lydia Ayers, was presented on Monday, 14 May.(photo by Jim Cottingham)

Meeting organizers gather at the banquet: Tom Ho (General Chair), Brigitte Schulte-Fortkamp (ASA Vice President), Charles Schmid (General Vice-Chair), Maurice Yeung (Co-Chair, HKIOA), Whitlow Au (Co-Chair, ASA), K.C. Lam (Technical Program Co-Chair, HKIOA)

Toward a high power non-contact acoustic source using time reversal

Pierre-Yves Le Bas, T.J. Ulrich, Brian E. Anderson, and J. James Esplin

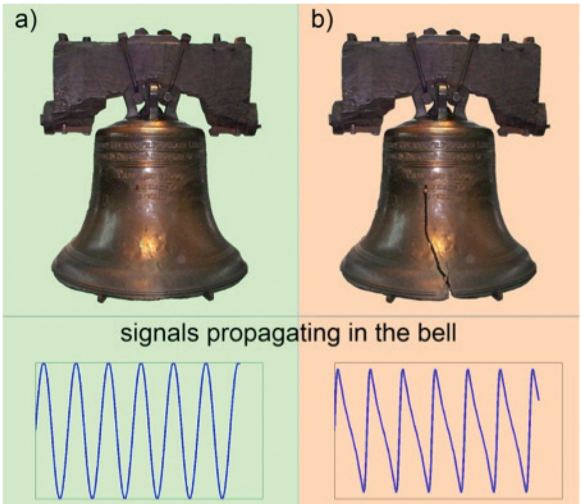

Figure 1: How sound is changed by the presence of defect. On the left an intact bell rings nicely and the wave is regular. On the right, the bell is unpleasant and the wave is distorted.

Non-linear acoustic methods are some of the most sensitive methods for evaluation of the integrity of solid samples. These methods were developed over the last ten years at Los Alamos National Laboratory (LANL (1)) and with other institutes worldwide. In short, those methods rely on the distortion of a sound wave in the presence of damage (cracks or other defects). Intact materials do not distort the wave. It is the characterization of the wave shape changes that is the heart of non-linear methods (see Figure 1).

These techniques will ultimately change how maintenance and quality control are applied in industry and will be a major leap forward in our ability to measure small amounts of damage in a material. If this goal can be reached, early damage can be detected and this will reduce the need to rely on statistics to decide when to replace critical parts. The main issue preventing the spread of these techniques is that they require high amplitude waves for the distortion to be detected (high amplitudes relative to those used in standard methods, but still modest enough to not damage the sample). To reach such amplitudes, sound sources need to be bonded to test samples. Non-contact sound sources exist, but they are too weak. A non-contact source capable of producing high amplitude waves would solve this problem and open up new frontiers for non-linear techniques. We approach a solution here through the use of a method called time reversal (2). Time reversal allows focusing of wave energy in time and space. Our research is based on the concept of applying time reversal to create a high amplitude non-contact sound source. The strength of time reversal is its simplicity (see Figure 2). You just need to record the sound at the point where you want to focus energy (which can be done without contact using a laser), then flip those signals around and broadcast the flipped signals and the wave will focus by itself.

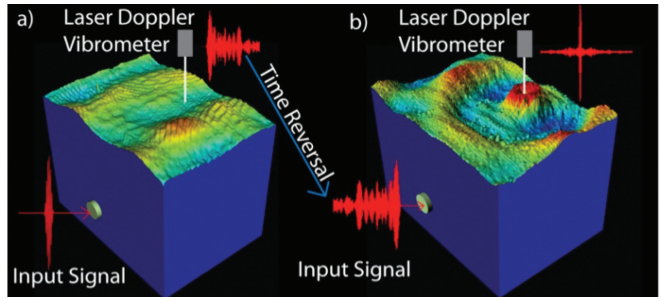

Figure 2: the principle of time reversal: to focus at a given point, just record the signal arriving at that point, flip it in time and send it back.

One of the great things about time reversal is that it works even better when the paths that the sound travels are complex. Our new source takes advantage of this by doing the time reversal process in the air inside a cavity (see Figure 3).

Using such a system, we were able to generate sound waves in a sample by applying time reversal and without physically touching the sample. The results are extremely encouraging, achieving almost 10 times the amplitude of a current air coupled ultrasound transducer, and lead us to believe that the idea can be developed for further non-linear applications. It also has been demonstrated that time reversal can be used to focus any component of the wave vector (3). Using this technique we have successfully demonstrated that this new source can generate in-plane motion via air coupling excitation. LANL is currently working to develop a complete

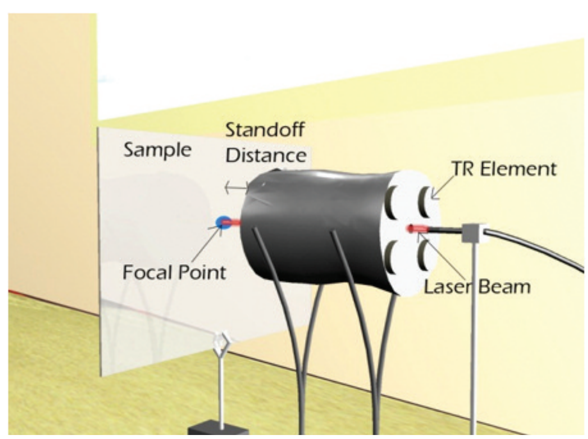

Figure 3: prototype: the time reversal process is done inside a cavity. The signal on the target is measured without contact using a laser.

continued on page 8

Echoes from Hong Kong

continued from page 7

system comprised of hardware and software that will generate the desired signal in a sample at amplitudes much higher (10 – 100 times) than any non-contact transducer currently available (4). Success in development of the time reversal non-contact source will lead to broad application of non-linear acoustics. Of particular interest are applications to objects that cannot be touched or are too small to have transducers attached.

This work is funded by the US Department of Energy via the Los Alamos National Laboratory LDRD program.

References

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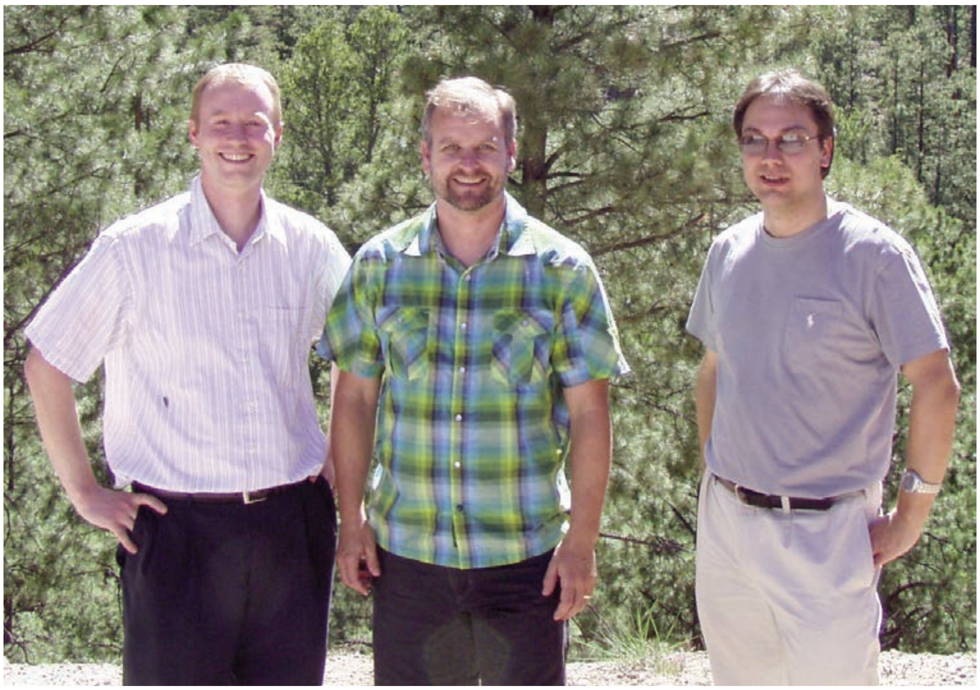
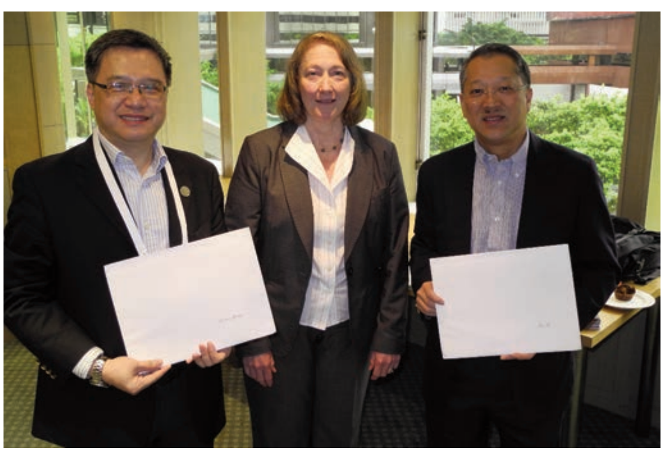
2. Anderson, B. E., *et al.*, *Acoustics Today* **4** (1), 5 (2008)

3. Ulrich, T. J., *et al.*, *Journal of Applied Physics* **106**, 1063 (2009).

4. Ulrich, T. J., Anderson, B. E. and Le Bas, P-Y, *Time Reversal Acoustic Noncontact Source*, 2010.



LeBas, Ulrich, and Anderson are with the Geophysics group at the Los Alamos National Laboratory. Anderson and Esplin are with the Physics Department at Brigham Young University. This article is based on paper 4pEAa3 presented at the 163rd ASA Meeting, Hong Kong



Meeting organizers Maurice Yeung and Tom Ho receive congratulations from Mardi Hastings

Face Change performance at the banquet

Five new Fellows presented at Acoustics 2012 Hong Kong

Five new Fellows were announced at Acoustics 2012 Hong Kong: Joel A. Lewitz, William Shofner, Annemarie Surlykke, Sten Ternström, and Christopher O. Tiemann. Only Ternström was able to attend, so no group photo appears in *ECHOES*. Our heartiest congratulations to our new Fellows!

Scanning the journals

Thomas D. Rossing

• **Whispering gallery waves**, observed in wineglasses as well as in cathedral domes, are the subject of an article in the February issue of *Physics World*. These waves, described by Lord Rayleigh and others, are due to waves being reflected from a curved surface, and thus they can be observed with light waves as well as sound waves. Ultrasonic whispering-gallery-like waves can be used to check pipelines for defects, and for sensing explosive hydrogen gas in chemical plants or in future hydrogen fuel-filling stations. Seismic whispering-gallery waves propagate inside the Earth by bouncing off its concave crust.

• The April issue of *Acoustics Australia* is a special issue on **wind turbine noise**. It includes 7 papers and 7 technical notes on various aspects of the subject and evolved from a conferrence and workshop on Wind Turbines and Low Frequency Noise in 2011. The lead paper includes an engineering analysis of the time and frequency scales from noise sources: leading edge turbulence, trailing edge noise, and blade-tower interaction noise. Other papers are devoted to measuring wind turbine noise emissions at appropriate locations and comparing predicted and measured noise levels. The measurement of infrasound at low levels requires a specific methodology, another paper warns.

Wind turbine noise has been the focus of a number of recent JASA papers and sessions at ASA meetings including the 157th meeting in Portland (see the Summer 2009 issue of *ECHOES*).

• Graphene is a monolayer of carbon atoms with remarkable electrical and mechanical properties. A paper published April 27 in *Physical Review Letters* reports on a new material that is an **acoustical analogue of graphene**. A plate of methyl methacrylate with a honeycomb lattice of cylindrical boreholes, which act like carbon atoms, while acoustic surface waves are the equivalent of electronic waves in graphene. Expressions for the Dirac frequency are given as a function of the radius and the depth of the boreholes. Experimental data from the structure are in reasonably good agreement with the predicted values.

• "Billboard science" is the title of an article on **how to present an effective poster paper** in the March issue of *Nature*. Presenters who follow a few basic rules in poster layout and who talk viewers through their work will draw a crowd. A killer poster will have clean lines, white space, intriguing images and a clear visual flow that supports a well-told story. The worst posters have panel after panel of tiny print. Fifteen simple guidelines for poster presentation are given in the article.

• **"Listening to the 2011 Magnitude 9.0 Tohoku-Oki, Japan, Earthquake"** is the title of a paper in the March/April issue of *Seismological Research Letters*. Researchers have brought the seismic vibrations of last year's magnitude-9.0 tremblor in Japan to life by speeding up the vibrations 100-fold, bringing them into the human range of hearing. Data recorded at a site between the quake's epicenter and Tokyo capture the thundrous blast of the initial tremblor as well as the rumbles of dozens of large aftershocks in the ensuing hour. Also included are a series of high-frequency vibrations resulting from small quakes that the Japanese tremblor triggered along the San Andreas fault in Parkside, California.

• Measurements of the **jet velocity in an organ pipe** driven by a thin jet, using particle image velocimetry, are reported in a paper in the 21 May issue of *Journal of Sound and Vibration*. It is concluded that a jet vortex-layer formation model is more relevant to the sound generation than the vortex-shedding model. The acoustic power is dominantly generated by the flow-acoustic interaction near the edge where the acoustic cross-flow velocity is larger.

• **Photoacoustic tomography (PAT)** can create multicontrast images of living biological structures, according to a review paper in the 23 March issue of *Science*. Light absorption by molecules creates a thermally induced pressure jump that generates ultrasonic waves which are received by acoustic detectors to form images. This technology overcomes the scattering of photons in biological tissue. The spatial resolution is on the order of 1/200th of the desired imaging depth.

• The bottlenose dolphin is one of very few animals that, through vocal learning, **can invent novel acoustic signals and copy whistles** of conspecifics, according to a paper in *Proceedings of the Royal Society B*, published online February 24. Furthermore, the paper explains, receivers can extract identity information from the invented part of whistles. In captivity, dolphins use signature whistles while separated from the rest of their group. In the wild, however, exchanges occur mainly when groups of dolphins meet and join at sea.

• Reduction of interior noise in the passenger compartment of an automobile with an **active electronic windshield** is reported in the 7 May issue of *Journal of Sound and Vibration*. In a test car of medium size, a reduction in sound pressure level up to 15 dB was found.

• The massive Japanese tsunami, which followed the Tohoku-oki earthquake in 2011, was the earliest and **best-detected monster wave ever**, a paper in the February 25 issue of *Science News* reminds us. A series of warning buoys were set up globally after the 2004 Indian Ocean tsunami killed a quarter of a million people. With new findings from the Japanese tsunami, scientists in the United States are working to develop a forecast system that will give people a better warning in areas likely to be flooded, such as the coasts of Washington and Oregon. Further information is available at http://nctr.pmel.noaa.gov/.

• **Neural mechanisms for the coordination of duet singing in wrens** are discussed in a paper in the 4 November issue of *Science*. Plain-tailed wrens cooperate to produce a song in which males and females rapidly alternate singing syllables. The paper describes how sensory information from each wren is used to coordinate the singing. Both sexes coordinate the timing of their singing based on feedback from the partner, but females may lead the duet.

• **Focused ultrasound can be used to expel calculi** (stones) from the kidney, according to a paper in the February issue of *The Journal of Urology*. The ultrasonic element is a 6-cm diameter, 2 MHz, 8-element array excited by synchronized outputs from an rf synthesizer. The acoustic beam is shaped

continued on page 10

Scanning the journals

continued from page 9

as an hourglass with the greatest energy concentration and highest pressure in the narrow focus region only 1 cm long and 1 mm wide.

• The **false killer whale can change its echolocation beam size** according to target distance and difficulty, according to a paper in the April 15 issue of *Journal of Experimental Biology*. To generate echolocation clicks, odontocetes produce short, ultrasonic signals with pneumatically driven pulses generated in the nasal complex and subsequently focused into a directional signal. During echolocation, air travels between two "monkey lips" and causes them to slap together, creating the echolocation pulses Air sacs and a melonlike structure filled with fat focus the emitted beam and match the impedance to sea water

• Acquisition of associative fear memories depends on the recruitment of a **disinhibitory microcircuit in the mouse auditory cortex** according to a paper in the 15 December issue of *Nature*. During the experiments, mice learned to associate a sound with an unpleasant stimulus so that the sound itself became unpleasant for the animal. Under normal conditions, the neurons of the auditory cortex are highly inhibited, but during fear learning a disinhibitory microcircuit in the cortex is activated; for a short time window during the learning process, the release of acetylcholine in the cortex makes it possible to activate this microcucuit and to disinhibit the excitory cells of the cortex. When the animal hears a sound during fear learning, that sound is processed much more intensely than normal, thus facilitating formation of memory.

• By using a highly sensitive single-electron transistor, it is possible to **detect surface acoustic waves at the single phonon level**, according to a paper in the 5 February issue of *Nature Physics*. Transducers were placed at the ends of a long chip of gallium arsenide to generate acoustic waves at a frequency of 932 MHz. A single-electron transistor, a "quantum microphone," was placed near the center. The transistor was able to detect acoustic waves at the single-phonon level. Strong coupling to quantum circuits may enable quantum investigations of phonon-phonon interactions and acoustic coupling to superconducting qubits.

• A paper in *Physical Review Letters* **108**, 104302, (6 March) reports a strong **intederaction between a nanosecond laser beam and a sonoluminescing plasma**. Light energy is absorbed and trapped in a region smaller than the sonoluminescing region for over 100 ns. The experiment suggests that the effects of Coulomb interaction are an important component of the theory of sonoluminescence.

• The **angular momentum and torque exerted by acoustic waves** have been simultaneously measured for the first time, according to a paper in the Aporil 11 issue of *Physics World*. It was found that their ratio agrees exactly with the theory predicted for acoustical and optical waves. The researchers levitated and twisted a rubber puck in water by bombading it with a vortex beam of ultrasound. The techniques are thought to have potential in medical imaging and treatment.

• A review article on **"Automatic Transcription of Recorded Music"** appears in the March/April issue of *Acta Acustica/Acustica*, The objective of automatic transcription is to derive a score-like representation from a given audio representation. It typically proceeds in three stages. 1. Pitch candidates are estimated for each time position; 2. Note onset positions within the music signal are estimated; 3. The information on note onsets and fundamental frequencies is fused to determine notes with the specific parameters. Systems are designed to cope with a wide range of music based on the equal tempered scale. A reasonalby high quality is obtainable for piano music.

• **The effects of self-motion on auditory scene analysis** are discussed in a paper posted online April 9 in the *Proceedings of the National Academy of Science*. Auditory stream analysis requires the listener to parse the incoming stream of acoustic information into perceptual streams in the midst of background noise. Formation of streams is not instantaneous and can be reset by sudden changes in the acoustic scene. Self-motion influences streaming in at least two ways: right after the onset of motion it resets the perceptual organization to one stream; then the organization is biased by the binaural cues discovered through motion.

• How the auditory system manages to extract intelligible speech from a complex background of sound (the **"cocktail party effect"**) is discussed in a letter posted in *Nature online* April 18. Using multi-electrode surface recordings from the cortex of subjects engaged in a listening task with two simultaneous speakers, the researchers demonstrate that population responses in non-primary human auditory cortex encode critical features of attended speech. It is demonstrated that the cortical representation of speech does not merely reflect the external acoustic environment, but instead gives rise to the perceptual aspects relevant for the listener's intended goal.

• **Cortical and thalamic connections of auditory cortex in marmoset monkeys** are discussed in a pair of papers in the May issue of *The Anatomical Record*. The auditory cortex includes three levels of processsing: a primary level, the core region, is surrounded both medially and laterally by a secondary belt region. A third level of processing, the parabelt region, is located lateral to the belt. To study the corticocortical connections of the lateral belt and parabelt, tracers were injected into both rostral and caudal portions of the lateral belt and parabelt. The results indicate that the organization of the marmoset auditory cortex is similar to other primates.

• Minke whales, like dolphins and porpoises, **use lobes of fat connected to their jawbones and ears to pick up sounds**, according to a paper in *The Anatomical Record* published online April 10. The cephalic anatomy of seven minke whales was investigated using computerized tomography and magnetic resonance imaging, verified through dissections. This fat body inserts into the tympanoperiotic complex at the lateral aperture between the tympanic and periotic bones and is in contact with the ossicles. There is also a second, smaller body of fat found within the tympanic bone, which contacts the ossicles as well.

• A **new material for violin strings**, spider silk, is described in a paper in the 13 April issue of *Physical Review*. More than 10,000 strands of so-called "dragline" threads were spun

continued on page 11

Scanning the journals

continued from page 10

together and treated with a gelatin solution, forming a thread that is, weight for weight, stronger than steel.

• Brillouin scattering spectroscopy has been used to **determine the speed of sound** at the high temperature and presure found in the lower mantle of the Earth, according to a research letter in the 3 May issue of *Nature*. Brillouin scattering is the inelastic scattering of light by acoustic phonons. In this case a carbon dioxide laser was used to heat the perovskite material.

• A MEMS **microphone that can be implanted in the middle ear** to help restore hearing is reported in the *IEEE Transactions on Biomedical Engineering* **59** (5). The MEMS accelerometer-based microphone, which has been tested in the ear canals of four cadavers, requires no external electronics. The sensor works by converting bone vibration in the ear to an electrical signal that represents the acoustic information.

• Unique wings allows a certain tree cricket from southern India, called *Oecanthus henryi*, to **sing a special song**, according to a paper published April 30 in the *Proceedings of the National Academy of Sciences*. Most male crickets produce sounds of a single pitch which depend on their size; this enables female crickets to estimate the size of a potential mate. The long, partitioned wings of this tree cricket, however, accommodate different types of bending, which enables the insects to make sounds that range from 2.3 to 3.7 kilohertz. At higher temperatures, the crickets tend to move their wings faster, making higher-frequency sounds.

Acoustics in the News

• "Is Silence Going Extinct?" is the title of a story in the March 18 issue of *The New York Times Magazine*. In Denali National Park in Alaska, for example, a single recording station captured the buzzing of 78 low-altitude props—the kind used for sightseeing tours—in a 24–hour period. Although national parks were created to preserve scenery, only in 2000 did the Park Service director issue systemwide instructions for addressing "soundscape preservation." In 1986, a midair plane crash above the Grand Canyon National Park — where sightseeing tours had operated virtually unchecked for almost 70 years — prompted Congress to pass the National Parks Overflights Act. Porpoises and whales have beached themselves fleeing the high-pitched shrieks of U.S. Navy sonar, researchers believe; they also blame the low-frequency booms ships use to search for oil and gas for fatally ripping through the organs that cephalopods like squid use to detect vibrations.

• Blind athletes are learning to play tennis using a foam ball filled with ball bearings that rattles when it bounces or is struck, according to a story in the June 8 issue of *The New York Times*. For these athletes, their ears become their eyes. The most important adaptation is the ball, which is larger and made of foam, wrapped around a plastic shell that holds the ball bearings. Other adaptations include a smaller court with a badminton net lowered to the ground, string taped along the lines and junior rackets with oversize heads. Players with some sight get two bounces, the completely blind three. Only one set is played, and an umpire calls the lines. Blind tennis is made possible, scientists say, by the adaptability of the human brain — which appears to repurpose its visual area, the occipital cortex, to process sound and touch in response to blindness.

• The hyrax is a small nocturnal mammal that is related to elephants and aadvarks, but male rock hyraxes have complex songs not unlike those of birds, according to a story in the April 19 issue of *The New York Times*. Bird songs show syntax in ordering of song components in different ways, but very few mammals make such orderly, arranged sounds. The five kinds of sounds hyraxes make can be described as " 'wail,' 'chuck,' 'snort,' 'squeak' and 'tweet.' " The songs probably don't carry any information in their arrangement of sounds, although the males may make them longer and more complicated to attract females, showing off their songs the way other animals might show off elaborate plumage or large antlers.

• A team that included a radiologist and violinmakers used a computed tomography (CT) scan to the Betts Stradivarius violin profile belonging to the Library of Congress, and used the data to construct a copy according to a story in the 9 December issue of *Science*. A computer-controlled router was used to carve the plates for four replica instruments. Professional violinists who played the instruments praised their tones.

• Thanks to help from a humanoid robot, scientists have learned a little more about how we solve the "cocktail party" probem, according to a story posted online on *Science Now* April 9. In one room, a human volunteer listening to a two-tone sound turned while a robot with microphones in its ears in another room turned its head in synchrony. Rapid head motion was found to reset the cocktail party effect.

• Birds navigate thousand s of miles, flying day and night even when the stars are obscured. How they do this is a mystery, but a story in the April 27 issue of *The New York Times* suggests that the inner ear may be involved in determining the strength and direction of the Earth's magnetic field as the birds fly. Recent research supports the idea that as yet undiscovered magnetoreceptive cells reside in a pigeon's inner ear.

• The President's Council of Advisors on Science and Technology (PCAST) released a publication *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*. Among the five recommendations offered: "catalyze widespread adoption of empirically validated teaching practices; launch a national experiment in postsecondary mathematics education to address the math preparation gap; and create a Presidential Council on STEM education with leadership from the academic and business communities to provide strategic leadership for transformative

continued on page 12

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Acoustics in the News

continued from page 11

and sustainable change in STEM undergraduate education."

- A study by the National Institutes of Health (NIH) highlights the growing number of research grants to older scientists, according to a note in the 24 February issue of *Science*. Whereas in 1980, almost 18% of principal investigators holding NIH's basic research (RO1) grants were 36 and younger and less than 1% were 66 and older, by 2012 those 66 and older made up almost 7% of grantees and the youngsters were at only 3%.

- Japan and the United States both face a similar problem: loss of manufacturing leadership, according to a story in the April 16 issue of *The New York Times*. The number of manufacturing companies in Japan dropped by a third, to 540,000, in the 10 years up to 2006. The share of manufacturing in Japan's overall economy has also shrunk to 18 percent. While the United States is still the world's largest manufacturing country, such industry now acounts for just 9 percent of its overall economy.