4.1 Final publishable summary report

- **An executive summary**

Lion-Tex project represents a break-through innovation in the field of textile printing. The step forward is represented by the possibility of bringing onto textiles the three-dimensional effect of lenticular images, and exploiting it for improving the efficiency of high visibility safety garments and devices.
The lenticular effect is a well known technology that allows reproducing a few 3-D effects on flat surfaces. Two or more images are interlaced (i.e. “cut” into very narrow stripes and put together, alternating one stripes of the first picture and one of the second) and covered with a lenticular layer, that is a transparent sheet, shaped as an array of semi-cylindrical lenses. Each semi-cylinder covers exactly the two (or more) interlaced stripes, acting as a magnifying lens: this way, the observer’s view is focussed on one of the picture, depending on the relative position. When the observer relatively moves respect to the lenticular image, he can see the picture changing.
The technology developed in the Lion-Tex project allows to recreate this effect on textiles, with an efficient, cost effective and robust innovative printing machine.
The machine is basically composed by a common ink-jet printer for textiles, a dryer, a second printhead for resin dispensing and a UV-curing light for freezing the resin.
Thanks to this innovative machine, the lenticular images (and textiles) production process is a lot simplified:

- The textile is positioned by the carpet;
- The ink-jet printheads print the interlaced image on the surface of the textile;
- The ink-dryer passes over the textile and fix the ink on the surface;
- The resin dispenser is positioned over the interlaced part and covers the image with an array on lenses;
- The UV-curing system freezes the dispensed resin so that it maintain the wanted shape and curvature;
- The lenticular textile is ready and the carpet advances for the production of the next portion.

The overall savings of the new process are a breakthrough. First of all raw materials: the polymeric array of lenses is directly built on the surface, “on-demand”, and so there is no more need for shaping and cutting pre-formed rolls and non more waste produced. The energy needed for forming the lenticular layer is much lower (up to 1:50) than that used for extruding the polymeric film and calander it into the final shape. Furthermore, being everything integrated and synchronized in one machine, there is no time needed for fine positioning and combine the printed image and the lenticular layer.

Beside all possible future applications of this new technology, the high visibility effect for safety garments is the one with the highest potential and gain.
High visibility garments (for example drivers emergency jacket) are commonly made of polyester textile very bright coloured (yellow, orange, green) and some reflective stripes. The lenticular plotter enables the creation of a new generation of safety garments characterized by an enhanced high visibility effect; the jacket, or part of it, is coloured with an interlaced bright image (e.g. green + yellow) and covered with the lenticular layer: all observers, depending on their relative position and movement, will see a colour-changing high visibility jacket, with a “flashing” effect from green to yellow that will capture much more their eyes. Human eyes, in fact, respond quicker to dynamic effect instead of static, so lenticular effect can really enhance the properties of safety garments.
The project accomplished all its objectives and developed a demonstrator of the lenticular plotter, not ready for commerce yet but able to produce small lots of lenticular textiles and a first prototype of lenticular high-visibility garment.

- **A summary description of project context and objectives**

The need for safety

As stated by the *European Agency for Safety and Health at Work* (OSHA)[1] and the *Canadian Centre for Occupational Health and Safety* (CCOHS)[2], high-visibility safety apparel (HVSA) is essential for people that work when there is low light and poor visibility and, in particular, where the working place involves moving vehicles.

The human eye responds best to large, contrasting, bright or moving objects: that's why high-visibility items allow people to be seen by drivers sooner and more readily. At the state of the art, worker visibility is enhanced by high colour contrast between clothing and the work environment against which it is seen.

In order to address this issue and minimise accidents, the EU launched directives 89/656/EEC and 89/686/EEC, which oblige employers to make available high visibility clothes to their employees.

In Europe 16 Million workers operate in low visibility environments, including roadway construction personnel and vehicle operators, utility workers, survey crews, emergency responders, railway workers and accident site investigators, school crossing guards, parking and toll gate personnel, airport ground crews and law enforcement personnel directing traffic, parking service attendants, workers in warehouses with equipment traffic, shopping cart retrievers, sidewalk maintenance workers, and delivery vehicle drivers, to name a few. Statistics report that every year 6000 of them are injured by vehicles or human operated equipment, because of a lack of visibility, specially in night time operations.

State-of-the-Art solutions consist in applying reflective material stripes onto the garment surface. These stripes are made of an open lens type reflective film consisting of high index reflective micro glass beads on a background of fluorescent material. However this passive solution is not effective if we consider that a recent study highlighted that the main cause is the late detection by the driver, since the vehicle lights are not able to illuminate effectively the side of the road[3]. This is in agreement with much anecdotal evidence from the roadside after vehicles have hit pedestrians. After hitting pedestrians at night, many drivers claim that they never saw the pedestrian, often reporting that the impact was the first warning they had of their presence[4]. Over the cost in human lives, also the social cost for persons injured has to be taken into account: estimating 10 days hospitalization and the costs for rehabilitation (the mean costs per inpatient day were 230 € (range: 154-311€) in general hospitals and 323€ (range: 209-400€) in university hospitals)[5], and 30 days inability to work (conservatively 60€ per day), it is possible to state that, globally, these accidents do account for a cost conservatively, 30 M€ per year related to such accidents.

Therefore, in spite of the norms and the attentions paid in the last 20 years, a lack of security in garments for workers is perceived. This technological gap can be filled thanks to innovative way of thinking the textile substrate. The textiles and clothing industry is one of Europe's leading industrial sectors and, in particular, the technical textile industry represents a greater and greater percentage of the total production of Western Europe countries.

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[1] European Agency for Safety and Health at Work (OSHA), http://osha.europa.eu/en/topics/accident_prevention/slips

[2] Canadian Centre for Occupational Health and Safety (CCOHS), http://www.ccohs.ca/oshanswers/prevention/ppe/high_visibility.html

[3] Werner Stengg, The Textile and Clothing Industry in the EU – A Survey, Enterprise Papers No. 2 – 2001, June 2001

[4] Industrial Fabric Products Review – February 2003

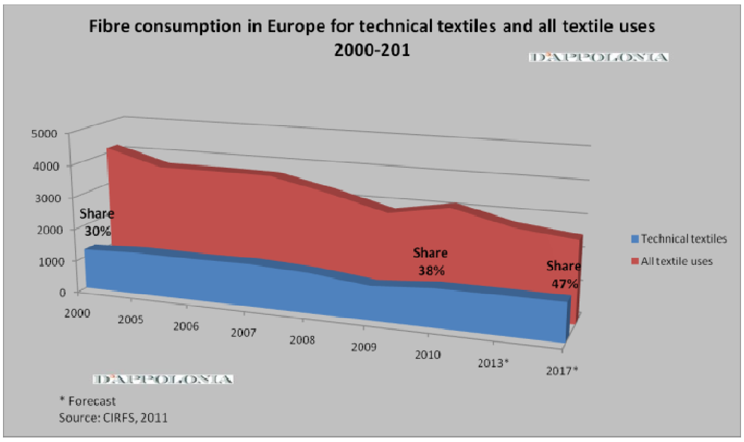
[5] Oostenbrink JB, Buijs-Van der Woude T, van Agthoven M, Koopmanschap MA, Rutten FF.; Institute for Medical Technology Assessment, Erasmus University Rotterdam, Rotterdam, The Netherlands; Unit costs of inpatient hospital days. [PubMed - indexed for MEDLINE]

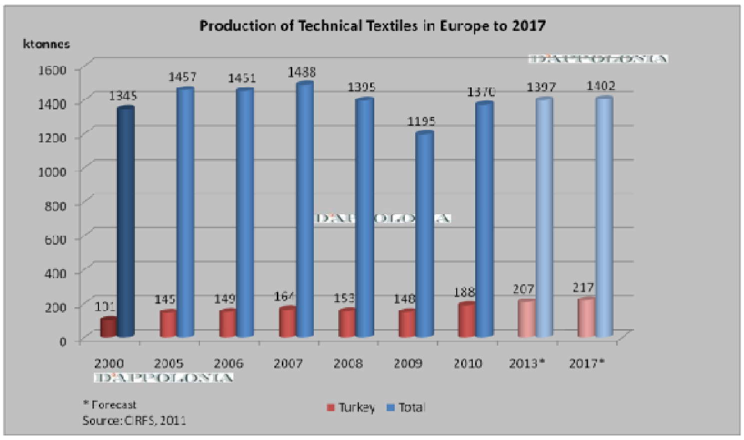
The need for technical textiles

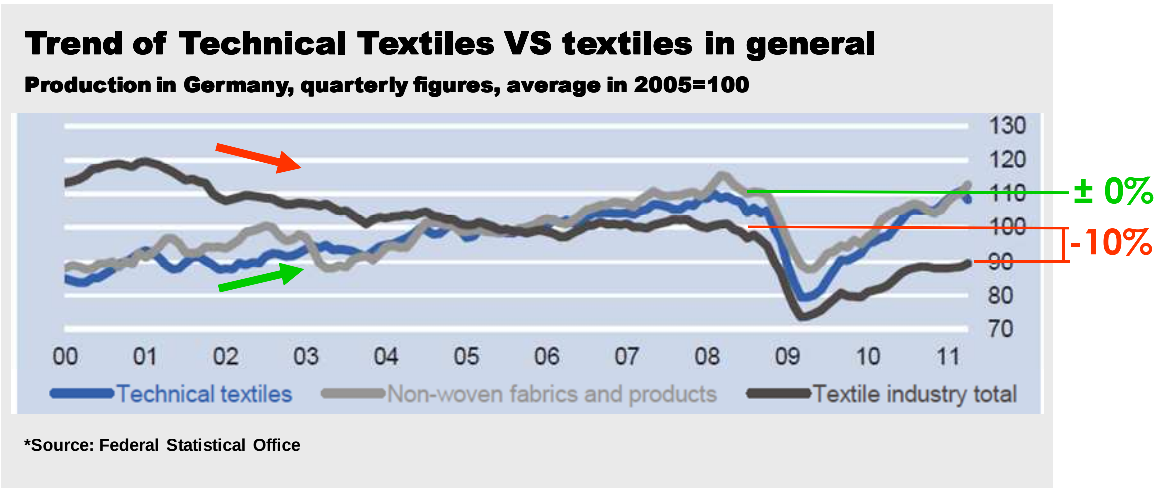
the worldwide consumption of fibers for technical applications was around the 40% of global consumption, that is 29 Mton on 72,5 Mton with an overall value of 130 Mld$[6]. The growth foreseen in next decade is of about 2,1% every year, challenging **89,3 Mton in 2020**[7].

In a general panorama of decline for the textiles market (-25% from 2000 to 2010), the technical applications have turned out substantially stable (- 5%, comprehensive of effect crisis).

The evolution of the technical textiles market for Europe is foreseen to be stable in next years, with the production volumes on the levels of the 2008 (CIRFS, 2011), equal to approximately 6% of the world-wide production of technical technical (~ 7,8 Mld$ in 2010)[8] (BCH, 2011)







The German market is a good reference to figure out the economic trend of high quality technical textiles in the Euro area.

From 2000 to 2008 (before the crisis) the total textile production has decreased of around 17%, while the technical textiles production has increased, in the same period, of 22%.

[6] DRA, 2002 – CIRFS, 2011 – Business Co-ordination House , 2011
[7] CIRFS, 2011
[8] CIRFS, 2011 & BCH, 2011

From latest results of 2011, so including the figures of the recent recession, we can say that the production of textiles has suffered an overall decrease of -25%, while technical textiles has increased the production of 22% (data 2001-2011).

According to these figures, despite the large volumes of textiles for fashion and apparel are migrating to Asian and BRIC countries, the production of technical textile remains one of the stronger asset of European manufacturing industry.

Among the other technical textiles, industrial protective clothing market in Europe and USA together share the greatest percentage of the global market. Rising emphasis on worker health/safety issues, stricter government mandates, technology innovation, and increasing pressure to reduce costs associated with workplace related injuries led disability and death, will stimulate the world industrial protective clothing market to reach US$7.7 billion by the year 2015.

Europe still represents a major producer of technical textiles, supported by the technological gap with emerging countries: that a niche added-value market, European manufacturing system shall maintain inside the boundaries.

The growth of the need for safety textiles in Asia will be driven by new manufacturing works and construction projects underway in Middle East, and Asia, particularly, India, China, and Vietnam. Additionally, apart from being the world's most populous countries, China and India have a large number of unprotected industrial workers and this offers a further potential for future growth.

This can represent an opportunities, for the SMEs involved in the 3D-LION project, to increase the technological gap with emerging countries and increase their competitiveness in such a difficult, but very large, market of safety textiles and garments.

The project idea

The Lion-Tex project is based on an innovative method of producing lenticular pictures, which allows them to be directly created on non-flat or bendable surfaces like textiles, thus realizing lenticular effects even on textiles, by creating a lenticular layer of a transparent resin directly on it.

A particular printing method is represented by lenticular images, a very well known technology, exploited in many fields such as photography and postcards, commercials and a great number of gadgets. Lenticular images are optical effects created by coupling a digitally treated picture (interlaced picture), as shown in Figure 1, and a layer of lenses (lenticular layer); the typical optical effects that can be reproduced are Flip, Morphing, Zoom, 3D and Moving effects.

Usually lenticular images consist of two elements: a digitally modified image, which is called "interlaced picture" and a layer of lenses called "lenticular sheet", which is produced by extruding a flat layer of plastic which is then thermally deformed by a calandra, in order to assume the shape of the required lens. The interlaced picture is usually printed on a substrate of plastic or paper and the layer of lenses is glued on it; sometimes the interlaced images can even be directly printed on the flat surface of the lenticular substrate.

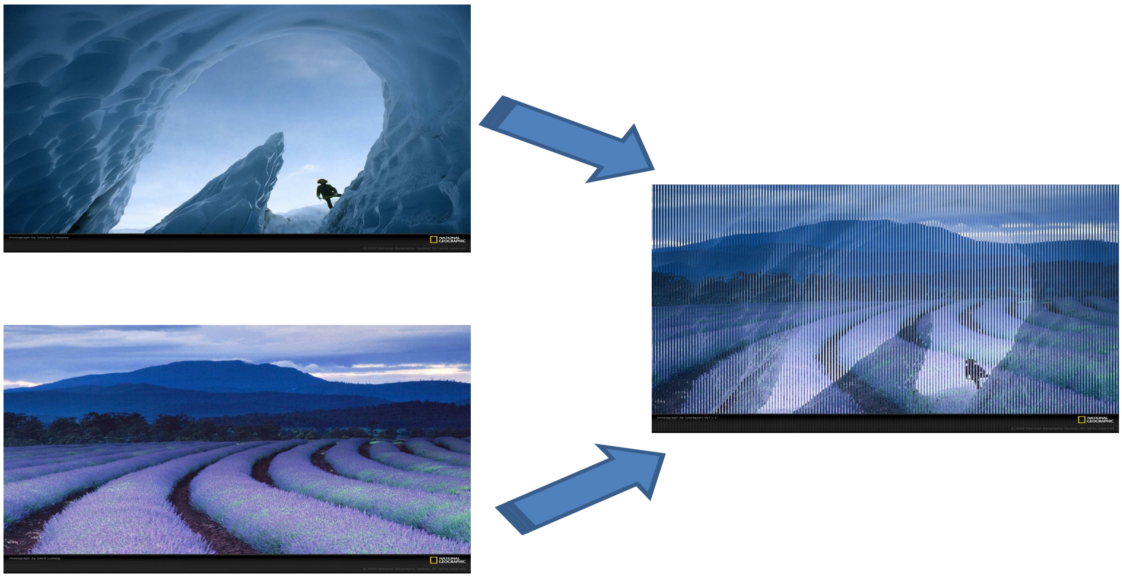


Figure 1: The interlacing process of two different pictures

At the state of the art, when Lion-Tex began, lenticular images were not exploited in textile industry, neither for fashion scope nor for high visibility function. With the current technology, it is rare to find applications on textiles and, in any case, they just consists of a patch, welded or sewed, which is not a fully integrated part of the garment. A lenticular patch can strongly affect the rigidity of fabric with two bad effects: it modifies the wearability of garments and it difficultly exploits the continuous 3D movements and bends of flexible textiles. Moreover, the patch cannot recreate a particular shape (a logo, a stripe, a basic shape) without a waste of materials: the lenticular sheets are usually squared and they shall be cut, adjusted and most of them are just thrown as process waste.

The innovative process consists of 2 fully integrated process steps:

- interlaced image is generated by dedicated software and then printed on the textile with an ink-jet printer;
- lenticular layer is created with an ink-jet dispenser machine, which is able to treat resins with high viscosity and to build 3D patterns.

In this way, lenticular layers can be easily created on every material, plastic, paper and textiles, introducing new opportunities of application. The innovative method of creating lenticular printed textiles can be exploited for safety purposes, adding to the common high visibility effects an additional "flashing" effects that represents an extremely important added value.

The process is industrialized in a lenticular automatic plotter.

The very interesting reached results convinced the owner of the idea (and of the previous patent Lion-Tex is based on) to go for a second patent and secure the concepts and the technologies of the Lion-Tex lenticular plotter.

- **A description of the main S&T results/foregrounds**

In line with the above mentioned needs, Lion-tex partners have set-up and performed three key research areas, namely:

- **The software:** interlacing software should manage innovative lenticular effects, related to the 3-D, bendable surfaces: the shape of lenses should be re-designed and optimized, first of all to adapt them to 3D surfaces and then because of the new optical effects provided by new interlacing software. **Gathered results:** a simpler and user friendly SW has been developed, to generate lenticular images; an innovative SW for integrating lenticular images onto image files; an innovative printer rip, that enables the translation of image files (*.jpeg; *.bmp; *.tiff) into a binary file that controls plotter and printheads movements.
- **The process:** resins had to be investigated, in order to find the ones possessing the right requirements for this application. The most suitable resin for lenticular effects must be transparent, dispensable by ink-jet printheads and flexible enough to be coupled to fabric substrates without cracking. The largest number of resins tested were UV curable resins: they should cure as fast as possible and, at the same time, avoid the proclivity to become yellow, as ageing effect. Moreover, the normal usage of printed fabric or garments should be investigated, in order to figure out the possible effects on the resin of common operation on textiles like washing or ironing, and avoid any possible related risk. The ink-jet resin dispenser should be integrated into a common ink-jet textile printer, in order to create a demonstration machine which allows at first step to print the interlaced image on the fabric, and then to print on that image the lenticular lenses, without moving the substrate to other machine or process station. This integration allows saving time in the printing process and decreases the need of calibration between the interlaced image and the lenticular sheet. The lenticular layer created by the ink-jet dispenser depends on several machine parameters and it should be optimized, in order to perfectly fit with the interlaced image. **Gathered results:** a set of new resins has been developed and the results of test on textiles demonstrated the feasibility of 3D lenses creation on the surface.
- **The product:** the final products, fabrics and clothing, should be tested as described in the reference norms, and grant a higher visibility effect for improving safety in dark low contrast environments. **Gathered results:** several samples of lenticular coated textile have been produced (and are still being produced by Vogue). The garment has not yet been tailored, but the consortium is ready to.

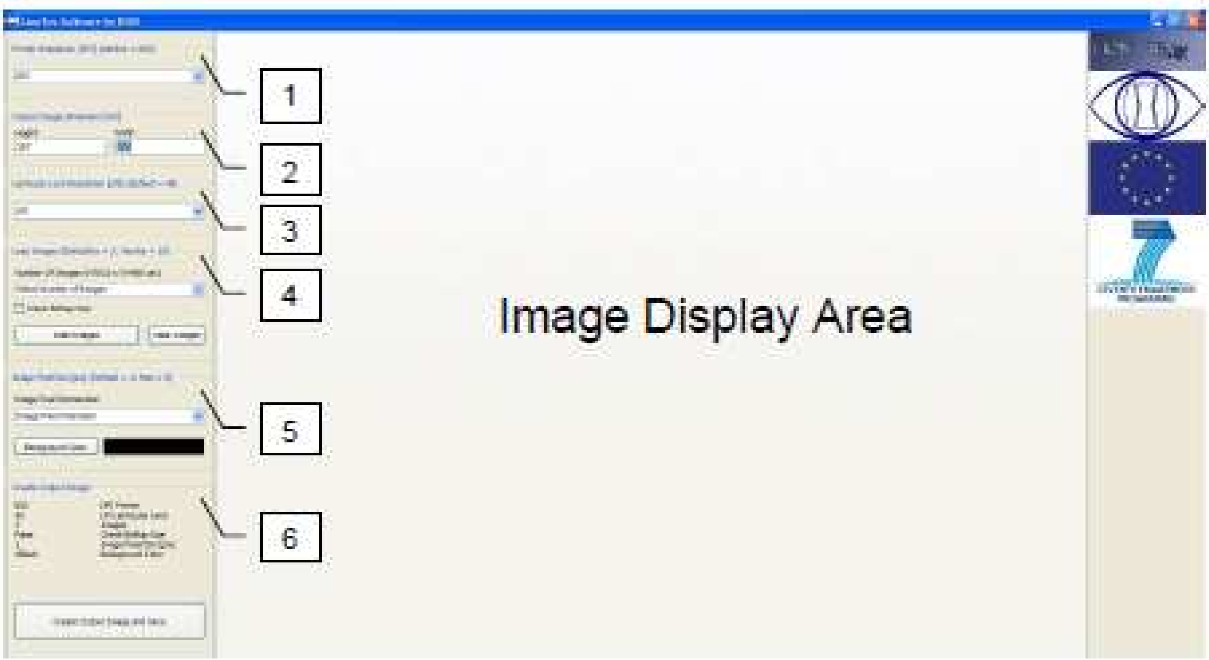
In order to overcome the previously introduced technical barriers, key S&T objectives have been set in each of the three areas, by the consortium: Software and control, the lenticular process itself and the high visibility textile.

As far as the **software** is concerned, the objectives **targeted in the proposal have all been accomplished within the project.**

Management of innovative lenticular effects. At the state of the art, different software can be exploited to create a flat interlaced image, by introducing only few parameters that describe the kind of effect one wants to obtain. The problem related to the lenticular printing on textile is that the software should interlace the images while taking into consideration that the substrate is not flat and it can be bent. The developed software can manage the whole process, from the creation of the interlace picture, to the requirements of lenticular arrays, to the synchronization of the two printheads. **Other basic shape interlacement**: pictures are “cut” and joined together along a basic shape required by PPE garments. The software allow to create an interlaced picture and insert it onto a not interlaced background, in order to ink-print the background and create ad-hoc patterns on the interlaced part of the image. Thanks to the developed software, the two printheads can be controlled in a synchronized way, for best results. **Definition of patterns**. The software can even calculate the optimized patterns (dimensions and parameters of the lenses, geometry of patterns) and send to the ink-jet dispenser the correct information to create the required lenticular sheet.

→**Accomplished mission.** Developing the software we have been concentrated on creation the interlaced images for the cylindrical lens structure because it seems to offer the most promising applications in the textile industry. The software creating the interlaced images will be easily adapted for the other types of lenticular structures. The software allows a user to design an interlaced graphics to work together with lenticular lenses of fitted structure resolution. The lens must be perfectly aligned with the image.
Typical graphics is a composition of two or more interlaced images, which constitute one picture.
The software is universal and can be used for preparing interlaced images for all mentioned above various lenticular effects.
In the software, the interlaced image is composed from a few input images. The result depends only on the content of the input images introduced by a user. The software is optimized for a few parameters, which can be selected according to requirements.
A user can choose between a few typical printer resolution values (DPI) and different lenticular lens "resolution" values (LPI). It is also possible to set the size (in mm) of the output image and the software can control this parameter and required proper dimensions of the input images (in pixels).
From the relationship DPI to LPI the software calculates the maximum number of images that can be interlaced. A user can chose arbitrarily a number between 2 and the maximum. The Number of the input images is the number of "frames" in the output image. All images are "BMP" type.
All parameters described above determine the image pixel dimension. This parameter refers to angle sensitivity of the output image. A user can chose between 1 and the maximum (calculated by the software). The smallest selected number corresponds to the highest angle sensitivity. If the result of multiplication of the image pixel dimension and the number of images is not equal to maximum number of images the software will automatically add a proper number of background pixels. An operator can also select a color of the background.

The main screen is presented in the following figure:

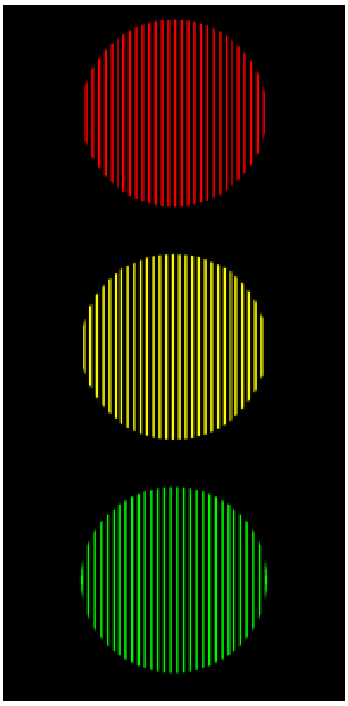
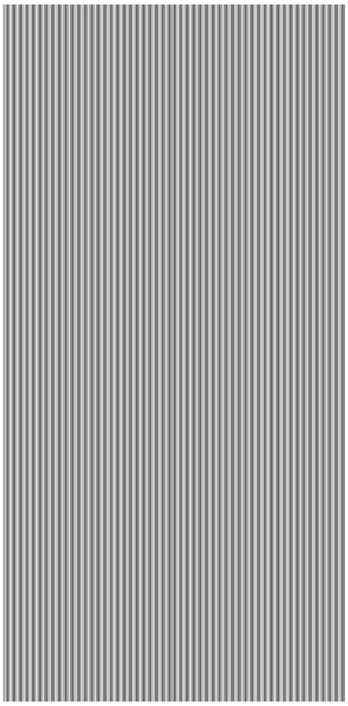


The interface contains six panels (the **Printer Resolution – [1], Output Image Dimension – [2], Lenticular Lens Resolution – [3], Load Images – [4], Image Pixel Dim – [5]** and **Create Output Image – [6]**) on the left side and the **Image Display Area** for loaded bitmaps - on the right. The subsequent sections will contain the description of panels functions.

Resolution of the printer. The printer resolution can be selected using the selection list located in the **Printer Resolution** panel [1].
The Printer Resolution (DPI) is the master parameter. It defines constraints between itself and two other parameters i.e. Maximum Number of Images (MaxNo in **Load Images** panel - [4]), Maximum Dimension of the Image Pixel (Max in **Image Pixel Dim** panel – [5]). These parameters can be also selected by an operator within allowed ranges, otherwise default values are applied. Consequently the above parameters modify the output image dimensions given in pixels. All selected values are displayed in **Create Output Image** panel – [6].

Dimension of the output image. The physical dimension [mm] of the output image can be changed using the edit boxes in the Output Image Dimension panel – [2]. The default value is A4 format. Any change of the Height or Width values results in change of dimension values in pixels.
Change of the Width of Output Image in mm (Output Image Dimension panel – [2]) from 210 to 420 results in the change of the output Image Width in pixels and the change to description from "W4960 pix" to "W9921 pix" .
The resolution of the lenticular lens structure can be selected using the list placed in the **Lenticular Lens Resolution** panel – [3]. Any modification of LPI affects the value of Maximum Number of Images (the MaxNo value in the **Load Images** panel – [4]) and the value of Maximum Dimension of Image Pixel (the Max value in the **Image Pixel Dim** panel – [5]).
If the lenticular lens resolution is not specified by a user program runs with the default value i.e. 40 LPI.

The software creates two images, starting from two (or several) initial BMP files: the images "UserName.bmp" which contains the interlaced image and the "UserName_LenticularLens.bmp" which contains the shape of lenticular structure. Both images **are saved** on a hard disk and **are NOT shown** in the main screen of the program.
The software is user friendly. Users should set or select the process parameters starting from the top panel and go subsequently to the bottom panel.
The lens printing parameters should be discussed in the next project stage when the image/lens printer is developed.

The whole process was initially validated at lab scale, but it still needed efforts to be put at industrial level: in particular it was necessary first to develop the resin(s) and the dispensing device and then to start the integration on a common industrial plotter for textiles. **Many improvements were required on the resins**.

Optimization of basic characteristics. The resins needed to create a lenticular sheet must be completely transparent and participate, with their optical behaviour, to the success of the lenticular effects. Moreover, since they are going to be dispensed on non-flat textile substrates, the resins shall be soft, in order not to stiffen too much the zone where they are applied and, they shall be bendable, for avoiding the risk of pattern cracking and, at the same time, they should not be absorbed by the fabric during the printing process. Thickness of the lenticular layer has to be in the range 0,2 to 1,4 mm, the radius of curvature for the lenses is to be evaluated and designed in accordance to the optical requirements.

Anti ageing additives. The first products that have been preliminary tested are UV curable resins, since those resins have the great advantage, with respect to other kind of polymers, to cure rapidly. The risk is related to the effect of ageing: UV curable resins are very sensitive, even after the curing phase, to UV radiation and they tend to become yellow or dark because of the exposition to the sun. Innovative formulations or additives can avoid or at least slow this ageing process and give to the lenticular printed fabrics a longer life.

Faster cure process. In the printing process that has been preliminary designed, the UV resins have a two-steps curing phase. Every drop of resin ejected by the dispenser is hit by a very concentrated UV spotlight, in order to maintain the required shape, instead of being absorbed by the textile or being smoothed by its own weight. This preliminary curing phase is not enough to completely fix the printed layer, it is necessary a second step tin which the fabric is exposed to a UV radiation source for a longer period. The best suitable resin for lenticular printing shall reduce these phases as much as possible: a 10 mW/cm^2 lamp can cure an area of 1 cm^2 in about 80-100 s, with a high power lamp, 50-100 mW/cm^2 the same area is cured in 15-20 s.

Ink-Jet dispensable. Not all materials are suitable or easy to be treated with ink-jet dispensing systems; these devices require the liquids to be dispensed to grant some physical parameters which should belong to a precise range of values, in order to make the jetting process work. One of the most important parameters is the viscosity of the fluid: since the connecting tubes and mainly the orifice have very small diameters (less than 100 microns) the fluid shall have a viscosity similar to water (1 cPs) to be easily treated. If the viscosity of the fluid grows over a certain limit, depending on the geometry of the dispensing device, it is necessary to reduce it, for example with heat. In some difficult cases heat is not enough and chemical additives are necessary to reach that target.

Bendable and suitable for textiles. The substrates on which the resins are jetted are not flat: they can be 3D shaped and further more they can be bent. The printed layer, and so the resin, shall follow the fabric in its movements, remaining always tight fitting and avoiding the risk of break.

The parameters that shall be studied and optimized were:

- **Viscosity of the resin**. Jetting devices work well when the material to be dispensed has a viscosity in a range of values very close to 1 cPs; more viscous materials (up to 100 cPs) can be treated by heating them up until their viscosity becomes lower and suitable for jetting;
- **Speed of curing process**. In order to create the lenticular layer, the resin is cured in a two-steps process. Spot-light freezes the dots of resin on the substrate which maintain the shape until the end of the deposition process and then the whole lenticular layer is cured with a UV lamp. It is important that the curing process is as fast as possible, to avoid the risk of deforming the original shape of the dispensed dots and for speeding the industrial production;
- **Stability to UV radiation**. It is the most common contradiction for UV curable resins. UV radiation activates the polymerization of the resin but, when the curing process is completed, it still has an impact on the resin: UV is the main cause of ageing of resins, which become yellow and opaque;
- **Resistance** to normal life cycle of clothing products (washing, drying, folding).

→**Accomplished mission.** Urethane acrylate: we synthesized different resins and three of them were selected and formulated with different reactive diluents:

- Resins: (Bencryl urethane acrylate A (141):
- Polyether polyol urethane acrylate based on aliphatic di-isocyanate
- Bencryl urethane acrylate B (137)
- Polyether and aromatic polyol urethane acrylate based on aliphatic di-isocyanate.
- Bencryl oil urethane acrylate C.
- Oil base polyol urethane acrylate based on aliphatic di-isocyanate

For the epoxy-acrylic oligomer we worked with a liquid epoxy resin making the reaction with acrylic acid. All resins were diluted in many different reactive diluents in order to find the best compromise of applicative requirement and final performance. The characteristics of all resins prepared and diluted with reactive diluents are reported in table 1.

Resin	**Reactive diluents**	**Concentration**	**Visc.Brookfield @25℃**	**Aspect**
Uretane acrylate SPN 137	Hexanediol diacrylate Propoxylated glycerol triacrylate	66%	4630 - 9850	transparent
Uretane acrylate SPN 141	TPGDA	57%	4375 - 8100	transparent
Uretane acrylate SPN 141	TPGDA	65%	n.a	transparent
Oil urethane acrylate HEA SPN 7924	TPGDA	75%	5000	transparent
Oil urethane acrylate HEA SPN 7949	HDDA	75%	6094	transparent
Oil urethane acrylate PETIA SPN 7967	HDDA	80%	23750	transparent
Oil urethane acrylate PETIA SPN 7967	HDDA	70%	7500	transparent
Oil urethane acrylate PETIA SPN 7967	HDDA	40%	2000	transparent

Table 1 - Urethane acrylic resin characteristics

For epoxy resin we worked with liquid epoxy resin and we made acrylation with acrylic acid. The resin was diluted in different reactive diluents the most promise compositions are reported in the table II.

Resin	Reactive diluents	Concentration	Visc.Brookfield @25℃	Aspect
SPN 7930	Sartomer Sr 444 *(pentaerythritol triacrylate*	50%	6093	light yellow transparent
SPN 7931	Sartomer SR 506 *(isobornyl acrylate)*	67%	4375	light yellow transparent
SPN 7998	no	100%	>500000	light yellow transparent
SPN 7998	Sartomer SR 506 *(isobornyl acrylate)*	70%	12500	transparent
SPN 7998	Sartomer SR 506 *(isobornyl acrylate)*	65%	4875	transparent
SPN 7998	Sartomer SR 506 *(isobornyl acrylate)*	60%	2750	transparent
SPN 7998	Sartomer SR 506 *(isobornyl acrylate)*	50%	750	transparent
SPN 7998	Sartomer SR 444 *(pentaerythritol triacrylate)*	50%	10500	transparent
SPN 7998	Sartomer SR 444 *(pentaerythritol triacrylate)*	40%	4875	transparent
SPN 7998	Sartomer SR 444 *(pentaerythritol triacrylate)*	30%	2250	transparent

Table 2 - Epoxy acrylic resin characteristics

Formulations reported in table I and II: 1.) Epoxy acrylic resin ***SPN 7930*** in pentaerythritol triacrylate 50%; 2.) Epoxy acrylic resin ***SPN 7931*** in isobornyl acrylate 67%; 3.) Oil urethane acrylate ***SPN 7924*** in TPGDA 75% + SR506 (10%); 4.) Polyether urethane acrylate ***SPN 141*** in TPGDA(57%); 5.) Oil urethane acrylate ***SPN 7924*** in TPGDA 75%; 6.) Oil urethane acrylate ***SPN 7949*** in HDDA 75%; 7.) Oil urethane acrylate ***SPN 7967*** in HDDA 40%; 8.) Oil urethane acrylate ***SPN 7967*** in HDDA 70% and Epoxy acrylic resin ***SPN 7998*** in isobornyl acrylate 65%. where tested in different fabrics.

The fabrics tested, HYPPOLUX (polyamide 100%), TEXAS (cotton 100%), RAMONA, (Cotton 97% elastane 3%) ASIA (rayon 93% elastane 7%) , SENSITIVE(no indication) were supplied by Vogue service SA.

To check resins performances regarding reactivity, adhesion, yellowing, hardness, flexibility they were formulated with photo initiator and were applied on the fabric by using a bar coater (90 mills thickness) and cured using a mercury lap (80w) with speed of 4 m/min for two times Also the fabrics behaviour under UV exposure were observed. The results are reported below:

- **Epoxy acrylic resin SPN 7930 in SR444 50%: 3% DAROCOUR 1173: Visc. Brookfield = 6094 cPs**

	HYPPOLUX	TEXAS	RAMONA	ASIA	SENSITIVE
Yellowing	No	Yes	Yes	Yes	No
Flexibility	No	Fail	No	No	No
Adhesion	No	Fair	Fail	Fair	Fair
Permeability	Yes	Yes	Yes	Yes	Yes

- **Oil urethane acrylate SPN 7924 in TPGDA 75% + SR506 (10%): 3% DAROCOUR 1173, Visc. Brookfield = 4500 cPs**

	HYPPOLUX	TEXAS	RAMONA	ASIA	SENSITIVE
Yellowing	No	Yes	Yes	Yes	No
Flexibility	No	No	No	No	Fail
Adhesion	No	Sì	No	Yes	Yes
Permeability	Yes	Yes	Yes	Yes	Yes

- **Polyether urethane SPN 141 in TPGDA 57%: 3% DAROCOUR 1173, Visc. Brookfield = 4375 cPs (applied 90 mills)**

	HYPPOLUX	TEXAS	RAMONA	ASIA	SENSITIVE
Yellowing	No	Yes	Yes	Yes	No
Flexibility	Fair	Fair	Fair	Fair	Fair
Adhesion	Yes	Yes	Yes	Yes	Yes
Permeability	Yes	Yes	Yes	Yes	Yes

- **Oil urethane Acrylate SPN 7924 in TPGDA (75%): 3% DAROCOUR 1173: Visc. Brookfield = 5000 cPs**

	HYPPOLUX	TEXAS	RAMONA	ASIA	SENSITIVE
Yellowing	No	Yes	Yes	Yes	No
Flexibility	Fair	Fair	Fair	Fair	Fair
Adhesion	Fail	Fair	Fair	Fair	Fair
Permeability	No	Yes	Yes	Yes	Yes

- **Oil urethane Acrylate SPN 7949 in HDDA (75%): 3% DAROCOUR 1173: Visc. Brookfield = 6094 cPs**

	HYPPOLUX	TEXAS	RAMONA	ASIA	SENSITIVE
Yellowing	No	Yes	Yes	Yes	No
Flexibility	Fail	Fair	Fair	Fail	Fair
Adhesion	Fail	Fair	Fail	Fair	Fail
Permeability	Fail	Yes	Yes	Yes	Yes

- **Oil urethane Acrylate SPN 7967 in HDDA (40%): 3% DAROCOUR 1173 Visc. Brookfield = 2000 cPs**

	HYPPOLUX	TEXAS	RAMONA	ASIA	SENSITIVE
Yellowing	No	Yes	Yes	Yes	No
Flexibility	No	No	Yes	No	Yes
Adhesion	No	No	Yes	Yes	Yes
Permeability	Yes	Yes	Yes	Yes	Yes

- **Oil urethane Acrylate SPN 7967 HDDA (30%): 3% DAROCOUR 1173: Visc. Brookfield = 7500 cPs**

	HYPPOLUX	TEXAS	RAMONA	ASIA	SENSITIVE
Yellowing	No	Yes	Yes	Yes	No
Flexibility	No	No	Yes	No	No
Adhesion	No	Yes	Fail	No	Yes
Permeability	No	Yes	Yes	Yes	Yes

- **Epoxy acrylic resin SPN 7998 in SR 506 (35%): 3% DAROCOUR 1173: Visc. Brookfield = 4875 cP**

	HYPPOLUX	TEXAS	RAMONA	ASIA	SENSITIVE
Yellowing	No	Yes	Yes	Yes	No
Flexibility	Yes	No	Yes	Yes	Yes
Adhesion	No	Yes	Yes	Yes	Yes
Permeability	Yes	Yes	Yes	Yes	Yes

The conclusion of the tests can be briefly summarized:

1. From results reported we can conclude that either resin type oil urethane acrylate or epoxy acrylate combine characteristics of adhesion, reactivity, transparency that indicate as candidate for the application;
2. Both synthesis process can be scaled up and are reliable;
3. For the oil urethane acrylate, 50% of row material comes from renewable source;
4. Some yellowing was observed on TEXAS, RAMONA and ASIA fabrics.

The printheads. At the state of the art, there are already ink-jet dispensing systems suitable for treating fluids like the resins above described. Anyway a deep optimization of these systems was crucial, to make easier the integration with the ink-jet printer for textiles and in order to grant the complete success of the whole project:

- **Optimization for resin printing**. The testing machine used for preliminary validation tests was a very versatile lab machine, the typical jetting parameters which could be set in a wide range of values, to be suitable to perform tests on many materials. Once that the resin(s) to be used have been confirmed, the dedicated printhead has been selected to fulfil the request for that material. The geometry of the reservoir, the tubing assembly, the heating system, the curing UV spotlight, the geometry of the orifice and the parameters of the electric wave input (voltage, current, frequency, shape of the wave) have been customized;
- **Creation of 3D layers**. Usually ink-jet dispensers are used to print very thin flat films of materials, which create a picture, a printed circuit or gaskets. In this application it is important that the printed film has a certain shape, to allow the observer to see the lenticular effect. For this reason it is important to study how jetting parameters affect the profile of the lenticular sheet, the thickness, the flexure and its radius.

As a final result of the project, in which all the improvements are summarized, the dedicated ink-jet dispensing device has been integrated into a common ink-jet printer for fabrics, as a demonstrator, to show how the process can be industrialized.

The proposed solution foresees the printing phase with the rolling carpet stationary and the two printheads independent from each other, that can move along the print area in the two plan direction one by one. Once the print area is completed, the rolling carpet can move forward for a distance equal to the printing area length. This solution eliminates the interdependency and the relative incompatibility between the two printheads. The final layout is presented into the following pictures.

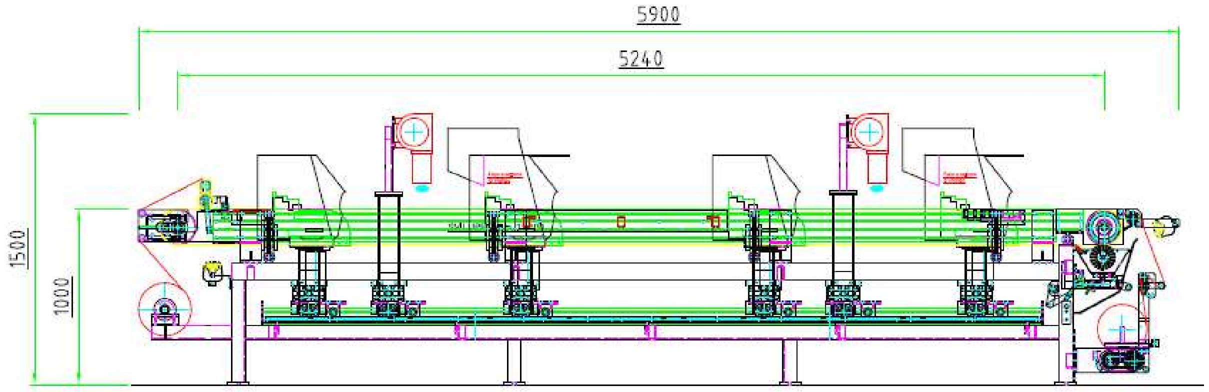


Figure 2: Side view of the machine with measures (mm)

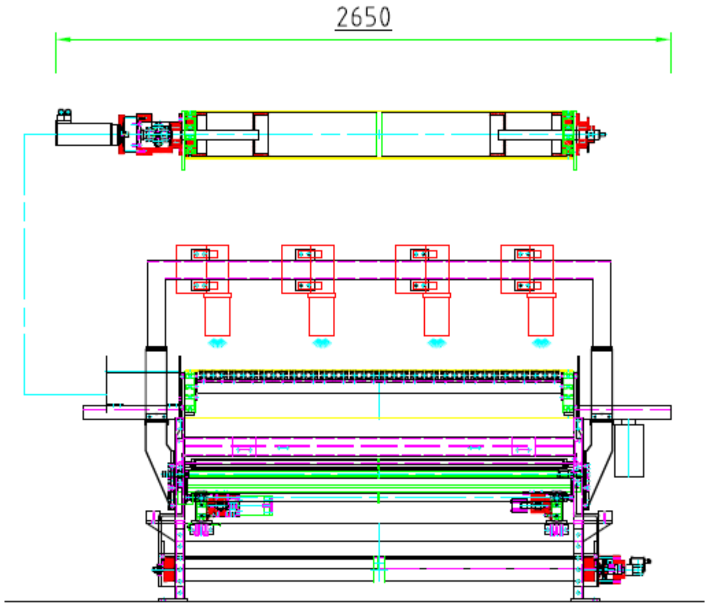


Figure 3: Frontal view of the machine (mm) – Infrared drying carriage in evidence

Also in this case, the machine speed is controlled by the slowest printhead. Main disadvantage is the fact that this printing system is considered outdated by the continuous printing.

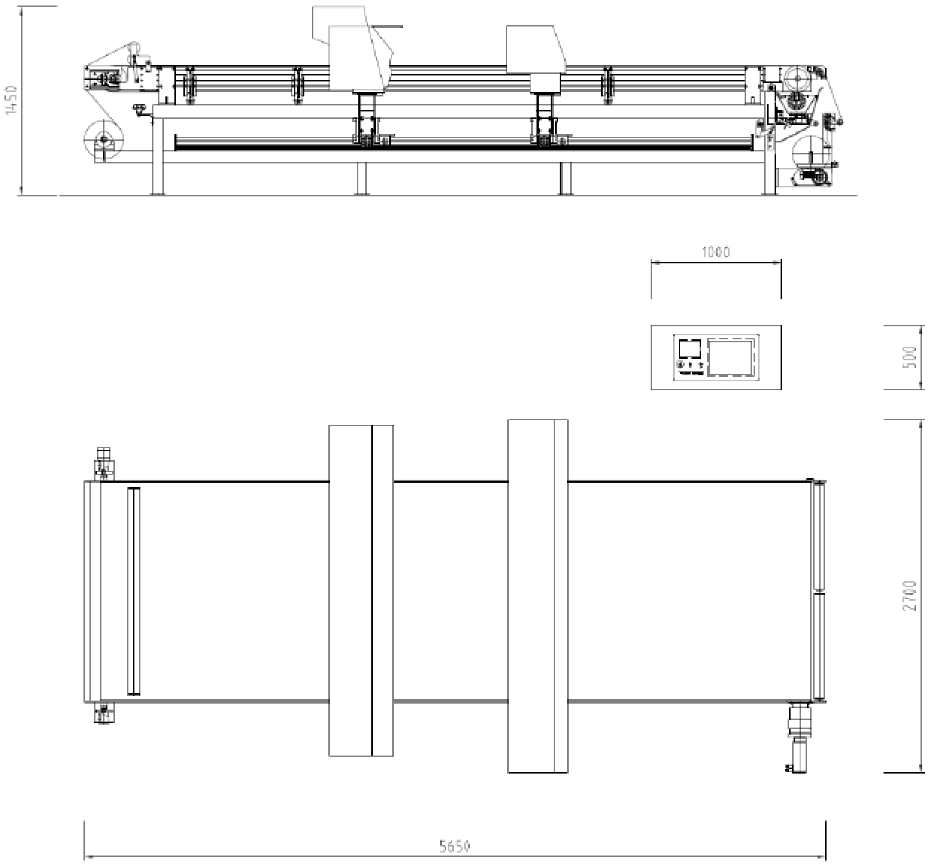


Figure 4: Side and top views with dimensions (control panel also present)

Version HS-B (high speed) of the plotter allows you to print at high quality with a variable speed from 20 to 40 [m^2/h]. The Lion-Tex version also allows to control resining head in order to deposit drops of resin on the basis of the reception of the drawing data and on the reading of the current position of the head itself. Via input / output digital signals, the resin deposition phase is handled synchronizing the deposition pulses with the actual position of the head and on the basis of design data acquired.

The Lion-Tex plotter consists of the following groups:

- Axial unwinding with pneumatic brake in controlled pull;
- Braking group;
- Plotter;
- Device for the deposit of resin;
- Rug for fabric transportation;
- Rear heater;
- Cleaning removable device for the carpet;
- Winding system;
- Ink supply system;
- Ink recovery tank.

Table 3: Main plotter features

Feature	Data
Printer	Ink-jet piezoelectric with variable drop - based on Mimaki JV33 160S
N° of printheads - Colours	4 piezoelectric printheads extra large with 1440 nozzles each - 8 colours on 8 batteries of 180 nozzles
Printheads height	Automatic positioning of printheads height - standard 1.5 - 7 [*mm*] Optional equipment: 0 - 8 [*cm*]
Printheads cleaning	Automatic cleaning cycle of printheads - nozzles efficiency controlled by laser
Printing mode	540 - 1440 [dpi] at 4,6,8 steps - mono and bidirectional
Fabric transportation	Motorized self-aligning unwinding system - Adhesive carpet – Motorized winding system
Printing width	Maximum 161 [*cm*]
Fabric roll diameter	Maximum 28 [*cm*]
Printing speed	4 Colours - 1440 x 1440 [*dpi*] 6 Colours - 720 x 1440 [*dpi*] 6 Colours - 1440 x 1440 [*dpi*]
Ink feeding	External colours feeder with n. 4+4 open reservoirs of 1,5 litres each
Allowed inks	Acid, Reactive, Dispersed, Sublimation 4 colours: Ciano, Magenta, Yellow, Black (CMYK) 8 colours: Ciano, Magenta, Yellow, Black, Red, Blue, Orange, Grey
Technical data from resin deposition head	Resin drop diameter: 0,4 mm Deposition step: 0,4 mm Head moving speed: 60 mm/1s Distance among nozzle and fabric: 1,5 - 2 mm Printing width: 1.500 mm Pneumatic feeding: filtered at constant pressure; 10psi fluid pressure e 90psi valve pressure.
Interface	USB 2.0
Operative environmental features	Operating temperature: 20-35 [℃] Humidity: 35-65 [%]

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The high visibility products:

The lenticular pictures are potentially interesting for many innovative applications. First of all, from the point of view of protection clothing, the lenticular effect can contribute to high visibility purposes, combining this new optical effect to the reflecting material and the fluorescent colours: a simple interlaced image that can flip from fluorescent yellow to orange will attract the attention of drivers more than today's safety clothing:

- When the industrial process and the machine will be ready, there will start the production of different fabrics with lenticular effects for high visibility purposes;
- In case of lenticular high visibility is equipped on Firemen PPE, also flammability tests according to specific norms will be evaluated before the commercialization of the product.

Figure 5: The lenticular effects on high visibility clothing

Innovative character in relation to the state-of-the-art

Lenticular effects are a very well known technology, which has already been adopted in few fields, especially in commercial signs and posters but also in toys, postcards or pins.

Up to now these optical effects are not exploited in the field of textiles or, at most, as patches applied or sewed on some T-shirt, with fashion purpose. Lenticular images are given by the interaction between two components:

- **Interlaced image.** The first step for creating a lenticular effect is to digitally modify the pictures, at least two, depending on the effect one wants to achieve. The images are first "cut" and then joined together, with a process called interlacement. In this operation it is important to specify some parameters, which will characterize the final optical effect and which should perfectly match with the lenticular layer: among the others, the most important is the LPI (Lens per Inch), which represents the density of lenses of the lenticular sheet; this value usually belongs to a range between 20 LPI (big posters, commercial signs) to 140-160 LPI for very detailed effect, like movies. In order to grant a good lenticular effect, the LPI of interlaced pictures and lenticular sheets must be the same;
- **Lenticular sheet.** In order to "decrypt" the interlaced image, it is necessary to put on it a sheet of transparent plastic material called lenticular sheet. Usually they are made of PETG, APET, and acrylic resins, but there are also lenticular sheets made from other resins, such as polycarbonate and polypropylene, manufactured on a custom order basis. The plastic film is extruded, cast or embossed for creating an array of identical convex lenses, designed to focus the light onto particular spots of the image on the back of the lenticular lens sheet. The parameters of lenses (radius of curvature, view angle, height) contribute to the final effect, by determining the viewing distance and the width of the effect.

There are two ways of creating a lenticular image. The first method consists in printing the interlaced picture on a paper or photo paper, with an ink-jet printer (300 dpi is usually the minimum resolution recommended), cover everything with a suitable adhesive film and then match the picture with the lenticular sheet in a laminator or press. The critical aspect of this method is related to the gluing process: the lenticular sheet shall be perfectly aligned with the interlaced image, to grant the best performance. Finally, on the back side of the card, it is applied a protective film for paper.

In a second manufacturing process, when applicable, the interlaced picture is directly printed on the back flat side of the lenticular sheet, thus avoiding the use of an adhesive film and minimizing the problems of alignment. Again, on the back side of the card, a protective film is applied.

Unfortunately none of these processes is suitable to transfer the lenticular technology on textiles; in fact most of the patches produced today are made with a not bendable lenticular sheet, that's why often it is hard to combine them with textiles. Even using a bendable lenticular sheet, the patches produced by the first method are in any case too thick, because of the multi-layer construction (lenses, paper and protective film) and consequently too stiff for textiles; the ones produced with the second manufacturing process can fit better but the result is a plastic patch, glued or sewed on the fabric, and that is not a complete integration.

- **The potential impact (including the socio-economic impact and the wider societal implications of the project so far) and the main dissemination activities and exploitation of results**

The technologies developed and integrated into the demonstrator have already shown the feasibility of Lion-Tex concept for a lenticular textile. The early business model and the exploitation plan defined in Lion-Tex highlighted also the possibility to extend the lenticular effect onto several different substrates and then products: plastic, metal sheets, paper, wood, films in general. Thanks to the high flexibility of the technologies developed and to this quite easy technology transfer, the overall impact initially foreseen for Lion-Tex project shall be reviewed and esteems of its impact could be even higher than initially expected.

Contribution to competitiveness of proposers

Thanks to the achieved results, the competitiveness growth of the participant SMEs is directly related to the possibility to introduce into the protective clothing sector an innovative product such as high visibility vests based on lenticular technology, and to the high potential shown by the plotter. The proposers represent a complete supply chain of SMEs active in textiles and protective clothing manufacturing: by entering the market with a high added value product such as lenticular high visibility vests, this partnership will be able to withstand the increasing competition from low cost labour Countries like China, India, Taiwan. The trend for protective clothing market shows indeed that by 2010 the Asian producers will have a predominant role unless European manufacturers will develop more sophisticated added value products instead of trying to compete on QCD (quality, cost and delivery). The complexity of lenticular high visibility vests features, the need for complementary know-how and the European scale of the tackled problems have therefore required a combination of specific skills across Europe. The structure of the proposers Group is highly complementary; each partner has a clear role in the value chain and is expected therefore to contribute to increase its competitiveness as highlighted below.

Table 4: Expected contribution of the project to the SME partners competitiveness

Partner + role in the supply chain	Contribution to competitiveness (and direct benefits)
MECC – manufacturer of the lenticular plotter	La Meccanica is the SME that is contributing more in the development of the know-how necessary for building the lenticular plotter. La Meccanica is also expected to be the exclusive producer of the machine, once it will be finalized and industrialized by next years, and then launched in the market. From an economic point of view, La Meccanica is expecting to produce and sell around **12 to 18 machines per year** (i.e. 1-1.5 per month). With an average price to final **customers of 150,000 - 170,000 €**,

<table>
<tr><th>Partner + role in the supply chain</th><th>Contribution to competitiveness

(and direct benefits)</th></tr>
<tr><td></td><td>it means an increase of turnover esteemed (in the conservative case) as 1.8 - 2.1 M€ (>+10% of the current turnover). La Meccanica has agreed with VOGUE (which is the owner of the IPR increase of turnover esteemed (in the conservative case) as 1.8 - 2.1 M€ (>+10% of the current turnover). La Meccanica has agreed with VOGUE (which is the owner of the IPR on the plotter) to be the exclusive manufacturer and will grant to VOGUE the royalties on the total selling (fixed percentage to be agreed).

La Meccanica is also expecting a further future income, thanks to the possibility of transferring the lenticular technology also on other machines of its portfolio, for example packaging machines and wood plotters: on the basis of the preliminary esteems, this will mean another +10% of the current turnover.</td></tr>
<tr><td>VOGUE – printing house</td><td>Vogue is a printing house, which core business is still strictly linked to the traditional sector. Besides producing lots of printed textile, one of the core activities is to design new patterns and collections for big fashion brands. Their will is to enlarge the market by entering an added value sector such as technical textile: unfortunately, without being characterized by a well known brand or specific enabling technology, this differentiation could be difficult or even counterproductive.

Lion-Tex technologies will grant Vogue to introduce itself in the safety equipment market with a breakthrough technology; the expectation is to produce a lenticular fluorescent fabric and sell it at 10-12 €/linear m (the final price will defined within the pricing strategy activity). The first year the foreseen production is of 50.000 - 150.000 liner m, meaning a turnover of 500.000 to 1,5 M€. The figures (produced and sold metres of fabric) are expected to increase year by year of around 5-7%.

At the same time, VOGUE could introduce new features and 3D patterns in the fashion market, as textile designers: this will directly affect the turnover of one of the core business, with a potential increase of 10%, up to 30% in case of mass success (“status symbol effect”) of the ne 3D fabric.

Vogue will also be in accord with La Meccanica for plotter production and marketability, and will get revenues from the royalties of future selling of Lenticular Plotters.</td></tr>
<tr><td>RIDAN - manufacturer of the safety lenticular</td><td>Ridan is a Polish SME having two main businesses: SW production and protective high visibility textile.

Their will is to introduce in their production lines the results coming from this project with the new lenticular high visibility garment, capable firstly to</td></tr>
</table>

Partner + role in the supply chain	Contribution to competitiveness (and direct benefits)
equipment	proceed side by side with the traditional technology based on the use of reflective stripes and then hoping capable to displace the old technology. Using the same assumptions made for Vogue, for RIDAN it is possible to estimate a selling price of **10-12 €/linear m** (the final price will defined within the pricing strategy activity). The first year the foreseen production is of **50.000 - 150.000 liner m, meaning a turnover of 500.000 to 1,5 M€. The figures (produced and sold metres of fabric) are expected to increase year by year of around 5-7%.**

A report from 3M, producer of Scotch Lite®, estimates that the European market for passive reflective stripes is of 46 Million meters per year. This figure is conservative for the fact that it has been calculated by taking into account the two primary applications for reflective stripes (approximately 80% of the overall market): the 16 Million Europeans who need protective clothing at work (life cycle: a new garment every year), the 240 Million European cars which must be equipped with reflective clothes for drivers in case of emergencies. Considering an average cost of the stripes of 4,90Euro/m, the turnover of this market is around 225MEuro/year.

Thanks to the technology developed in Lion-Tex, the stripes will not be anymore necessary, since the fabric itself will have a reflective and high visibility effect, stronger than reflective stripes. The fabric for manufacture the garments will slightly increase its cost but, at the same time, the reflective stripes will be not necessary, decreasing the overall price of the garment, related to raw materials and assembling. Considering the production capabilities of the partners, as well as their established marketing channels, the partners conservatively expect to reach 8% of the overall potential European market after two years of production (end of 2017).

A previous feasibility study performed by Vogue, with the support of the entire consortium, has estimated that the initial target price of a lenticular high visibility vest for car drivers is 10 Euro/vest. However it has been estimated that after two years of production, the target price will relevantly decrease reaching 7 Euro/m, due to the large quantities of manufactured product.

Table 5: Current and future target prices

Company	Sub component	Initial Target price* (2015)	Estimated Target Price (2017)
Vogue	Base textile + printing	4 Euro/vest	3,2 Euro/vest
Ridan	Cutting, sewing and assembly	3 Euro/vest	2,2 Euro/vest
	Distribution, marketing, promotion	2 Euro/vest	0,8 Euro/vest

Taking into account the estimated price of **7 Euro/vest** after two years of production and the expected production, the overall turnover generated by the Lion-Tex will be equal **to (225M * 8%) = 18 MEuro, equal to 2,57M of vests,** three years after the project conclusion. Based on the role and expected contribution to the value chain (as reported in the exploitation scheme in the following section) the following economic benefits are expected:

- Vogue will get a fraction of the whole incomes of **about 8MEuro;**
- Ridan will get a fraction of the whole incomes of **about 8MEuro.**

The owner of the lenticular plotter IPR is VOGUE. La Meccanica has agreed with VOGUE to be the exclusive manufacturer and will grant to VOGUE the royalties on the total selling. Moreover the lenticular plotter machine will have on board installed the software developed by RIDAN, with the support of INOS.

La Meccanica is expected to be the exclusive producer of the machine, once it will be finalized and industrialized, and then launched in the market. At the same time RIDAN will be the unique provider of the software to be installed on board of the lenticular machine. From an economic point of view, La Meccanica is expecting to produce and sell around 12 to 18 machines per year (i.e. 1-1.5 per month). With an average price to final customers of 150,000 – 170,000 €, it means an increase of turnover esteemed (in the conservative case) as 1.8 – 2.1 M€ (>+10% of the current turnover). For each machine an average cost of 30,000 € can be assigned to the license of the industrial Software provided by RIDAN thus an increase turnover esteemed as 400 - 500 k€.

Both the companies are expecting further future income; thanks to the possibility of transferring the lenticular technology also on other machines of its portfolio, for example packaging machines and wood plotters: on the basis of the preliminary esteems, this will mean another +10% of the current turnover. Special agreements will be set up among the partners: end-users will therefore benefit of special discounts on the cost of the product. Ongoing agreements indicate a **30%** off the market price for Ridan. This will also ensure a quicker penetration on the market also for the companies involved in production.

Technology Transfer – Fashion

The market of fashion textile is definitely the nearest to the safety garments application of Lion-Tex technologies. In particular the target products will be: **T-Shirts, skirts, jeans and trousers with fashioned effect integrated on them; Logos of the producer/designer of the garment; Fashion accessories: bags, purses, briefcases, scarf, gloves, pouch; Shoes**, boots, sport shoes.

With the current technology, it is rare to find applications on textiles and, in any case, they just consists of a patch, welded or sewed, which is not a fully integrated part of the garment. A lenticular patch can strongly affect the rigidity of fabric with two bad effects: it modifies the wearability of garments and it difficultly exploits the continuous 3D movements and bends of flexible textiles. These important arguments, combined with a deep knowledge, experience and expertise in clothing design, can represent a key issue for entering the fashion market too. The consortium is aware of the further steps that should be evaluated for the technology transfer of Lion-Tex technology into the fashion market but, thanks to Vogue Service's long experience in the field, most of the basic knowledge are already part of the expertise.

Technology Transfer – Anti-counterfeiting

It is estimated that counterfeiting is a $600 billion a year market[9], which has grown over 10,000% in the past two decades, also because of the increasing consumer demand, and it expected to go on with a similar trend in next future. People who purchase counterfeit merchandise risk funding nefarious activities, contributing to unemployment, creating budget deficits and compromising the future of legal activities: the problem is that people, in most cases, are not aware of buying a counterfeit product.

According to statistics, the top 10 brands counterfeited include Microsoft, Nike, Adidas, Burberry, Louis Vuitton, Sony, Lacoste, Reebok and Benson & Hedges, most of them belonging to the textile sector, fashion, sport and footwear.

ìEspecially in those fields, some brands decided to adopt different countermeasures for distinguishing the original and genuine goods and revealing fake products: **holograms, watermarks, other visual effects on logos.**

Figure 6 Lenticular watermarks on official papers

This could represent a further potential market for the Lion-Tex technology, identified by the consortium. The lenticular effect can be easily set up directly on logos or other part of the fabric, paper or other kinds of substrate, as a distinctive element of genuine goods.

Vogue and Ridan are expecting to have an additional economic benefit related to the fact that they will be able to enlarge the market of the final product to other interesting textile sectors, like fashion and anti-counterfeiting devices. The turnover can thus be increased of around 8,2 MEuro/year from 2012, thanks to the production of fashion articles like clothing (80€/each, 65000 pieces/year) wearable articles like gloves, caps, bags and everything that, for example, can be marked with logos (45€/each, 45000 pieces/year) and anti-counterfeiting marks on t-shirts, shoes, luggage (15€/each, 100000 pieces/year).

The overall economic impact on the consortium participants is therefore approximately **22 MEuro** by 2017. **Whilst the initial demand is expected to be satisfied by the SME proposers, the expected growth in the demand and their geographical dispersion will be far beyond their joint capability to satisfy. Hence the consortium recognises the need to transfer the methodology and related technologies to a wider industrial community by offering licensees all over Europe, generating royalty revenues.** The estimated turnover increase gives a clear return on the investment into the project by the Consortium and by the REA, demonstrating the cost-effectiveness of the proposed research.

Societal Impact at European level

The EC recognised the seriousness of protecting workers through the Directives 89/656/EEC and 89/686/EEC, that oblige to use High Visibility warning clothing when operating in low visibility environments. The 16 Million workers who perform their tasks during the night or in low visibility environments are distributed all over Europe, giving the **European Dimension to the problem** addressed by the project. Such workers include roadway construction personnel and vehicle operators, utility workers, survey crews, emergency responders, railway workers and accident site investigators, school crossing guards, parking and toll gate personnel, airport ground crews and law

[9] International Anti-Countefeiting Coalition, www.iacc.org

enforcement personnel directing traffic, parking service attendants, workers in warehouses with equipment traffic, shopping cart retrievers, sidewalk maintenance workers, and delivery vehicle drivers, to name a few. Statistics reports that every year **6,000 of them is injured by approaching vehicles or human operated equipment.**

Over the cost in human lives, also the social cost for persons injured has to be taken into account: estimating 10 days hospitalization and the costs for rehabilitation (the mean costs per inpatient day were 230€ (range: 154-311€) in general hospitals and 323€ (range: 209-400€) in university hospitals)[10], and 30 days inability to work (conservatively 60€ per day), it is possible to state that, globally, these accidents do account for a cost conservatively, 30 M€ per year related to such accidents.

By making workers in first instance much more visible (being illuminated and shifting colours), Lion-Tex will contribute to decrease this impressive statistics. In this framework the availability of the intended system will significantly contribute to **improve quality of life, health and safety of workers** thus improving their working conditions.

The issue is also relevant for European citizens more in general terms. A breakdown of the statistics for 1998 reveals that 270,415 injuries occurred typically. The total casualty rate for pedestrians in that year was 78 per 100,000 population, and pedestrians constituted 27% of all road injuries. Eighty-four percent of all collisions between pedestrians and a single vehicle involved cars or taxis, and these vehicles constituted 85% of all collisions when a pedestrian was injured or killed. Most remarkably, forty-two percent of all road accidents occurred at night, as defined by the lighting-up time. This is a considerable proportion given the decreased traffic flow for long stretches of this period. This issue is particularly relevant as far as children are concerned and is the main driver for companies in children clothing and footwear manufacturing to integrate light emitting devices in jackets or shoes.

The **impact on employment** is mostly related to the business generated by the Lion-Tex sales, creating employment opportunities for production and selling of the entire system. Based on the expected initial market penetration of the system in the European market, the proposers expect that 217 new job opportunities will be created by the end of 2014, based on the industry norm of 150 kEuro of sales per employee. If we consider the long term period scenario and the entering in new markets as specified in the previous section, based on the same industry norm, we may expect the creation of further 76 additional jobs.

The Lion-Tex fabric will have a positive impact on environmental issues. The current production process of the lenticular layer has a high impact on environment, related to the energy consumption for extruding and thermal-shaping of the polymeric sheet and to the waste material management. Lion-Tex, instead, will decrease that impact, thank to the completely different production process, based on drop-on-demand approach and the avoidance of waste.

Furthermore, the great number of road-workers' injuries per years usually require medical aid within specialistic hospitals, typically available in an average range of 50 km from the working place. Conservatively estimating 16,000 accidents per year, we can expect that at least 5 million km are

[10] Oostenbrink JB, Buijs-Van der Woude T, van Agthoven M, Koopmanschap MA, Rutten FF.; Institute for Medical Technology Assessment, Erasmus University Rotterdam, Rotterdam, The Netherlands; Unit costs of inpatient hospital days. [PubMed - indexed for MEDLINE]

covered by ambulances. Considering that an average vehicle emits 225 gram CO_2 per kilometre, we can save up to 168 tonnes CO_2 per year.

Steps to bring about the impact

Being the core of project such an innovative and efficient machine, several improvements will be induced by Lion-Tex, from an increased sustainability of the textile processes to a positive societal effect, to an economic boost of European industry. All those are expected to reach higher and higher targets according to a scheme for implementation, organized in following levels:

- **Short-term level:** the project consortium is completed by two end-users (VOGUE, -RIDAN) so they will immediately experience the potential of Lion-Tex innovative machinery (VOGUE) and lenticular high visibility effect (RIDAN) and give to the market an evidence by direct measurements on the field;
- **Medium-term level:** at the beginning, Lion-Tex will be industrialized and optimized to be adopted by the main target sector (high visibility garments and other lenticular safety equipment), and this would bring to the extension of the benefits potentially to the whole textile sector;
- **Long-term level:** thanks to the efforts for making Lion-Tex machine as much fast and flexible as possible, there is the possibility of releasing dedicated optimization for other sectors, with slight efforts. In the medium/long term objective, Lion-Tex could be proposed for other products like lenticular advertising prints (e.g. bus shelters, postcards, billboards) and anticounterfeating textiles.

The partners foresee that **a time to market of about 12 months** will be needed in order to further develop the technology from the level of a product-like prototype, to the full industrial scale. **Industrialisation activities as well as production capacities building** will be needed in order to be able to bring the intended product to the market.

Keeping this in mind, the partners are fully confident that Europe offers excellent conditions to support in the take-up of the proposed technology, such as:

- A highly developed economy and a conscious society;
- Regulatory and legislative framework, aiming at defining specific features for high visibility clothing, namely:
  - EN 471:2003A European Standard for high-visibility clothing;
  - 89/686/EECA European Commission directive, about high-visibility clothing.
- Interested industrial partners having internal objectives to promote sustainable development and the use of high quality protective clothing;
- European as well as national policies actively promoting sustainable development, environmental friendliness, and aligned innovations.

However, in order to bring about the expected impacts and have a broad market introduction of the novel technologies, the following conditions need to be met to the greatest extent possible:

- Economic viability;
- Technical performance with regard to energy saving as well as cost saving potential;
- Together with market awareness and positive market framework conditions.

Industrial and Economic impact

The innovative features implemented by Lion-Tex will strongly affect the cost and then the appealing to customers of the new generation of knitting machine.

- **Energy saving.** The current production process of the lenticular layer has a high impact on environment, related to the energy consumption for extruding and thermal-shaping of the polymeric sheet and to the waste material management. Lion-Tex technologies, instead, will decrease that impact, thank to the completely different production process, based on drop-on-demand approach and the avoidance of waste. A preliminary estimation has been done using the Lion-Tex demonstrator; the energy consumed by the whole lenticular production system (ink printing and lenticular sheet production and application) can be reduced by more than **50%**;

- **Workshop optimization.** According to the preliminary design of the new lenticular plotter developed in Lion-Tex, the volume of this new printing machine is slightly more in respect of a traditional ink-jet printing machine. The main advantage is that in this machine all the production stages are integrated. Thanks to this feature, the space occupied by the calendering plant for production of lenticular plastic sheets and the space needed for the preparation, cutting and application on textiles/paper/other of the lenticular foil are not necessary. A preliminary estimation has been done, the volume occupied by the whole lenticular production system (ink printing and lenticular sheet production and application) can be reduced by more than **50%**.

  Correlated to this aspect there is the simplification of the logistic in terms of transport of the parts of the lenticular system Lion-Tex with respect to the current one (calender plant installation) that results in a reduction of transportation costs and of greenhouse gases emission.