What a Wonderful Wave

Nicole Kessissoglou

Nicole Kessissoglou and Steffen Marburg in Manchester, UK, in June 2023; personal photo, used with permission.

I have been fortunate to have experienced a number of serendipitous events that ignited (and reignited) my passion for waves in structures and sound fields. The first event was undoubtedly the most important because it kick-started my research journey. I was a PhD student in mechanical engineering at the University of Western Australia, Perth. At the time, I was already many months into my PhD and rather lost (although this was not the fault of my wonderful supervisor). I knew that I wanted to pursue a PhD on active vibration control; however, I was not thinking expansively and as such, had not considered structures beyond simple beams or plates. Unfortunately for myself, active control was the flavor of the 1980s and 1990s and the year was already 1994. I was starting to feel despondent that I was too late to the topic and not up to the task of doing a PhD.

Let me digress with two important factors leading to my fortuitous event. The first is that I had commenced my PhD in the days when journals were only available in hard copy. The second is that the department included a strong academic group on structural vibration. The group was led by the late Michael Norton (whose excellent book on noise and vibration I still use for teaching and research), Brian Stone (whose enthusiastic teaching on spring-mass-damper systems using only chalk and a blackboard was truly inspirational), and, of course, my supervisor, Jie Pan (who recently told me he is now the oldest professor in the department!). Needless to say, there were quite a number of PhD students being supervised by these academics. So, to this day I don't know who left a discarded page in the photocopy room on Eric Ungar's (1961) article in *The Journal of the Acoustical Society of America* (*JASA*). After a few moments perusing the page, I experienced a eureka moment, I would study active vibration control of *beam-stiffened plates*!

But my luck didn't stop there. I acquired the full paper and fell in love with the approach that Ungar took in modeling a symmetrically reinforced beam-stiffened plate as three subsystems in the direction of wave propagation, namely, plate 1, beam, and plate 2. Ungar showed that by considering the coupling between different wave types at the boundary interfaces of the beam and plates, maximum energy transmission through the beam occurred at optimal wave-matching conditions between flexural waves in the plate and flexural waves in the beam (termed flexural coincidence), and at optimal wave-matching conditions between the plate flexural waves and torsional waves in the beam (torsional coincidence). This detailed understanding of the wave propagation and transmission shaped my philosophy and approach toward research problems that I have upheld throughout my entire career. I was then able to tailor the design of the active control system to target only those transmitted waves (okay I confess, it was probably my supervisor who designed the active control system). This work led to my first journal paper that was published in *JASA* (Kessissoglou and Pan, 1997). Seeing the printed paper in the university library was one of the happiest moments of my life. I felt immortalized!

Fast forward two decades from my lucky discovery in the photocopy room, at which stage I was an associate professor at UNSW Sydney. I hadn't made active control a career focus and as it turns out, I still wasn't thinking expansively. As far as I was concerned, active (or passive) noise and vibration control was a technique to attenuate the *total* acoustic or vibrational field. That was all about to change.

In 2015, I was invited to give a talk at an Australasian conference called KOZWaves (K for Kiwi is a nickname for a New Zealander and OZ for Aussie is a nickname for an

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Australian). It was a small, intimate conference devoted to all branches of wave science. This conference wasn't on my radar, and I didn't anticipate getting much out of it (and furthermore, I was only able to attend two out of the three days). I had unwittingly become stuck in a routine of attending the same large annual conferences primarily focused on acoustics and vibration and typically attended by researchers in mechanical engineering. KOZWaves turned out to be a refreshing experience in which I met a range of researchers from physics and mathematics as well as from engineering, all with a common interest in waves.

During KOZWaves, I was listening to a talk from an applied mathematician, William Parnell, on the topic of active cloaking of elastodynamic systems (Norris et al., 2014). Although admittedly I couldn't follow most of the math, his talk provided another eureka moment. Can we use active control to cancel a specific wave component? I was once again excited by active control of waves. My first attempt was to cancel a wave component of the displacement field in a finite structure. This turned out to be more challenging than anticipated, so attention was turned to active manipulation of sound scattering and radiation from structures in acoustic domains of infinite extent. A literature survey soon revealed that similar acoustic cloaking using active control had been introduced by Jordan Cheer (Cheer, 2016). However, it was the first time I had considered the possibility of manipulating waves in extraordinary ways, which, in turn, led to a fervor when I discovered acoustic metamaterials.

Throughout 2015 and 2016, I was mentioning my keen interest in acoustic metamaterials to anyone and everyone. I was quite obsessed! In June 2016, I successfully gatecrashed a metamaterials workshop in Edinburgh, Scotland, that was being hosted by William Parnell. Similar to KOZWaves, it was a fantastic, small, intimate conference from which I learned a lot (mostly that once again, I was late to the topic). Somewhere along the way, I must have mentioned my interest in metamaterials to my colleague, Alex Skvortsov, who is based in Melbourne, Australia, and whom I kept bumping into at conferences (including KOZWaves). Alex was equally keen on metamaterials, and we agreed to recruit a PhD student to the topic. Our mutual interest and shared philosophy on an in-depth understanding of wave phenomena became the catalyst for our beautiful work on wave scattering in locally resonant soft coatings. Come full circle nearly 10 years later, William Parnell and I are currently collaborating on cloaking, and Alex Skvortsov, William Parnell, and I are currently collaborating on subwavelength resonance of inclusions in a soft material.

There have, of course, been numerous other important serendipitous events, notably chance encounters with colleagues earlier in my academic career who became long-term collaborators and lifelong friends. I joined UNSW in 2003 and a couple of months later, I met Roger Kinns, who was visiting another academic at UNSW. We bonded over my casual mention of Cambridge University, Cambridge, United Kingdom (I was about to spend a couple of months there and was terribly excited). As it turned out, Roger is a Cambridge graduate, and he provided me with lots of useful information and contacts. Our continued enthusiastic conversations on Cambridge led to Roger becoming a collaborator for many years and cosupervisor of my PhD students. I met Steffen Marburg (see photo) at a conference in France in 2005. Steffen was quite obsessed with Australia at the time, and there were not many Australians at the conference. On hearing my Aussie accent one lunchtime, he cornered me and insisted on visiting to identify a collaborative project (and we are still collaborating) (see my photo).

I feel very fortunate to have worked with many wonderful and generous people on waves in structures, fluids, and soft materials. But it was Ungar's paper (1961) that provided the serendipitous spark for waves that is still burning. To the person who left Ungar's work in the photocopier room, I am forever grateful.

References

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Contact Information

Nicole Kessissoglou
n.kessissoglou@unsw.edu.au

School of Mechanical and Manufacturing Engineering
UNSW Sydney, New South Wales 2052, Australia