TEXTILE LIGHT DESIGN

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How can light be integrated as an active part into a textile surface? What would it mean to work as a textile designer with light as an integrated active part of a textile surface?

The combination of textiles and light is not new—often textiles are used for lamp shades—spreading, filtering and colouring the light of the inherent light source. However the possibility to integrate light into textile structures generates new ways of lighting designs. In the last years, a range of lighting materials have been investigated in textile applications from artists, designers, researchers and companies. The integration of LEDs, electroluminescent wires, fluorescent and phosphorescent materials, as well as optical fibres have been tested and first products have reached the market, both craft and industrially produced, (cf. Philips Lumalive (2004-2009); Worbin (2006, p.23); Lene N. Iversen (personal communication, October 2006); Glofab (n.d.); Luminex (2003-2006); LBM (n.d.), SubTela (n.d.)).

Current research into the impact of light on health shows that daylight, through its dynamic changeability, has a crucial impact on the well-being of the human body. The whole wavelength spectrum, as well as increasing and decreasing light intensity triggers positively the circadian body system. Therefore future artificial lighting systems should incorporate these aspects as much as possible, (cf. Boyce (2003, p.95-97, 458; 478-479, 487); Cimo (2006); Dess (2000); Licht und Gesundheit (2008)).

A design example which is investigating the interaction of light, textiles and health is Light Sleeper: a silent alarm clock a work by Rachel Wingfield (2001). The integration of electroluminescent wires in beddings simulates with their lighting a natural dawn to wake you up.

The collection of projects in this paper discusses examples of light emitting textile design research, which explore aesthetic, functional, and conceptual opportunities of PMMA optical fibres in textile applications, through a practiced based research approach. (The projects have been developed in the School of Art and Design Berlin Weißensee and The Swedish School of Textiles, between 2005-2008. Many thanks for all the support from technicians, cooperation partners and sponsors.)
OPTICAL FIBRES

PMMA (PolymethylMetaAcrylate) optical fibres have been used throughout all projects. (Below the term optical fibres will always refer to PMMA optical fibres).

Optical fibres are very interesting to work with in a textile context, being similar in their outer appearance to a transparent monofilament makes it possible to integrate them into a textile structure as any other traditional yarn material. They are able to become a real part of a textile structure and at the same time they allow the textile structure to become a real light source.

Optical fibres are a new material in textile applications. To be able to integrate them successfully, i.e. to create a smooth light-surface, new investigations need to be carried out. (Originally, optical fibres have been developed to transmit light as fast at possible from one end to the other without shining of light at their sides.) The basic issue is to create the right bending angles in optical fibres through textile techniques to provide lighting at their whole length. The challenges and ways how to integrate them into textile structures will be described in the following Phases 1-5.

PHASE 1: woven light - powered by sun energy

How could a textile surface incorporate lighting in one woven structure? Hand weaving techniques have been chosen to explore how to integrate optical fibres for lighting into weaving structures.

The aesthetic aim of these experiments has been to investigate how to create an even all over lighting surface through optical fibres, which can be applied in interior spaces. Three sets of experiments have been carried out on a computer controlled shaft hand loom; optical fibres with ø 0,25mm have been used for all experiments.

The first group investigated optical fibres in different weaving structures. Light tests showed that the integration of optical fibres in double layered structures — both compound weaves and double weaves — generated a stronger light effect, than within one layered structures (only exception were some panama bindings). Therefore double layered structures were further investigated. Optical fibres were combined with a wide range of white materials: from transparent to opaque, from soft-fleecy till smooth and shiny.
The second material has been used as a reflection layer for the light emitted from the optical fibres, optical fibres and the second material dominating each one side of the double layered structure. Using only white materials offered the possibility to see the pure material impact on the light intensity and quality. See figure 1.

The second group continued investigating double layered structures by combining optical fibres with synthetic metallic yarns. Samples, where double layered parts and parts with only optical fibres stand beside each other, showed clearly noticeable differences in light intensity. The double layered sections, using metal yarn as reflection layer, show a stronger light intensity. These samples visualized, again, the importance of a reflection layer. Beside that, the colours of the metal yarns had an impact on the light colour — testing all samples with a white LED lamp – showed slight yellowish and reddish tones by the use of brass and copper yarns. See figure 2.

The third group explored the integration of relief elements — crocheting knots into the surface during weaving, or weaving in silk petals, and additional colours. The 3D elements create shadow effects in the light surface. The piece with the integrated silk petals created, on one side, a pure light surface, and on the other side, a multiple toned yellowish light surface. See figure 3.

A further important element for all set ups were; to use a transparent monofilament warp, to cover the optical fibres as little as possible. Choosing a transparent warp material allows the two sides of a double layered structure to appear as pure as possible. Thereby both – lighting and reflecting layer – can function as optimally as possible. All samples were finally lightened up through a white LED lamp, as well as a light projector including a colour wheel. Presenting the samples with white light, showed the pure material impact on the light. Demonstrating the samples through different coloured lights opened up for future investigations towards the interplay of structure, material and coloured light.
In Summary can be said that the experiments resulted in a range of samples, which showed different possibilities of how to integrate optical fibres into weaving structures.

**PHASE 2: industrial weaving**

Working on concepts of lighting for an everyday environment – creating big window screens for public buildings et cetera – raised questions about industrial production possibilities. Is it possible to weave PMMA optical fibres on industrial machines? The aesthetic goal stayed the same, i.e. to create an even all over lighting surfaces through optical fibres in a woven structure?

A broad range of experiments on an industrial shaft loom (Dornier) have been set up, to see if optical fibres can withstand the industrial production process. Previous optical fibres were only integrated into the weft system of weave structure, now they were investigated in the weft- and the warp system. The thesis work *The screen – a textile installation* by Lene N. Iversen (personal communication, October 2006), inspired to introduce optical fibres in the warp system as well. In her thesis she had successfully integrated PMMA optical fibres into the warp system of a hand loom. Integrating optical fibres into the warp system, opens up for larger scale opportunities for lighting textiles.

Based on previous experiments double layered structures were chosen, as well as real metal yarns as reflecting material for the light emitted through the optical fibres. The experiments using optical fibres (ø 0.25mm) in the weft system resulted in a range of samples which were able to create a lighting surface. Some bindings provided lighting over the whole width of the fabric, and some samples were only able to lighten up parts. First light tests showed, surprisingly, a sparkling effect in the lighting surfaces. What has happened? Hand woven samples never showed any sparkling lighting. After examination of the production process, it was realized that the cylinders for taking down the fabric, were covered with sand paper. The sand paper had caused scratch damages in the fibres and therefore a sparkling effect arose. By further tests the cylinders were taped and the sparkling effect minimized. The tests using optical fibres (ø 0.5mm and ø 0.75mm) in the warp system resulted in a range of samples which were able to light up until a length of approximately seven meters, by an eight meter warp length.
In summary can be said the experiments resulted in different samples of how optical fibres could be integrated in industrial weaving process, both in weft and warp system. Extending the range of optical fibre thicknesses showed new variations in the aesthetic expression of the lighting surface. Sparkling effects could be generated, and a much more structured, linear light effect appeared by the use of thicker qualities.

Beside the already mentioned challenges of using optical fibres on an industrial machine other basic issues are to avoid: strong bending angles of fibres (thick qualities will break and thin qualities will have problems with loss of light), scratching the surface, cutting of fibres through grippers, and too insensitive feeding systems.

**PHASE 3: light patterns**

The aim for this series of experiments has been to further explore the aesthetical possibilities of optical fibres in woven structures; how to go from monochrome textile light-surface to more complex surfaces, how to compose more complex patterns of light textiles and light tones in woven surfaces.

Nature inspired patterns have been used to investigate the composing of light and not light in one surface. Using double layered structures allows creating *two coloured patterns* – light and not lighting, and vice versa on the back side of the fabric. By using this traditional technique a light pattern can be generated. Experiments have been executed on a jacquard machine (Vamatex SD 1701). See figure 4.

Relief structures, based on the same *two coloured pattern* system, have been investigated to further explore the shaping of light in woven structures. The result is a range of samples which show how different relief structures can be generated by combining cotton, Pemotex and optical fibres. Pemotex is a
heat sensitive yarn which shrinks after heating up. Thereby by partial use in a pattern, areas of the pattern will shrink. Optical fibres however will bubble up and therefore create relief shaped lighting areas. Samples including optical fibres need to be heated very carefully. Experiments have been executed on a jacquard machine. See figure 5.

By shifting the experiments to industrial machines a crucial element of the hand weaving experiments got lost, the transparency of the warp material (as only unbleached cotton warps on the machines were available). Transparency had been a functional choice towards minimizing the blocking of the light emitted through the optical fibres. Additional to that it had created a very specific airiness and lightness of the daylight aesthetic of these pieces. Besides that a transparent warp allows to increase the aesthetic expression possibilities in one warp immensely. Being unable to use industrial machines, a shift towards hand weaving was initiated, to test the possibilities of creating light patterns in the desired material aesthetic.

Testing the double layered bindings on a transparent warp, to create two coloured patterns, was not successful. The transparency melted lighting on front and backside visually to one layer and a monochrome impression arose. Therefore three layered bindings were introduced to gain the wished effect of light and no light and vice versa on back side. Three layered binding allowed modulating even more light shades in one surface. See figure 6.

To summarize, it can be said that the series of experiments presents different possibilities of creating light patterns in a woven structure. By the use of an opaque warp, two layered bindings are sufficient to create patterns, however by the use of a transparent warp, three layered bindings are needed to create similar effects.
PHASE 4: industrial knitting

Having explored light in 2D surfaces widely, investigations towards lighting in a 3D surface started, and therefore a shift towards the integration of optical fibres into knitted structures had been initiated.

The starting point was the question: Can optical fibres be knitted on industrial machines? To begin with, the optical fibres have been knitted as any ordinary yarn on a circle knit machine (Meyer Relanit 0,8). Light tests were not successful; the light didn’t travel further than two to three loops and then stopped completely. The bending angle in the optical fibres, which is created by knitting loops, is too sharp to transmit the light further. Therefore the light burst out strongly at the first loops and afterwards a total loss of light becomes consequence.

Next step was to test optical fibres through inlay technique, which allows a horizontal integration of a yarn in a knitted structure, through knitting on a flat knitting machine (Stoll CMS 330 TC). Thereby sharp bending angles could be avoided, allowing the light to continue travelling. Promising inlay technique has been found in a plain knitted surface, but as the aim was to integrate optical fibres in a 3D structure, or rather a 3D shape, a new challenge appeared: in a 3D knitted object the yarn is been knitted in a constant transition from front bed to back bed, back bed to front etc, and thereby the optical fibres as an inlay have to follow from front to back, back to front etc. This transition forces the optical fibre back into a sharp bending angle and transmission of light can not be successfully ensured. See figure 7, page 8, (cf. Jansen, 2008, pages 58-59).

Independently from investigations into the integration of optical fibres into knitted structures 3D knitting has been explored. 3D shapes have been knitted on hand flat-knitting machines and afterwards programmed and knitted on an industrial flat-knitting machine. Surprisingly, not the same shapes arose, even by the same exact use of materials, bindings and amount of loops etc. These experiments on industrial flat-knitting- machine showed that 3D shaping requires a quite complex programming and production process (and that the transfer from hand production to industrial production is not as easy as changing weaving technology). Therefore the decision was made to focus on developing ways of knitting three-dimensional as simple as possible and to exclude asymmetric shapes for the moment. Hence a
continuous exchange between hand knitting, hand flat-knitting machines and industrial flat-knitting machines has been explored, to investigate 3D seamless shaping.

In summary can be said that optical fibres are able to knit industrially, but a successful transmission of light has not been achieved yet. Furthermore to create a 3D seamless shape is possible, but requires quite complex development processes.

**PHASE 5: Light Shell**

The *Light Shell* project is concerned with the question of how to create a space-shape which supports a feeling of well being for the human body through the media light and textile. Research has shown that daylight has a crucial impact on the feeling of well being for the human body. Therefore optical fibres have been chosen as a light source, as they can be directly connected to sunlight – for example through a Parans Solar System (Parans Solar Lighting AB (n.d.); Parans Solar Lighting AB (2008); Parans Solar Lighting AB [visit, July 2, 2008]) – or/and to an LED system, which could simulate the dynamic changes of daylight. Several experiments have been done to create 3D knitted space-shape integrating a dense lighting surface based on the integration of optical fibres.

As industrial knitting with optical fibres has not been successful in terms of light transmission, alternatives for integrating optical fibres into knitted structures have been looked for. See figures 8-9. Finally the integration of fine optical fibres into plain knitted metal structures, produced on circle knit machine, by 'simulating' a similar binding as in previous weaving experiments has been tried out. The optical fibres go on top of a certain amount of loops and underneath, on top, underneath etc. Thereby two things could be generated: bending angles over the length of optical fibre, which forces the light to exit on the entire fibre length, and creating a reflecting layer for the light through the metal knit structure. Example see figure 10.
Surprisingly the light tests in short plain pieces didn’t show a difference in lighting between bended and not bended parts of optical fibres (ø 1mm). However the light tests in weaving structures, by using ø 0.25 – 0.5mm optical fibres, showed a clearly noticeable difference in lighting: from no light, little or strong light, depending on different bending angles. Nevertheless, applying this technique of weaving in optical fibres by hand into 3D shapes showed differences in lighting, as the fibres are not only bended up and down, but also around different wide curves.

Results of this project are two models presenting two space-shape concepts incorporating dynamic lighting:

- Design concept 1: is a horizontal lying oval shaped space, which is based on a lying body position. The space offers its visitor space of privacy for a moment of personal time-out, being surrounded by an embracing dynamically changing light. The model is presented in scale 1:10. See figure 11.
- Design concept 2: is a round cupola shape, which can house two bodies comfortable in a lying and sitting body position. This concept aims as well to surround its guests with an embracing gesture of dynamically changing light for a personal moment of time-out. The model is presented in scale 1:20. See figure 12. Both design concepts could be placed in private or public spaces, (cf. Jansen 2008, pages 7-31).
In summary it can be said that by combining industrial and craft production techniques visualisations of *Light Shells* – how to create spaces for well being through light and textiles – have been developed in form of models. The models are able to be connected to a variety of light sources and therefore can demonstrate a dynamic changing of light in a three-dimensional space.

**DISCUSSION**

The field of Smart Textiles introduces new generations of materials into the field of textile design. These materials challenge traditional working methods, techniques and production possibilities and force the involved designers to develop new ways of working. Therefore one can say the field of Smart Textiles opens up for a shift in design practice. Not only do new materials generate new working methods and aesthetic and conceptual possibilities for textiles, they also oblige the designer to gain knowledge outside of their traditional field. Knowledge about electronics, programming, light and light technology needs to be implemented, and therefore does not only influence the field of tasks for the designer. Besides that, it will also need to involve design education, to make future designers being able to approach these new dimensions of designing. The field of Smart Textiles, for example working with lighting design, opens up more and more towards a dynamic and interactive design approach in textile design, which marks a big shift in the fields design practice.
Craft and industrial processes have been used to explore the lighting possibilities for optical fibres in textile structures. Does craft stand against industrial? No, they in fact complement each other very well in a practice based design research approach. Both feature individual strengths: craft based processes allow a very free and direct working access and high flexibility in material choices and technical decisions. On the other hand industrial processes allow testing future visions in a bigger scale. Besides that, both ways create very specific aesthetic expressions. The work in the field of Smart Textiles develops a new type of working within craft, it allows to go beyond current industrial possibilities, and thereby pushes the industry towards new potential. Being able to merge them, like in *Light Shell*, enables to create future visions for textiles.

The series of projects and experiments presented in this paper have initially started in weaving technology; exploring possibilities of how light can be integrated into a woven structure. A range of lighting expressions and conceptual applications areas have been investigated and are presented through samples and prototypes produced both through craft and industrial possibilities.

Out of these two-dimensional explorations into textile light design, three-dimensional investigations have been initiated. Resulting in models which integrate 3D knitting technology as well as working methods from weaving with optical fibres, by *weaving in* by hand optical fibres into 3D artefacts.

Transferring knowledge from one technology to the other has enhanced the possibility to create future visions of lighting design through the media textile.

This paper has discussed a varying range of examples which explore aesthetical possibilities of how optical fibres can be integrated as an active part into textile structures. The final models of *Light Shell* visualize experiments in creating concepts of spaces for well being through the media light and textiles.

Besides that, all examples of light investigations lay a base for new design technologies in weaving and knitting technology towards the integration of optical fibres into textile structures.
REFERENCES


FIGURES

Figure: 1-3 Photos: by author (2006)

Figure: 4-6 Photos: by The Swedish School of Textiles (2007)
Figure: 7-12   Photos: by Henrik Bengtsson, Imaginara (2008)