Shard-Speakers: An Inquiry into the History, Sonic Properties, and Musical Possibilities of Quartz Crystal Singing Bowls

Anastasia Clarke
New York University
adc10011@nyu.edu

ABSTRACT

In this paper, the NIME "shard-speakers" is situated within the cultural context of the typical uses of crystal singing bowls, specifically acknowledging the origins of crystal bowls as re-purposed by-products of the silicon chip manufaturing process, and their subsequent adoption into the toolkits of New Age sound healing practitioners. Following this discussion is a first-person anecdotal account of the author/composer's sonic explorations using crystal singing bowls in combination with the shards of broken bowls and custom electronics to create a body of recorded, acoustic, and electroacoustic musical works named *Crushed Matrices #1-7*. The last section of this paper explains how the extended musical techniques unearthed through the *Crushed Matrices* investigations informed the creation of the shard-speakers, and the electronically-generated musical content that was composed for them in the form of a sound artwork, *Ode on Crushed Matrices*. This recording was fed into the shard-speakers via tactile transducers on resonating bodies for the 2022 inaugural installation of the work, which at the time of writing is the only installation of the work to date. The paper's conclusion addresses the relationship of this body of work to the NIME 2023 conference's theme of "Frugal Music Innovation," correlating or otherwise characterizing its relationship to several of the core competencies set forth by the Frugal Innovation Hub: adaptability, lightness of weight, mobile design, affordability, local material sourcing, and ruggedness.

Author Keywords

Music composition, computer music, instrument design, multichannel audio, sound healing

CCS Concepts

• **Applied computing** → **Sound and music computing**; Performing arts
• **Applied computing** → **Arts and humanities**; Performing arts
• Hardware → Emerging technologies → Emerging interfaces

1. INTRODUCTION

This paper chronicles the lines of inquiry, performative research, and material experiments that have led to the development of a new interface for musical expression in the form of an 4-speaker array made out of the shards of broken quartz crystal singing bowls, with affixed tactile transducers and resonating bodies. Referred to henceforth as "shard-speakers," this work was created by the author of this paper, composer and sound artist Anastasia Clarke (who also performs as AC Diamond), for the purpose of building a lightweight, tourable, easily-shippable instrument that could be used in performances, installations, or hybrid performance-installations. The shard-speakers are also a conceptual response to the author's research into crystal singing bowls, undertaken through performances developing extended techniques for crystal singing bowls and shards and conducted between 2017-2021 under the premise of an episodic performance, *Crushed Matrices*. The shard-speakers were first imagined and proposed for sculptural installation in 2019, and were finally created and shown in 2022 as sound sculpture on the occasion of the group show *Grave New World* curated by Kit Mills and Kristen Leonard for ABC No Rio in New York, NY.

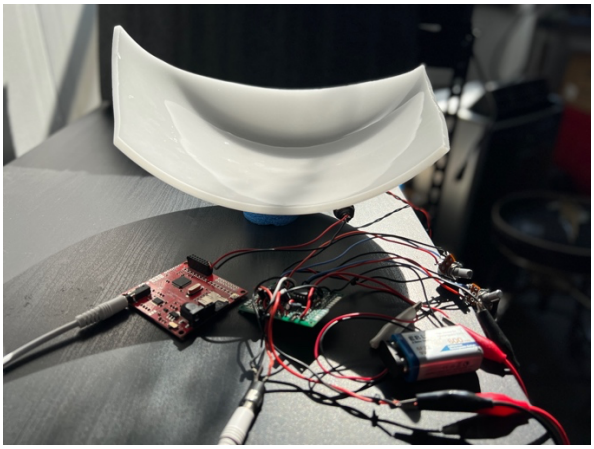

Figure 1. Shard-speaker with electronics.

2. BACKGROUND

Because the author is not aware of any academic writing on crystal singing bowls as musical instruments, many sources cited in this paper originate in digital mediums for contemporary folklore — "About" pages on retailer websites, blog posts, online journal articles, and other web-based resources. In contrast to the author's characterization, these sources frame crystal singing bowls as practitioner tools, rather than as musical instruments. In most descriptions, these high-end sound healing tools are to be activated by sound healing "practitioners," some of whom may hold certificates in the "proper" usage of these bowls. They are sometimes activated in combination with sound healing tools such as gongs, drums, and tuning forks; and as a complement to other healing modalities in general [1, 2, 3]. The bowls are most often made available in pitches that are said to correlate to the different energy chakras of the human body, colors of the rainbow, and different emotional or physical states, and are often sold as sets that create a musical scale [4, 5].

2.1 Sound Production and Acoustic Qualities

For most, sonic production with the crystal singing bowls is easy to achieve: a seude or rubber dowel is dragged gently and evenly around its upper rim, until the sweet spot between speed and pressure is located, activating the bowl's resonant frequency. When played as intended, the bowl produces a stable, clearly-pitched tone that is closer

NIME' 23, May 31–June 2, 2023, Mexico City, Mexico.

in harmonic structure to that of a sine wave (fewer overtones) than the tones produced by bowls made of bronze or other metal alloys (more overtones).

When the bowls are broken into shards – an extrapolation on the original instruments, which is specific to the author's work – the ability to resonate shards by dragging a dowel is obliterated. The shards must be struck, dragged, or otherwise vibrated to activate their resonant frequencies. Although each shard sounds with an audible fundamental pitch, they emit a more complex overtone structure due to variations in size, shape, and geometries of the respective pieces — in other words, timbral qualities are much noisier than either bronze or crystal singing bowls.

2.2 Manufacturing Process and Origins

The manufacturing processes for crystal singing bowls are generally considered proprietary; however, two manufacturers of crystal singing bowls provide top-level descriptions of their manufacturing process which are consistent with one another, suggesting that crystal singing bowls are generally produced in roughly the same manner, with the same materials: Crystal Tones states that their "[crystal] bowls are made from 99.992% pure crushed quartz and heated to about 4000 degrees in a centrifugal mold" [6], while Shanti Bowl indicates that the bowls they sell are made out of "99.8% pure silicon quartz," mixed with "sand in a spinning mold, in a process that heats the mixture to about 4000 degrees" [7].

According to the website *Crystal Singing Bowls UK*, crystal singing bowls were actually lab equipment appropriated from a process belonging to the silicon chip manufacturing industry, known as the Czochralski process [8]. In this context, the bowls are called crucibles, and are used as melting pots to extract large crystals from molten silicon: "In a lab environment, the quartz crucible is filled with chunks of polycrystalline silicon and heated in an argon filled furnace (to purge all air) to around 1,425 degrees. Once fully melted, a precisely oriented rod-mounted seed crystal is dipped into the molten silicon. The seed crystal's rod rotates counterclockwise and the crucible rotates clockwise simultaneously. The rotating rod is then drawn upwards extremely slowly – over a number of hours – allowing a large 1-2 metre, roughly cylindrical, single-crystal, boule/ingot to be formed" [8].

Similarly, Zacchia Blackburn, crystal bowl practitioner and owner/founder of Sunreed Instruments, states on his company's website that "crystal bowls have been used in healing modalities since the 1980s," and corroborates that "the computer industry made very high quality, pure silicon quartz crystal bowls utilized to grow pure silicon chips for their computers. If the bowls were not precise enough, they were thrown out. . . . Apparently, someone on the way to the trash bin discovered they have incredible pure sounds, also, and decided to stop discarding them! This birthed the singing crystal bowl industry" [9].

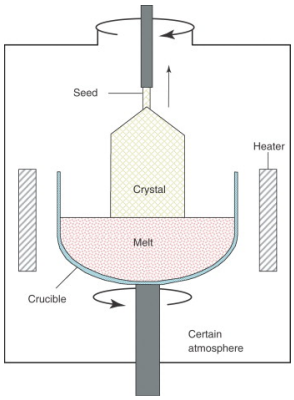

Figure 2. Diagram of the silcon crystal creation and extraction process using the Czochralski method, using a quartz crucible as a heating chamber [10].

While no one in particular is credited with this discovery, Blackburn does give us a vague sense of timeline, stating that "crystal bowls have been used in healing modalities since the 1980s." *Crystal Singing Bowls UK* takes a different approach to placing a date on the origins of crystal bowls: "Although we will discuss the timeline of events in the last few decades of the bowl's manifestation, it is important to consider that many people have a recollection and perception of using the crystal singing bowls in ancient times, parallel universes, other dimensions and past lives" [8]. In attempting to write a comprehensive story of the crystal singing bowls' origins, then, one must consider how New Age lore, spiritual orientations, and oral histories may have intertwined with the commercial interests of the persons selling these instruments.

Indeed, these pieces of lab equipment-turned-musical-instruments (or sound healing implements, depending on who you ask) offer a unique timbral quality that differentiates them from metallic singing bowls — not only in their overtone structure, but in the sound produced by the "frosted" exterior texture characteristic of bowls produced by Crystal Tones, CVNC, and other prominent manufacturers. While the interior of the bowls are finished with a smooth, glassy interior; the exterior surface is left rugged and grainy, yielding friction between the rubber or suede mallet, and the rim of the bowl. The resultant timbral quality is a noisy, breathy, ethereal addition to the loud, resonant sine-like tone that each bowl produces. Once a bowl has reached a point of steady oscillation, the "frosted" sound becomes less prominent in the overall overtone structure, and the sine tone-like behavior of the bowl takes precedence.

Given that crystal singing bowls are comprised almost entirely of pure quartz, a discussion of the manufacturing process would not be complete without also addressing the sourcing of quartz. After all, these instruments are touted for their "high vibrational" properties — that is, their ability to call in benificent, otherworldly spiritual forces — so it would provide peace of mind to know that they are sourced responsibly. But are they?

Where meta-analyses on the impacts of quartz crystal mining don't yet exist, some recent journal articles shine light on considerations that an informed consumer might entertain before purchasing crystals or gemstones. *The New Republic*'s "Do you know where your healing crystals come from?" (2018), *The Guardian*'s "Are healing crystals the new blood diamonds?" (2019), and *The Years Project*'s "Are crystals sustainable?" (2022) highlight the fact that it is not possible to separate a discussion of the practices of the crystal mining industry from a discussion of the open pit and strip-mining techniques used in the harvesting of rare-earth metals such as copper, iron, gold, copper, and cobalt [11, 12, 13]. As the crystal bowls themselves are by-products of the semiconductor industry; so, too, are quartz deposits a by-product of industrial efforts, in this case the search for precious metals: "alongside the gold [or other metals], miners often find seams of jewelry-grade crystals as they excavate huge swaths of land" [11]. Within this context, there is no shortage of evidence that human rights and labor violations, as well as abject disregard for environmental sustainability, are the norm; and "ethical" mines the exception.

All three articles mention pressure placed on the company Goop by its consumers in the form of an online petition [14] asking the trendsetting brand to take action to source its crystals ethically [11, 12, 13]. The public pressure placed on this high-profile company points to a wider trend among both large and small crystal resellers to ignore, gloss over, or minimize the importance of traceability, transparency, and ethical mining practices as a part of their sales pitch. There are, however, exceptions to this trend — resellers who've made ethical practice a selling point of their brands. Julie Abouzelof of Moonrise Crystals has an entire section of her website devoted to education on ethical practices in the crystal industry. She characterizes her approach in the form of a directive: "Do detailed research on geology and mineralogy, the mining and lapidary practices in each region, and the current socio-economic-political situation. Wrestle with ambiguous moral questions" [14].Similarly, Stephen Kacha of Kacha Stones

describes his home crystal-digging operation as "as eco-friendly as mining gets," but notes that "it isn't going to make much of an impact on global trade" [12]. Both retailers acknowledge the difficulty of making an impact when wrestling with the collossal force that is the mining industry, its culture of secrecy, and its history of corrupt labor and environmental practices [13].

Given all of this, it is safe to say one simply cannot be certain of the source of quartz used to create crystal singing bowls. Crystal Tones, a prominent manufacturer in the United States, offers a feeble nod toward the goal of transparency on their website, while also maintaining a characteristic level of vagueness: "Our Crystal Singing Bowls are made with only the purest quartz crystal . . . that is sourced from a location within the United States," they say. They do not name specific mines, regions, or affiliations; nor do they claim alignment with sustainable environmental practices [16]. We do know that in the U.S. many states are home to a handful of small, family-run mines that have little impact on the surrounding environment; and at the same time, we also know that mines in New Mexico, North Carolina, and certainly others have contributed to environmental destabilization as a result of irresponsible land usage practices [15, 17]. Possible negative impacts of such mining operations include soil erosion, water contamination, and habitat and landscape destruction [11, 12, 13].

A further investigation of impacts of crystal mining practices and their relationship to the production, manufacturing, and marketing of crystal singing bowls could be undertaken, but is beyond the scope of this paper. For now, we must rely on the sources quoted herein, and the otherwise unprovable lore that crystals hold onto the energies and intentions of all hands through which they pass. To this end, it would seem that companies selling crystals or creating products using genuine crystals, such as crystal singing bowls, would aim to assure customers that they stand in ethical alignment with environmental and human rights issues. The reality, however, is that quartz crystals are a non-renewable resource harvested all over the planet for wide range of purposes, scientific and spiritual. Regardless of the use-case, it seems to be hardly possible at this time to trace specific crystal sources used in crystal bowl production.

3. COMPOSITIONAL INQUIRIES

Having undertaken the above discussion on the origins, sonic properties, and intended usages of crystal singing bowls, it is now possible for the reader to consider the metaphorical, metaphysical, and literal implications of the author's use of the shards of broken crystal singing bowls as musical instruments in themselves, with functionalities different from, yet related to, those of intact crystal singing bowls. To make room for such consideration, a first-person anecdotal summary of the author's work with crystal singing bowls and their broken shards follows. This summary accounts for the development of an expanded sonic language for the use of crystal singing bowls in combination with hardware electronics and computer music practices, which ultimately led to the creation of the shard-speakers.

Crushed Matrices is a serial composition that explores sonic atmospheres using crystal singing bowls, the shards of broken crystal singing bowls, and electronics. Its title harkens from a conversation I had with the mystic Susan Isabelle, who identified herself to me as a practicing psychic and Keeper of the 13th Mayan Crystal Skull. Susan Isabelle owns a metaphysical shop housed in a former gas station in Mount Shasta, CA, which sells bronze singing bowls, crystals, and other metaphysical objects. She told me that my newly-purchased crystal bowls, acquired at a nearby shop in town, would eventually break, as the process of crushing quartz into fine powder, casting it with resin, and spinning into a bowl had the effect of weakening or undermining the strength of the quartz crystal's natural hexagonal matrices. Regardless of the veracity of this statement, I would later return to this description for artistic inspiration.

Within four months of sonic experimentation with my first set of bowls, Susan Isabelle's proclamation became prophesy: During a generative rehearsal session for an improvisational electroacoustic work, I accidentally created hairline cracks in my two bowls by tossing small hematite magnets, coins, and other small metal objects into them for percussive effect.

Shortly after my initial moment of devastation, my teacher Laetitia Sonami suggested that I use the shards in a performance. Her proposition, rooted in our shared lineage of DIY and experimental instrument-building practices, prompted the creation my first work using the shards of broken crystal singing bowls in coordination with computer electronics.

3.1 *Crushed Matrices #1*

This was a live electroacoustic performance given as a part of an informal performance series/open mic, "Thursday Night Special," at Mills College in Oakland, CA, 2017. This constituted my first performance using a contact microphone affixed to one shard of a crystal singing bowl, and another shard scraping against it. These sounds were processed through a custom-built quad delay and frequency shifter/ring modulator progammed in Max/MSP. The work was not recorded.

3.2 *Crushed Matrices #2*

This was a recorded quadraphonic work created at Mills College in Oakland, CA, 2017. The previous iteration of the work revealed the sonic limitations of the contact microphone, which effectively filtered out the shards' high-frequency "frosted" texture. I wanted to utilize this timbral feature of the shards, so for this iteration of the work I foregrounded those granular textures by using stereo miking techniques to capture the variety of sounds achievable through scraping and crunching the frosted sides together, as well as balancing the shards atop one another and "teetering" them. To capture a sense of the motion required to produce such sounds, I experimented with two stereo close-miking techniques — two AKG C451 B small-diaphragm condenser microphones in an X-Y configuration, and two AKG C414 XLII large-diaphram condenser microphones positioned in a Blumlein pair — and moved between the microphones in active performance with the shards. The resulting sounds are evocative, to me, of wind and ice. These qualities which were brought forward using filtering and EQ in the final mix.

The work also features the sounds of the Tocante Zenert [19], an invention of Peter Blasser which is a handheld, touch-based solar-powered electronic instrument emitting filtered noise from an embedded speaker. The presence of the embedded speaker allowed this instrument to be recorded using the same miking techniques described above, creating the illusion of the Tocante as a stereo instrument without the performative hindrance of a wire.

The way I generated acoustic sounds with the shards is directly borne of my experience as an electronic music composer: I would not have imagined the sound-world created by the scraped shards if I had not previously worked with "dirty" analog signals and filtered noise as mediums in the electronic music studio. Thus, it seemed appropriate to include both together, as distinct voices in a piece.

This work was recorded in the Pauline Oliveros room at Mills College. Although originally intended for a quadraphonic array, a stereo mixdown was featured on Reality Tunnels (Idle Chatter #005), a cassette compilation curated by my colleague Muyassar Kurdi for Fabrica Records (see Appendix).

3.3 *Crushed Matrices #3*

This was a live classroom performance in a composition seminar taught by Zeena Parkins at Mills College, 2017. This live performance represented an attempt to integrate the sonic worlds unlocked in *Crushed Matrices #2* with my live performance practice, which draws heavily upon improvisation and unpredictable noise-emitting rituals. To this end, I used both a contact microphone on a shard and "plein air" miking techniques previously discovered in the studio, along with

recorded samples of intact bowls and live-manipulated microphone feedback. This performance was not recorded.

3.4 *Crushed Matrices #4*

One of the most adventurous iterations, this was a live bowl-breaking ritual performed in Mills College's Greek Amphitheater in Oakland, CA, May 2018. In the only fully acoustic iteration of *Crushed Matrices*, I made use of the amphitheater's sonic qualities. At this point, I felt I had to "finish" breaking apart some of the larger pieces of the bowls I'd broken and used in previous iterations of the work, in order to pack more efficiently for their shipment back to New York via Amtrak Express. I did not feel it was appropriate or respectful to the crystal bowls to do this without some degree of ceremony, so I organized a final performance at Mills (which also marked my last performance before graduation from their MFA in Electronic Music and Recording Media program).

For this performance, Sally Decker created drones on intact singing bowls while I dragged, scraped, knocked, and (gently) kicked singing bowls that were already partially-broken, intermittently causing them to break further throughout the duration of the roughly 20-minute performance. The smaller shards that were created during the performance were placed in ad-hoc groupings, and struck against one another to perform improvised melodies. The scales of these melodies were determined by the size and shape of each shard.

The performance took place during sunset, beginning in sunlight and ending in darkness. Darkness exposed the fact that the shards acted like flint for starting a friction fire, igniting visible sparks as they were scraped against the rough concrete floor of the amphitheater.

An archival videorecording exists of this work (see Appendix).

3.5 *Crushed Matrices #5*

This was a live electroacoustic performance given at Basilica Hudson's annual 24-Hour Drone event. The event invites audience members to settle in with sleeping bags overnight for a 24-hour performance marathon. I performed with my collaborator, Blue, at 7 AM, after music had been going on since noon the previous day. I set up my electronics and intact singing bowls in the center of the room and played them through various effects programmed in Max/MSP. Blue dragged shards around the empty aisles of the performance space, attaching them to their body to yield bell-like drones that seemed to fling around the space in a sort of organic spatial surround. The unamplified sound of the dragged shards was surprisingly loud in the concrete warehouse space, singing and screeching in concert with my electronics. The venue was effectively cast as a gigantic performance interface. Our performance was serendipitously joined by morning birds, which were captured in my microphone's delay line, adding a welcome ecological aspect that contributed to the organic-industrial quality of the work.

Electronic sounds used in this performance introduced for the first time some custom-built digital instruments and effects that have since become hallmarks of my language: Firstly, the work was underscored by "Noise Bath Sound Party," a digital instrument that subjects two channels of filtered noise and four sine tones through a series of tremolo-like VCAs run at rates anywhere from 0.1–12 hz, providing endless options for rhythmic variation.

Secondly, I made use of an amplitude-reactive, crassly inaccurate pitch-following synthesizer, "Env Flow," programmed in Max/MSP, intended to mimic the timbral qualities of the intact crystal singing bowls being gently struck with a mallet, while also providing a sense of discord and "out of tune"-ness that two intact fixed-pitch bowls alone could not provide. Env Flow allowed me to create more bowl-like sounds without actually buying, carrying, or needing space for more bowls.

Lastly, I routed the microphone signal from the intact crystal singing bowls through a delay patch with four delay lines. Each iteration of delay could be transposed using a list of MIDI values that could be edited on the fly. The effect also includes options for changing tempo divisions, cutoff and resonance on a variable low/high/bandpass filter, and an option to auto-modulate delay time using sample-and-hold. This custom effect was later dubbed the "Robust Sequential Trans-Delay," which turned the steady drone of the intact singing bowls into often-slow, melodic, tonal arpeggiations.

A MIDI controller with faders and potentiometers was used to perform parameter changes on all of these effects, and to mix between them.

This 60-minute iteration of *Crushed Matrices* was audiorecorded, and some short video excerpts exist (see Appendix).

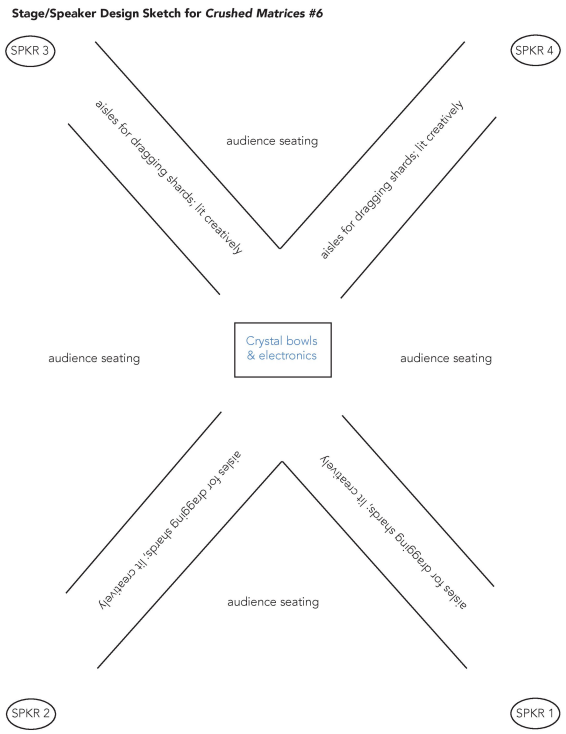

Figure 3. Floor plan derived from the Crushed Matrices #5 (created after the performance, as a proposal for a future performance).

Figure 4. Blue dragging shards (attached to strands of mylar tape) down the aisles of Basilica Hudson.

3.6 *Crushed Matrices #6*

This was the final performance in the episodic series. It constituted a live electroacoustic performance at The Old Stone House Musical Ecologies Series in Brooklyn, NY, 2019. For this performance, elements of *Crushed Matrices* were effectively woven with fragments

from two programmatic works, *Self/Work* and *LHTBAILHTDAAMI,* serving as the conceptual as well as sonic "glue" for this meta-performance. One could think of this performance as an instance of three works happening simultaneously, weaving in and out of one another in search of new ways to relate distinct sonic vocabularies.

Indeed, *Crushed Matrices* as an episodic performative investigation dissolved at this point into the rest of my work. Work with the singing bowls, and the digital instruments inspired by and/or created for them, had become an integral part of my compositional language.

A videorecording exists of this performance (see Appendix).

4. SHARD-SPEAKERS

In late 2021, I was offered an opportunity to exhibit my sound art work in a group gallery show. Since 2019 I had been entertaining the idea to turn the shards into speakers, which would take a hybrid form as sculptures, playback devices, and electroacoustic instruments, depending on use case. I acquired a range of inexpensive tactile "puck" or "frog" transducers from Dynaudio and Tectonic, and built several LM386 amplifiers to drive them (until realizing it was more cost-effective to purchase four LePai LP-2020A Class-D amplifiers to do the same job). I affixed the transducers to the frosted, convex side of the shards using epoxy resin to adhere them.

Figure 5. An 8 Ohm "Frog" transducer by Tectonic, adhered to the frosted side of an 11 inch shard.

Once affixed, the transducers became a base for balancing the shards, polished- and concave-side up, emulating a speaker cone (Figure 1).

The next problem to solve involved finding appropriate resonators upon which the transducers and shards could sit. Early in my composing process, I began using plastic storage totes flipped upside down. I quickly noticed that the flexibility of this material encouraged visible bouncing and vibration of the shards on top of the transducers, which I found compelling and playful — but I also didn't want the shards to bounce so much that they would travel on their pedestals, and potentially fall off and break. To solve for this problem, I attached 3M Dual-Lock tape (similar to Velcro, but made of a harder plastic) to the backs of the transducers, and to the surface of the resonators, so that the shards could be snapped on/off of any objects used as resonators. With this simple innovation, the shards could now occupy a stationary position on the surface of their resonators, while also having the literal "wiggle room" necessary to achieve the desired sonic, design, and engineering goals. The use of the Dual-Lock tape also made it easy to disassemble the setup for safer transport of the materials.

At the time of writing, it is important to me that I do not become attached to any one type of resonator for these shards, and that I do not attach myself to any particular shards themselves (as there are many to choose from). By remaining open to different material configurations, I am able to continually explore new acoustic, spatial, and visual terrain each time the installation is mounted. From a logistical standpoint, I do not have to store the resonators in my small studio; nor ship them over large distances when touring the work.

For the first installation of this work in 2022, I sourced a discarded media console shelf, which I found on the street on the way to the gallery. I turned the console on its side (with the closed thin chipboard back facing up, open shelves facing the floor), wrapped it neatly in duvetene, and cut 4 small slits in the duvetene corresponding to the desired locations of the shards, under which I ran speaker wire and affixed the 3M Dual-Lock tape for attaching the shards. I then elevated the console on six bricks, resulting in a functional resonator that could hold all four shards (Figure 6).

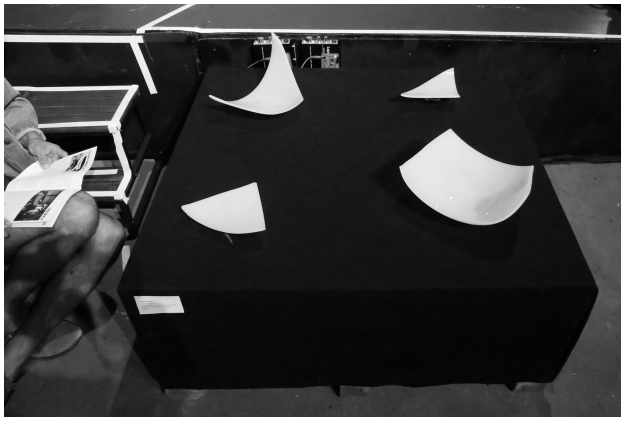

Figure 6. Shard-speakers on single resonator for *Grave New World* at C-Squat, New York City, July 2022.

The work was shown as an installation again in 2023 (Figure 7). For this show, presented in a white-walled gallery, I arranged to borrow from the venue four hollow white pedestals of varying shapes and sizes. Upon arrival, I intuitively set up the pedestals and shards in an ad hoc arrangement. For part of the evening, I performed with additional electronics stationed on a taller pedestal behind the installation.

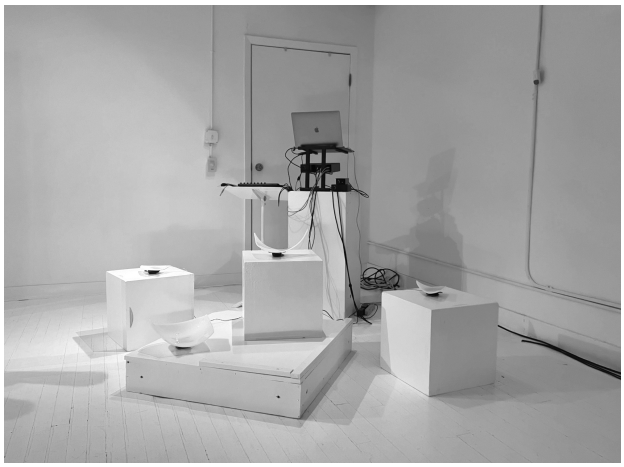

Figure 7. Shard-speakers bathed in pink light, for *Haptic Drift* at TheaterLab, New York City, March 2023.

4.1 *Ode on Crushed Matrices*

Ode on Crushed Matrices is the name of a four-channel audio work composed specifically for playback on four shard-speakers, which was shown at both *Grave New World* (Figure 6) and *Haptic Drift* (Figure 7).

Although it was important to me to integrate and acknowledge the discoveries of *Crushed Matrices* in developing the essential sonic vocabulary for this installation, the new design and sonic possibilities also prompted the building of a new instrument in Max/MSP which provides the rhythmic, transient attacks that drive most of this composition. The "Click Delays" — now a Max for Live instrument — use the self-noise of an LFO-controlled bandpass filter sweep sent

through multiple delay lines, chained in series, to create feedback that results in polyrhythmic clicking. Placing two instantiations of this instrument against one another and assigning them to left and right channels, the instrument functions in stereo to create danceable grooves. I then created a 90-minute stereo soundscape featuring three sections of Click Delays, interspliced with two sections of field recordings (rain on a pizza box, backdropped by spring peepers) and a section of intact crystal singing bowl drones; and turned this into two different, unsynced soundscapes by exporting the mix at its mid-point (45 minutes), and swapping the order of two halves to yield four channels of audio. I loaded the pair of stereo recordings onto a pair of robertsonics WAV trigger cards, and fed the audio into two LePai amplifiers from the WAV triggers via 3.5mm stereo audio cables. The result is a lightweight, portable, scalable multichannel sound installation that travels and packs well, has easily replaceable parts, and can be powered on just three AC adapters.

5. CONCLUSION

The shard-speakers are decidedly a Frugal Music Innovation, relating to at least three of the core competencies set forth by the Frugal Innovation Hub at Santa Clara University, California [18]. They exemplefy adaptability in their approach to re-purposing "broken" materials, and in the author's approach to creating evolutionary work with the shards of crystal singing bowls in general; mobility in their emphasis on creating a lightweight and portable setup; green/local sourcing in their commitment to finding large resonators close to installation sites rather than investing in ground or air transport of custom art objects; affordability in that the electronic parts used to create the shard-speakers were purchased for under $300 USD; and ruggedness in that the shards are used exactly as they came – there has been no extra sanding applied to their edges, no polishing, no adjustment at all to the materials. Everything is handmade, and the entire process can be reproduced easily to create more sets of shard-speakers.

6. ETHICAL STANDARDS

This work is not funded, and the author is not aware of any potential conflicts of interest.

Though edges appear sharp, the instruments described in this paper are not sharp enough to cause injuries without a significant application of force; and have not caused any known injuries to persons or animals.

7. REFERENCES

[1] "Sound Healing With Crystal Bowls Certified Online Course," *Academy of Sound Healing*. https://academyofsoundhealing.com/online-course-level-1-foundation-certificate-sound-healing-with-crystal-bowls (accessed Jan. 31, 2023).

[2] "Crystal Singing Bowl Practitioner Certification Program," *The Om Shoppe and Spa*. https://theomshoppeandspa.com/classes-and-events/crystal-singing-bowl-practitioner-level-one/ (accessed Jan. 30, 2023).

[3] Z. Seraphine, "Crystal Singing Bowl Practitioner Certification Program." *Quantum Resonance Productions*, 2020. https://zenseraphine.com/csb-practitioner-certification-program (accessed January 20 2023).

[4] Z. Seraphine, "The Ultimate Guide to Clearing Your Chakras With Crystal Singing Bowls." *The OM Shoppe and Spa*. https://www.theomshoppe.com/the-ultimate-guide-to-clearing-your-chakras-with-crystal-singing-bowls/ (accessed January 20 2023).

[5] "Crystal Singing Bowls and Chakra Balancing" *Crystal Tones*. https://www.crystalsingingbowls.com/chakra-balance.htm (accessed Jan. 30, 2023).

[6] S. Rose, "What Are Crystal Singing Bowls?" *Crystal Tones*, 1999. https://www.crystalsingingbowls.com/cms/index.php/what-are-crystal-singing-bowls/ (accessed January 30 2023).

[7] "Crystal Singing Bowls: The Complete Guide (Updated 2022)," *Shanti Bowl*, 2022. https://www.shantibowl.com/blogs/blog/the-definitive-guide-to-crystal-singing-bowls (accessed Jan. 30, 2023).

[8] "History and Development of the Crystal Singing Bowls," *CRYSTAL SINGING BOWLS UK*. https://www.crystal-singing-bowls.co.uk/history-and-development (accessed Jan. 31, 2023).

[9] Blackburn, Z. "A Short History and Introduction to Crystal Bowls." *Sunreed Instruments*. https://sunreed.com/a-short-history-and-introduction-to-crystal-bowls/ (accessed Jan. 30, 2023).

[10] G. Müller, J. Friedrich, *Encyclopedia of Condensed Matter Physics*, Amsterdam: Elsevier, 2005, pp. 262-274. Accessed: January 30 2023 [Online]. Available: https://www.sciencedirect.com/topics/chemistry/czochralski-process

[11] Atkin, E. "Do You Know Where Your Healing Crystals Come From?" *The New Republic*, 2018. https://newrepublic.com/article/148190/know-healing-crystals-come-from (accessed Jan. 30, 2023).

[12] E. Wiseman, "Are crystals the new blood diamonds?," *The Guardian*, Jun. 16, 2019. https://www.theguardian.com/global/2019/jun/16/are-crystals-the-new-blood-diamonds-the-truth-about-muky-business-of-healing-stones (accessed Jan. 30, 2023).

[13] G. Sotelo, "Are crystals sustainable?" *The Years Project*, 2022. https://theyearsproject.com/latest/are-crystals-sustainable (accessed January 20 2023).

[14] "Demand Goop Sell Ethically-Sourced Healing Crystals!" *Care2 Team*, 2018. https://www.thepetitionsite.com/610/572/227/demand-goop-sells-ethical-crystals/ (accessed Jan. 30, 2023)

[15] Abouzelof, J. "Why Are Ethical Crystals So Hard to Find? Confronting the Dark Side of the Healing Stone Industry," *Moonrise Crystals*. https://moonrisecrystals.com/ethical-crystals-hard-to-find/ (accessed Jan. 30, 2023).

[16] "Made in the USA." *Crystal Tones*. https://www.crystalsingingbowls.com/cms/index.php/madeinusa/ (accessed Jan. 30, 2023).

[17] "SELC holds quartz mine accountable for pollution to trout stream," *Southern Environmental Law Center*, 2015. https://www.southernenvironment.org/news/selc-holds-quartz-mine-accountable-for-pollution-to-trout-stream/ (accessed Jan. 30, 2023).

[18] "About Us - School of Engineering - Santa Clara University," *Santa Clara University*. https://www.scu.edu/engineering/labs--research/labs/frugal-innovation-hub/about-us/ (accessed Jan. 30, 2023).

[19] P. Blasser. "Uses of Zener Noise," *YouTube*, 28 May 2015. https://www.youtube.com/watch?v=ZxYhwLglky4 (accessed Apr. 7, 2023).

[20] A. Clarke, "Crushed Matrices 2019." http://bit.ly/40OmRlp (accessed Apr. 7, 2023).

8. APPENDIX

Audiovisual documentation for various iterations of *Crushed Matrices* and *Shard-Speakers* can be found on the author's portfolio website at https://anastasiaclarke.info, or at the following URLs: http://bit.ly/40OmRlp (*Crushed Matrices*), http://bit.ly/3zI1C8O (*Shard-Speakers*).