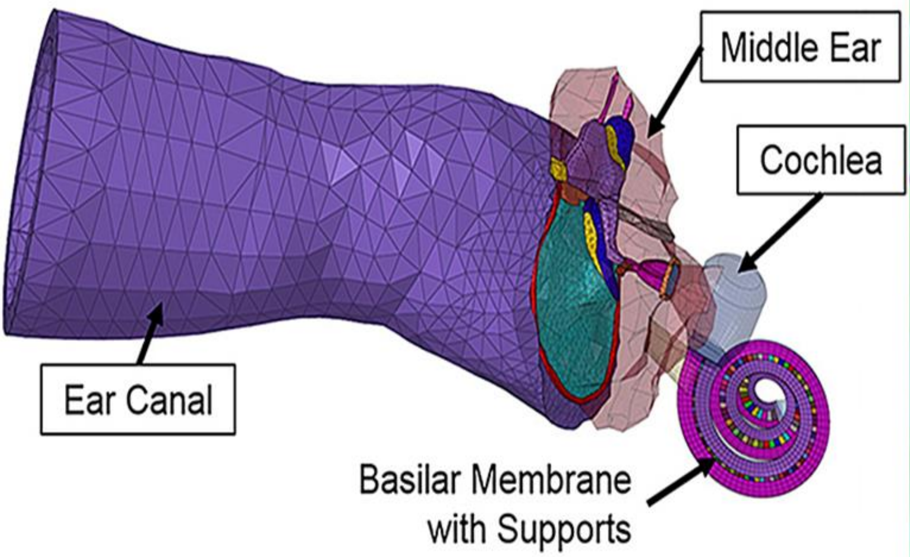
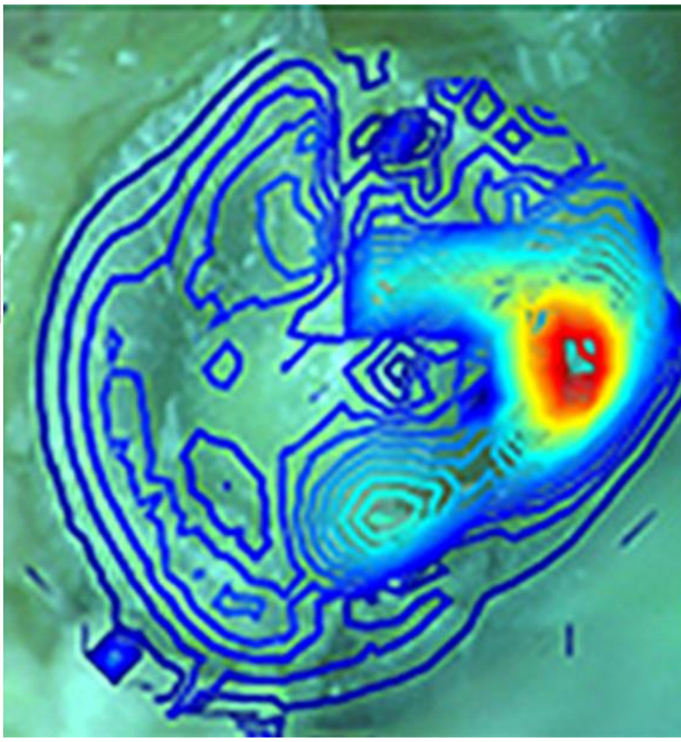
Trendsetting in hearing research





A trend-setter in hearing research

Celebrating the iconic career of Prof. Rong Z. Gan

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We had a chance to virtually sit down (July 26, 2022) for an interview with Prof. Rong Zhu Gan. In her field, she is one of those personalities that needs no introduction. For the uninitiated, she is the George Lynn Cross Research Professor, Presidential Research Professor, Charles E. Foster Chair, and Prof. of Biomedical and Mechanical Engineering, School of Aerospace & Mechanical Engineering at The University of Oklahoma and has been there for 25 years. More importantly, she is one of the pioneers in the field of ear mechanics. She has done it all – middle ear, inner ear, FE modeling, implantable devices, tissue biomechanics, and a lot more.

In this interview, we want to expand on her many achievements and dig into different facets of her personality. The questions below were chosen to explore not only her technical prowess but also her life, motivation and vision moving forward. The article is divided into two sections. The interview is certainly center stage for this piece. There is an extended version of the interview available for download including a “short” list of publications that displays in all its glory the broad-spectrum of Prof. Gan’s contributions in many fields. It is an absolute pleasure and a privilege for Polytec to be associated with a stalwart personality that is Prof. Gan.

Figure 1: Professor Ron Z. Gan. Click here for her full biography

Tell us about your childhood. What was your upbringing like?

I was born and raised in a special family in China after World War II. My father, Ying Gan, left China to study in the West from 1935 – 1943 about 10 years. He received both a bachelor's and master's degree in mechanical engineering from the University of Cambridge and studied at Military Academies in the United Kingdom and the US, such as Royal Sandhurst Military College in UK and the US Army Command and General Staff College in Leavenworth, Kansas. My father returned to China on October 1, 1943, through a long special flight from Washington, D.C. to Chongqing, China (with Military Attaché to Chinese Ambassador, General Zhu, Simin, carrying the US President Rossford's invitation letter to China's President Chang Ki-Shi for the Cairo Meeting of the US, UK and China Presidents). My father was then appointed a Major General and instrumental in protecting China's borders from Japan, and by the War's end, was a national hero.

In 1949 when Chinese Communist Party took over the mainland China, my father stayed in China and settled in high education as a professor in mechanical engineering at Northeast University, Hunan University, and finally at Huazhong Institute of Technology or currently named Huazhong University of Science and technology in Wuhan. During the time from 1950 to 1955, the change of high education system in China following the Soviet Union and pollical movement named "Thought Remodeling" at universities has moved my father's rank at the university gradually down until imprisoned in 1955 as the "anti-revolutionist".

Because of his Western education, my father was deemed an enemy of the people along with 550,000 others in 1957 by given the distinction of being a Rightist, which meant the government considered him at risk of having pro-capitalism, anti-communist views. My father was imprisoned from 1955 to 1956 and again from 1969 to 1976 during China's Cultural Revolution. The Rightist caped him for 26 years until 1983 when it was finally corrected by Deng, Xiaoping, the leader opened the door to the West and ended 10 years of Cultural Revolution disaster in China.

My childhood was filled with stories my father told us: his life and studies at the UK and US and his classmates at Cambridge such as Hua Luogeng, Wang Zhuxi, and Zhang Wenyu, the worldwide well-known mathematician, physicist, and rocket expert, respectively. I was so fortunate to meet them in Beijing when I was young. The influences from my father built my determination to enter the best university in China and to be a scientist in physics or engineering. I was all time the number 1 student in my elementary and high schools and worked hard for my future education goal. In the meantime, I experienced the sufferings of my father and entire family from the political discriminations and financial punishments by the government since 1957, but I never thought I would not have the right for the high education because of my father as Rightist. I think my childhood experiences in family and father's sufferings had great impact to my future career success. I am the oldest of 8 children in my family and have been the most responsible since the childhood.

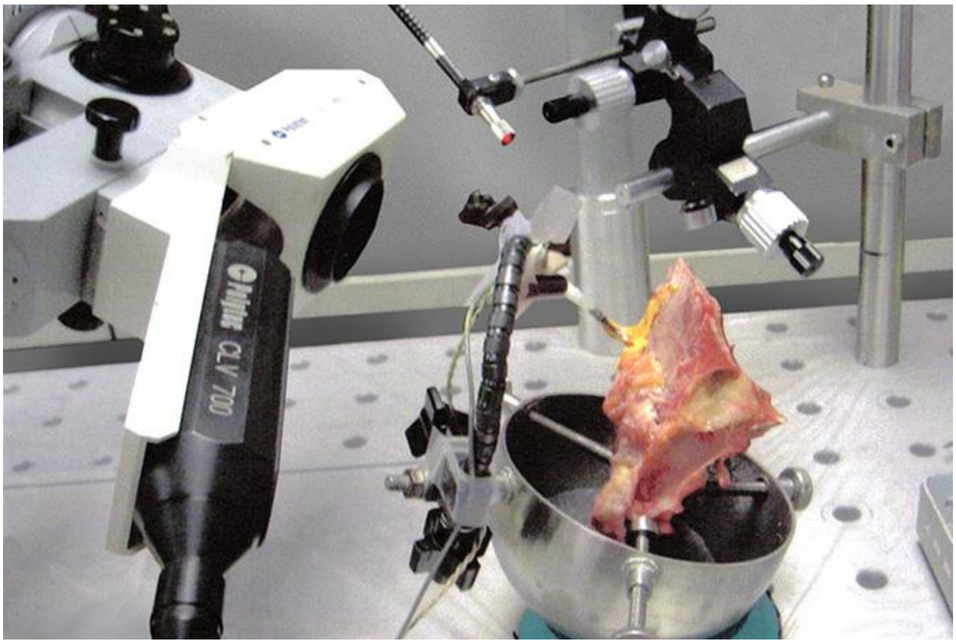


Figure 2: Function evaluation of the Direct Drive Hearing System (DDHS) in fresh human temporal bone (TB) with Polytec laser Doppler vibrometer (LDV)

Where does the ethos about hard work come from?

In 1963 I attended the Chinese National College Entrance Examination and had the highest scores in Mathematics, Science, and Engineering category over the State – Hubei Province, but I was not accepted by any university. Then, my mother took me to see the Communist Party Secretory and President of Huazhong Institute of Technology, Zhu, Jousi, and begged him for not terminating my college education opportunity because of father's designation as a Rightist. Zhu valued very much my talent as a young student and then a very special process on my case was created by the Education Department of Hubei Province. A special report emphasizing my talent and being able to reeducate from a Rightist family was sent to China Central Government's Education Department for approval of acceptancy to a college. Two weeks later, I received the acceptance notice to Huazhong Institute of Technology.

Figure 2: Characterization of mechanical properties of ear tissues, including dynamic tests using LDV with acoustic or electromagnetic loading.

What role has vibrometry played for you and for the field in general?

My career in biomedical engineering, particularly in biomechanics, began in 1978 when the higher education and graduate program resumed in China. I passed the entrance exam and came back to Huazhong University of Science and Technology (HUST) to study Mechanics and then transferred to Biomechanics introduced by Prof. Y.C. Fung, the Father of Modern Biomechanics, when he visited HUST. From 1978 to 1995, I completed the MS and PhD studies and the Postdoc training which were all in the field of cardiopulmonary system and blood flow.

In 1995, at the Biomedical Engineering Society spring meeting, Hough Ear Institute in Oklahoma City posted a position for Director of Engineering to develop the implantable hearing device. When I met Dr. Ken Dommer, who was the Research Director at Hough Ear Institute and Professor of Physiology at University of Oklahoma Health Sciences Center at the conference, I was impressed by the implantable hearing device research because the middle ear consisting of ossicular bones, soft tissues, and joints for sound transmission is a perfect mechanical structure/system. Research on middle ear fits well with my background in biomechanics and my 10-year industry work experience in China would be suitable for device design and manufacturing process. I also believed that hearing research is more related to solving human health problem than the basic research in lung biomechanics I was working on. Therefore, I made the decision of changing my major research direction to hearing. My first project was to complete the design and functional tests of the middle ear implantable hearing device which is an electro-magnetic hearing device with the magnet implanted at the middle ear ossicular chain and the coil placed inside the ear mold in the ear canal, called Direct Drive Hearing System (DDHS).

How did you decide going into hearing research?

The Hough Ear Institute is one of the first institutes to use Polytec laser Doppler vibrometer (LDV) for research in human ears or temporal bones. I led the research team at the institute to setup the experiment with LDV in human temporal bones to test the DDHS by measuring vibrations of the eardrum or tympanic membrane and middle ear ossicles (e.g., stapes footplate). The hearing device is designed to increase stapes footplate movement using coupled electromagnetic drive. Laser vibrometry has played a critical role for completing the measurements on DDHS function. With all the LDV data, we submitted IDE (investigational device exemption) application to the U.S Food & Drug Administration (FDA) and finally Soundtec DDHS was approved by the FDA in 2001 as the 1st middle ear implantable device in the US market. Furthermore, 4 journal articles were published through the device development including the LDV measurement, mass loading on ossicles and middle ear function, biomaterials, and clinical trial.

The laser vibrometry technology involved in the implantable hearing device research for hearing health is one example of using Polytec LDV in my research projects since 1995. After joining The University of Oklahoma faculty in 1999, the LDV has been used in all my projects with the publications listed in this article. The 27 years of my research experiences since 1995 have demonstrated that laser vibrometry is the leading research technique in hearing research field in all aspects. **I would like to state that without the laser vibrometry we would not have today's biomechanical research for auditory system.**

I am also so glad to have Polytec's and Mario Pineda's direct instruction and great support on Polytec's LDV technology since day one when I joined the Hough Ear Institute in Oklahoma (HEI). Without his help on advanced Polytec vibrometry, I could not reach today's level of accomplishments in hearing research field over so many different areas. I appreciate so much for his initial and consistent support through 27 years. I am also grateful to have Dr. Vikrant Palan following Mario's work in Oklahoma region and coming to my lab every year or whenever there is a need in our research project. Thanks, Vikrant, for his leadership and humble personal character, which is the great value for a young leader in today's industry sectors.

What do you think is the future of hearing research?

I think the future of hearing research should be focusing more on protection and restoration of hearing through the translational research from animal model to human and development of therapeutics for hearing restoration including hearing protection devices (e.g., earplugs) and implantable devices (e.g., middle ear reconstruction, cochlea implant, central hearing system implant).

Here are some important research areas:

- Computational modeling for predicting structure-function relationship
- Animal studies for direct connection to hearing
- Therapeutics for hearing restoration
- Implants or implantable devices for hearing restoration

With regards to the technological development, LDV and imaging technologies will provide major technical tools supporting both research and clinics.

If you could award significant funds for hearing research, which areas do you think would make a difference in the lives of people?

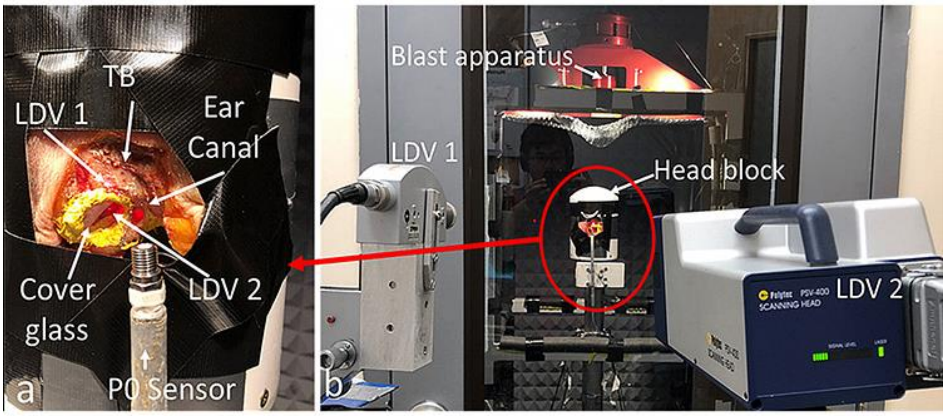
My research work in last 10 years has been in high intensity sound or blast induced hearing loss and protection mechanisms using the experimental approach in human temporal bones and animals and the 3D computational model of human and animal ears. If I could award significant funds for hearing research, I would like to continue this direction because it has more challenges than the normal sound induced hearing loss and would make a difference in the lives of veterans.

There are two areas I am interested in: On one hand providing quantitative descriptions of auditory injuries after repetitive exposure to blast (or high intensity sound) in relation to the blast intensity, number of exposures, frequency of occurrence, and post-exposure progression time and on the other hand, determining the protective mechanisms of hearing protection devices in the central and peripheral auditory system in response to repetitive blast. To our knowledge this state-of-the-art approach has not been experimentally applied to evaluating the biomechanical and neurophysiological bases for auditory blast injuries.

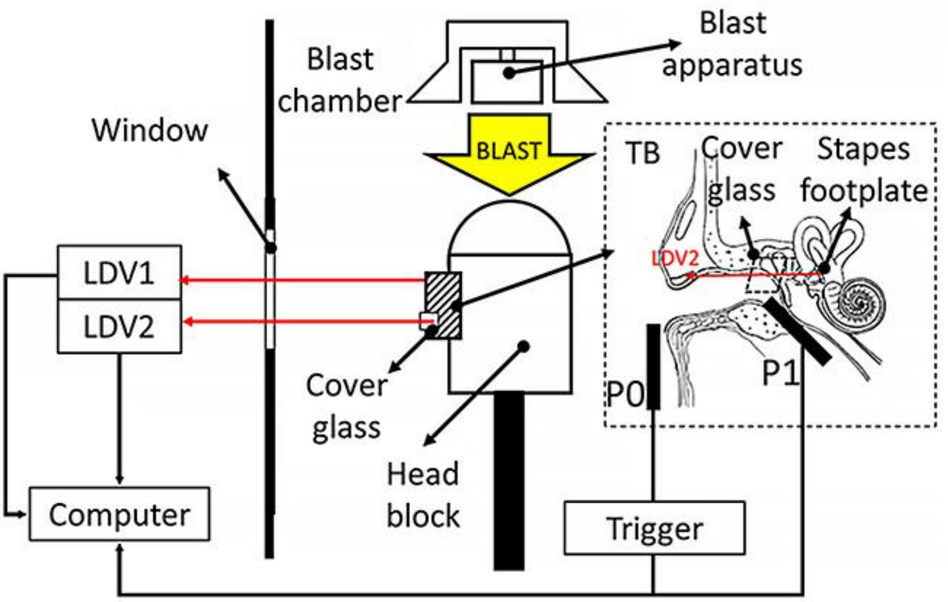
Image section

In order to demonstrate that our 3D multi-scale FE model of the human ear can be extended to simulate the blast damage, we correlate the outputs of the FE model of the ear to the auditory brainstem and cortex with an association to traumatic brain injury (TBI)-induced damage of the central auditory system.

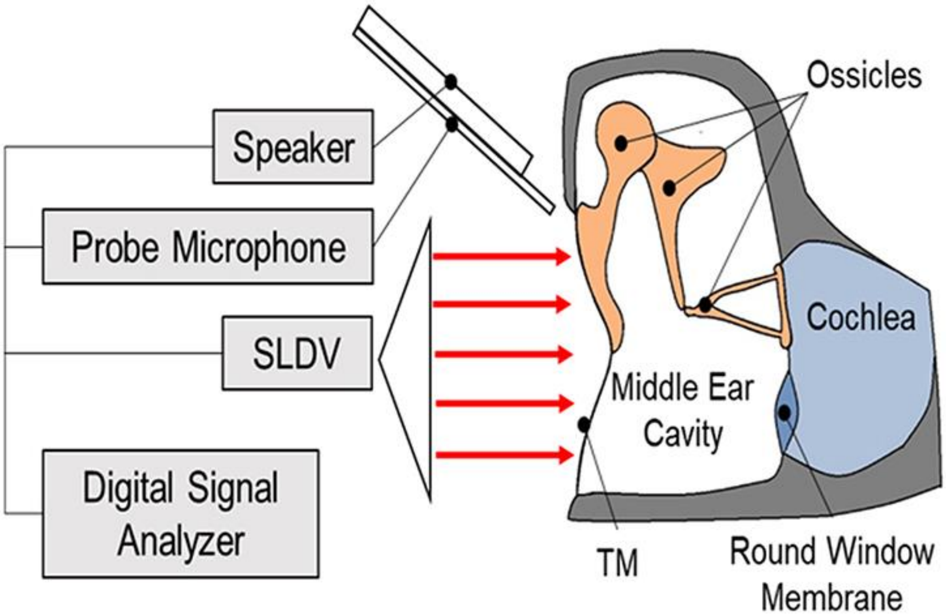
3. Real-time measurement of the stapes footplate movement during blast using two vibrometers; *Jiang et al., Hear Res, Vol. 403, 2021*



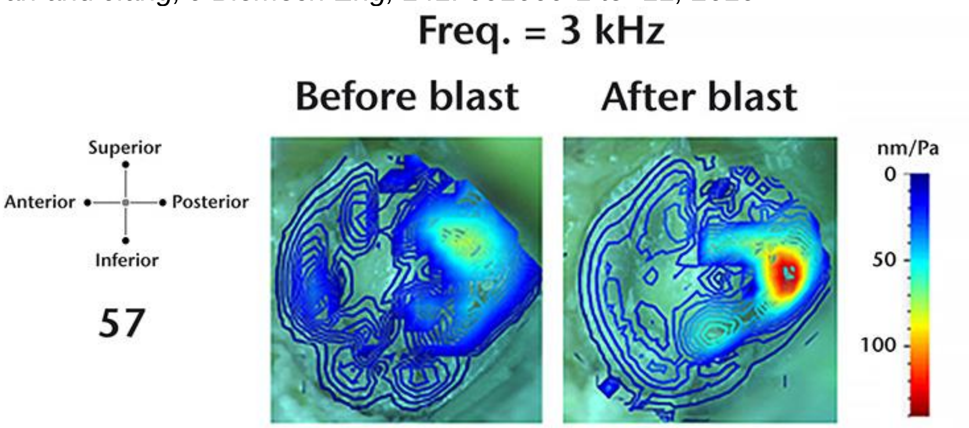
4. Experimental setup for blast response measurement; *Jiang et al., Hear Res, Vol. 403, 2021*



5. Experimental setup for scanning LDV measurement on tympanic membrane



6. Example tympanic membrane deflection shape (3 kHz) before and after blast exposure; *Gan and Jiang, J Biomech Eng, 141: 091009-1 to -11, 2019*



What advice will give to a young researcher?

My advice for young researchers is to seek innovation, collaboration, and publish the work on time. To be successful in research career, you must always stay motivated and work hard.

As I mentioned earlier, my doctoral research and postdoctoral training were all in blood flow and biomechanics of soft tissues (e.g., blood vessels), especially in lungs before I joined Hough Ear Institute. The success for such a huge change of research field is due to my strong background in biomechanics and mechanical engineering. As a young researcher, particularly working in interdisciplinary areas (e.g., biomedical engineering), you must have 100% confidence in your original trained area but spend most of your time working on a new direction because there must be innovation to solve the problem.

What are the attributes of a successful researcher?

- Hard working character
- Mentoring skill for students as a postdoc
- Collaboration for teamwork
- Leadership for research direction
- Keeping the focus on the accomplishment at each stage.

What do you like to do in your spare time?

I enjoy history and nature beauty very much through my life. Whenever there is a chance of travel to a meeting or taking a vacation, I would like to visit a museum, scenic spots and places of interest, collect souvenirs, take pictures, etc.

I now have two young grandkids at age almost 8 and 4 years old. I would like to spend some time with them and enjoy seeing them growing up.

Failure is sometime the fertile soil of future successes. Please give us an example of your favorite failure.

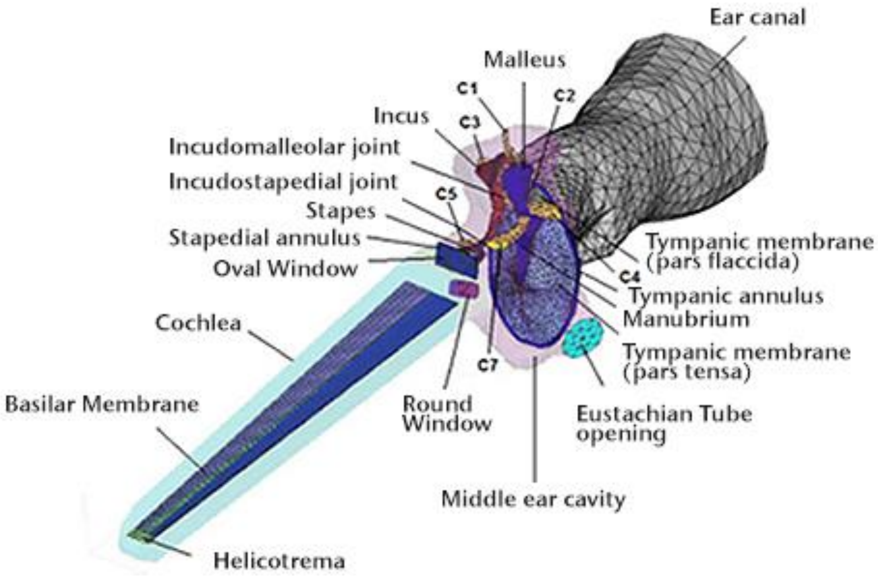
I have successfully secured federal fundings from NIH, NSF, and DoD in the past 20 years (2003 – present) through some failures in proposal/grant applications. However, I did not give up and learned from the failure for future success. One example is the failure to renew my 1st NIH R01 grant project on “Ear Biomechanics for Restoration of Hearing” in 2010. That project was based on improvement of tympanometry measurement for middle ear function, the 3D finite element model of the human ear, and characterization of middle ear tissues’ mechanical properties. Those contents were good but needed to move to the next level with research focus on otitis media, a most common middle ear disease in young children.

In 2011, I created a new proposal entitled “Biomechanical Measurement and Modeling of Normal and Diseased Middle Ears”. The clinical utilities of the human ear FE model were emphasized by developing several otitis media ear models with model-derived “Auditory Test Curves”; measurements of ear tissues’ dynamical properties over frequency and time domains were proposed; and the animal model of otitis media in chinchilla was proposed. This successful NIH project has great impact on our DoD research project using the chinchilla blast animal model and the 3D FE model of the human ear for blast wave transmission.

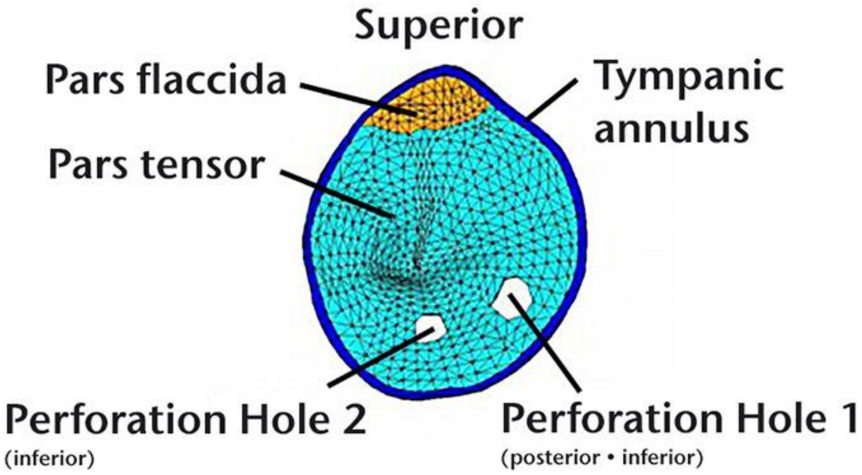
Image section

This image section shows the 3D finite element (FE) model of the human ear with the 2-chamber straight cochlea for simulation of tympanic membrane (TM) perforation and the effect tympanic membrane perforation on stapes movement. The model was validated with LDV measurements in human temporal bones (TB).

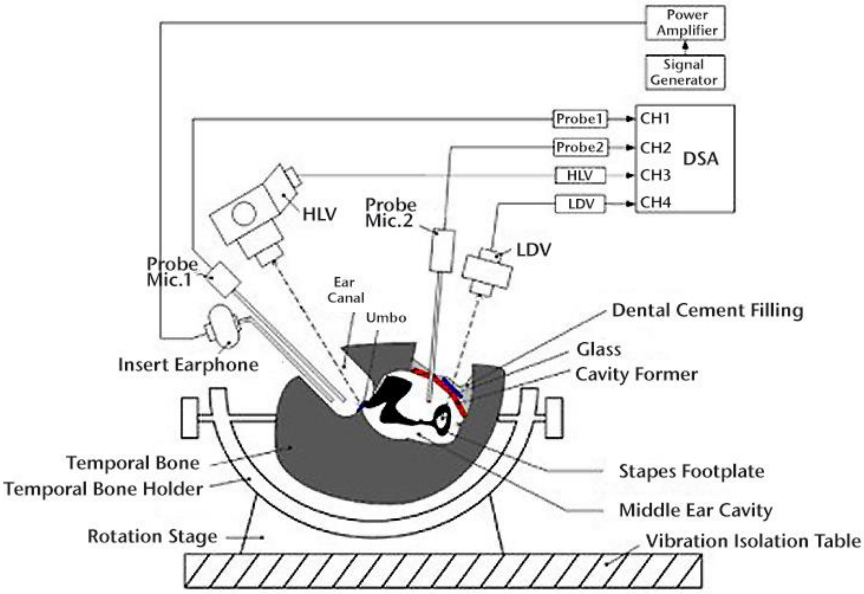
1. 3D FE model of the entire human ear with 2-chamber straight cochlea validated by LDV measurements



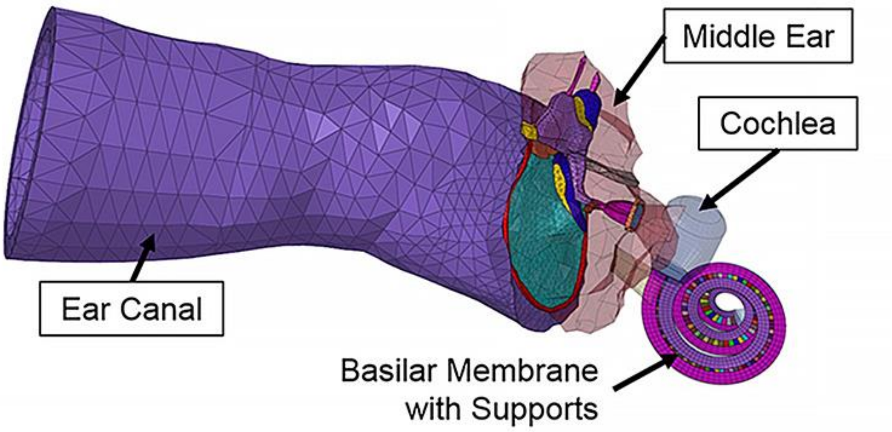
2. Perforated tympanic membrane model; *Gan et al., J. Acoust Soc Am Vol. 126: 243-253, 2009*



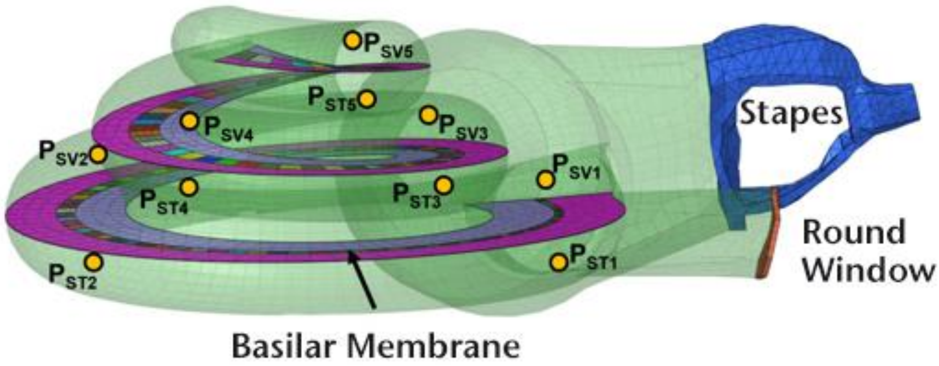
3. Experimental setup in TB with LDV measurement at stapes footplate



4. FE model of the entire ear including inner ear with 2-chamber spiral cochlea



5. Pressure distribution in the basilar membrane; *Brown et al., J Biomech Eng, Vol. 144: 014503-1 to -6, 2022*



What are your core principles?

- Determination – The future is totally in your own hands.

- Perseverance – No matter what environment, persevere and work hard. It is the most important character especially when you do not have equal right to compete with others. It is also the key for success.
- Team working character – Appreciate anyone who helped and supported me in every stage of my life.
- Mentoring response to your students and fellow researchers because I am a professor.

Say you had a chance to have lunch with anyone in the history of humanity. Who would it be and why?

I would like to have lunch with someone who is interested in China's modern history. My personal experience and family history in the past 70 plus years or since 1949 have demonstrated that the communist region under Mao is the darkest time in China's history. There were endless political/mass movements or revolutions anti-intellectuals until reaching the peak - 10 years of Cultural Revolution disaster. Deng, Xiaoping took the power after Mao died in 1976 and Deng finally realized the sufferings of 550,000 Rightists and their families along with all other people's enemies. Deng opened the door to the West. China entered the bright economy reform years. However, China is a communist country, and the communist party has superpower to control everything, so there is no real freedom in China.

What are the plans after retirement?

I may not be able to immediately stop certain professional activities such as reviewing research grants and attending some meetings after retirement. However, I will gradually move to another type of life: no scheduled school activities, no every Friday 5 pm lab meetings, etc.

One plan after retirement is to write a book-autobiography about my life and family. I want my experiences and my father's history to pass to the young generation. I would also like to travel with my daughter's family and grandkids.

Watch bonus content: Webinar by the World Association for Chinese Biomedical Engineers

For Prof. Gan's technical achievements, which span several decades, we recommend watching her webinar hosted by Columbia University and organized by World Association for Chinese Biomedical Engineers: https://www.youtube.com/watch?v=te0uCY4-r_o&list=PLBT6cl5oab0G4XXm90WH-Mta0h1KUDI3Q

How would you like to be remembered?

I consider myself an exceptional person from a special family with great talent since childhood, having industry career in 10 years, and outstanding academic career over 40 plus years. At age 40, I came to Canada and the US as a student to study mathematics and biomedical engineering; at age 50, I entered a new research field and established the well-funded transformable research program in Biomechanics for Protection and Restoration of Hearing at University of Oklahoma. I would like to be remembered as a Professor and Scientist who has never given up and is always willing to catch up the opportunity.

Polytec

Dr. Gan's journal publications using Polytec LDV technology in hearing research (1997 – 2021)

Part I: Implantable Hearing Devices

1. ***Gan, R. Z.**, Wood, M. W., Ball, G. R., Dietz, T. G., and Dormer, K. J. Implantable hearing device performance measured by laser Doppler interferometer. *ENT-Ear, Nose & Throat J.* 76 (5): 297-309, 1997.
2. ***Gan, R. Z.**, Dyer, R. K., Wood, M. W., and Dormer, K. J. Mass loading on ossicles and middle ear function. *Annals of Otology, Rhinology, and Laryngology*, Vol. 110, No. 5: 478-485, 2001.
3. Dormer, K. J, and **Gan, R. Z.** Biomaterials for implantable middle ear hearing devices. *The Otolaryngologic Clinics of North America*, Vol. 34, No. 2: 289-297, 2001.
4. Hough, J., Dyer, R., Dormer, K., Matthews, P., **Gan, R. Z.**, and Wood, M. Middle ear electromagnetic implantable hearing device-initial clinical results. In: The Function and Mechanics of Normal, Diseased and Reconstructed Middle Ears. J. Rosowski and S. Merchant (Eds). Kugler Publications, Netherlands, pp. 353-366, 2000.
5. ***Gan, R. Z.**, Sun, Q., Dyer, R. K., Chang, K-H, and Dormer, K. J. Three dimensional modeling of middle ear biomechanics and its application. *Otology & Neurotology*, Vol. 23(3): 271-280, 2002.
6. **Gan, R. Z.** TIHS: A totally implantable hearing system. *The Hearing Journal*, Vol. 61 (9): 33-38, 2008.
7. ***Gan, R. Z.**, Dai, C., Wang, X., Nakmali, D., and Wood, M. W. A totally implantable hearing system – Design and function characterization in 3D computational model and temporal bones. *Hearing Research*, Vol. 263: 138-144, 2010.

Part II: Sound transmission through the ear (human and animals)

1. ***Gan, R. Z.**, Wood, M. W., and Dormer, K. J. Human middle ear transfer function measured by double laser interferometry system, *Otology & Neurotology*, Vol. 25, No. 4, 423-435, 2004.
2. **Gan, R. Z.**, Dai, C., and Wang, X. Biomechanics of otitis media with effusion in human ear. In: The Fifth World Congress of Biomechanics (Dieter Liepsch ed.), Medimond Publishing, pp. 527-533, 2006.
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4. **Gan, R. Z.**, Cheng, T., Nakmali, D., and Wood, M. W. Effects of middle ear suspensory ligaments on acoustic-mechanical transmission in human ear. In: Middle Ear Mechanics in Research and Otology. A. Huber and A. Eiber (Eds.). World Scientific Publishing, pp. 212-221, 2007.
5. *Dai, C., Cheng, T., Wood, M. W., and **Gan, R. Z.** Fixation and detachment of superior and anterior malleolar ligaments in human middle ear: experiment and modeling. *Hearing Research*, Vol. 230: 24-33, 2007.
6. Dai, C., Wood, M. W., and **Gan, R. Z.** Tympanometry and laser Doppler interferometry measurements on otitis media with effusion model in human temporal bones. *Otology & Neurotology*, Vol. 28 (4): 551-558, 2007.
7. *Dai, C., Wood, M. W., and **Gan, R. Z.** Combined effect of fluid and pressure on middle ear function. *Hearing Research*, Vol. 236: 22-32, 2008.
8. *Dai, C. and **Gan, R. Z.** Change of middle ear transfer function in otitis media with effusion model of guinea pigs. *Hearing Research*, Vol. 243: 78-86, 2008.
9. *Dai, C. and **Gan, R. Z.** Change in cochlear responses in an animal model of otitis media with effusion. *Audiology & Neurotology*, Vol. 15:155-167, 2010.

10. Guan, X. and **Gan, R. Z.** Effect of middle ear fluid on sound transmission and auditory brainstem response in guinea pigs. *Hearing Research*, Vol. 277: 96-106, 2011.
11. *Guan, X. and **Gan, R. Z.** Mechanisms of tympanic membrane mobility loss in acute otitis media model of guinea pig. *J. Association for Research in Otolaryngology (JARO)*, Vol. 14: 295-307, 2013.
12. *Guan, X., Li, W. and **Gan, R. Z.** Comparison of eardrum mobility in acute otitis media and otitis media with effusion models. *Otology & Neurotology*, Vol. 34(7): 1316-1320, 2013.
13. **Gan, R. Z.** Diagnosis and characterization of middle-ear and cochlear functions. *J. Korean Academy of Audiology*, Vol. 9: 95-112, 2013.
14. *Guan, X., Chen, Y., and **Gan, R. Z.** Factors affecting loss of tympanic membrane mobility in acute otitis media model of chinchillas. *Hearing Research,* Vol. 309: 136-146, 2014.
15. *Zhang, X., Guan, X., Nakmali, D., Palan, V., Pineda, M., and **Gan, R. Z.** Experimental and modeling study of human tympanic membrane motion in the presence of middle ear liquid. *J. Association for Research in Otolaryngology (JARO)*, Vol. 15: 867-881, 2014.
16. *Chen, Y., Guan, X., Zhang, T., and **Gan, R. Z.** Measurement of basilar membrane vibration in guinea pigs with reverse and forward driving. *J. Association for Research in Otolaryngology (JARO)*, Vol. 15: 933-943, 2014.
17. *Wang, X., Guan, X., Pineda, M., and **Gan, R. Z.** Motion of tympanic membrane in guinea pig otitis media model measured by scanning laser Doppler vibrometry. *Hearing Research*, Vol. 339: 184-194, 2016.
18. Guan, X., Seale, T. W., and **Gan, R. Z.** Factors affecting sound energy transmission in acute otitis media model of chinchilla. *Hearing Research,* Vol. 350: 22-31, 2017.
19. *Wang, X. and **Gan, R. Z.** Surface motion of tympanic membrane in a chinchilla model of acute otitis media. *J. Association for Research in Otolaryngology (JARO)*, Vol. 19: 619-635, 2018.

Part III: Blast wave transmission through the ear

1. *Jiang, S., Smith, K., and **Gan, R. Z.** Dual-laser measurement and finite element modeling of human tympanic membrane motion under blast exposure. *Hearing Research*, Vol. 378: 43-52, 2019.
2. ***Gan, R. Z.** and Jiang, S. Surface motion change of tympanic membrane damaged by blast waves. *J. Biomechanical Engineering*, Vol. 141: 091009-1 to -11, 2019.
3. *Jiang, S., Dai, C. and **Gan, R. Z.** Dual-laser measurement of human stapes footplate motion under blast exposure. *Hearing Research*, Vol. 403: 108177, 2021. https://doi.org/10.1016/j.heares.2021.108177

Part IV: Dynamical properties of ear tissues

1. Zhang, X. and **Gan, R. Z.** Dynamic properties of human tympanic membrane - experimental measurement and modeling analysis. *Int. J. Experimental and Computational Biomechanics*, Vol. 1, No. 3: 252-270, 2010.
2. Zhang, X. and **Gan, R. Z.** Experimental measurement and modeling analysis on mechanical properties of incudostapedial joint. *Biomechanics and Modeling in Mechanobiology*, Vol. 10: 713-726, 2011.
3. *Zhang, X. and **Gan, R. Z.** Dynamic properties of human round window membrane in auditory frequencies. *Medical Engineering & Physics*, Vol. 35(3): 310-318, 2013.
4. ***Gan, R. Z.**, Nakmali, D., and Zhang, X. Dynamic properties of round window membrane in guinea pig otitis media model. *Hearing Research*, Vol. 301: 125-136, 2013.
5. *Wang, X., Nakmali, D., and **Gan, R. Z.** Complex modulus of round window membrane over auditory frequencies in normal and otitis media chinchilla ears. *Int. J. Experimental and Computational Biomechanics*, Vol. 3: 27-44, 2015.

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10. *Liang, J., Engles W.G., Smith, K.D., Dai, C., and **Gan, R. Z.** Mechanical Properties of Baboon Tympanic Membrane from Young to Adult. *J. Association for Research in Otolaryngology (JARO)*, Vol. 21: 395-407, 2020.

Part V: Contributions of LDV measurements to 3D modeling of human & animal ears

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Outlook

Laser vibrometers are indispensable and reliable measurement tools for the investigation of the vibrational behavior and structural dynamics in countless applications ranging from biomedical to entomological studies, for characterizing microstructures and microtechnology to testing of technical components and machinery. The non-contact and non-invasive characteristics of laser vibration sensors often are the game changer for challenging measuring tasks, and its ease of use and efficiency easily exceed conventional methods in a wide range of applications.

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