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Light, Technology, and Kinetics in Costume Design

*By Jessica Telfer**

In a world where filmed media captures a large percentage of the viewing population, many live performing arts have turned to technological advances to enhance performance quality and engage an audience. Collaborations and innovations in technologies have created new opportunities and allowed costume designers to progress into new mediums. This paper examines the use of technology in costume design with a focus on dance, theatre, and circus. These advances are used to enhance character and create optical appeal in the performing arts. Costume design has relied on fiber and fabric manipulation to communicate character and mood to audiences. Advances in technologies have opened the door for costume design to jump into the twenty-first century by utilizing technologies such as fiber-optics, 3D printing, light-reactive fabric, and kinetics. These are becoming more accessible and allowing character creation opportunities ranging from Broadway to cosplay. Examining these four different types of technologies integrated into fabric, this paper looks at their application, demonstrates their use in creating mood and character, and contrasts utilization in both entertainment and by the general population. It demonstrates that costume design is an open field for innovations that is hampered by slow adoption rates, funding, and barriers to accessibility.

Keywords: *Costume Design, Technology, Performing Arts, Innovation, Design Concepts*

Introduction

Theatre and live performances are an ancient art form, with a history spanning at least four thousand years. Costume Design, a supporting element of performance, has a less clear history, but evidence of costuming can be traced back to the sixth century BCE[1] with clear guidelines and practiced medium emerging via commedia dell'arte in the sixteenth century CE and the professional title emerging in the nineteenth century[2]. Over the past three hundred years the craft has expanded over many live performance mediums with notable venues such as film studios and Broadway elevating some practitioners and designs to global recognition. Within the scope of performing arts, especially in mediums other than film and television, budgetary resources are often scarce. The long history and global nature of performing arts shows an innate human need for this type of entertainment and creative outlet, and while film and television have helped bridge distance, language,

*Associate Professor of Arts Management/Costume Designer, Ann Lacy School of Dance and Entertainment, Oklahoma City University, USA.

1. Iris Brooke, *Costume in Greek Classic Drama*, New York: Dover Publications, 2003.

2. Triffin Morris, Gregory DL Morris, and Rachel E Pollock, *A History of Theatre Costume Business: Creators of Character.* New York: Routledge, 2021.

and monetary barriers, live performance spaces remain the most accessible training platform for future professionals, hobbyists, and initiates to this craft. Live performance also creates a different experience for audiences and allows for more experimentation and industry growth. To compete with the large budgets, industry size, and wide reach of filmed media, live performing arts are a perfect incubator for new and innovative visual elements introduced in the design and creative elements of process. Over the past fifty years, leaders in theatrical design, specifically costume, scenic, and lighting designers and those working under that creative umbrella have used combination technologies to advance their craft and its visual impact, and usefulness. Many technologies invented in the past century are finally moving into this creative space to produce more integrated designs, supporting the story and optical impact. In a discipline such as costume design, where many expansions in material focus on fabric and fabrication techniques, the addition of fiber optics, kinetic elements, three-dimensional (3D) printing, and light reactive fabric can elevate designs from mere garments to an enticing, effective, and dynamic supporting player in live story telling.

Literature Review

Due to the novel and constantly changing nature of this type of technology, established literature on fiber-optic fabric, kinetic fabric, 3D-printed fabric, and light-reactive fabric is limited. Literature on the topic of theatre and costume history is widely available, as are texts on many schools of costume design. While the philosophy and practical application of costume design has many giants within the field of academic study, such as Rosemary Ingham and Liz Covey (1992), Barabara and Cletus Anderson (1984), and Richard La Motte (2001) who have analyzed and described the creative process of design and fabric manipulation extensively, the underpinning philosophy of practical application and methodology remains relatively unchanged. Instead, it is the materials with which to execute the design that have changed. Despite the amount of time that fiber-optic fabric has been available, there is a lack of scholarly work on the material outside the medical or scientific fields. Zidan Gong et al. (2019) discuss a myriad of applications within the medical field for wearable fiber-optics, such as medical alerts or wearable light therapy, and Saiful Hoque et al. (2022) write about new manufacturing processes for fiber-optic fabric that would open the applications and uses of this material to more user-friendly fabric. Kinetic fabric is in its infancy. Most literature regarding this medium is museum reviews or scientific papers on the manufacturing, rather than the application, of the product. For both kinetic and three-dimensional costumes, magazines and reviews of fashion collections proved very useful. Ultimately, literature on this is topical rather than academic and focused primarily on consumer reviews, editorials, and scientific journals. Some forays in the academic side of the performing arts application can be seen by Katie Remark (2022) with her research into 3D printed sets, properties, and costumes and Faye Hall (2020) whose work dives into

the definition and innovation of kinetic materials used for costume and fabric design. Howe Baum (2022) discusses the practicalities and newest technologies in fiber, but not the application of these technologies in performing arts. To explore the application of neoteric technologies in fashion and performing arts, I relied heavily on periodicals and less traditional forms of literature such as YouTube, blogs, online reviews of performances, and the testimony of creators themselves. The lack of scholarly work in a traditional sense on this topic and the much larger availability of non-traditional literature as it pertains to the performing arts demonstrates not that this material lacks use, but the unique lack of emphasis on traditional modes of research via scholarly papers and focus on the production of art for the purposes of the performance. Hopefully this paper can help to bridge that gap.

Methodology

This paper relies heavily on qualitative research, fundamental research, and has large utilization of secondary rather than primary research. The research design developed a quest to discover new ways to mix technological innovations with costumes and create wearable art with a scientific edge. Research examined current innovations within the fashion, garment, and costume industries, seeking examples that pushed the boundaries of current technology and early adopters of new technologies. Adoption rates were examined based on reviews of costume designs with focus primarily within the United States. Within my own costume shop I was able to test some of these technologies and incorporate them into my own designs, allowing a minute case study that focused on affordability, ease of use, ability to fit the parameters of the design concept, and learning curve.

Results

The purpose of this research was to examine new technologies available to costume designers, find adoption points, prevalence of adoption, the time that each technology was on the market, and barriers that might stand in the way of costume designers adopting these resources to enhance their designs. Studying these four costume technologies showed that the costume industry adopts at a far slower pace than the fashion industry. Rather than leading the industry, they fall on the right side of the bell curve as late adopters. Usually costume designers, and more importantly their funding sources, will not risk resources on innovative technologies until they are widely available at a lower cost. Fashion designers are the earliest adopters and are more willing to take the risks of using less proven and costly technologies to give them an edge against competition. With late adoption, costume designers risk losing compelling story-telling opportunities, increased fabric waste, and lower audience retention. This pattern is unlikely to change without funding changes and training

opportunities that allow a safety net for costume designers to take risks with new technology.

Discussion

Creating costumes that have an extra level of creative or technical interest has always been of interest to me and made me passionate about staying on top of innovations within the world of costume design. Studying these new advances occupies a large part of my research. It is rare to be able to apply these new technologies. Due to the limited budgets in education, the additional limit of being hired on to a project that needs this extra level of design creativity, and a hesitation to adopt new or rare mediums in parts of the industry, it is exciting to be able to move these elements from the theoretical and studied to the practical application. I have had multiple opportunities to incorporate lights into my costumes, starting with a firefly costume in 2013 for Oklahoma City University's *Home for the Holidays* directed by Jo Rowan. Being able to see technology advance so quickly in twelve years is very exciting. Some of the discussion on fiber-optics will focus on my design for *Hang Your Lights* a tap number choreographed by Shadoe Brandt and featured in multiple performances during the holiday season from the opening night of Safari Lights at the Oklahoma City Zoo and Botanical Garden to *Holiday Spectacular* at Oklahoma City University directed by Tiffany van der Merwe. This discussion will also feature applications by other artists exploring the limitations and possibilities of kinetic costumes, a medium that has so much potential to expand out of the museum and high fashion arena, 3D printed fabric and fiber, a design area that is primarily utilized to create accessories but has so much possibility to be a part of the future of most costume creation, and the future of light-reactive fabric, a popular in the industry surrounding the costume play (cosplay) subculture that has yet to fully break in to the stage costume world. It is my hope that one day I can explore all these fiber technologies as deeply as I have been able to explore fiber-optic costuming.

Costume Design: Story Telling and Collaboration

The performing arts are a collaborative field. Led by a director, the creative team consisting of a scenic designer, costume designer, lighting designer, and sound designer (along with their supporting teams) use their disciplines to tell the playwright's story. This means that all artistic vision is led by the director and serves the ultimate purpose of advancing the plot. Costume designers play an important role in character creation within performing arts. In-depth analysis of character, psychology, story, plot, and motivation allow designers to paint a picture of the person on stage using garments to communicate intent and personality to an audience. Attributes such as color,

texture, time-period, style, and contrast help these creative elements to combine into one cohesive unit. While no creative element should take on the primary focus, using accents can help elevate a moment in the visual story or grab the audience's attention. While a light-up costume or gravity defying headpiece may not fit into every story line or be fitting for every story (they are unlikely to be appreciated in a play such as Arthur Miller's *Crucible*, for example), as live entertainment shortens its run time and focuses on spectacle and delivering as many high impact moments as possible, elements like a light-reactive costume can be the final element that sells one artist's show over another. Blending multiple disciplines that previously functioned as separate departments means that current professionals need to widen their knowledge base to allow for comfort in multiple areas of production design.

Fiber-Optics

The history of fiber-optic fabric is closely related to the history of fiber-optics in the technology sector. The original medium for light transmission via fine transparent rods was glass used in a variety of capacities, from dental work in the 1890s to television in the 1930s[3]. While humankind has long had a fascination with wearable glass, forays into garments made of glass, such as the 1893 dress of Princess Eulalia of Spain (made by the Libby Glass Company)[4] lacked the flexibility and endurance required by garments meant for the stage. It would not be until the 1980s when Plastic Optic Fiber (POF)[5] became available that the flexible thread made of polymethyl methacrylate could be incorporated into woven fabric. POF has the appearance of fishing line. While it cannot conduct as efficiently as its glass counterpart, it is less brittle and therefore has a higher number of applications. The low cost of producing the thread allows it to be used in conjunction with other fiber types and either woven (most common) or knitted into fabric. Once the fibers have been incorporated, the long fibers left are bundled together with electrical tape and inserted into a small housing connected to an LED (light-emitting diode). These fabrics can then be cut to assemble a garment. Depending on the type of control connected to the LED, these fiber-optic fabrics can be controlled by the user with a small button or, with a more intelligent and larger battery pack, be controlled by an application on the user's phone. The LED lights allow for a variety of colors to be displayed in the fabric. Companies such as Lumisonata, a leader in the fiber-optic fabric and garment industry, allow for full color mixing and programming

3. Jim Johnson. "History of Fiber Optics." Timbercon: A Radiall Company. October 18, 2018, https://www.timbercon.com/resources/blog/history-of-fiber-optics/

4. Allison Marsh. "The Rich Tapestry of Fiber Optics: The Tale of the Material That Knits the World Together Has Many Surprising Threads." *Spectrum*, July 2020.

5. Kenneth Eben. "Plastic Optic Fiber-An Evolving Technology: POF Technology Has Much to Offer to the Device Industry". *Medical Design Briefs*, November 1, 2013.

with a digital application that mirrors twenty-first century light boards and utilize user-friendly touch screen sliders for changing and custom-mixing colors or programming. The light is shot down each fiber in the garment with a brighter node where the fiber terminates at the end of the fabric. Every few inches on the fiber are small imperfections in the fiber that create a brighter spot. Fabric and garment manufacturers can manipulate the intensity and saturation of the light by grouping fibers closer together allowing for pattern on the garment to be formed via light.

Fiber-optic materials found their way into theatrical use quickly, but those uses were limited and did not enjoy widespread adoption. Disney theme parks were an early adopter for fiber-optics, using them primarily in floats or merchandise, with less use in costuming of park cast. They even incorporated it into the sidewalk in Epcot. Disney's early use of light in non-traditional capacities and their devotion to light up entertainment after sunset hours in the park made them a very public venue to showcase the use of light-up technology in live and interactive performing arts. Small forays into fiber-optic fabric can be seen in major performing arts venues. Melanie Wargo of Electric Diva Creations designed massive fiber-optic wings for an anti-bullying musical, *Taking Wing: Legends of Emimencia* in New York City's New Work's Theatre Festival in 2017.[6] Wargo's designs heavily utilize fiber-optics and her primary design venue is the concert and festival circuit. In 2018, Inter Woven Design Studio created fiber-optic tutus for the Brooklyn Ballet's Waltz of the Flowers in their production of *The Nutcracker*[7]. More visible use of fiber-optic fabric in a design was Zac Posen's dress created for actress Claire Danes to wear to the Met Gala in 2016. However high-profile use, while it helps with visibility for the technology, does not necessarily encourage widespread use or ease of adoption.

The most visible and widely accessible use of fiber-optic fabric and garments has been by cosplayers and costume influencers on platforms such as Instagram and TikTok. Influencer Asta Darling had 142,000 views in November 2022 of her partnership with Lumisonata on Instagram, featuring a fiber-optic ballgown. Creator Shay on TikTok had 1.4 million followers accompany her as she created her fiber-optic costume from scratch in September 2021. By 2025, the price point and availability of fiber-optic fabric has expanded drastically, taking what was a niche material in 2015 to a product that is widely available on platforms such as Amazon. A 47.2-inch by 39.4-inch section of fabric costs $69.88 USD, and Lumisonata offers a full range of pre-made garments already connected to their application ranging from hats at $38.69 to custom made wedding dresses in the thousands. This price is high for smaller theatres and dance companies, but not entirely prohibitive. What makes it so much more accessible is the wide availability and the versatility that

6. Gina Vincenza. "Behind the Scenes with Fiber Optics Costumes on Broadway." Costume Rigging Tips and Tricks. Wix Site, December 7, 2017, https://info74177.wixsite.com/costumerigging/single-post/2017/12/07/behind-the-scenes-with-fiber-optics-costumes-on-broadway

7. Interwoven Design Group, LLC. "Fiber Optic Tutu." Get Interwoven Design. Accessed April 21, 2025, https://www.getinterwoven.com/our-work/fiber-optic-tutu/

vendors, motivated by consumers that use costumes as a hobby rather than an integral part of their industry. Fiber-optic fabric also has a very user-friendly side. Clever patterning and cutting allows an adept draper/cutter to pattern based on where light sources originate and requires a very low-level understanding of how light works to manipulate both the fabric and the light source. Applications that control the lights are very intuitive and allow for a maximum of creativity.

A Case Study: Hang Your Lights

Hang Your Lights is a tap number to the song "Hang Your Lights" sung by Jamie Cullum and choreographed by Shadoe Brandt for the Star Dance Company based out of Oklahoma City University's Ann Lacy School of American Dance and Entertainment. The original concept was "the spirit of Christmas trees and their joyfulness" and it was meant to fit seamlessly into both the larger show of *Holiday Spectacular* and to exist as a stand-alone performance. Under the direction of Artistic Director/Director Tiffany van der Merwe, Brandt and I worked to create a tap number that celebrated the magic that light brings to the coldest and darkest part of the year in the northern hemisphere. Brandt envisioned a number where the audience could experience darkness, allowing them to focus on the sounds of the tap shoes without the distraction of a full stage of performers and other creative elements. While this concept might work for a devoted concert dance audience, it is a hard sell for a broader commercial audience that includes both devotees and neophytes. This presented a challenge for the production design: creating a dance that needed to embody the sensation of darkness while still functioning as a visual medium. As a designer, I needed to find a costume medium that would allow this production value to become a reality. Using fiber-optic costumes allowed the stage to darken significantly while still illuminating the performers and providing visual interest to the audience. A cast of nine dancers, double cast, wore black polyester satin trousers and button-front long-sleeved dress shirts with black acrylic wool fedoras. A white-front fiber-optic vest purchased from Lumisonata was worn over the dress shirt. The back of the vest was black acetate. Black ribbons were added to the front of the vest, replacing the original hook fastening that could not withstand the bounce of tapping dancers. Staff in the Ann Lacy School of American Dance and Entertainment Costume Shop used fiber-optic fabric from LYML.E1 to add tuxedo stripes to the sides of the trousers and to add a hatband and fabric "feathers" to the hats (Figure 1).

Figure 1. Hang Your Lights Costume Rendering

Source: Jessica Telfer, 2024

Two students enrolled in Arts Management Costume Lab were assigned to operate the costumes during performances. They trained using rehearsal videos to learn the lighting cues mapped out by the costume designer. The fabric source from LYML.E1 via Amazon did not connect to the Lumisonata application, and, for this show, I lacked the time and resources required to re-circuit the individual computer chips that programmed the board to a Lumisonata battery pack. I do think that this is possible and does not require much advanced computer programming or electrical knowledge. This limited the number of changes possible with the pants and hats and meant that changes to these had to be limited to moments when dancers left the stage and my crew backstage could manually press buttons to change colors. For a cohesive design, we selected two pant colors and chose to add the magical element via the remote changes made possible by the wireless connection provided via app to the vest. Colors were inspired by the overall theme of Christmas and moments of lighting change were inspired by dance formation changes. Before the first event of the season, cast and crew came together in a studio that allowed for near darkness to practice together and give the wardrobe crew a chance to time their work to the dancers in real time.

The wardrobe crew and the ability to remotely control the lights greatly increased the ease with which these costumes could be incorporated. My previous work with light-up costumes involved wired lights, low battery capacity, and unwieldy large costumes. Being able to work with costumes that were known and established garment types that also lit up opens an entirely new world for working with these costumes. Battery life for the costumes ranged from six hours to forty-eight, depending on how long they were on and how they were used. Using crew to control the costumes meant that the cast could focus on their dancing and performance and rely on wardrobe to troubleshoot. Being able to use these fabrics in real life scenarios meant an opportunity to test the durability and practicality of this tech-enhanced fabric. The crew experienced wi-fi going out mid performance (the crew on the

other side of the stage had access to cellular service and took control of all lights until wi-fi was restored). Cross-training the two wardrobe crew members meant that either member could control all lights and knew both wardrobe crew tracks in the event that a crew member was out. With the Lumisonata program (Figure 2), multiple costumes could be linked together, and cues could be built, mirroring the process of programming stage lighting.

Figure 2. Lumisonata Phone Application

Source: Lumisonata, 2025

The effect of multiple costumes magically changing colors was breathtaking and elicited gasps from the audience at every show. At our first event, the opening night of *Safari Lights* at Oklahoma City Zoo and Botanical Garden, the front lighting was so bright it washed out the colors from the front (the stage was elevated and in the round). Lessons learned from this event led lighting designer Steve Estes and moving light designer/stage manager Evelyn Walter to only use high angled lights placed in the attic of our home theatre (Kirkpatrick Auditorium on Oklahoma City University's main campus) when lighting the dance number from the front and to rely more on angle side lighting and a colorful Cyc to help create light and visual interest that was ambient rather than overwhelming (Figure 3). Due to the physical nature of dance, the costumes experienced regular wear and tear. This was primarily seen in the tuxedo stripes down the sides of the trousers. After repeated knee lifts, the fibers for the stripe would rip out of the connector that attached the bundled fibers to their light source. Later versions of the costume allowed more slack in the wiring to allow for this movement, but regular repairs needed to be made using electrical tape and needle nose pliers. Even LYML.E1 changed their manufacturing during this process, switching from a small metal flange to a long skinny rubber one to replace the electrical tape and make it harder for the fibers to disconnect from the LED casing. The process of design and costume creation began in July

2024, and the first performance took place in November 2024. This meant both the costume shop and an unaffiliated vendor based out of China were refining their manufacturing during this short time frame. Fabrics ordered prior to October 2024 had the old metal manufacturing and all fabrics ordered later had the new rubber fixture.

Figure 3. Hang Your Lights performance at OCU Donor Gala, November 2024

Source: Oklahoma City University, 2024

To allow for ease of operation and cohesive changes, both the hat and the trousers are controlled using a small single-use button connected to a small computer chip housed in a minute plastic case with a charging port (Figure 4). This connects via two insulated wires to a larger plastic case out of which each individual cable for a 7.5" section of fiber-optic fabric. This allows cutting and re-patching of the fiber-optic fabric as the entire fabric is not controlled by a single cable. It also means cutting along the lines between each area allows them to be used on different areas of the garment. We utilized this to make a manufacturing choice to allow us to control multiple garments with one central electrical source.

Figure 4. Fiber Optic Hat and Tuxedo Stripe with One Light Control

Source: Jessica Telfer, 2024

The biggest learning curve within the costume shop was allowing enough slack in the wires for performers to be able to lift their legs, bend at the waist, and have full head mobility. Slack wires and control packs were stored in a pocket in the vest

and cables were paged into the pocket or held in place with internal loops within the trousers. Because the fibers are not conducting electricity, just light waves, keeping all wires separate from the garment meant that when wires were damaged or control packs ceased to work, they could easily be switched out using the flanges. I led work on costume creation, assisted by two student staff members, a senior and sophomore. The fiber-optic material can be sewn on a sewing machine with no damage (provided that the actual electrical wires are not sewn through) and the only impact is additional light "beads" where the small nicks to the fiber create stronger light bleeds due to a new termination location at stitching marks. Depending on how the LED light source is attached to the fabric, the garment can be hand-washed, avoiding the light-housing. In garments where the light source is sewn into the garment, only spot-cleaning is available.

After twelve years of working with light-up costumes and various forms of LEDs incorporated into costumes, this was by far the easiest application and opened the door for many more possibilities, both in dance and beyond. The price point, self-contained and rechargeable batteries, and ease of utilization make it far more attainable for lower budget productions. The smaller learning curve means that training takes less time and is worth the cost in personnel hours. A creative costume designer can easily incorporate this into designs without sacrificing huge budgetary resources. The impact that this type of costume has on the audience shows a reward on investment. Beyond application in costume design, the process outlined in the case study above shows that wearable fiber optic fabric can be easily altered, sewn, and operated with a minimal learning curve. This opens the door to other industries such as sportswear or wearable medical devices and shows that collaborations across fashion, theatre, and the sciences show a wealth of opportunity.

Kinetic Fabric

Kinetic fabric has so much potential. This fabric is amorphous and so new to the industry that it lacks a fully formed definition. Some fabricators define it as any fabric rigged or created to have exaggerated movement when stimulated. Others have added complex pleating diagrams to their fabric and garment creation and attached the pleats to computer controlled animatronic devices, allowing the garments to move as though they have a life of their own. The most notable artist to pioneer and apply this technology is London-based fashion designer Lisa Jiang, whose exhibit, Moments in Motion showed at The Combine in Toronto in October 2024. Jiang pairs her fashion degree with fine art to create garments that become art installations. Using a soft silk organza, she pleats them into intricate folded bundles and dyes the outer edge before attaching them to a basic circuit that uses the tension of the fabric to move it independently. The fabric takes on a life of its own, with vivid colors and intricate pleats mimicking a tightly petaled flower or sea creature

that curls and extends in a complex, but seemingly random pattern. In an interview with Julian Battersby from The Combine, Jiang said:

> Tension is what drives a lot of the movement, like the right play of fabric tension when the motors are in motion. But on my first attempt, the effect was too unpredictable, and sometimes the fabric would get tangled. So, the updated version is done with my partner, Timothy Boll, and that one's properly coded.[8]

The prohibitive element to this type of costuming process appears to be the need to understand circuits and coding. Other designers interpret kinetic fabric based more on the inherent nature of movement created by the fabric. Fabric and fashion designer Hannah Starkey, also based in the United Kingdom, knits fibers into unique patterns, maximizing and capitalizing on the stretch that knit creates to make a fabric that appears to grow and change shape when moved or stretched. The kinetic nature is captured not by added motors and circuitry, but by the wearer of the garment moving and stimulating movement in the fabric. Clever placement of color enhances the illusion, with the closed exterior of the fabric pre-stretch one color and the interior of the fold that is exposed with movement a vibrant contrasting color (Figure 5).

Figure 5. Kinetic Fabric designed by Hannah Starkey

Source: Faye Hall, 2020

Dutch fashion designer, Iris van Herpen, took the term "kinetic" in yet another direction, using close repetitive, carefully arranged patterns or pleats on her dresses to create the illusion of movement. Primarily neutral-toned, these garments use kineticism rather than color to capture the eye. She incorporated sculptural creations that sat on top of the garment and had a delicate balance on wires so that they moved as the model moved, giving them a life of their own in her Fall 2019 collection. Like Jiang, van Herpen used silk organza as well as silk moire. She used laser cutting techniques to provide both accuracy and a low weight finished edge. She also

8. Julian Battersby. "Between Paper and Real Life" *The Combine*, October 2024.

utilized strategic dyeing of the fabric to enhance the sense of movement. Much like Starkey's work, it is the wearer that motivates the kinetic element, as opposed to a separate entity or capturing more advanced technologies. The sculptural additions that van Herpen added for kinetic effect would be cumbersome for practical wear and movement-based performance, but the concept could be easily adapted to allow the fluttery and intricacy these garments evoke to be captured for the character creation by costume designers.

Costume designers working for Cirque du Soleil have been early adopters (and inventors) of innovative costume technologies. Early examples of experimentation with costumes that took on kinetic traits can be seen in Eiko Ishioka's (deceased 2012) costumes for *Varekai* (2002). Made of Lycra and vibrantly colored, these costumes transformed performers into otherworldly creatures with spines, fins, and feather-like appendages that appeared to move on their own. Meredith Caron, costume designer for Cirque du Soleil's 2012 *Amaluna* followed this type of aesthetic with costumes that added dimension to performers while incorporating intensely pleated fabric into her costumes that incorporate the movements of multiple performers to enhance the sense of movement. Heavily beaded headpieces move tremulously with the slightest vibration from a performer's head. Building an otherworldly atmosphere that still allows heavy movement is a signature of shows produced by Cirque du Soleil and variations of this design concept can be seen repeated from show to show, building on the heritage created by the early designers for this company.

While these high-profile designers have access to expensive tools and assistance in programming and creation, their use of pleating provides opportunities for designers within the lower budget sphere the possibility of creating garments with this enhanced sense of movement from sometimes pleating patterns alone. Jiang's coded and motorized self-moving garments require several specialized skill sets and experts that are not within the reach and budget of most designers working outside the sphere of Broadway or Cirque du Soleil. It is within reason to expect that this type of technology will become accessible to a larger audience within the next ten or fifteen years. Already creators inspired by Jiang's work are emulating it, and at times directly copying, drawing into the spotlight the delicate balance between inspiration and artistic ownership that has a far less developed and rigorous copyright program than other disciplines. As Cirque du Soleil's early innovations in creating exterior movement in costumes shows, there is a thirst for this type of costuming asset. It is within the reach of lower budget productions using the mechanisms that have existed for thousands of years, pleating and sculptural draping. The clever uses of folding and building with fabric can be captured and used to create a sense of exterior movement without copying an innovator or outsourcing for expertise from other disciplines.

3D Printing in Costume Design

Three-Dimensional (3D) printing is another device that can be used to create kinetic elements in costumes. This technology, invented in 1981 by Dr. Hideo Kodama[9] underwent many refinements in the three decades before it reached the capacity to print fabric. Iris van Herpen, regularly a leader and new adopter of technologies in the garment industry, used 3D printed garment pieces in her Spring/Summer 2010 collection entitled "Crystallization" and her Spring 2013 collaboration with Julia Koerner and Materialise entitled "Voltage". In 2024, she designed a 3D printed wedding dress for Mariana Pavani. This dress was the result of 600 hours of design work on the software Zbrush using a 3D body scan of Pavan and took 41 hours to print. Designer Zac Posen has worked with 3D printed fabrics and garments including two looks for the Met Gala in 2019. These looks, "Rose Petal Dress" worn by Jourdan Dunn and "Glass Dress" worn by Nina Dobrev have a heavier visual weight than pieces made by van Herpen. "Rose Petal" dress consists of 37 large textured undulating dark rose iridescent petals that used electric beam melting (EBM) to create a printed titanium frame. The petals also used a 3D printing technique in plastic polymer with vibrant color added in paint post printing. "Glass Dress" is made of plastic (Somos Watershed XC 11122) and used an ultraviolet (UV) laser in the manufacturing process. The final effect is that of a dress with all the folds and layers of fabric that appears to be frozen in action and rendered in a hard translucent shell. In contrast, van Herpen's work relies on interlocking layers of printed material and brings a delicacy more reminiscent of lace or an intricately embroidered trim. Layers of the same motif repeat in the garments creating a moveable and wearable garment. While both "Crystallization" and "Voltage" showcase van Herpen's highly sculptural style, they differ from Posen's work. Posen's garments have a hard plasticine element to them, appearing like armor. Van Herpen's garments move with the body and drape. The armored aspect is more reminiscent of an exoskeleton and the structural moments have a softness created by many small spines and layers that create a fuzzy effect from plastic as opposed to a hard shell. Other designers have adopted this new technology, with Balenciaga using this medium for their Fall/Winter 2023/2024 collection and designer Anouk Wipprecht creating a hybrid 3D printed/kinetic garment known as the "Spider Dress" that moved 3D printed "arms" over the shoulders of the model using robotics.

While these garments are attention grabbing and awe inspiring, their manufacturing technique is highly prohibitive for lower budget venues. The time, knowledge, personnel, and material used are beyond the budgets of all but the biggest live performing arts venues. Even when introduced to the performing arts, as seen in a 2020 Just Dance video game release that featured a performer in a 3D printed basket-like hood, it is an expensive process. The creation of her skirt and

9. UtiliMaker, "The Complete History of 3D Printing" accessed May 1, 2025 https://ultimaker.com/learn/the-complete-history-of-3d-printing

hood from a lightweight printed plastic that still allowed her to fully move and perform required a large team of designers and creators with a diverse set of backgrounds and disciplines to create a single garment for a popular and high grossing video game. Film has moved into this space easily with high budget productions like *Iron Man* and *Malificent* using the technology to make their iconic and titular characters' costumes. Ruth E. Carter dived deeply into 3D printing for headpieces and other elements to bring Wakanda to life in *Black Panther,* a logical extension of the world created in Wakanda that relies heavily on printing technologies for so much of the plotline.

So where does this leave the live performing arts? 3D printing has been overused for creating accessories and add-ons to garments and underutilized to create the actual garment. While Posen's model may not be practical for most designers, van Herpen's model can be inspirational. Fabric can be printed in four ways: chainmail, geometric coding (G-code), modeling in Computer-Aided Design (CAD), and infill method as shown by Sara Alvarez[10]. It is quite likely that 3D printed fabric is the future of fabric manufacturing. Currently fabric is manufactured as woven or knitted. Knitted garments can be made in an additive process with minimal waste, but most garments are assembled in a subtractive manner. Fabric is manufactured in long rectangular lengths. Pieces of the garment are cut from this fabric and then assembled, creating waste from remnants of the fabric that are too small or the incorrect shape, grain, or pattern to procure additional garment pieces. With 3D printing, the pieces for the garment can be printed in the exact size, shape, and with the proper pattern, greatly reducing waste from the manufacturing process. Additionally, because these printers use plastic, these garments can use recycled raw materials for manufacture and create a cyclical manufacturing process. While costume shops are a very small portion of the waste experienced by the garment industry, due to their large dependence on re-use of items in established costume stocks held by rental houses or individual costume houses, the ability to use CAD to create a costume that is then printed will greatly reduce the time spent on cutting fabric and the waste generated in that process. While the current use of 3D printing is relegated to creating structural elements, accessories, jewelry, and armor, creating viable fabric and more importantly, stretch material is possible with 3D printing. The most common use is the chainmail printing technique that prints small individual forms that interlink. Many designers and textile innovators utilize this method. It can allow for kinetic elements such as easy expansion and compression and has many more applications than clothing (such as architecture and engineering and space technology). More intriguing for costume design manufacturing are the three other options. G-code and CAD are similar in their ideology. G-code is the coding for how the fabric will be assembled. It requires the designer to be able to code, although this coding is easier to learn. CAD is a program regularly used in theatrical

10. Sara Alvarez, "How to 3D print fabric-Step by step" posted February 6, 2022 by Sara Alvarez, YouTube, 5:31, https://www.youtube.com/watch?v=6MQSxgcn9i0

design by scenic and lighting designers. Costume shops are slowly adopting this programming for pattern making, although many shops still rely heavily on antiquated hand drafting techniques due to budgets that do not allow for the software or a lack of training in the field. Within their counterpart, the fashion industry, it is hard to find shops and studios not utilizing computer programming for most pre-assembly applications. Using CAD, a costumer can design the piece and have the printer print it. Easier for a novice in 3D printing is the final method, this uses pre-programmed elements in the printer without an additional software or knowledge of coding. Most 3D printing is done with solid shells and geometric interiors allowing for less material usage and a lighter weight object. By setting the exteriors at zero, home or shop manufacturers of the 3D printed fabric can capitalize on the geometric interior as the pattern of the fabric, creating a tightly linked lace like pattern. For dancewear, this strong, stretchy material printed on a tight geometric pattern opens a host of opportunities. Introductory 3D printers with this capability cost $4,000-$5,000 USD meaning that without a higher operational budget, this technology is within reach, but not necessarily a realistic investment at this time. Some shops are working to adopt it, such as the Royal College of Arts in London for their 2017 production of *Farewell My Concubine,* with printed gauntlets, pleated fabric, and elaborate collars (Figure 6). 3D printing is entering the theatrical world via scenic and properties design. Hopefully as more scenic shops acquire printers, 3D printing can be used by the costumes shops or allow more acceptance for that budget line in annual production expenses.

Figure 6. 3D Printed Collar for Farewell My Concubine

Source: Royal College of Arts, 2017

Light-Reactive Fabric

Returning to the interplay of light and costumes, the final exciting invention on the horizon of costume design is light-reactive fabric. This fabric has several names: light-responsive, photochromic, and UV reactive. Early versions of this concept

already exist in the performing arts and were captured heavily in performances of the late twentieth century: glow-in-the-dark costumes. In my personal design portfolio, I have used glow-in-the-dark multiple times, most recently with glowing tap dancers dressed as large dolls that come to life in Oklahoma City University's 2016 production of *Home for the Holidays* directed by Jo Rowan. Fabric with these reactive capabilities and paints that respond to blue light and ultraviolet to enhance costumes are widely available, easy to use and incorporate into costumes, and have a very affordable price point. Costumes can be bought pre-assembled, or fabric can be acquired that is treated with light sensitive chemicals and assembled to a designer's vision. This form of light reactive costuming and theatrical design is enjoying a resurgence in popularity with less renowned companies such as *Vertigo* acrobatics show heavily using it in their 2021 season of touring shows.

Figure 7. Light Reactive Fabric

Source: fabricshow, 2025

This technology is also enjoying growth beyond the glow-in-the dark version and is entering a "change in the sun" era. The technology is similar, but instead of trapped in low light and dark performance spaces, fabric is now being treated to change colors in sunlight (Figure 7). These optically adaptive fabrics are moving into the typical early adopters: fashion designers and cosplay influencers. Anrealage's Spring/Summer 2024 collection "Invisible" revealed logos when exposed to UV light on a catwalk and Dior's Autumn/Winter 2023 used photochromic textiles made by Joana Vasconcelos that appear one color in the sun and another when removed from sunlight. Costume influencer Asta Darling made a "Sleeping Beauty" dress using solar reactive dye in June 2023. The fabric was dyed by Darling and turned from pink to blue when exposed to sunlight. Solar dyes are inexpensive and available from a variety of vendors but become permanent when exposed to sunlight and do not return to their original color when removed from the sun. The magic seen in the Dior and Anrealage collections is created using silver halide or organic molecules that allow the garment to be "restored" back to the original when removed from the UV or sunlight. Yarns that have these properties are in the infancy of manufacturing and are not widely available but have the potential to reach the mass market in the

next ten to fifteen years. However, these progressions in light-reactive fabric can be mimicked using the current technology or a clever collaboration between lighting designer and costume designer. Violinist Lindsey Stirling impressed fans at a concert in December 2024 with a costume that was taupe and then vibrant indigos and violets. Clever lighting and use of wavelengths not usually seen in the performing arts made the costume appear to change color. While technology is steadily progressing, designers have a thirst to use light-reactive material in new ways beyond concert, circus, and dance settings. This type of medium has so much potential to create characters and tells stories in the live performing arts while giving a visual boost at a very low-cost point.

Conclusion

There is so much potential available for costume designers to incorporate technology into a traditional fabric and fiber medium. While there will always be a need to preserve the traditional and stick to the garment forms of the past, the potential for innovation and telling stories based on emotion, fantasy, or future, enhanced by the addition of light or movement, is undeniable. Lighting enhanced costuming is easily obtainable, even in spaces where money, resources, or training are low. These additions to costumes require a small investment and low learning curve with a high reward. Utilizing collaboration with the lighting designer, a costume designer can use a combination of light and treated fabrics to allow a character's garment to change colors magically in front of the audience's eyes or incorporate fiber-optic fabrics to allow the couple in love to literally glow with the light of falling in love as they move through a touching pas de deux. Other advances in fabric and fiber technology still seem out of reach for most costume designers. Companies such as Cirque du Soleil and Warner Brothers studios have extraordinarily large budgets compared to the average theatre, dance, or circus company. Costumes that require 3D printing require the equipment to print them. While the learning curve on a 3D printer is relatively low, the upfront investment is beyond the usual operational budget for most costume shops that prefer to allocate that money for machines used daily in the shop. It is likely that this will change in the next decade or two as this type of technology becomes more mainstream in the fashion industry. It is likely that most shops will begin to use this technology because of partnerships with scene shops that already have one. It is also likely that universities will be quicker to adopt this technology as their mandate is training future professionals within the field and their funding structure can allow for grants to purchase equipment for that purpose.

Despite the stunning visual impact of kinetic costuming, it is unlikely that this will be adopted on a large scale by the costuming community. It has limited uses and its needs in character building are very specific. The high cost and learning curve that necessitates learning coding, robotics, and potentially wiring will decrease

its adoption as freelance designers and their teams are usually at full capacity with their usual show load and unable to spend significant time learning new programs and techniques. It is likely that when characters requiring a sense of kinesis are required, designers will stick to the current widely adopted methods: pleating, light weight fabric, latex appendages, and vera-form armors.

Costume creation is an ever-evolving discipline. Designers have a responsibility to spend time incorporating new techniques and learning new methods of character creation to allow themselves to stay ahead of the trend. This is especially important in the live performing arts where budgets and demand can be lower, but the majority of costumers work in these parameters. Staying competitive helps secure a designer's desirability in a crowded field and allows this profession to continue to contribute to the viability of live performance. The ability to use small tricks that deliver large impact on a lower budget allows these designers to stand out and helps the performing arts continue to draw an audience, thereby helping everyone in the industry. Beyond their usual character and historical research, costume designers can use advances seen in high fashion as a research mechanism to inspire high-impact creativity.

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