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Innovative Knitted Fabrics Containing Lateral Propagation Optical Fibres Designed for Children with Autism – Preliminary Study

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Abstract
The article presents an analysis of preliminary research on the functionalisation of knitted fabrics in such a way that they can perform a therapeutic function and be used as a chromotherapy tool for children with autism. Knitted fabric with optical fibres comprisesan innovative approach to the topic of helping the sick and their families, where colour therapy treatment can be performed at home, following the recommendations of the attending physician or therapist.

Key words: *colour therapy, autism, fibre optic, knitted fabrics.*

Introduction

For several years, scientists have been reporting new methods of the modification of textiles intended to endow them with new properties, and smart textiles have ceased to be just technological innovations and have become commonly available products.

There are well-known solutions where textiles have replaced the electronic components previously used, acting as sensors, relays, transmitters, receivers or power supply elements [1-3]. In addition, textiles can act as barrier elements (provide protection against electromagnetic radiation), or, when appropriately designed, use electromagnetic induction and form a textile charger subassembly [1-7]. However, it should be remembered that the development of smart textiles requires engineering knowledge in many areas: in the field of textiles, electronics, computer science and automation.

A relatively new way of functionalising textile products is to give them luminescent properties by application of light snakes to the textile surface and placing them in the fabric. This type of product is used in safety-enhancing clothing e.g. as a reflective vest for a pedestrian or mountain rescuer. Outfits with glowing elements are very popular at fashion shows and among celebrities who want to shine during public events and at banquets [8-16]. Nevertheless, light-emitting textile technology needs to be refined and extended to cover a wider spectrum of applications.

The present publication shows how to combine knitted fabrics with lateral propagation optical fibres to create interactive mats for autistic children.Autism is defined as a developmental disorder of early childhood, characterised by impairment of social interactions, communication deficits, such as delayed speech development or lack of speech, limited interests or nagging behaviours, focusing specifically on objects in the immediate vicinity. Another symptom of autism is withdrawal – avoiding contact with the outside world – including people and the environment. Autism is also characterised by no reaction on the part of the child to uttered commands, a lack of desire to play with peers, problems with expressing emotions or with communication. It happens that the child learns syllables and the first words correctly, and after a while seems to forget all that been learnt, and the development of speech is clearly delayed compared to other children. The child often creates a specific own language, used during play, which, however, is not used to communicate with other people.

Although there are many factors that increase the risk of autism, the specific causes of this disorder are still unknown. It is assumed that manifestations of the onset of the autistic spectrum should appear before the third year of the child's life. The symptoms are usually observed by the child's parents – they notice that their child is too polite, very calm, does not react to noise, does not observe people entering the room, and stiffens on an attempt to lift him/her up. In addition, the child stares for hours at one point, such as a ticking clock, does not babble and does not try to speak. The diagnosis of autism is not easy, as the intensity of symptoms as well as the disease presentation itself can vary. It happens that initially the child develops properly, and then suddenly begins to demonstrate unusual behaviors. Autistic children confine themselves in their own world, which is slightly distorted, but absorbing enough that the child does not see the need for contact with people in his/her immediate surroundings. Suddenly and for no reason the child ceases to speak to its mother, treats everyone around as if they did not exist, does not allow to be touched, and stiffens when hugged or lifted. Such a child does not want anything, does not ask parents for new toys, does not show a reaction to pain, and does not enjoy the arrival of his/her beloved grandmother. When given a favorite chocolate, he/she does not show any enjoyment of its taste; or perceive the caregiver's smile as something nice. An autistic child at some point stops talking, and even if he/she says something, it is illogical, like repeating constantly words or slogans from TV ads, saying "he" instead of "me", using phrases incomprehensible to others. Children with autism often have unusual behaviors, can wave their hands nervously, or spin around. They also become attached too much to certain items, and when such an object is taken away from the child, it panics. The habits of children with autism acquired till then are very important, changing the way to kindergarten or school, or changing the furniture in the room is very stressful for them [18-21].

It is necessary to closely observe and analyse the child's behavior, communication with the environment and general development, and if any disturbing abnormalities are observed, it is extremely important to diagnose them properly and

start appropriate therapy as soon as possible. Unfortunately, due to the fact that the causes of autism are not fully understood, treatment of this condition is very difficult. The treatment most commonly used is TEACCH (Treatment and Education of Autistic and Related Communication Handicapped Children), which involves combining the actions of parents with the work of therapists. Another method is so-called behavioral analysis, i.e. the "small steps" method, which aims to encourage good behaviour and reward the child for such. The RDI (Relationship Development Intervention) method is also known, which is an option method in which you first need to get to know and accept the world of a child with autism, then to show him/her a normal world and give the child a choice. It is important that it should be the choice of the child, who cannot be forced to do anything. In addition to these mainstreams in therapy, there are some supporting methods, such as the Developing Movement Method, music therapy, sensory integration, dog therapy, or a modified version of the Good Start Method. Chromotherapy, using a knitted product with light-emitting structures incorporated, has been proposed as an assistive method in the work. Chromotherapy is a colour therapy involving exposure of a person to certain colours by irradiation with light of a specific colour and saturation, or staying in a room painted in a specific colour. Healings caused by exposure to colours were already known in ancient China, India and Egypt. In many cases, autism is associated with unusual reception of the world through the senses. People on the autism spectrum can perceive the usual stimuli as low-intensity stimuli (feel practically no handshake) or very intense ones (the handshake is very painful) [18, 24].

In such situations, light therapy can be used to regulate the level of arousal of the child, which is useful especially when inhibiting aggressive behaviour. Colour therapy can fundamentally improve the energy level of the child's functioning. Children who are not interested in the environment, who have very poor communication abilities, can become more active, more interested in the world under the influence of colours, and thus it can be easier to make contact with them. Aggressive and hyperactive children, on the other hand, can be muted and calmed by exposing them to the right colour [25-29]. The main purpose of chromotherapy in the process of revalidation of children with autism is to induce own activity of the person undergoing the therapy and facilitate contact with the caregiver. With the help of chromotherapy, children can explore the world using their senses, and thus stimulate and develop the elementary cognitive processes. The variety of stimuli makes experiencing them in such a small space an excuse for getting to know and understand one's body, giving an opportunity for sensory integration training. Chromotherapy complements traditional methods of revalidation, allows to understand the surrounding world better and helps to organise the whole of the impressions received by children. One or more senses of the child can be stimulated, depending on the need. The basic principle of chromotherapy sessions is full acceptance of the method of receiving the stimuli proposed that the child has chosen. We create the right atmosphere, do not set requirements or give commands, and give the child the freedom to behave. In such therapy, it is necessary to accept the children as they are, and even the simplest opportunities to do something should be considered valuable [24-31].

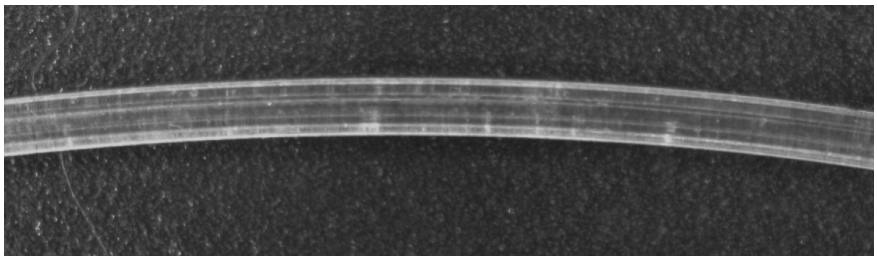


Figure 1. *Lateral propagation optical fibre seen under a microscope lens.*

Research methodology

A classic fibre optic cable is nothing more than a closed structure made of glass or plastic which utilises light to transmit information. Such a dielectric transmission medium, which can simultaneously act as an electrical insulator and optical conductor, is based on optical fibre technology and is designed to transmit optical signals without loss or distortion. Fibre optic cables consist of a centrally located core, a surrounding outer layer and a protective coating (called a jacket), and can take the form of a single fibre, bundle of fibres or fibre optic board (welded fibres). Fibre optics are widely used in optotelecommunication, sensor technology, metrology, biomedicine, lighting systems and military systems. Additionally, the use of optical fibres as sensors to measure values such as pressure, temperature, location, deformation and stress is also known. [1-4] In this work, a rare type of fibre optic will be presented and used for research purposes: the lateral propagation optical fibre. This is called a light diffuser fibre and is most often produced by mechanical incision of the fibre in such a way that dispersion of the light beam can be obtained. The appearance of a lateral propagation optical is presented in ***Figure 1***.

For this work, a lateral propagation optical fibre of 0.75 mm diameter was selected, as well as a semiconductor laser emitting light of 405 nm wavelength and 1mW optical power. The optical fibre is made with PMMA.

As part of the experimental work, two variants of knitted fabrics with lateral propagation fibre optics were produced using two different techniques: a specialised knitting machine and a digital device for applying structures to the surface of flat products.

Experimental work

The first stage of the experimental work focuses on the development of technology for the application of fibre optic structures onto the surface of knitted fabrics. As a substrate, a polyester knitted rib stitch fabric with a surface mass of 526 g/m^2 and thickness of 0,46 mm was selected. The wale density of the knitted fabric was 51 and the course density 45. The design of the knitted fabric-fibre optic system was prepared using emCAD software (DAHAO), presented in ***Figure 2.a***. With this system, the user can design any pattern and transfer it to an actuator device, because the machine control system recognises the file prepared in a given format, processes the pattern and produces the designed shape. The emCAD professional design system, due to its high efficiency, can meet the

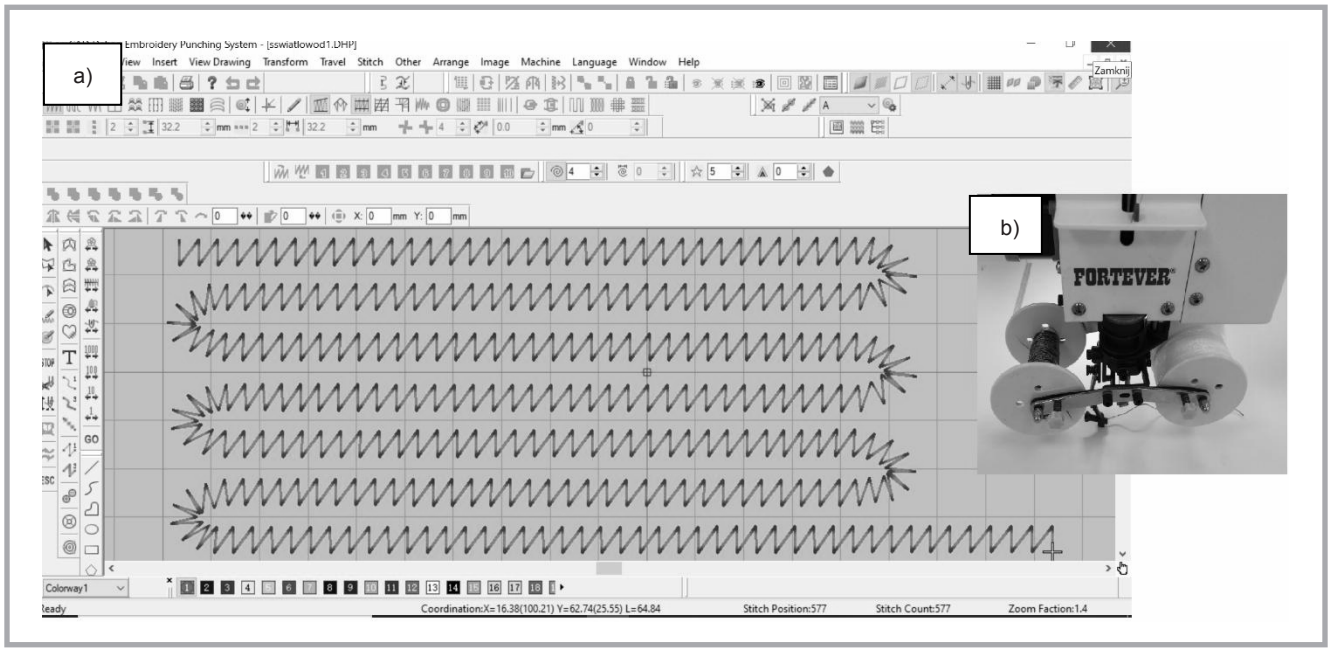


Figure 2. *a) Design of the application of optical fibres onto a knitted structure prepared using emCAD software, b) attachment for applying optoelectric structures onto knitted products.*

requirements of a professional operator. The optical fibre application process was carried out on a device, unique on a nationwide scale, for permanent application of small spatial structures to textiles manufactured by Fortever, equipped with a specialised attachment and element continuous handling system applied. The appearance of the attachment is shown in ***Figure 2.b***.

The process of application of various structures to knitted products by this method requires considerable commitment from the operator, full control of all the operating parameters of the threads used during application, and the use of a special needle for mesh products. The work resulted in the creation of a knitted product with a fibre optic network applied according to the design, the appearance of which is shown later in the article.

The second stage of the experimental work was based on manufacturing a textile product containing optic fibres introduced into the structure of the product in the weft form. The result is a rib stitch knitted fabric with optical fibres, the structure of which is shown in ***Figure 3***.

The number of wefts incorporated in the knitted fabric corresponded to the number of fibre optics applied onto the knit structure in the first stage of the work.

The optical fibre used for the purpose of this work transmits blue light of 405 nm wavelength (blue light), but with the possibility to emit a different wavelength, as shown in ***Figure 4***.

Knitted products containing fibre optics are shown in ***Table 1***.

The methods of creating knitted products containing implemented lateral propagation optical fibres presented in the work can be used to manufacture blankets for children with autism, stimulating or tranquilising according to the colours used and be adapted to the needs of the potential user of the product manufactured.

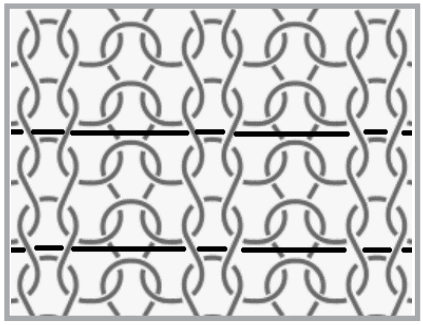


Figure 3. *Structure of knitted fabric with optical fibres.*

Color	Wavelength (nm)
Violet	380-450
Blue	450-495
Green	495-570
Yellow	570-590
Orange	590-620
Red	620-750

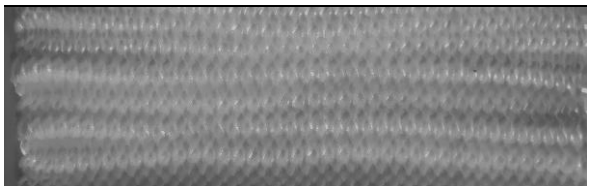
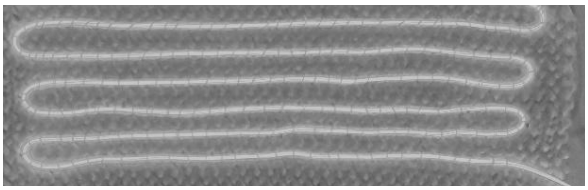
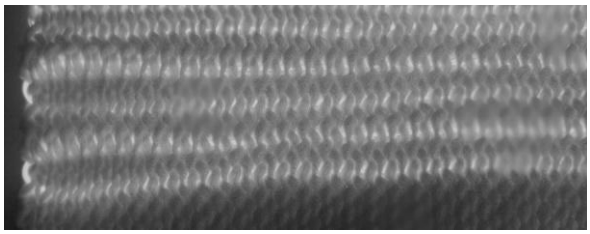
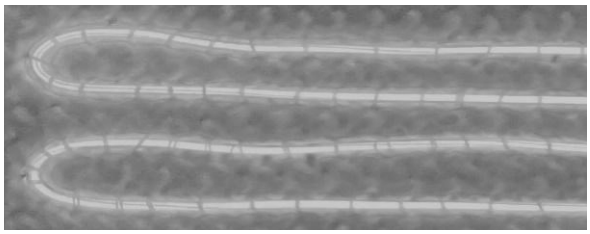
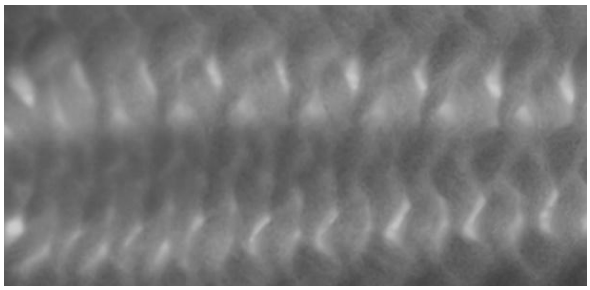
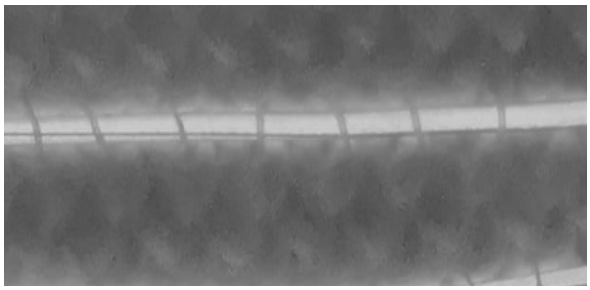
Figure 4. *Wavelength and colour of light seen.*

Conclusions

The solution presented in the work is a preliminary study on the method for functionalising knitted fabrics in such a way that they could have a therapeutic function and be used as a chromotherapy tool for children with autism. Knitted fabric with optical fibres is a novel approach to the issue of helping patients and their families, where colour therapy procedures can be carried out at home following the recommendations of the attending physician or therapist. Home textiles have accompanied people since time immemorial, thus fitting them with therapeutic elements and thus giving them a medical function is an interesting solution of an engineering nature. This type of treatment tool will be more likely to be accepted by a small and difficult patient than classic therapeutic devices.

The implementation of optical fibres onto the surface or into the structure of a knitted product can be obtained with traditional technologies using a flat crochet machine and digital device for applying elements onto the surface of the knitted fabrics. Depending on the needs,

Table 1. *Knitted products with optical fibres.*

Knitted fabric with fibre optics applied on the surface	Knitted fabric with incorporated fibre optics
	
	
	

the number of fibre optics implemented into textiles can be modified; it is also possible to supply optical fibres with light waves of different lengths which will be observed by colour changes of the element applied. The colors should be selected according to the patient's condition, and to whether we wish to stimulate or calm down the child.

Application

Products manufactured in this way can be used in medical (phototherapy) and therapeutic devices as knitted floor mats, wall decorations, bedspreads, curtains, or blankets for colour therapy for autistic children.

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