SMART TEXTILE BASED REMOTE IDENTIFICATION SYSTEM

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ABSTRACT

Within this research a smart textile based light sensor was developed and integrated into a technical demonstrator of a remote identification system. This sensor is based on polymeric optical fibers (POFs) which contain fluorescent dopants and allows a remote detection using an optical laser pulse for identification. A possible use case for this system is remote identification to avoid "friendly fire" incidents. The smart textile sensor can be integrated with a very low footprint in protective textiles or other equipment of the individual. Besides defense applications, the system could also be adopted for applications in which a safe, secure and fast remote identification is needed.

Key Words: SMART TEXTILES, OPTICAL FIBERS, PROTECTIVE WOVEN FABRICS, FIBER BASED SENSORS

1. INTRODUCTION

Although communication technologies have been revolutionized over the decades, casualties due to "friendly fire", in combat situations remain a constant risk. [1,2] Within this research a remote identification system for primary use in military and security applications has been developed. The identification system works as follows: An interrogation laser pulse is sent out by an individual wanting to identify another individual at intermediate range as a possible enemy or a "friend" in complex combat situations. If this pulse is absorbed by an allied soldier, the active material integrated into the soldier's protective (e.g. woven textile) equipment, absorbs and processes the pulse and a message is generated and immediately sent back to identify the ally and thus to prevent collateral damage. The whole communication loop occurs within milliseconds, i.e. fast response. The interrogation pulse, which is sent out by a laser, gets absorbed by optical fibers integrated in the textile patch. These fibers contain a fluorescent dye, which ensures that a high fraction of the incident light is coupled into the optical fiber. The fibers can be woven into or embroidered onto the fabric, the former ensuring a high level of material protection. Subsequently, the woven optical fibers are bundled and connected to a photodiode. The signal that is encoded in the laser pulse is converted to the electrical domain by the photodiode, detected and processed by a dedicated module and if recognized as a valid message, a response is sent back to the interrogator. A schematic representation of the identification system is given in Figure 1.

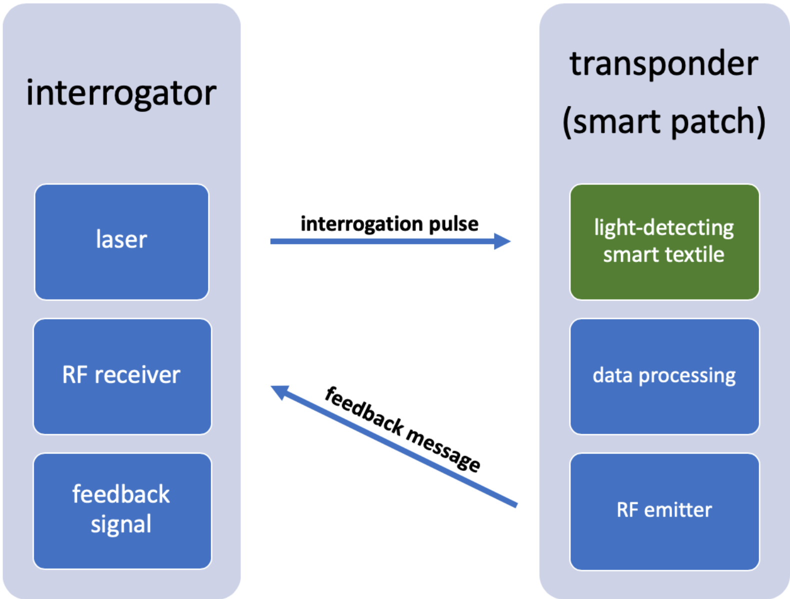

Figure 1 Schematic representation of the smart textile based remote identification system

2. MATERIAL AND METHOD

This paper focusses on the integration of the optical fibers into the fabric and the impact of the exposed fiber surface on the signal strength. Polymeric optical fibers consist of an inner core, usually made of PMMA, and a cladding made of a material with a smaller refractive index, such as PTFE. [3] When light is coupled into the fiber, it is transmitted through the fiber core towards the fiber endings. The light transmission results from the difference in refractive index of the polymeric materials. [4]

In order to function as a light sensor within the identification system, the laser light, sent out by the interrogator must be coupled into the optical fiber. In general, efficient light incoupling into POFs occurs at the endings, which is not suited for this application. Therefore, POFs that contain a fluorescent dopant were selected for further development. Here, the perpendicular incidenting light is absorbed by the fluorescent dopant and (partly) re-emitted along the fiber core. The re-emitted light signal can be observed at the fiber endings.

Based on preceding research and discussions within the consortium the following requirements for the smart patch were formulated:

- Ability to capture photons send out by the interrogation laser
- Conversion of the optical signal into an electrical signal
- Integration of transponder electronics for signal processing and feedback signal
- Robust and suited for field trials (mechanical stability).

Several POFs that are commercially available, were evaluated for further prototyping. Those fibers differ in their absorption and emission properties, their diameter and their mechanical stability. Their power conversion efficiencies were determined at different laser wavelengths.

In the course of further prototype development, the chosen fibers were integrated into a textile by either technical embroidery or weaving. The embroidered samples were fabricated using a technical embroidery machine (ZSK JCZA 0109-550) equipped with a W-head for positioning the POFs. The woven samples were realized using a fully automatic sample weaving loom (CCI Evergreen) while inserting the optical fibers either in weft or warp direction in combination with a polyester yarn (Trevira CS, 37 tex).

2. EXPERIMENTAL RESULTS AND DISCUSSION

Based upon the power conversion efficiency at the aimed interrogation wavelengths, one fluorescent POF type was chosen for textile integration. Compared to the other POFs this fiber showed besides the highest power conversion efficiencies, also a good mechanical stability. However, the diameter of 0.75 mm and a marked red color counteracts the camouflage of a typical uniform in military environments.

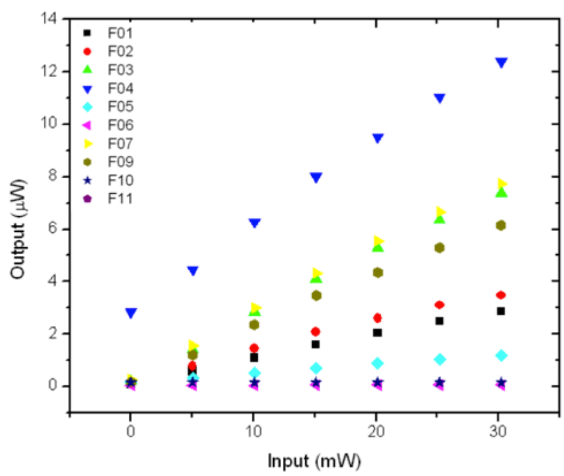

Figure 2 Measurements of the fibers light output at different incidenting light strenght for the evaluated fluorescent POFs (F01-F11).

In order to convert the incident photons into an electrical signal, the fibers were bundled, fixated by using an optical non-intruding glue and attached to a photodiode. For further protection, this connection was secured by an epoxy resin filled 3D-printed casing. The first prototypes were handstitched onto a fabric and connected through the photodiode to signal processing electronics.

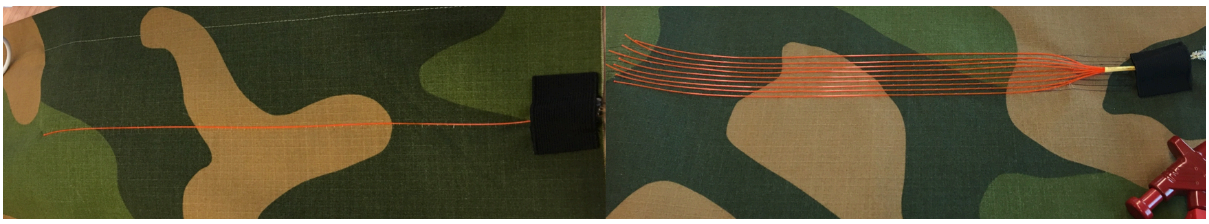

Figure 3 First prototypes of hand stitched optical fibers connected to a photodiode (1 vs 9 fibers.

The patches, shown in Figure 3 differ in their amount of fibers, 1 and 9 respectively. After exposure to the interrogating laser light, a nine-fold increase in signal strength was measured. This proved the general concept of using the fluorescent POFs as a photodetector. Accordingly, prototypes comprising the maximum amount of fibers that fit onto the photodiode surface were fabricated by embroidery.

Figure 4 Embroidered prototype comprising 19 fluorscent POFs.

For an application in a military environment a low visible profile of the smart patch is essential. Therefore, the integration of the optical fibers by weaving was investigated, this also ensure a mechanical protection of the fibers. However, this also reduces the exposure surface of the POFs and the output signal strength will be lower, as less laser light can be absorbed. Different weaving patterns were tested in order to find an optimum in active fiber surface and fiber protection, based on the measured output signal. Four different weaving patterns were realized in the fabrication of the smart patches: 1/1 plan-, 2/2 twill-, 1/3 twill- and 3/1 twill-weave. [5] The optical fibers were inserted in weft direction. The active area of each patch was 10 x 12 cm and consisted of 19 parallel optical fibers.

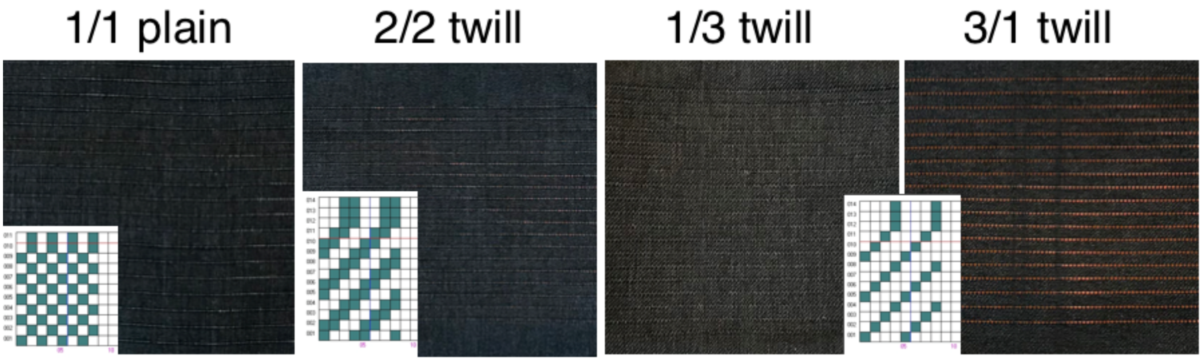

Figure 5: Woven smart patches using a dark brown Trevira CS yarn (256 picks/10 cm in warp direction and 297 ends /10 cm in weft direction).

The impact of the different weaving pattern on the signal strength, compared to the embroidered sample comprising the same amount of optical fibers and the same active patch area, was tested using a defined laser pulse. From the graph in Figure 6 it becomes evident that the integration using weaving, lowers the light absorption and therefore the output signal. However, contrasted with an improved fiber protecting due to the integration in the weave and a strongly reduced visible impact.

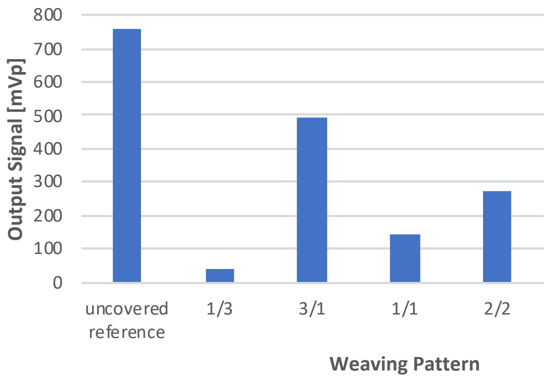

Figure 6 Impact of weaving pattern on output signal strength

Based on the strength of the output signal, the 2/2 twill weave was chosen as design for the further development of the smart patches, as this pattern ensures a high fiber protection combined with a low visibility. These patches were designed in a pouch design to bear the electrical system including data processing, reply signal sending and power supply. Figure 7 shows a smart patch that was used in the field trials. Herein the electronical components are protected by stable flight case foam. The buckles on the back enable the attachment to a combat vest or other equipment.

Figure 7 Smart patch with a 2/2 twill weave a) front view, b) open pouch w/o the read-out electronics, c) back view, d) smart patch attached to a combat vest.

3. CONCLUSION

This research led to the development of a technical demonstrator of a smart textile patch which is part of a remote identification system. Fluorescent POFs were successfully integrated into a fabric by means of weaving. The variation in the weaving pattern from a plain weave to different twill weaves changes the visibility of the optical fiber and therefore strongly influences the signal strength due to a reduced active area that can absorb the light pulse. By thorough characterization, a weaving pattern was chosen which on one hand ensures a strong signal over long distances without disturbing the uniforms camouflage. Based on the light-to-signal ratio we chose the 2-2 twill weave for the development of prototypes. This textile sensor was integrated into a textile patch and attached to signal processing and communication electronics. In field-trials, a fully equipped light-detecting smart patch was tested under different use-case scenarios. Those tests demonstrated the applicability of the remote identification system, even at long interrogation distances.

ACKNOWLEDGMENTS

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