ECHOES

THE OPTICAL MICROPHONE

Jürgen Peissig
Sennheiser Electronics GmbH & Co. KG
Germany

A new acoustical transducer principle offers solutions for special measurement applications. The most established microphone principles—the dynamic microphone and the condenser microphone—yield very good audio performance in a variety of applications from rugged stage operation to high fidelity audio recording in the studio. Yet there are some situations where these electro-acoustic transducer principles lack in audio performance.

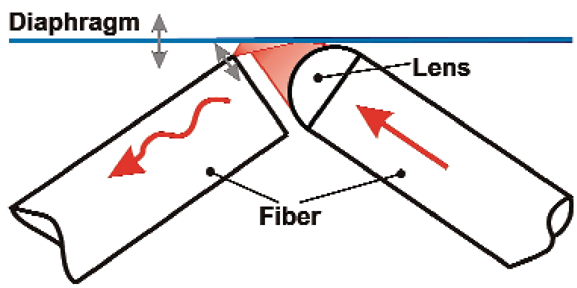

Fig. 1. Schematic construction principle of the optical microphone with lenses on the fibers. A constant intensity low noise light source emits light to the back of the microphone diaphragm via the transmitting fiber. The excursion of the microphone diaphragm then yields to a modulation of the light intensity in the receiving fiber (left).

Optical transducer principles offer some specialties compared to other principles. The conversion of the acoustical signal is completed in two steps. First the sound is picked up by a membrane which transforms a constant source of light into an intensity-modulated light signal. The intensity modulation is proportional to the excursion of the membrane. In a photo detector such as a PIN diode (P-region, Intrinsic region, N-region) the light signal is then transformed into an electrical signal.

Advantages compared to other microphones—The microphone head can be placed distant to the light source and the photo detector. More than 300 feet of fiber-optical cable can be placed between those components without degrading the quality of the audio signal.

The optical microphone is completely insensitive to electrical and magnetic stray pick-up and thus gives the guarantee to measure only the acoustical signal at the position of the microphone head even in the presence of very strong electrical or magnetic disturbance (RF or static fields).

The optical microphone does not need electrical wiring to the microphone head. This eliminates possible interference with electromagnetic compatability (EMC) regulations and allows the use of the microphone in hazardous locations (UL/HazLoc) where explosive gases or dust are present.

The optical microphone: Construction principle—Figure 1 shows the schematic set-up of the optical principle with lenses on the optical fibers. A transmitting fiber brings low noise, high intensity infrared light from an LED (light emitting diode) to a diaphragm. This light is focused onto the moving membrane (diaphragm) and reflected to the receiving fiber. The focus of the lens is adjusted so that the focal point is positioned exactly on the edge of the receiving fiber when the membrane shows no excursion. The focal point covers the opening of the receiving fiber exactly by half. When diaphragm excursion takes place, the focal point moves either onto the opening of the fiber (higher light transmission coefficient) or away from it (lower light transmission coefficient). This results in intensity modulation of the infrared light in the receiving fiber and at the photo PIN diode.

The practical realization of the optical microphone head shows several difficulties:

For good audio quality the position and the tilt of the transmitting fiber and the receiving fiber relative to each other and to the membrane may not show tolerances larger than 1-5µm and about 0.5-3° from the optimum positions. The fiber itself has a diameter of 200-230µm and the distance from the diaphragm to the lens is approximately 50µm. The lens radius curvature may not

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We hear that...

• ASA Fellow **Sheila Blumstein** has been named to Fellowship in the American Association for the Advancement of Science (AAAS) for her contributions to our understanding of the relationships between language and the brain. She is the Albert D. Mead Professor of Cognitive and Linguistic Sciences at Brown University. She has used functional magnetic resonance imaging to better understand the brain.

• ASA awarded $1000 to **Pen-Yuan Hsing** and **Wei-Kang Huang**, Taipei Municipal Lishan Senior High School for their project on “Enhanced Cooling of Microelectronic Devices by Using the Thermoacoustic Effect” entered in the 2005 Intel International Science and Engineering Fair. Honorable Mention awards went to **Courtney Anne Rafes**, Northwest High School, Justin, Texas for a project on “An Ear to the Track: An Ultrasonic Train Wreck Avoidance System”; and to **Jhe-Rong Wu**, Taipei Municipal Chien-Kuo Senior High School, Tapei City, Taiwan for a project on “Phylogenetic Analysis of Crickets by Acoustic Behavior and Mitochondrial DNA Sequencing.” Each winner received a one-year ASA membership. Hsing and Huang also won expense-paid trips to attend the European Union Contest for Young Scientists in Russia.

In the Physics category in the same competition, the Intel Foundation presented a $1000 award to **Emily Rae Drabek**, Eastern High School, Pekin, Indiana for her project on “A Vibroacoustical Study Comparing the Out-of-Plane Motion of Violin Bridges Under Different Boundary Conditions Using Holographic Interferometry.”

• **Patricia Kuhl**, Professor of Speech, University of Washington, has been elected Chair-Elect of the AAAS section on Linguistics and Language Science. Pat is a past president of ASA, an ASA Fellow, and a recipient of the Silver Medal in Speech Communication.

Letter from the editor

Again, the editor did not receive any Letters to the Editor. Thus, the space will be taken by a **Letter from the editor**.

We would like to include brief letters from our readers in every issue. ASA members are apparently a notably happy group and have few complaints. However, we know that they are also a thinking group and have thoughts about acoustics or related issues. We encourage you to share them with other readers.

In this issue we have added something new: Good books I have read. Although JASA already includes full-fledged book reviews and *Acoustics Today* reports on new publications, one of our readers suggested that we encourage mini-reviews of books, old or new, by readers. Joe Curtin has written such a commentary on an autobiography by a well-known ASA member, Gabi Weinreich.

If you like the idea, please send us your brief comments on old or new books in acoustics or related fields.

Best student paper awards (Minneapolis)

Animal Bioacoustics
Alison K. Stimpert, Hawaii Institute of Marine Biology

Acoustical Oceanography
First: Michael G. Morley, Univ. of Victoria, Canada
Second: Julie N. Oswald, Scripps Inst. of Oceanography, Univ. of California—San Diego

Architectural Acoustics
First: David T. Bradley, Univ. of Nebraska—Lincoln
Second: Erica E. Bowden, Univ. of Nebraska—Lincoln

Engineering Acoustics
First: Miguel A. Horta, Pennsylvania State Univ.
Second: Stephen B. Horowitz, Univ. of Florida

Musical Acoustics
First: Harald Jers, Cologne, Germany
Second: Jyri Pakarinen, Helsinki Univ. of Technology

Speech Communication
First: Tarun Pruthi, Univ. of Maryland
Second: Byron D. Erath, Purdue Univ.

Structural Acoustics and Vibration
First: Noah H. Schiller, Virginia Polytechnic Inst.
Second: Benjamin J. Doty, Jet Propulsion Lab.

Underwater Acoustics
First: Weichang Li, Massachusetts Inst. of Technology and Woods Hole Oceanographic Inst.
Second: Jason D. Holmes, Boston Univ.

Young Presenter Awards in Noise
Courtney McGinnes, Rensselaer Polytechnic Inst.
Steve Ryherd, Univ. of Nebraska—Lincoln

Young Presenter Award in Signal Processing in Acoustics
Siddhartha Sikdar, Univ. of Washington

ECHOES

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The Optical Microphone

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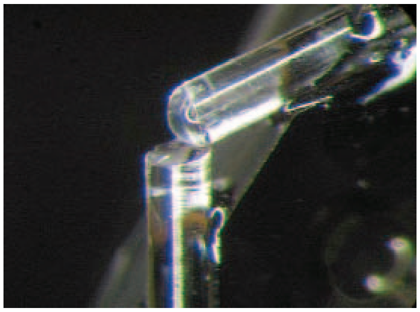

Fig. 2. Transmitting optical fiber with lens (top) and receiving fiber without lens (bottom) fixed in the carrier frame (right). For better visibility the diaphragm was not mounted yet.

Fig. 3. Pre-production sample of the optical microphone. The diameter of the microphone is 1/2 inch.

Fig. 5. Application of the optical microphone in the high-Tesla area of an MRI scanner for patient communication purposes.

tolerate distances larger than 5µm.

To yield these tolerances in a series production process the lenses are MEMS (micro-electro-mechanical-systems) manufactured and the fiber is placed in a micro-machined carrier frame which itself sits in a plastic housing holding the membrane and the strain relief. Figure 2 shows the actual fiber glued onto the carrier frame. The membrane is placed on a membrane ring and is adjusted to the housing in a calibration process. This production process yields optimal performance of each individual microphone and is capable of compensating for other tolerances in the microphone head.

The transmission coefficient K changes with diaphragm excursion (distance to the fibers). It rises quite linearly toward a peak at a lens to fiber distance of 50 µm, and then decreases quite linearly. The microphone can operate either on the increasing (membrane is closer to the lens) or on the decreasing slope (membrane is further way from the lens) of the curve. The practical excursion of the membrane is only in the range of 500-1000 nm, thus yielding a good linear audio performance when the favorable working point is on the middle of the steepest slope.

Figure 3 shows a pre-production sample of the optical microphone. The microphone has a diameter of 1/2 inch to be compatible with standard microphone measurement equipment. The frequency response of the microphone is shown in Fig. 4.

Applications—Since the optical microphone contains no metal and no current or charges are flowing, it can be beneficial in the following situations:

- Operation under strong magnetic or electric or RF fields. The optical microphone guarantees, that the audio signal is absolutely free from any disturbances that might be caused by those fields.
- Operation in hazardous locations. The optical microphone cannot generate ignition of explosive atmospheres or dust since it uses no electrical wires.
- Undetectable operation. Since the optical microphone does not contain metal, it cannot be detected by metal detectors.
- Operation in high humidity.

As an example, Fig. 5 shows an application of the optical microphone in an MRI scanner for patient communication. The optical microphone does not disturb the imaging process since it contains no significant metal parts. The audio signal of the microphone is completely free from stray pick-up of the rapidly changing strong magnetic field components in the core zone of the MRI.

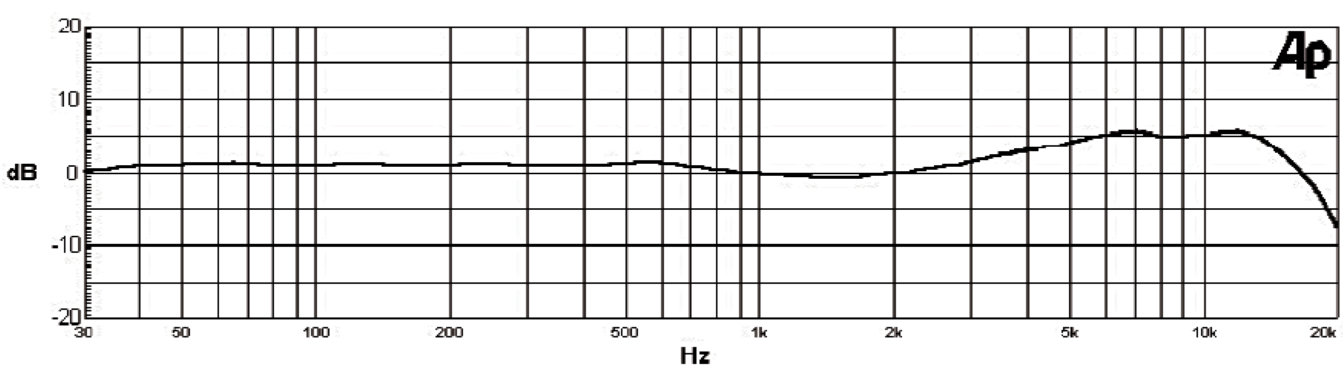

Fig. 4. Relative frequency response of the optical microphone.

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The Optical Microphone

Jürgen Peissig is project manager for research projects at Sennheiser Electronics. He is responsible for Sennheiser research activities in Germany and in the new Sennheiser Research Laboratory in Palo Alto, California. He received a Ph.D. in physics from the University of Göttingen in the fields of electroacoustics, psychoacoustics, and digital audio signal processing. After working at the Universities of Göttingen and Oldenburg and a stay at Bell Labs, he joined Sennheiser in 1995. He also teaches electroacoustics at the University of Hanover.

ASA returns to Providence

The Acoustical Society of America has held three meetings in Providence (chaired by Bruce Lindsay, Bob Beyer, and Stan Ehrlich) and the last one was in 1978. This interesting New England seaport has much to offer the visitor. And as always, ASA meetings have much to offer attendees.

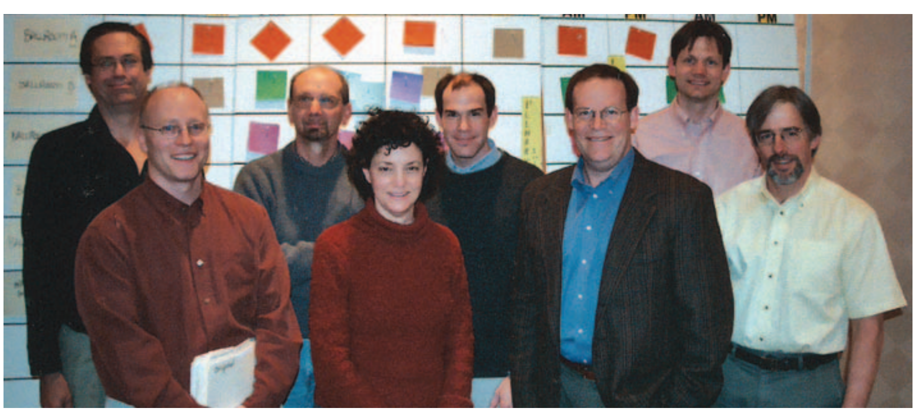
The city, second largest in New England, was founded by Roger Williams, a New England preacher who was driven out of Massachusetts by the strict Puritans and named in honor of "God's merciful Providence."

The meeting will use the facilities of the Rhode Island Convention Center and the Westin Providence Hotel. The technical program includes 1046 papers organized into 104 sessions. Exhibits of acoustical instruments, materials, and services will be conveniently located in the Convention Center. A Distinguished Lecture will be presented by Nikolai Andreevich Dubrovskiy, Director of the N. N. Andreyev Acoustics Institute, Russian Academy of Science and President of the Russian Acoustical Society. A tutorial lecture "2004 Sumatra Earthquake and Tsunami: Multidisciplinary Lessons from an Oceanic Monster" we be given by Emile A. Okal of Northwestern University on Monday, June 5 at 7:00 p.m.

Other features of the meeting include a "Hot Topics" session, featuring the fields of Acoustical Oceanography, Education in Acoustics, and Underwater Acoustics, a Student Design Competition, a Gallery of Acoustics, and a Grant Writing Workshop. A short course on Underwater Acoustic Communications, with Pierre-Philippe Beaujean as the instructor will take place Sunday and Monday, June 4-5. Technical tours include a tour of the acoustic test facilities at the Naval Undersea Warfare Center in Newport, RI on Monday.

The movie, *Touch The Sound*, featuring Evelyn Glennie will be shown on Wednesday, 7 June from 7:30 p.m. to 9:15 p.m., at the Providence Place Cinemas 16 (entertainment level), Providence Place Mall. Members of the ASA are invited to this special showing without charge but you must pick up a voucher at the ASA Registration desk for admission to the theater. Some members of ASA heard Ms. Glennie in concert at the ASA Vancouver meeting. For Evelyn, who is deaf, sound is palpable and rhythm is the basis of everything. The film follows her remarkable story from her native Scotland through California, New York, and England.

Rhode Island, the "Ocean State," is easily our smallest state in area, so that legendary mansions, scenic beaches, and interesting historical sites are within minutes of Providence. Newport has summer homes of some of the world's wealthiest families, as well as being the home of the Newport Jazz Festival and America's Cup yacht racing. The International Tennis Hall of Fame is located here. Mansions include the Breakers (home of Cornelius Vanderbilt), the Elms, Marble House, Rosecliff, and many others.



Members of the Technical Program Organizing Committee for the Providence meeting.

Acoustics in the seventies

Thomas D. Rossing

As I write this, I am packing to move to Stanford, and by the time you read it, I will be a Californian. Although packing up an office is a chore, it is also sort of fun to go through 35 years of papers and mementos.

I just came across the little booklets that the American Institute of Physics used to distribute annually to the media: "Physics in 1970," etc. The sub-fields of physics were listed alphabetically, and so Acoustics came first.

Big news in 1970 was the use of light to amplify sound waves. Edward Cassedy and Martin Piltch flashed the light from a ruby laser into a birefringent quartz crystal and amplified an ultrasonic pulse about ten times. The amplification is similar to an effect known as stimulated Brillouin scattering. Another bit of news was that Robert Beyer and Joie Jones showed that two beams of sound interact only when they are collinear, thus substantiating the theory of Peter Westervelt.

In 1971 William Rhode and Brian Johnstone independently used the Mössbauer effect (gamma-ray resonance spectroscopy) to observe the motion of the inner ear and showed that the motion of the basilar membrane is not linear. Elsewhere researchers used liquid-surface ultrasonic holography to produce acoustic holograms of living as well as preserved specimens.

Two top stories in 1972 dealt with aids for the hearing impaired. Researchers at the Callier Hearing and Speech Center in Dallas have experimented with a system that replaces the headphone of a hearing aid with a coil of wire and a permanent magnet glued to the eardrum. Magnetically coupled hearing aids permit placement of the entire device at ear level without danger of acoustic feedback and preserve sound localization ability. The other newsworthy device was the artificial cochlea developed by Martin Sonn, Wolfgang Feiset and Geza Jako. A 35-millimeter-long array of 37 electrodes is implanted in the cochlea to set up electric fields in close proximity to viable nerve fibers along the basilar membrane.

Acoustics does not appear in the 1973 booklet, but in the 1974 edition, infrasound and scattering of sound on sound are discussed. Westervelt showed that it is possible to use nonlinear sound interactions to produce the absorption of sound by sound and the displacement of a liquid-gas surface under the influence of acoustic radiation pressure, surface tension, and gravity. One application of this is the attenuation of sound in superfluid helium.

Applications of acoustic holography in the medical field were big news in 1975. Single-frequency ultrasonic waves transmitted through the body can be made to interact, at a liquid surface, with a holographic reference wave. Laser light reflected off the rippled surface reconstructs the transmitted image. Certain tumors are more readily detected by ultrasonic holography than with x-rays. Also in 1975, Floyd Dunn and John Brady showed how the ultrasonic absorption coefficient increases with increasing temperature, and Thomas Muir and Charles Culbertson showed that modulated neodymium glass lasers fired into a freshwater lake generated highly directive pure-tone sounds.

In 1976 terahertz phonons were generated by two different methods: using super-conducting film tunnel junctions; and applying short infrared laser pulses to a piezoelectric crystal. The latter method produced phonons with frequencies up to 2.5 THz. These match some of the lower frequency properties of crystal lattices. Also in 1976, Ochs, Snowdon, and Kerlin studied the effect of ribs on the vibration modes and the transmissibility of flat plates.

In 1978 Philip Marston extended Robert Apfel's methods for acoustically levitating liquid drops to observe shape oscillations in drops. Modulating the acoustic waves at a frequency near the natural frequency of quadrupole shape oscillations (typically a few hundred hertz) significantly enhances the amplitude of oscillation. Drop oscillations were observed by using "rainbow interferometry" which makes use of light reflected and refracted by the drops. Also in 1978 Lawrence Sulak and colleagues detected sound generated thermally by proton pulses in water. Such thermooptic techniques are useful for detecting muons and neutrinos deep under water.

Members of the Technical Program Organizing Committee for the Providence meeting.

Recollections of Paul Sabine and the Harvard Underwater Sound Lab.

Laymon Miller

I worked with Paul Sabine, ASA President 1935-37, quite extensively more than 60 years ago! I was 23 and he was 63 when we first met. We were brought together by Ted Hunt's Underwater Sound Lab at Harvard University (HUSL). I had already been there about eight months when Paul arrived in June 1942 from the Riverbank Acoustical Laboratory in Geneva, Illinois. We were surrounded by much younger people in those days, and we considered anyone over 40 "old age." So, by our definition, Paul Sabine fell into that "old age" category. But, he was spry and witty, and he certainly didn't deserve that description. In fact, his grasp of our problems and his technical know-how soon convinced us that we were very wrong in our first judgments of him based on age alone.

Our World War II objective was to devise an acoustic homing torpedo for US Navy pilots: to be air-dropped and to search for an enemy submarine known or suspected to be in the area. The project was given jointly to our Harvard Lab and to Bell Labs, and we were directed to work together cooperatively but competitively, which we did. The program was very successful but we will not go into any operational details here.

One significant requirement of that program was to research and design transducers that would be carried by the torpedo and which, hopefully, could "hear" the sounds made by the enemy target and steer in on those sounds. We were all novices and had little to go on. Fairly early in our work, we realized that we needed a facility for measuring the characteristics of any transducers that we might attempt to build. "Hydrophones" (like underwater microphones) were the transducers used for "listening only," and "Projectors" were transducers that could both transmit sound and receive sound (such as sending and receiving the popular "ping" of the ship-borne or submarine-borne sonar system). That need for a measurement facility ultimately led to the building of a "Calibration Station" on a barge floating in the Charles River and to the acquisition of a "Fur-lined Tank" for indoor use. The Calibration Station was fitted with all the necessary equipment to measure the frequency response and the directivity patterns of our transducers in a relatively "free field" (free of strong reflections and interferences that would alter the data). Due to our heavy work load, we eventually had to build and instrument a second calibration station on Spy Pond in North Cambridge, alongside Route 2. Yet, we needed simpler and faster routines for measuring some of the other important characteristics of our transducers.

Hence, the "fur-lined tank" became a necessity. No, it really wasn't fur-lined. That was just the popular term that we used to describe its function. Its exterior was a steel tank about 5 ft x 8 ft in floor area and about 5 ft tall, with some hoisting gear at the top to lower and raise transducers inside. There was a large rubber tank inside the metal tank, and the space between the rubber and steel walls was filled with viscous castor oil. The wall of the rubber tank was 2 in. thick, and it was made of "ρc (rho c)" rubber, which was a special formulation that very nearly matched the acoustic characteristics of water: the Greek letter ρ is the density of the rubber and c is the velocity of sound in the rubber. The product of ρc for the rubber lining very nearly equaled that of water. Because of its good sound absorbing characteristic, castor oil was used to fill the space (about 8 to 12 inches wide) between the metal tank and the Úc rubber tank. The chamber inside the rubber tank was then filled with ordinary water. The significant feature of this tank was that it provided a water load (somewhat approximating a water "free-field") to a transducer; the rubber and castor oil allowed sound to pass through these materials and to be dissipated without any noticeable reflection of sound back into the test chamber where it might influence the test results. Essentially, it was an anechoic chamber for testing in water. However, it was not large enough nor reliable enough to allow directivity measurements of a transducer. It served adequately for measuring the frequency response of a transducer and determining its efficiency of operation, as we were experimenting with various transducer designs.

So, it was into this situation that Paul Sabine was placed in June 1942. With his known background at the Riverbank Acoustical Laboratories and acknowledged expertise in calibration work, it was an obvious decision to have him in charge of that tank and all the measurements that would be made using it. He came to be known as our "King of the Tank." The tank was located where it could be equally accessible for both the torpedo and the sonar groups. From time to time, Paul had Bob Payne, Jim Faran, John King, Johnny Reitz, Ellen Gallishaw, and Mrs. Margaret Mason as his helpers at the tank. Paul Kendig, Rensler McDowell, and I made occasional measurements there, too. When desired, confirming tests could be made at our calibration stations on the Charles River or on Spy Pond to check on sensitivity and directivity in a more nearly "free field." Some very effective (and novel) transducers had their earliest tests in the tank.

Paul Sabine's first wife, Mabel, mother of Hale Sabine, died in 1929 and Paul married Cornelia in 1938. Paul and Cornelia became good friends of my wife Lucy and me outside of lab work. Paul was so modest he never told us of his very thorough background in acoustics nor of his deep involvement with the Riverbank Acoustical Laboratories in Geneva, Illinois. Of course, we knew of Wallace Clement Sabine by reputation, but Paul did not stress his relationship with Wallace. About the only thing that Paul ever said about himself was that he had been the Acoustical Consultant for Radio City Music Hall in New York City. I do not remember that he ever mentioned that he had been the President of the Acoustical Society only a

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Good books I have read

Confessions of a Jewish Priest by Gabriel Weinreich

(The Pilgrim Press, 2005, ISBN 0-8298-1695-X)

Joseph Curtin

Though readers of *ECHOES* probably know Gabriel Weinreich best for his contributions to musical acoustics, in this beautifully written memoir he chronicles none of his scientific achievements, focusing instead on his other career–for many years he was both a fulltime physicist and the pastor of an Episcopalian church. Born in Vilna, then part of Poland and a major center of Jewish intellectual life, Weinreich was the son of an eminent linguist and scholar, and his childhood was steeped in secular Jewish culture. By the time he was twelve, however, he and his mother were fleeing the Nazis by train across Russia; they eventually rejoined his father and brother in New York.

Along with science, Weinreich's enthusiasms included musical composition, and for some years he took lessons with a former pupil of Rimski-Korsakov. After finishing his doctorate in physics at Columbia, he worked for seven years at Bell Labs and then joined the faculty of the University of Michigan. The intellectual, emotional, and spiritual journey that changed him from a Jewish atheist into, well, a Jewish priest is the central narrative of this book.

Though "Confessions" is rich in events, memories, and anecdotes, they are summoned mainly in service of reflections on a wide range of topics. Chapter titles include Ordination, Anti-Semitism, Language, Self-discipline, Religion, Morality, Music, and Faith. In "Science," he compares mathematics to a game of solitaire, while "physics is a game played against Nature as your opponent. You make a move, then Nature makes a move. Thus the physicist is always trying to outwit an opponent who is infinitely more clever, a task that would be hopeless were it not for one thing: *Nature does not cheat*…." And neither, he argues, does God.

In a particularly moving chapter entitled "Crucifixion," he revisits a heartbreaking encounter with his first wife. Having abandoned Weinreich and their two children a year earlier, she has narrowly survived a suicide attempt–and will not survive her next one. The chapter is a meditation on human anguish, and how the Crucifixion offers a saving perspective on suffering that might otherwise prove unbearable.

"Resurrection" deals with Christ's return from the dead, and with Weinreich's own near brush with mortality. Just before Easter, 2002, an MRI scan of his brain showed a tumor "the size of a tangerine." He recounts that in the weeks prior to surgery, "I had ample time for nightmares in which I was having my head cut open while totally powerless to resist." The descent under anesthesia was "the closest experience to sudden death that I can imagine." Though mostly recovered now, "I can never again climb a ladder, walk very fast, or preach formal sermons without a script in front of me…Yet at the same time my vision of the universe has become sharper and its colors more resonant; the people around me have become more interesting, more beautiful, more challenging to understand; and the simple hope that the sun will rise again tomorrow, far from being a triviality, has become an assurance of faith, of hope, and of love."

This is a beautiful, valuable book—one that can and should be read more than once.

Joseph Curtin, a violinmaker in Ann Arbor, Michigan, recently received a MacArthur Foundation award. He participated in the Workshop on String Instruments at the ASA meeting in Vancouver and wrote a report on "What's New in Violins" in the Fall 2005 issue of ECHOES.

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few years earlier (and some of us were such newcomers to acoustics that we did not know it either). We did know that Paul was a warm, friendly, knowledgeable and wonderfully stabilizing force for all our younger men and women at HUSL.

At the end of the war, Paul and Cornelia returned to Riverbank. Some of the advances made in underwater sound measurements and methodology can be attributed to Paul's painstaking details and influence. John Kopec's book *The Sabines at Riverbank* can provide a much more thorough description of Paul's life-time contributions to acoustics. His work in underwater sound was only a tiny part of it all. We were indeed blessed to have him with us.

Laymon Miller has had a long and varied career in acoustics at the Texas College of Mines (now UTEP), University of Texas, Harvard Underwater Sound Lab, Penn State Ordnance Research Lab (now Applied Research Laboratory), and Bolt Beranek & Newman.

Scanning the Journals

Thomas D. Rossing

• Physicist **Seth Putterman**, well known to ASA members, is the subject of a biographical feature in the 27 October issue of *Nature*. "Ignoring the mainstream of physics," says the article, "Seth Putterman has a knack for bringing long-forgotten mysteries back to the fore." A case in point is sonoluminescence, light generated by sound, which was known as long as 60 years ago but has recently become a "hot topic" in physics (see *ECHOES* Winter 1993, Spring 1997, Fall 1997, Winter 1998, Spring 2002, and Summer 2003, for example). Putterman firmly believes that the flash seen at the center of the bubble is created by electrons being shaken out of their atomic orbits, whereas others suspect more conventional chemistry is the culprit.

• Micromachined fluid-filled variable impedance waveguides intended to mimic the mechanics of the passive **mammalian cochlea** have been fabricated, according to a paper in the January 21 issue of *Proceedings of the National Academy of Sciences*. Experimental tests demonstrate acoustically excited traveling fluid-structure waves with phase accumulations between 1.5 and 3 π radians at the location of maximum response. The achieved orthotropy ratio of 8:1 in tension is insufficient to produce the sharp filtering observed in animal experiments and many computational models that use higher ratios. A mathematical model incorporating a thin-layer viscous, compressible fluid coupled to an orthotropic membrane model is validated.

• Bright and responsive "ultralight" **violins** may be the instruments of the future, according to an article in the 2 December issue of *Science*. The article reports mainly on the 33rd annual convention of the Violin Society of America held in King of Prussia, PA in November. Joseph Curtin, an Ann Arbor violin maker who recently won a MacArthur Foundation Fellowship (see Winter 2006 issue of *ECHOES*), is one of the makers featured in the article. Curtin was a presenter at the special session and workshop on Design and Construction of String Instruments at the ASA meeting in Vancouver (see Fall 2005 issue of *ECHOES*). Balsa wood and carbon-fiber composites are materials that have been used for experimental ultralight violins. Although few people will agree with Fan-Chia Tao that "Within a generation, the wood violin will be as obsolete as the wooden tennis racket or the wooden golf club," makers such as Curtin feel that some things in the traditional violin design can be improved. ASA members Carleen Hutchins, Gabriel Weinreich, and Norman Pickering are quoted in the article.

• Crowded footbridges can exhibit **lateral synchronous excitation**, according to an article in the 3 November issue of *Nature*. This is not unlike the collective synchronization of biological oscillators such as neurons and fireflies. One example was observed on London's Millennium Bridge on opening day, when it began to sway from side to side. Pedestrians fell spontaneously into step with the bridge's vibrations, inadvertently amplifying them. Generalizing the ideas developed in mathematical biology can provide a unified picture of what happened on the Millennium bridge five years ago, both for the bridge vibrations and the crowd dynamics.

• Physicists in France have developed a new form of "touch-screen" technology that relies on detecting sound waves and **locating their source by time reversal**, according to a paper in the 14 November issue of *Applied Physics Letters*. Time reversal in acoustics (see Winter 2002 issue of *ECHOES*) is an efficient way to focus sound back to its source in a wide range of materials including reverberating media. A wave still has the memory of its source location. The technique has been demonstrated in a glass plate 400x300x5 mm. Tapping the plate at various positions and detecting the resulting sound waves with a simple sensor connected to a personal computer transforms the plate into an interactive surface. The number of possible touch locations is shown to be directly related to the mean wavelength of the detected acoustic wave.

• Congenital deafness results in abnormal synaptic structure in auditory nerve endings. If these abnormalities persist after restoration of auditory nerve activity by a **cochlear implant**, the processing of speech signals would likely be impaired. A research report in the 2 December issue of *Science* describes experiments in which deaf cats were stimulated for 3 months with a six-channel cochlear implant. Auditory nerve fibers exhibited a recovery of normal synaptic structure in these cats. This rescue of synapses is attributed to a return of spike activity in the auditory nerve and may help explain cochlear implant benefits in childhood deafness.

• **"Singing icebergs"** is the subject of an article in the 25 November issue of *Science*. Seismic tremors were recorded near the continental margin of Dronning Maud Land, Antarctica whose spectra consisted of narrow peaks with a fundamental frequency around 0.5 Hz and more than 30 harmonic overtones. The spectral peaks varied slightly with time (frequency gliding), and amplitude was inversely proportional to frequency. The tremor signals change from harmonic to non-harmonic and vice versa. It is proposed that the iceberg tremor signals represent elastic vibrations of the iceberg produced by the flow of water through tunnels and crevasses.

• People regularly exposed to loud noise over several years are more likely to develop a benign tumor called an **acoustic neuroma** that causes hearing loss according to a paper in the February 15 issue of the *American Journal of Epidemiology*. People exposed to loud music were most likely to develop acoustic neuroma, while those exposed to machines, power tools and construction were slightly less likely, according to a study at Ohio State University.

• It should be possible to produce coherent light with frequencies of 20 THz or more by subjecting crystals to **shock waves**, according to a paper in the 13 January issue of *Physical Review Letters*. Emission peaks would have fre-

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Scanning the Journals

quencies that are up to 2 times higher than phonon frequencies. Observation of these peaks requires that there be spectral components of atom velocities at these higher frequencies around the shock front, which requires that the shock front be very sharp.

• **Phononic crystals** are the subject of a feature review in the December issue of *Physics World*, Phononic crystals are novel materials that offer exceptional control over sound and other mechanical waves. The writers characterize them as "a revolution in acoustics." When a wave passes through a phononic crystal, interference leads to the formation of "band gaps" that prevent waves with certain frequencies from traveling through the structure. The periodic variation in the density and/or speed of sound that is needed to make a phononic crystal can be achieved by making air holes in an otherwise solid structure. This leads to the phenomenon of "negative refraction" which can be exploited to make super lenses that can beat the diffraction limit. Controlling the dispersion relation for phonons both inside and outside the band gap could lead to breakthroughs in both fundamental research and applications.

• Sound waves in a fluid behave much like light waves in space. **Black holes** even have acoustic counterparts, according to an article in the December issue of *Scientific American*. Like spacetime, condensed matter looks like a continuum when viewed at large scales, but unlike spacetime it has a well-understood microscopic structure governed by quantum mechanics. Moreover, the propagation of sound in an uneven fluid flow is closely analogous to the propagation of light in a curved spacetime. By studying a model of a black hole using sound waves, physicists are attempting to gain insight into the possible microscopic workings of spacetime. Spacetime, like a material fluid, may be granular and possess a preferred frame of reference that manifests itself on fine scales, contrary to Einstein's assumptions.

• Researchers have linked the hormone aldosterone to the quality of **hearing as we age**, according to a paper in the November issue of *Hearing Research*. The more of the hormone that older people have in their bloodstream, the better their hearing is. The hormone is known to also regulate kidney function and plays a role in controlling levels of two crucial chemicals in the nervous system, potassium and sodium. For nerves to send signals crisply and work properly, these two chemicals must be in precise proportion. Levels of potassium are particularly crucial in the inner ear. Of particular interest to ASA members is the fact that two of the authors of the paper are the father and son team D. Robert Frisina and Robert D. Frisina who are both members of the ASA.

• A new report on **bubble fusion** appears in the 21 January issue of *New Scientist*. Rusi Taleyarkhan and his colleagues at Purdue University report on new experiments in which the external neutron beam has been eliminated and bubbles are induced in dissolved uranyl nitrate by alpha particles from the radioactive decay of uranium. The researchers got the same results with deuterated water, acetone, and benzene. To answer critics, the researchers used four different types of particle detectors and reported seeing 5000 to 7000 neutrons per second at the energy levels expected for deuterium-deuterium fusion.

• Gaze control circuitry in the forebrain of barn owls mediates **spatial attention for audition** as well as for vision, according to a paper in the January issue of *Nature*. When the forebrain circuit was activated, midbrain responses to auditory stimuli at the location encoded by the forebrain site were enhanced and spatial selectivity was sharpened. The sharpening of auditory tuning curves that resulted from gaze fields activation in barn owls is considered quite remarkable, because auditory tuning curves are the sharpest observed in any part of the brain in any species. The sharpening is caused by an enhancement of responses specifically to interaural timing differences.

• The January/February issue of *Acta Acustica/Acustica* includes a review paper of 15 pages entitled "A Tutorial on "**Scattering and Diffusion Coefficients** for Room Acoustic Surfaces" by T. J. Cox, B.-I. L. Dalenback, P.D'Antonio, J. J. Embrechts, J. Y. Jeon, E. Mommertz, and M. Vorländer.

Acoustics in the news

• A sonic device known as a Long Range Acoustic Device (LRAD) helped ward off a pirate attack on the cruise ship *Seabourn Spirit* off the coast of Somalia, according to a story in the November 8 issue of the *Chicago Tribune*. The device, developed for the military after the 2000 attack on the USS Cole in Yemen, uses a narrow intense beam of sound in order to keep small boats from approaching U.S. warships. Although within the beam sounds can reach 150 dB, neither the LRAD operators or others in the immediate area are in danger.

• The ability of some large animals to hear infrasound may allow them to anticipate natural disasters such as tsunamis before humans can, according to a recent television program on *PBS*. This ability may give elephants and other animals enough time to react and flee to safety. On the morning of December 26, 2004, for example, workers at an elephant camp in Thailand were awakened by the trumpeting and wailing of elephants. The huge animals broke their chains and stampeded up a nearby hill. Moments later a terrifying sound overtook them: the sound of a towering wave of water crashing ashore and overwhelming everything in its path.

• People who have a difficult time hearing conversations in the midst of cocktail party chatter may benefit from an ear training program developed at the University of California, San Francisco, according to a story in the November issue of

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Acoustics in the news

AARP Bulletin. The interactive software program, called LACE (Listening and Communication Enhancement) training, runs on a personal computer. It feeds the brain exercises that include rapid speech as well as sentences spoken in noisy situations and against a competing voice. The exercises help users with skills critical to communication, like listening, attention and focus.

• Musical training can help the brain process the spoken word, according to a story in the November 17 *San Francisco Chronicle*. Musical experience helps the brain improve its ability to distinguish between rapidly changing sounds that are key to understanding and using language. Children, who aren't good at rapid auditory processing and are at high-risk for becoming poor readers may especially benefit from musical training. What is promising about the study, researchers believe, is the notion that the brain isn't an immutable organ fixed at birth but is adaptable and people can change their mental agility.

• Conductors of bands and orchestras are much better at localizing sound sources than non-musicians, according to a story in the November 22 issue of *The New York Times*. The study, whose results were reported at a conference of the Society for Neuroscience, is part of an examination of the way in which auditory and visual information is integrated in the brains of highly trained musicians.

• The "updates" page in the December issue of United's inflight magazine *Hemispheres* briefly describes noise-canceling headphones and noise-isolating earphones. In the former, microphones sample the acoustic environment and try to generate a sound that will cancel low- and midrange-frequency background noise. Noise-isolating earphones, on the other hand, try to shut out as much ambient sound as possible by making an air-tight fit in the ear canal. They are most effective for high-frequency noise.

• *Forbes.com* posted a note, dated December 1, about how cochlear implants work, that attempts to explain why implants restore hearing for some, but not for others. The main bottleneck is a structure called the "endbulb of Held," which contains a large number of synapses where signals pass from one auditory nerve cell to another. In congenitally deaf cats cochlear implants worked when endbulb synapses received electrical signals for three months. The study suggests that there is a window with congenital deafness that shuts just before puberty.

• A new advanced combat helmet allows soldiers to better localize sounds, according to a story on KGO-TV (San Francisco, Oakland, and San Jose) based on a *Discoveries and Breakthroughs in Science* tape produced by AIP. The new helmet, designed by acousticians, sits away from the ear, which allows more sound to enter the ear in a direct path. Tests on this and several other helmets were described in paper 4pPP3 at the 149th ASA meeting in Vancouver.

• A very thoughtful editorial "Poor acoustics can hinder learning" appears in the December 8 issue of the Kingsport (TN) *Times-News*. "Levels of noise that do not interfere with perception of speech in adults may interfere significantly with the perception of speech by children." The author, a clinical audiologist who also writes regularly for the *Times-News*, mentions that the ASA and other organizations helped to develop standards for classroom acoustics in 2002.

• "The Real Death of Print" is the title of a news feature in the 1 December issue of *Nature*. "Despite clashes with publishers over copyright," the story says, "Google's plan to make millions of books available online is turning the tide for efforts to digitize the world's literature. The move to digitize books is set to transform the worlds of publishers, librarians, authors, readers and researchers. The president of the American Library Association says he is not worried that libraries could become obsolete. As well as providing access to books, they serve as a place for people to meet and study, he says. The director of e-books for a major publisher thinks the future of reading lies in small electronic devices from whose screens people will read books wherever they are. Having a mixture of e-books and print books could be the answer.

• In an effort to understand bird calls, scientists at the University of Alberta have recorded and analyzed the sounds of black-capped chickadees, according to a story in the December 24 issue of the *Toronto Star*. "Songbirds learn their vocalization from caregivers, just like people," the researchers say. "They're potentially a good model for human speech and perception." The next step in the research is to test how good human volunteers are at distinguishing avian chirping and then to start looking at how humans perceive animal vocalization.

• A simple sonic device that can continuously monitor the concentration of gas emitted by bacteria has been developed at Penn State University according to a story in the December 26 issue of the *Pittsburgh Post-Gazette*. The device includes a small loudspeaker and a pair of microphones that determines the resonance frequency of a tube; changes in gas composition cause changes in the speed of sound. One application of the device is to monitor microbial fuel cells in which bacteria digest organic matter in wastewater to produce hydrogen to power the cells.

• An artist and a doctor are hoping to make a new map of the "sonic body" by revealing its sounds, from veins to organs and muscles, according to a news report on *BBC News*, December 27. The noises they record using sensitive medical equipment from stethoscopes to scanners will then be made into an interactive art installation triggered by visitors walking through a model of a body. People will need to walk around the installation to trigger the sounds.

• Few high school cheerleaders have won awards at international science fairs and appeared on national television, but Courtney Rafes of Justin, Texas has, according to a story in the December 23 issue of the *Dallas Morning News*. Courtney's entry in the 2005 Intel International Science and Engineering Fair won an honorable mention from ASA (see "We hear that…" in this issue) and also brought her offers of a $20,000 scholarship and an internship with the Department of Homeland Security as well as an appearance on TV. She designed a system that uses ultrasonic waves to detect broken train tracks to warn of impending collisions.

• Heavy use of IPods and MP3 music players may contribute to hearing damage, according to a story in the January 10 issue of *The Wall Street Journal*. Some doctors see younger and younger patients with signs of noise-induced hearing loss that wouldn't typically emerge before middle age. Portable music players, which blare music directly into the ears, may be partly to blame. Hearing specialists at centers such as the House Ear Institute in Los Angeles, the Children's Hospital, Boston, and the American Academy of Audiology say the effect they are seeing may be only the beginning, because accumulated noise damage can take years before it causes noticeable problems. Several companies now market headsets that aim to black out background noise so that the music can be heard better at lower volumes.

• Electronic stethoscopes, which make it easier to separate heart and lung sounds from a background of noise, make up only about 10% of the global stethoscope market, according to a story in the January 19 issue of *The Wall Street Journal*. Some electronic stethoscopes gather ambient noise through a thin slit around the chest piece and use it to cancel noise conducted through a patient's body. Another improvement is the development of special ear tips that make a tighter seal in the doctor's ear canal. Noise-reducing electronic stethoscopes are now seeing increasing use.

• "How to Listen for the Sound of Plutonium" is the intriguing headline of an article in the January 31 issue of *The New York Times* which reports on a secret meeting of the science and technology directorate of the Central Intelligence Agency. The meeting brought together hundreds of the government's top experts in nuclear intelligence to address a problem that had bedeviled Washington for decades: how to know, with precision, when a country is about to cross the line and gain the ability to build an atomic bomb. Research has focused on better detection of "four basic, but inconspicuous, signatures that covert nuclear facilities and materials can emit: distinctive chemicals, sounds, electromagnetic waves and isotopes, or forms of the same element that have different numbers of neutrons, a subatomic building block." Details about the sounds, and how to detect them, are not given, but it is interesting that the headline writer picked up on an acoustical subject.

• A lawsuit has been filed in San Jose federal court asking to limit iPod sound output to 100 dB, according to a story in the February 2 issue of the *San Jose Mercury News*. The suit notes that in 2002 France required Apple to limit the iPod's sound output to 100 dB, but that the iPod sold in the United States is capable of producing music with sound levels between 115 and 130 dB. The user's manual includes a warning that "permanent hearing loss may occur if earphones or headphones are used at high volume," the suit acknowledges, but it does not advise listeners what is a safe volume.

• An expert on noise and hearing loss at Wichita State University has found sound levels as high as 120 dB in personal music players, according to a story in the January 30 issue of the *San Jose Mercury News*. With ear buds there's no escape from the intensity. Dangerous Decibels, an Oregon public health project, estimates that of the roughly 40 million Americans with hearing loss, 10 million cases can be attributed to noise-induced hearing loss.

• "Risks Fall, Hopes Rise for Hearing Implants" is the comforting headline of a story in the March 7 issue of *The New York Times*. Earlier a high incidence of meningitis was found in deaf children with cochlear implants, but this was mainly in children with an implant type that is no longer on the market. Deaf children already stand a higher than normal chance of contracting meningitis, an infection of the fluid surrounding the brain and spinal cord, because they often have abnormalities in their inner ears. On the other hand, early implantation is important. Kids who are implanted by age 3 or 4 have language that is pretty normal and can be educated in mainstream classes rather than in special schools for the deaf. In the past 20 years, it is estimated that 11,000 American children have received implants. Early implantation is encouraged so that children can hear in the crucial years to learn language.

• In an attempt to give the public audible evidence of what is normally invisible, artist Carrie Bodle created a multi-speaker sound installation on the Green Building at MIT, according to a story in the September 12 issue of *The Boston Globe*. The speakers broadcast audio representations of sound waves embedded in the Earth's upper atmosphere each day from noon to 1:00 p.m. for a week in September. In another story about the "Sonification/Listening Up" installation, the September 16 issue of the MIT newspaper *The Tech* reported that some listeners likened the experience to an airplane circling overhead while others described it as a "big didgeridoo."

• The debate over whether the Navy's use of sonar to detect submarines is harming whales and other sound-sensitive species is back again, according to an editorial in the March 7 issue of *The New York Times*. This time the battleground is the waters off the southeastern states where the Navy hopes to establish a training area for sailors to practice their sonar skills in a shallow ocean environment. The National Oceanic and Atmospheric Administration (NOAA) has expressed significant concerns about the proposed sonar activity, including its potential to injure or kill beaked whales, which are especially sensitive. The agency also contends that the sound thresholds the Navy deems acceptable are well above the levels known to disrupt marine mammal behavior in the wild. While no one can deny that the Navy needs to conduct sonar training in shallow waters, the editorialist writes, it behooves the Navy to move with extreme caution.