

# Light microscopy study of 24 samples originating from the Shroud of Turin

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The aim of the present study is a description of fibers originating from the Shroud, i.e. fibers of Shroud weaving, fibers of sewing threads, and fibers possibly originating from the Holland cloth and/or other cloth fibers. Some particles of interest have been studied likewise.

The study was done with an Olympus CX41 microscope equipped with bright field, phase contrast and cross polarized light, for the most part in magnitude 100x, 200x, 400x and a few in 1000x. The microscope was mounted with an Olympus ColorView I digital camera in 2080 x 1544 resolution.<sup>1</sup> 22 samples, collected and mounted by Giulio Fanti<sup>2</sup>, came from Giovanni Riggi di Numana's dusts<sup>3</sup> vacuumed from the Shroud in 1978<sup>4</sup> and 1988 and 2 samples from a piece of fabric numbered F15001, kept in Fondazione 3M cut from "C-1r"<sup>5</sup> area.

The samples have been microscoped and micro photographed by the author; subsequently brought to the University of Copenhagen to be microscoped and analyzed by Senior Researcher, PhD Lisbeth G. Thygesen<sup>6</sup> (LGT). Most kindly Thygesen finally has reviewed this paper.

Likewise, all samples have been analyzed for human body material focusing on those samples suspected of "blood" or "body fluids". This was done on Institute of Forensic Medicine by PhD Christian G. Westring and PhD Erik Sorensen.<sup>7</sup>

The different fibers exhibit their characteristic structures most prominent in cross polarized light, but as it will be shown some fiber features and particles are best seen in phase contrast and bright field light.

Fibers extracted from F15001 are known non-image fibers. But it must be remembered that, although we investigate fibers vacuumed from image areas (face, hands, feet, buttocks), these fibers originate from the reverse side of the Shroud, an area which does not exhibit the same macroscopic image characteristics as the front side.

It is important to recognize natural fibers, their structure, surface, coloring and appearance, the influence of manipulating etc. to avoid misinterpretations.

The ends of fibers have different appearances. For example a non broken end is tapering, whereas a broken end keeps the fiber diameter or become frayed into fibrils.

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<sup>1</sup> For those, who are not familiar using a microscope, some remarks are necessary. Images are in 2D, but with the microscope you have the possibility of a 3D study. Because of transparency you are literally able to walk through a fiber from the nearest point to the most distant by moving the object lens. Therefore the same specific fiber area may look quite different from surface to the core of the fiber.

<sup>2</sup> Cf. *Jose-Niels Samples: detailed list in the map: Rogers & Riggi di Numana's material - TS fibers and dusts aspired from the TS*", Giulio Fanti's file section of Shroud Science Group, SSG. Please open Fanti's and the present paper contemporarily for details.

<sup>3</sup> The aspired locations are defined as *hands, face, feet, buttocks* and *C-14* area. The vacuuming was done from the reverse side of the Shroud.

<sup>4</sup> Cf. SSG, file section, Barrie Schwartz: *Riggi's Vacuum Experiment*.

<sup>5</sup> Mechthild Flury-Lemberg grid nomenclature from *Sindone 2002*.

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Cross polarized light clearly demonstrates characteristic cross striation in flax fibers. By some authors this striation has been named *growth nodes*.<sup>8</sup> However, striation originates from mechanical stress and humidity levels either during growth, harvesting or post harvesting processing.<sup>9</sup> Consequently, in this paper striations are denoted *dislocations* instead of kinks, kink bands, nodes or growth nodes.

The headlines in bold below describing each sample has been kept in Giulio Faint's original text with addition of sample area and year.

The scale bar number refers to the total length of the bar.

Abbreviations:

bf: bright field

µm: micrometer

p: polarized

pc: phase contrast

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<sup>8</sup> Raymond Rogers was convinced that these structures were growth nodes. This statement has been questioned, cf. the literature review by José Botella-Munoz, *An attempt to understand the so called "growth nodes" in flax fibers*, SSG file section: *José*.

<sup>9</sup> Cf. Lisbeth G. Thygesen; Michaela Eder; Ingo Burgert: *Dislocations in single hemp fibres – investigations into the relationship of structural distortions and tensile properties at the cell wall level*. *J Mater Sci* (2007) 42:558-564.  
Lisbeth G. Thygesen, Jørgen B. Bilde-Sørensen, Preben Hoffmeyer: *Visualisation of dislocations in hemp fibres: A comparison between scanning electron microscopy (SEM) and polarized light microscopy (PLM)*. *Industrial Crops and Products* 24 (2006) 181–185.

Karolina Nyholm, Paul Ander, Stig Bardage and Geoffrey Daniel: *Dislocations in pulp fibres – their origin, characteristics and importance – a review*. *Nordic Pulp and Paper Research Journal* (2001).

### #1) TS warp fiber coming from F15001 fabric

1½-2mm long fiber. Thickness 11-14µm. The fiber is frayed in the left and right end and broken off in the right end.<sup>10</sup> This fraying is due to wear and tear: defibrillation, i.e. the microfibrils separated and sticking out from the main fiber. In polarized light fibers and microfibrils as well exhibit dislocations (not shown here).

A thickening, app. 30µm, adheres to and encircles the fiber and seems not part of the this fiber but parenchyma cell debris from neighbor fibers.



Fig 1. Frayed part of fiber; bf, scale bar 50µm

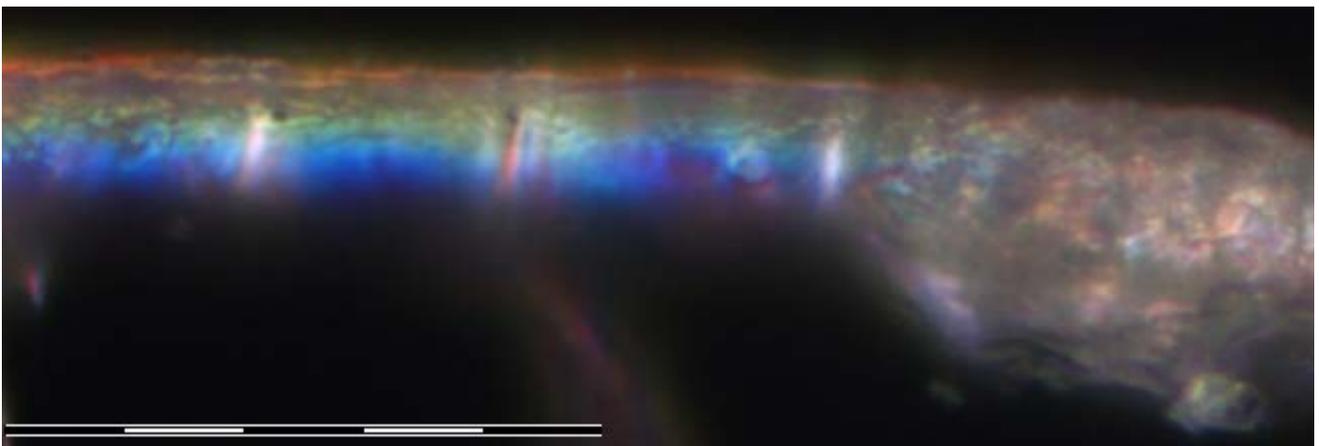
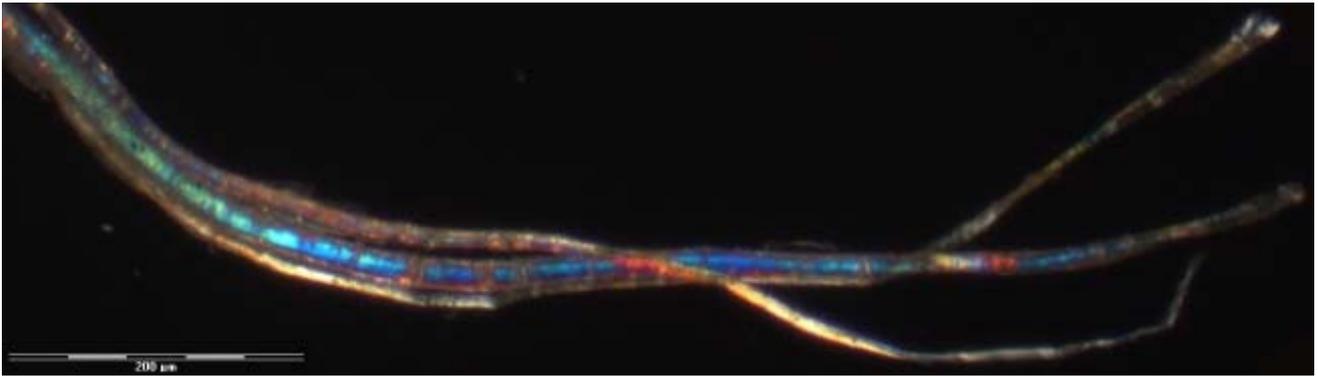


Fig 2. Thickening; p, scale bar 50µm

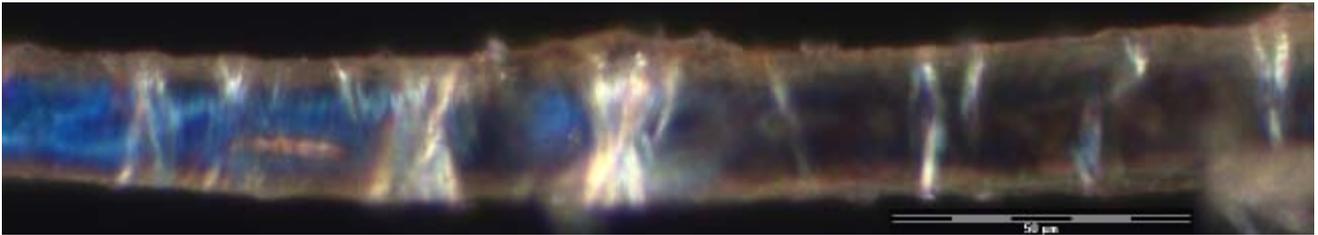
### #2) TS weft fiber coming from F15001 fabric

The sample is consisting of three fibers, 3 mm long, lying tight to each other and split up to the right. Dislocations exhibit many different forms for example “X”, “Y”, “I” and “λ” etc. due to the focusing depth, the microfibril angle of the cell wall and the placement of the fibre relative to the polarized light. If the microscope is equipped with a rotating sample stage, it is possible to highlight the dislocations and dim the fiber (not shown here).

<sup>10</sup> *Left* and *right* terms as seen in the microscope. The transmitted object light is inverted through the lenses.

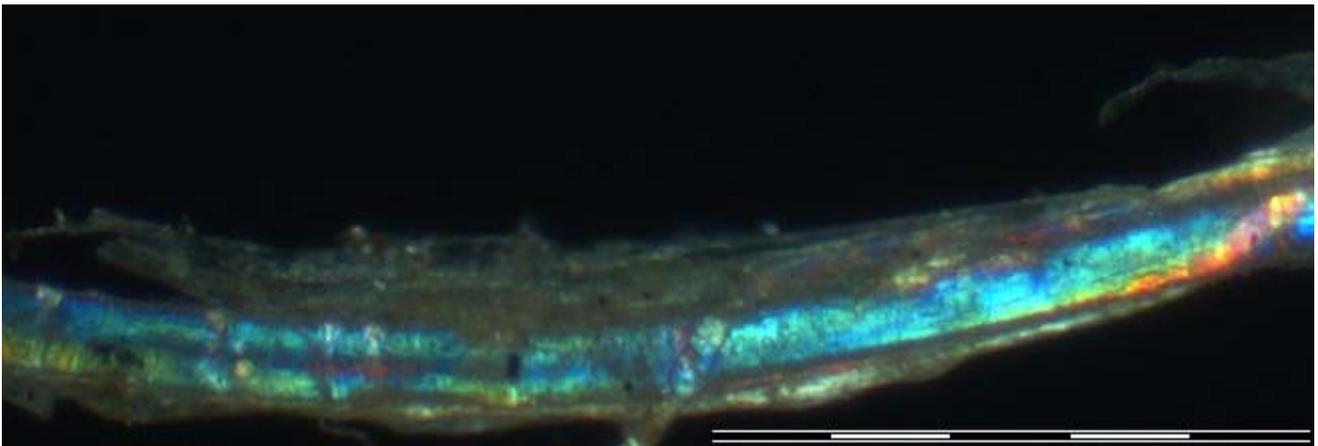


*Fig 3. Three fibers, which split up to the right; p, scale bar 200μm*



*Fig 4. Dislocations of different shape and inter-dislocation distance; p, scale bar 50μm*

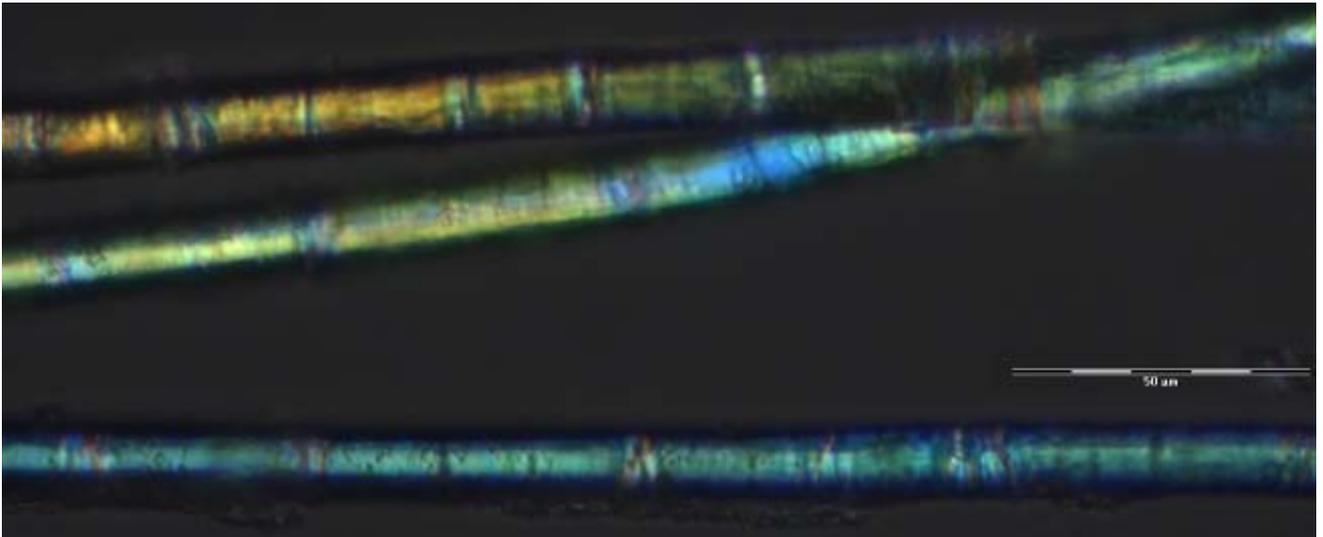
Cell debris from neighboring fibers is seen in different amount.



*Fig 5 Linen fiber with a thick layer of cell debris; p, scale bar 100μm*

### **#3) Linen/(cotton) fibers coming from sewing of F15001 fabric**

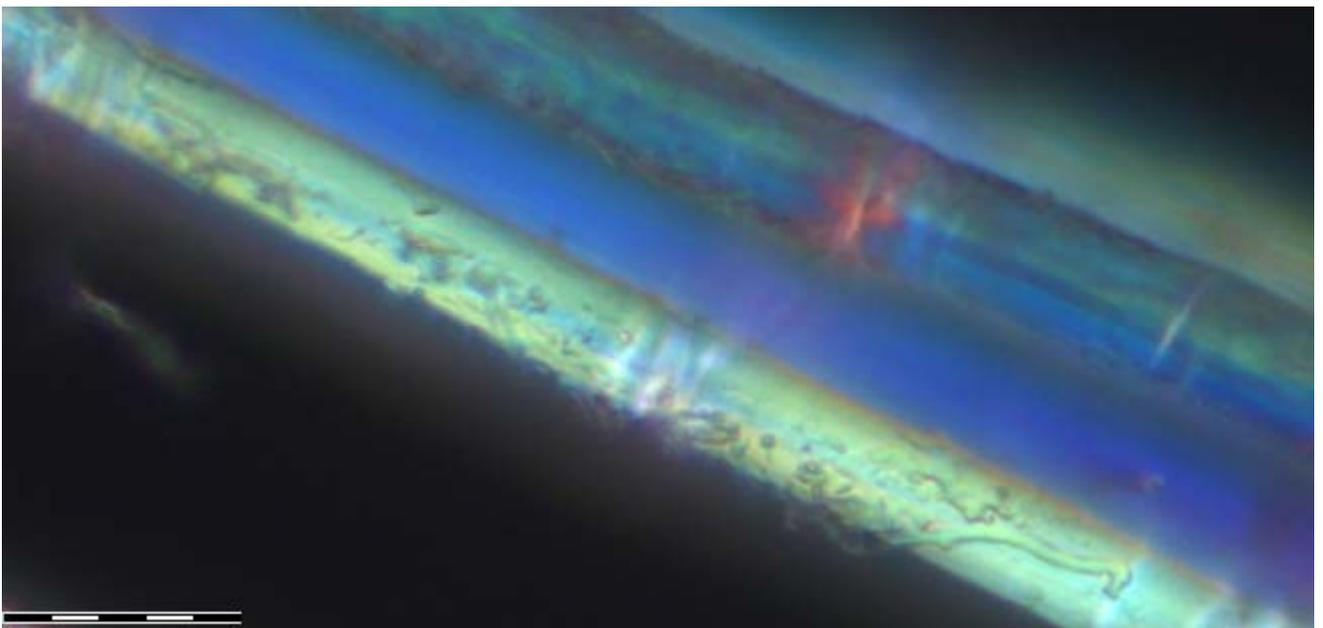
In the right end three thin linen fibers, 5-7μm in diameter, but the upper with a thickening when crossing the underlying fiber. This fiber diameter ranges from 6,5μm to 18μm. No cotton fibers are observed.



*Fig 6. Fibers of different shape. The upper fiber becoming thick when crossing the middle fiber; p, scale bar 50μm*

Amorphous layers are spread over the fibers.

Such layers are sometimes seen also in fibres taken directly from a plant stem using precision tweezers. It is assumed to be debris from the middle lamella, which in flax mostly consists of pectin.



*Fig 7 Amorphous surface layer on two fibers; scale bar 20μm*

In the middle of the sample you see a tangle. The arrows focus on a line fiber fractured in both ends.

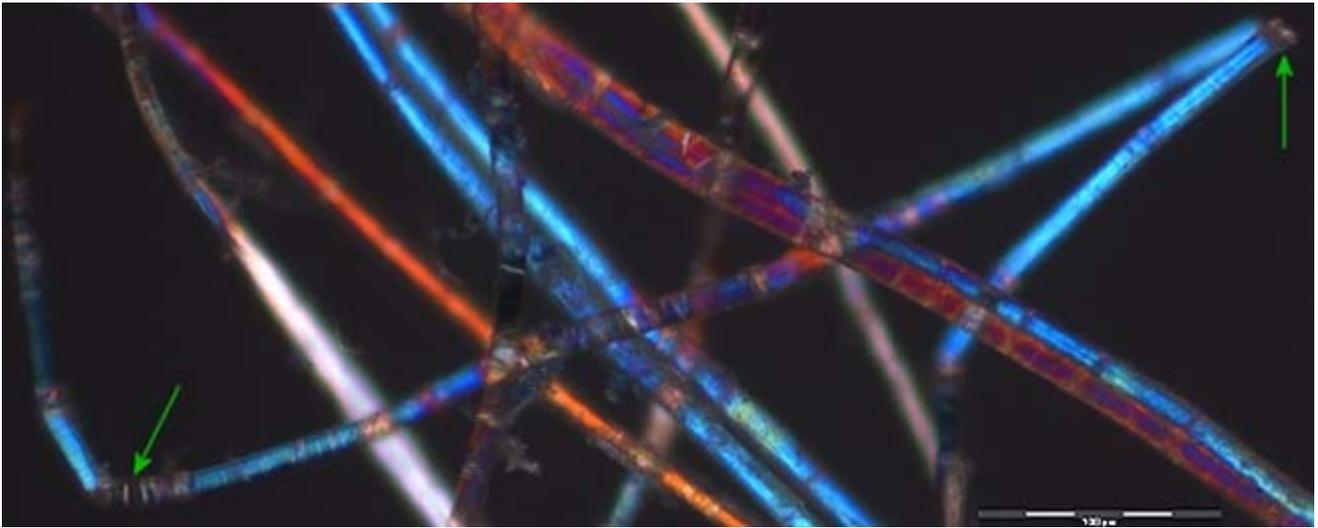


Fig 8 Fracture upper right indicated by arrow. Curve and grey mass indicated by left arrow; p, scale bar 100µm

In the left “leg” of the same fiber the fibrils in bundles run longitudinally along the fiber.



Fig 9 Left “leg” with bundles of fibrils; their individual thickness indicated by red writing. The image of the fiber has been rotated 28 degrees clockwise compared to fig 8; p

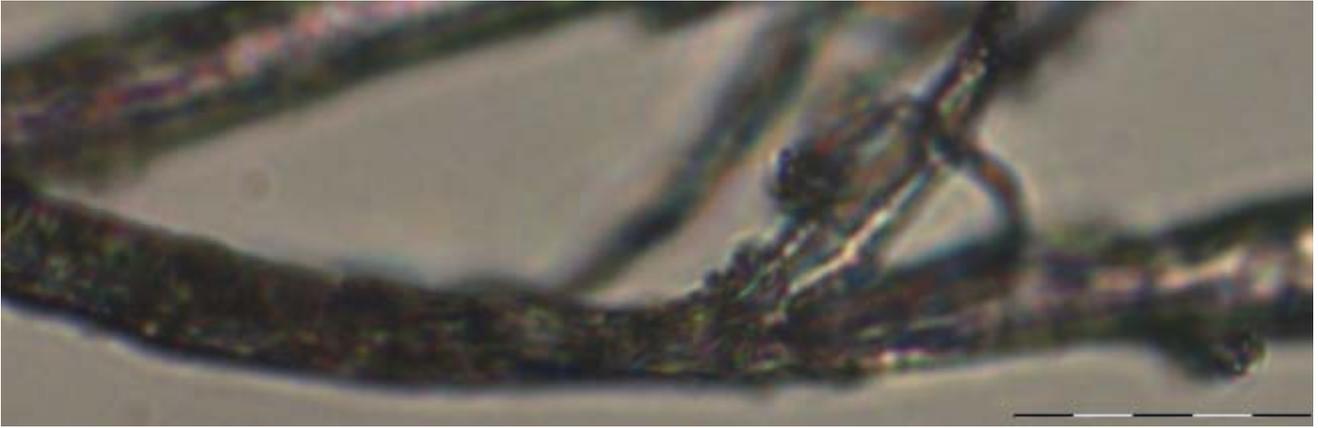
In the right end the fracture is “open”.

The fiber continues downwards left and bends in a curve of different angles, thus creating a curve of segments. Right before the perpendicular angle cell debris as a “grey mass” surrounds the fiber.



Fig 10 The image to the left represents the “open” fracture. The image to the right represents the bending area surrounded by cell debris; p

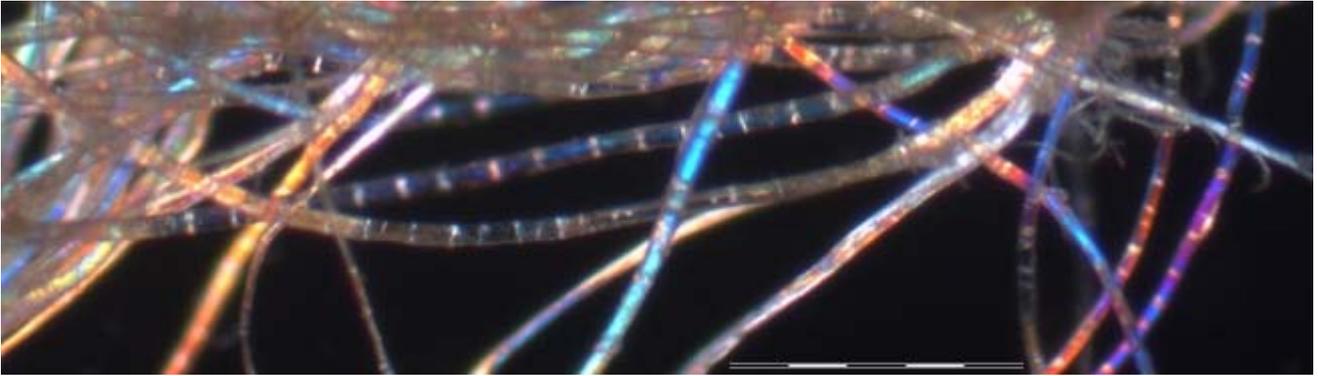
More linen fibers have different diameter along their length; in this case due to fraying of the main fiber in other cases due to twisting.



*Fig 11 The narrowing of the lower fiber presumably caused by fraying; bf, scale bar 50 $\mu$ m*

**#4) Linen fibers of sewing thread coming from F15001 fabric**

A 3mm long cream coloured bundle consisting of 50-60 fibres and some fiber fragments of different thickness - the thickest four times the thinnest. The linen fiber dislocations are more uniform in morphology and regularity of distance.



*Fig 12 Bundle of linen fibers with regular dislocation distance. Selection; p, scale bar 200 $\mu$ m*

**#5) Cotton fiber coming from filter “f”, Face Area 1978**

A long flat in length twisted fiber.



*Fig 13 Cotton fiber; p, scale bar 100 $\mu$ m*

**#6) TS fiber coming from filter “h”, Buttocks Area, 1978**

The fiber is much frayed. Fibrils are bristling curved from the main fiber.

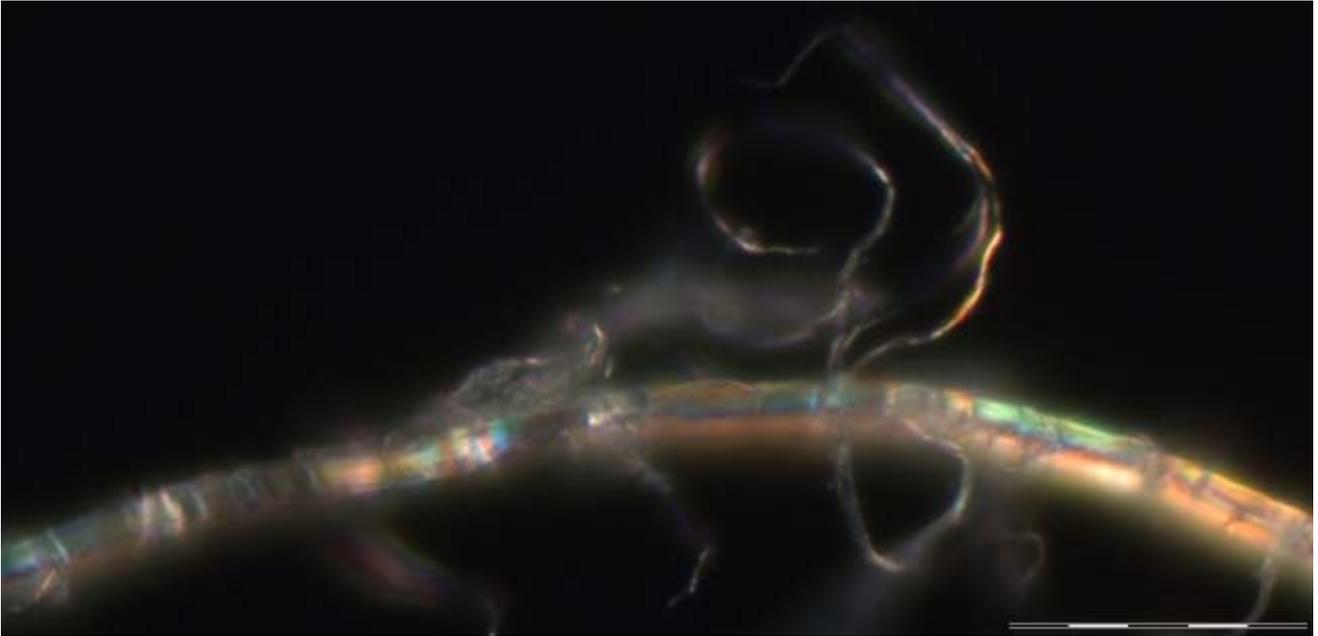


Fig 14 Frayed linen fiber; p, scale bar 50 $\mu$ m

**#7) TS linen fibers coming from “h” filter, Buttocks Area, 1978**

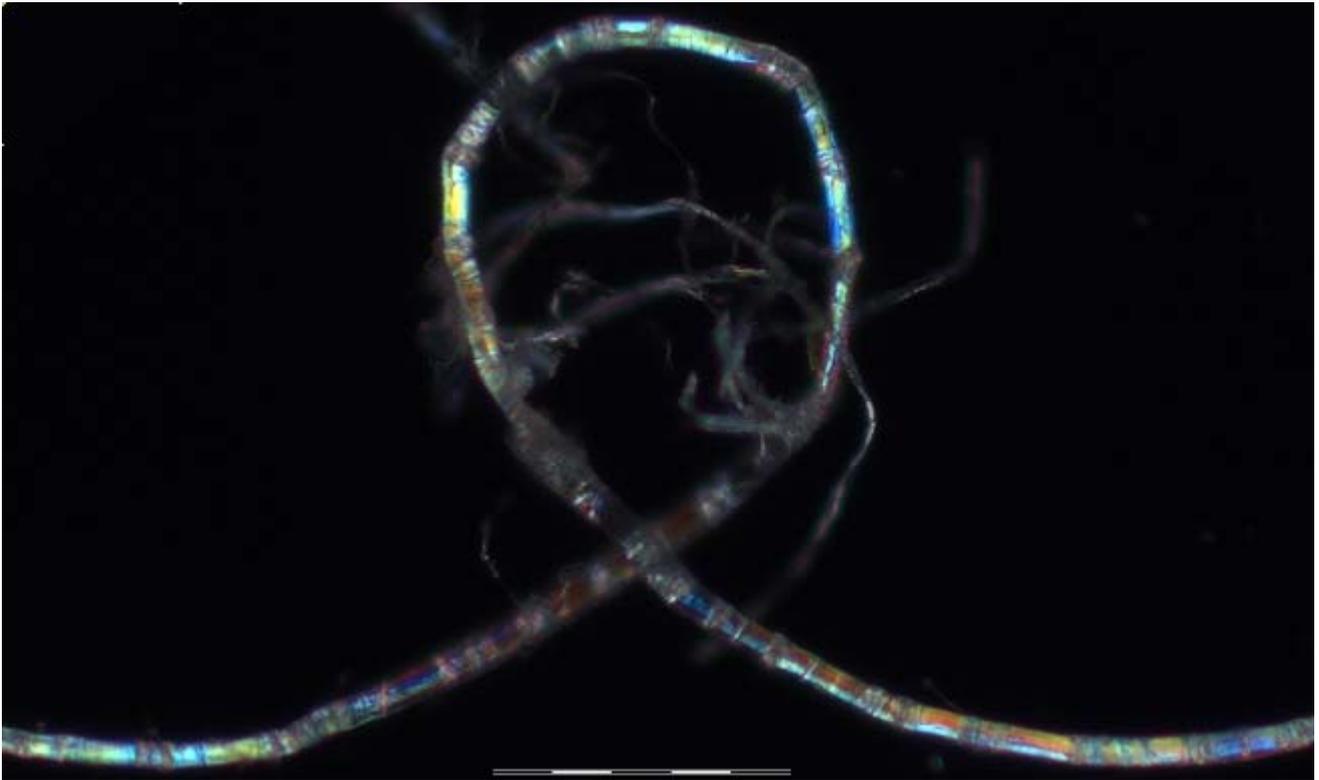
Some dislocation areas are thickened and denser than others. Displacement from side to side – without breaking – is observed.



Fig 15 Dislocations. Note the different diameters and slight displacement of the right segment; p, scale bar 20 $\mu$ m

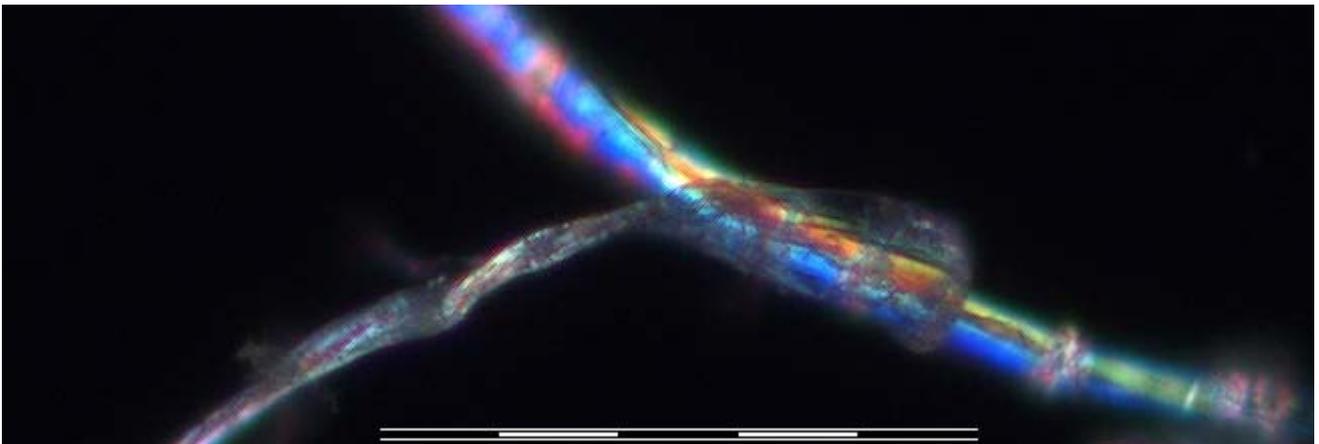
**#8) TS linen fibers coming from “h” filter, Buttocks Area, 1978**

The main fiber is frayed, especially at the loop. The loop is formed by bending at the dislocation sites like “joints”, not in between.



*Fig 16 Linen fiber forming a loop made up by segments. Note the bending takes place at the dislocation area; p, scale bar 100µm*

Presumable the sample only consists of a single fiber, which divides into a peel (primary cell wall) and its main part. This peel still adheres to the main fiber.



*Fig 17 Main fiber with peel still adhering, bending backwards and down left; p, scale bar 100µm*

**#9) TS linen fiber coming from “h” filter; oil 1.515, Buttocks Area, 1978**

Buckling upwards at dislocation level; less visible on the opposite side.

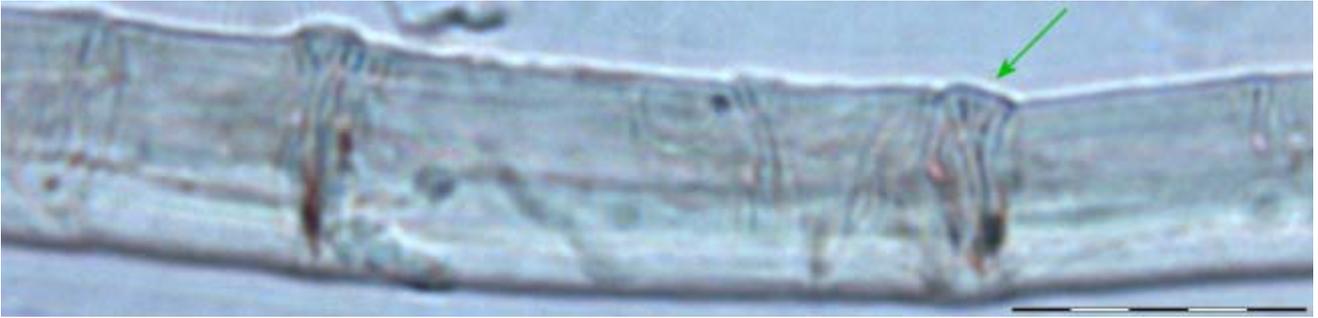


Fig 18 Arrow pointing at buckling; pc, scale bar 20 $\mu$ m

**#10) TS linen fiber coming from “h” filter; oil 1.515, Buttocks Area, 1978**

Dislocations of different appearance and a partial fracture with buckling show up clearly in this fiber.



Fig 19 Linen fiber showing distinct dislocations and a fracture with buckling (green arrow), see fig 20; p, scale bar 50 $\mu$ m

In phase contrast microscopy the partial fracture is easily recognized together with a typical buckling.

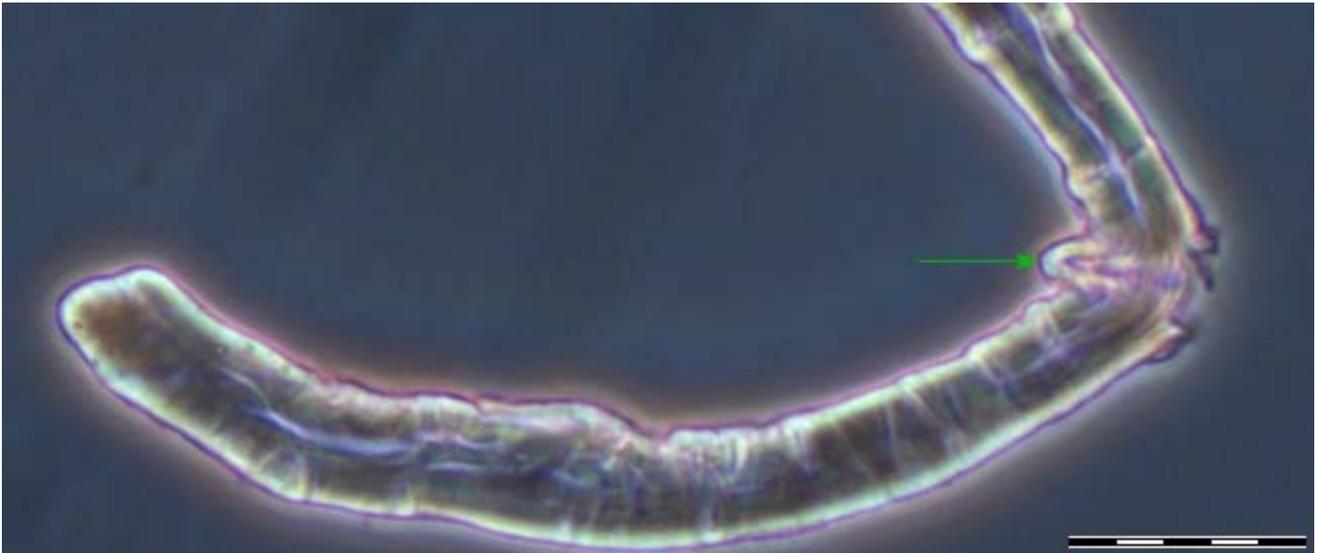


Fig 20 The same fiber as fig 19 turned counter clockwise. Buckling indicated by arrow. Fibrils are seen like bridges crossing the partial fracture.; pc, scale bar 20 $\mu$ m

**#11) TS linen fiber coming from “F” filter, Face Area 1978**

A long fiber of different thickness along its entire length, fractured a little before its right end. In the left 1/3 the fiber is spliced into three parts.



Fig 21 Long linen fiber showing a fracture far right; splicing in three parts far left; p, scale bar 200 $\mu$ m

**#12) TS linen fiber coming from “F”, Face Area 1978**

>3 mm long, frayed fiber. The frayed fibrils are often fastened at the dislocation level and sticking out from the dislocations of the main fiber in all directions like sea grass.



Fig 22 Fibrils, like “sea grass” fastened at dislocation level; bf, scale bar 100 $\mu$ m

At the right end of the fiber there are several loops with fiber fractures.



Fig 23 Linen fiber with loops formed by bending in segments at dislocation level. The pink striated background is an artefact from a pencil; bf, scale bar 50 $\mu$ m

A round, light brown object has been identified. The Department of Forensic Genetics has by common assent judged the object not being an erythrocyte - perhaps a drop of oil (LGT).

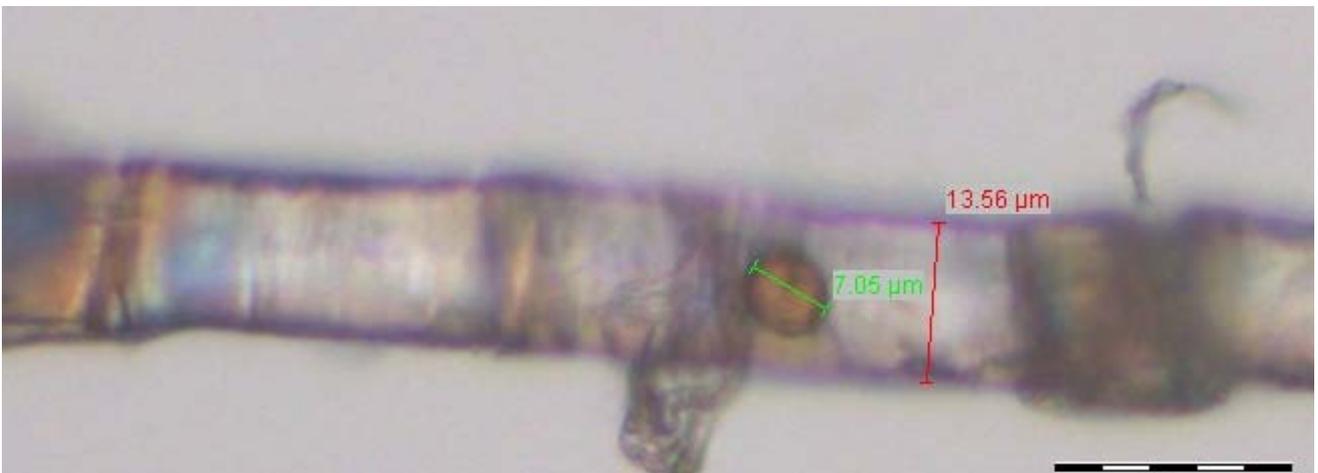


Fig 24 A round object with same dimensions as a human erythrocyte; p, scale bar 20 $\mu$ m

**#13) TS linen fiber coming from “F” filter; oil 1.515, Face Area 1978.  
Particles of probable body fluids (blood?) included.**

Short, thin fiber. On the left part of the fiber a small “drop” adheres, proposed to be blood. However, no significant blood corpuscle structures are observed. This “drop” has not been analyzed by the Department of Forensic Genetics.



*Fig 25 A "drop" of foreign material; bf, scale bar 20µm*

The other end of the fiber is thickened for a short distance. This part of the fiber has most probably been squeezed by handling in the preparation process (LGT).



*Fig 26 A rectangular thickening of the fiber most probably formed by squeezing, cf. fig 27; pc, scale bar 50µm*



*Fig 27 Squeezing of a dry hemp fiber by tweezers. Note the thickening; bf, scale bar 100µm. Courtesy of L.G. Thygesen*

**#14) TS linen fibers coming from “F” filter; oil 1.515, Face Area 1978**

A fiber uniform in thickness. Some objects of different forms are seen. They do not belong to fiber material (LGT).

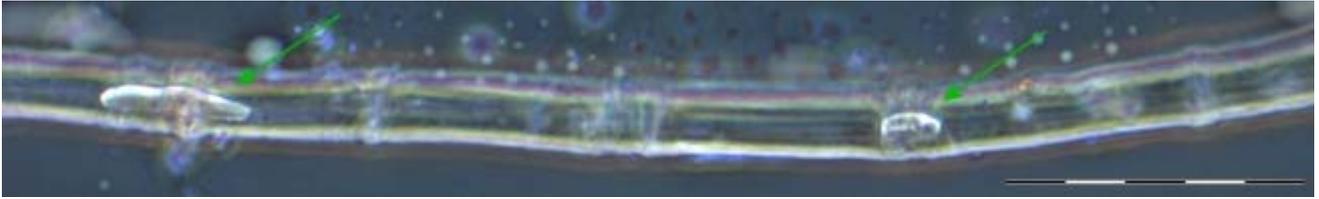


Fig 28 Objects of unknown origin (arrows) seem placed on the fiber surface; pc, scale bar 50 $\mu$ m

**#15) TS particular linen fiber coming from “h” filter;” dried” in two areas, Buttocks Area, 1978**

3-4mm long fiber showing well-defined dislocations sometimes including fractures and small displacements from side to side.

This aspired fiber is naturally not cut but torn out by the vacuum procedure. Fibers fracture and brake off at the dislocations, not in between.

The “dried” areas consist of cell debris from other fibers (LGT).



Fig 29 Left: cell debris. Right: a displacement of the right “leg”; bf, scale bar 50 $\mu$ m

**#16) 2 TS particular linen fibers coming from “h” filter; “dried” in various areas (one fiber is under sticky tape), Buttocks Area, 1978**

2 mm long fiber with changing diameter. The “dried” areas are situated between the nodes as narrowed areas, presumably formed by twisting (LGT).



Fig 30 Narrowing of fiber; pc, scale bar 50 $\mu$ m

**#18) Holland Cloth (?) fiber coming from “h” filter, Buttocks Area, 1978**

3-4mm long fiber, different from a typical Shroud flax fiber, but surely a plant fiber (LGT).

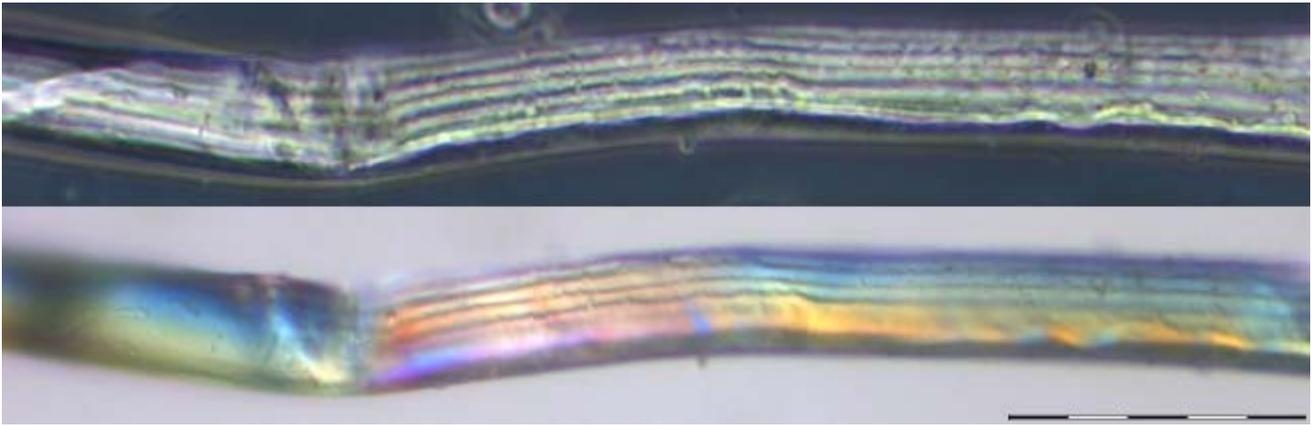


Fig 31 The same part of the fiber seen in *pc* (above) and *p* (below); scale bar 50 $\mu$ m

**#19) Holland Cloth (?) fiber coming from “h” filter, Buttocks Area, 1978**

3-4mm long fiber, different from a typical Shroud flax fiber, but surely a plant fiber.

A well defined border of a layer is visible. If the layer originates from fibers it could be pectin, but it is not seen in fresh fibers. Could it be glue from a sticky tape (LGT)?

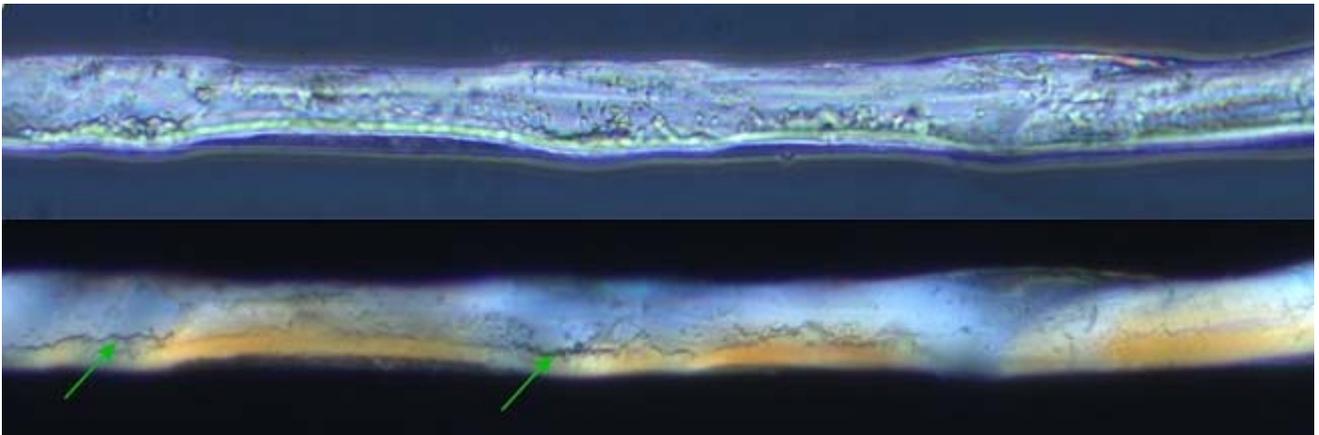


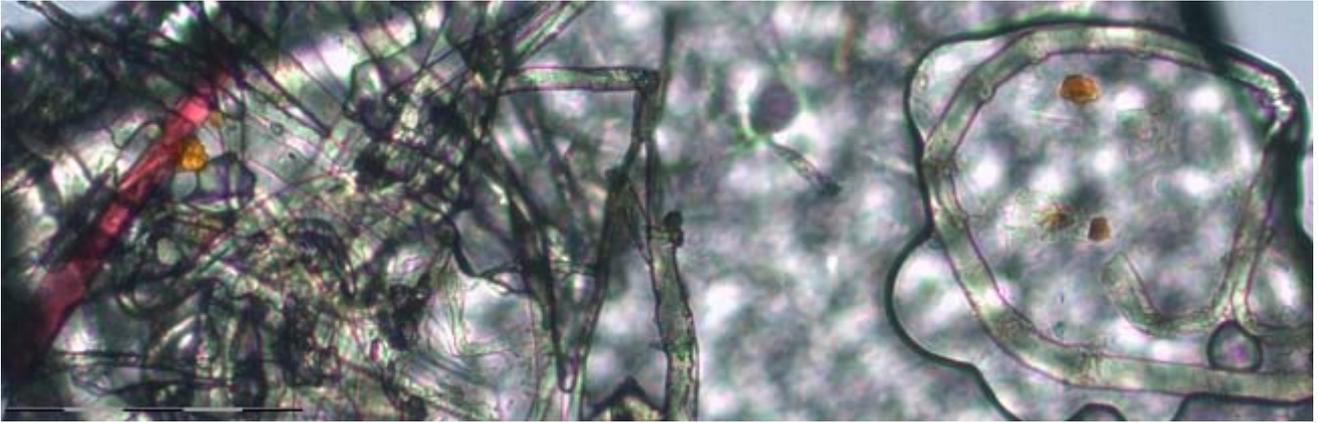
Fig 32 The same part of the fiber seen in *pc* (above) and *p* (below). The border of the layer is indicated by arrows; scale bar 50 $\mu$ m

**#20) fibers and particles in “e” sticky tape from “i” filter, 1988**

A 3 x 0,5-0,75 mm long sticky tape containing fibers and particles of different thickness and morphology.

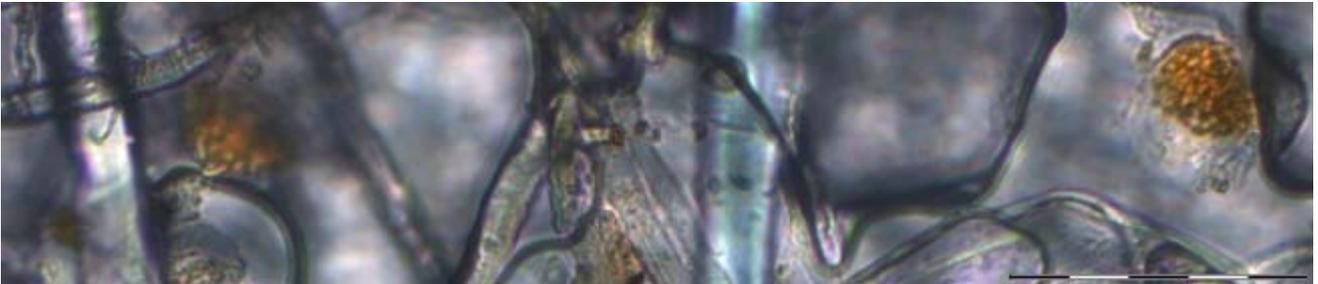
In bright field part of a red fiber is located in upper left corner and a paler one in the centre of the tape. This fiber may origin from the red fabric that covered the Shroud, when it was rolled up.

The flax fibers of different magnitude are spread over the tape, for example in the upper right corner of the tape. This fiber in a loop encircles brown-yellow particles. The particles of different shape and magnitude are also found disseminated down half the length of the tape.



*Fig 33 Left: red fiber with brown particle. Right Flax fiber loop encircling brown particles; bf, scale bar 100µm*

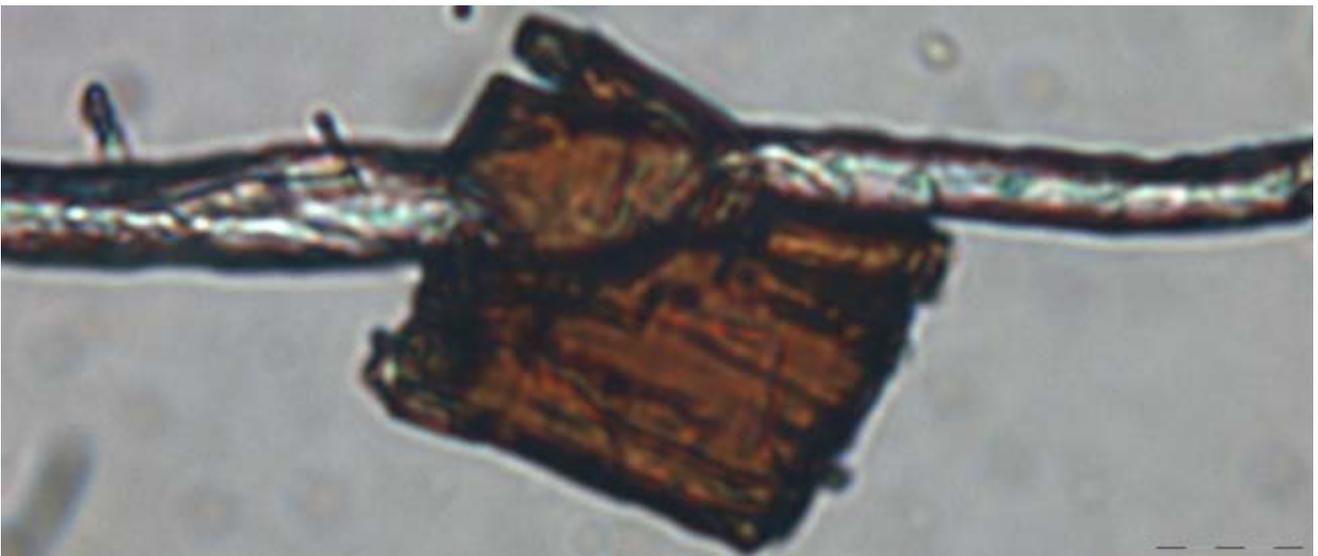
A bluish fiber running through half of the tape being paler from upwards and downwards might be a fiber from the blue satin border, removed in 1998 by Mechthild Flury-Lemberg before the 1998 Expo.



*Fig 34 Brown particles spread over the image. A blue fiber crossing the centre of the image; bf, scale bar 50µm*

**#21) TS linen fiber with a dark-red particle (blood?) coming from “h” filter, Buttocks Area, 1978**

Thin flax fiber. In the middle of the fiber adheres a rectangular brown-red particle estimated by The Department of Forensic Genetics to be part of a plant fiber. This was confirmed by LGT and diagnosed as a piece of bark from the flax stem.



*Fig 35 Flax fiber with a piece of bark from the flax stem; bf, scale bar 20µm*

**#22) Dark red (blood?) particle with mildew (?) coming from “h” filter, Buttocks Area, 1978**

A ball made of 1µm small “threads”, which are not plant fibres (LGT).<sup>11</sup> Inside and intertwined with this ball of threads a lightening of rusty coloured mass, which judged by The Department of Forensic Genetics might be blood. There is probably enough material to test for haemoglobin and subsequently make a STR-profile (DNA-profile).

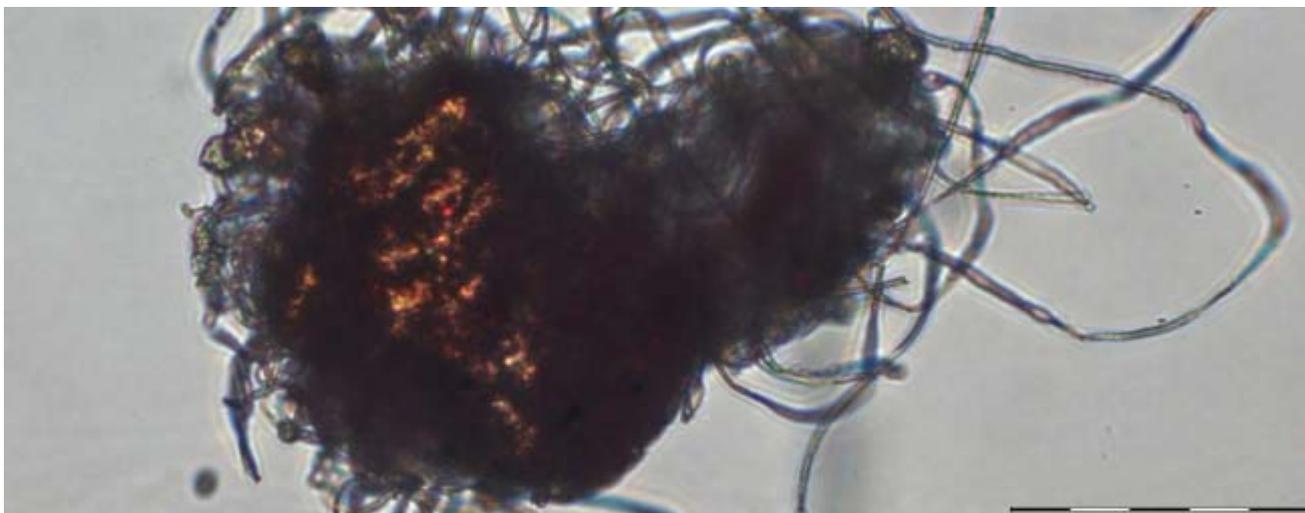


Fig 36 “Red mass”, probably blood, partly hidden in a ball of unknown threadlike structures; bf, scale bar 50µm



Fig 39a Same as above, but with different lighting for better discerning “the red mass”, now black – useful area for Raman; bf, red square: 50 x 50µm . Courtesy of L.G. Thygesen

**#23) TS fiber and dark-red (blood?) particle coming from “h” filter, Buttocks Area, 1978**

Small, 0,5mm frayed flax fiber. In the middle adheres a purple-red particle. The particle is too red to be blood (Department of Forensic Genetics).

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<sup>11</sup> Lisbeth G. Thygesen has made preliminary confocal laser scanning microscopy (CLSM) on this object. Interpretation of data is not finished.

Likewise the image of the “threads” has been scrutinized by Department of Mycology, “Statens Serum Institut, Copenhagen. No one from this department wishes to make statements if not allowed to microscope the sample directly. Fungi cannot be excluded.



Fig 37 Bright red particle of unknown origin; bf, scale bar 50 $\mu$ m

**#24) Body fluids (?) particles coming from TS sample F15001**

A gray-brown, polymorph particle, which is not of human origin (Department of Forensic Genetics).

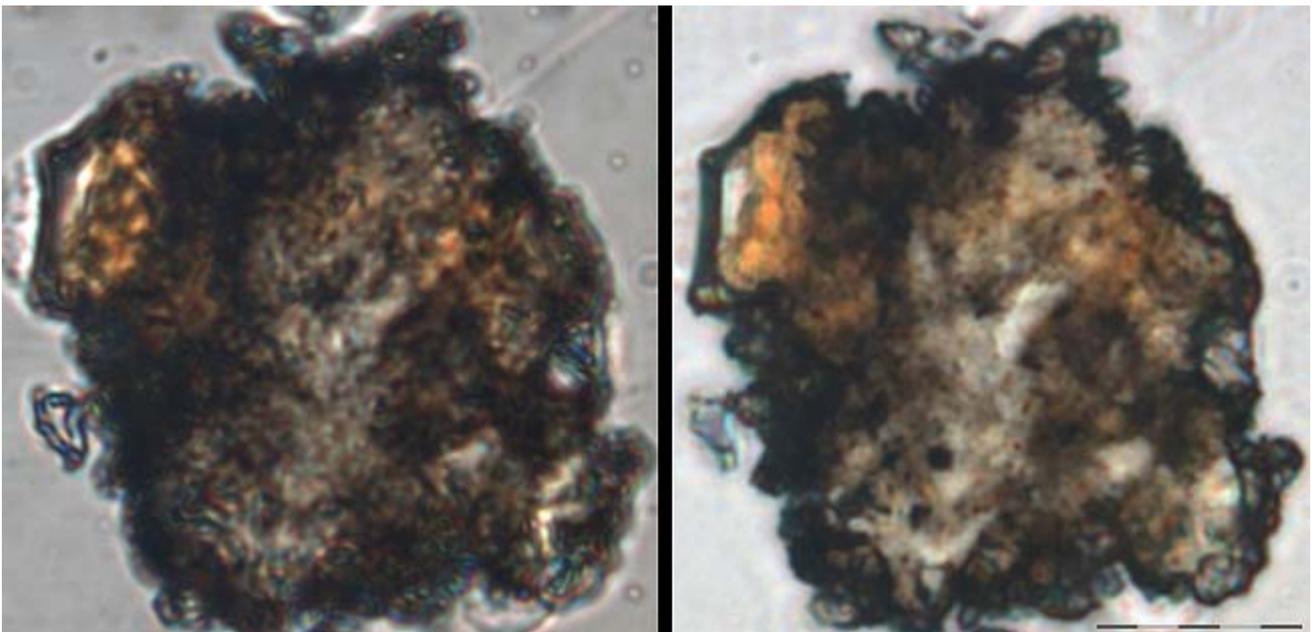


Fig 38 Polymorph particle seen in bf left and pc right; scale bar 20 $\mu$ m

**#25) Linen fibers also from TS and particles coming from “h” filter, Buttocks Area, 1978**

A sample consisting of particles and several fibers of different origin, i.e. one cotton and several flax fibers. Fibers of interest are mentioned below.

In the upper right corner of the image there is a thick, frayed flax fragment. Bundles of fibrils are visible, one sticking out upper right of the main fiber.

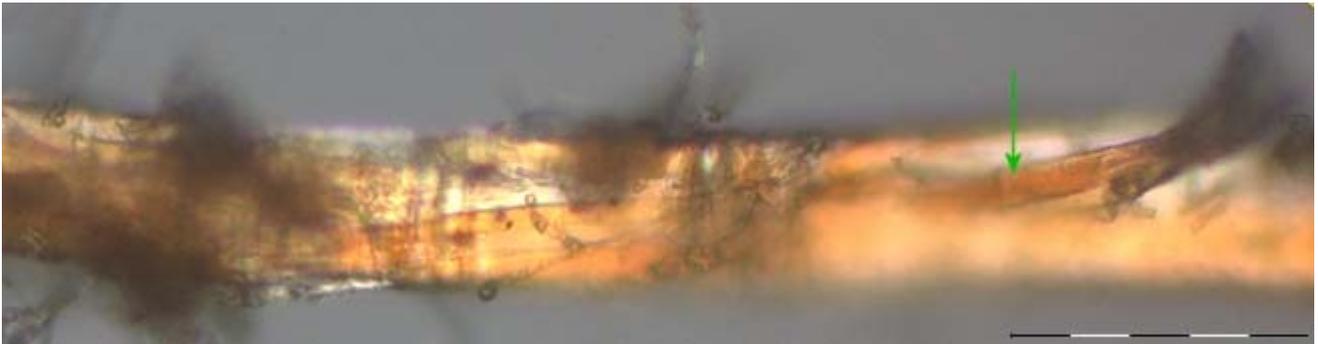


Fig 39 Fibril “on its way up” from the main fiber to the right (arrow) and embedded to the left; p, scale bar 50 $\mu$ m

Brown coloured flax fragment, quite different from fiber types presumably artificially coloured.

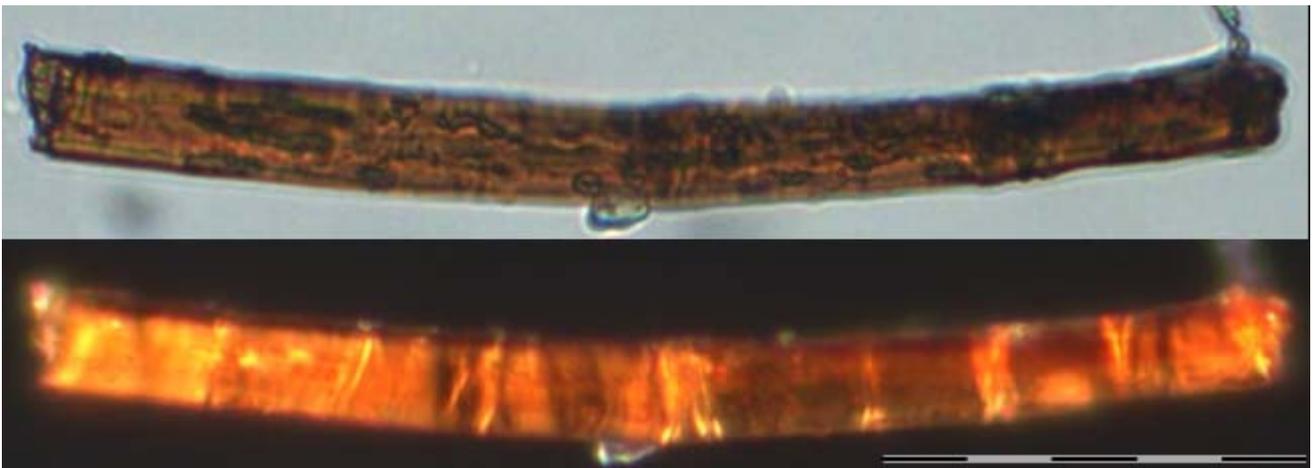


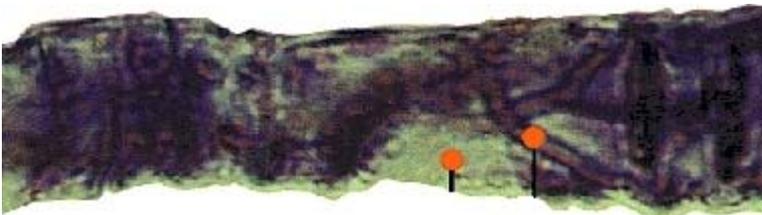
Fig 40 Brown coloured flax fragment, top: bf, bottom: p; scale bar 50 $\mu$ m

In the lower left corner of the image a linen fiber with fracture and a snake/cobblestone-like layer is observed. This layer is similar to the layers, which by some researchers have been interpreted as a “biocoating”, i.e. a mix of fungi and bacteria called “Lichenotelia”.<sup>12</sup> On hemp fibers - which can be compared to flax - LGT has sometimes seen approximately similar layers estimated to be pectin. But in this case it is impossible to rule out traces of biologic activity (fungi and/or bacteria).

<sup>12</sup> Cf. Leoncio Garza-Valdes’ and Stephen Mattingly’s interpretation in *The Turin Shroud, the Illustrated Evidence*, pp 95-103.



*Fig 41 Surface layer of a flax fiber. Note the snake-like structure and compare it to fig 45, bf; scale bar 20 $\mu$ m*



*Fig 42 The image shows Stephen Mattingly' and Garza-Valdes' "biocoating"*

### **Addendum**

It has been postulated that one of the characteristics of the linen under the blood stains of the Shroud was the fact, that no fiber has been broken. Breaking of fibers would happen, if the Shroud had been removed from the body as a consequence of blood adhering to the skin and fibers. This postulate presupposes that all fibers on the Shroud are intact, but they are not in the present sample areas. Several fractured fibers have been detected from the different macroscopic sample areas.