Forensic Fiber Examinations

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1 INTRODUCTION

This document describes the procedures for the microscopic examination, identification, and comparison of fiber evidence as well as the acceptance criteria and conclusions that can be reached. The procedures apply to fiber samples that have been previously removed from evidentiary items and have been mounted on glass microscope slides.

This document specifies the procedures for the typical examinations performed on fiber evidence. The case scenario or contributor request(s) may result in a different examination approach. In those instances, information will be recorded in the case notes stating which examinations will be performed or omitted (e.g., evidence will only be examined for carpet type fibers), as well as the rationale for the different examination approach (e.g., case scenario, contributor request.) The rationale will be recorded in the case notes or state where that information is recorded (e.g., incoming communication, communication log.)

2 SCOPE

This document applies to Examiners in the Trace Evidence Unit (TEU) and Chemistry Unit (CU) that conduct fiber examinations in the Hairs and Fibers discipline.

3 EQUIPMENT

- Comparison microscope, magnification range approximately 40x to 600x
- Polarized light microscope, magnification range approximately 40x to 400x, with eyepiece reticle
- Fluorescence microscope, four filter combinations encompassing Ultraviolet (UV), Violet, Blue, and Green wavelength regions
- Stereobinocular microscope, magnification range approximately 2x to 40x
- Microspectrophotometer (MSP): Craic MSP 121, Craic QDI 2010 or equivalent
- Fourier Transform Infrared (FT-IR) Spectrometer with microscope attachment: Nicolet 6700 Continuμm, Nicolet is50, or equivalent
- Diamond compression cell
- Xylene substitute, Xyless, or Xylene®
- Glass microscope slide(s) and cover slip(s)
- Quartz microscope slide(s) and cover slip(s)
- Glycerin
- Ethanol
- Permount® mounting medium
- Microscope camera
- Probe, scalpel, forceps
- Berek compensator (or equivalent compensator such as a sliding wedge)
- Full wave (lambda) plate

4 SAMPLING

A. Individual fibers are selected from the specimen at the discretion of the Examiner.

1. These individual fibers may not necessarily be representative of all fibers from the specimen.
2. Fibers may be chosen based on the need to identify a particular component by a specific technique and by its availability or presence in a specimen.
3. If multiple fibers exhibiting the same microscopic characteristics have been identified from the same questioned specimen, a minimum of five (if available) will be selected for further examination and comparison of the optical properties and microspectrophotometry, as appropriate.
    i. At a minimum, one fiber will be selected for FT-IR, if appropriate.

5 PROCEDURE – DOCUMENTATION

A. The presence or absence of fibers can be determined based on a microscopic examination of the glass microscope slide(s) containing debris. The absence of fibers will be recorded in the case notes with a statement such as "no fibers were found" or the absence of any reference to fibers on an item implies no fibers are present.
B. If fibers are present, they can be identified individually or collectively at the discretion of the Examiner. At a minimum, a general statement regarding the presence of fibers will be recorded in the case notes.
C. If fiber examinations are not conducted for items of evidence, statements such as "no fiber exams" or "hair exams only" will be used as documentation in the case notes.

6 PROCEDURE – FIBER COMPARISON

A. The fiber samples will be compared at the same time in the same field-of-view utilizing the comparison microscope.
B. If a comparison of fibers will be conducted, questioned fiber(s) will be examined to determine suitability prior to the comparison to one or more known samples.
    1. This does not preclude the ability to preliminarily characterize the known fiber sample(s) prior to the assessment of the questioned fibers to identify questioned fibers that will undergo further examination and/or comparison (ex. target search).
C. If the microscopic characteristics including general size, shape, configuration, and color of the fibers are the same utilizing the comparison microscope, the optical properties of the fibers may be analyzed and compared using polarized light microscopy and fluorescence microscopy. Some of these characteristics apply only to manufactured fibers and are identified below. If an unexplainable difference is found for any of these characteristics listed below, the comparison process will cease, and the fibers cannot be associated to each other. This information will be recorded on the Fiber Chart. The general classification of manufactured fibers can usually be determined based on the optical properties of the fiber. Natural fiber type can usually be determined based on the microscopic characteristics of the fiber.
    - Fiber Color
        - The fiber color may be uniform or may vary along the length of the fiber. Record the color and any apparent variation in the color, if

present. This characteristic applies to both natural and manufactured fibers.

- Fiber Luster
  - The presence, absence, and relative abundance of delustrant present in manufactured fibers will be recorded. This characteristic applies only to manufactured fibers.
- Fiber Cross-Section
  - Record the apparent cross-sectional shape of the fiber. This can be conducted via optical cross-sectioning or by physically cross-sectioning the fiber. This characteristic typically only applies to manufactured fibers, although it may be useful in the identification of certain types of natural fibers.
- Fiber Diameter
  - The approximate diameter of fibers can be measured using an eyepiece reticle. If fiber diameter is variable within a sample, documentation of the diameter range is recommended. This characteristic typically only applies to manufactured fibers.
- Other Characteristics
  - Record any surface damage, manufacturing striations, or other characteristics noted in the sample.
- Becke Line
  - The determination of n-parallel and n-perpendicular relative to Permount® based on the direction of movement of the Becke line in relation to the fiber using plane polarized light. This characteristic typically only applies to manufactured fibers.
- Retardation (Path Difference)
  - The retardation will be determined through the use of a Berek compensator (or equivalent). This characteristic typically only applies to manufactured fibers.
- Birefringence
  - The birefringence can be estimated by dividing the retardation by the diameter of the fiber. A full-wave plate may be used to help determine the sign of elongation. This characteristic typically only applies to manufactured fibers.
- Pleochroism (Dichroism)
  - The presence and/or degree of pleochroism present in a sample will be recorded. This characteristic applies to both natural and manufactured fibers.
- Fluorescence
  - At each of the four excitation wavelengths (Ultraviolet, Violet, Blue, and Green) the color and intensity or the absence of fluorescent emission will be recorded. This characteristic applies to both natural and manufactured fibers.

D. Other techniques
    - Other identification and comparison techniques such as micro-solubility examinations or drying twist test may be used as deemed appropriate by the Examiner. The technique used and the results will be recorded in the case notes.

7 PROCEDURE – MICROSPECTROPHOTOMETRIC ANALYSIS

If fibers exhibit the same microscopic characteristics and optical properties utilizing the characteristics listed above, they may be compared using microspectrophotometry. Colored fibers will be analyzed in the visible (380nm-800nm) region. When information in the visible region is limited, or at the discretion of the Examiner, fibers may be analyzed in the ultraviolet (240nm-380nm) region.

7.1 Sample Spectra Collection – Visible Region

A. The following procedure is applicable to the Craic QDI 2010, Craic MSP 121, J&M TIDAS S 800 or equivalent microspectrophotometers.
    1. Set the instrument parameters to include analysis in the visible region (380nm – 800nm).
    2. Focus on the sample slide with the collection aperture adjacent to the fiber to be analyzed. Ensure the best integration time for scanning is set.
    3. Collect a Dark Scan.
    4. Collect a Reference Scan. Note: A new Reference Scan must be collected if the stage is moved more than one field-of-view away from the position of the last Reference Scan, a new sample slide is introduced, or if changes are made to the optical settings (e.g., new objective, source intensity, Köhler illumination).
    5. Move the fiber to be analyzed under the collection aperture. Collect a Sample Scan.
        i. Fibers should be scanned in the same orientation for comparison.
    6. Collect at least five (5) spectra from each manufactured fiber sample to be compared. Collect at least ten (10) spectra from each natural fiber sample to be compared.
    7. Save the results in an appropriate electronic folder.
    8. The Examiner may compare a single spectrum which best represents the samples collected or a mean spectrum of all the samples collected. Similar types must be compared (single spectrum compared to single spectrum or mean spectrum compared to mean spectrum). If spectra containing the mean are printed or saved electronically, the word “mean,” or the letters “mn,” must be part of the text describing the spectra.
    9. For Legacy cases, all of the spectra generated will be printed and included in the case notes. In the event of large numbers of spectra, instead of printing the spectra, a CD may be burned with the data for inclusion in the case notes. For Forensic Advantage (FA) cases, the spectra will be imported into the Case Record Object Repository. Spectra must include the FBI Laboratory

number(s), specimen number(s), the date of collection, and the operator's initials.

7.2 Sample Spectra Collection – Ultraviolet Region

A. The following procedure is applicable to the Craic QDI 2010, Craic MSP 121, and, J&M TIDAS S 800 or equivalent microspectrophotometers.
    1. Remove the fiber from the glass microscope slide, remount the fiber on a quartz microscope slide, and cover it with a quartz cover slip using glycerin as the mounting medium.
    2. Set the instrument parameters to include analysis in the ultraviolet region (240 nm - 380 nm).
    3. Focus on the sample slide with the collection aperture adjacent to the fiber to be analyzed. Ensure the best integration time for scanning is set.
    4. Collect a Dark Scan.
    5. Collect a Reference Scan. Note: A new Reference Scan must be collected if the stage is moved more than one field-of-view away from the position of the last Reference Scan, a new sample slide is introduced, or if changes are made to the optical settings (e.g., new objective, source intensity, Köhler illumination).
    6. Move the fiber to be analyzed under the collection aperture. Collect a Sample Scan.
        i. Fibers should be scanned in the same orientation for comparison.
    7. Collect at least five (5) spectra from each manufactured fiber sample to be compared. Collect at least ten (10) spectra from each natural fiber sample to be compared.
    8. Save the results in an appropriate electronic folder.
    9. The Examiner may compare a single spectrum which best represents the samples collected or a mean spectrum of all the samples collected. Similar types must be compared (single spectrum compared to single spectrum or mean spectrum compared to mean spectrum). If spectra containing the mean are printed or saved electronically, the word "mean," or the letters "mn," must be part of the text describing the spectra.
    10. For Legacy cases, all of the spectra generated will be printed and included in the case notes. In the event of large numbers of spectra, instead of printing the spectra, a CD may be burned with the data for inclusion in the case notes. For FA cases, the spectra will be imported into the Case Record Object Repository. Spectra must include the FBI Laboratory number(s), specimen number(s), the date of collection, and the operator's initials.

7.3 Comparison Criteria

A. Compare sample spectra within each region to determine if differences can be observed.
B. Adjust the absorbance and wavelength scaling so each spectrum can be analyzed in its entirety.

C. The position of the peak maxima, peak minima, peak width, and peak slope must all be considered.
D. Fiber samples are consistent in their microspectrophotometry spectra when no unexplainable differences are found.

8 FT-IR Analysis

If manufactured fibers exhibit the same microscopic characteristics and optical properties and color by MSP analysis (if appropriate), fiber samples may be analyzed utilizing FT-IR. One fiber per evidentiary item will be analyzed when applicable. The analysis involves two steps: a comparison of the known and/or questioned fibers to one another and an identification of the polymeric material. Natural fibers are not typically analyzed utilizing FT-IR.

8.1 Sample Analysis

A. Remove a portion of the fiber, place it on a diamond compression cell (or equivalent), and compress it. Remove one window and place the remaining window and compressed fiber on the microscope stage. If flattening the fiber using a diamond compression cell is not appropriate, alternative sample preparation techniques may be used at the discretion of the Examiner. The sample preparation technique used will be recorded in the case notes.
B. Collect the sample spectrum followed by a background spectrum. Save the results in an appropriate electronic folder and print the spectrum for Legacy cases. Repeat for additional samples.
C. The remaining fiber may be dry-mounted on a glass microscope slide with a glass cover slip, or it may be mounted using Permount® mounting medium and a glass cover slip.

8.2 Sample Identification

The instrumental reference library may be used for polymeric identification of a fiber. When polymeric identification of a fiber is made, a copy of the library spectrum will be included in the case notes.

8.3 Comparison Criteria

A. Compare sample spectra within each region to determine if differences can be observed. Using the software, overlay the spectra to be compared. Adjust the transmittance and wavenumber scaling so that each spectrum can be analyzed in its entirety. The presence and position of all absorption peaks must be considered.
B. Two samples are consistent in their infrared spectra when no unexplainable differences are found.
C. Include a copy of the fiber spectra in the case notes.

9 Procedure – Fiber Conclusions

A. If the fiber samples exhibit the same microscopic characteristics and optical properties utilizing the appropriate techniques outlined below, it can be concluded that the fibers are consistent with originating from the same source, or another

source comprised of fibers that exhibit the same microscopic characteristics and optical properties. A notation will be placed in the relevant portion of the case notes recording this fiber association.

B. For manufactured fibers, comparison microscopy, polarized light microscopy, fluorescence microscopy, microspectrophotometry, and FT-IR (on one fiber per evidentiary item) will be conducted when applicable.
C. For natural fibers, comparison microscopy, polarized light microscopy, fluorescence microscopy and microspectrophotometry will be conducted when applicable.
D. If an unexplainable difference is observed between the fiber samples, it can be concluded that the fibers are not consistent with originating from the same source. This information will be recorded in the relevant portion of the case notes.
E. If there are insufficient microscopic characteristics or optical properties to determine whether or not the fibers are consistent with originating from the same source, the Examiner may determine that no conclusion can be reached. This information will be recorded in an appropriate place in the case notes.
F. If no fiber associations are found in a case, a summary statement may be made in the case notes recording this. This is left to the discretion of the Examiner.
G. Fibers may be identified as to their type (e.g., "The debris recovered from the tape is an acrylic fiber."). When fiber types are reported, all appropriate analytical techniques used to make a fiber identification must be performed and recorded and the identification must be verified by a second qualified Examiner. In rare instances, it may not be possible to fully characterize a particular fiber. When reporting fiber identifications without full characterization, the Examiner will state the possible fiber identity (e.g., "an acrylic-like fiber") and provide a reason why full characterization was not conducted.

10 FIBER VERIFICATION

A. Fiber associations and/or identifications which are reported are verified by a second qualified Examiner.
B. A fiber verification encompasses an examination of the microscopic characteristics and optical properties of a fiber obtained using comparison microscopy, polarized light microscopy, and fluorescence microscopy to include any calculations performed, and a review of all data produced using microspectrophotometry and infrared spectroscopy.
C. These verifications are recorded by the signature of the verifying Examiner and the date of the verification on the Verification Form or in FA.

11 CALCULATIONS

$$\text{Birefringence} = \frac{\text{Retardation (nm)}}{\text{Fiber Thickness (nm)}}$$

12 LIMITATIONS

Fibers cannot be identified as originating from a particular source to the exclusion of all other possible sources comprised of fibers which exhibit the same microscopic characteristics and optical properties.

13 REVISION HISTORY

Revision	Issued	Changes
06	01/28/2022	Reformatted entire document and updated references throughout. Added CU Examiners to the Scope. Updated Sampling section. Added that fibers need to be run in same orientation for MSP comparison and reference to the J&M TIDAS S 800.
07	08/15/2024	Removed SBAU references