Manipulation of metalized textile fibers for laser structuring

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Abstract

The recent progress in intelligent textiles requires metalized fibers with structured electrical paths or circuits. New applications can be found as sensor elements, illumination and electrical power supply. A polyimide fiber metalized by sputtering and galvanic processes could serve as basis material. Typical thicknesses of these metal layers are in a range of 50 nm up to 5 µm [1, 2]. The need of achieving structure sizes in the order of 2-15 µm in the metal coating without damaging the polyimide fiber can be satisfied by utilizing ultrashort pulse laser structuring [3]. The paper describes the results of the fundamental investigation of laser structuring of fibers. The diameters of the applied fibers were in a range from 100 µm up to 250 µm. The development of a handling- and positioning system for the alignment of fibers with respect to the laser focus will be presented. Based on the results of the fundamental investigations, an advanced demonstrator of a laser structuring tool was developed. The results of the laser structuring process will be discussed.

1. Requirements for fiber manipulation

The most challenging requirement is to keep a positioning accuracy of 5-10 µm of the laser focus along the geometrical axis of the positioned fiber. The diameter tolerance of 1-3 µm of the fibers and the fiber position deviation, induced by vibrations and mechanical behaviors of the fiber positioning system, have to be less than 5 µm in sum to guarantee the required structuring results. This is due to the fact that the depth of focus of the structuring laser is in a range of 5-10 µm in order to achieve the desired structuring resolution.

2. Optic design

Basic investigations of ultrashort pulse laser structuring were performed using a 515 nm wavelength laser and pulse durations of 500 fs. The depth of focus should be as large as possible to relax the very high positioning requirements. Figure 1 shows the developed and simulated optical scheme. A focusing module, consisting of two lenses, bundles the laser beam onto a two axis scanning mirror. Two collimation lenses and a 90° mirror are the next optical elements in the optical path. A movable aspherical mirror was designed for the rotation of the laser focus around the metalized textile fiber, arranged in the center of the aspherical mirror. It will be positioned (moved) along the fiber axis during structuring. The maximum structuring length was defined to be 20 mm. As the fiber is moved in between the structuring steps only, a very high manufacturing accuracy was obtained and therefore complex structures like helices and double helices can be formed. The developed optical design was transferred into the mechanical model.

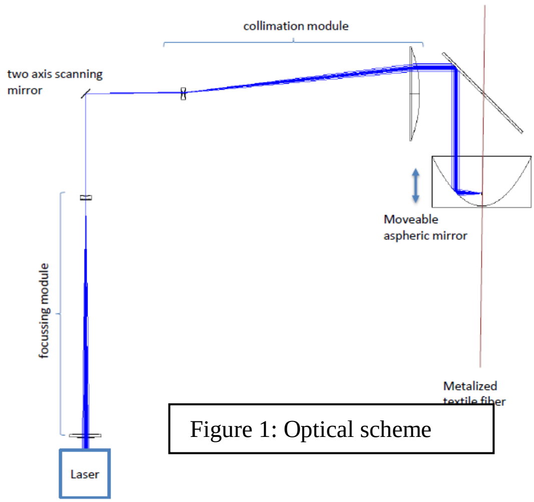

Figure 1: Optical scheme

3. Design and realization of the fiber handling and positioning system

The fiber handling and positioning system was built using a base plate (750 mm x 750 mm) for mounting the optical elements and two very precise air bearings with a concentric accuracy of less than 2 µm (see figure 2). The fiber will be inserted into precisely machined V-grooves (on the driven gear mounted on the air bearings) and clamped by elastic elements. By rotating the air bearings, the incremental fiber transport is realized. By the control of the two motors and the motor control software, the fiber will be tensioned to prevent a bending of the fiber. During the laser structuring process, a constant force with a maximum load of 0.5 N is applied. By changing the mechanical properties of the fiber spring rate during the laser structuring process, the compensation of the increase of fiber length will also be reached by the tensile load control. The use of commercial bobbins allows the continuous structuring of metalized textile fibers with an overall length of up to one kilometer.

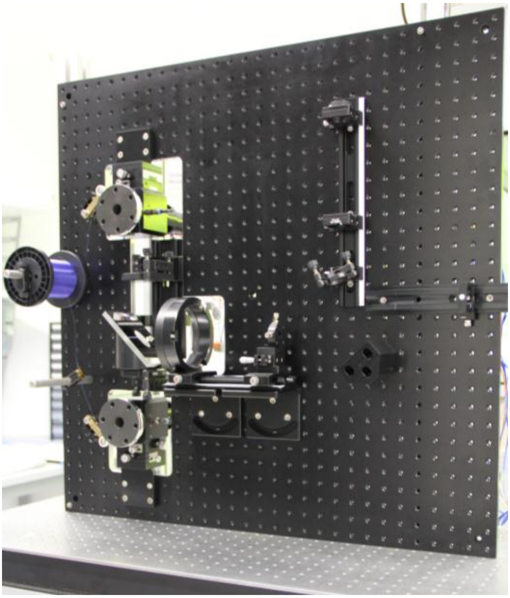

Figure 2: Opto-mechanical setup of the demonstrator

4. Results of laser structuring of metalized textile fibers

Several laser parameters such as wavelength, pulse duration, pulse energy, and pulse overlap were investigated. Different types of fibers and metallic layer systems (Silver, Copper) were tested as well. Structure sizes down to 2 µm were realized (see figure 3) using a 10 x microscope lens with a numerical aperture of 0.25 for laser structuring.

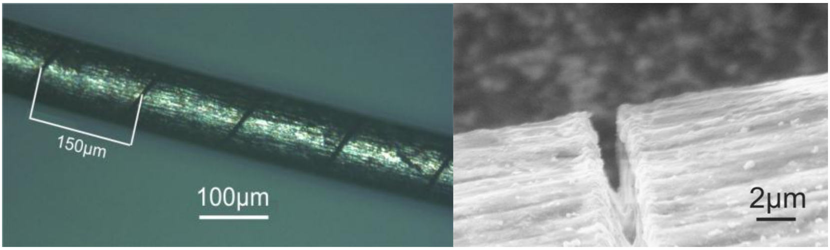

Figure 3: Photomicrograph of the laser structured fiber (left), SEM image showing the structured gap in detail (right)

5. Summary

Based on functional tests of ultrashort pulse laser structuring, the optical- and mechanical design of a fiber handling and positioning system was developed and realized. The integration of the demonstrator into a commercial machine automates the laser structuring process and reduces its structuring uncertainty to a few microns.

Acknowledgement

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