Towards Physical Manifestations of Light in Kinetic Art

An exegesis presented in partial fulfilment of the requirements for the degree of

Master
of
Creative Enterprise

at Massey University, Wellington,
New Zealand

Kaysha Anne Bowler

2019

Abstract

This exegesis explores the development of kinetic art that focuses on giving life to physical light sources through the design and implementation of custom-built light systems. By reviewing three significant fields: audiovisual art, kineticism and custom performance technologies, a trend was identified which emphasises the physicality of art and technology. Custom-built fibre optic light systems have been developed to physicalise LEDs (Light Emitting Diodes), evoking tangible and visceral experiences of kinetic audiovisual art. Two new works, *ether* and *expanse*, have been developed for application within the realm of live music performance. Key applications, installation and performance, are discussed, providing context to the novel and immersive experiences evoked by the works through their modular design.

Acknowledgements

This is by no means an exhaustive list, as there are many people who I wish to thank, for without their support this research would not have been possible.

To my supervisors, Dr Bridget Johnson, Dr Jon He and Dr Mo H. Zareei. Thank you for the encouragement, guidance, patience and support throughout this process. Words cannot express the gratitude I hold for the lessons, advice, knowledge and wisdom that you have all given me. Bridget, thank you for pushing me to succeed and for showing me that the answer is always in the art. Jon, thank you for your patience and for opening my mind to new ideas. Mo, thank you for insight and inspiration. You have all had such a massive contribution towards my development as an artist. For this, I am extremely grateful.

To Andre Ktori. Thank you for your patience, your kindness and for always encouraging me to look beyond the horizon.

To Dr Catherine Hoad. Thank you for opening my mind, for always encouraging me, for your wisdom, and for helping me to see something that I couldn't see in myself. Thank you for exchanging cat memes of the highest calibre.

To Birgit Bachler and Dr Blake Johnston. Thanks for your advice, encouragement, endless support and for always providing top quality banter.

To Jonny McGregor and Callum Campbell. Thank you for being a part of this epic journey, for being co-creators of the spiciest memes, and most importantly, for being my fellow co-founding members of *The Jalas Foundation*. May our legacy touch the lives of many.

To Estère Dalton. Thank you for your friendship, inspiration, support and collaboration. I look forward to our work together in the future.

To Sabrina Lawson, Autumn Yuill Proctor and Crystal Phillips. Thank you for being the greatest of friends, for the Bunnings, Jaycar and coffee/lunch dates, for motivating me throughout the process of this research, for proof-reading my work and for always looking out for me. May we forever reign the dirty lab, and may it always remain dirty (until I clean up my mess that is).

To Kelly Moneymaker. Thank you for your wicked sense of humour, your authenticity, for always having my back and for being a wonderful and vibrant divine being. I'm incredibly grateful to have you as one of my closest friends.

To Ethan Thompson. Thanks for your friendship, for dedication towards documenting my work, and helping during the final sprint. Thank you for always keeping me on my toes, and for reciprocating my extremely dry sense of humour.

To my big brothers: Royce, Jemal, Bren and Tyrone. Thank you for teaching me to be brave, for looking out for me over the years, and for shaping me into the woman I am today.

To Jemal. Your compassion, inspiration and support made the biggest difference during this past year of growth. Thank you for being my rock and for being there for me when I felt like no one else was. Shine on, you crazy windmill.

To my parents, Christine and David. Thanks for being amongst my best teachers in life, and for your support throughout my studies. Thank you for letting me walk my own path into myself, even if you didn't understand or agree with my life decisions. Thank you for all of the sacrifices you've both made for me over the years; nothing you do goes unnoticed.

To Mum. You will always hold a special place in my being. I'm incredibly lucky to have you as my biggest supporter, my best friend, and my mother. Thank you for your quirky sense of humour, for your strength, for encouraging me to be myself, and for always believing in me.

To Princess. Thank you for being a part of this new chapter of my life, and for always being by my side. You are truly unconditional and bring so much love, light and joy into my life. Even though you can't read this, never cease being brrrrrtiful.

To Jack Purvis. This would have been extremely hard to complete without your encouragement, motivation, positivity and support during the final stretch. Thank you for making everything brighter, for being *wonderful* and for making the little things matter the most. I look forward to spending more time with you.

For Margaret Roberts,

"Resting where no shadows fall."

Table of Contents

List of Figures

Chapter One
Introduction

Light is the visual entity that pervades many aspects of our lives. Recent advancements of technology have extended the capabilities, impact and experience of live musical performances through the development of kinematics, and customised performance technology. This technology often involves developing customised systems that nuance the control of mediums, such as light and sound, enabling artists to give life to objects and mediums through the incorporation of kineticism. This exegesis explores the development of two new works, *ether* and *expanse*, that use fibre optic cables to physicalise LEDs (Light Emitting Diodes) in audiovisual and kinetic applications. In realising this, new experiences are crafted through the development of fibre optic light systems that focus on giving life to physical light sources through the design and implementation of kinetic and mechatronic systems.

1.1 Motivation

As an audiovisual artist, my creative practice is informed by both elements of light and sound. During my undergraduate degree, I was introduced to new forms of music technology and the practice of lighting music. My musical background has informed my approach towards lighting design, allowing me to treat light as a dynamic performative element, akin to that of a musical instrument. This experience led me to create art that utilised both light and sound, to craft immersive and dynamic audiovisual experiences. I was seeking an alternative approach to creating audiovisual works that evoke visceral experiences. As audiovisual art is commonly

experienced digitally, kineticism proved to be an exciting avenue to explore alternate forms of audiovisual art that uses physical elements of light.

1.2 Research Objectives

The main research objectives of this exegesis were developed based on the motivation laid out above in Section 1.1.

The research objectives behind this project are:

- to use mechatronic and kinetic systems to give life to physical light sources,
- to provide new immersive experiences of kinetic art.

With these research objectives in mind, this exegesis aims to present new visceral experiences of audiovisual art to the field through the development of custom performance technology.

1.3 Exegesis Outline

This exegesis presents the process of developing two new works, *ether* and *expanse*. Chapter Two presents a review of three fields that have informed the creative work: audiovisual art, kineticism and custom performance technologies, which in conjunction provide a platform for the creative work to exist. Chapter Three presents *ether, expanse*, and the methodology used during the process of developing these works. Chapter Four discusses artistic applications of *ether* and *expanse*, applying the work in different fields and offering insights into how the work has been applied, configured, contextualised, and may be improved in the future. Chapter Five summarises the ideas presented in this exegesis and reflects on the state of the field now that *ether* and *expanse* have been developed.

Chapter Two
Related Works

This chapter explores significant related works that inspired and influenced the creative work presented in this document across three fields: audiovisual art, kineticism, and custom performance technologies. In combination, these three fields informed the multi-disciplinary nature of the creative work developed during the course of this research.

2.1 Audiovisual Art

Audiovisual art is a practice that commonly takes place in the digital world, where it takes a screen-based or non-physical form. Digital modes of presentation provide experiences that remain intangible, often neglecting interactions within the physical world through the use of screens, projectors and lasers. Works by artists such as Ryoji Ikeda[1], Alva Noto[2] and João Martinho Moura[3] often utilise this digital nature of presentation. Much audiovisual literature considers the visual element to be projection-based, consisting of image, animation and video content; resulting in physical light sources, such as LEDs, as being less prominent. This section explores audiovisual art and the interactive properties that it possesses, discussing significant audiovisual works that utilise two main interactive concepts, the ‘audiovisual illusion,’ and ‘synchresis.’

---

[1] http://www.ryojiikeda.com

[2] http://www.alvanoto.com

[3] http://www.jmartinho.net

2.1.1 Audiovisual Interaction

The nature of audiovisual art suggests a close proximity between audio and visual elements. Ian Andrews suggests that audiovisual indicates a performance practice, rather than a fixed media setting as the audiovisual practice refers to its sonic counterpart, with tension, release, and suspended expectation being inherent to its language [1]. This sub-section will discuss two significant interactive audiovisual elements: ‘synchresis’ and the ‘audiovisual illusion.’

The ‘audiovisual illusion’ is when the audience accepts that there is no direct interaction between the audio and visual elements on a sub-conscious level. Maloney proposes that this ‘illusion’ effects the audience by allowing them to “approach their listening (in cinema and in audiovisual performance) with the idea that there is a purposeful, or even real, link between sound and image” [2]. If the audience presumes that the combination of the two mediums is purposeful, then this will sub-consciously shape their perception of the experience. This illusion refers to the sensory modalities have opposing or different structural behaviours within a piece. *Wave V.1* (Figure 1) by NONOTAK Studio [3] is an audiovisual installation that embodies the ‘audiovisual illusion'. The sonic textures and dimensions of the piece are not in cohesion with the visual narrative of projected light, resulting in a disjointed sense of audiovisual interaction. However, this illusion does not subtract interest and impact of the experience. Instead, this illusion only becomes prominent if the audience is actively seeking a deeper meaning within the audiovisual relationship.

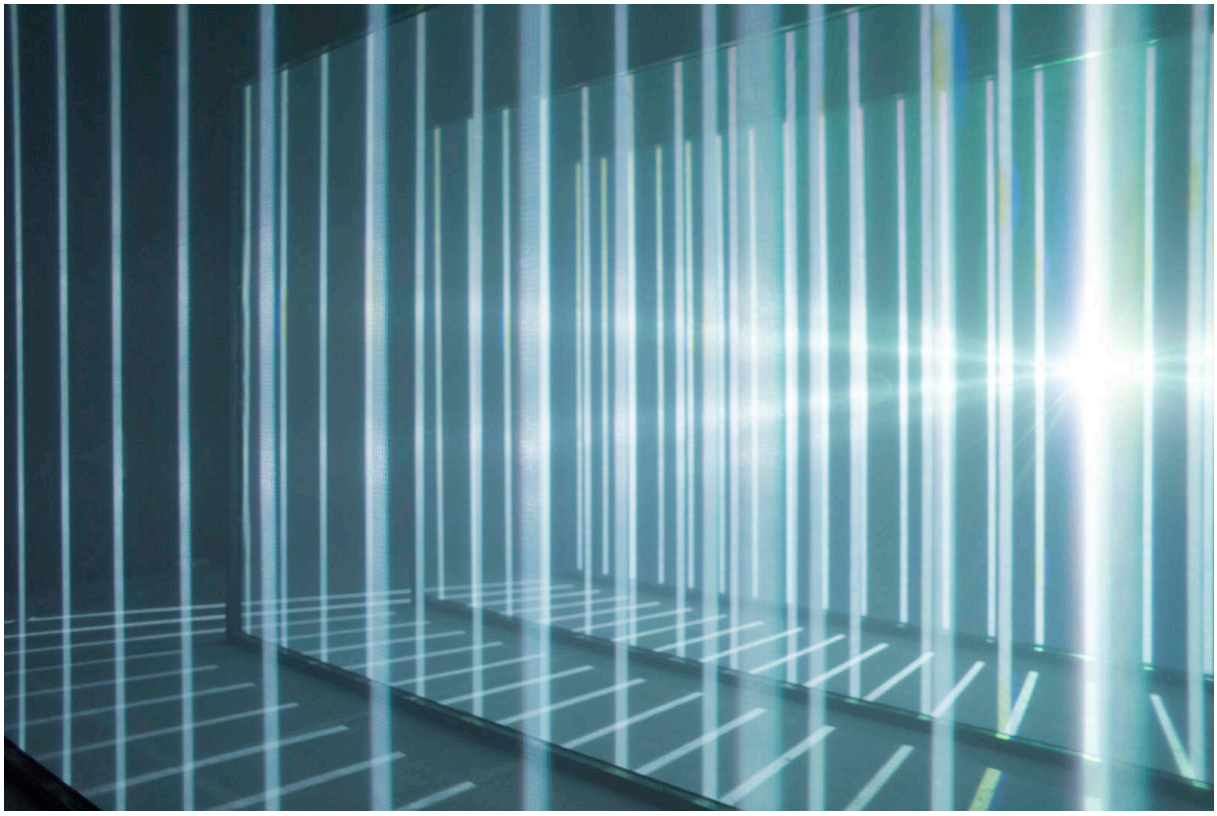

Figure 1. *Wave* audiovisual installation [3]

Michel Chion's *Audio-Vision: Sound on Screen* presents audiovisual concepts contextualised within the realm of film sound theory. However, these concepts are readily translatable to other fields that are central to the audiovisual experience. Chion asserts that auditory and visual elements in combination give rise to meanings that would not otherwise exist, resulting in a mode of perception transcending the experience of a singular sensory modality [4]. 'Synchresis' is a term coined by Chion, referring to the occurrence of auditory and visual phenomenon at the same time. Nicolas Bernier's *frequencies (light quanta)* (Figure 2) is an audiovisual installation that consists of 100 edge-lit acrylic panels with laser etched graphics [5]. *frequencies (light quanta)* uses synchresis to animate the graphic panels as a computer-based algorithm triggers and synchronises short bursts of light and sound. Another example where this 'synchresis' is at the core is *interference [dac],* an audiovisual installation by Technical Earth, the collaboration between Jim Murphy and Mo Zareei [6]. Through loudspeaker-mounted mini projectors, sound waves interrupt the projection of light waves as the speaker cone rattles, providing a tight

synchronisation between the two modalities. Through ‘synchresis,' both *frequencies (light quanta) and interference [dac]* possess strong and engaging audiovisual narratives through tight synchronisation between audio and visual elements. ‘Synchresis’ and the ’audiovisual illusion’ are concepts that will be kept in mind when developing and presenting the creative work.

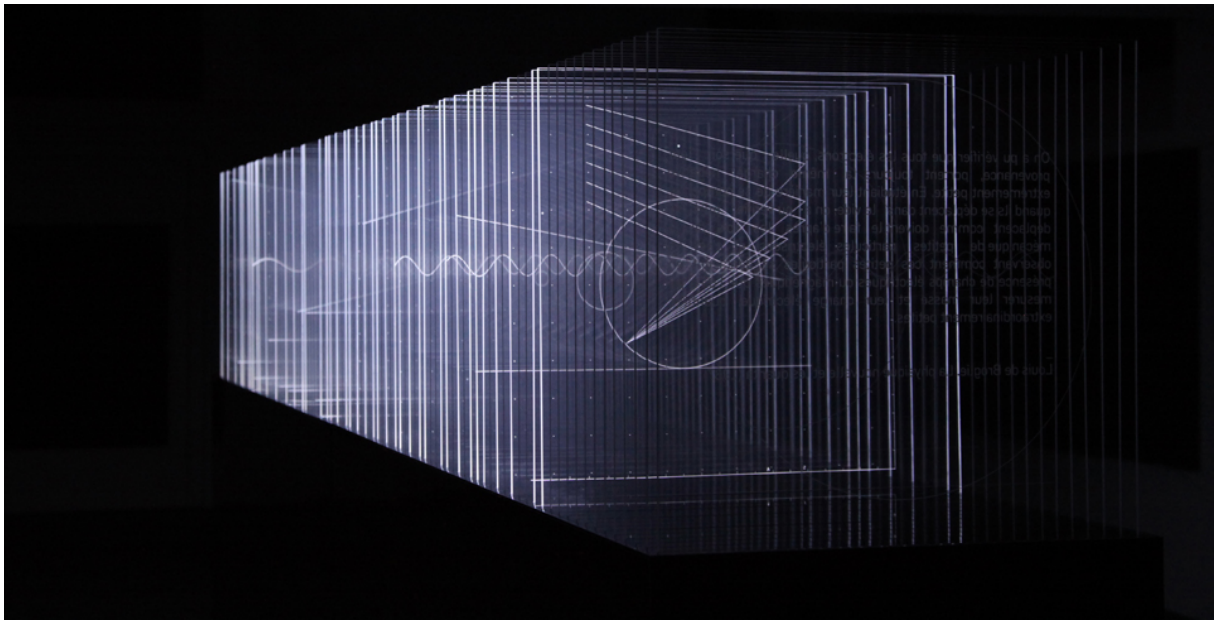

Figure 2: *frequencies (light quanta),* 100 edge-lit acrylic panels with etched graphics [7]

2.2 Kineticism

Kineticism is a form of art that relies on motion for effect. Kinetic art was notably popularised in the mid-twentieth century with developments allowing for nuanced control of characteristics of light and sound. A particular approach within kinetic art is the utilisation of motors, actuators and electromagnetic tools to afford artistic expression by generating movement with mechanical systems. Artists such as Trimpin[4], Zimoun[5] and Pe Lang[6] have incorporated kineticism into their work through their use of electromechanical components.

[4] https://www.foundationforcontemporaryarts.org/recipients/trimpin

[5] https://www.zimoun.net

[6] https://www.pelang.ch

The widespread availability and affordability of micro-controllers, such as Arduino and similar, have equipped artists with the ability to create their own custom tools to further their artistic pursuits. Arduino systems "readily afford non-engineers the ability to explore mechatronic systems, allowing relatively untrained artists to create musical robotic works" [8]. Organisations like NIME[7] (New Interfaces for Musical Expression) explore the development of musical robotics, instruments, interfaces and immersive technology that furthers the pursuits of musical artists.

Seminal artist Trimpin explores sonic expression through his use of mechanical systems. *Klompen* allows extended rhythmic control over a large-scale installation of clogs equipped with solenoids. *Der Ring* (Figure 3) is a large-scale kinetic installation that uses electromechanical components to afford motion, giving the illusion of perpetual motion and creating a doppler sound effect [9]. Through his use of electromechanical technologies, Trimpin was able to visualise, control and interact with sounds and sound sources within his works in new ways. This provides musicality to objects that are not often observed in musical contexts through the combination of everyday objects and MIDI (Musical Instrument Digital Interface) controlled electromechanical components.

Following on from Trimpin's work, there was a rise in the field of Musical Robotics, furthering the use of electromechanical components for musical expression. The works of Eric Singer [11] and Godfried-Willem Raes [12] (The Logos Foundation) focused on using actuators for both live performance and installation contexts. Stemming from this work, artists such as Ajay Kapur [13] and Jim Murphy [14] furthered the axes of freedom for expressive control within the field of Musical Robotics. A common thread here is the incorporation of the MIDI protocol, allowing musicians to control and play them as instruments with a familiar musical protocol. Through the combination of mechanical systems and the MIDI protocol, the

[7] https://www.nime.org

physicality of sound objects became a branch within music technology, contributing to new fields, instruments and trends.

Figure 3: Trimpin with *Der Ring,* an electromechanical kinetic sound sculpture [10]

Alongside the developments of musical robotics, Swiss artists Pe Lang and Zimoun developed works which focused on using mechatronics as sound actuators within installations. Their works are large-scale and consist of many sound objects often referred to as prepared DC motors or actuators, attached to materials such as wires, cardboard boxes, wood, and cotton balls [15]. Sound is generated by actuating, hitting and moving these objects within their installations. By presenting their works in installation spaces, they are able to be seen as more than sonic objects, allowing the visual element to also become prominent. *32 prepared d-c motors, 230 light tubes, cardboard boxes 105x105x105 cm* by Hannes Zweifel and Zimoun suspends a grid of 307 cardboard boxes from the ceiling below fixated light tubes [16]. The boxes are connected to DC motors which provide slow

movement, creating evolving light patterns on the floor of the dark room and altering the room's ambience as the boxes move (Figure 4).

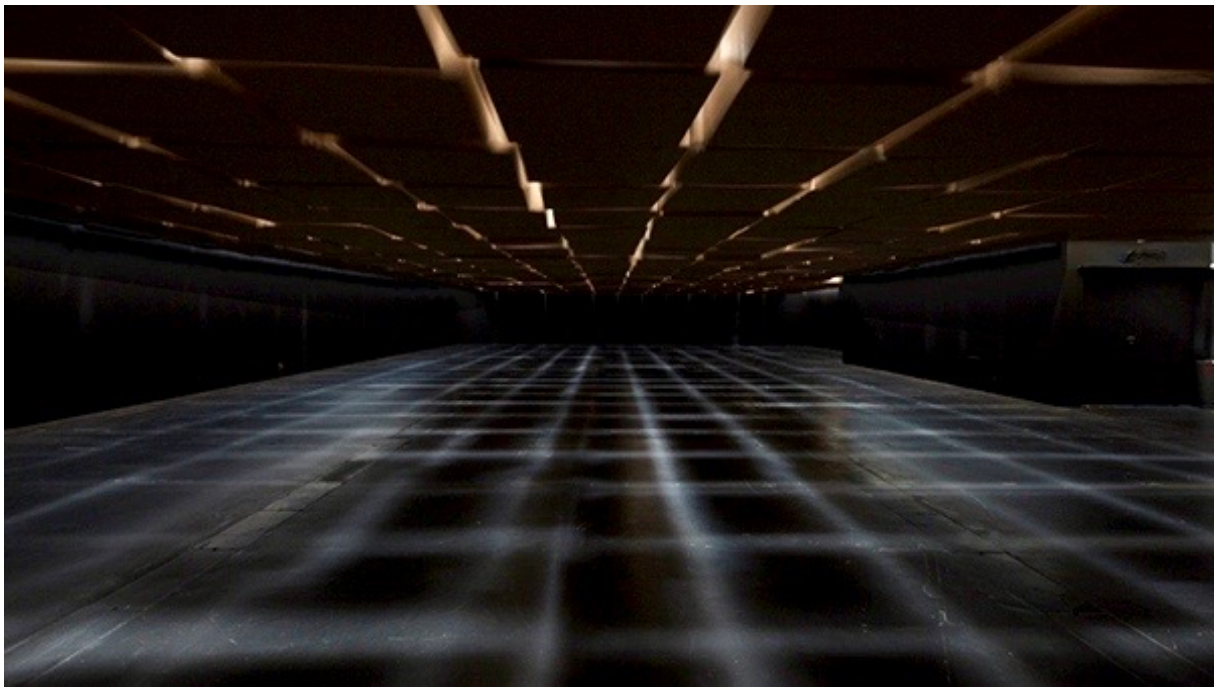

Figure 4: Light patterns within the space of installation, *32 prepared d-c motors, 230 light tubes, cardboard boxes 105x105x105 cm* [15]

The application of kineticism is not limited to music practice; electromechanical technologies have also been explored in sculptural and visual-based works. Jean Tinguely, Len Lye and Takis are amongst many kinetic artists whose works use electromechanical technologies and principles that nuance elements of light and sound. By incorporating elements of kineticism, the experience of their works are enhanced through motion. *Water Whirler* (Figure 5) is a kinetic sculpture in Wellington, New Zealand by artist Len Lye, which creates patterns of motion with water as a revolving pole emits water [17]. Through kineticism, the medium of water is experienced in a different way and brought to life in the context of kinetic art.

Figure 5: *Water Whirler,* kinetic art installation in Wellington Harbour, New Zealand [17]

As another contemporary example involving kineticism and light, *Deep Web* is an immersive kinetic audiovisual installation and performance by WHITEvoid, the collaboration between light artist Christopher Bauder and composer/musician Robert Henke [18]. An amorphous sculpture of light and multidimensional sound is brought to life through kinetic lights and lasers, crafting an immersive and ephemeral sensory experience.

Kineticism has come to be known as an emergent trend in the audiovisual realm. The use of electromechanical technologies to enhance the audiovisual experience through actuation in both performance and installation contexts is becoming prevalent. Kineticism nuances the expressivity and experience of both audio and visual elements through the movement of physical and tangible objects, presenting more immersive and innovative forms of kinetic audiovisual works that intersect digital art with the physical world. This is significant as it will both inform and impact the development of the creative work.

2.3 Custom Performance Technology

The incorporation of light and visual elements is critical to live music practice, which commonly uses extensive lighting rigs, LED screens/walls, and interactive media. The customisation of technology for live music is integral to the performances of musical artists as it attempts to encourage new experiences. Although the development of custom tools for live performance is not a new concept, it has become more relevant and important in recent years due to rapid advancements and the widespread availability of technology and the many affordances that it harnesses. Some of the most notable artists pushing the boundaries with immersive live performances within popular music are Nine Inch Nails, How To Destroy Angels, Sigur Rós, and Bjõrk. Live shows produced by these artists and their production teams incorporate the development of new forms of technology, often manifesting as interactive staging and visual elements.

Custom-built performance technologies are an important aspect to these artists' live shows, as they do not merely use this technology to illuminate the artist. Here, the technology is used to create an extension of the musical performance, that contributes to wider audience engagement. Audience engagement has become increasingly important in recent years due to the rise of the digital age and media streaming, placing a great level of significance on the

experience of live shows. Bergstrom and Lotto assert that artists are able to transcend their performance practice through “using tools that they have largely developed themselves specifically to facilitate each performance at hand” [19].

Moment Factory is a multimedia company that specialises in creating “compelling multimedia worlds” [20]. They played a huge role in defining the live events industry, particularly with their work for Nine Inch Nails’ *Lights In The Sky World Tour.* This tour oversaw the evolution of the music performance stage as a “metaphysical visual extension of the band and their music; an instrument that reacts to the band’s position, movements and intensity” [21]. How To Destroy Angels’ Art Director, Rob Sheridan, became a part of the live performances for their 2013 North American Tour, using light and the stage as his instruments during their performances [22]. A mechanised structure of surgical tubing was developed for these shows (Figure 6), which acted as a wall between the artists and the audience. Sheridan projected light onto this structure during their performances, and was also responsible for moving the structure, which has changed the way that the stage and set design are used in live music shows.

Figure 6: How To Destroy Angels’ surgical tubed projection curtain onstage [22]

To look to another example, Bjõrk's *Cornucopia* is a theatrical live show developed in collaboration with other artists, musicians and designers, presenting her live music in a unique sci-fi pop theatrical music concert [23]. *Cornucopia* incorporates scenography, digital art, stage design and costume design to craft interesting, exclusive and exciting experiences. Designer Iris Van Herpen and light artist Nick Verstand made *Sphaera* (Figure 7*)*, a dress that acts as a visual aura around Bjõrk during the show, turning bioluminescent at specific moments. Through bioluminescence, *Sphaera* adds visual interest to Bjõrk's costume, and sparks a new trend within performance costume design. This is important to keep in mind when developing the creative work, as new experiences may arise through developing novel forms of performance technology.

Figure 7: *Sphaera,* Bjõrk's bioluminescent light dress [24]

2.4 Intersections

Across the fields of audiovisual art, kinetic art and custom performance technologies, there is a prominent trend that focuses on physicalising art and technology. Within organisations like NIME, new interfaces, instruments and technologies are developed to enhance musical expressivity, often using mechanical systems in their design. If this trend is applied to the field of visual art within musical experiences, this will pave way for new experiences when working with light and sound. In order for this field to be expanded, custom performance technologies will provide the perfect platform for new forms of technology to be developed. Through the development of novel forms of performance technology, I propose that new experiences will unfold within the realm of live music performance.

Chapter Three
Implementation

With trends identified in Chapter Two, two new artworks, *ether* and *expanse*, were developed. These works attempt to incorporate tangible forms of light into customised performance technology. This chapter presents *ether* and *expanse,* and the design methodology employed throughout the process of development. *ether* and *expanse* utilise fibre optic technologies, shifting focus from digital media and towards the physical world through the visualisation of tangible light.

3.1 Methodology

An iterative design methodology [25] was employed to reflect on and inform the development of *ether* and *expanse*. Iterative design was used as each work involved the creation of custom technology, which enabled the works to progress rapidly through the various development stages. Whilst *ether* and *expanse* are presented as separate artistic pieces, they are both a part of the same initial iterative cycle as both used the same developed technology, but vary with their contrasting applications. In accordance with the accompanying Business Plan Document, this is significant as both works utilised the developed technology in different formats, which resulted in lower production costs and effective use of time and materials.

The three dimensional CAD (Computer Aided Design) modelling software, SolidWorks, was used to design custom parts and prototypes before they were manufactured. Custom parts were 3D printed, and laser cut out of perspex, allowing for rapid production and progression of the creative work through the iterative cycle. Following the life cycle discussed, *ether* was developed by exploring fibre optic technology, and led to the development of a customisable hardware system that would enable its application in kinetic installation contexts. Wellington artist/producer Estère [26] commissioned the development of *expanse* for her live show *Into the Belly of Capricorn* after seeing the developed technology of *ether.* The development process for the individual works are discussed in-depth in Sections 3.2 and 3.3.

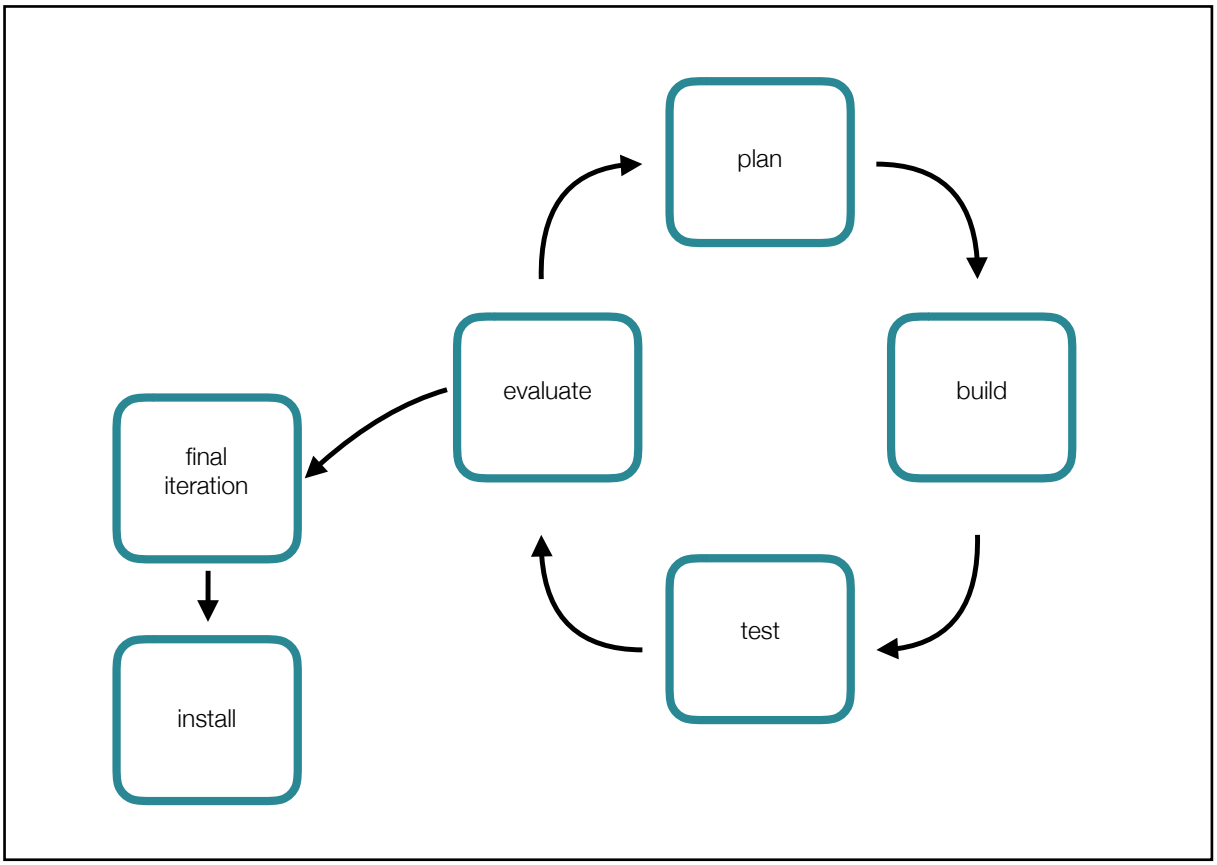

Figure 8: Diagram of the followed iterative design methodology

A cyclical model of development involved prototyping, testing, evaluating and implementing changes. Upon the completion of a cycle, each work was evaluated in accordance with the design specifications discussed below in Sub-Sections 3.2.1 and 3.3.1. If changes were

needed, additional rounds of the cycle would begin, only progressing through to the next stage of development upon meeting design specifications (Figure 8).

3.2 *ether*

ether is an audiovisual installation exploring tension and release with revolving fibre optic cables. Through the amalgamation of light, sound and kinematics, the audiovisual experience is accentuated by giving life to physical light sources. Inspired by naturally occurring phenomena in the physical world, paired mechanical ends of the system are accordingly referred to as tendril arms as they resemble stemming thread-like appendages of plants. The individual fibre optic cables make up the tendrils with their intertwining, stretched-out and fluid nature.

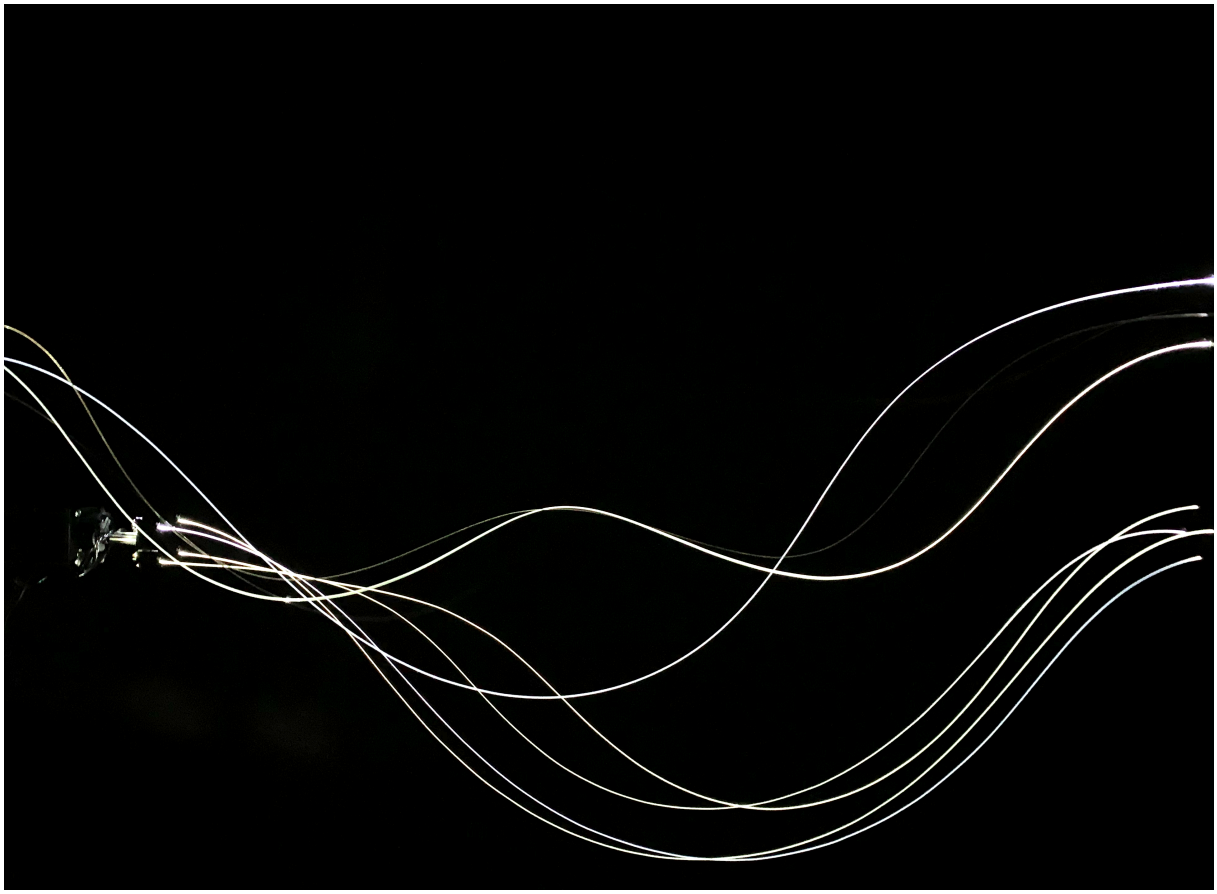

Figure 9: A fluid *ether* tendril arm installed in a blacked out space

Conceptually, *ether* visualises the invisible fibres that connect us all, with kineticism enhancing the movement of the crossing of paths of the tendrils. With this concept in mind, the fibre optic cables were used as they were tangible, more readily affordable and were modular by nature.

3.2.1 Design Specifications

The design criteria were formed by considering a number of objectives, which were informed conceptually, technically and in line with accompanying Business Plan Document. In order to be successful, the final system of *ether* should:

- be programmable, so that it may be applied in varying contexts,
- have a rigging system enabling the installation between common structural entities like truss towers, microphone stands etc, so it can be travelled with easily and installed in spaces with equipment that are ubiquitous amongst the music and theatre industries,
- have a low-cost reproducible design so that multiple units can be produced,
- be portable and easily transportable, to allow for multiple installation contexts and travel on airplanes,
- allow the interchangeability of fibres, affording modularity and customisation for the space of installation,
- have bright light sources, so that it can operate in environments of varied light settings,
- feature an isolated light source per individual fibre, so that each fibre is controllable allowing it to be composed for and performed with.

The technology driving *ether* is a mechatronic system, consisting of a stepper motor, motor driver, motor clamps and a microcontroller to afford motion. The system was designed around fibre optic cables because of their tangibility and alignment with the research objectives. Fibre optic cables do not emit heat like LEDs, and have a significantly lower cost in contrast with LED strips and other counterparts. Two rigging/installation assembly systems were explored, with

half coupler clamps and microphone stand thread adapters. Half coupler clamps enabled the tendril arms to be installed from truss towers and other common structural staging entities, while thread adapters allowed for the installation on microphone stands. These two rigging assemblies were used as they are commonly used to install lights and other forms of technology within live music productions.

3.2.2 Iteration One

The goal of Iteration One was to produce an MVP (Minimum Viable Product) as proof of concept of the use of fibre optic cables and physical light sources in kinetic applications. In designing the first prototype of *ether,* the most important criteria to address were to make sure that the system could be provided with motion, as well as the ability for the fibres to maintain regular tension. In achieving these two aspects, Iteration One of *ether* was developed (Figure 10). Iteration one consisted of a basic mounting system that provided rotation from both sides of a tendril arm, with the key focus of this being the maintenance of tension of the fibre optic cables. Some smaller design goals were developed within Iteration One that contributed towards the overarching design criteria for the final system. These smaller goals included the design of an LED mounting system, a fibre optic clamping system and a structure that connected both of these to a motor.

Iteration One used a NEMA 17 Stepper Motor[8], and an EasyDriver Stepper Motor Driver[9]. The use of a stepper motor and driver allowed stepping and directionality of the motor to be controlled and programmed. This is especially important as the final iteration will be programmable. The Teensy 3.6[10] microcontroller was used because of its built-in MIDI library,

---

[8] https://components101.com/motors/nema17-stepper-motor

[9] https://www.sparkfun.com/products/12779

[10] https://www.pjrc.com/store/teensy36.html

allowing for management and programmability of MIDI data. The system was programmed using the Arduino IDE[11] (Integrated Development Environment), with Teensyduino[12] and was coded in C/C++. Iteration One was programmed to rotate within set boundaries and was stand-alone, non-reliant on user input for operation.

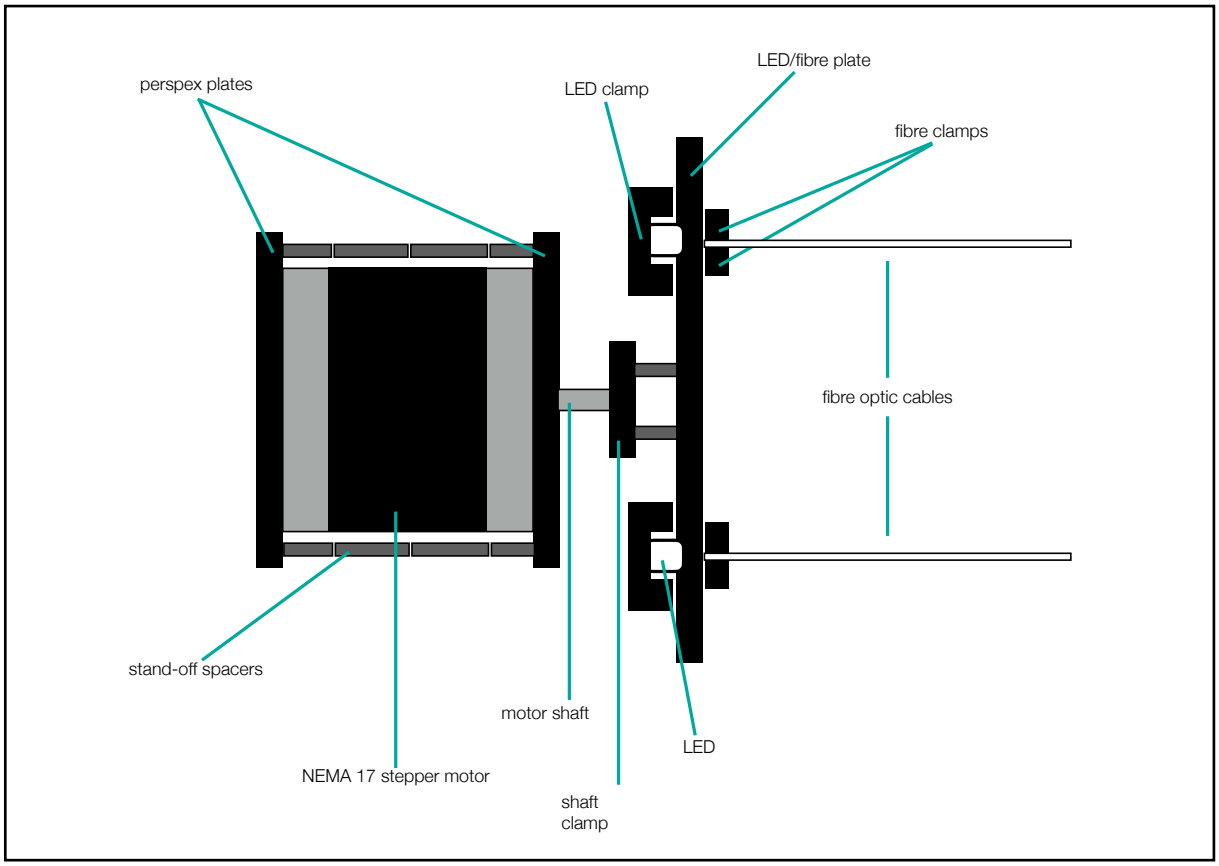

Figure 10: Diagram of *ether* Iteration One

Whilst Iteration One achieved its purpose with the visual concept and design goals central to the MVP, the system fell short resulting in it not being ready for performance or installation, primarily due to the absence of a rigging system. This provided a platform to explore *ether* with Iteration Two, addressing technical design issues in an improved system.

[11] https://www.arduino.cc

[12] https://www.pjrc.com/teensy/teensyduino.html

3.2.3 Iteration Two

Iteration Two of *ether* involved re-designing the structural system to meet the design criteria. This system needed to consider the incorporation of a half coupler clamp[13]. The clamp (which is standardised) led towards the system being ready for installation in a fixed media setting, as a clamp allowed it to be installed from common stage structural entities. A modular staged platform system was designed for this change (Figure 11). This design afforded modularity to the system, allowing easy access to the electronics. Threaded rods replaced the stand-off spacers used in Iteration One, as threaded rods were more affordable, accessible and customisable, adhering to keeping the design and production costs low. Threaded rods were also incorporated into the motor shaft clamping system, extending the distance between the motor shaft and the LED/fibre plate, solving a technical issue where the LED wires were inhibiting the rotation of the motor shaft. For this change, both the motor shaft clamp and the LED/fibre optic plates were re-designed to accommodate for the new threaded rod mounting system.

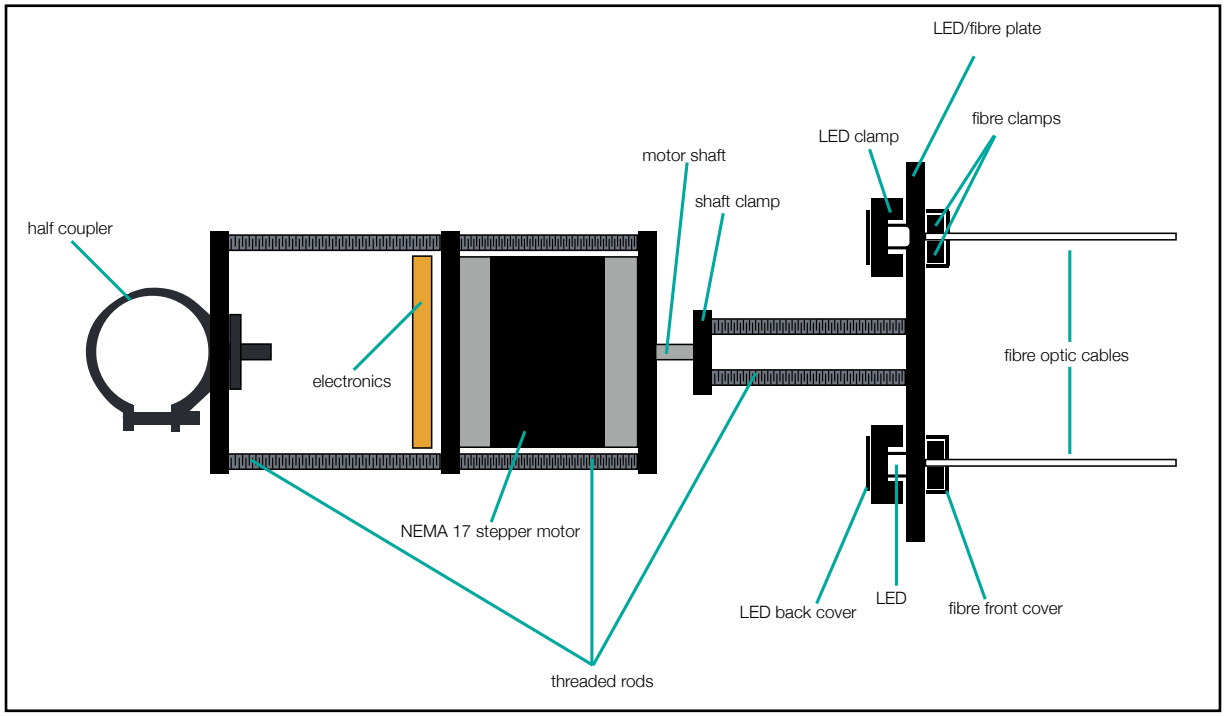

Figure 11: Diagram of *ether* Iteration Two

[13] https://www.surplustronics.co.nz/products/9636-half-coupler-slimline-100kg-black

Two new parts, the fibre optic front plate and the LED back plate, were also developed to minimise the amount of light pollution from the LEDs. A half coupler clamp, a common fixture device amongst the lighting and theatre industries, was incorporated into the rigging assembly design to allow for installation between truss towers.

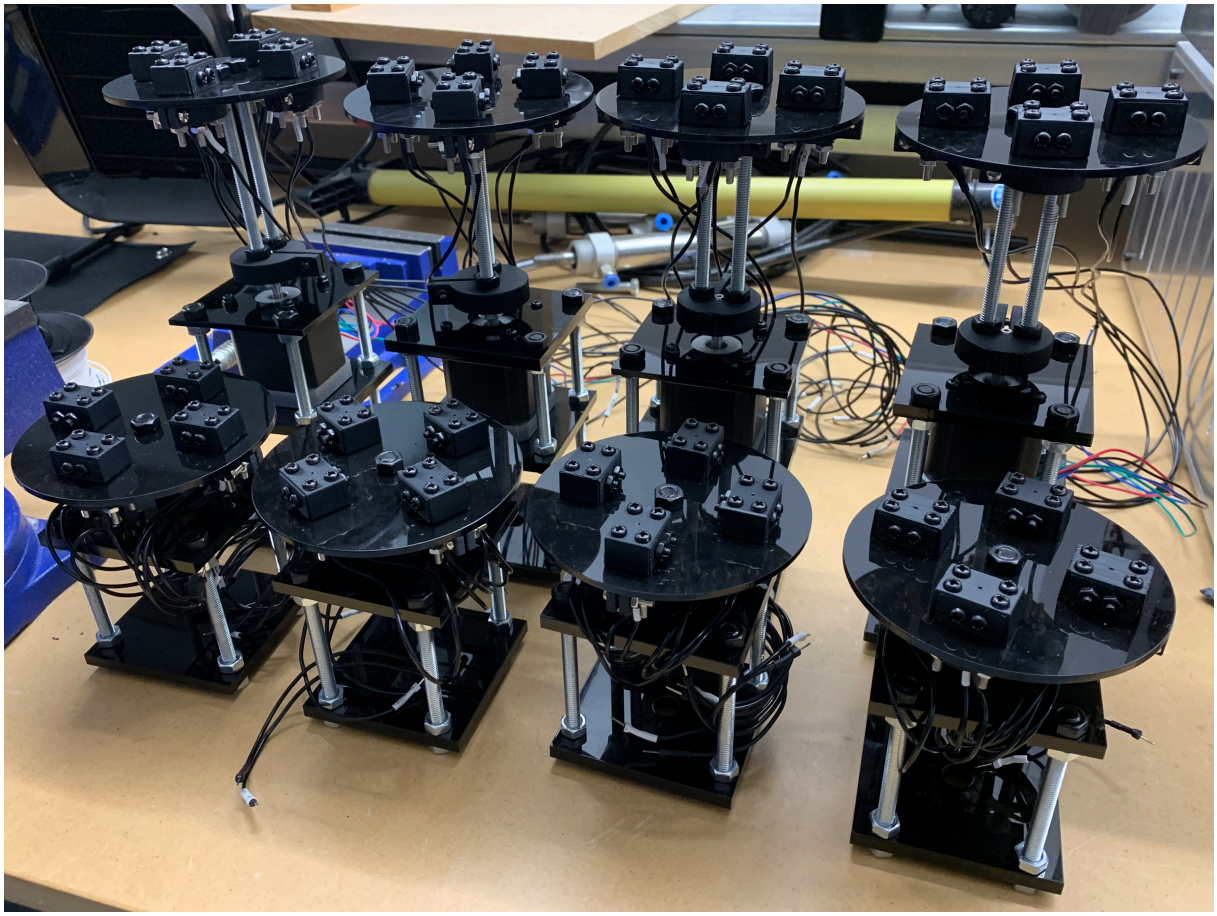

Figure 12: Iteration Two *ether* systems, ready for installation

Upon completing an iterative cycle, Iteration Two was ready for installation (Figure 12), and was installed in a blacked out space attached from sticks of truss (Figure 13). Four tendril arms were built to test in a fixed media installation with each tendril arm setup between four sticks of truss, creating an immersive square of light around the installation space. From the installation, it was discovered that although the half coupler clamping system was effective, the sticks of truss did not align with *ether* aesthetically, and compromised the seamless nature of installation. The visible orange LED lights indicating the operating motor driver and the light refractions on the

truss towers interfered with the visualisations of the tendrils. These factors led to the final iteration of *ether*, with some smaller changes to the design assembly.

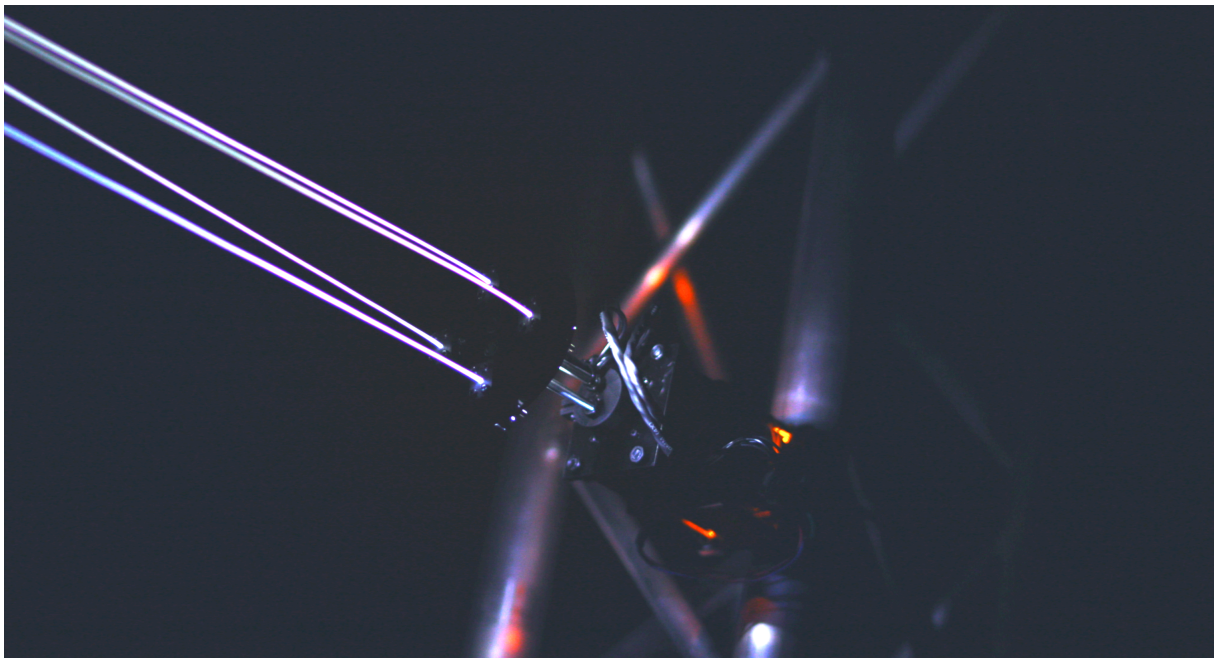

Figure 13: Iteration Two of *ether* rigged from a truss tower during the test installation

3.2.4 Final Iteration

The final iteration presents a new enclosure assembly (Figure 14) that addresses the short-falling design of the staged mounting and half coupler system in Iteration Two. To align with multiple design criteria and to increase the scope of places the system could be installed, an enclosure assembly was introduced that incorporated a microphone stand attachment system, making it faster and easier to install. This new design (Figure 15) facilitated the re-direction of focus back towards the illuminated fibre optic cables, as well as helping the piece to achieve aesthetic cohesion.

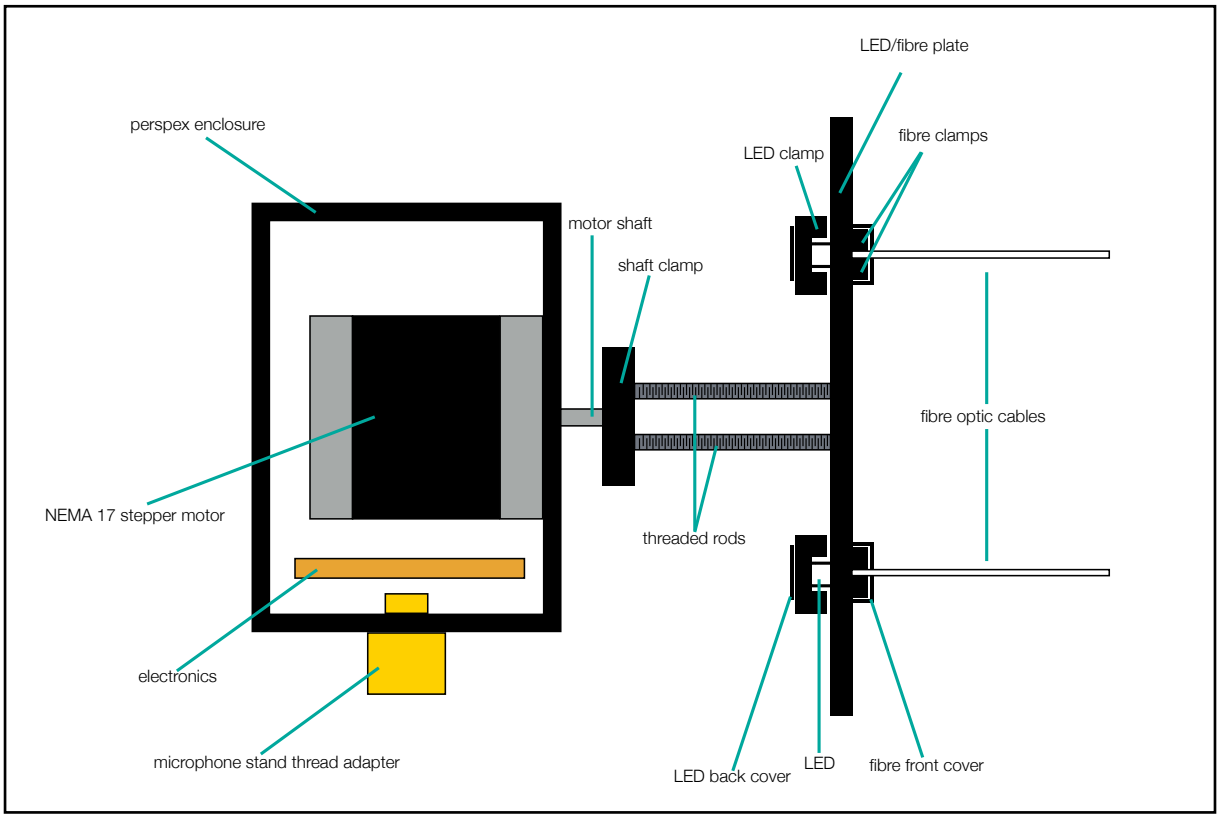

Figure 14: Diagram of the Final Iteration of *ether*

Figure 15: The Final Iteration of *ether*, installed upon a microphone stand

3.2.5 System Compendium

This section discussed the development of the fibre optic system that drives *ether*. Through the use of fibre optic cables, *ether* visualised physical tendrils of light that represent the fibres the connecting us all. In its current state, *ether* explores this fibre optic technology and autonomously moves the tendrils within the space of installation. Artistic applications of *ether* in installation contexts are discussed in Chapter Four, and the accompanying Business Plan Document.

3.3 *expanse*

Following the final iterative cycle of *ether*'s Final Iteration, *expanse* was commissioned for the upcoming live show *Into The Belly of Capricorn* for the Wellington artist/producer, Estère. *Into The Belly of Capricorn* seeks to take the audience on a journey into the unconscious mind through an imaginative and immersive exploration of sound, music and visual production elements. *expanse* is a wearable application of the fibre optic light system that has been developed during this research, and is a visual extension of Estère's musical performance via a custom-built light system that interfaces with the performance DAW (Digital Audio Workstation), Ableton Live. *expanse* is presented as a working prototype, currently being developed in collaboration with Estère, along with a fashion/costume designer and other collaborators of the live show. The prototype of *expanse* is a fibre optic electronics system (Figure 16). Key development milestones are explored in the accompanying Business Plan Document.

Figure 16: *expanse* Prototype System with illuminated fibre optic cables

3.3.1 Design Specifications

The design criteria and goals for *expanse* were developed based on the aesthetic and functional requirements of Estère's live show, as well as the primary objectives of this research; to bring physical light sources to life. In this case, the motion of the light was based on using the movement of the human body with Estère wearing a garment interwoven with illuminated fibre optic cables. By incorporating the fibre optic light system into a wearable format, a light body was created, aligning with the themes and concepts being explored within Estère's live shows. The design specifications for *expanse* were developed with Estère to ensure that the system was reliable, optimal and novel for her performances. The prototype system for *expanse* should:

- be easily controlled by musicians or technicians, synchronising the lights with Estère's music,
- utilise RGB (red, green and blue) LEDs, to allow the creation of a custom colour palette,
- be designed using a compact enclosure assembly so that it can be fitted into a garment,
- be easily transportable for travelling and touring,
- be able to visibly stand out amongst stage lighting and varied light settings,
- use a modular and detachable system for the fibres so that the garment can be washed or altered,
- be reliable and performance ready.

The iterative design methodology used differs with *expanse,* as there were a number of collaborators involved who had input at various stages of development. The prototype of *expanse* will be ready to use within the production rehearsals and for the development of the garment with a fashion/costume designer. The prototype will be a compact pack that will contain the electronics and a fibre optic mounting system. Similarly to *ether,* the Teensy 3.6 was chosen as the microcontroller as *expanse* will be using usbMIDI as its communication and control protocol when interfacing with Ableton Live. The system was programmed in the Arduino IDE, using the Teensyduino libraries. Diffused RGB Piranha LEDs[14] were chosen for their brightness and increased ability to focus the light source into the fibre optic cables from its diffused lens. These LEDs have four pins: red, green, blue, and common anode. By having three colour pins, the microcontroller was programmed to use PWM (Pulse Width Modulation), which allowed each pin to be controlled individually and blended together to form custom colours. This allowed each LED and its colour pins to be individually controlled, contributing to the programmability of the system.

3.3.2 Performance Conditions

Before a prototype of *expanse* could be developed, a number of potential critical problems needed to be mitigated in order ensure that its application is optimal for use in a full-scale music production. As lighting and digital media are integral to modern live music performances as discussed in Section 2.3, the technical performance, visibility and spectacle of the developed fibre optic technology will be compromised if the limits and operative requirements of the system are not determined with vigorous testing and evaluation. A key problem that could potentially jeopardise the performance of *expanse* is the visibility of varied lighting conditions of live performance environments. In order to ensure that this problem is mitigated, the fibre optic

[14] https://www.adafruit.com/product/1451

technology was tested in performance conditions particular to live music, as well as being subject to stress testing in order to determine the endurance and viability of *expanse*.

A production rehearsal space was chosen to test varied lighting conditions. For the purposes of testing the visibility of the fibre optic technology against varied light intensities, it was important to use lighting dynamics of popular music concerts. By doing so, the technology could be tested reliably and the levels of operation against varying light intensities of production lighting fixtures could be determined. To best mimic the stage set up, the lighting fixtures were arranged to illuminate a performer in the middle of a stage with a generous amount of front light so that the performer is able to be seen (Figure 17). This is important as the visibility of the performer is a top priority within live musical performance lighting. If this was not tested vigorously then it would result in unrealistic performance deliverables.

Figure 17: Fibre optic visibility test with *ether* tendril, with generous front light

This testing identified three states of lighting conditions:

- Optimal: a harmonious balance between lighting fixtures and the fibre optics,
- Minimum: no deduction of intensity from external lighting fixtures making it very hard to see the fibre optic lights,

- Maximum: compromising the intensity of external lighting fixtures allowing the fibre optics to stand out.

From this, it was discovered that the fibre optic cables were discernible amongst the light from lighting fixtures, but was most effective when the external lighting fixtures were at a lower intensity. In consulting with Estère and the lighting designer of the show, it was decided that the lighting fixtures and the fibre optic cables would interact in an asynchronous manner, with the lighting fixtures moving between states of being on and off, giving the fibre optic cables room to be the focus at particular points during the live show. This testing also identified other aspects that could compromise the effect of the fibre optic lights in a wearable application, particularly the fabric/texture of the fitted garment and the focus of the light emission into the fibre optic cables. A sheet of black fabric was used in place of a garment behind the fibre optic cables during the light testing. This fabric had a reflective gloss that created glare refractions, which informed the collaboration and specifications with the fashion/costume designer. The focus of light into the fibre optic cables was prominent alongside these light refractions, as the lack of focus into the cables created intensive discrepancies between illuminated fibre optic cables.

3.3.3 *expanse* Prototype

The prototype of *expanse* consists of a system with six LEDs inside an enclosure, designed to be fitted into a garment. The system is user controllable from Ableton Live, equipping the user with control of basic parameters of the LEDs by interacting with MIDI data (Figure 18). This prototype is wired and connects to Ableton Live via USB (Universal Serial Bus) and is configurable as a MIDI OUT device that uses MIDI CC (Control Change) data to control parameters of the LEDs.

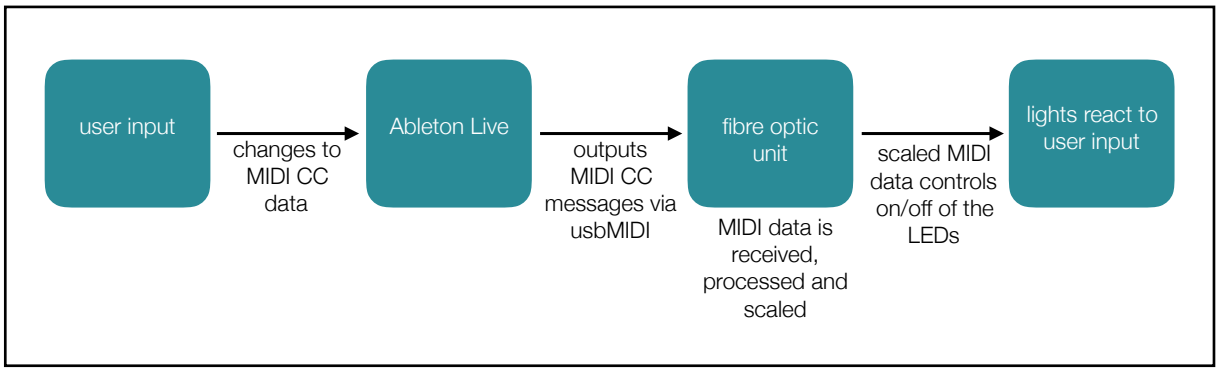

Figure 18: *expanse* user interaction diagram

A custom colour palette was built into the firmware of *expanse* so that the intensity levels and desired colour of each LED could be controlled intuitively by the performer, which kept the system simple to use. In Ableton Live, the MIDI CC control interface possesses the same characteristics as audio whereby an ADSR (Attack, Decay, Sustain, Release) envelope controls the parameters of the LEDs, making it intuitive and simple for musically-minded people to understand and use by drawing in automation (Figure 19).

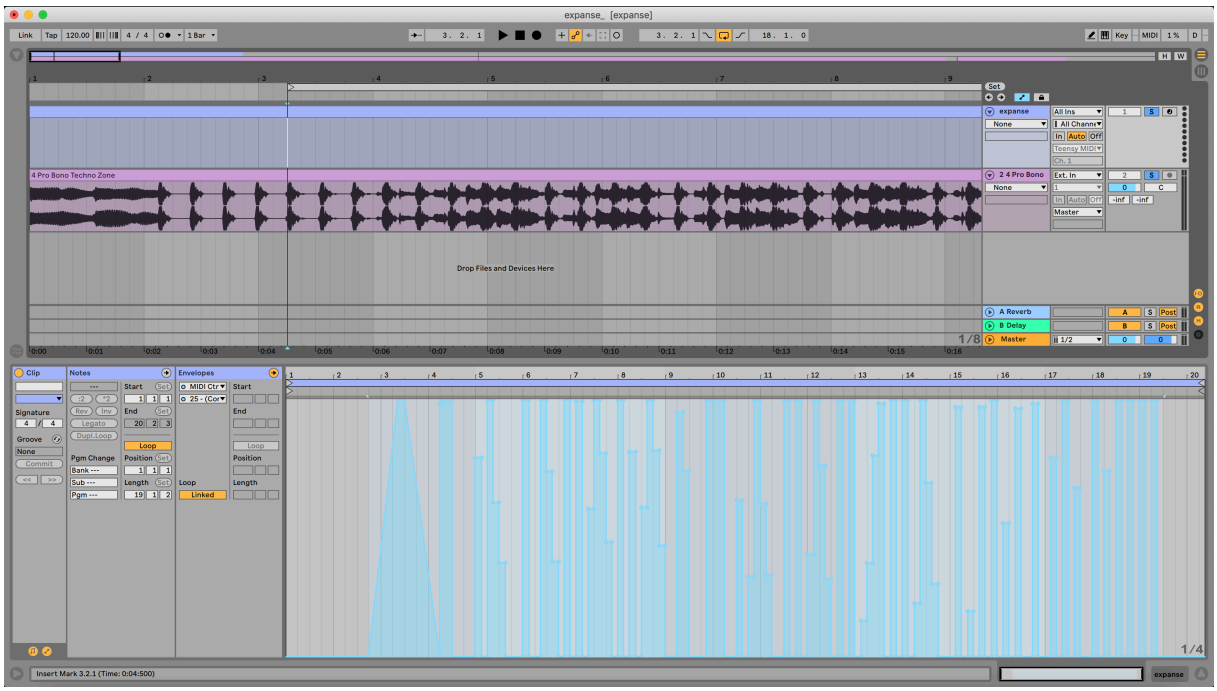

Figure 19: *expanse* automation control in Ableton Live

In this prototype, each LED occupies four MIDI CC channels, translating to a channel each for red, green, blue and white colours, while MIDI velocity values from 0 — 127 control the brightness of each LED. The LEDs are individually controllable, so that each LED can be programmed to operate together or individually. As an alternative to drawing in automation, the system can also be controlled via interaction with an external MIDI controller/keyboard, which makes it performable and interactive for seamless integration into live music performances. This is a significant feature for custom performance technologies to possess, as this makes it easy for a performer to interact with onstage, as discussed in Section 2.3.

As the technology was designed to be wearable, the enclosure system was designed to be compact, modular and light weight. Similarly to *ether*, a fibre optic clamping system was designed to secure the fibres to the electronics enclosure. The design implemented into the prototype allowed for either the clamp attachment system to detach from the enclosure, or for the fibre optic cables to be interchangeably removed from the clamps. This meant either the fibres could be disconnected from the electronics enclosure, or the fibre clamping system could be detached so that it could stay with the garment. The clamping system incorporates a three layered design: a bed layer to house the LEDs, a middle layer to align the fibres with the light source, and a top layer to secure and clamp the fibres in place. This clamping system attaches to the main enclosure assembly (Figure 20), and permits ten fibres to be fixed to a single LED, providing potential for abstract designs to be made with the fibres when incorporated into a garment.

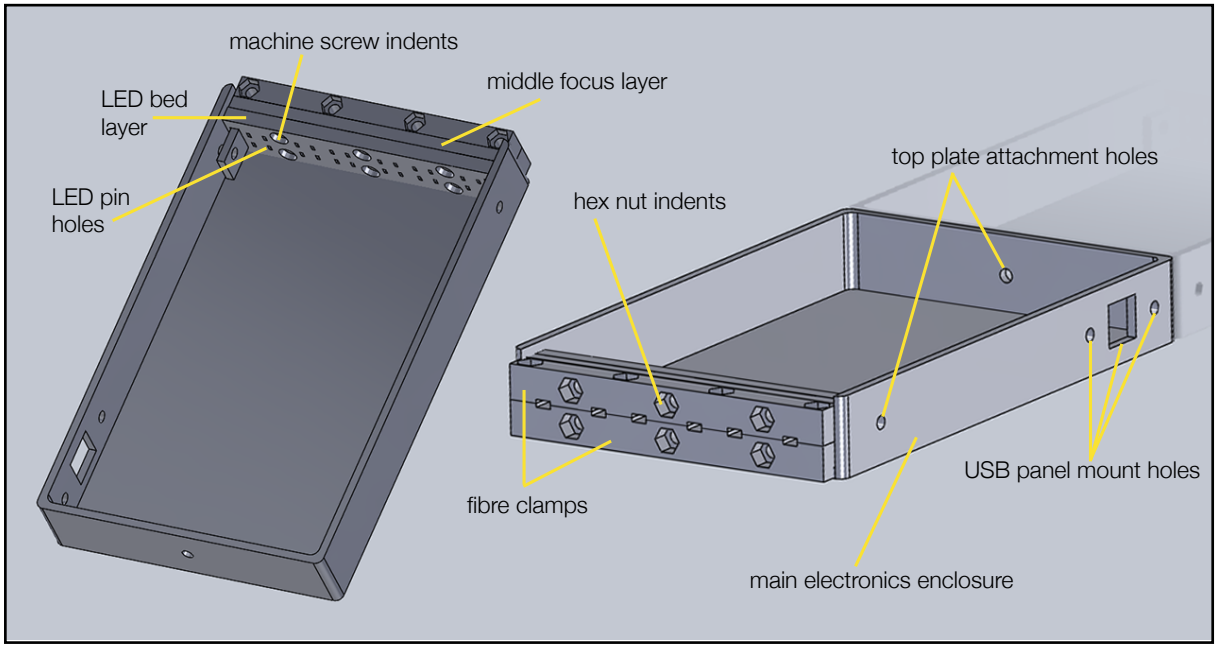

Figure 20: CAD enclosure assembly for *expanse*

Once this prototype was built, stress testing was carried out to ensure the system was reliable in production rehearsals for the festival shows. Stress testing involved pushing elements of the system, particularly the visibility of the fibres, to determine their limits. This provided useful insights into whether or not the system was stage-ready, and technical aspects that needed to be addressed or altered. This process allowed the system to be feature locked so that its overall functionality could be determined for the festival shows. From this, the technical requirements for collaboration with a fashion/costume designer were able to be determined, allowing the system to progress to the next step of development. Some design ideas for the arrangement of the fibre optic cables were also made (Figure 21), which gave Estère, the fashion/costume designer and other collaborators a better understanding of what the final system might look like and how it will work in with other elements of the live shows.

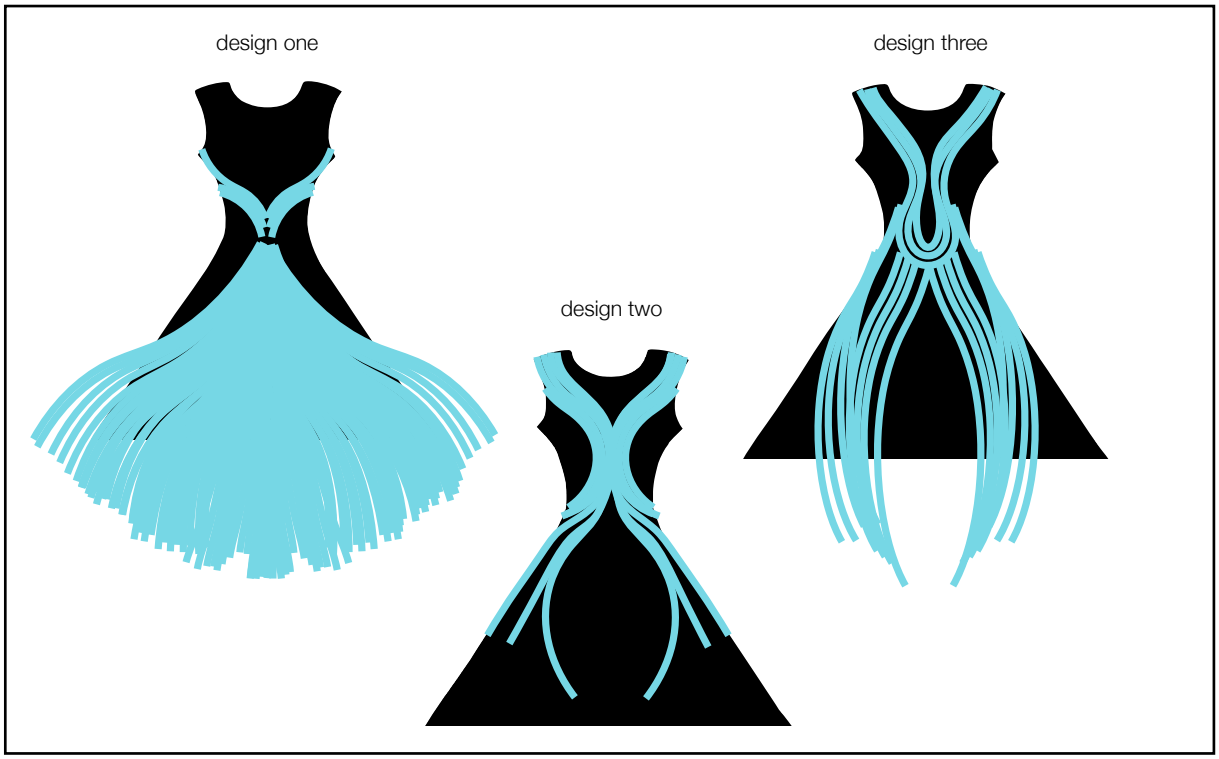

Figure 21: *expanse* fibre optic garment design ideas

3.3.4 System Compendium

This section discussed the design specifications, development and testing processes of the initial system and prototype of *expanse.* Developed for Estère's upcoming live show *Into The Belly of Capricorn, expanse* gives life to a light body by incorporating the developed fibre optic light systems into a wearable garment. In this application, *expanse* is not kinetic in design, but instead becomes kinetic as Estère performs and moves. This enhances the themes and concepts explored during the show, evolving and coming to life as Estère takes the audience on a journey into the unconscious mind. *expanse* is ready to be user tested within the upcoming production rehearsals for Estère's live show, alongside being ready to progress to the next stage of development with a fashion/costume designer.

Chapter Four
Applications

This chapter presents artistic applications of the developed fibre optic technologies for kinetic audiovisual art, discussing completed, planned and proposed applications as presented in line with the accompanying Business Plan Document. Future improvements, applications and features are discussed for *ether* and *expanse,* along with their viability, potential configurations and manifestations of the developed fibre optic systems for Estère's live show. *ether* has already been shown in two installations, discussed below.

4.1 Artistic Applications

The fibre optic systems central to both *ether* and *expanse* were designed to be multifaceted, with the ability to be applied across different contexts and applications enabled through their modular design and configurability. As presented in the accompanying Business Plan Document, two main applications have been identified: fixed media and performance oriented applications. To date, *ether* has been applied in two public events showcasing its modularity and configurability in varying contexts.

4.1.1 *Exposure Exhibition*

Through customisability and configurability, the fibre optic systems are effective in fixed media applications. A modular design allows for consideration of various configurations and installations. Throughout the iterative design process, *ether* was designed to be configurable and modular to the space of installation. The positioning of the structural entities and the length of the fibre optic cables contribute to different experiences of the piece, whereby the physical form alters the way that the fibres move, behave and interact with space. During the *Exposure Exhibition* of 2019, the final iteration of *ether* was installed with the microphone stand attachment system. This design meant that bigger structural entities, such as truss towers, were not necessary for installation. Instead, this provided more freedom when configuring the tendril arms within the installation space. Within this installation, *ether's* tendril arms were installed in parallel pairs, descending from a mid-point that confronted spectators 'face to face' with a revolving fibre optic light system, visualising an other-worldly entity navigating existence within the installation space (Figure 21) [27]. *ether* was setup in this configuration to present a challenging and confronting experience to the audience. An audio element was required in this installation to enhance an other-worldly and challenging sensory experience, utilising an etheric spatial soundscape composed for this installation.

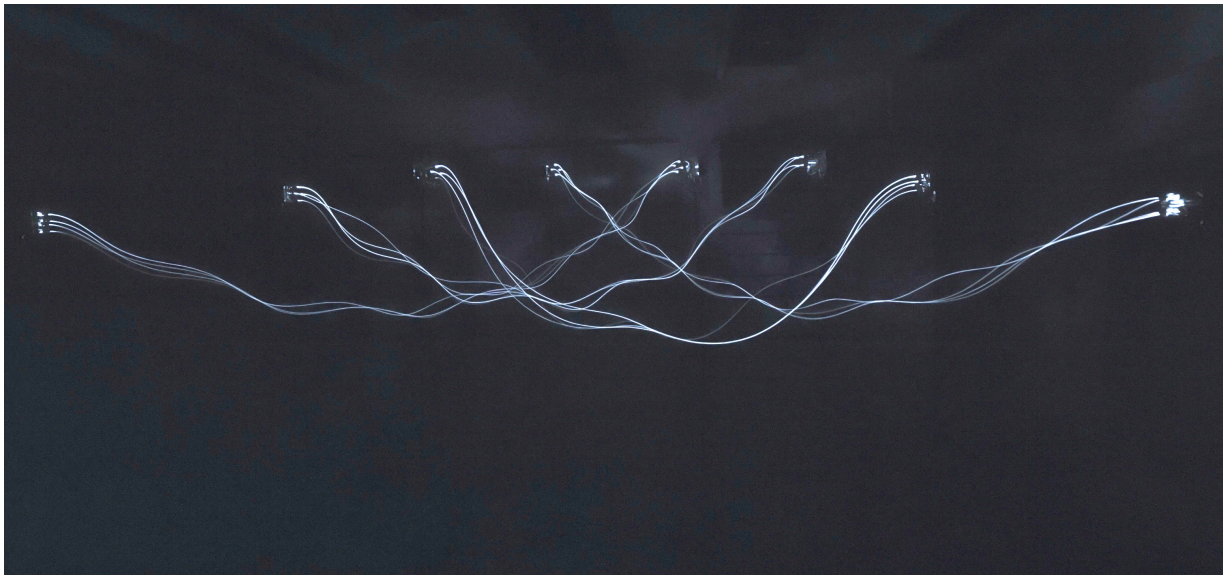

Figure 22: *ether* configuration for the *Exposure Exhibition* of 2019

4.1.2 VNZMA Event

The configurability of *ether* in fixed media applications can be explored in many ways. After the *Exposure Exhibition*, *ether* was curated for installation as a stand-alone light sculpture for the VNZMA (Vodafone New Zealand Music Awards) Artisan Awards, which took place on the 4th of November

2019. The work was featured in the control rooms of the event space. Within this event, the work artistically emphasised the ‘internal brain’ of the recording consoles, likened to a visual representation of the internal neural networks and nervous systems of the Neve and SSL (Solid State Logic) consoles inhabiting the control rooms. One tendril arm was installed between the monitors at the rear of each console, at the forefront of the separating glass windows so that the tendril arms were visible from the inner live room of the recording studio (Figure 22). This simple configuration aligned effectively with the concept, providing a subtle ambience to the control rooms. Because of the separate space of installation from the main live room where the event took place, the work did not require a sound element and was instead installed strictly as a sculptural light installation. This shows how the work is able to adapt to the requirements of varying applications.

Figure 23: *ether* tendrils setup for the VNZMA Artisan Awards

4.1.3 Performance Oriented

As proposed in Section 2.4, performance oriented applications are an important avenue in the development and contextualisation of this research. The incorporation of kineticism in light as part of live music performances will extend the experience of the audiovisual phenomena. Although *expanse* was developed to be incorporated into a fashion garment, the system could be re-configured and adapted to take form as or within other visual elements within Estère's live show. This could oversee *expanse* as extending to be a part of the wider stage and scenographic design, as well as other props and wearable costumes for the other performing musicians accompanying Estère onstage. The possibilities are endless when considering the overall design, layout and format, which contributes to an abundance of configurations and applications for the developed systems. By being customisable, these systems are able to be tailored to the requirements of a particular live show, allowing for new and novel experiences to unfold.

4.2 Future Considerations

This section presents future features that could be implemented into both *ether* and *expanse* to enhance their effect, interaction and experience. Additionally, future works are proposed exploring possibilities beyond *ether* and *expanse*.

4.2.1 *ether*

Extending from the final iteration of ether, there are key features that will expand its effect and allow it to become a performative kinetic light instrument. The integration of a MIDI system will contribute to this, allowing it to interface with Ableton Live and other DAWs. Alongside this, transferring the motion from the motor via a slip ring or other systems will enable continuous,

infinite rotation of the tendril arms, eliminating the restrictive LED wires of the Final Iteration. The lack of cable restriction will nuance the expressivity of the motor acceleration and rotation of the tendril arms, invoking performative actions. Other electromechanical parts may also enhance future systems, such as exploring the placement of the tendril arms with linear actuators, allowing the tendrils to move side to side, or front to back within space. Alongside this, the implementation of an LED control system via the basic MIDI firmware built into the final iteration will allow it to be user programmable. Including RGB LEDs and the control algorithm used in *expanse* could extend the visual capabilities of a future system, enabling more elaborate visual effects. Customising the placement of fibres on the tendril arms could also be explored in a future system, contributing a variety of light patterns with different effects.

4.2.2 *expanse*

As *expanse* is currently a prototype for Estère's live show, there are key features to be explored and implemented into future iterations in order to extend the capabilities, impact and operation of the system. Some future features include the integration of a wireless communication protocol and hardware system, and enabling colour blending in real-time from Ableton Live. The implementation of a wireless hardware system will free Estère of restrictive cables and potential hazards involved with a wired setup, allowing her to move freely during her performances. This system will involve the development of two components— a transmitter (TX) and a receiver (RX) pack. The TX pack will be connected to a computer and will receive MIDI data from Ableton Live via the usbMIDI function built into Teensyduino, scaling and sending MIDI data to the RX pack that will be connected to the lights and worn by Estère. RF (Radio Frequency) modules will be used to achieve this wireless configuration.

Although the current control system of LED colour is satisfactory for *expanse*, the introduction of a new control scheme enabling colour blending from Ableton Live will increase the user

programmability/performability by allowing the user to blend colours in real-time, as opposed to interacting with a fixed palette as exhibited in the prototype. This could enable interesting experiences in live music performance to emerge, particularly if the lights and colour are significant to a live show.

4.3 Future Steps

Extending from *ether* and *expanse*, future works may explore designing custom interfaces to control the developed fibre optic systems. Such interfaces may surpass the use of a DAW, which may enable the control of kinetic audiovisual systems to become its own performance practice with unique, context specific interactions that are more effective at controlling such systems.

In future systems, elements of sound could be explored alongside light, stepping away from using sound as a supportive element. This may involve using dimensions of light and sound to influence and affect the other. Within live music performances, large-scale works are common, so adapting and building upon current configurations will be something to consider alongside the development of new large-scale, site-specific works.

Chapter Five
Conclusion

This exegesis has examined three significant fields that inform *ether* and *expanse*: audiovisual art, kineticism and custom performance technologies. Because of a trend focusing on the physicality of mediums across the fields of musical robotics and kinetic art, there is room for the development of kinetic works that have the ability to be audiovisual by nature. The realm of live music performance has provided a perfect platform for these works to be developed, which enables new experiences to emerge through its incorporation into live musical performances.

The following research objectives were outlined in Section 1.2:

- to use mechatronic and kinetic systems to give life to physical light sources,
- to provide new immersive experiences of kinetic art.

In addressing these research objectives, *ether* and *expanse* were developed using an iterative design methodology. By using this design methodology, features such as modularity and customisation emerged as a result of developing the works over multiple iterative cycles. The fibre optic light systems that have been developed throughout the course of this research are central to both *ether* and *expanse*, which have focused on physicalising LEDs through utilising fibre optic cables. Two key areas of application were identified: installation and performance, allowing both pieces to be developed and explored within different contexts. Through their modular design, *ether* and *expanse* were able to be tailored for other formats of presentation, as

discussed in Sub-Section 4.4.1, where *ether* was selected as a light sculpture for the VNZMA Artisan Awards, instead of an audiovisual piece. This is notable, as the context and application of presentation ultimately determines how the work is installed and experienced. Because of this, *ether* and *expanse* were both developed for two contrasting formats, with other potential applications discussed in the accompanying Business Plan Document.

5.1 Final Remarks

Through the development of kinetic fibre optic light systems, this exegesis has presented two works that physicalise light in kinetic applications, evoking new embodied visceral experiences. It is clear that there is a lot of potential for new forms of kinetic art, expression and performativity to arise across many contexts and applications by nuancing elements of light. Kineticism nuances the visceral and other-worldly experiences of the developed fibre optic light systems. The use of kinetic and mechatronic systems ultimately enhance our interactions with the physical world by experiencing and observing kinetic audiovisual art. The possibilities are limitless for applications, scale and manifestations of the fibre optic systems developed. To this end, the realm of live music provides an exciting and interesting platform for new experiences to arise through developing and centralising immersive kinetic works into musical performances.

Bibliography

[1] I. Andrews, "The Expanded-contracted Field of Recent Audio-Visual Art." Scan: Journal of media arts culture 6 (2009).

[2] K. Maloney, "Sounding Images and Imaging Sounds-Audiovisual Interactivity in Performance." Sight Lines Thesis Projects (2005).

[3] NONOTAK Studio, "*Wave*," 2018 | *NONOTAK Studio* [Online]. Available: https://www.nonotak.com/_WAVE [Accessed: 30-Sep-2019]

[4] M. Chion, et al. 'Audio-Vision : Sound on Screen', 1994. Columbia University Press.

[5] N. Bernier, "*frequencies (light quanta)*," 2014 | *Nicolas Bernier.* [Online]. Available: http://www.nicolasbernier.com [Accessed: 26-Sep-2019]

[6] Technical Earth, "*interference [dac]*," 2017 | *Technical Earth.* [Online]. Available: https://www.technical-earth.com/interference-dac [Accessed: 26-Sep-2019]

[7] Aesthetica, "Q+A with Aesthetica Art Prize Longlisted Artist Nicolas Bernier," 2016 | *Aestheica Magazine.* [Online]. Available: https://www.aestheticamagazine.com/q-and-a-nicolas-bierner/ [Accessed: 26-Sep-2019]

[8] J. Murphy, A. Kapur, and D. Carnegie, "Musical Robotics in a Loudspeaker World: Developments in Alternative Approaches to Localization and Spatialization," *Leonardo Music J.*, vol. 22, no. 1, pp. 41–48, 2012.

[9] “Sound Artist Trimpin Triumphs With Der Ring,” 21-Jun-2006, *Futuremusic Presents ::: Digihear?* [Online]. Available: https://futuremusic.com/news/june2006/trimpin.html [Accessed: 20-Sep-2019].

[10] “Trimpin,” *Trimpin ::: Foundation for Contemporary Arts*. [Online]. Available: https://www.foundationforcontemporaryarts.org/recipients/trimpin. [Accessed: 20-Sep-2019].

[11] E. Singer, and A. Kuffner, “The Gamelatron by zemi17 and the League of Electronic Musical Urban Robots,” September 2011. Retrieved from <gamelatron.com/>.

[12] G. W. Raes, “A Personal Story of Music and Technologies,” Leonardo Music Journal 2 (1992) pp. 29–35, p. 29.

[13] A. Kapur, “A History of Robotic Musical Instruments,” In Proceedings of the International Computer Music Conference (ICMC), Barcelona, Spain (2005).

[14] A. Kapur, M. Darling, J. Murphy, J. Hochenbaum, D. Diakopoulos, Trimpin, “The Karmetik Notomoton: A New Breed of Musical Robot for Teaching and Performance,” in Proceedings of NIME 2011, Oslo, pp.228-231.

[15] “32 prepared dc-motors, 230 light tubes, 307 cardboard boxes by Zimoun Hannes Zweifel - Bern, Switzerland / Rennes, France,” 03-Mar-2014, *IdN* | [Online]. Available: https://www.idnworld.com/potm/ZimounHannesZweifel-Installation [Accessed: 29-Sep-2019].

[16] “Zimoun,” *Zimoun* | [Online]. Available: https://www.zimoun.net/. [Accessed: 29-Sep-2019].

[17] L. Lye. “Water Whirler,” *Wellington Sculpture Trust* | Available: https://www.sculpture.org.nz/the-sculptures/water-whirler [Accessed: 25-Sep-2019]

[18] C. Bauder, R. Henke, “Deep Web,” 2016 | *WHITEvoid.* [Online]. Available: https://www.deepweb.art [Accessed: 25-Sep-2019]

[19] I. Bergstrom, and R. Beau Lotto, "Soma: Live musical performance in which congruent visual, auditory and proprioceptive stimuli fuse to form a combined aesthetic narrative." Leonardo 49.5 (2016): 397-404.

[20] Moment Factory “About Moment Factory - We create multimedia & immersive experiences,” *Moment Factory* | [Online]. Available: https://momentfactory.com/about [Accessed: 29-Sep-2019].

[21] Moment Factory, “Nine Inch Nails, Lights In The Sky Tour,” 2008. *Moment Factory.*| [Online]. Available: https://momentfactory.com/work/all/all/nine-inch-nails-lights-in-the-sky-tour [Accessed: 25-Sep-2019]

[22] P. Kirn, “Behind the Veil: Reznor's How To Destroy Angels Makes Poetry in Light,” 2013. *CDM | Creative Digital Media*. [Online]. Available: https://cdm.link/2013/04/behind-the-veil-reznors-how-to-destroy-angels-makes-poetry-in-light/ [Accessed: 25-Sep-2019]

[23] AnOther, “The Story Behind Björk's Blooming Iris Van Herpen Gown,” 30-May-2019. *AnOther* |. [Online]. Available: https://www.anothermag.com/fashion-beauty/11744/the-story-behind-bjork-s-blooming-iris-van-herpen-gown. [Accessed: 27-Sep-2019].

[24] I. Van Herpen, “Dress for Björk's Cornucopia,” *Iris van Herpen* | [Online]. Available: https://www.irisvanherpen.com/news/dress-for-bjrks-cornucopia. [Accessed: 27-Sep-2019].

[25] Enginess, "What is Iterative Design? (and Why You Should Use It," 20-Apr-2018, *Enginess* | [Online]. Available: https://www.enginess.io/insights/what-is-iterative-design. [Accessed: 19-Sep-2019].

[26] "Estère," *Estère* | *NZ Artist Directory* | *NZ Music Commission*. [Online]. Available: https://www.nzmusic.org.nz/artists/soul-funk/estere/ [Accessed: 5-Oct-2019].

[27] K. Bowler, "ether," 2019, *Kaysha Bowler* | [Online]. Available: https://www.kayshabowler.com/ether [Accessed: 5-Nov-2019].