LASER ENHANCED DYEING OF WOOL FOR TEXTILE DESIGN

Paper A20

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ABSTRACT

A laser assisted dyeing technique for wool based textiles, allowing surface pattering of the textile substrate, is presented in this paper.

Laser technology can offer digital design capabilities combined with the ability for bespoke or short run production. This dry technology, if used as an alternative to traditional textile wet processing, has the potential to offer increased environmental sustainability through significant reduction in energy and wastewater effluent.

This study examined the effect of CO_2 laser irradiation as a pre-treatment to dyeing 100% wool fabric with reactive dye and it's potential as a creative tool for textile design. Using a 10.6μm, 60 Watt CO_2 laser, optimum laser processing parameters for treating wool, were determined. Tests were then performed to analyse the effectiveness of the laser pre-treated and dyed fabric. Reflectance spectrophotometry, dye exhaustion and colour difference values were determined, revealing that laser treatment has an increasing effect on the colour difference value. Microscopic analysis of the laser treated/dyed fabric showed that CO_2 laser irradiation could be used to remove the outer scales from individual wool fibres on the surface of a woollen textile. The removal of these scales allows dye to penetrate the fibre at an increased rate.

Potential design applications of the technique have been explored. Investigations concluded that laser irradiating targeted areas on the woollen cloth followed by dyeing, could be used to achieve differential dyeing between irradiated and non-irradiated areas on the textile surface. After dyeing, the laser marked areas appeared tonally darker on the surface of the cloth. This tonal differentiation was then used to examine quality of line and mark making that can be achieved to impart successful tonal surface patterning on woollen textiles.

INTRODUCTION

The consumption of water and energy used in current dyeing and finishing processes in the textile industry pose significant environmental concern (DEFRA, 2011). By offering alternative solutions to traditional textile wet processing through laser technology, there is potential to increase environmental sustainability through significant reduction in energy and wastewater effluent.

Advantages of the CO_2 laser as a dry process have positive implications for reduction of wastewater and processing time of textile production in comparison to traditional wet finishing methods. These advantages have been beneficial to denim manufacture in creating laser-faded effects on denim (Costin & Martin, 1999; Ortiz-Morales et al, 2002). As such CO_2 laser use has become increasingly commonplace in the textile industry (Ondogan, 2005). The use of laser technology on other textile substrates presents numerous further opportunities for sustainability in the field of textile research (Allwood et al, 2006).

Various studies have examined the effect of laser irradiation on the properties of synthetic fibres and fabrics in which, both UV (Bahners et al, 1993; Wong et al, 2007; Kan, 2008) and IR (Montazer et al, 2012; Bahtiyari, 2011) irradiation have been reported to increase dye absorption properties of synthetic polymer substrates, resulting in improved dye performance.

Very few studies have investigated the effect on wool properties, however a small number have shown that laser irradiation can reduce felting and shrinkage of woollen textiles (Nourbakhsh et al, 2011) and that UV irradiation can improve the dyeability of wool

(Periolattoa et al, 2014). A combination of laser and plasma treatments was shown to increase hydrophillia as an all over treatment on woollen textiles (Czyzewski, 2012).

While the aforementioned studies go a long way to test and explain the phenomenon on synthetic textiles, focusing on improved overall performance, very few have discussed the possibility of design outcomes, from targeting specific areas of the textile substrate (Bartlett, 2006; Wallace, 2013). The potential for the CO_2 laser, as an effective surface design tool for wool has not been documented, nor has the correlation between laser parameters and their effect on dyeing wool textiles. Herein lies an opportunity for investigation. With CAD controlled laser software, digital design opportunities are plentiful. The aims of the following investigation were to ascertain the effect of CO_2 laser irradiation on surface and dyeing properties of wool substrates, and secondly; for results to be analysed in relation to their potential as a technique for textile surface design.

METHODOLOGY

Research in the area of laser processing for textile design straddles multiple fields of enquiry. As a multidisciplinary study, it has been necessary to approach the research using multiple methods, allowing the outcomes to stand up with rigor on all straddled fields which would traditionally fall under the separate categories of textile design, textile chemistry and textile engineering. Therefore, defining a specific methodology for this research has been guided by both scientific research methods and design research methods.

The diagram in Figure 1 attempts to show the synthesis of scientific and creative approaches to textile design research in this study. It displays how practice has been used to develop and

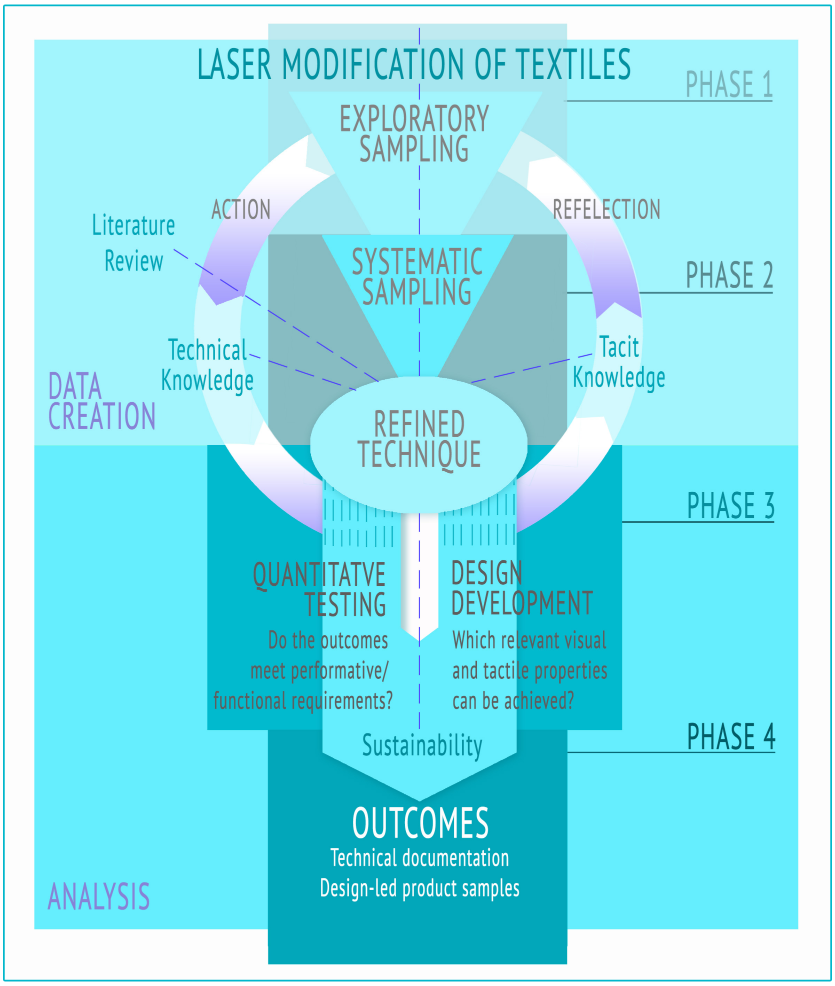

Figure 1 Synthesising Scientific and Creative Approaches to Textile Design Research

to analyse data. Critical reflection on each phase informs practice whilst employing and building on tacit knowledge and technical understanding. Material samples and written documentation are generated throughout. The following section aims to further explain each phase of the research approach as shown in the diagram.

This study consists of a practice-based approach to textile design research in which knowledge is generated as the practice progresses. The work can be described as *Research through design* (Frayling, 1993) where design practice was used as an essential part of the research both in conducting investigation and as a means of expressing the results. Figure 1 shows the practice divided into two sections, *data collection* and *analysis*. The combination of design practice and systematic sampling was used as a method of data collection for material research and for developing new processes for existing technologies (the laser). Work created as part of the practice then became the data for analysis.

The overarching aim of this research was to achieve novel and sustainable methods of applying surface design by modifying textile substrates by use of a laser technology. Phase 1 begins with this broad aim. While establishing workshop conditions for this research, an initial exploratory phase allowed experimentation with a wide range of parameters and materials. Philpott (2007) discusses exploratory play as "*a process of knowledge generation... which allows practice-led research to flourish and advance beyond that which could be achieved by scientific research methods used in isolation,*" (p. 2). Supporting Philpott's comment, through this 'playful' phase in the research, a familiarity between laser settings, graphic elements, material weight and composition was established. McCullough (1996) describes this exploration as learning the *affordances and constraints* (p. 248) of a new medium. This learning builds a cumulative tacit knowledge of material and medium properties.

In reference to the subject of research discovery, Polyanyi (1966) suggests that tacit knowledge involves the foresight to anticipate a solution to an undetermined or *hidden* problem. It could be argued that one difference between scientific discovery and creative discovery is the starting point. As Barrett and Bolt (2007) suggest, in creative arts practice, strategies are not predetermined, but emerge from action over time. Rather than starting with a narrow problem that needs solving, a creative, playful approach in the initial stages of this research allowed a number of new techniques to emerge, which could then be further refined by a more systematic approach in phase 2.

Reflective practice has been applied across all phases of this research, shown in the diagram as circular, passing through and feeding into each phase. A reflective process has been integral to decision making to provide direction and generate ideas during and after practical work or reflection *in* action and reflection *on* action (Grey & Malins, 2004). In both instances critical reflection informs the next actions to be taken and the process repeats. Schon (1991) describes this as, "*a reflective conversation with the situation" (*p. 97) emphasizing the cycle back and forth between reflection and action or "*Practice raises questions that can be investigated through research, which in turn impacts on practice"* (Grey & Malins, 2004, p. 1).

While design research methods were suitable for textile sampling and developing techniques at studio scale, a technical understanding of the process and fabrics is also important for this research. Thus, this practice also consisted of systematic scientific experimentation to establish quantifiable results using laser technology. Phase 2 provided proof of concepts as well as the ability to quantify, explain and refine the effects achieved on textile substrates, allowing techniques to be controlled and replicated.

Phase 3 of the research, shown in Figure 1 shows two strands of analysis examining the aesthetic and functional properties. Again the synthesis of design and scientific approaches proved to be fundamental in identifying and demonstrating both the creative opportunities through visual means and the technical and performance properties through industry standard testing. Together revealing viability for their potential commercial context.

A third important framework of analysis considers the processes and outcomes in terms of their environmental sustainability.

The outcomes of the research are noted in the diagram as phase 4. Using the developed process, physical designs are created and informed discussion of potential advantages, impacts and viability are documented.

This paper reports on the second and third phases of the research, working within the broad constraints and affordances established in the creative phase, refinement of which is further described in the results and discussion. This included testing the technique, therefore the technical language and quantifiable measurements used, reflect engineering and industry testing standards described in the experimental conditions. Finally the process is tested for it's design potential using a mark making test sheet that has been derived from a more personal, creative design intention. The function of design in this instance is a form of analysis with an aim to establish how the authors personal design language may be translated to fabric using the newly established technique.

This discussion has shown how practice has been used to develop and to analyse the data. Visual samples and written documentation are generated throughout. Critical reflection on this informs practice whilst employing and building on tacit knowledge and technical understanding.

EXPERIMENTAL CONDITIONS

The following conditions and equipment were used throughout this research for laser processing, dyeing, testing and analysis of the work. Each experiment was repeated a total of three times and the mean and standard deviations recorded.

Materials

A pre-scoured woven 100% wool fabric supplied by Drummond Parkland (Huddersfield, UK) was used throughout the experiment. The fabric is a plain weave construction with a mean fibre diameter of 19.7 microns. Samples measuring 40mm x 12mm at a weight of 1.25g were used for testing purposes.

Laser

The laser marking process was conducted using a Synrad carbon dioxide (CO_2) source laser. This laser operates at a wavelength of 10.6μm producing a continuous wave beam in the far infrared spectrum with a maximum power of 60 Watts. An infrared Laser was chosen to harness the photothermal properties to modify woollen fibres. The laser has a fixed focal length, which was established prior to experimentation. All experiments were carried out with the laser beam in focus on the surface of the textile substrate. Winmark software was used to mark solid raster shapes for parameter testing and for all over laser marking. Graphics were processed at a resolution of 100dpi using a greyscale reduction to convert images to laser ready files.

The window of laser processing parameters to cause effect on the material properties for wool was expected to be small. This was confirmed experimentally to range between 50-60kW/cm^2. Below this, insufficient energy density is delivered to the fabric to allow a phase change to occur. Above this pyrolysis negatively impacts the material properties. Therefore, laser irradiation of fabrics was carried out at power densities of 51kW/cm^2, 54kW/cm^2, 57kW/cm^2 and 60 kW/cm^2 including an untreated control at 0kW/cm^2. To ensure an even processing of the substrate surface, the laser irradiation passed over the fabric 5 times at a constant laser scanning speed of 5000mm/s.

Dyeing

An Ahiba infrared dye machine was used in the dyeing phase of experimentation. This machine allowed controlled temperature and agitation throughout the dyeing process. Dyeing occurs by adding dye, fabric sample and auxiliaries in airtight cylinders with each fabric sample occupying it's own vessel. Concentrations of chemicals used during the dye process were expressed as a percentage on weight of fibre (owf). The dye recipe used Lanasol Blue CE Reactive dye from Town End Dyes, UK, at a 4% dye concentration and the auxiliaries as described. The procedure used in this experiment was as follows. Fabric undergoes a 15-minute pre-treatment at 50^{o}C in a 1:100 liquor ratio containing 2% owf acetic acid, 5% owf sodium sulphate, 1% owf Albegal B and water. Dye is then added and the dye bath warmed to 80^{o}C for 30 minutes. Finally 1% owf ammonia is added and processed at 80^{o}C for a further 15 minutes. After dyeing, the samples are removed from the dye bath, rinsed and allowed to air dry.

Microscopy

A Nikon Optiphot optical microscope was used to examine the effects of laser irradiation on treated fabric samples at a magnification of 10x. A Phenom Scanning Electron Microscope (SEM) at a magnification of 5000x allowed further analysis of the effects of laser irradiation on individual textile fibres.

Reflectance Spectrophotometry

CIE colour space is a colour evaluation method that compares the sample to be tested to a standard (white). Numerical data was recorded using a reflectance spectrophotometer to measure CIE L*a*b* values, described as follows:

L*	Black = 0 (Lightness/ Darkness) White = 100
a*	Red = Positive Value Green = Negative Value
b*	Yellow = Positive Value Blue = Negative Value

Testing for this experiment was performed using a Data Colour Spectraflash 600 Plus-CT. Each sample to be treated was folded into four before being placed beneath the aperture to prevent light transmission through the sample. Measurements were repeated three times per sample and rotated by 90^o degrees between each measurement. An average was then calculated. The Figures were then used to calculate colour difference values (ΔE*) using the following equation:

$$\Delta E^* = [\ (\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2\ ]^{½}$$

Where ΔL*, Δa* and Δb* are the differences in colour measurements between laser irradiated front and untreated reverse sides of the textile samples.

Dye Exhaustion

Dye exhaustion is the percentage of dye absorbed by the fabric from the dye bath solution. In this experiment a Unicam SP1800 UV/visible spectrophotometer was used, set at 610nm, the maximum absorbance wavelength specific to the chosen dye. Three absorbance measurements were taken from each exhausted dye bath and an average was used to calculate Exhaustion (%E) using the following equation:

$$\%E = 100 \times (Abs_0 - Abs_1) / Abs_0$$

Where Abs_0 is the absorbance of the original dye bath solution at a wavelength of 610nm and Abs_1 is the absorbance of the remaining dye bath liquor after the dyeing process has taken place.

RESULTS AND DISCUSSION

Surface Observation

To examine the effect of laser treatment on the surface properties of wool, laser irradiation at increasing power outputs was performed prior to dying the wool with reactive dye. Five squares of 100% wool were laser treated at power densities of 51kW/cm^2, 54kW/cm^2, 57kW/cm^2, 60 kW/cm^2, at 5000mm/s and an untreated, 0kW/cm^2 control. Prior testing had established the range of laser parameters in which to operate.

Visually, a change in colour can be seen between each of the laser treated samples and the untreated control as shown in Figure 2. As laser power increases, the colour change appears to show increasingly darker shades of blue. On the lowest parameter settings this change is subtle. On the highest settings, pyrolysis becomes evident on the wool fibre.

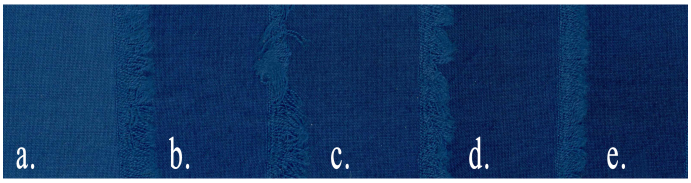

Figure 2 Laser pre-treated, dyed wool samples subject to power densities of a.) 0, b.) 51kW/cm^2, c.) 54kW/cm^2, d.) 57kW/cm^2 and e.) 60 kW/cm^2

Figure 3 shows microscopic images of laser treated wool before and after dyeing at increasing laser processing power outputs. 3a shows the untreated control. Here there is a consistent, even tone across the fibres. In 3b and 3c however, it can be seen that individual fibres, which have been subject to the laser irradiation, are darker in colour. In 3b the contrast between lighter and darker fibres is subtle. In micrograph 3c, where a higher power density has been used, the contrast has increased significantly. Increased carbon can be seen in micrograph 3d. The darker colour is a result of pyrolysis followed by dyeing however; these areas of burnt debris sit on top of the damaged wool surface and are easily removed by gentle abrasion. As well as degrading fabric structure, this may result in poor colour fastness to washing and rubbing.

The results indicate improved dye performance on the surface fibres of wool that has been subject to laser irradiation. As the laser power density increases, so too does the dye performance on the substrate. However, too high a power will begin to discolour and degrade the wool fabric, as the heat begins to burn and char the surface. The results indicate a delicate balance of textile properties effected by laser treatment and highlight the importance of finding the correct laser parameters to work effectively on each fabric substrate. In this case power densities beyond 60kW/cm^2 are excessively damaging to the woollen fibres, therefore not suitable for the aims of this investigation.

The morphology of the irradiated surfaces was further examined by scanning electron microscopy (SEM). SEM was carried out on an area of the wool fabric that had been subject to laser irradiation of 57kW/cm^2 at a velocity of 5000mm/s. The micrograph in Figure 4 shows the wool fibre strands on the processed area. Two particular fibre strands of note, labelled A and B can be clearly seen. The characteristic scales of a natural wool fibre can be seen on

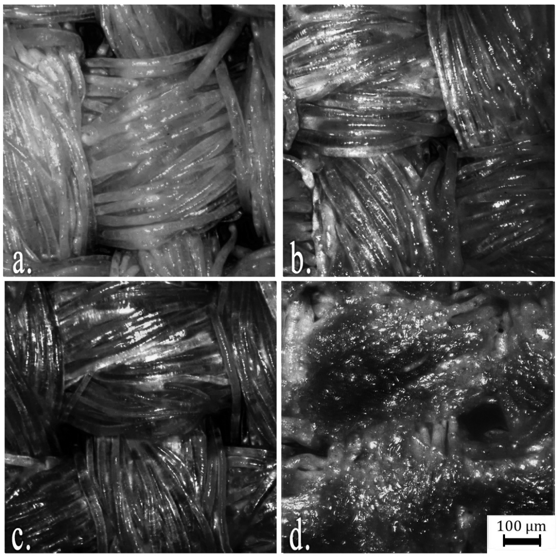

Figure 3 Micrographs at 10x magnification of laser pre-treated, dyed samples subject to power densities of a.) 0, b.) 54kW/cm^2, c.) 57kW/cm^2 and d.) 60 kW/cm^2

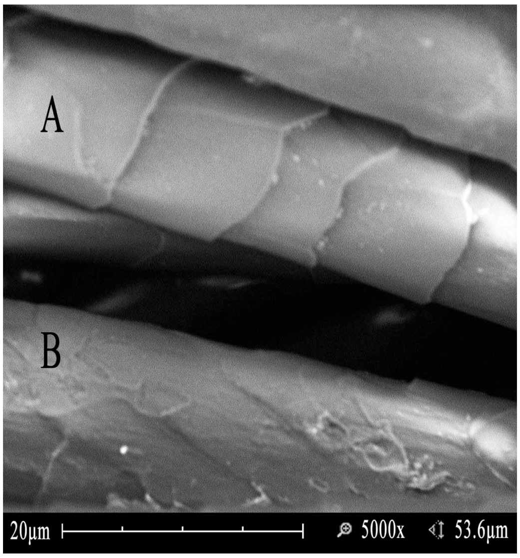

Figure 4 SEM micrograph of laser irradiated wool

strand A, this strand had not been subject to laser irradiation. On strand B however, the scales on the surface of the fibre appear less pronounced; they have been ablated by laser irradiation.

The scales on a woollen fibre are formed from a tough slightly hydrophobic lipid layer. The removal of the scales of a wool fibre allows easier penetration of the dye into the core of the fibre (Smith et al, 2010). The darker colour properties seen in Figure 2 can be attributed to improved dye absorption by the laser modification of wool fibres.

From SEM and optical microscopic evaluation, laser parameter settings suitable for further testing have been identified and the effect of laser irradiation on individual wool fibres has been discussed.

Dye Exhaustion

The power settings 51kW/cm^2 to 60kW/cm^2 were chosen to provide a range of results for testing purposes without causing thermal damage to the woollen textile. The samples were then dyed with Lanasol blue reactive dye in controlled conditions.

At optimal conditions of 100^{o}C, 75 minutes (Lewis, 1982), the dye bath has the potential to be fully exhausted at the end of the dyeing process. A fully exhausted dye bath would result in insufficient dye remaining in the liquor for adequate absorption readings to be taken using a spectrophotometer. To ensure only partial exhaustion, a high concentration of dye at 4% owf was chosen and the dye bath held at sub-optimal dyeing conditions of 80^{o}C for 30 minutes.

After dyeing, the absorbance of the remaining liquor from each of the five parameters was measured using a spectrophotometer. This was then used to calculate percentage exhaustion relative to the initial dye bath concentration, before dyeing.

The results show an overall increase in exhaustion of the dye bath as laser power increases as seen in the graph in Figure 5. This indicates a corresponding increased dye uptake by the fabric substrates. At the lower than optimal temperatures of 80^{o}C, exhaustion of dye has increased by a significant 9-10% on all laser treated samples.

Colour Measurement

The laser irradiated samples were measured before and after dyeing, using a reflectance spectrophotometer for CIE L*a*b* values. The colour difference values have been plotted on the graph in figure 6, examining competitive dying between laser irradiated front, and untreated back of the samples.

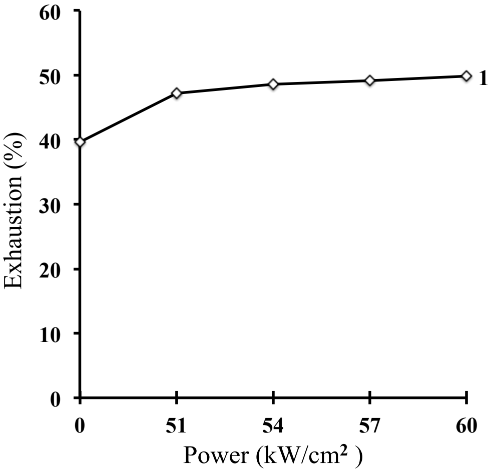

Figure 5 Graph Showing % Exhaustion of Dye from Dye Bath at Increasing Laser Power Densities.

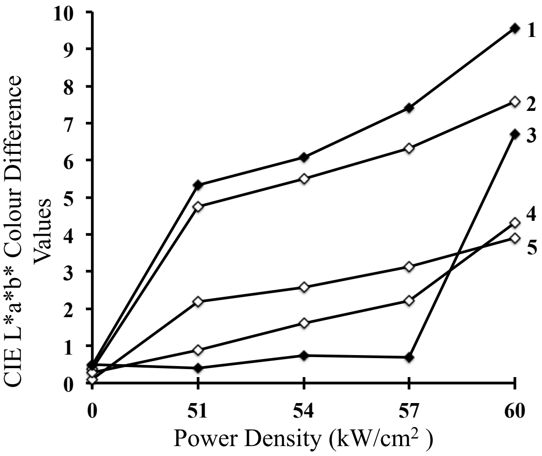

Figure 6 CIE L*a*b* Colour Difference: 1) ΔE_1, 2) ΔL^*, 3) ΔE_0, 4) Δa^*, 5) Δb^*.

Before dyeing the colour difference between laser treated parameters and untreated control was measured. The graph (ΔE_0 line 3, figure 6) shows a very shallow fluctuating line with values below 1, up to 57kW/cm^2. Beyond this power density, the colour difference soars to a difference value of 6.71 revealing the threshold laser parameter before discolouration occurs. This shows that up to 57kW/cm^2 laser discolouration prior to dyeing has not had a significant effect on the colour levels after dyeing.

After dyeing, a graph pattern showed a rising curve for each of the difference values. At 51kW/cm^2 we see a significant increase in colour difference (ΔE1*) and darkness (ΔL*) of the laser treated substrate, which continues to rise with increased laser power. There is a less significant rise in yellowing (Δb*) nonetheless an increase is present. Similarly a slight increase in Δa* values occurs, both rising steeply after 57W/cm^2. The graph patterns indicate a consistent increase from 51-57W/cm^2. After 57W/cm^2 however, a steep slope in the graph indicates the increase in dye uptake intensifies significantly beyond this power density. The highest colour difference in tested range that did not cause discolouration or thermal damage to the textile surface was identified as 57kW/cm^2. We can conclude this to be the optimum setting to gain greatest dye uptake without causing unwanted degradation to the wool fibre. Beyond this parameter, discolouration and unwanted pyrolysis prior to dyeing has been observed.

Tables 1 and 2 show CIE L*a*b* values for both front and reverse of the samples. It can be seen in Table 1 that colour remains consistent between untreated reverse sides and the control across all samples with a SD of less than 0.5. If competitive dyeing were taking place we would expect the reverse side samples to show decreasing colour levels proportional to the increase on the laser treated front. Together with the morphological information derived from the SEM images, this suggests that the laser modification of wool fibres allows more dye to enter the fibres on the laser treated surface. The increased dye exhaustion verifies that a greater affinity for dye is attained.

Table 1 CIE L*a*b* Figures and SD for Untreated Reverse Side of Laser/Dyed Samples.

Power Density (kW/cm^2)	L*	a*	b*
0	30.40	-9.18	-23.17
51	29.83	-8.72	-23.20
54	30.92	-9.05	-23.24
57	30.23	-9.14	-23.02
60	30.76	-9.08	-23.09
SD	0.43	0.18	0.09

Table 2 CIE L*a*b* Figures and SD for Irradiated Front of Laser/Dyed Samples.

Power Density (kW/cm^2)	L*	a*	b*
0	30.40	-9.18	-23.17
51	25.09	-6.53	-22.32
54	25.42	-6.47	-21.64
57	24.22	-6.03	-20.80
60	23.19	-5.16	-18.78
SD	2.78	1.50	1.68

Laser Pre-treatment For Textile Design

The colour difference between treated and untreated areas of the fabric substrate are significant at 57kW/cm^2, showing potential for CAD controlled laser treatment to be used as a design tool/technique.

A mark making test sheet was created using graphic software as shown in Figure 7. Eight small strips of imagery consisted of block and linear patterns alongside painterly marks, multi-tonal, gradiated and photographic designs. The test sheet was designed to include a wide range of markings and visual textures to explore the quality of line, tonal differentiation and overall aesthetic that can be achieved using the newly developed laser assisted dyeing technique.

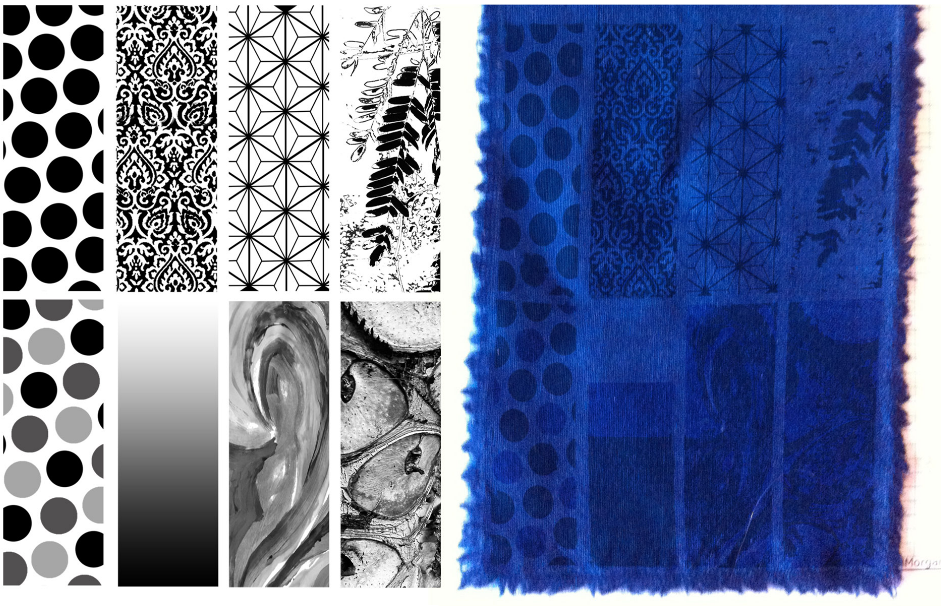

Figure 7 Laser marking test sheet as a CAD
and processed on a wool textile sample.

Wool fabric was laser marked with the test markings using a CO_2 laser with a power density of $57kW/mm^2$ and a velocity of 5000mm/s. After dyeing with blue reactive dye, examination of the sample reveals that a precise level of detail was achievable for both linear and block filled shapes. However, the tonal gradients and painterly effects have not translated as successfully, appearing to form solid shapes without the subtle tonal variations that are present on the original test sheet. The photographic imagery has also lost significant tonal detail. Further tests exploring alternative colour reduction methods for graphic files, such as halftone reproduction, may allow painterly and photographic effects to be achieved.

From the results of the test sheet, the most effective graphics were chosen to take forward for design development. Geometric patterns consisting of solid, undulating and linear shapes were laser marked on 100% wool fabric, followed by dyeing with reactive dye. The resulting samples, shown in Figure 8, give a subtle tonal all over pattern. The technique has the potential to be used on woollen textiles of varied constructions and weights that could be suitable for fashion or home interior applications.

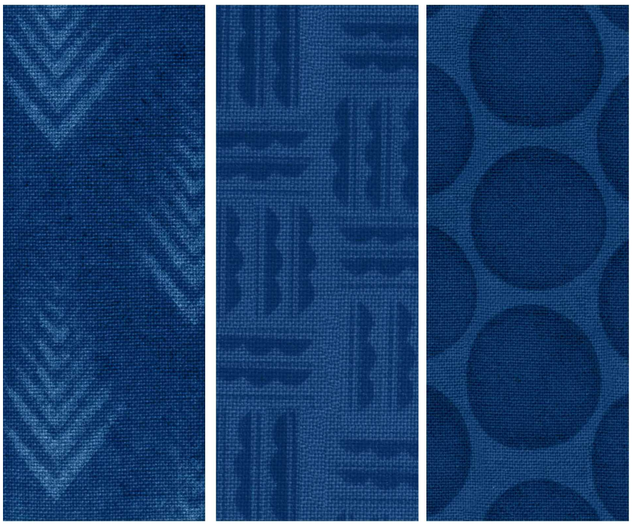

Figure 8 Design Samples: CAD controlled tonally darker
areas produced by laser irradiation prior to dyeing.

Discussion of Results

This study has found that a CO_2 laser marker can be used to irradiate wool fabrics prior to dyeing to achieve differential dye uptake across the surface of the cloth. Through practice, a technique has been derived allowing a pattern to be marked on wool using a CO_2 laser followed by dyeing. After dyeing, the laser-marked pattern will appear tonally darker on the surface of the cloth. Microscopic analysis has shown that laser irradiation removes the outer scales from individual wool fibres on the surface of a woollen textile. It has been discussed how the modification of these scales allows easier penetration of dye into fibre, so that laser marked areas will allow an improved dye absorption compared to the non-treated areas. Usually, high temperatures and long processing times are required to achieve maximum dye uptake on wool, however this study has shown that dyeing laser pre-treated wool at a reduced temperature of $80^{o}C$ can achieve an elevated level of dye uptake. A purely scientific approach may have resulted in an improved dye performance for the textile substrate. However, following a desire to create a new surface design tool encouraged breaking the 'rules' of optimal colouration, instead using sub-optimal dyeing conditions to exploit specific textile properties to gain differential dye uptake. The contrasting colour results could then be used for surface design purposes.

As well as an apparent visual effect, dye exhaustion results have indicated an increasing amount of dye uptake is achieved as the laser power density delivered to the fabric is increased. Colour data testing corroborates, increased colour intensity occurs after dyeing as laser power density increases.

Analysis of CIE L*a*b* colour difference values of laser treated wool before dyeing confirms that increased colour difference is a result of increased dye uptake, not from laser discolouration, up to a power density of $57kW/mm^2$. This is the optimum power density to achieve greatest colour difference before pyrolysis begins on the surface of the wool fabric. Up to this optimum level, parameters can be chosen to achieve a variety of mark making and gradiated tonal effects. The technique can be used to create halftone, linear and monochrome effects on textile substrates.

This laser enhanced dyeing technique to create surface design offers potential reductions in energy and wastewater effluent through reduced dyeing temperatures and improved dye performance.

This process may seem akin to screen printing, however as the laser marking operates a remote, non contact set up, the potential to place designs on finished products and across garment seams would allow manufacturers to customize blank products to meet the requirements of retailers and consumers. Furthermore, combining the functionality of the laser to perform multiple production tasks at once, such as pattern cutting as well as the laser dye technique, would allow additional environmentally sustainable benefits to the process compared to outsourcing each individual stage of the production process, for example, fabric manufacture, screen printing and garment production in addition to storage and transport between these phases. Combining techniques in one stage has potential to offer fast response in today's fast changing market, with easily changed CAD files allowing smaller product runs than financially permitted by exposing individual screens for screen printing or die cutters for product pattern cutting.

The laser technology used is commercially available and accessible to small businesses as well as to the larger manufacturer. This means that the techniques developed could be easily transferred to creative textile businesses including fashion and homeware applications. The innovation could be used within both niche and mainstream markets enabling designers and makers to remain competitive within the high-end design market. The results will also be relevant to larger manufacturing and retailing business enabling design innovation alongside contribution to developing environmental strategies, thus increasing their competitiveness within the global market.

CONCLUSION

A novel method of textile surface design for wool has been presented. Additional sustainability benefits and positive impacts for manufacturing have also been discussed.

This design-led research investigated the technical aspects of laser processing for textile design with creative aims. Further in depth technical knowledge has been gained from working to a rigorous scientific line of questioning, allowing an insight and thorough understanding into the workings of laser technology and associated software, as well as an elevated understanding of the chemical/physical effects that can be achieved on wool substrates. Like the stonemason or weaver learn the technical processes of their craft to become a master craftsperson, so too has the technical understanding of the laser system allowed the technology to become a tool with which to create. The processes that have been developed have allowed a freedom to design using a brand new ‘toolbox’ of techniques. The combination of tacit knowledge gained from creative experimentation together with the technical knowledge gained from quantitative testing and analysis have been imperative to evolving techniques which can open new creative opportunities for textile design whilst being viable and communicable for industrial/commercial application.

Results have established that an increased dye uptake is achievable on the surface of a wool fabric by laser irradiation. Experiments have shown that CAD files can be used to mark out targeted areas to create specified designs. The reason for the increased dye uptake has also been explained. Overall dyeing time and temperature have been reduced from standard practice, displaying potential for a significant reduction of energy during dye production. Further work to examine mechanical properties of the laser irradiated fabrics, such as fastness to washing, rubbing and tensile strength testing would be required to ensure dyeing quality met current industry and consumer standards.

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