2020-10-13-DeepPIV-Fiber-Optic-Assembly-Report-Final-DK.docx
Project: 901809.00 DeepPIV/ Deep Sea Bioinspiration
Author: Denis Klimov (EE) with input from Aaron Schnittger
Rev(10/13/2020): initial release

Deep PIV Fiber Optic Assembly Report

Description of issue:

- DeepPIV fiber optic assembly (**drawing [10]**) leaked in December 2018 under pressure during deployment ~ 600m depth. Several milliliters of oil intrusion into pressure housing were observed. In subsequent testing in the pressure chamber on shore, it was found that most assemblies are leaking at the rate of about milliliters in several hours. Denis Klimov and Aaron Schnittger were tasked with figuring out why it leaked and mitigate the issue.

Project progression:

- Fiber optic penetrators were a suspected part since the assemblies would leak at about the same rate, and observed leaking both sides of assembly suggesting a systematic issue rather than random (such as faulty O-rings). Subsequently, several fiber optic penetrators were sectioned and it was confirmed that the gaps between epoxy and the steel part of penetrator allowed water intrusion. Presence and size of the gaps would also explain a consistent rate of water intrusion (**Sectioning Report [1]**)
- Since epoxy shrinkage was suspected to be a reason for appearance of gaps, drastic reduction of the epoxy thickness was considered. For instance, by using a glass tube to reduce the volume of the epoxy. Prototype of such design, consisting of two penetrators and fiber bundles connecting them, was ordered from Coastal Connections (Ventura CA) and tested under pressure (**Prototype Test [2]**). It, however, leaked, and was subsequently sectioned revealing multiple issues with structure of epoxy fill (**Sectioning Report [3]**)
- The team therefore returned to the original design of the penetrator, and the following paths were considered:
    - Reducing the size (diameter) of the epoxy fill from 0.610" to 0.400" (**Drawings [11], [12]**)
    - Improving adhesion of epoxy to the stainless steel penetrator, and to the optical fibers.
- Tests on adhesion of epoxy to optical fibers with various surface preparations and treatments were conducted (**report Yellow SMF-28 fiber [4]**)
- Tests on adhesion of epoxy to stainless steel were conducted and it was determined that acid etching was crucial (see reports for comparing different treatments of the stainless steel including mechanical honing and acid etching **[5]** and by etching time **[6])**
- Team proceeded with etching stainless steel parts, which by itself required overcoming several obstacles:
    - Figuring out how much etching is sufficient; how often reagent (acid) would need to be replaced;
    - How to shield surfaces that do not be affected by acid, such as O-ring surfaces and outer surface;
    - Sometimes parts would exhibit rusting on the inside, acid neutralizing step was added
    - How to process batches of parts, and follow appropriate safety procedures
    - Final procedure described in **Etching Report [8]**
- Further tests with etched penetrators revealed hard epoxy fills still leaking. Tests using clear acrylic penetrators were conducted, confirming epoxy shrinkage to be a reason for pulling off the internal surface of the penetrator model creating air gap. Second layer of soft rubbery compound was added and tested (**Acrylic Cylinder test [7]**)
- Final configuration was devised with two-part fills and strain relieve tubing, with two assembly successfully tested under pressure. Concept configuration is shown on (**Fig 1**) and assembly procedure described in report **[9]**

References

1. 2019-03-13-Penetrator-Sectioning-Report.pdf (11 pages)
2. 2019-04-16-Prototype-Test-2 (18 pages)
3. 2019-05-01-Prototype-Sectioning-Report-10 (16 pages)
4. 2019-06-05-Yellow-SMF-28-Fiber-Comparison-2 (10 pages)
5. 2019-06-07-Stainless-Steel-316-Adhesion-1 (8 pages)
6. 2019-06-19-Stainless-Steel-316-Adhesion-by-Time-2 (10 pages)
7. 2019-10-01-Acrylic-Cylinder-test (3 pages)
8. 2020-03-04-Etching-Report (13 pages)
9. 2020-10-12-OF cables for Deep PIV – DK (11 pages)
10. A-201954-17.SHT4.pdf (1 page drawing)
11. P-1002444-18_FbrOptPlg.Rev.A (1 page drawing)
12. P-1002444-18_FbrOptPlg.Rev.B (1 page drawing)

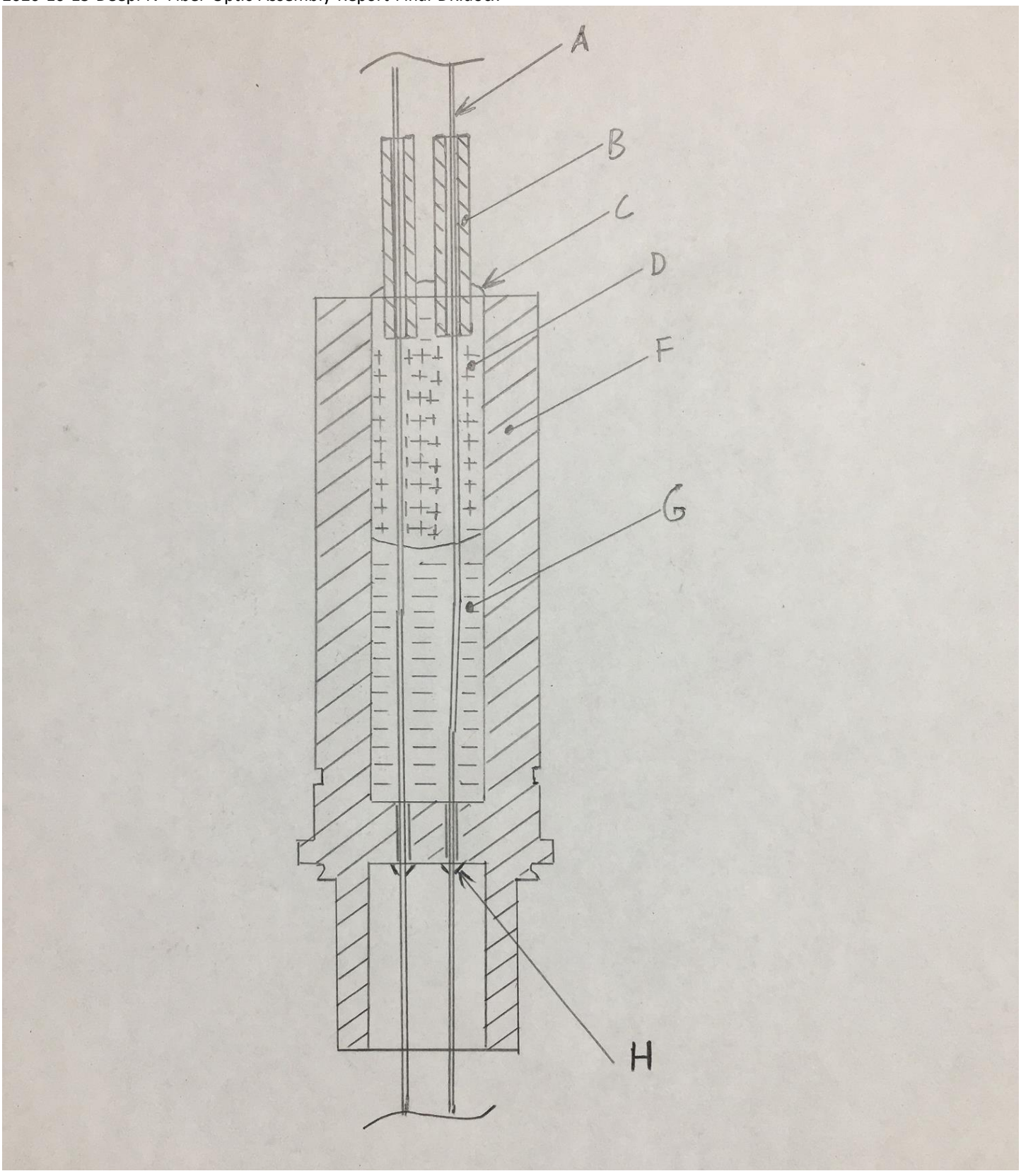

Fig 1: Schematic diagram of Fiber Optic Penetrator potting assembly
A: Optical fibers, cleaned with acetone (x2)
B: Strain tubing 1.25”, abraded, cleaned with acetone, potted length 0.25” (2x)
C, D: Soft (rubbery) potting compound (Devcon Flexane 80 Liquid 15800)
F: Stainless Steel Penetrator (drawing FIBER OPTIC CABLE PLUG; P-1002444-18), acid etched, acetone cleaned
G, H: Hard two part epoxy-Loctite E-60NC

2019-03-13-Penetrator-Sectioning-Report.docx

Project: 901809.00 DeepPIV/ Deep Sea Bioinspiration

Author: Denis Klimov (EE) (sectioning), with input from Aaron Schnittger (MT); (potting; pressure testing).
Penetrator design: Jon Erickson (ME)

Description of issue:

- DeepPIV fiber optic assembly leaked in December 2018 under pressure during deployment ~ 600m depth. Several milliliters of oil intrusion into pressure housing were observed. In subsequent testing in the pressure chamber on shore, it was found that some test assemblies are leaking, and some do not.

Design:

- The integrity of the fiber optic assembly against water intrusion is provided by "Penetrator" which is a stainless steel tube with O-ring seal to underwater connector; with optical fibers potted inside of the tube (Fig 1.)
- The fiber specifications: 4 ea of SMF-28; 1550nm SM Fiber; 9 um core; 900 um PVC jacket
- Penetrator dimensions:
  - Full length 2.65 inch x Full OD 0.875 inch
  - Tube OD 0.785 inch x Tube ID: 0.605 inch
- Potting specifications:
  - Hard epoxy (applied first); diameter 0.605" x ~ 0.9" long:
    - Lok-Tite E-30CL Hysol Epoxy
    - Nominal pot life 30 min. Actual ~ 1 hour (longer than nominal).
  - Soft epoxy (applied second); diameter 0.605 x ~ 0.65" long;
    - Lok-Tite E-05CL Hysol Epoxy
    - Nominal pot life 30 min. Actual ~ 0.5 hours.

Test samples of sectioned penetrators:

- Sample 1 (Fig 1.) DID NOT leak during pressure testing. Difference from Sample 2 highlighted in YELLOW
  - New penetrator tube used for potting process
  - Fiber was fixed to the bottom of the tube using green modeling clay
  - Tube was cleaned with acetone
  - Fiber was cleaner with denatured alcohol
  - Both Epoxies were de-gassed in the vacuum chamber at ~ 30" mercury vacuum for 5-10 minutes
  - Epoxies application at atmospheric pressure. Paying attention to removal of air bubbles
  - Cure time between applications of hard and soft epoxy: overnight (at room temperature)
  - Cure time before applying pressure: ~ 5 days at room temperature.
  - Application and curing location: Lab B138
  - Hydraulic oil used for pressure testing: 30W Chevron
  - Pressure test specs: 5800 PSI; 10 cycles at 500 PSI/ minute ramp-up and down; final cycle held at 5800 PSI for 1 hour
  - Sectioning: Isomet 5000 diamond saw; Isocut Plus 11-2293-016 cutting fluid mix 1:9 to RO water ratio; diamond blade 5"x0.015" (Fig 9,10)
- Sample 2 (Fig 2.). DID leak during pressure testing. Difference from Sample 1 highlighted in yellow
  - Stainless steel tube was reused from previously potted penetrator. Old potting material scraped from the tube, and tube was bead-blasted using glass media
  - Fiber was fixed to the bottom of the tube using red modeling clay in order to prevent epoxy leakage during potting process
  - Tube was cleaned with acetone
  - Fiber was cleaner with denatured alcohol
  - Both Epoxies were de-gassed in the vacuum chamber at ~ 30" mercury vacuum for 5-10 minutes
  - Epoxies application at atmospheric pressure. Paying attention to removal of air bubbles
  - Cure time between applications of hard and soft epoxy: overnight (at room temperature)
  - Cure time before applying pressure: ~ 2 days at room temperature.
  - Application and curing location: Lab B138
  - Hydraulic oil used for pressure testing: 15W Royal Purple
  - Pressure test specs: 5800 PSI; 10 cycles at 1000 PSI/ minute ramp-up and down; final cycle held at 5800 PSI for 1 hour
  - Sectioning: Isomet 5000 diamond saw; Isocut Plus 11-2293-016 cutting fluid mix 1:9 to RO water ratio; diamond blade 6"x0.025" (Fig 9,10)# #

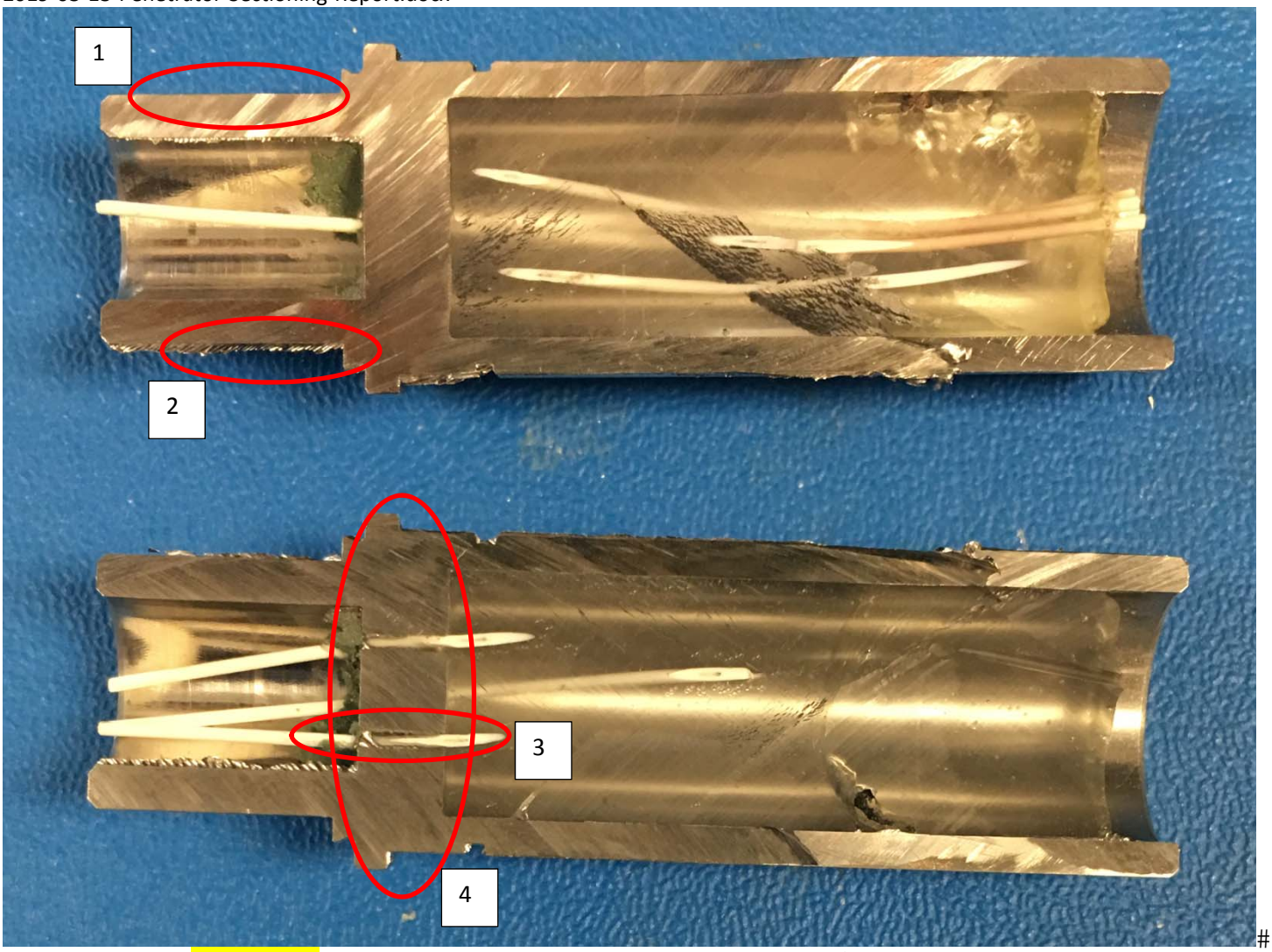

Fig 1. (Sample 1). Did not leak under pressure. Note the difference in presence/ absence of burrs on the edge depending on the blade transition from air to steel or steel to air (Illustration circles 1,2). Bottom of the penetrator has thick base designed to withstand the water pressure up to ~ 1000 meters (Illustration circle 4). Base has 4 small (0.040”-0.062”) holes designed for passing individual fibers (Illustration circle 3).

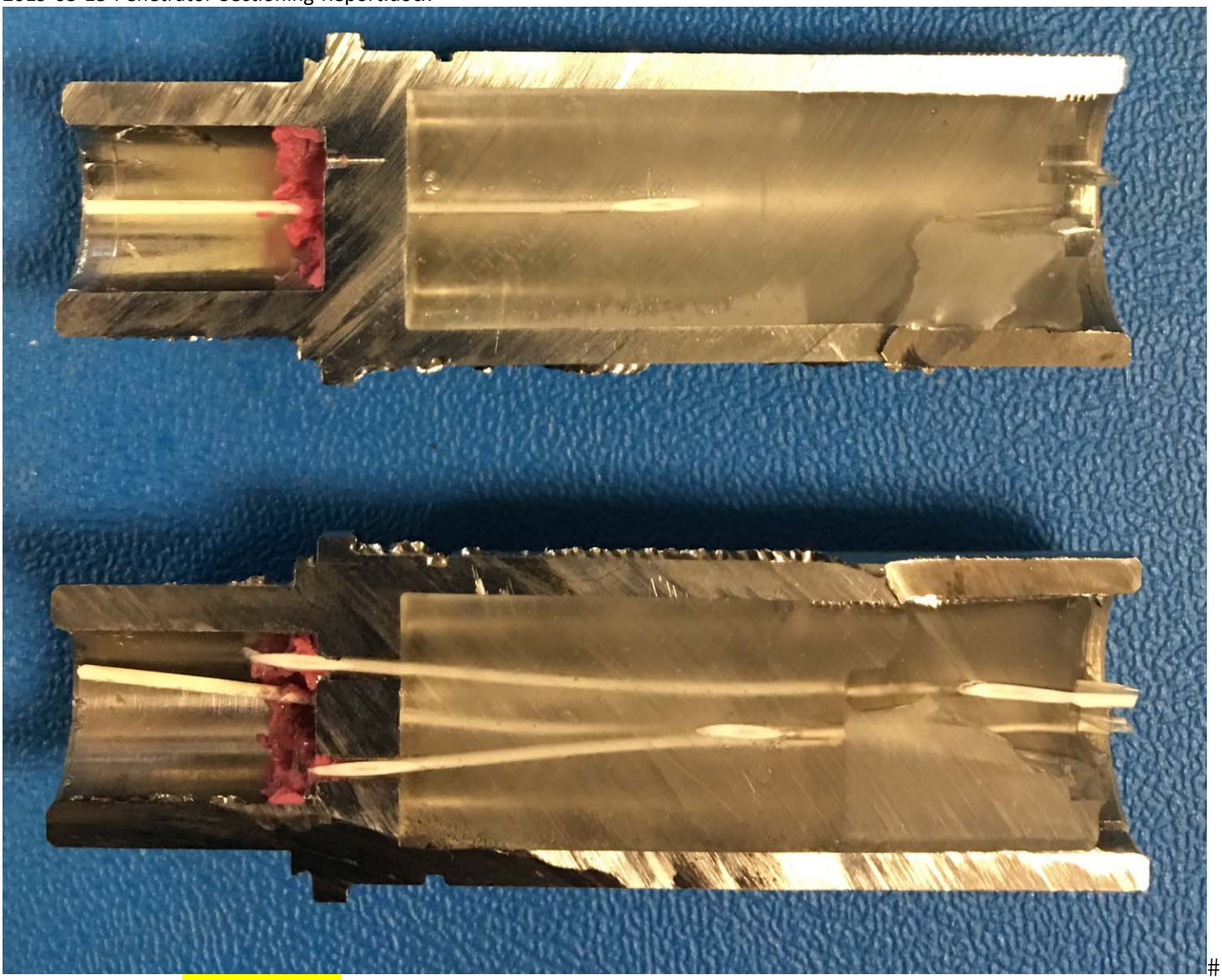 #

Fig 2. (Sample 2). Developed leak under pressure.#

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Fig 3. (Sample 1). No perceived gap between epoxy and optical fiber. Fiber can be pulled out by force, but some level of adhesion is present. No signs of liquids in the gap(s). (Illustration circle 1)#

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Fig 4. (Sample 1). There seems to be gap visible between the epoxy and the penetrator tube thru most of potting perimeter (illustration circles 1, 2). It is not clear if the gap is an artefact of cutting process or was it present before cutting. The argument against artefact is that the gap looks the same on top and bottom part of the picture irrespectively of blade transition from epoxy to steel or steel to epoxy (Illustration circles 3, 4) as compared to transition from steel to air and air to steel visible on Fig 1.

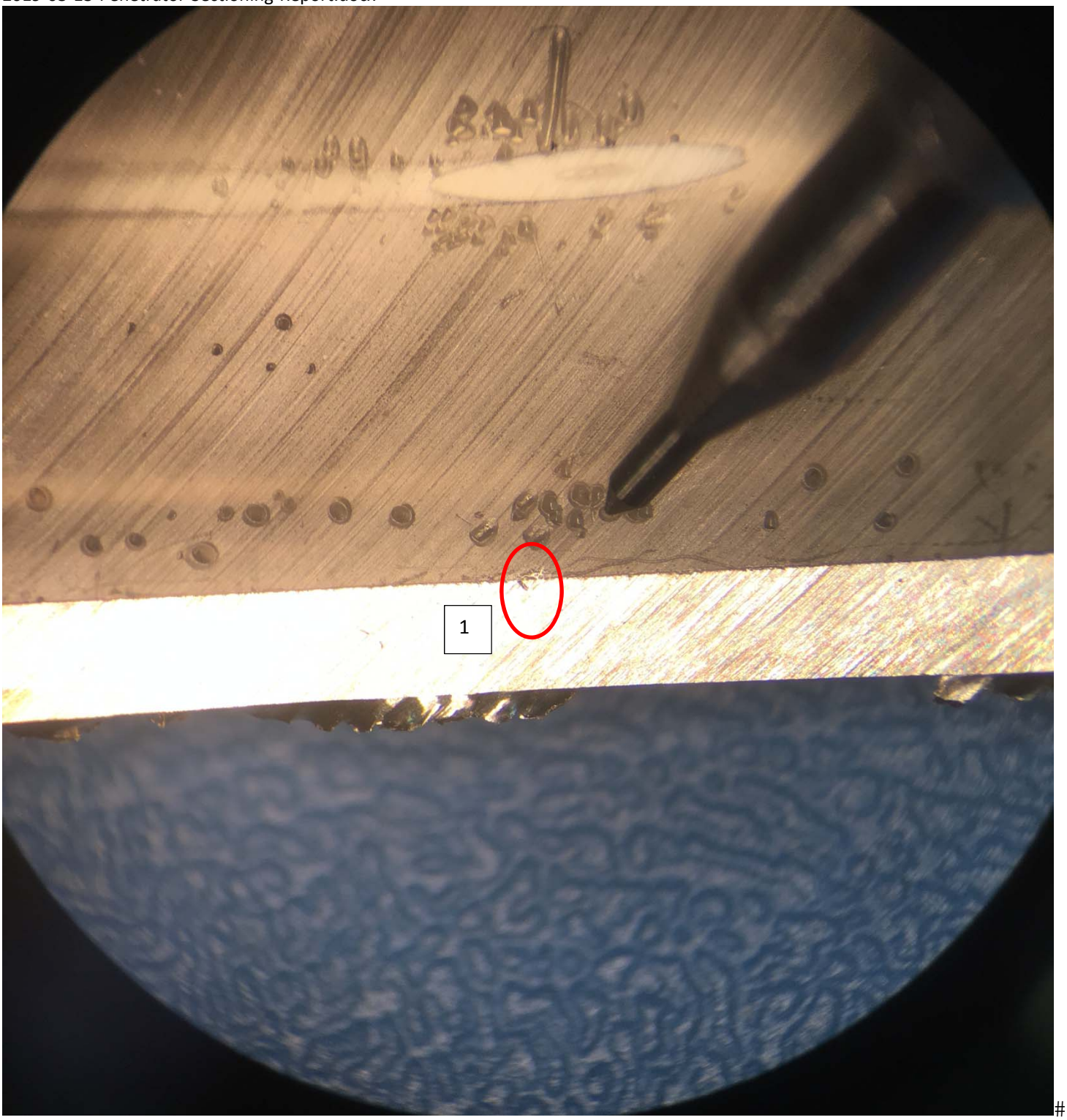

Fig 5. (Sample 2). There seems to be liquid present between the epoxy and the penetrator tube. When pressed with probing tool, micro droplets of liquid come out of the gap (Illustration circle 1)#

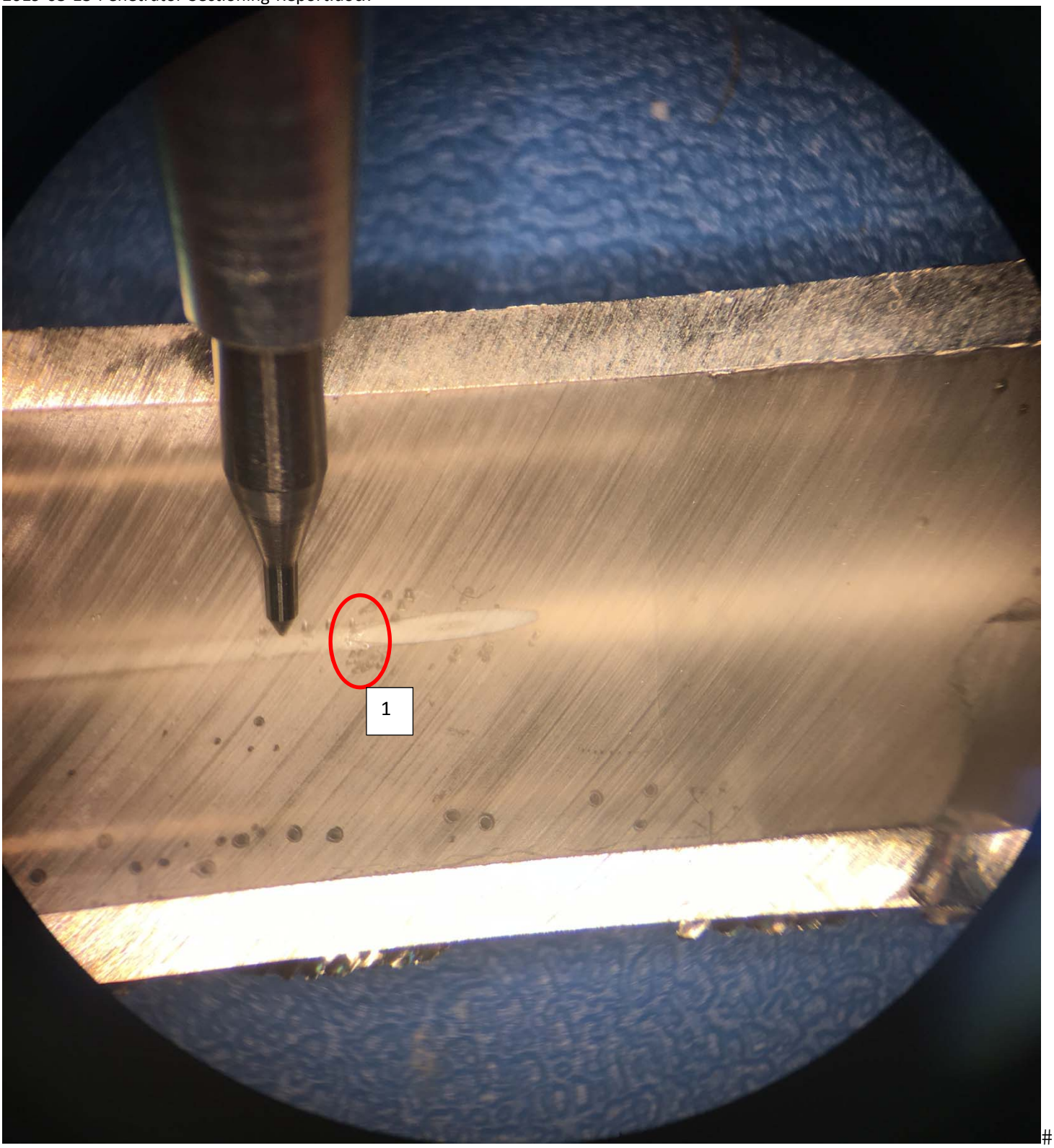

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Fig 6. (Sample 2). There seems to be liquid present between the epoxy and the optical fiber. When pressed with probing tool, micro droplets of liquid come out of the gap (Illustration circle 1)#

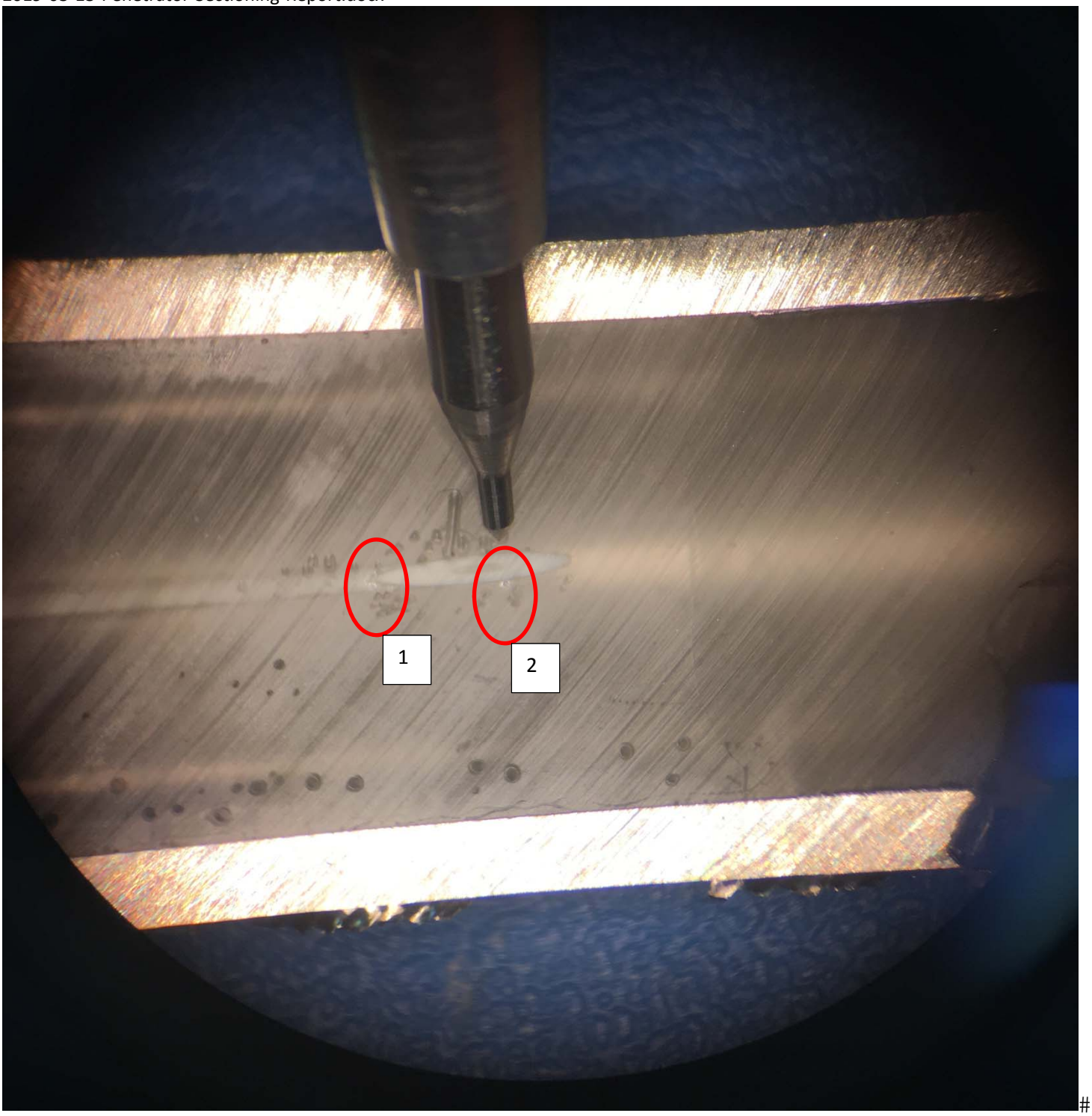

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Fig 7. (Sample 2). There seems to be liquid present between the epoxy and the optical fiber. When pressed with probing tool near other side of fiber section; micro droplets of liquid come out of the gap near that spot as well (Illustration circles 1, 2)#

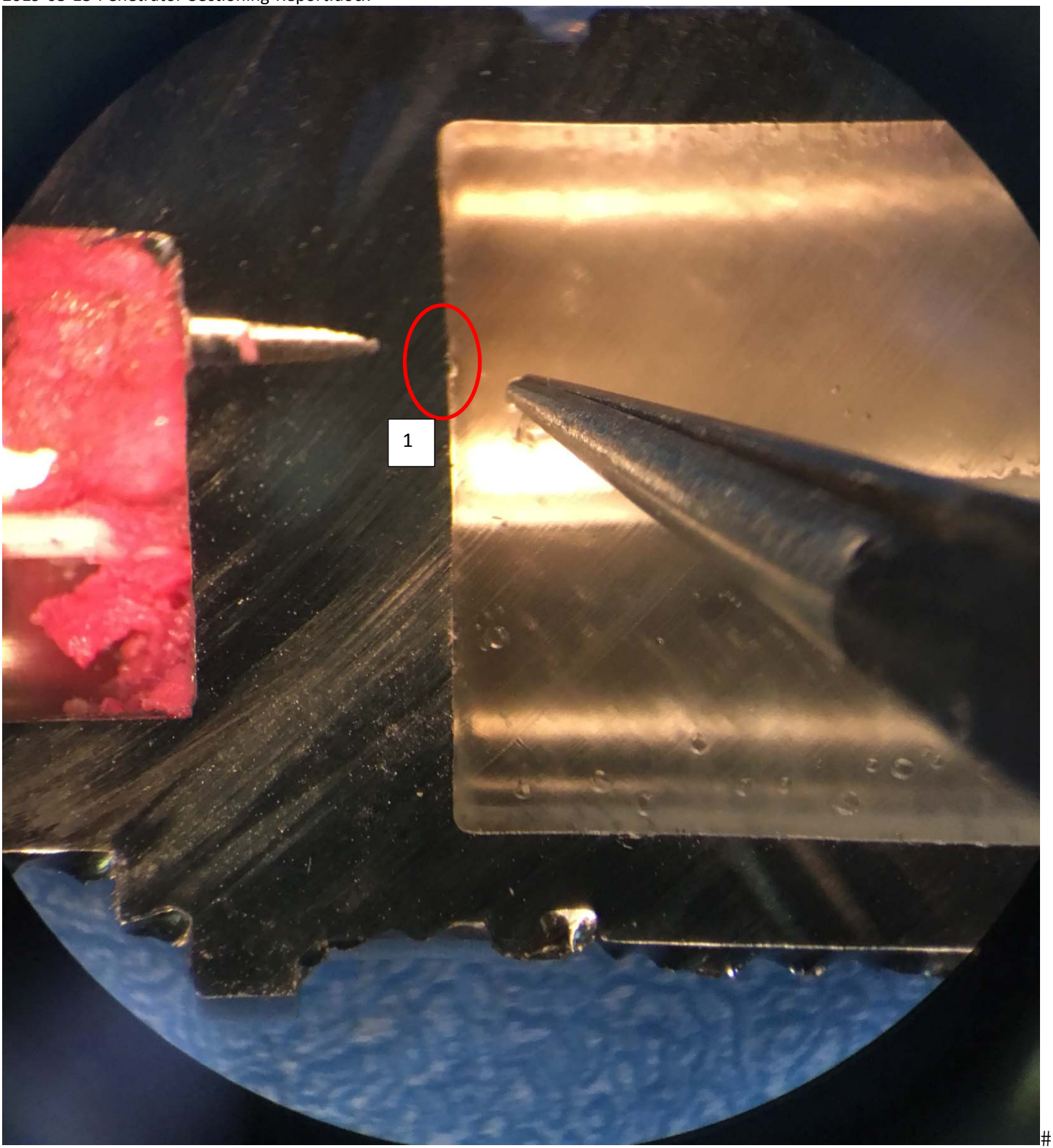

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Fig 8. (Sample 2). Similar to Fig 6, 7; when pressing with probing tool near the edge on the bottom of the potting pocket, micro droplets of liquid come out of the gap (Illustration circle 1). Visibility of the droplet is not so great in this picture; but it is visually apparent when viewing under stereo microscope

Fig 9. (Sample 3). Isomet 5000 automated sectioning saw setup#

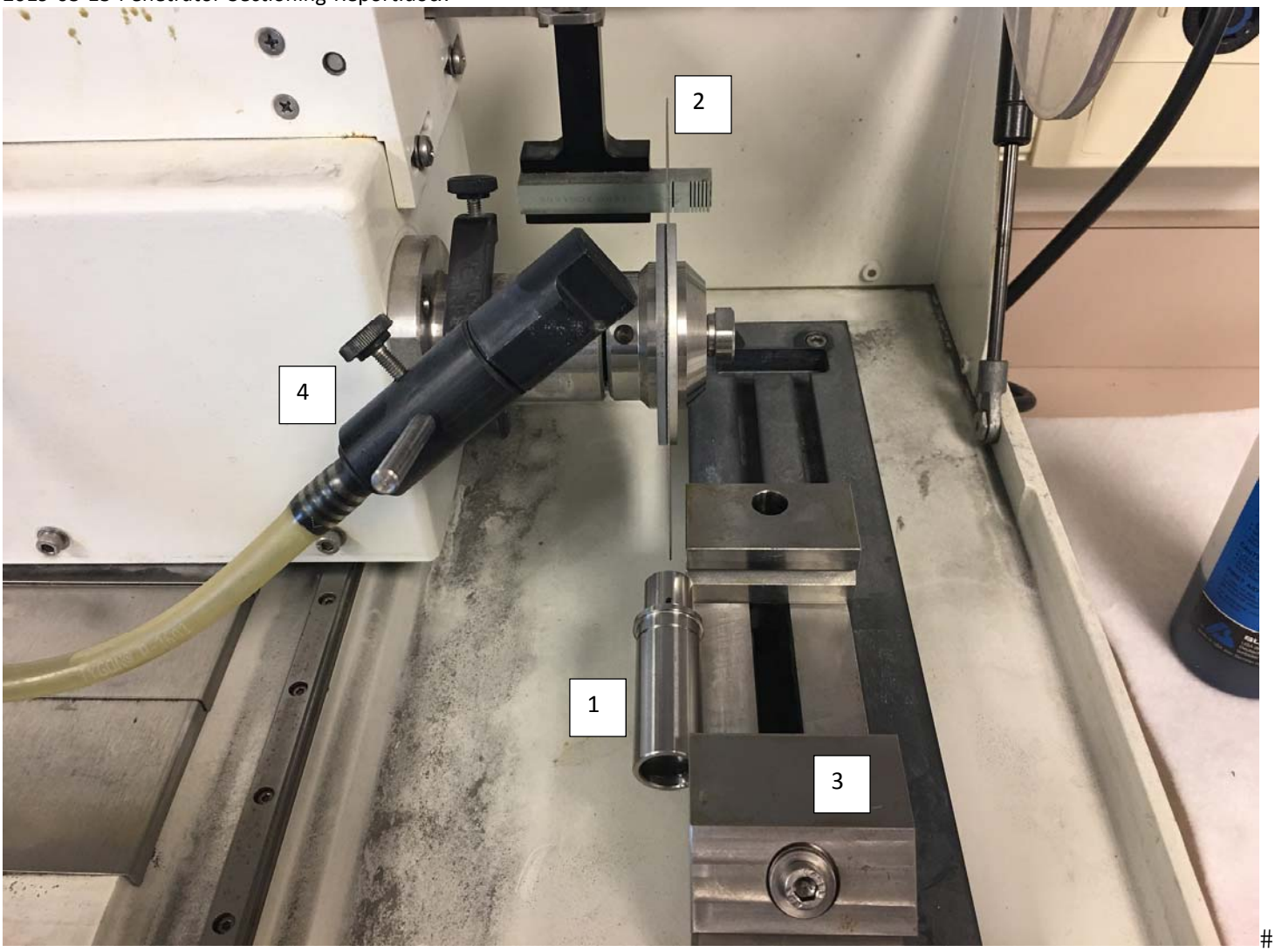

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Fig 10. (Sample 3). Sample positioning in the Isomet 5000 saw.
1: Sample
2: Diamond blade
3: Sample holding vise
4: Coolant jet tube#

2019-04-16-Prototype-Test-2.docx

Project: 901809.00 DeepPIV/ Deep Sea Bioinspiration
Author: Denis Klimov (EE)
Input from: Aaron Schnittger (MT); (pressure testing); Jon Erickson (ME)

Test sequence. Note yellow high-lighted areas for difference between steps.

1. Prepare for testing
    - Check light transmission on 2 fibers (Fig. 5-7, Klimov) - done
        - 4/10/2019 morning: one fiber transmits, other does not. Trimming 5 mm both sides did not help.
        - 4/10/2019, afternoon: non-working fiber was trimmed by 1" steps, and after 2 steps fiber is transmitting.
    - Trim optical fibers to fit the test assembly – done 4/10/2019
        - Fiber trimming was selected based on available spacing 1.5" deep by 0.75" wide (Fig 2,3)
        - Both fibers were trimmed to 7.5" in length, based on available spacing and folding in about 5 sections. One fiber was folded; unfolded, and transmission tested – worked fine. Fibers were marked with red and black permanent marker.
        - Both fibers folded and fixed with heat shrinking tubing for pressure testing (Fig. 8, 9)
2. Pressure testing – normal, old NAVY specification
    - Apply to fibers, and sections between O-rings with moisture-detecting dye – done 4/10/2019 (Schnittger)
    - Pack assembly into bag with salt water – done 4/10/2019 (Schnittger)
    - Pressure test specs: - done 4/11/2019 (Schnittger)
        - 5800 PSI (4000m depth)
            - 10 cycles at 500 PSI/ minute ramp-up and down
            - Final cycle - hold at 5800 PSI for 1 hour
    - Release pressure, remove bag with assembly, remove assembly from salt water; clean and dry – done 4/11/2019 (Schnittger)
        - Salt water bag was ruptured and hydraulic oil got inside of bag.
        - Assembly was washed with soap, warm water, and soft brush.
        - Assembly was rinsed with RO water and left to dry until Monday.
    - Remove 2 connectors and check for presence of water in the dry volume – done 4/15/2019 (Schnittger)
        - Both dry volumes were found flooded (Fig 15)
        - Pressure was observed in the "dry" volumes on both sides; suggesting that water intrusion occurred thru some sort of 'soft' interface capable on acting like a valve; and not thru opening or a gap which would allow pressure release.
        - Water intrusion was most likely thru penetrators and not by O-rings, since moisture-detecting dye did not detected water between O-rings (Fig 16, 17)
    - Check light transmission on 2 fibers – done 4/15/2019 (Klimov)
        - Black fiber was transmitting; while red did not transmit (Fig 10, 11)
        - Red fiber was subsequently trimmed with 1" steps and inspected after each trimming; but even after trimming both sides to 1" long length (sections which were never folded); the fiber does not transmit, suggesting internal damage to one fiber (Fig 12)
        - The spiral steel jacket is flooded as observed thru clear heat shrink jacket (Fig 13, 14).

Fig 1. Prototype received from Coastal Connections 4/9/2019

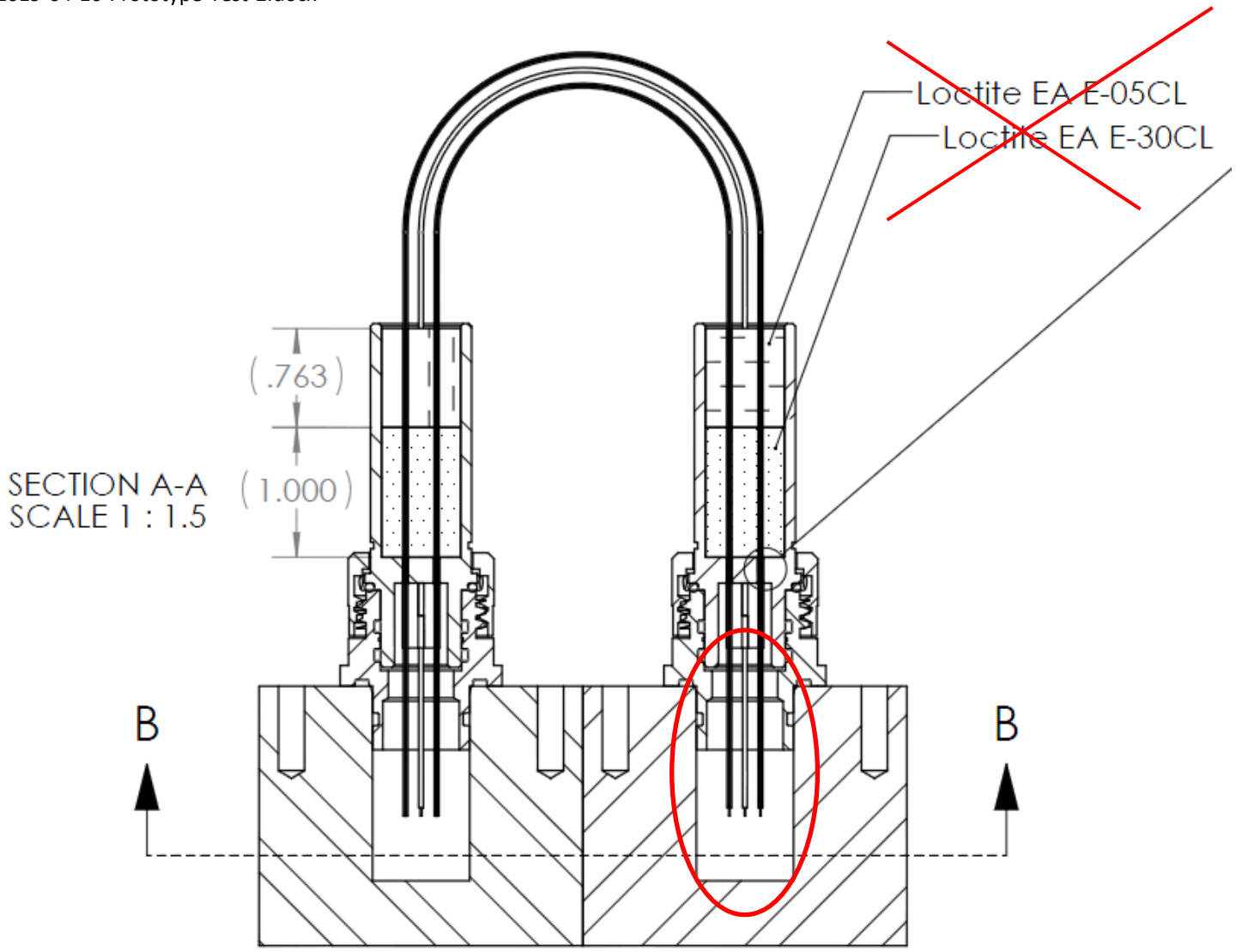


Fig 2. Pressure test setup. Optical fibers need to be trimmed in order to fit the part (see also Fig 3). Note: test assembly with 4 fibers dated 1/9/2019 is shown.

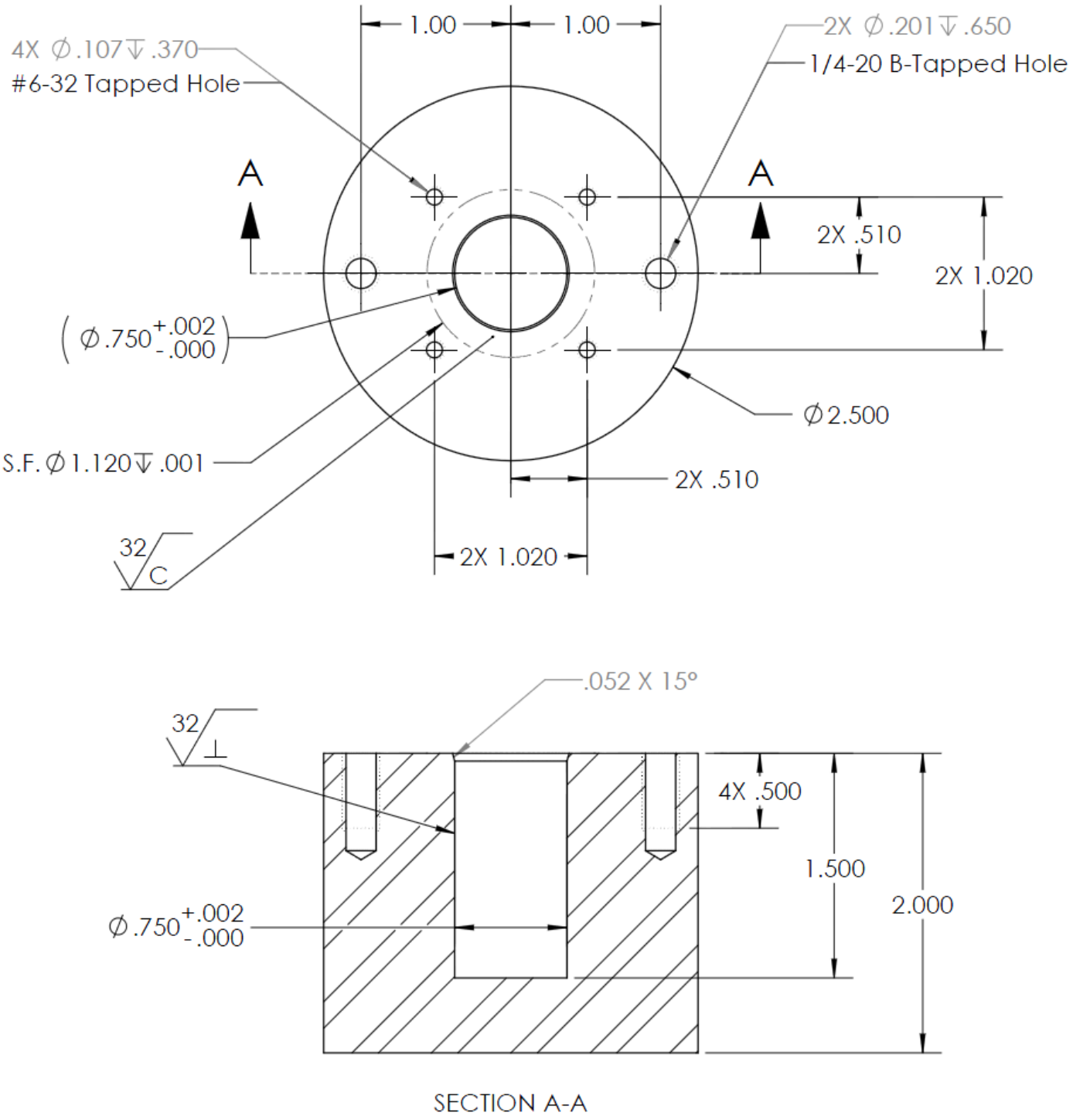


Fig 3. PIV Fiber End TEST – part emulating dry pressure housing

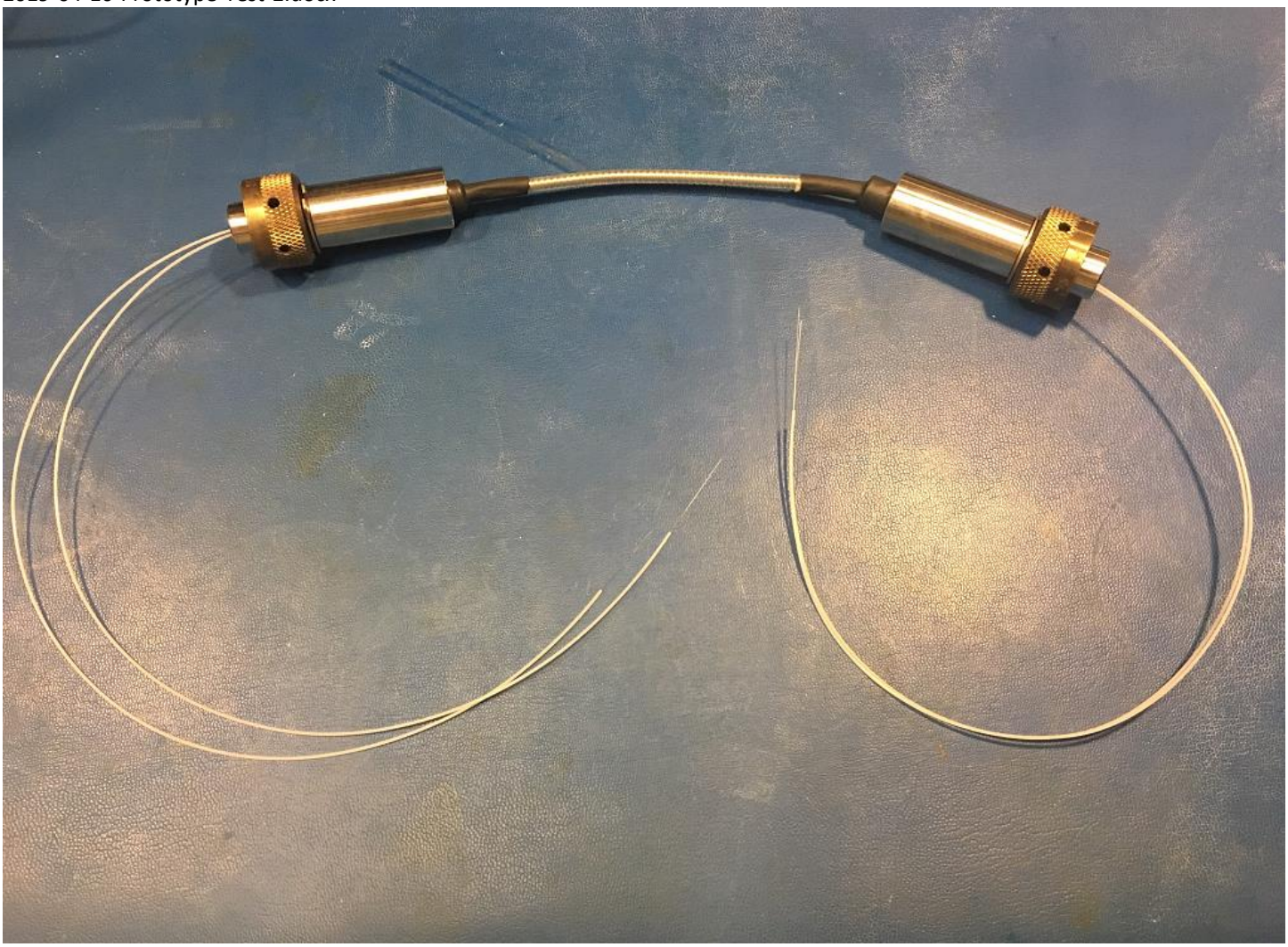


Fig 4. Prototype unpacked

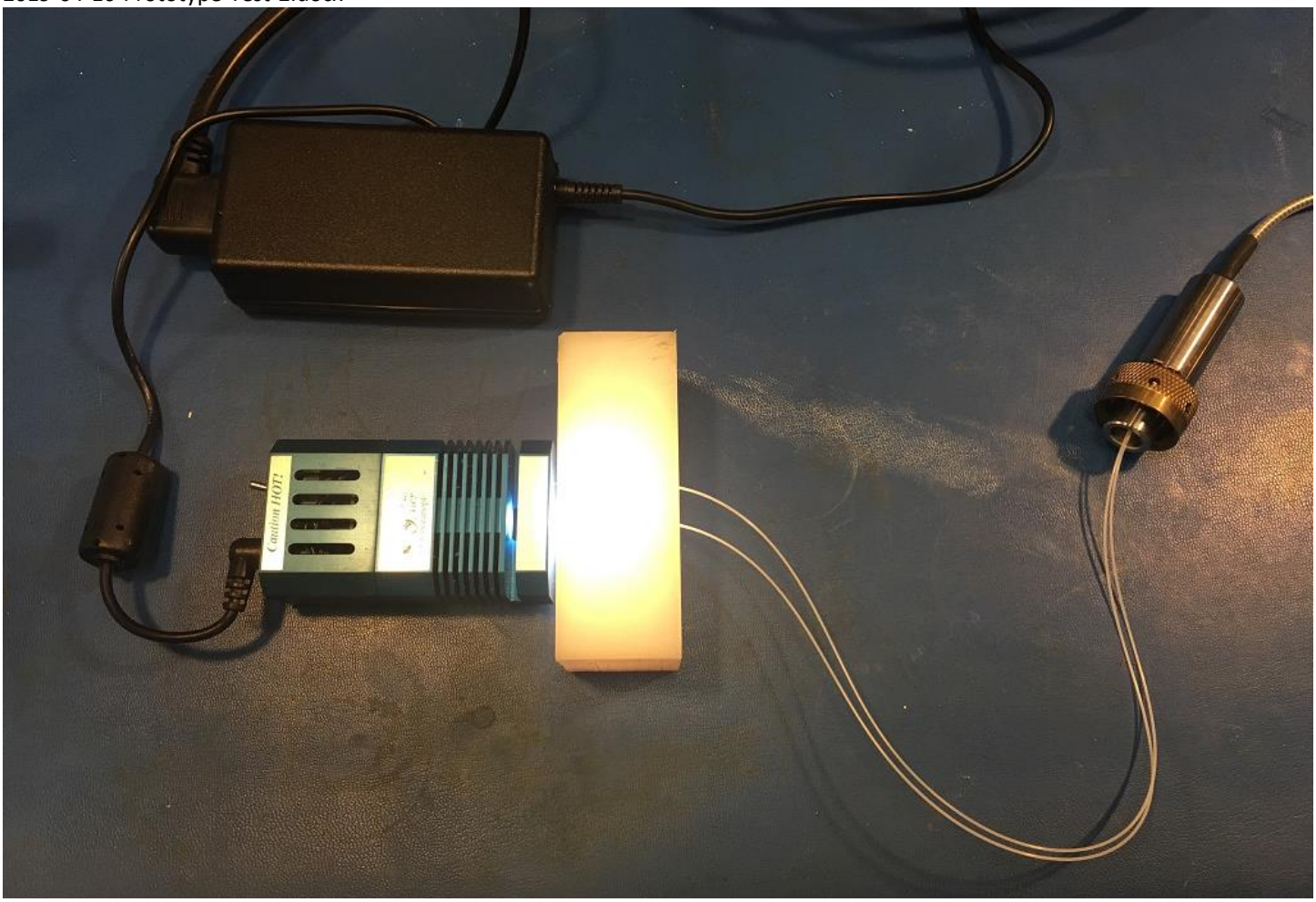


Fig 5. Optical connectivity test, injection side

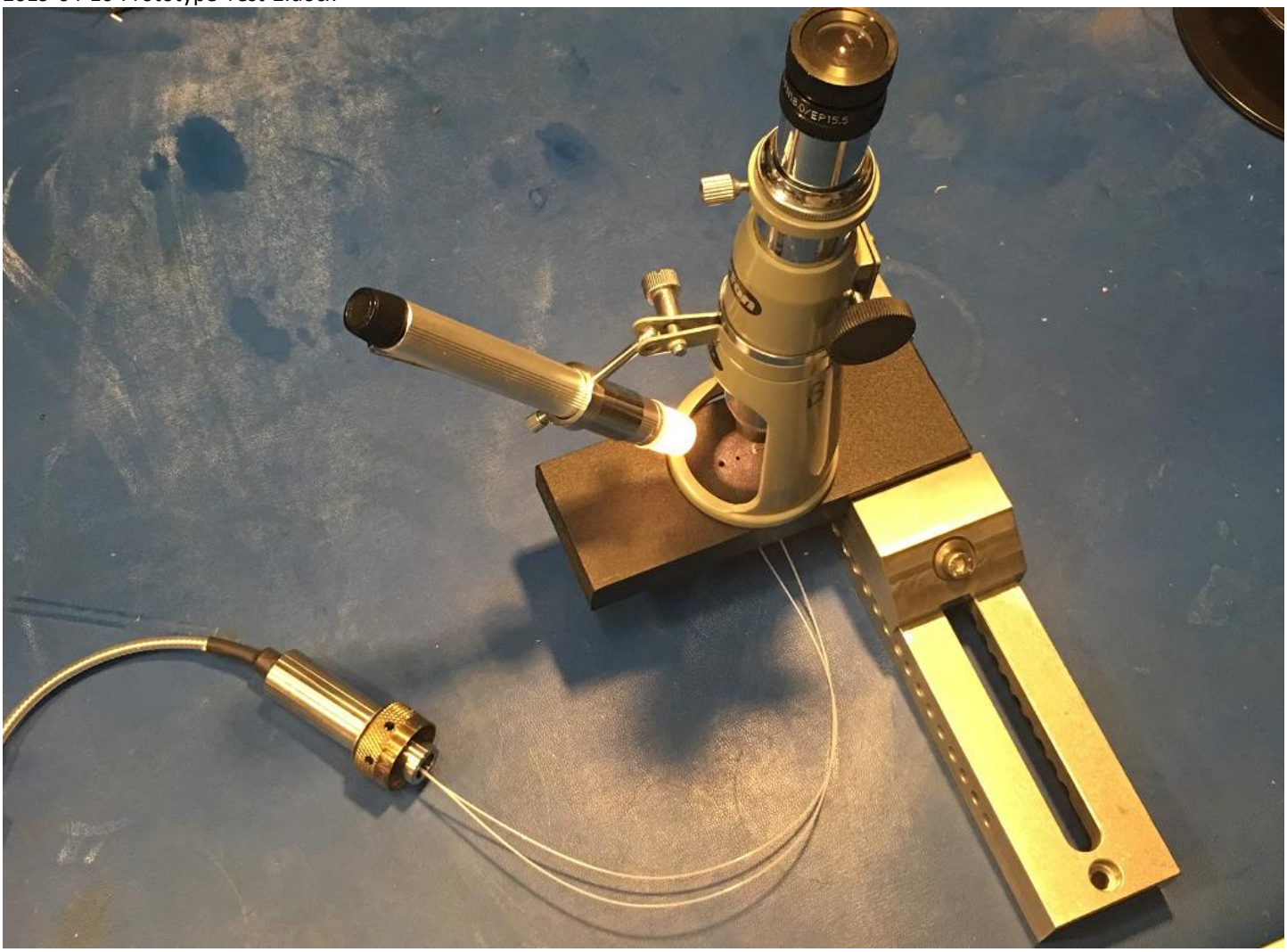


Fig 6. Optical connectivity test, emission/ inspection microscope side

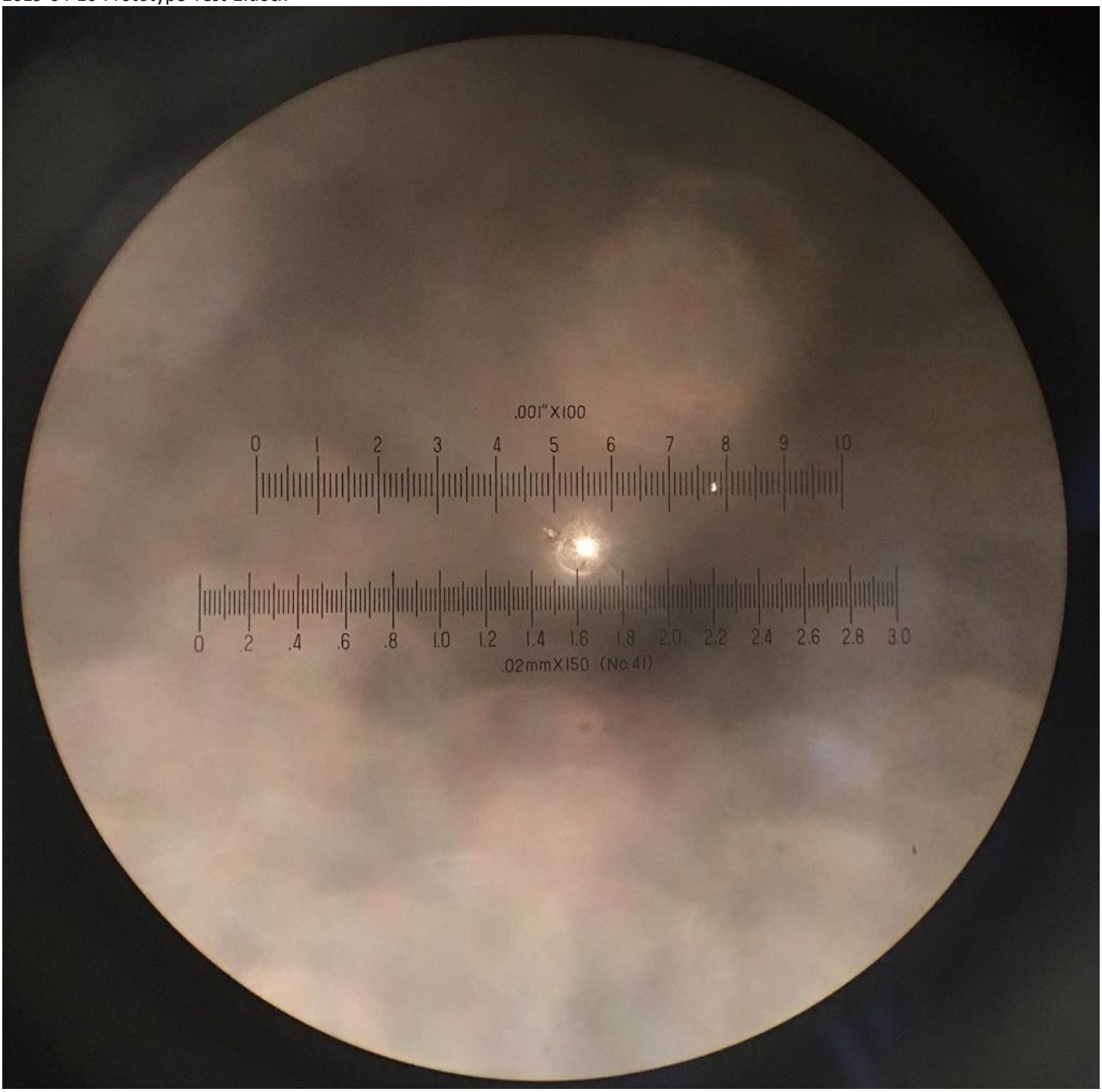


Fig 7. Optical connectivity test, microscope view of the optical emission from the tip of the fiber

Fig 8. Assembly before pressure testing. Both fibers were trimmed to 7.5” length, and folded into about 0.75” wide x 1.5” long envelopes held with heat shrink tubing (4/10/2019).

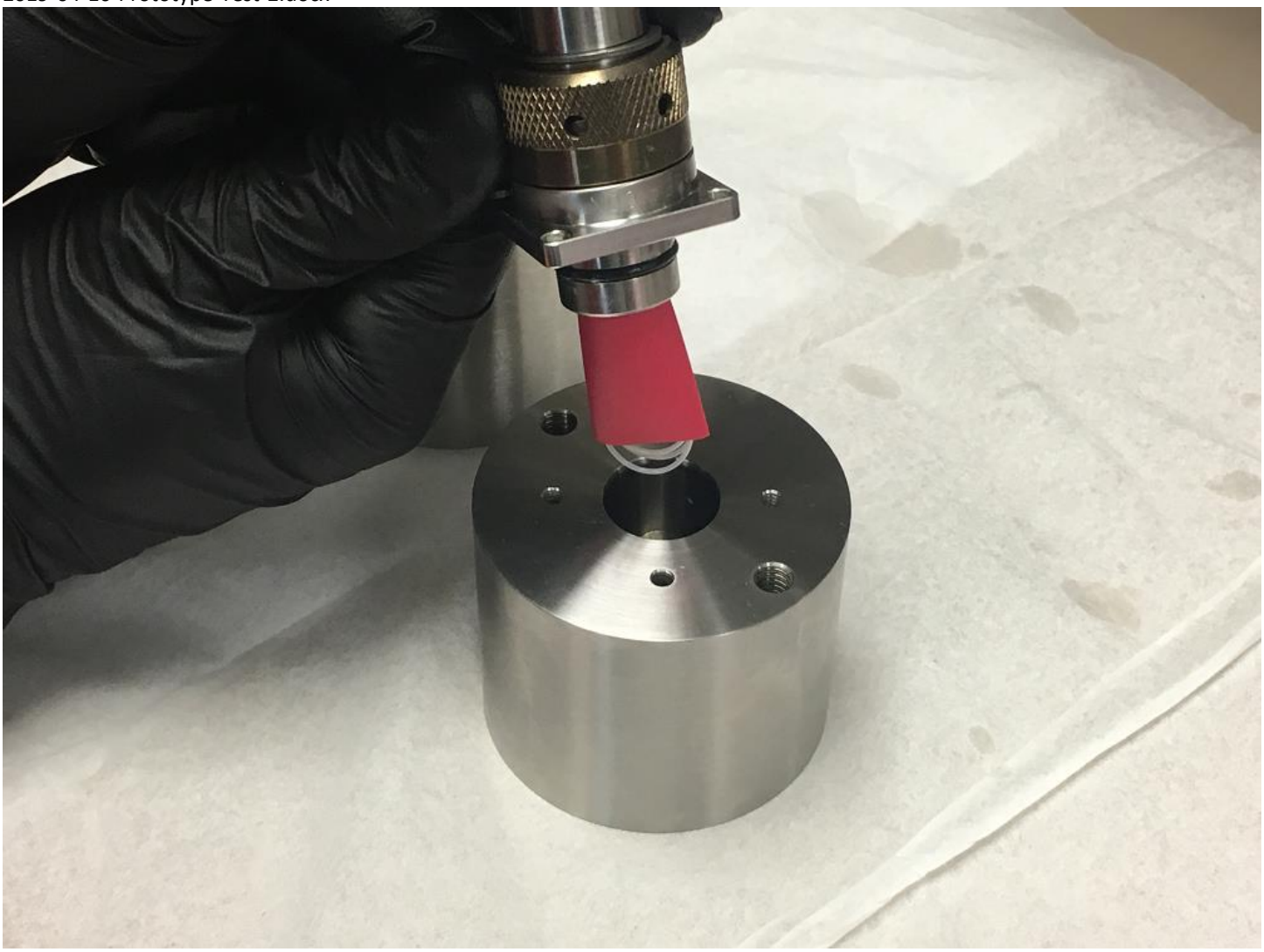


Fig 9. Same as Fig 8, before closing flange to the dry housing (4/10/2019)

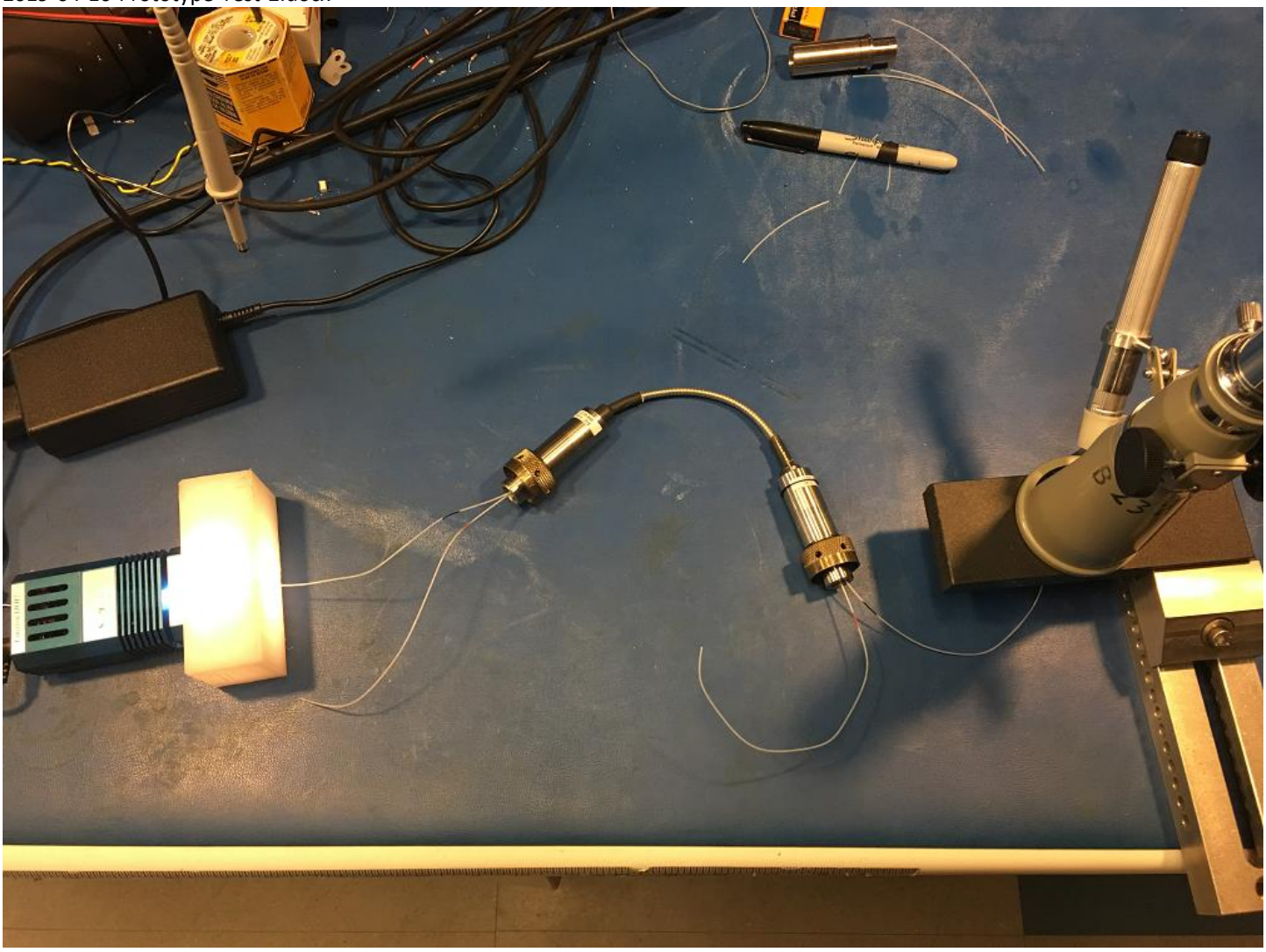


Fig 10. Testing optical transmission after pressure testing. Fiber marked ‘black’ is transmitting; fiber marked ‘red’ is not (4/15/2019)

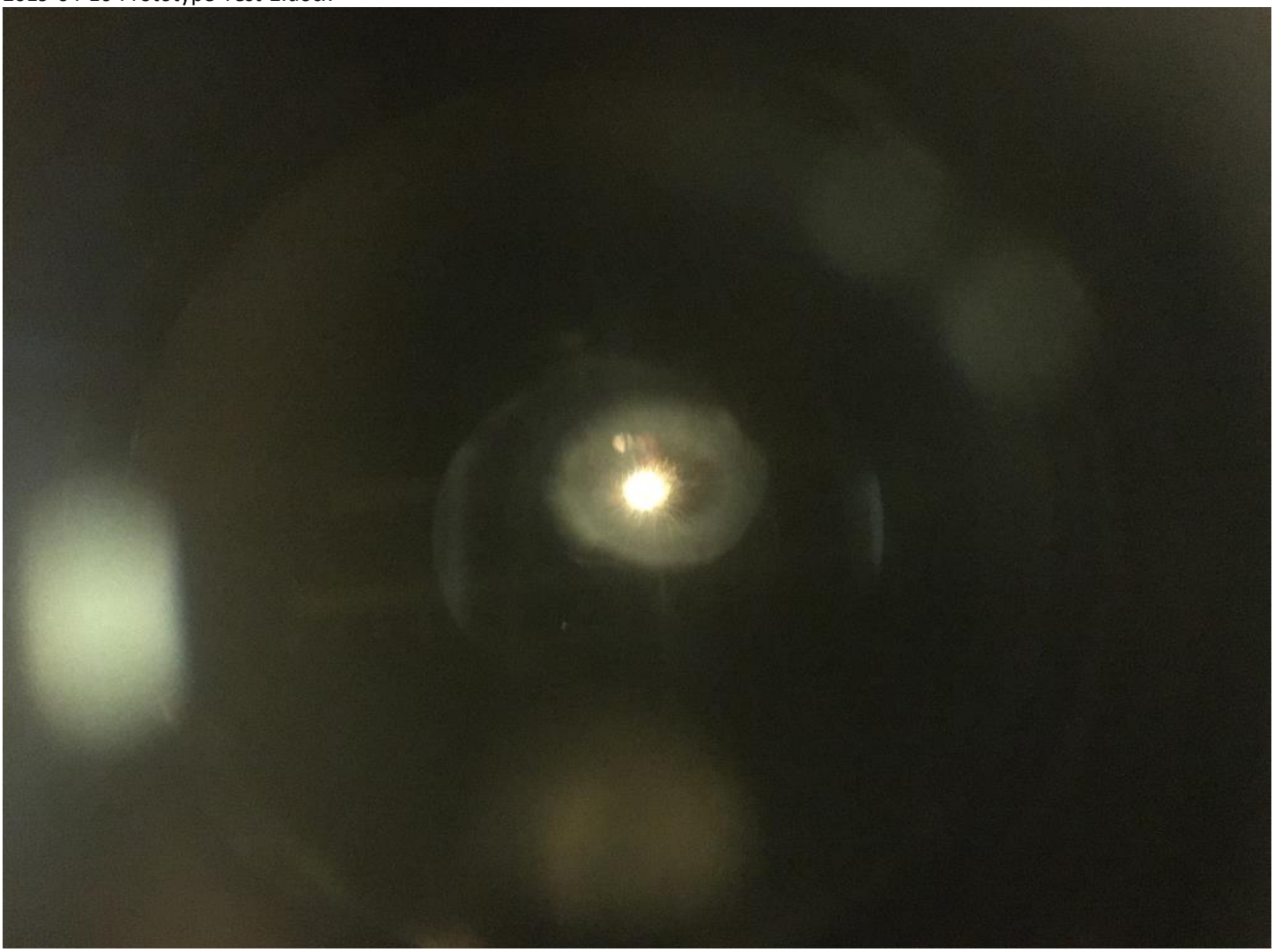


Fig 11. Testing optical transmission after pressure testing; measuring microscope view. Fiber marked 'black' is transmitting (4/15/2019)

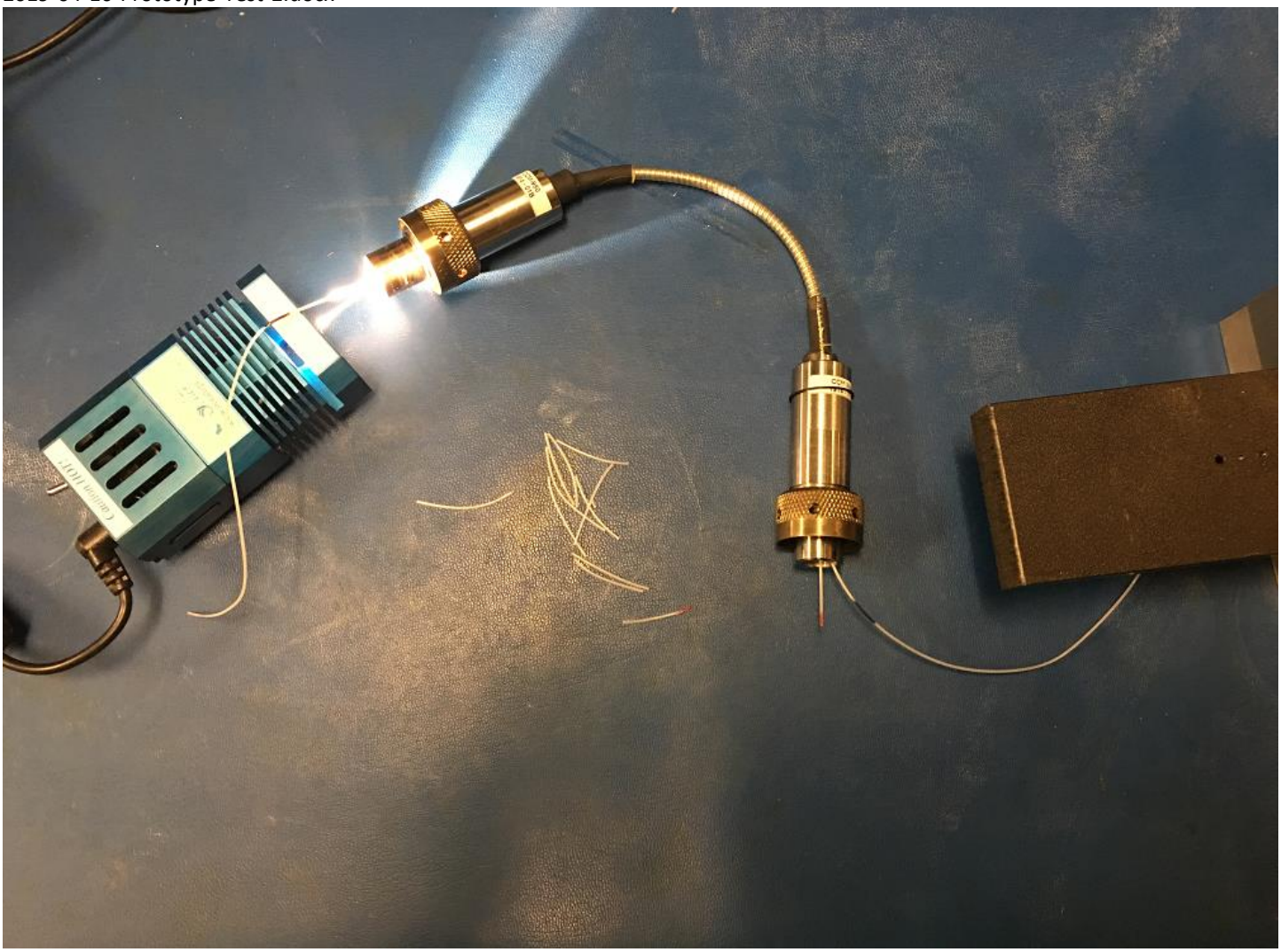


Fig 12. Testing optical transmission after pressure testing. Fiber marked “red” is sequentially cut by 1” at the time alternating on both sides. Even after 1” (straight section) left on both sides, red fiber is not stansmitting; suggesting internal damage to the fiber (4/15/2019)

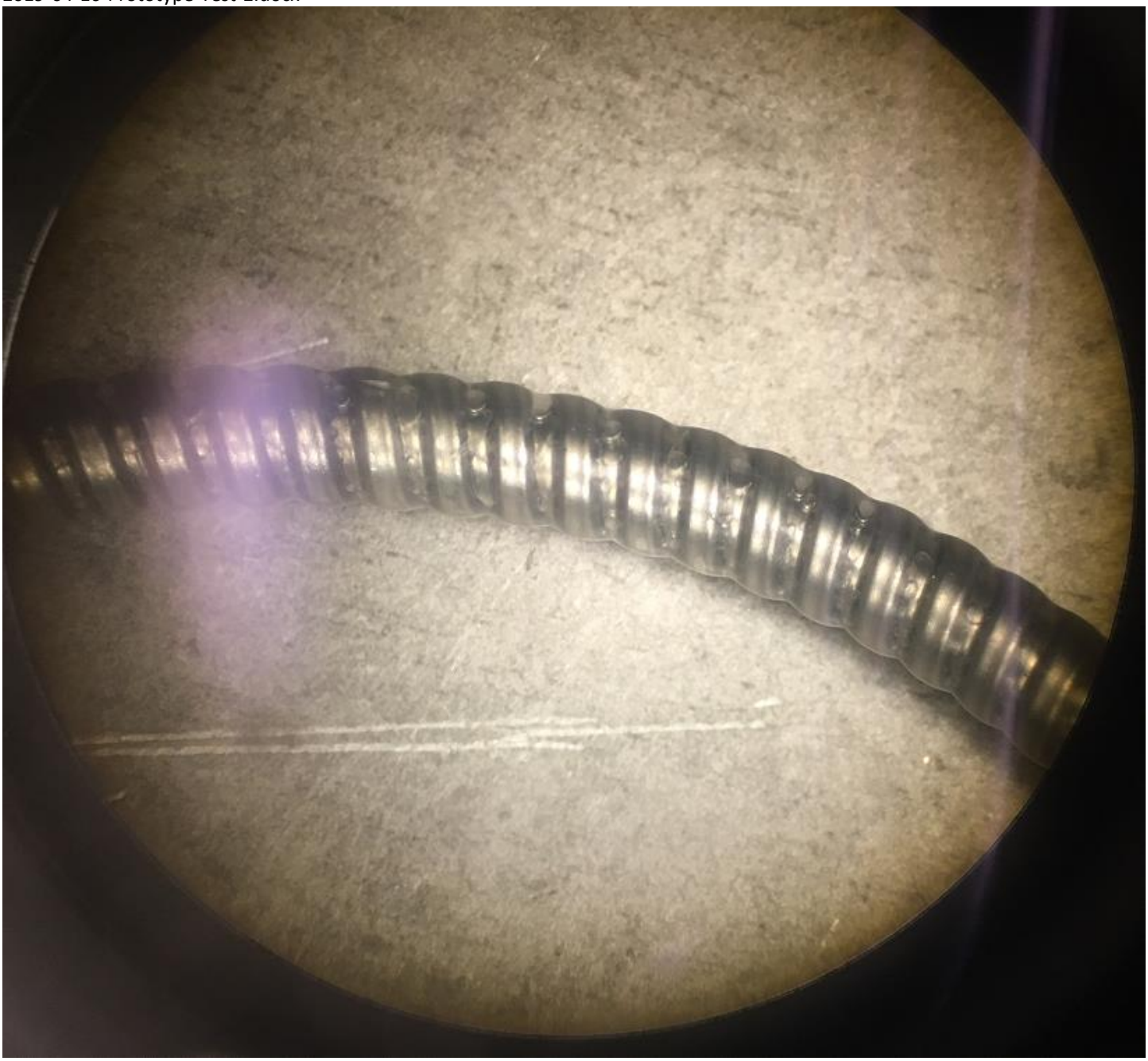


Fig 13. After pressure testing. Spiral jacket under heat shrinking tubing is flooded; air bubbles are visible (4/15/2019)

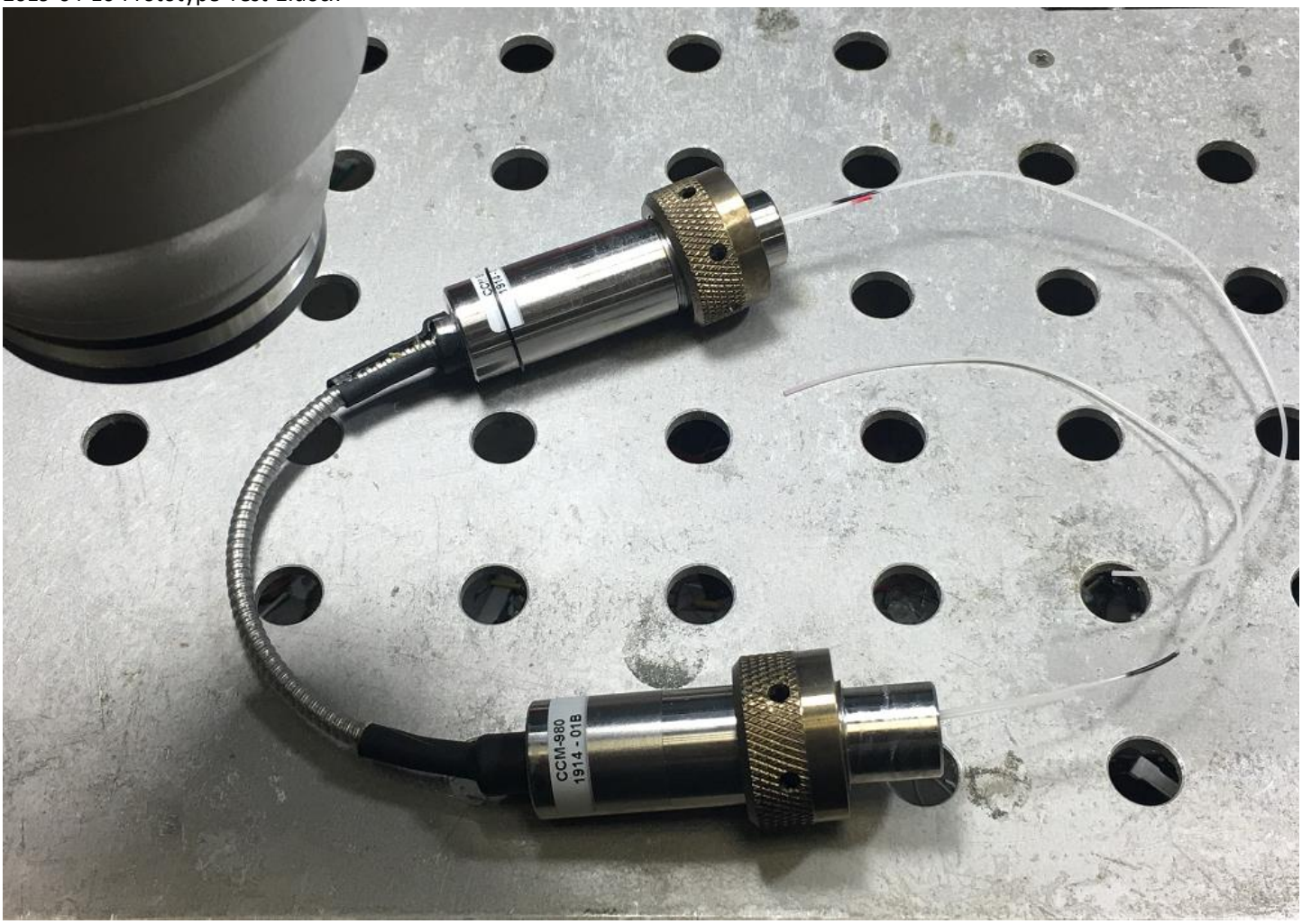


Fig 14. After pressure testing. Assembly after microscope.

Fig 15. Assembly opened after pressure testing. Mixture of water with liquid-detecting dye is visible (4/15/2019, photo by Schnittger)

Fig 16. Assembly opened after pressure testing. Pressure relieve mechanism (4/15/2019, photo by Schnittger)

Fig 17. Assembly opened after pressure testing. Penetrator photo (4/15/2019, photo by Schnittger)

2019-05-01-Prototype-Sectioning-Report-10.docx

Project: 901809.00 DeepPIV/ Deep Sea Bioinspiration
Author: Denis Klimov (EE)
Input from: Aaron Schnittger (MT); (pressure testing); Jon Erickson (ME); Andy Devine at Coastal Connections.
Related document: "2019-04-16-Prototype-Test-2.docx" (description of assembly in question and testing procedure)

Description of issue: prototype of underwater fiber connection link, containing 2x SMF-28 fibers (Coastal P/N: CCM-980, RevA Draft 3; received from Coastal Connections 4/9/2019); had leaked under pressure during pressure testing performed at MBARI 4/11/2019. Here is a summary of observations following pressure testing:

- Both penetrators leaked flooding dry volumes on respective (both) sides.
- The middle part (with spiral steel jacket) is flooded.
- One of the two optical fibers was damaged somewhere inside and no longer transmitted light (both fibers were verified for light transmission prior to pressure testing)
- Pressure was observed in the "dry" volumes on both sides even 3 days of storage at atmospheric pressure.

Sectioning:

- One penetrator was cut off the middle connection part near the strain relieve; and was cut longitudinally in about half resulting with 2 parts, further referred as Side A and Side B (Fig 1)
- Equipment: Isomet 5000 diamond saw; Isocut Plus 11-2293-016 cutting fluid mix 1:9 to RO water ratio; diamond blade 6"x0.020"; feed rate 0.050"/ min
- Microscope photo images with observations and comments:
    - 7 photos of Side A middle section, from left to right (Fig 2-8)
    - 2 photos of tweezers touch test of white and blue epoxy (Fig 9, 10)
    - 5 close-up photos of various areas of interest: fibers on the right and left side, void in the blue epoxy; diagonal fault/ cracks area in the glass tube, and interference pattern on the interface between glass tube and blue epoxy (Fig 11-15)

Conclusions:

- More likely area of water intrusion is somewhere in center of the glass tube:
    - Either between blue epoxy and glass tube where the adhesion is weak and/or gap present (Fig 9, 12, 14)
    - Or, in the blue epoxy along the optical fibers; perhaps where is the transition from 2 clear plastic tubes containing optical fibers (Fig 11), to 1 plastic tube containing both optical fibers (Fig 15). This area is, unfortunately, not visible in the subject section.
- Glass tube is observed to be fractured in multiple places. One could argue this happed during sectioning; however, diagonal fracture lines may indicate typical failure under axial load, as observed by Jon Erickson (Fig4, 13). This might be a result of too high/ uneven contact pressure on the glass tube in the point of contact with metal (Fig 2).
- It is not immediately clear why the optical fibers are blue on the one side of penetrator, and white/clear or another (Fig 11, 15)
- Failure of one optical fiber may indicate that the industrial-grade spiral jacket assembly is not rated for the type of axial loads exerted during pressure test. Alternatively, fiber failure could be explained by week support of the spiral jacket near the glass tube (Fig 7)

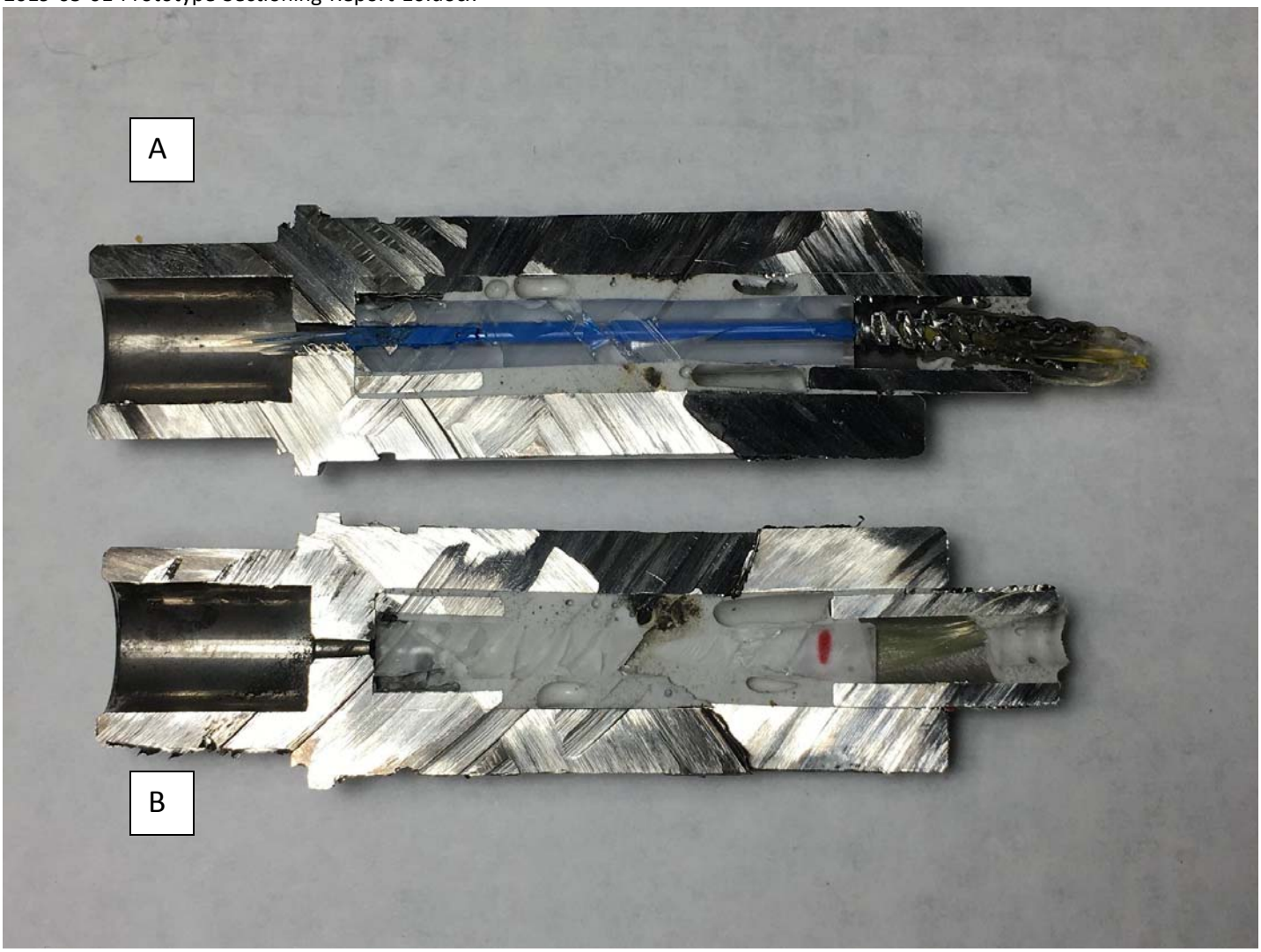


Fig 1. One of penetrators was cut off the assembly and sectioned longitudinally, resulting in 2 pieces: Side A which is thicker and contains larger piece of glass tube and optical fibers; and Side B which is thinner with smaller piece of glass tube, and no optical fibers.

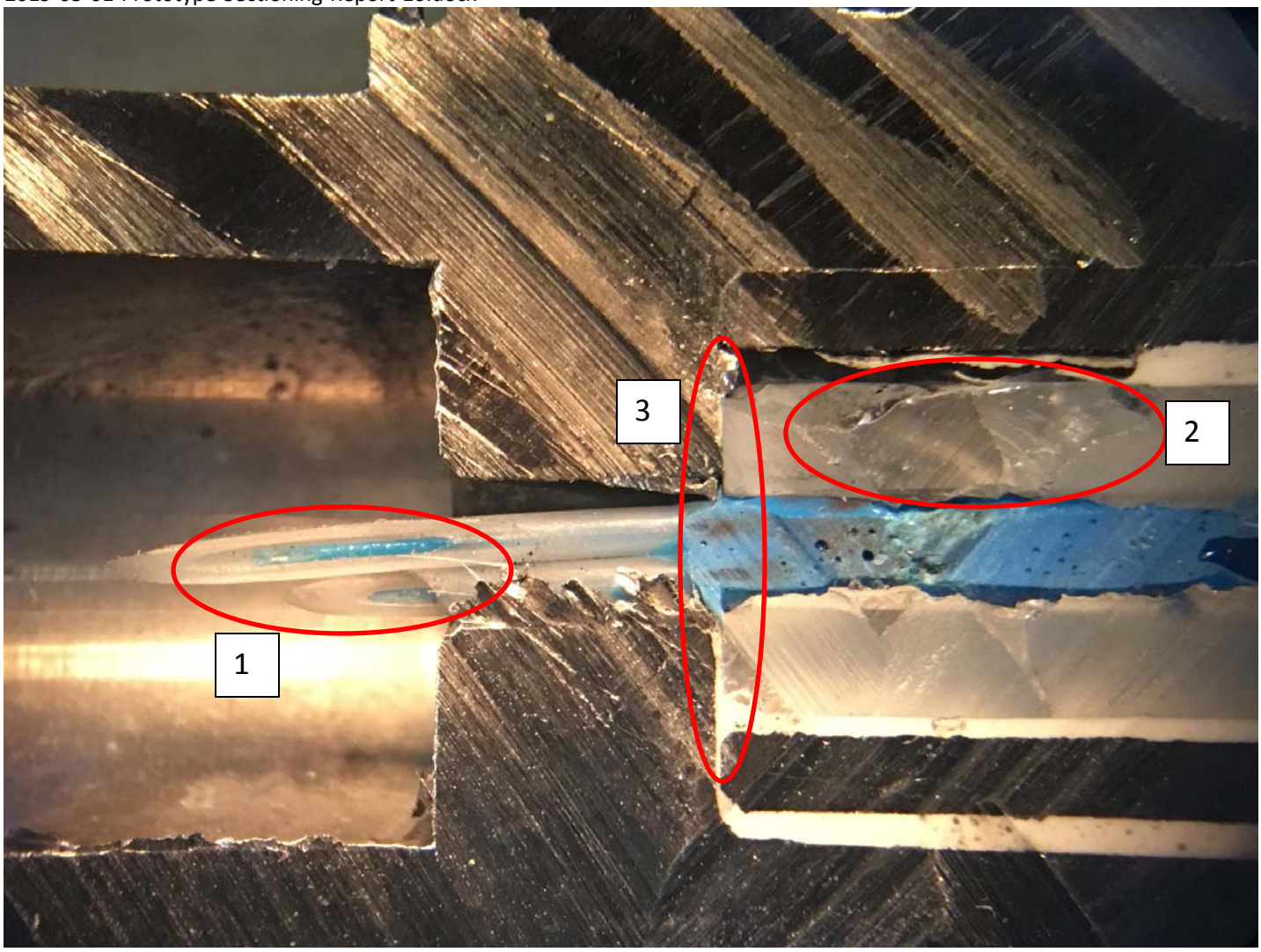


Fig 2. Middle section photo 1 of 7 (counting left to right). Visible elements: (1): two fibers, blue in color; each is contained in individual clear plastic tube; (2): multiple fractures in the glass tube; (3): glass tube is placed in very close proximity (or touching) the base of metal penetrator

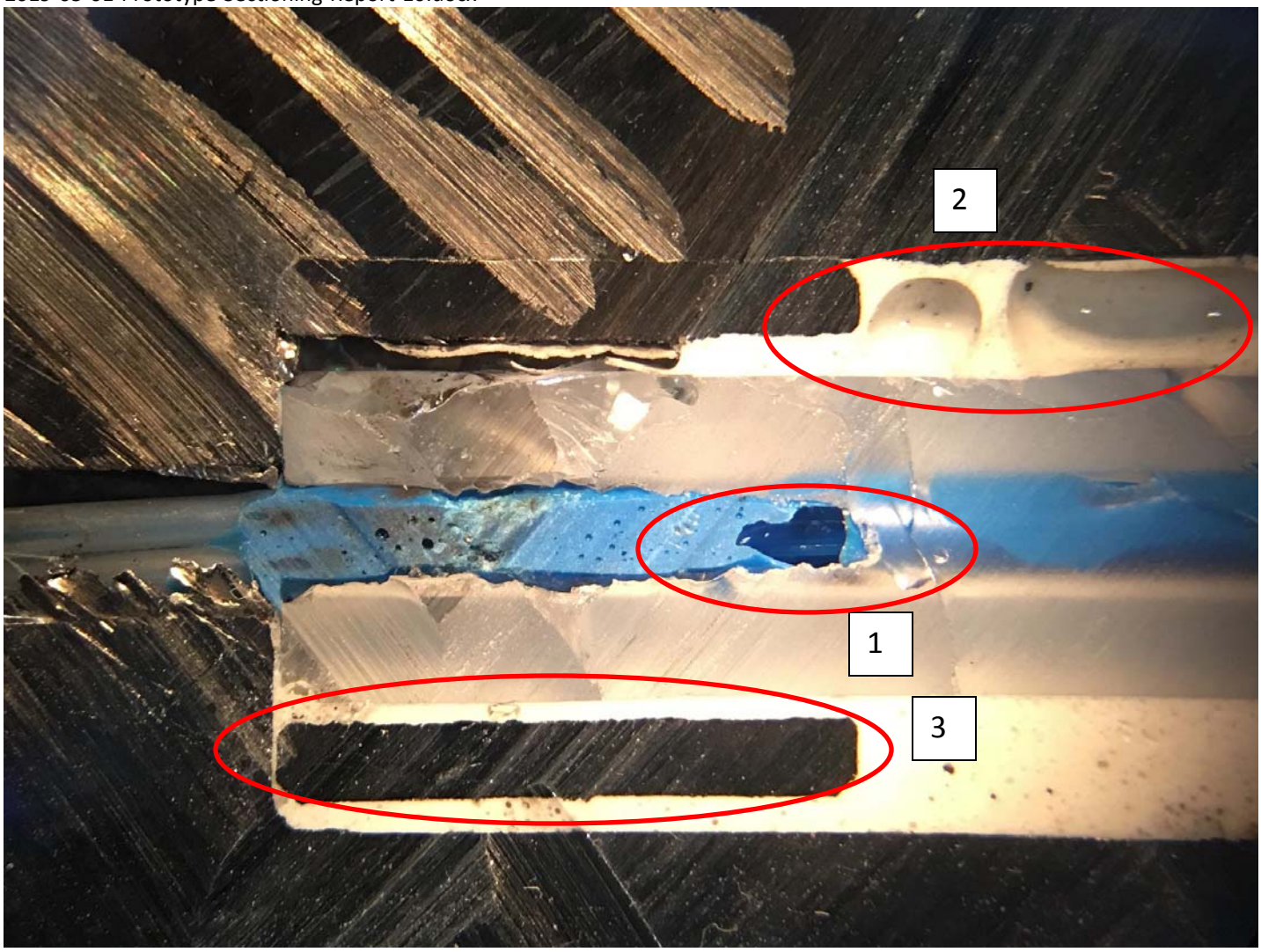


Fig 3. Middle section photo 2 of 7 (counting left to right). Visible elements: (1), (2): large voids in blue and white epoxy; (3): metal alignment ring

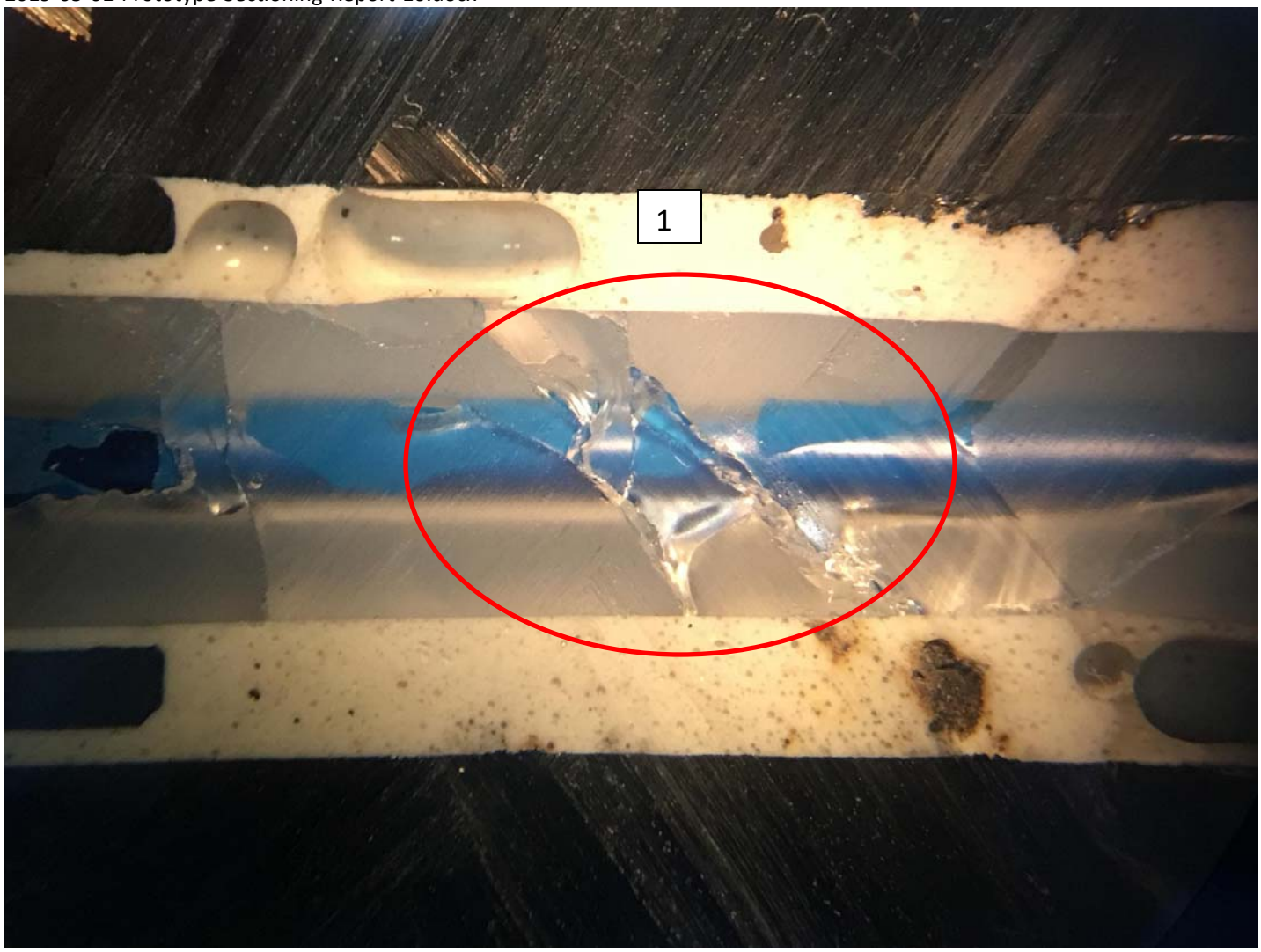


Fig 4. Middle section photo 3 of 7 (counting left to right). Diagonal faults area (1) in the middle of glass tube, suggesting possible fracturing under axial load (observation by Jon Erickson)

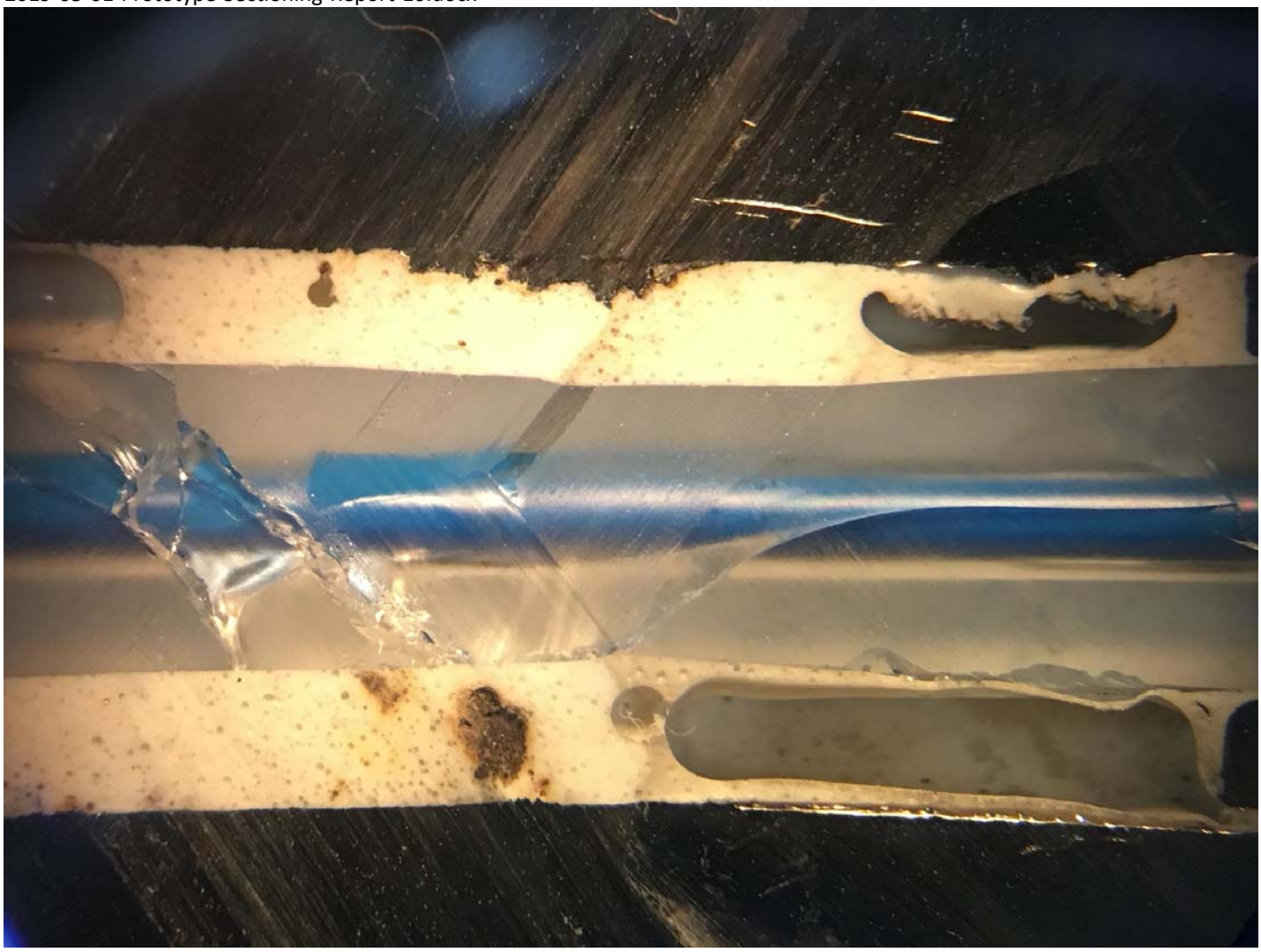


Fig 5. Middle section photo 4 of 7 (counting left to right). Large cavities are visible in the white epoxy

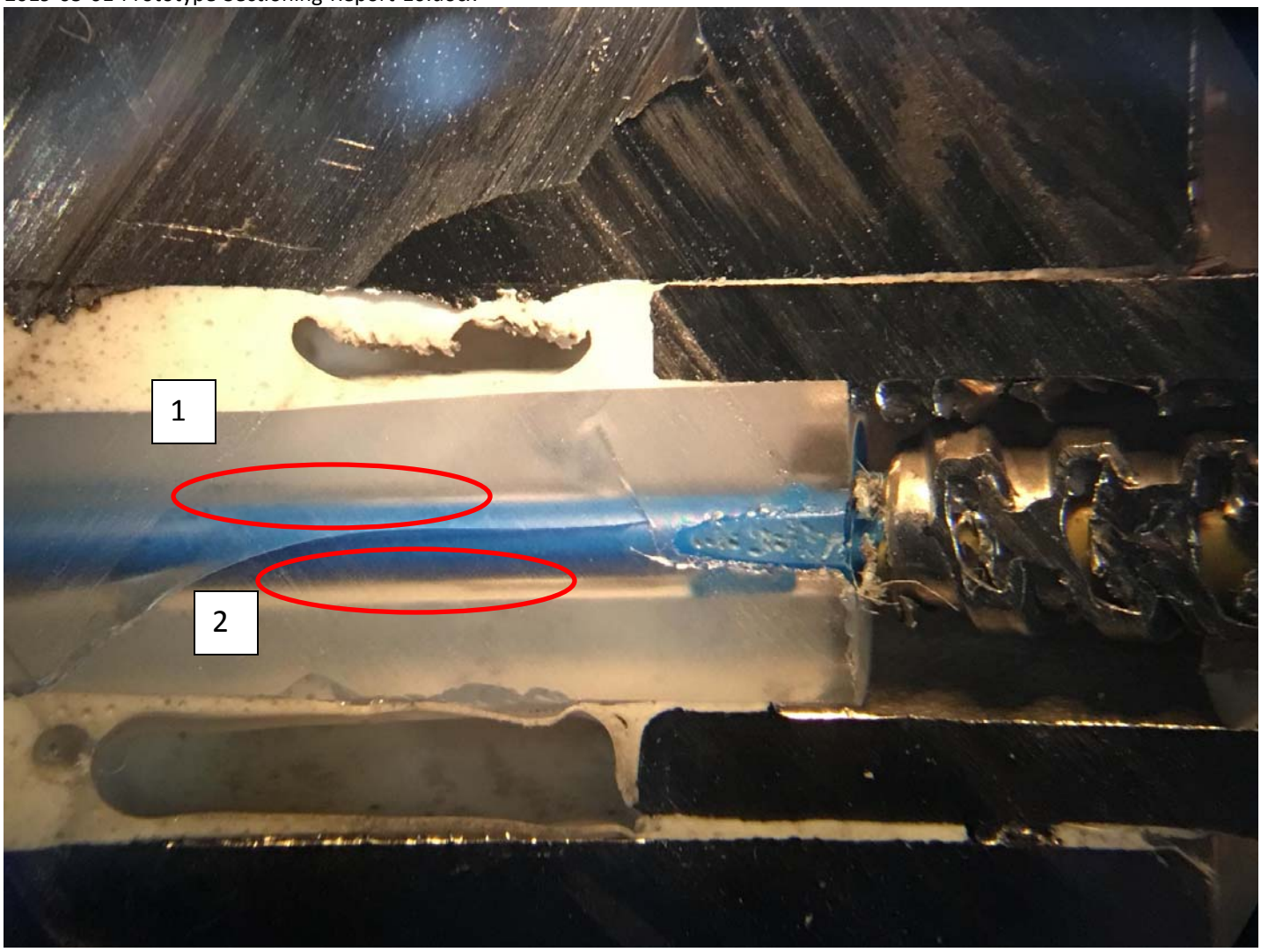


Fig 6. Middle section photo 5 of 7 (counting left to right). Area of gap/ weak adhesion between glass tube and blue epoxy. Some areas of blue epoxy appear bright-blue, which is presumably area of good contact (2), and some – pale blue, where there is a gap between epoxy and glass, such as area (1). See also Fig 9.

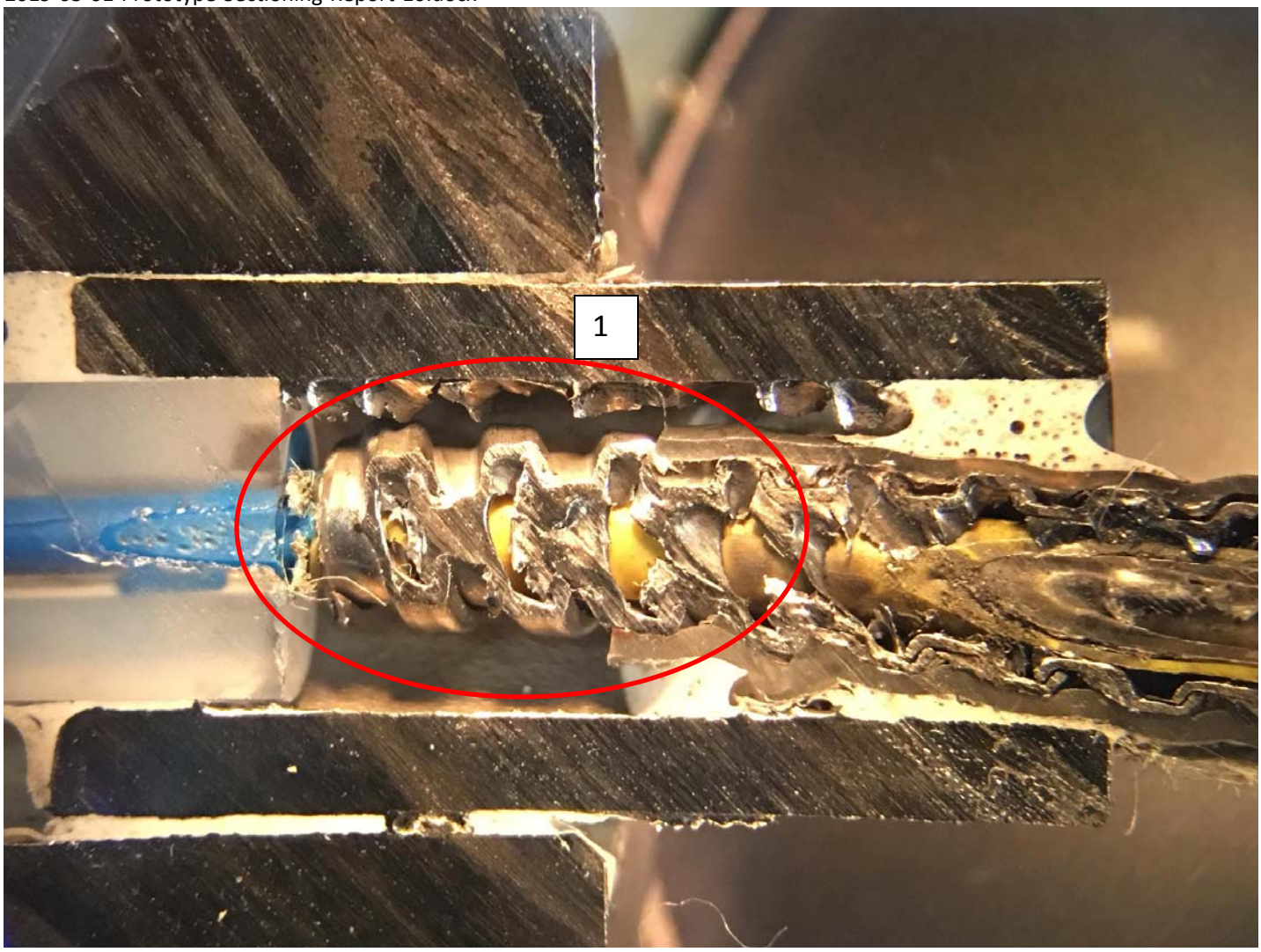


Fig 7. Middle section photo 6 of 7 (counting left to right). Weak support of the steel spiral tube in the area (1) where optical fibers are entering glass tube may lead to optical fiber fracture in this area (observation by Jon Erickson).

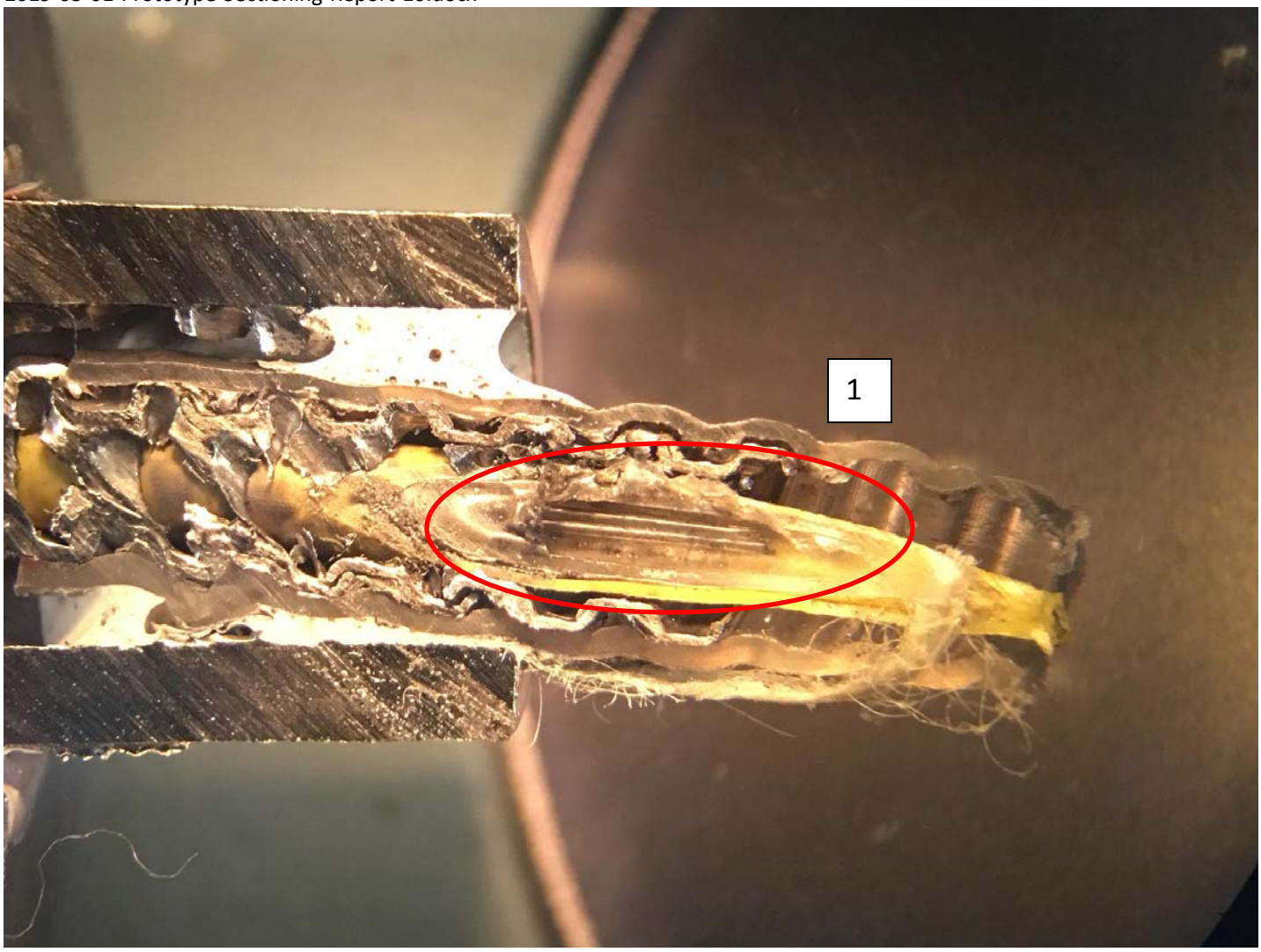


Fig 8. Middle section photo 7 of 7 (counting left to right). Two optical fibers (1) contained in one clear plastic tube

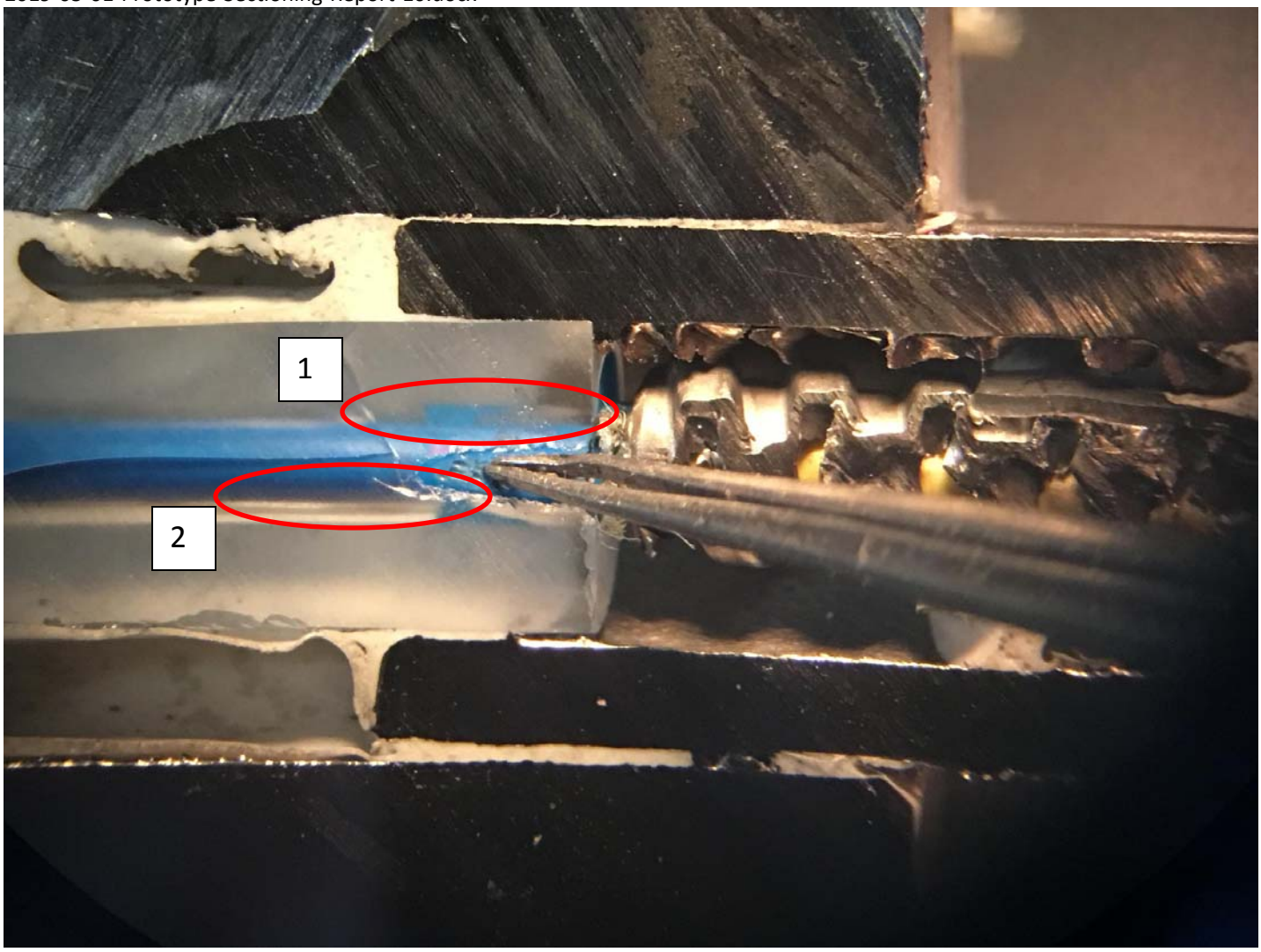


Fig 9. Tweeresz touch test on the blue epoxy area. Test revealed noticeable gap (1), (2) between blue epoxy and glass tube, with liquid moving in the gap depending on the direction of the touch.

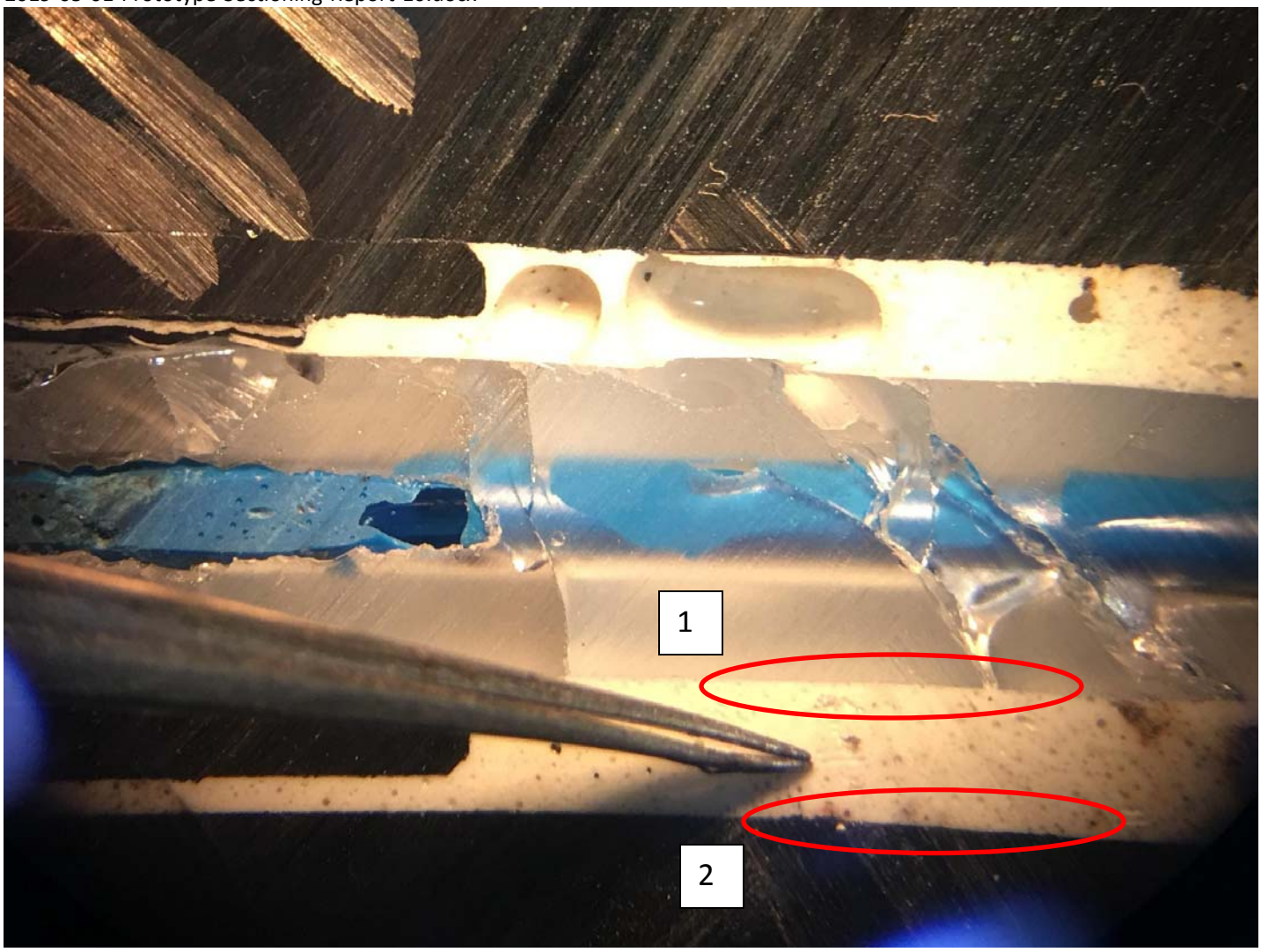


Fig 10. Tweezers touch test of white epoxy area. This test did not reveal any perceived gaps between white epoxy and glass tube (1) or white epoxy and steel penetrator (2). No evidence of delamination, or liquid in the interface.

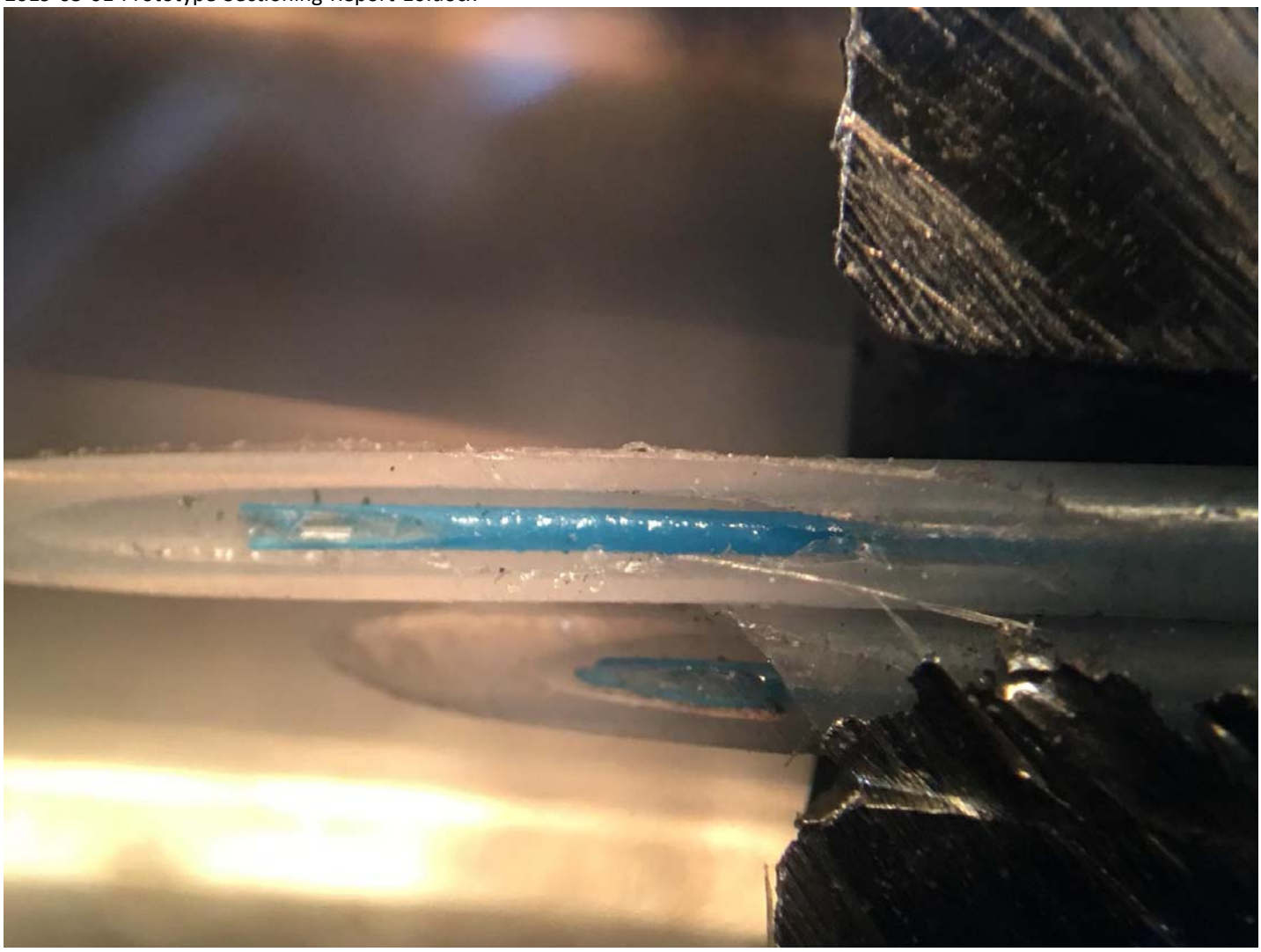


Fig 11. Close-up photo 1 of 5. Blue fibers contained in individual clear plastic tubes.

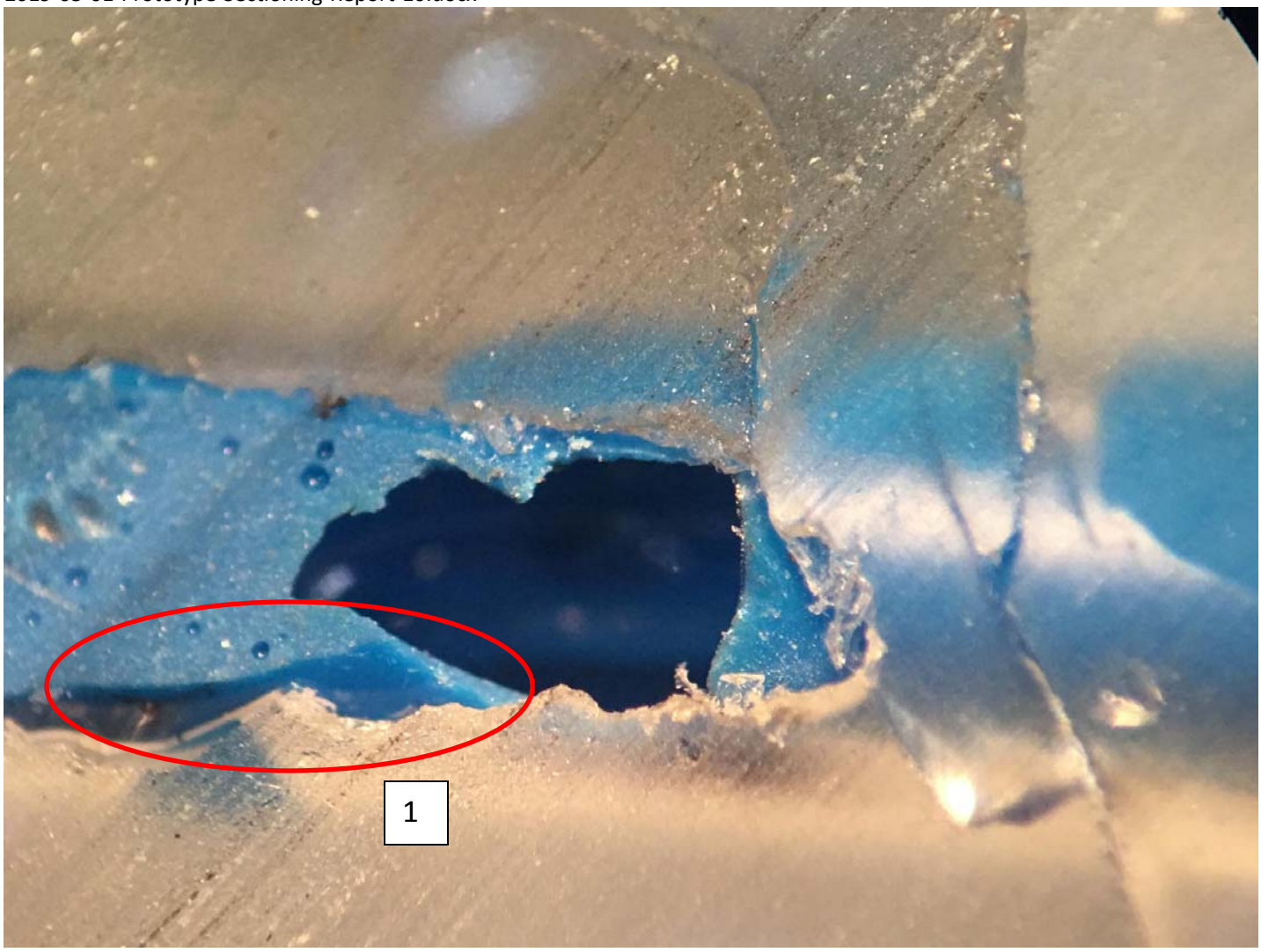


Fig 12. Close-up photo 2 of 5. Large void in the blue epoxy. Glossy surface of the blue epoxy where glass pieces broke off (1) may indicate the weak adhesion between epoxy and glass tube

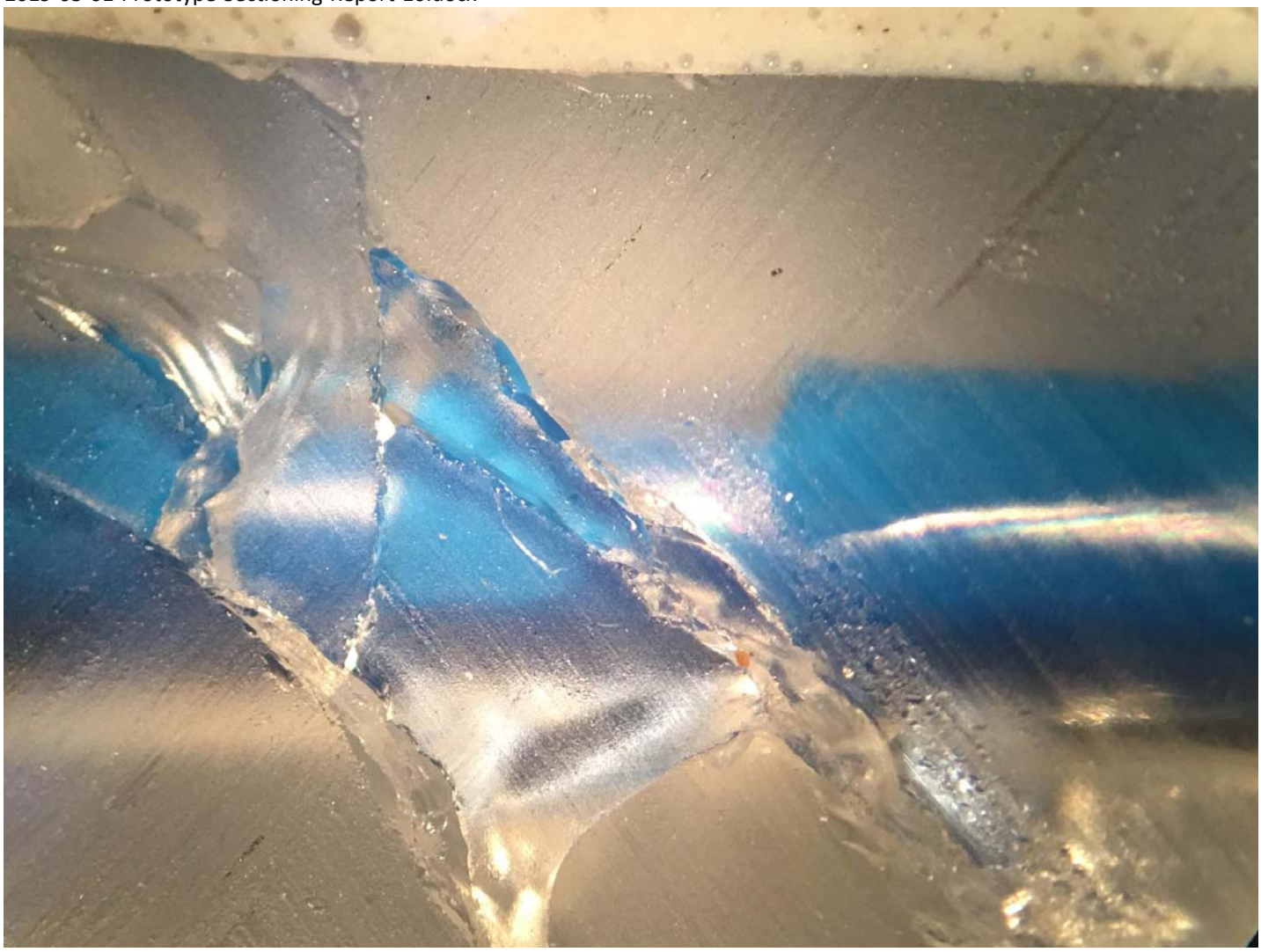


Fig 13. Close-up photo 3 of 5. Diagonal faults area in the middle of glass tube, suggesting possible fracturing under axial load (observation by Jon Erickson)

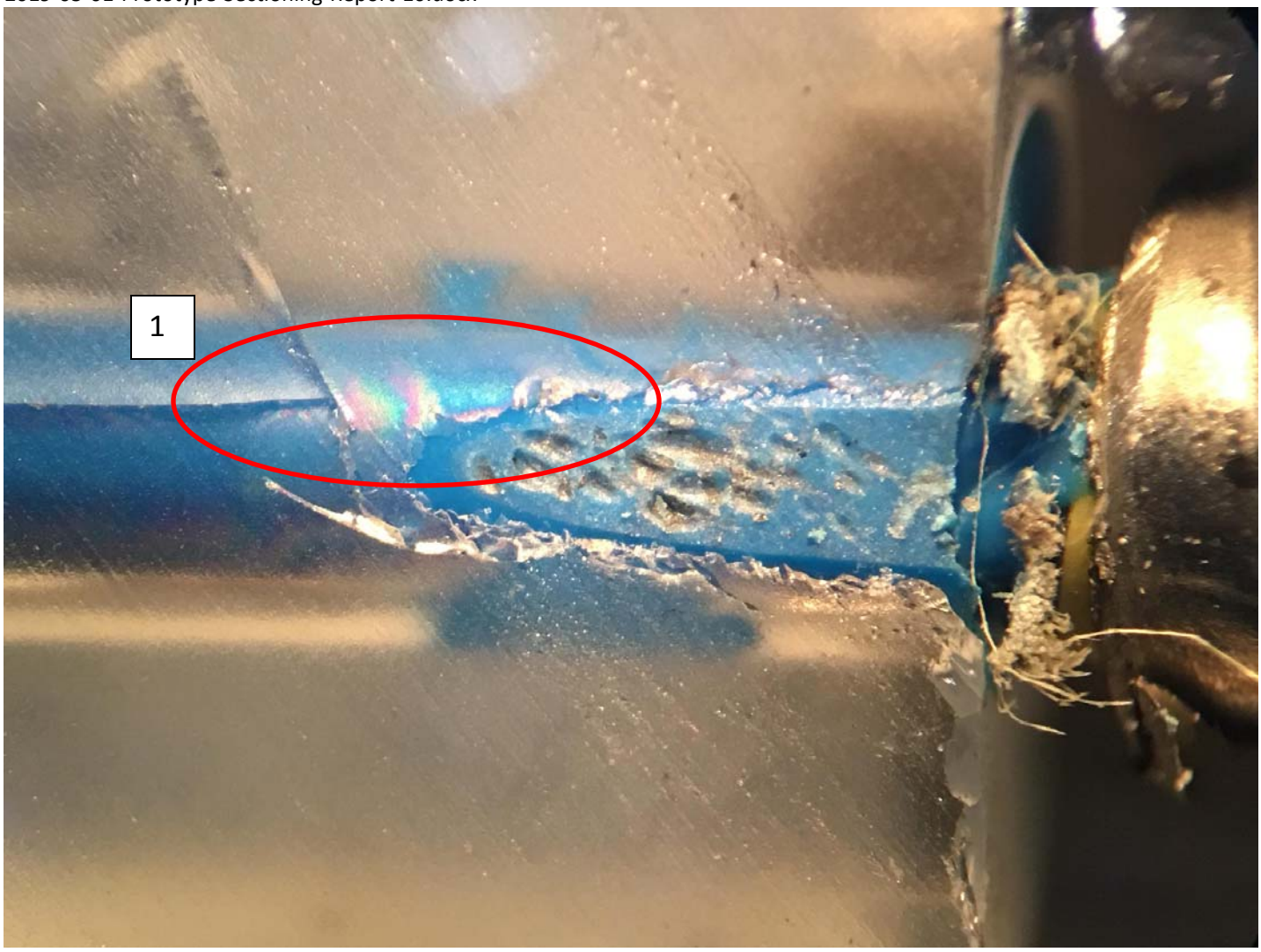


Fig 14. Close-up photo 4 of 5. Optical Interference pattern on the interface between blue epoxy and glass tube suggests the gap to be on the range of several micrometers.

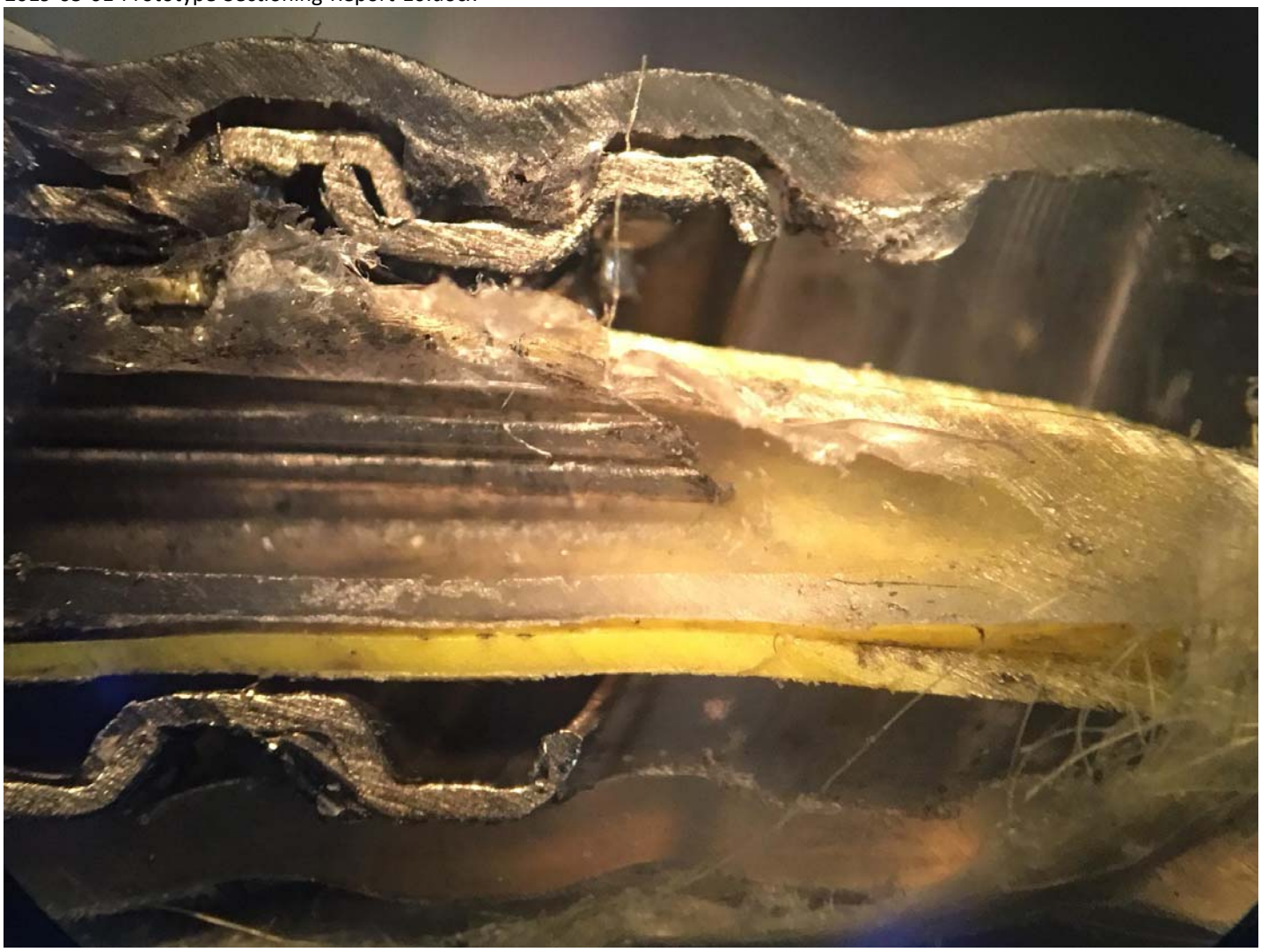


Fig 15. Close-up photo 5 of 5. Two optical fibers contained in one clear plastic tube

Project: 901809.00 DeepPIV/ Deep Sea Bioinspiration
Author: Denis Klimov (EE)

Description of issue: SMF-28 fiber received from Coastal Connections in 2019 is yellow in color as oppose to white in previous order in 2018.

- Coastal Connections indicated the products are identical (except color) from the same manufacturer (Fig 1)
- Part number description on invoices are identical (Fig 2, 3):
    - S-XXXX-9/125/.9-120 -- No Connectors on 1550nm SMF-28 Fiber with 900um tight buffer, 120 Meters Long
- Part number/ description on the spools are slightly different (Fig 4)
    - Manufacturer:
        - White, 2018 order: Nufern
        - Yellow, 2019 order: not specified
    - Fiber:
        - White, 2018 order: SMF-28e+
        - Yellow, 2019 order: SMF-28
- Fiber diameters:
    - Both measured to be 0.84 +/-0.01 mm
- Under microscope, cross-sections of both fibers appear to be very close in design and construction, aside from different color
    - Fig 5: view with light injection on the other side
    - Fig 6: view without light injection
- Melting test results suggest some difference in thermal properties:
    - Yellow, 2019 order:
        - Melting point of yellow buffer is lower,
        - And/ or yellow buffer has higher surface tension

Observations:

- White and Yellow buffer fibers appear to be close in design and construction, but difference between buffer materials goes further than just color, exhibiting slightly different physical properties such as melting point.
- Adhesion / comparison test is needed between white and yellow buffered fibers.

Continue to next page

Adhesion test results

- Test performed 6/6/2019 (Fig 9) (Aaron Schnittger, Denis Klimov)
- Pull test performed 6/10/2019 (Denis Klimov)

Fiber treatment	Epoxy 60 minutes EA E-60NC (black)		Epoxy 120 minutes EA E-120HP (gray)	
	White buffer fiber	Yellow Buffer fiber	White buffer fiber	Yellow Buffer fiber
Alcohol only	✓	✓	✓	✓✓
Acetone only	✓✓	✓✓✓	✓✓✓✓✓	✓✓✓✓✓
Alcohol with abrade 150	✓✓✓✓	✓✓✓✓✓	✓✓✓✓✓	✓✓✓✓✓
Acetone with abrade 150	✓✓✓✓	✓✓✓✓✓	✓✓✓✓✓	✓✓✓✓✓
Abrade only 150	✓✓✓✓✓	✓✓✓✓✓	✓✓✓✓✓	✓✓✓✓✓

Legend:

✔: Weak adhesion; fiber easily delaminates from the epoxy layer

✔✔: Moderate adhesion,

✔✔✔: Solid adhesion, but buffer material delaminated from epoxy clean and clear

✔✔✔✔: Solid adhesion, and there are traces of buffer material remains on the epoxy layer after delamination

✔✔✔✔✔: Very strong adhesion, chunks buffer material remains attached to epoxy, fiber breaks apart on delamination

Observations:

- Yellow buffer adheres better than white one.
- 120 min Epoxy adheres better than 60 min epoxy
- Mechanical abrasion is generally more effective than Acetone or Alcohol only

Conclusion:

- Combination of 120 min epoxy with easily reproducible acetone-only treatment offered top rated adhesion on both white and yellow buffered fiber.

From: "John Lu" <john@coastalcon.com>
To: "Denis Klimov" <klimov@mbari.org>
Cc: "sales" <sales@coastalcon.com>
Sent: Tuesday, June 4, 2019 1:43:22 PM
Subject: RE: RFQ - 18949

Hi Denis,

Our SMF28 900um tight buffered fiber comes from the same manufacturer.

Sincerely,
John

From: Denis Klimov <klimov@mbari.org>
Sent: Tuesday, June 04, 2019 1:08 PM
To: John Lu <john@coastalcon.com>
Cc: Sales <sales@coastalcon.com>; andy coastalcon.com <andy@coastalcon.com>
Subject: Re: RFQ - 18949

John,
is it the same manufacturer or different?

Denis Klimov

From: "John Lu" <john@coastalcon.com>
To: "Denis Klimov" <klimov@mbari.org>
Cc: "sales" <sales@coastalcon.com>, "andy" <andy@coastalcon.com>
Sent: Tuesday, June 4, 2019 12:41:31 PM
Subject: RE: RFQ - 18949

Hi Denis,

No difference in fiber, still SMF-28, just the color of the jacket is different.

Sincerely,
John

From: Denis Klimov <klimov@mbari.org>
Sent: Tuesday, June 04, 2019 12:33 PM
To: John Lu <john@coastalcon.com>
Cc: Sales <sales@coastalcon.com>; andy coastalcon.com <andy@coastalcon.com>
Subject: Re: RFQ - 18949

Hello John and Andy,
we did received the package, 120 meters of SMF-28 fiber with 900 um tight buffer, thank you!

I have a question however, it came with yellow buffer this time, as opposed of white buffer received before.

Do you think of any differences between them aside of color?

thank you!

Denis Klimov

Fig 1. Email exchange with John Lo at Coastal Connections

Coastal Connections

Remitance:
Coastal Connections
2085 Sperry Ave, Suite B
Ventura, Ca 93003
Phone: 805-644-5051
Nancy@coastalcon.com

Invoice

Invoice	Invoice Date	Due Date
17691	6/14/2018	6/14/2018

PAID 06/18/2018

Bill To

Monterey Bay Aquarium Research Institute
Attn: Denis Klimov
7700 Sandholdt Rd
Moss Landing, CA 95039
klimov@mbari.org

Ship To

Monterey Bay Aquarium Research Institute
Attn: Denis Klimov
7700 Sandholdt Rd
Moss Landing, CA 95039

P.O. No.	Terms	Ship Date	Shipped Via
Conf# 17492	Credit Card	6/14/2018	FedEx Ground

#	Item	Description	Ship	Back Order	Each	Total
1	Single-Mode Cable	S-XXXX-9/125/.9-120 -- No Connectors on 1550nm SMF-28 Fiber with 900um tight buffer, 120 Meters Long.	1	0	120.00	120.00T
		FedEx Package 1 Tracking #: 781427664589				
		Sales tax on items sold in Ventura 2017 Q2+			7.75%	9.30

Fig 2. Invoice for 2018 order

Coastal Connections

Remitance:
Coastal Connections
2085 Sperry Ave, Suite B
Ventura, Ca 93003
Phone: 805-644-5051

Invoice

Invoice	Invoice Date	Due Date
18966	5/24/2019	5/24/2019

PAID 05/28/2019

Bill To

Monterey Bay Aquarium Research Institute
Attn: Denis Klimov
7700 Sandholdt Rd
Moss Landing, CA 95039
klimov@mbari.org

Ship To

Monterey Bay Aquarium Research Institute
Attn: Denis Klimov
7700 Sandholdt Rd
Moss Landing, CA 95039

P.O. No.	Terms	Ship Date	Shipped Via
Conf# 18949	Credit Card	5/24/2019	FedEx Ground

#	Item	Description	Ship	Back Order	Each	Total
1	Single-Mode Cable	S-XXXX-9/125/.9-120 -- No Connectors on 1550nm SMF-28 Fiber with 900um tight buffer, 120 Meters Long.	1	0	120.00	120.00T
		klimov@mbari.org				
		FedEx Package 1 Tracking #: 787463928806				
		Sales tax on items sold in Ventura 2017 Q2+			7.75%	9.30

Fig 3. Invoice for 2019 order

Fig 4. Fiber spools. On the left: 2018 order (white jacket); on the right: 2019 order (yellow buffer)

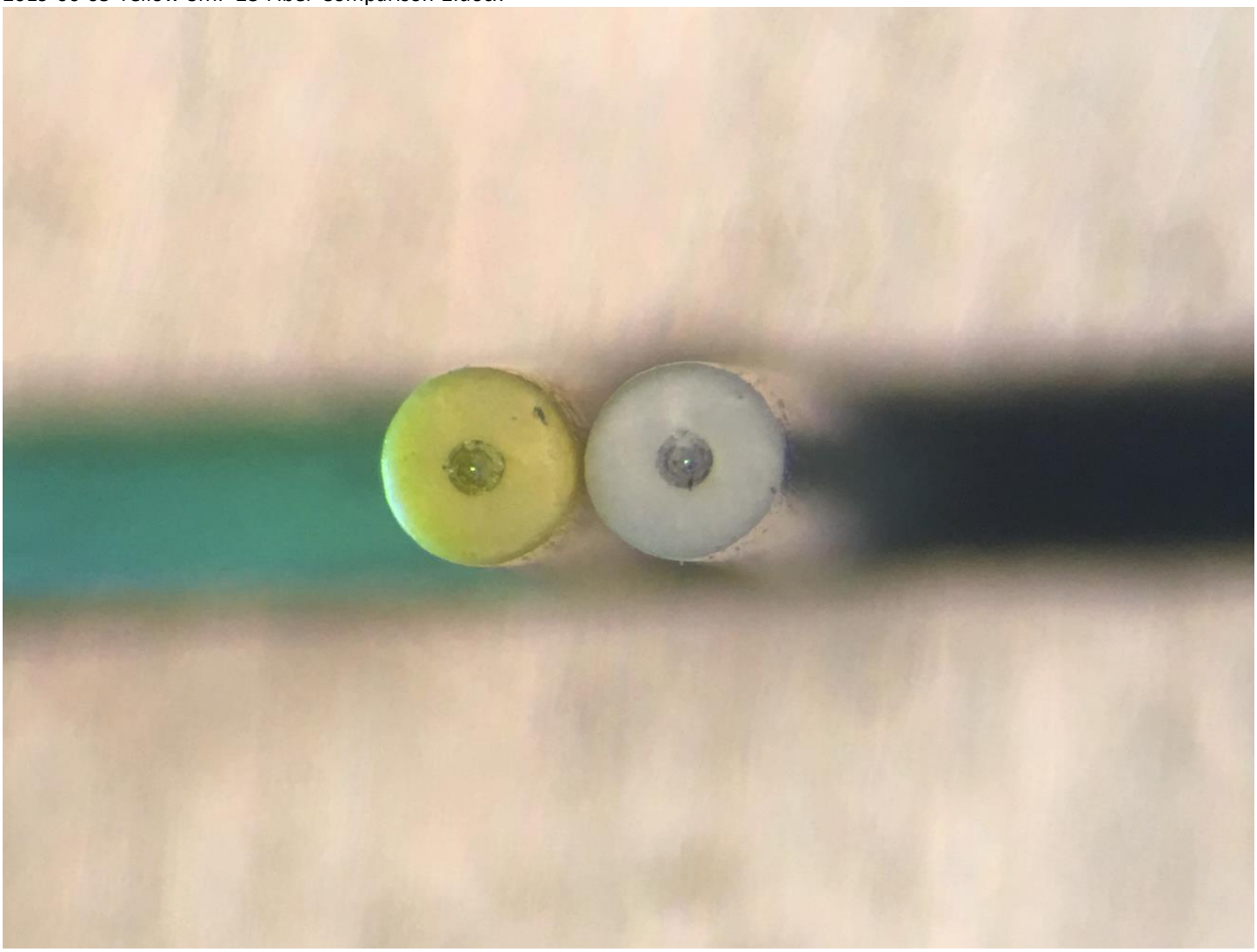


Fig 5. Photo of fiber tips with white light injected on the other side. Yellow and white fibers appear very close in construction aside of buffer color

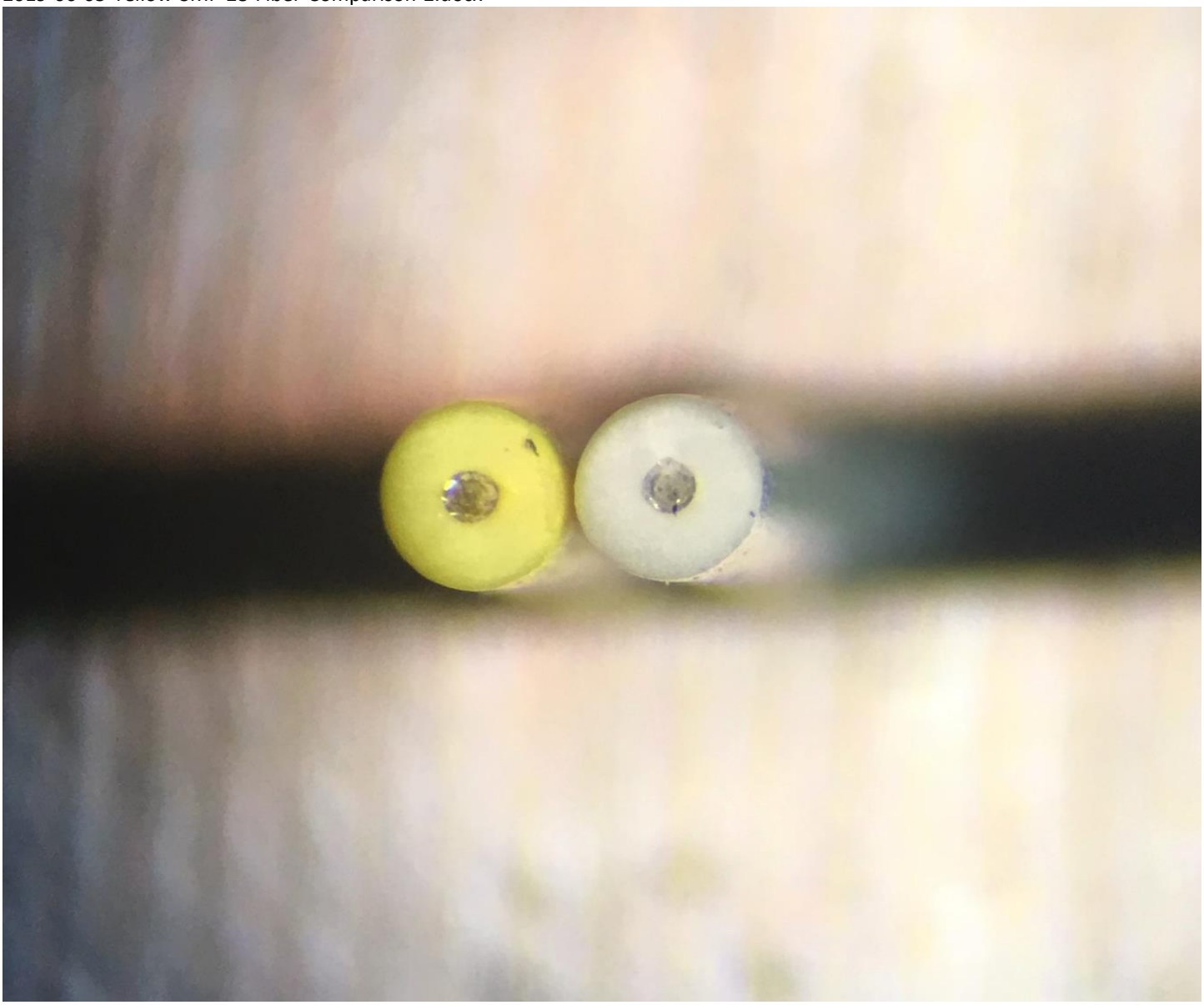


Fig 6. Photo of fiber tips illuminated from the top (no light injected). Yellow and white fibers appear very close in construction aside of buffer color

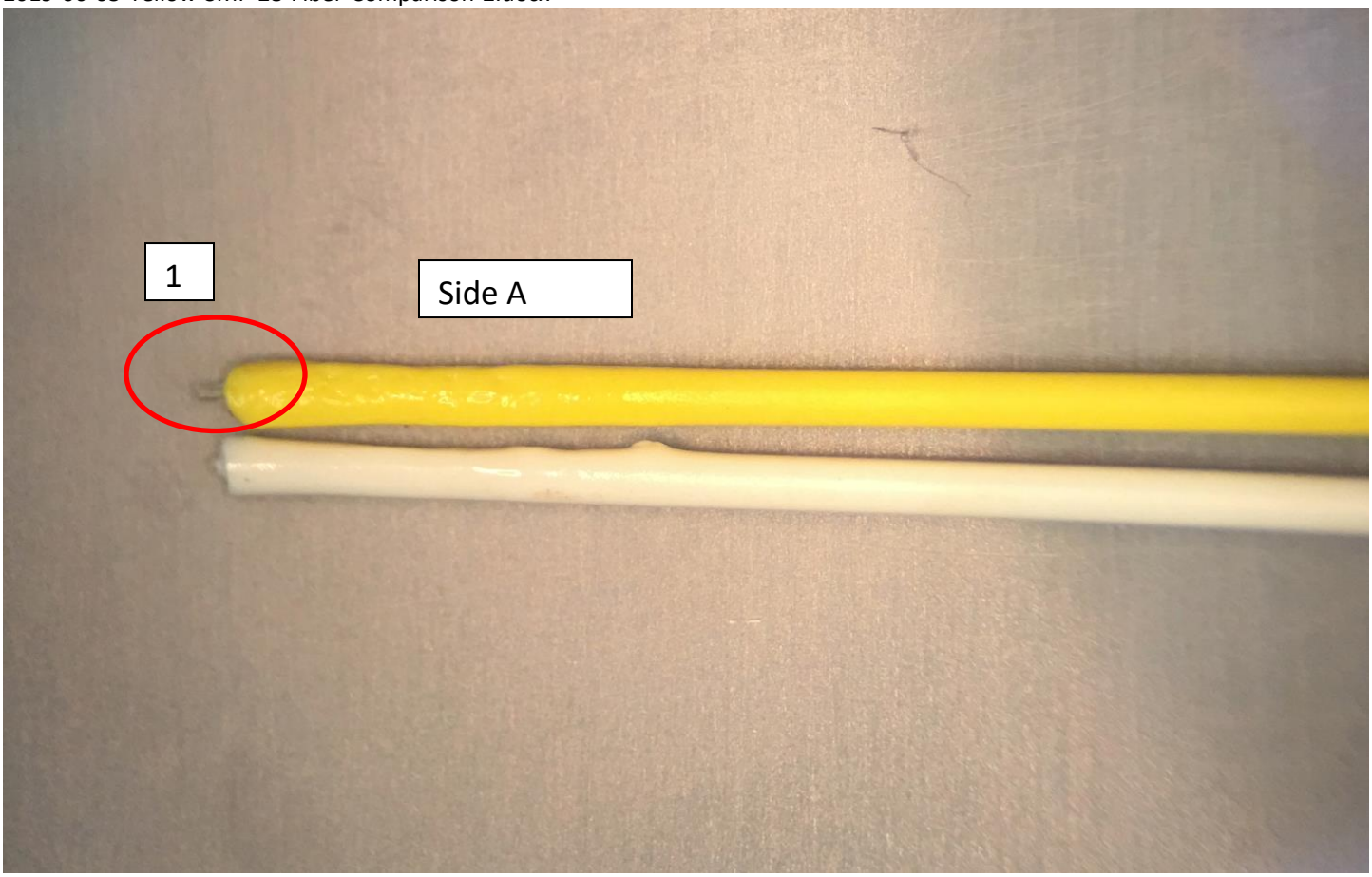


Fig 7. Two fibers (Side A) after subjected to the same hot air flow with 190C temperature. Note that as result of exposure resulting with softening/ melting, the yellow buffer retracted more than white buffer suggesting lower melting temperature, and/or higher surface tension

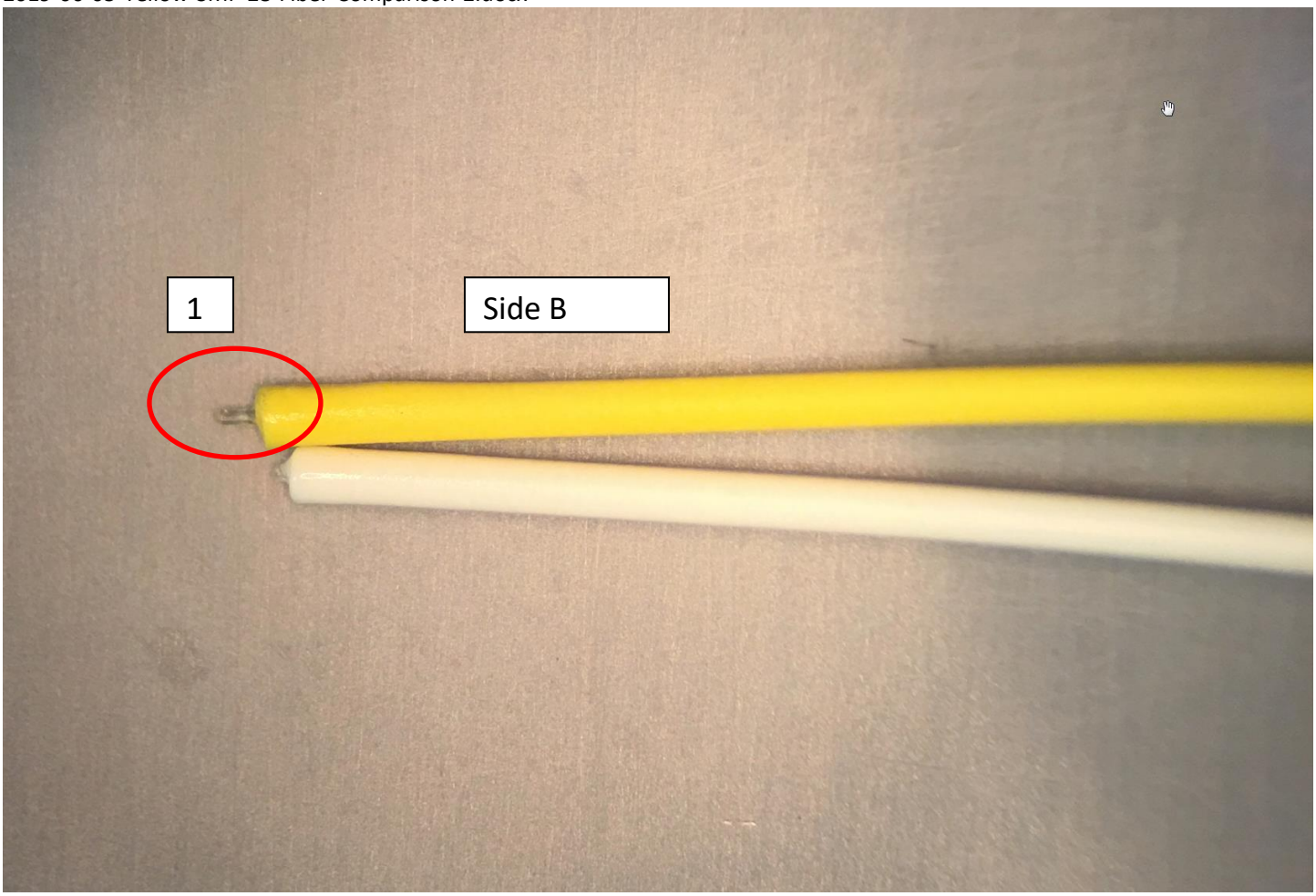


Fig 8. Same as Fig 6; except Side B was exposed to the same hot air conditions, with the same result: yellow buffer retracted more than white buffer suggesting lower melting temperature, and/or higher surface tension

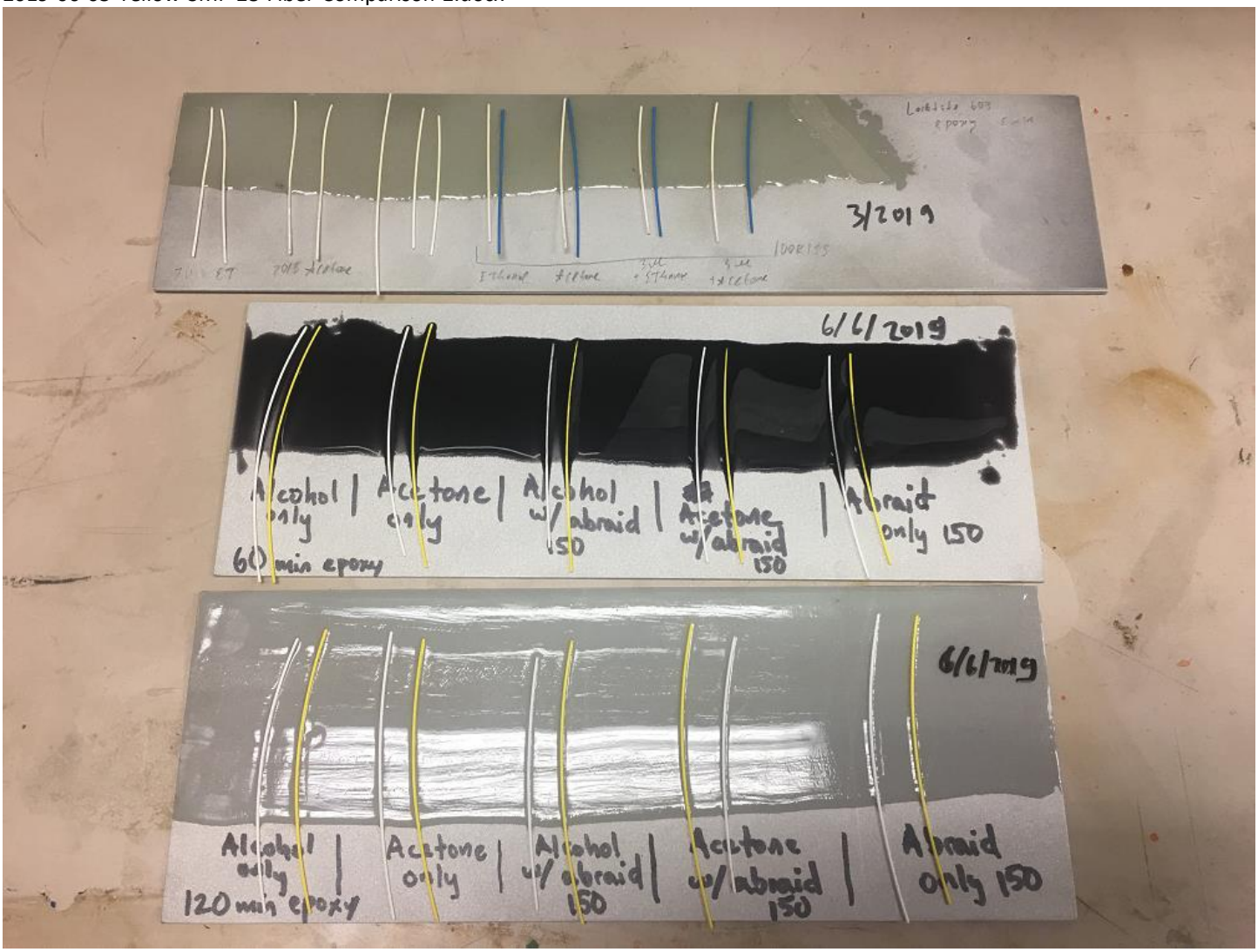


Fig 9. Adhesion test:
Top panel: 3/2019; epoxy 5-minutes Loctite 603
Middle panel: 6/6/2019, epoxy 60 minutes EA E-60NC
Bottom panel: 6/6/2019, epoxy 120 minutes EA E-120HP
In all cases epoxy is cured at room temperature minimum of 2 days.

2019-06-07-Stainless-Steel-316-Adhesion-1.docx

Project: 901809.00 DeepPIV/ Deep Sea Bioinspiration

Author: Denis Klimov (EE)

Description of issue: test of adhesion of epoxy to 316 Stainless Steel with various surface treatments

- Samples process description:
  - 4 samples were produced from cutting fiber optic penetrator into 4 segments (Fig 1)
  - Samples were treated differently (see Fig 1), cleaned with acetone, and layer of epoxy was applied to each (6/14/2019 at 18:00)
  - Samples were cured over the weekend at room temperature
- Pull test was conducted 6/17/2019 at 10:00

Fiber treatment	Epoxy 60 minutes EA E-60NC (black)
Sample #1 (control)	✓
Sample #2 (hone finish)	✓✓
Sample #3 (acid etching plus bead blasting)	✓✓✓
Sample #4 (acid etching)	✓✓✓✓✓

Legend:

✔: Very weak adhesion; epoxy easily delaminates clear from the metal

✔✔: Weak adhesion, epoxy delaminates clear from the metal with some effort

✔✔✔: Moderate adhesion, epoxy breaks off the metal in pieces

✔✔✔✔:

✔✔✔✔✔: Very strong adhesion, layer of epoxy material remains attached to the metal

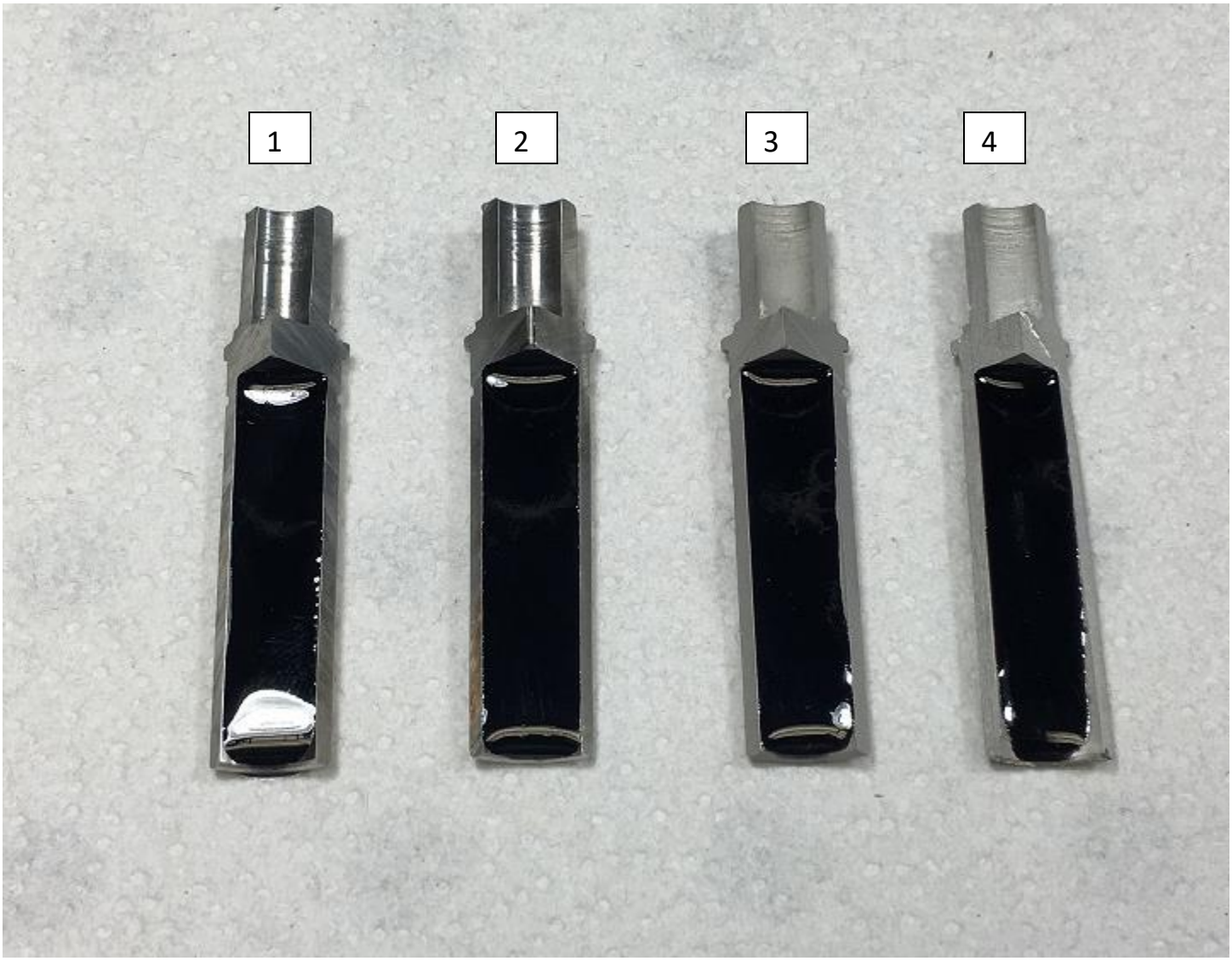


Fig 1. Samples of fiber optic penetrator made of 316 Stainless Steel, sliced in 4 sectors, with epoxy applied:

Sample 1: Original machining finish (lathe), control sample
Sample 2: Honing finish, applied by rotating and reciprocating abrasive wheel (Fig 2).
Sample 3: HCl acid etching (Fig 3), followed by bead-blasting
Sample 4: HCl acid etching (Fig 3)

Epoxy used: 60 minutes EA E-60NC (black)
Surface cleaning before application of epoxy: acetone (on all samples)

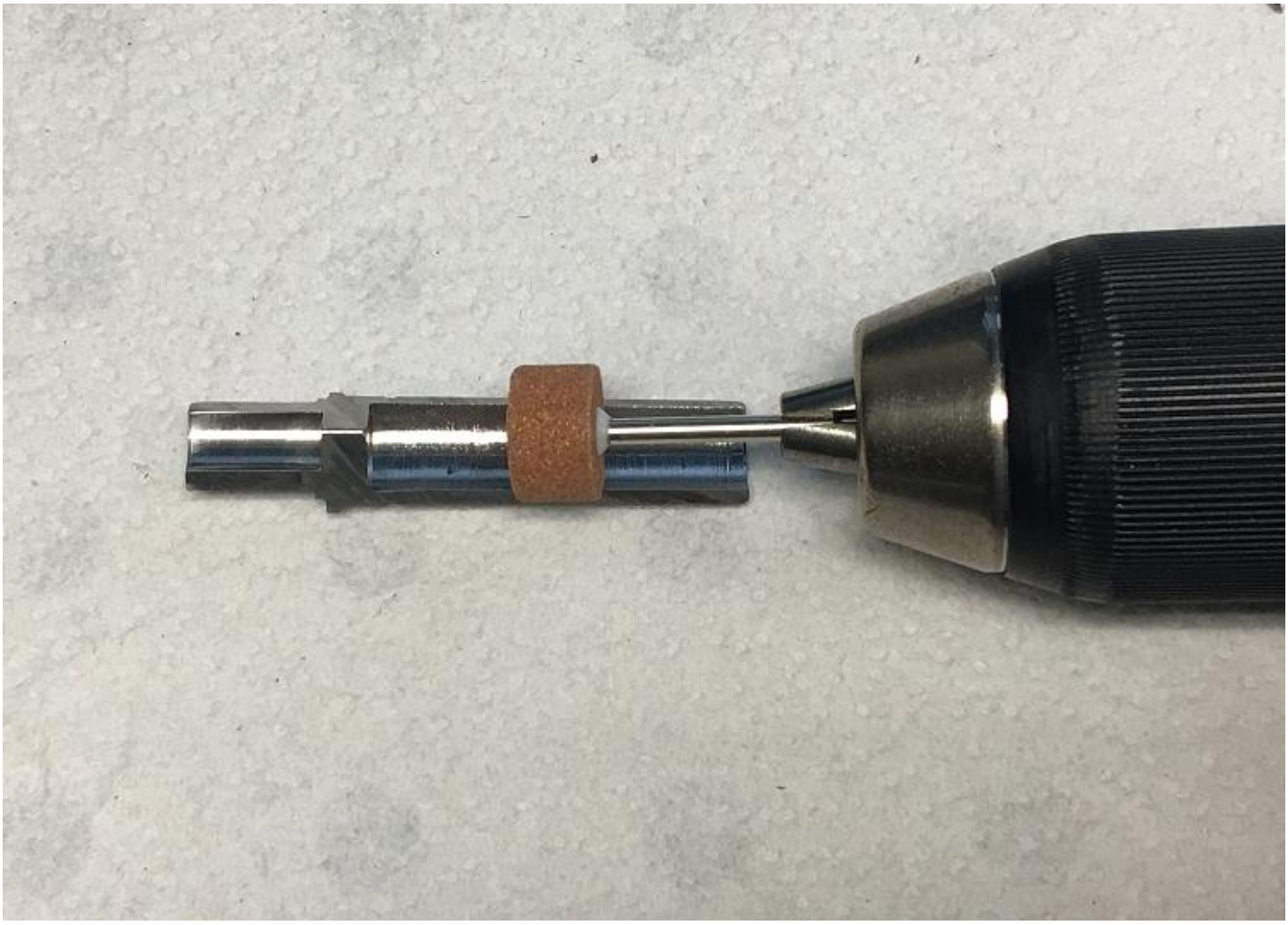


Fig 2. Sample #2, application of honing finish

Fig 3. Samples #3 and 4#, application of etching finish by concentrated HCl acid overnight ~ 17 hours. One of samples was followed up with bead blasting on both sides and became sample #3

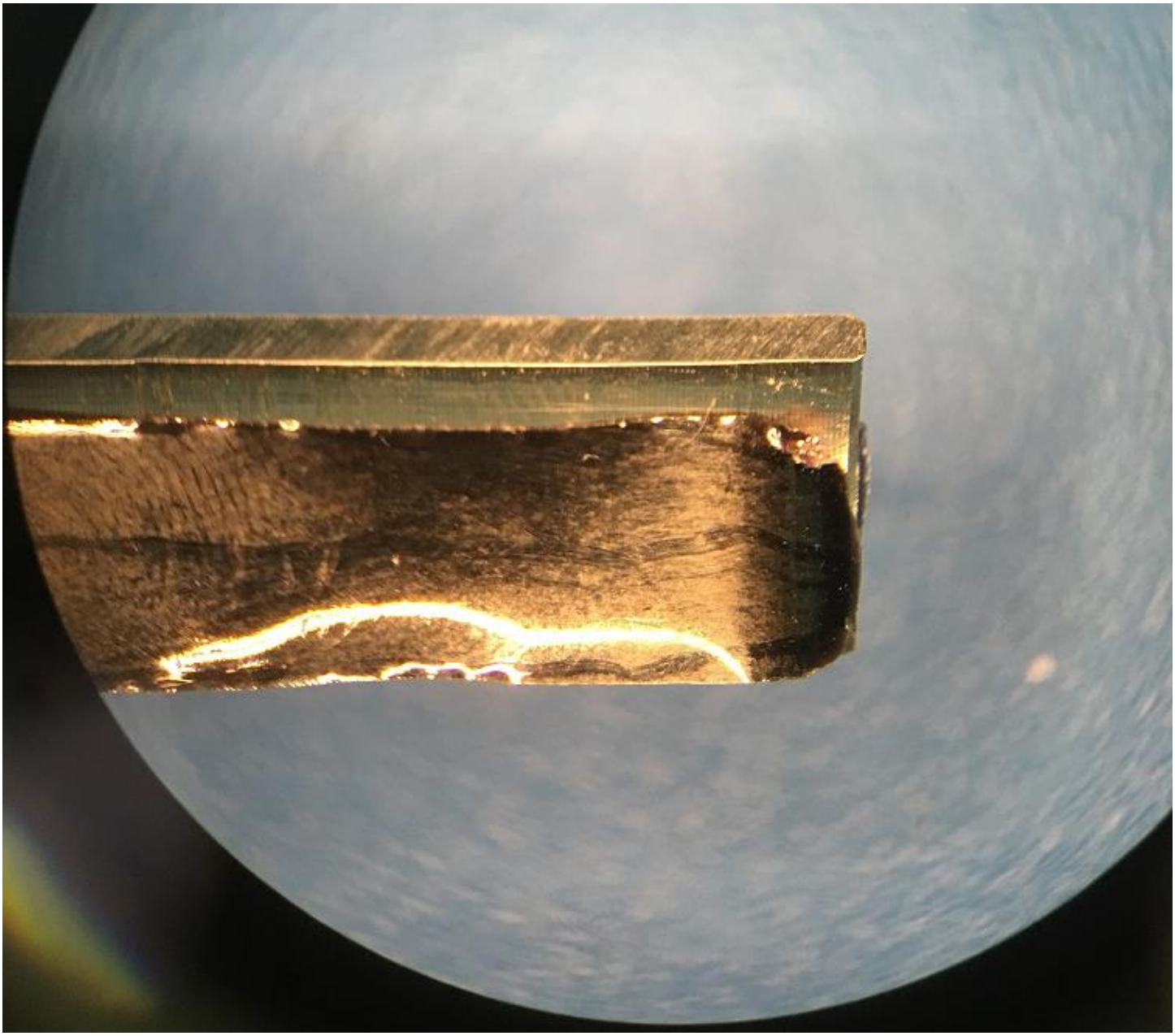


Fig 4. Pull-test on sample #1 (control). Clean separation of epoxy from metal

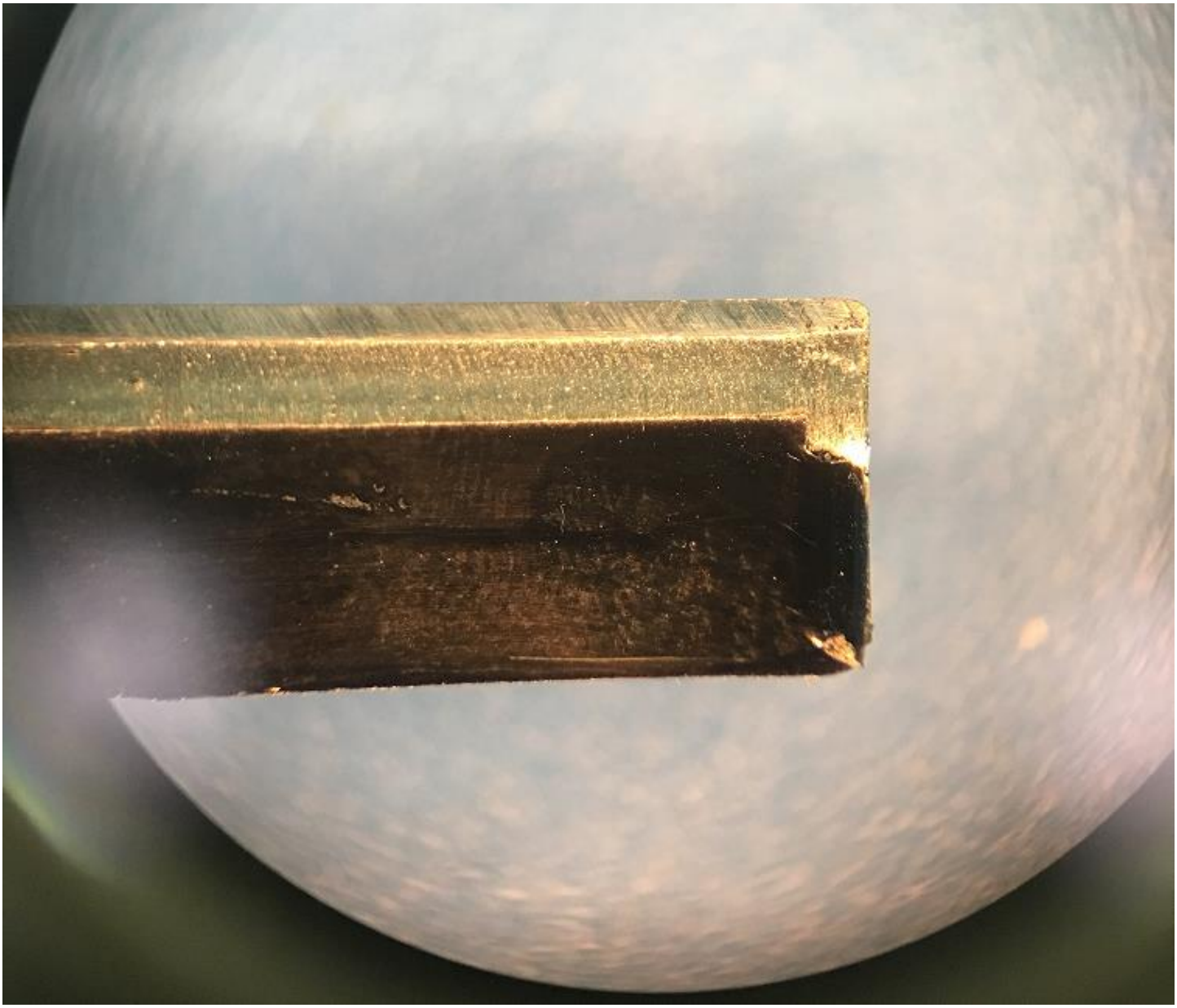


Fig 5. Pull-test on Sample #2 (hone finish). Clean separation of entire epoxy strip from metal with slightly higher force compare to Sample #1

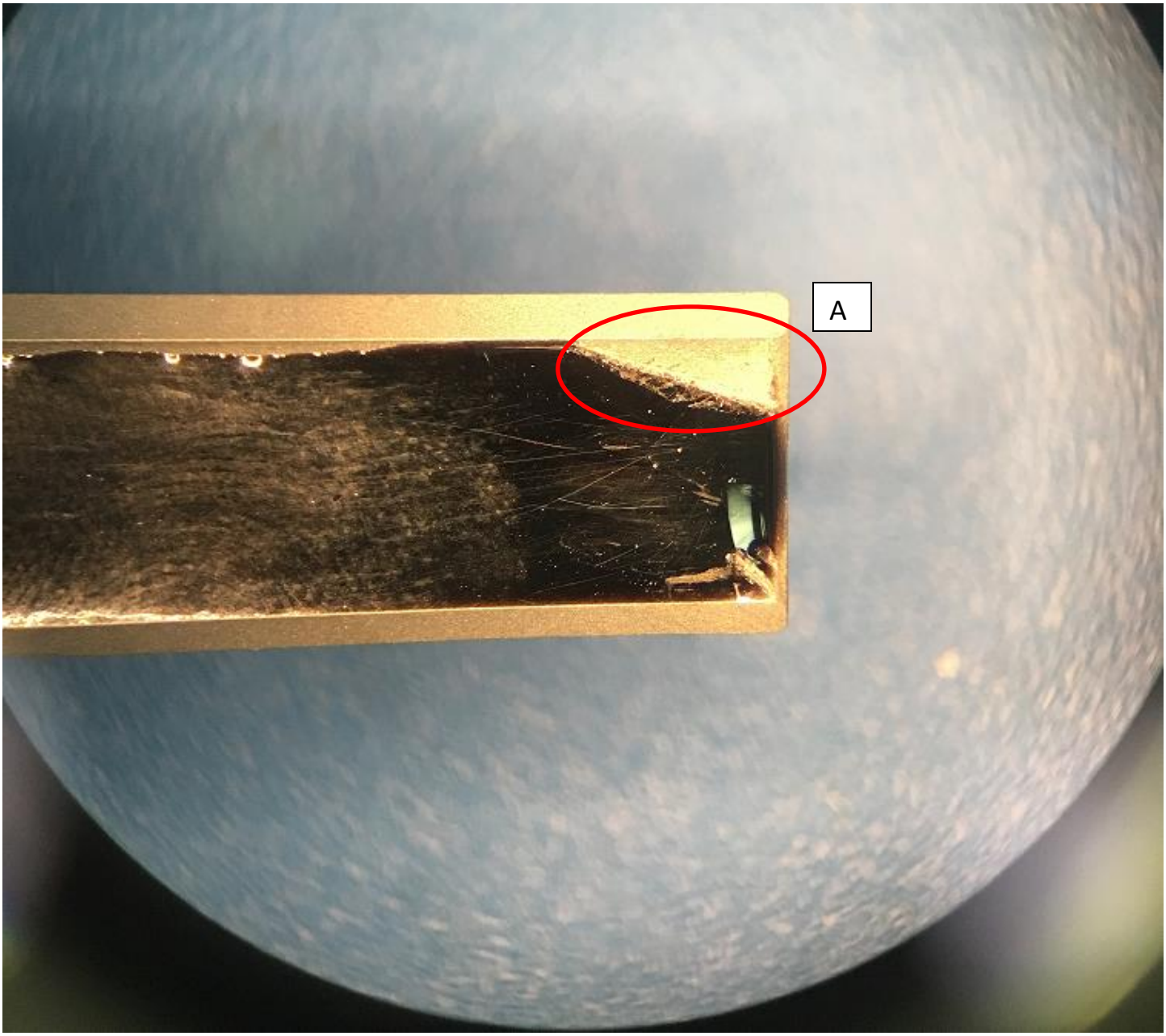


Fig 6. Pull-test on Sample #3 (acid etching plus bead-blasting). Small pieces (A) can be broken off the epoxy strip relatively clean but the rest is staying attached.

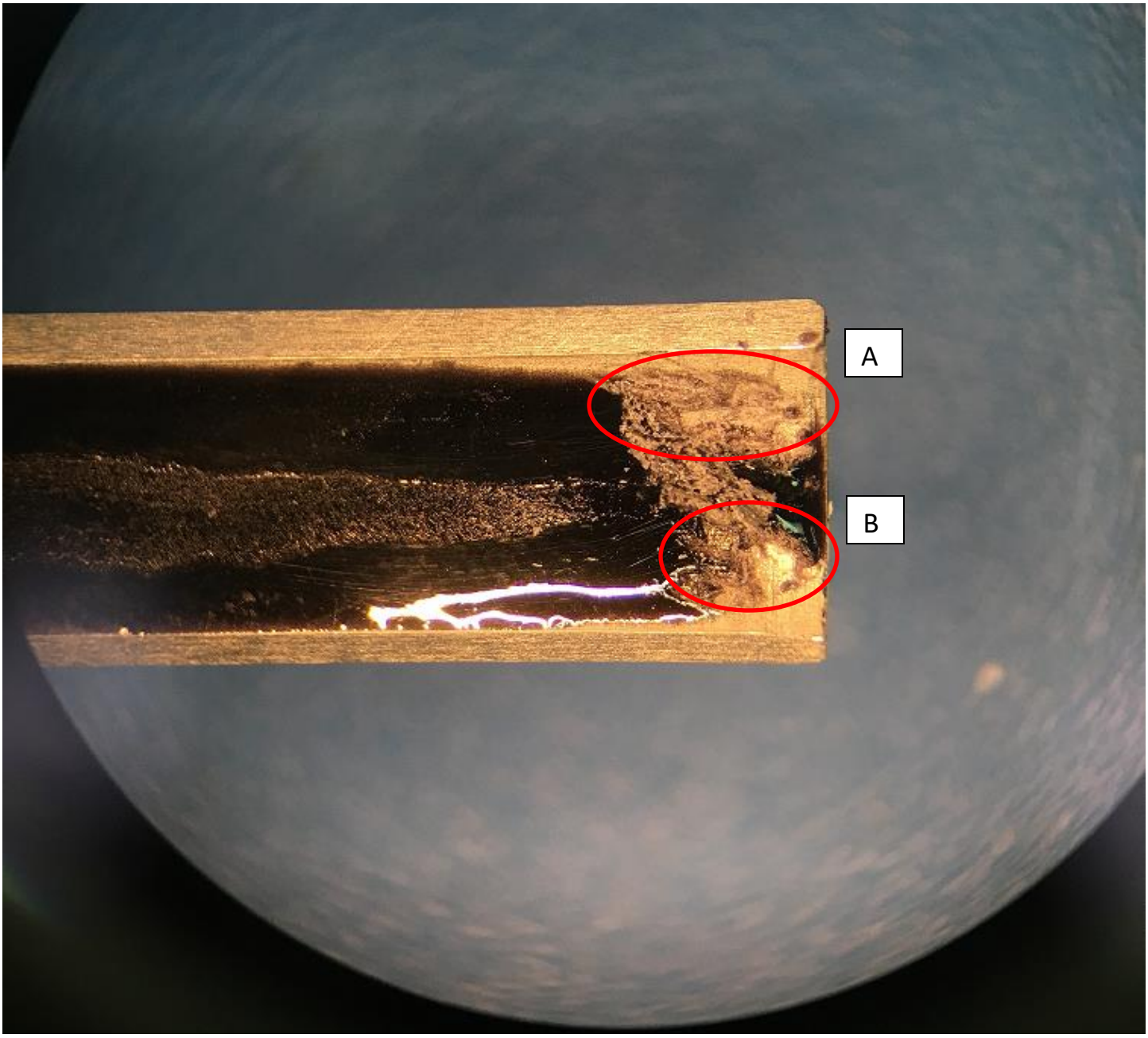


Fig 7. Pull-test on Sample #4 (acid etching). Small pieces (A, B) can be broken off, but the layer of epoxy is still attached to metal indicating excellent adhesion

2019-06-19-Stainless-Steel-316-Adhesion-by-Time-2.docx

Project: 901809.00 DeepPIV/ Deep Sea Bioinspiration
Author: Denis Klimov (EE), with input from Edward Peltzer
Related document: "2019-06-07-Stainless-Steel-316-Adhesion-1"

Description of issue: In a test on type of surface treatments, it was determined that chemical etching is superior for epoxy adhesion compare to untreated stainless steel as well as mechanical honing and bead blasting (report file name "2019-06-07-Stainless-Steel-316-Adhesion-1.doc"). Overnight ~ 17 hours immersion exposure to large amount of the HCl acid was used, which was probably exxesive, with black and white deposits on the surface observed, which took some effort to clean. Here, the goal is to optimize the treatment time with acid added to the cavity of the fiber optic penetrator only.

- Sample process description (6/18/2019, with Edward Peltzer)
  - A fiber optic penetrator is prepared for acid etching by plugging the bottom hole with modeling clay from the short cavity side or bottom as seen on Fig1.
  - Fiber optic penetrator is placed into beaker and concentrated HCl acid is added into cavity using 3ml polyethylene disposable pipette (Fig 1)
  - Sample is checked every hour:
    - 1 hour exposure; internal walls appeal light gray (Fig 2)
    - 2 hours exposure; foam is visible at the surface of the acid (Fig3)
  - After 2 hours exposure, the acid is removed by means of pipette, and fiber optic penetrator washed with tap water and DI water; and tried.
- Epoxy application and pull test.
  - Fiber optic tube is cleaned with acetone by pouring acetone in, and out, and dried at room temperature
  - Epoxy (60 minutes EA E-60NC, black) is applied to the internal surface; and cured for 24 hours at room temperature
  - Pull test is performed using tweezers by prying the layer of epoxy off the stainless steel surface (Fig 4).
- Results and comparison to 17 hours etched sample (6/19/2019)
  - Almost clean separation of epoxy layer from 2-hour etched stainless steel with considerable effort was observed; with edges and some traces of epoxy remain attached (Fig 5)
  - Surface structures are visually compared between 2 hours and 17 hours etching sample (Fig. 5-7). Deeper, more developed granular structure is evident in 17 hours sample
  - Results of pull test in table below.
- Continued etching 6/20/2019 (Peltzer, Klimov)
  - Adding 6 hours of etching to previously 2 hours etched part (Fig. 8)
  - Etching new 0.4"-bore part for 4 hours (Fig. 9)

Fiber treatment	Epoxy 60 minutes EA E-60NC (black)
Sample #4 from 2019-06-07 report (acid etching 17 hours)	✓✓✓✓✓
Sample #5 (2 hours etching)	✓✓✓

Legend:
✔: Very weak adhesion; epoxy easily delaminates clear from the metal
✔✔: Weak adhesion, epoxy delaminates clear from the metal with some effort
✔✔✔: Moderate adhesion, epoxy breaks off the metal in pieces and layer delaminates with considerable effort
✔✔✔✔: Moderate adhesion, epoxy breaks off the metal in pieces but bulk remains attached.
✔✔✔✔✔: Very strong adhesion, layer of epoxy material remains attached to the metal even with heavy scraping

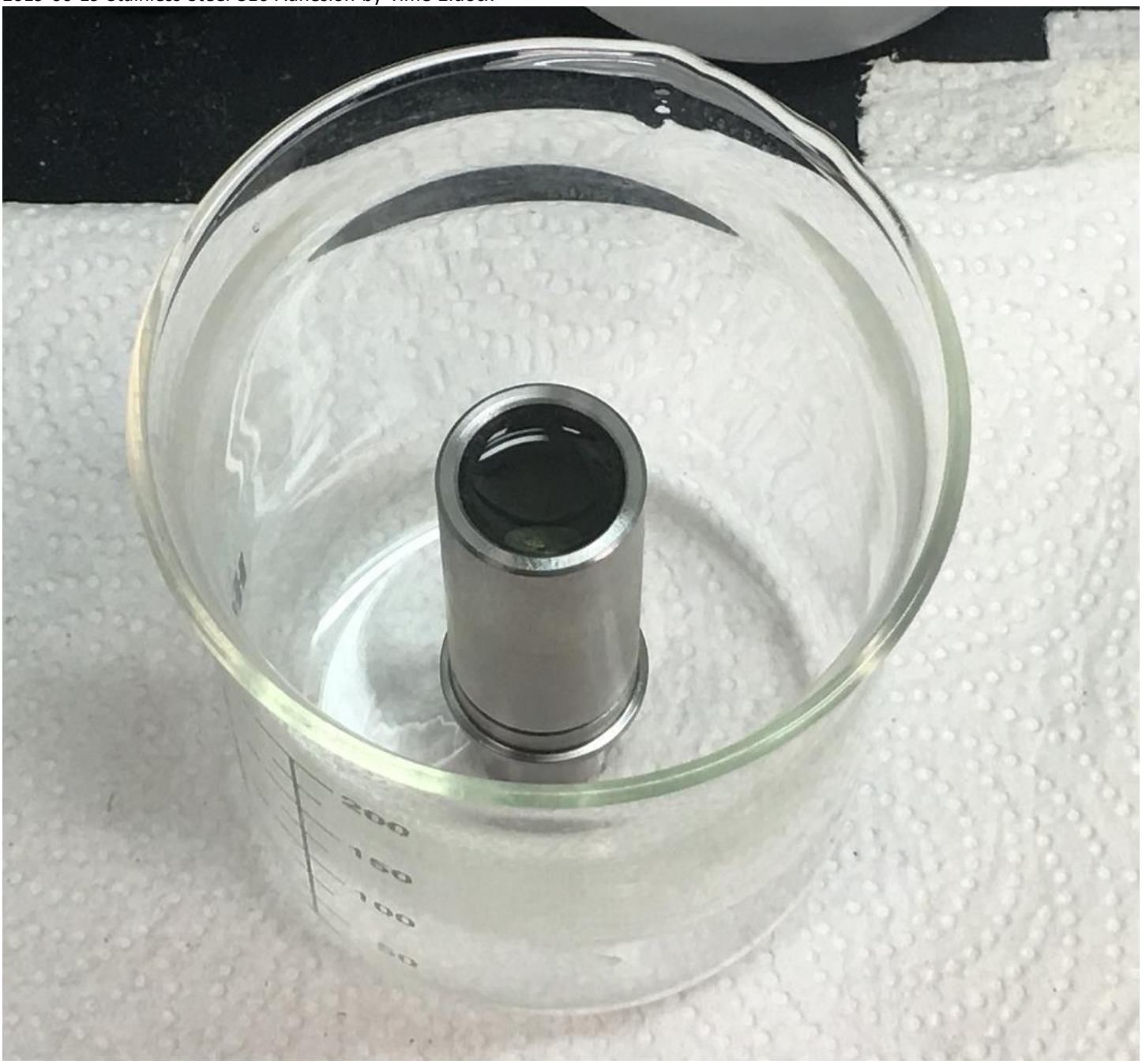


Fig 1. Fiber optic penetrator is placed into beaker and concentrated HCl acid is added into cavity ~ 2 mm below the top. Here, photo is taken several minutes after adding acid (0 hours)

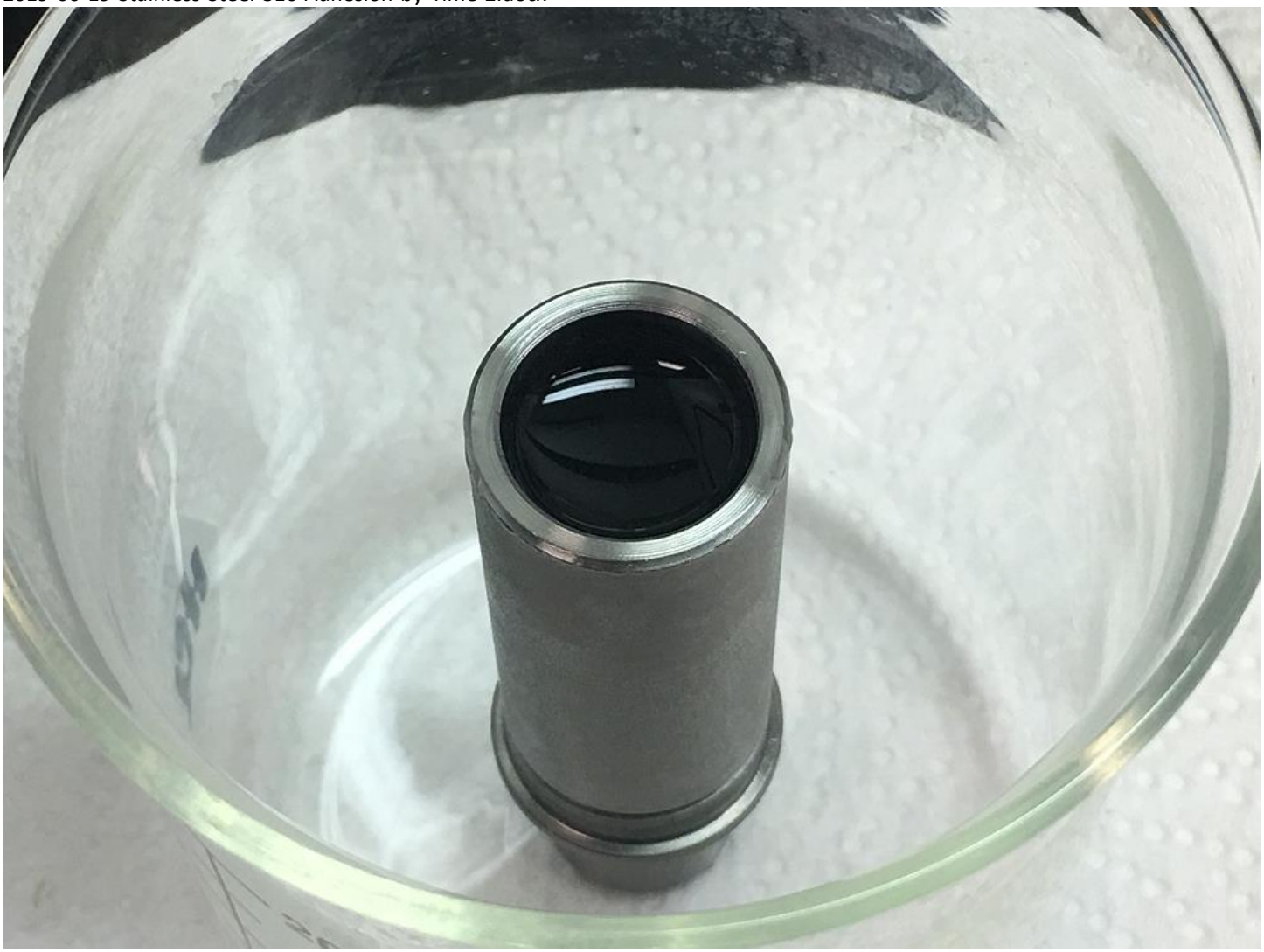


Fig 2. Fiber optic penetrator after 1 hour of exposure to concentrated HCl acid (6/18/2019)

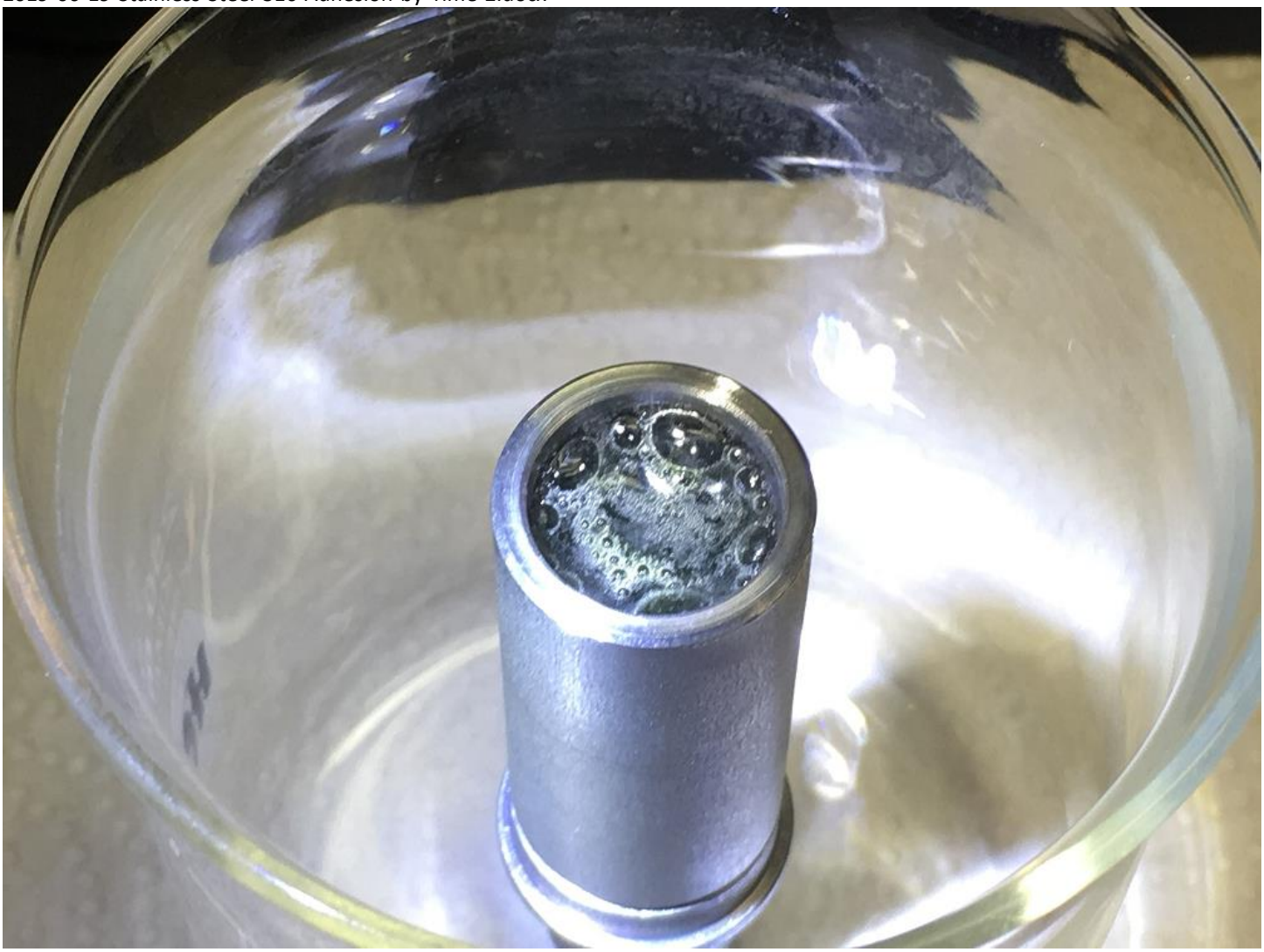


Fig 3. Fiber optic penetrator after 2 hours of exposure to concentrated HCl acid. Foam appearing on the acid surface. (6/18/2019)

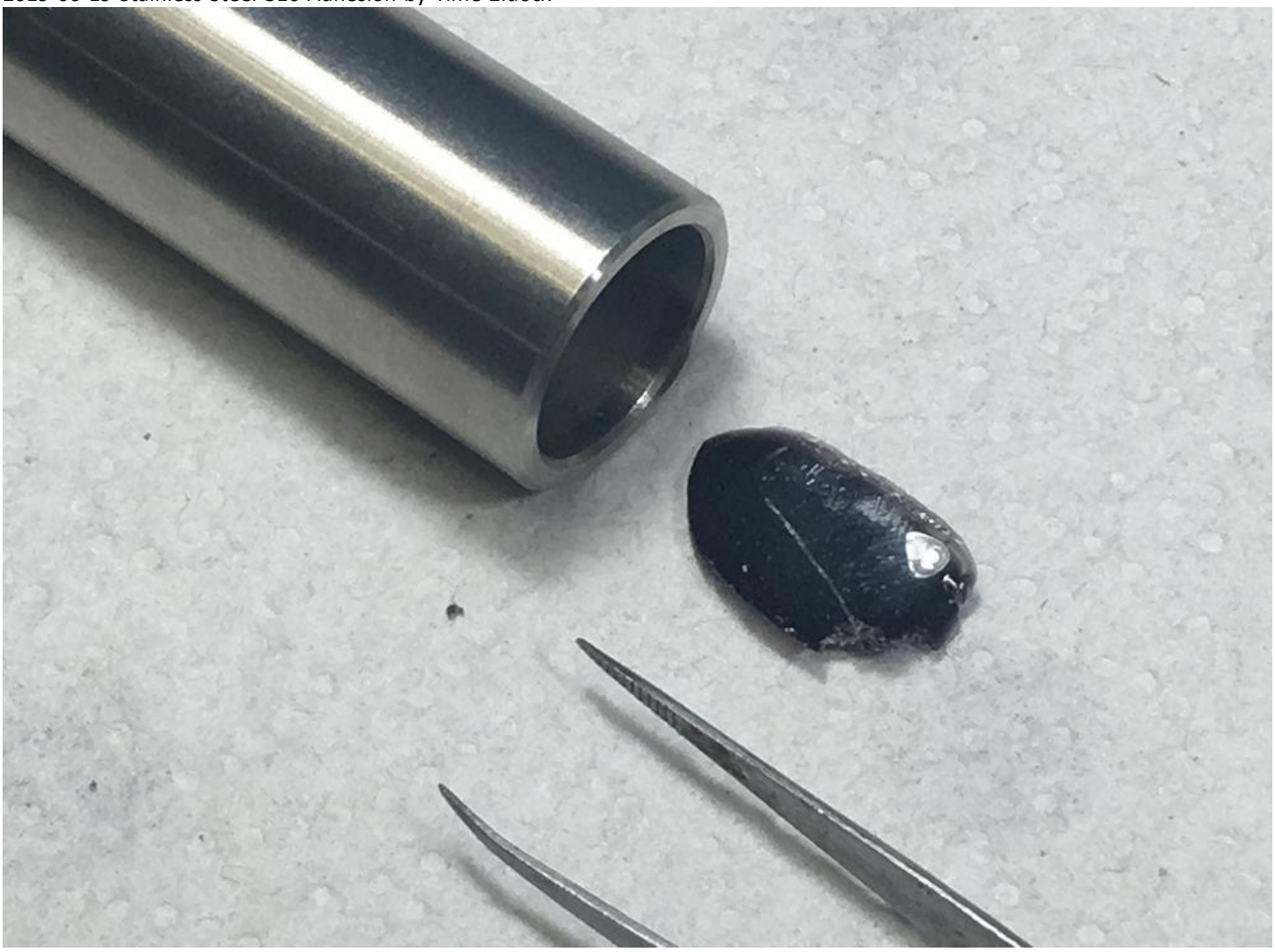


Fig 4. Pull-test on a sample #5 (2-hours etching). Almost clean separation of epoxy from metal with considerable efforts

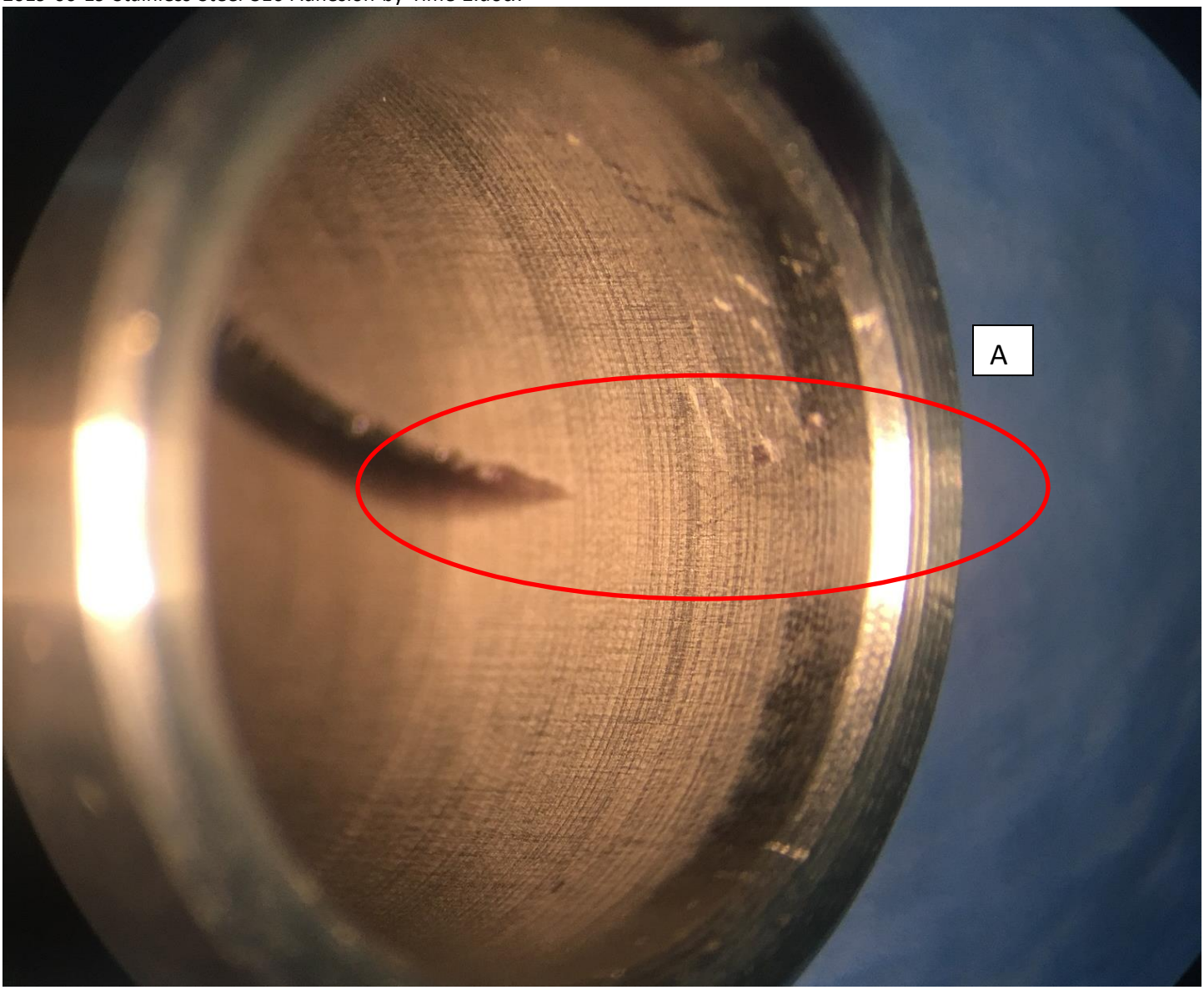


Fig 5. Sample #5 (2 hours etching) internal wall. Area "A" is compared with 17 hours etching sample #4 (see Fig 7)

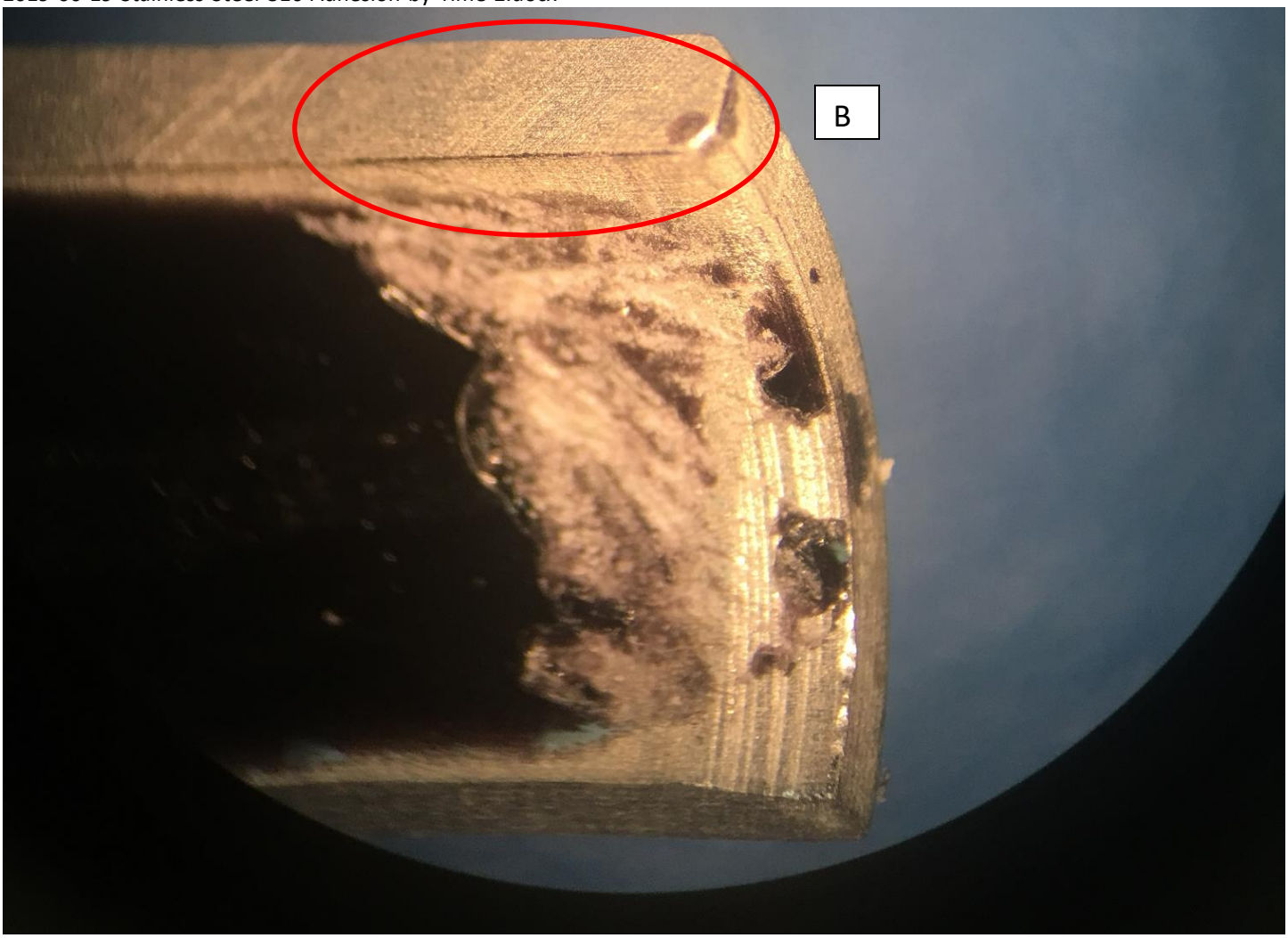


Fig 6. ~17 hours etched sample #4 from previous report. Area "B" is compared with 2 hours etching sample #5 (see Fig 7)

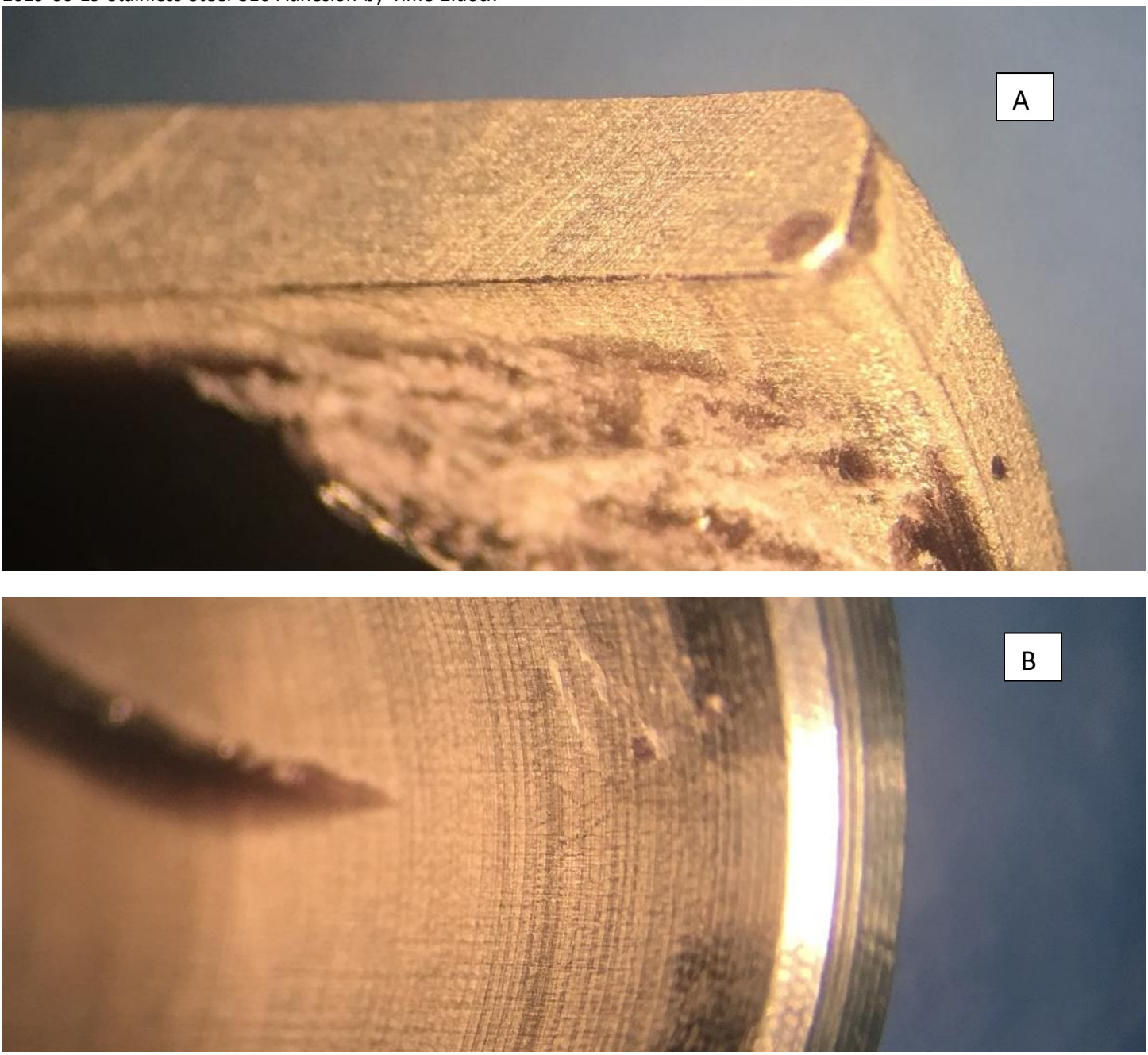


Fig 7. Visual comparison of surface structure between 17 hours etched sample #4 (A) and 2 hours etched sample #5 (B). Deeper, more granular surface structure is evident in 17 hours sample.

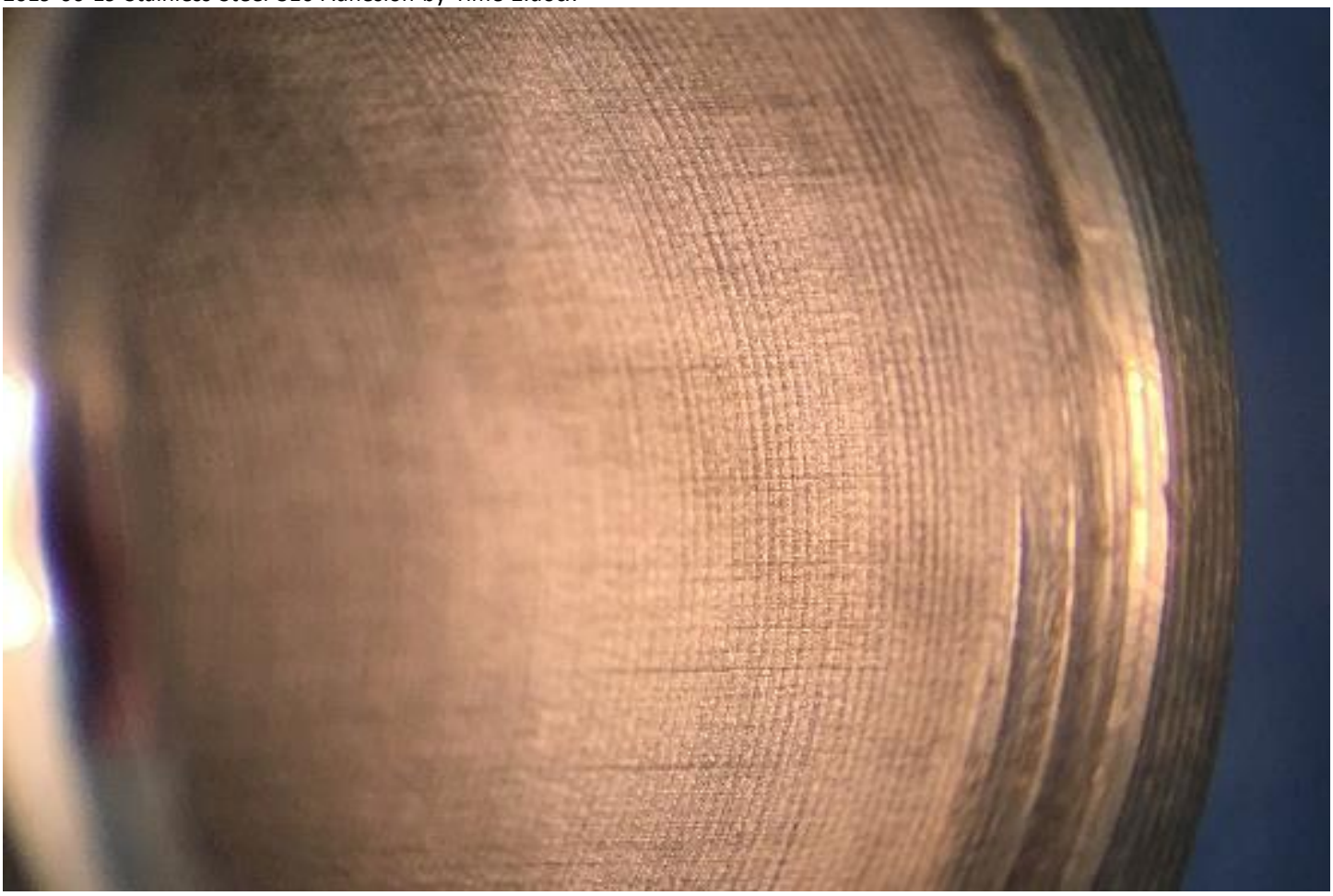


Fig 8. Additional 6 hours of etching in 2-hours intervals (8 hours total) (6/20/2019, Peltzer, Klimov)

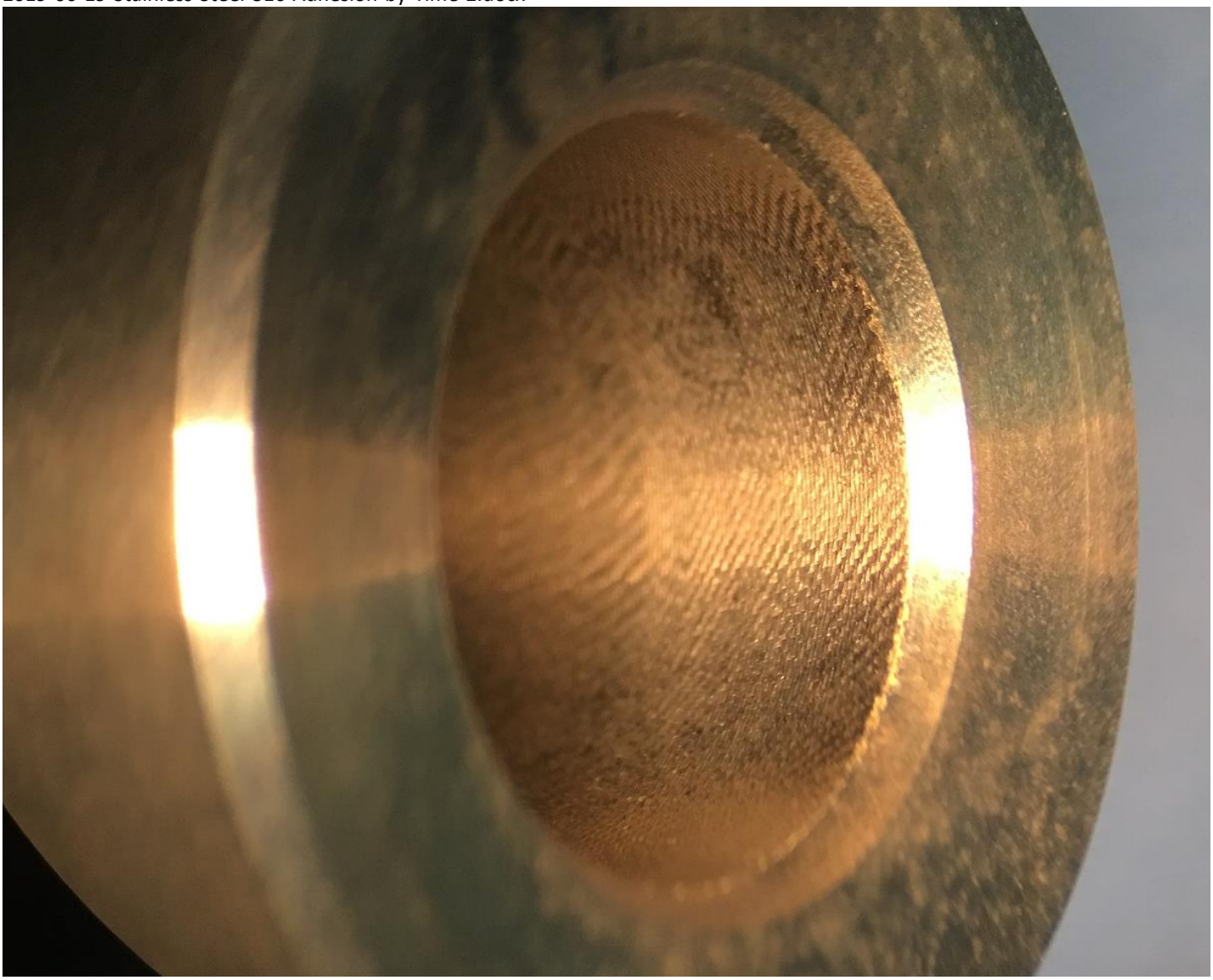


Fig 9. New 0.4”-bore penetrators, 4 hours of etching in 2-hours intervals (6/20/2019, Peltzer, Klimov)

2019-10-01-Acrylic-Cylinder-test.docx

Project: 901809.00 DeepPIV/ Deep Sea Bioinspiration

Author: Denis Klimov (EE), with input from Aaron Schnittger

Description of issue: despite the improved adhesion of hard epoxy to the inner wall of the fiber optic penetrator, the test assembly leaked yet again. We suspect the shrinkage of the epoxy to be a reason for physical reduction of the dimeter of the fill, with epoxy pulling off the inner wall.

- This is a test of epoxy shrinkage, visualized via model of fiber optic penetrator made of cast acrylic
  - Acrylic part is 1.000" OD x 2.000" Long
  - Inner cavity is 0.400" ID x 1.800" Long mimicking the cavity of the stainless steel penetrator.
- Hard epoxy test (Samples 1-3, **Fig 1**)
  - Sample 1: 7/8/2019 hard black epoxy, with yellow fiber. Delamination from the inner wall observed after epoxy had being cured, visible on the photo.
  - Sample 2: 7/9/2019 hard black epoxy, with strain relieve tube installed. No delamination from inner wall observed.
  - Sample 3: 7/8/2019 hard black epoxy fill. Delamination from the inner wall observed after epoxy had being cured, and is visible on the photo
- Hard epoxy + Devcon rubbery fill (Samples 4-5, **Fig. 2**)
  - Sample 4: Hard black epoxy (volume A) + Devcon rubbery (Volume B). No delamination.
  - Sample 5: Hard white epoxy (volume A) + Devcon rubbery (Volume B). No delamination

Conclusions:

1. Shrinkage and delamination of epoxy in the volume mimicking real assembly, is confirmed.
2. Two-volume fill with rubbery top fill did not experience delamination.

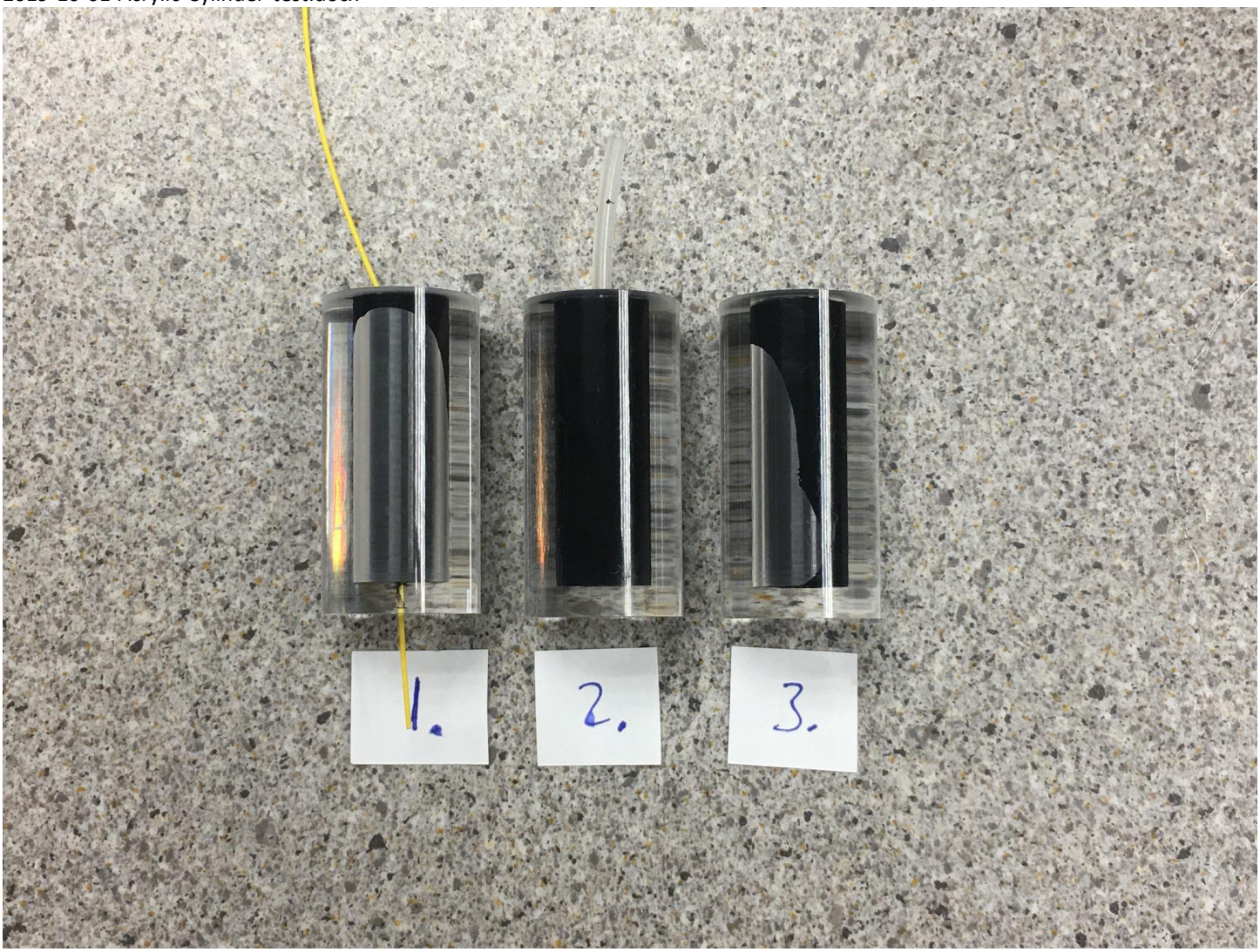


Fig 1. Hard epoxy, single fill volume samples

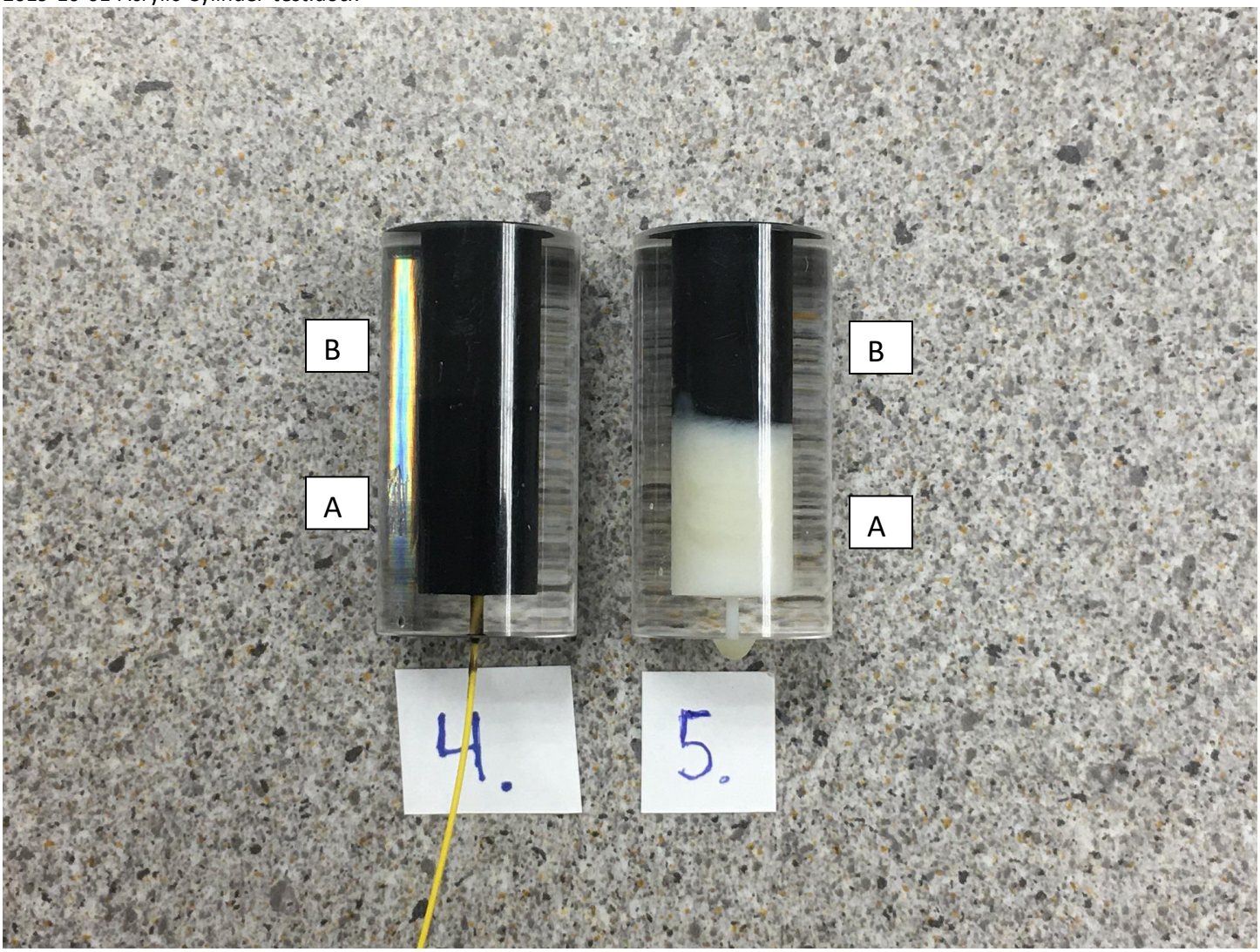


Fig 2. Two-volume fill, hard epoxy (Volume A) + Devcon rubbery fill (Volume B)

2020-03-04-Etching-Report.docx

Project: 901809.00 DeepPIV/ Deep Sea Bioinspiration
Author: Denis Klimov (EE);
Rev(02/19/2020): initial draft text release
Rev(03/04/2020): feedback from Edward Peltzer on safety procedures is implemented

Chemical etching of fiber optic penetrator

- Purpose of etching: to improve adhesion of the epoxy and polyurethane to the material of fiber optic penetrator
- Materials:
  - Silicone tube (refer to item A on Fig 1)
  - Concentrated Hydrochloric acid (HCl) 37% by weight, 63% water or 12M HCl solution (see item B on Fig. 1 for approximate fill level)
  - Fiber optic penetrator plug (see item C on Fig. 1)
  - Suitable rubber plug (item D on Fig. 1)
  - Acid-resistant UHMW stand (Fig. 2)
  - Acid-catching tray (Fig. 2)
  - De-ionized water to wash parts
  - Sodium Bicarbonate ($NaHCO_3$) 1M solution to neutralize acid solution (Fig. 6)
  - Beaker to hold penetrators and sodium bicarbonate (Fig. 6)
- Safety procedures
  - Etching must be performed under appropriate chemical fume hood to catch Hydrochloric acid and hydrogen gas form escaping the etching setup
  - Personal Protection equipment (PPE) when handling concentrated acid:
    - Gloves rated for acid exposure must be worn when handling acid and parts of etching setup
    - Eye protection is required
    - Lab coat is required.
    - Full face shield is recommended during procedure explained in Fig 5.
- Basic procedure:
  - Beginning of each etching session (typically in the morning). Perform and log the following:
    - Assemble each penetrator with silicone tube and plug as shown of Fig 1
    - Place penetrators on stand E in a tray F, placed in the appropriate chemical fume hood (Fig 2)
    - Fill each penetrator with concentrated Hydrochloric acid to about half of the silicone tube.
    - Purge the air from the lower chamber of each penetrator by holding the penetrator upright and carefully pressing a lower rubber cap against a tray, until air bubbles stop coming out of the lower chamber (Fig 3). Add acid if necessary to completely cover the metal.
  - During the day:
    - Check the color of the acid several times per day, if acid is getting too dark-green and dirty, exchange the acid, and reduce etching time on subsequent etching setups (Fig 4)
  - By the end of the etching for a day. Perform and log the following:
    - Drain waste acid into appropriate waste container (Fig 4)
    - Disassemble and wash each Fiber Optic Penetrator etching assembly as shown on Fig 5. Be extremely careful taking apart each Fiber Optic Penetrator etching assembly. The best way is to take them apart while full covered by the water. That way any residual acid is immediately being dissolved by the water.
    - Neutralize the acid by using Sodium Bicarbonate solution (Fig 6)
    - Wash penetrators again in de-ionized water (Fig 7)
    - Clean and dry penetrators (Fig 8)
  - Inspect penetrators
    - Penetrator of sufficient etching of good quality should be uniform, matte in surface finish, and silver in color, like shown on Fig 9.
    - Insufficient etching typically looks like in Fig 10. Continue etching the next day/session.
    - Issue with corrosion due to insufficiently neutralized acid typically looks like in Fig 11.

Appendix 1. Example Etching Log

- 7/17/2019 Etching Day 1
  - 09:50: Inserts SN 5, 6, 7, 8 set with acid with plugs on bottom and tube on top
  - 17:20: Inserts removed, washed in tray. Some acid present in plugs. Face shield, gloves, lab coat used.
  - 17:25: Inserts 4x set in 1M NaHCO3 in a beaker
  - 18:25: Inserts 4x washed, with water and dried with acetone
    - Day 1 etching: 7.5H
- 7/20/2019 Etching Day 2
  - 10:00: Inserts SN 5, 6, 7, 8 set with acid with plugs on bottom and tube on top
  - 17:30: Acid removed, washed
  - 17:35: 1M NaHCO3 set
  - 18:26: NaHCO3 removed, washed, paper dried
    - Day 2 etching: 7.5H
    - Total etching: 15.0H
- 7/21/2019 Etching Day 3
  - 08:25 Acid set #5, 6, 7, 8; filled bottom part too by gently pressing on bottom plug
  - 22:25 Acid removed, washed
  - 22:30 $NaHCO_3$ set
  - 22:35 $NaHCO_3$ removed, dried (paper towel)
    - Day 3 etching: 14 hours
    - Total etching: 29.0 hours
- 7/22/2019 Etching Day 4
  - Inserts SN 5, 6, 7, 8 inspected under microscope – look good => 14 hours etching is acceptable
    - Needs good mechanical washing of black deposits
    - 5 min acid neutralize is OK
  - 11:50: Acid set, both top and bottom
  - 21:25 Acid removed, washed, set in $NaHCO_3$ d
  - 21:30: $NaHCO_3$ removed, washed, paper dry
    - Day 4 etching: 9 hours
    - Total etching: 38 hours
- 7/23/2019 Etching Day 5
  - 14:30 Inserts 5, 6, 7, 8 acid set, both top and bottom
  - 18:05 acid removed, washed, $NaHCO_3$ set
  - 118:10 $NaHCO_3$ removed, washed, paper dry
    - Day 5 etching: 3.5 hours
    - Total etching: 41.5 hours
- 7/24/2019 Etching Day 6
  - 12:00 inserts 5, 6, 7, 8 acid set both top and bottom
  - 18:30 acid removed, washed, $NaHCO_3$ set
  - 18:35 $NaHCO_3$ removed; washed, acetone dried
    - Day 6 etching: 6.5 hour
    - Total etching: 48 hours
- 7/25/2019 Etching Day 7.
  - Inserts 5, 6, 7, 8. Top tube added in order to limit corrosion on the sides of insert
  - 15:50 acid set
  - 21:10 Acid removed, washed, $NaHCO_3$ 5 min, washed, acetone dried
    - Day 6 etching: 5.5 hour
    - Total etching: 53.5 hours
- 7/26/2019Etching Day 8
  - 11:30 Inserts 5, 6, 7, 8 acid set (with top tube, bottom plug, both top and bottom)
  - 20:30 Acid removed, washed, $NaHCO_3$ removed; washed, acetone dried
    - Day 6 etching: 9 hours
    - Total etching: 62.5 hours

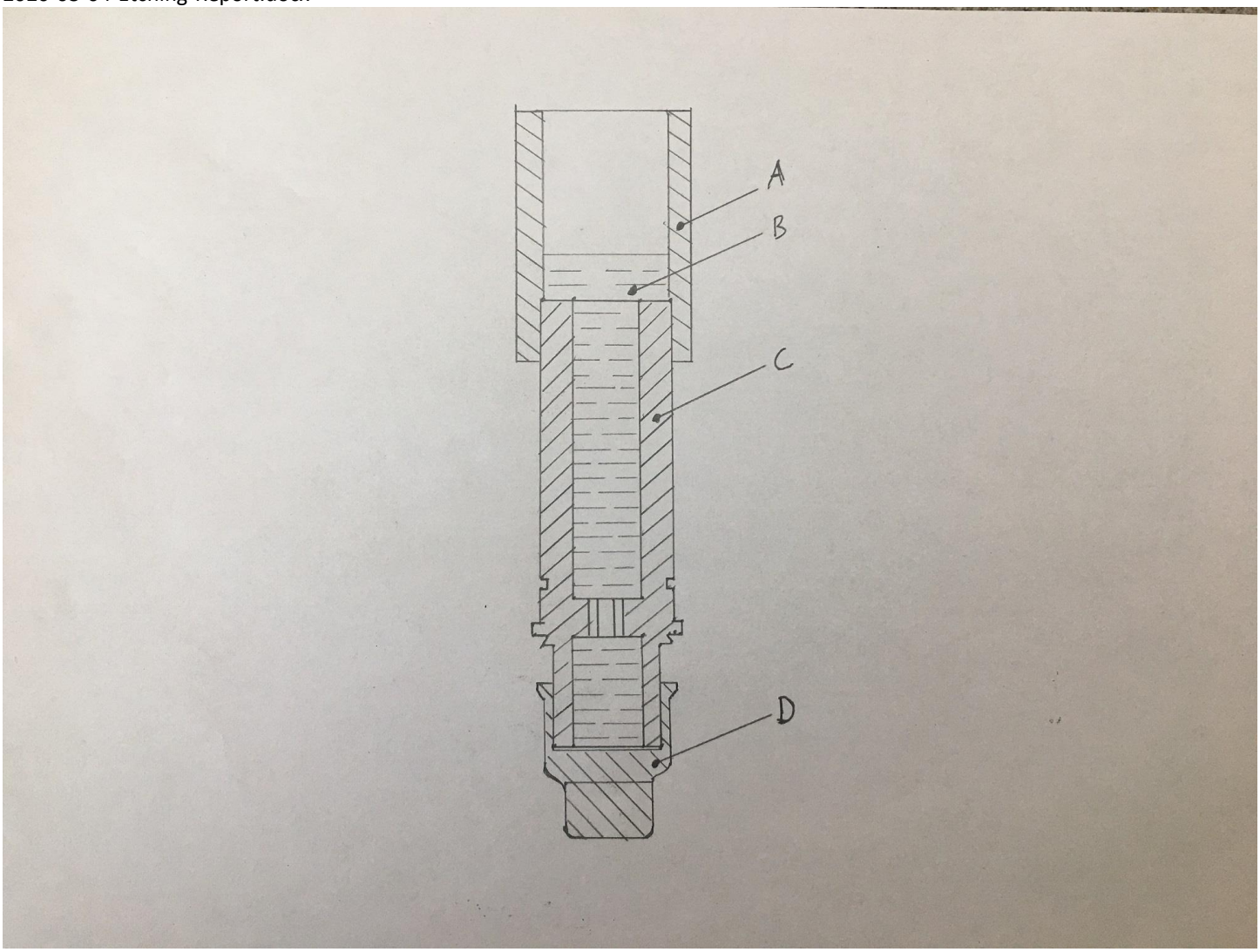


Fig 1. Schematic diagram of Fiber Optic Penetrator etching assembly:
A: Silicone tube, 0.75” ID x 1.0” OD x 2” long
B: Concentrated Hydrochloric acid (needs to fill both lower and upper chambers of penetrator, and cover top end)
C: Fiber Optic Penetrator (“Fiber Optic Cable Plug”, drawing P-1002444-18 Rev B, drawn by Job Erickson 4/25/2019 shown)
D: Rubber cap plugging bottom side of the Fiber Optic Penetrator

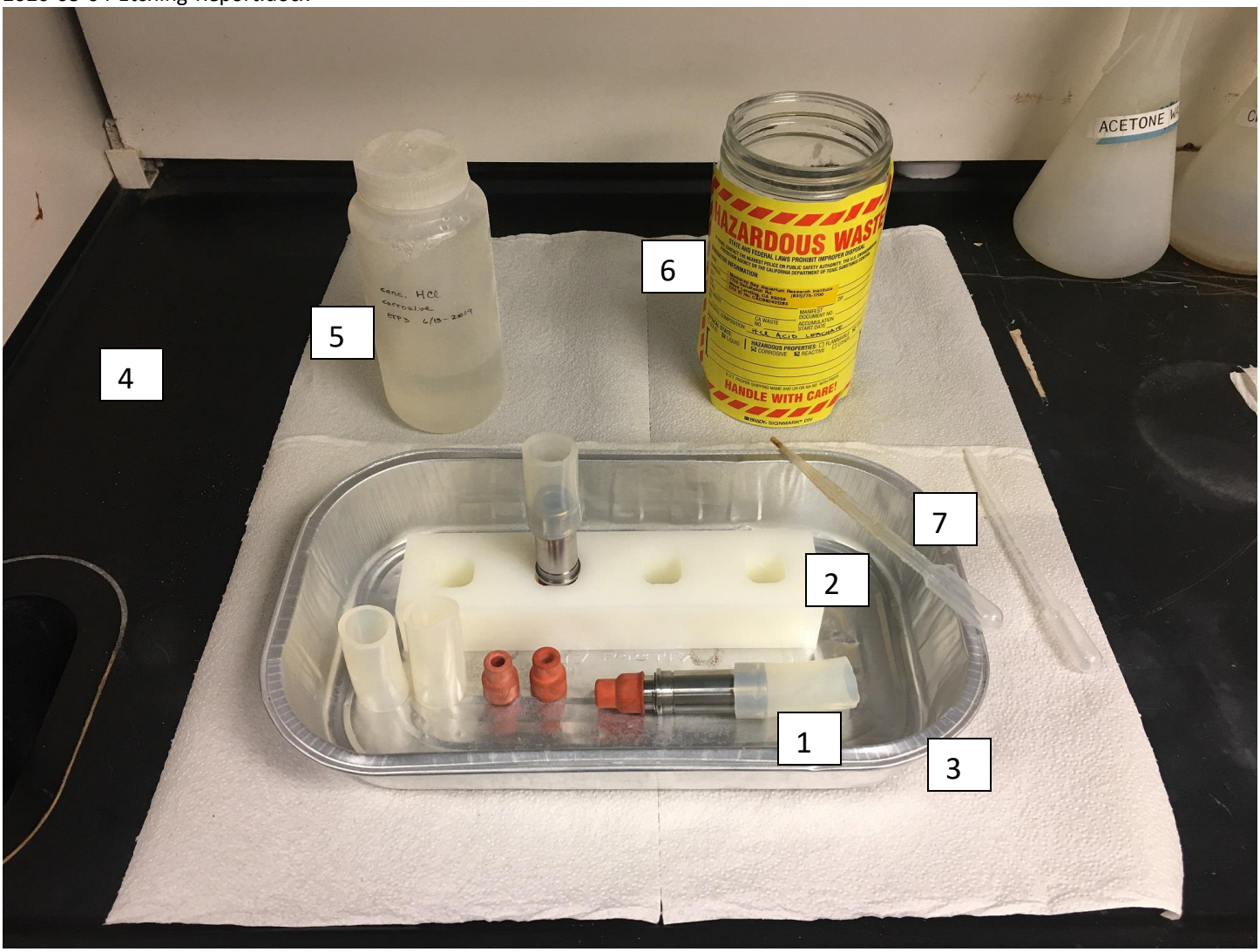


Fig 2. Typical etching laboratory setup:
1: Fiber Optic Penetrator etching assembly
2: Acid-resistant UHMW stand
3: Acid-catching tray
4: Chemical fume hood
5: Bottle containing concentrated Hydrochloric acid
6: Container for waste Hydrochloric acid
7: Acid-resistant pipette

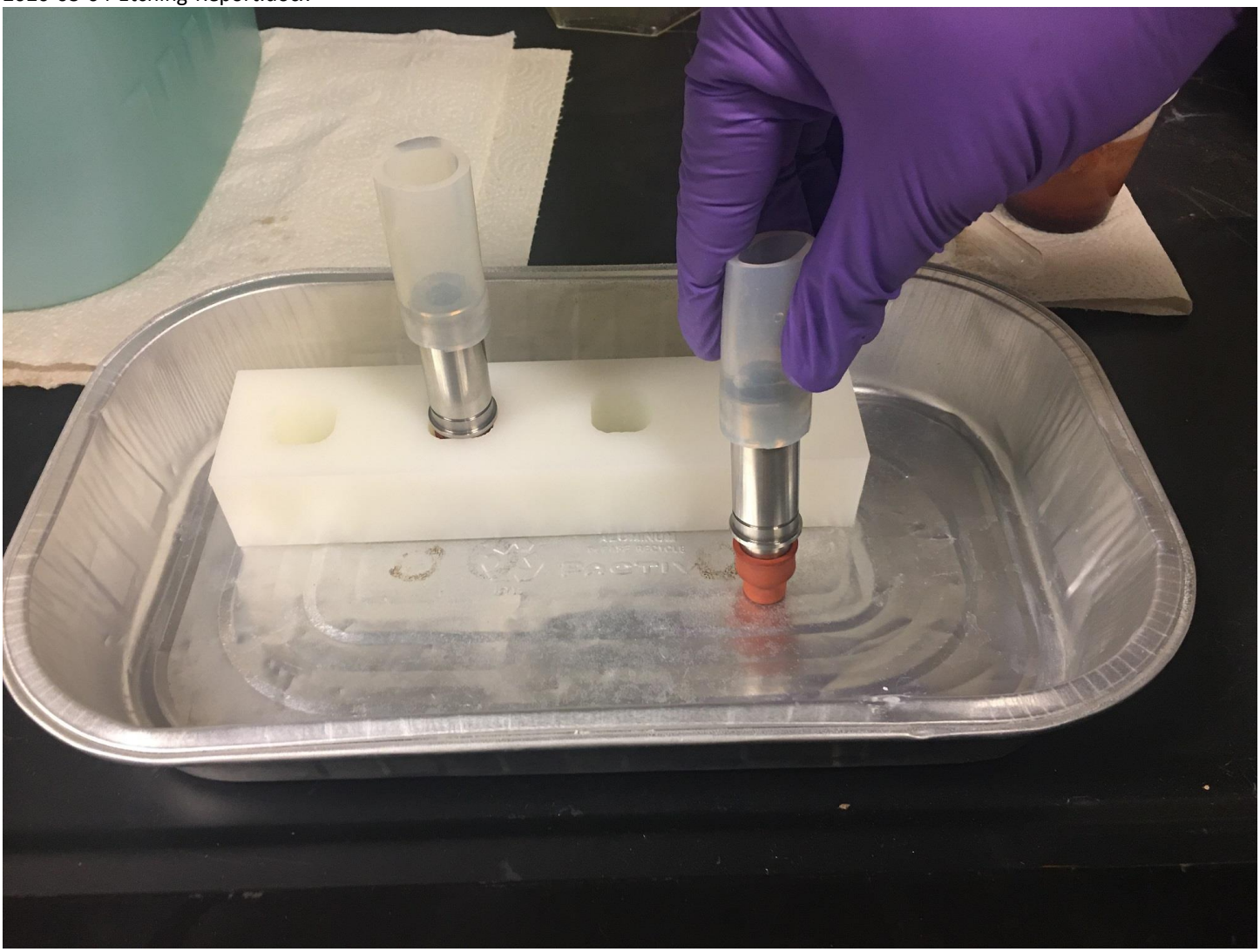


Fig 3. Typical air purging setup. Hold the Fiber Optic Penetrator etching assembly upright and carefully press lower rubber cap against a tray multiple times, until air bubbles stop coming out of the holes connecting lower and upper chambers. Make sure the steel is completely submerged in the acid. Add acid if necessary

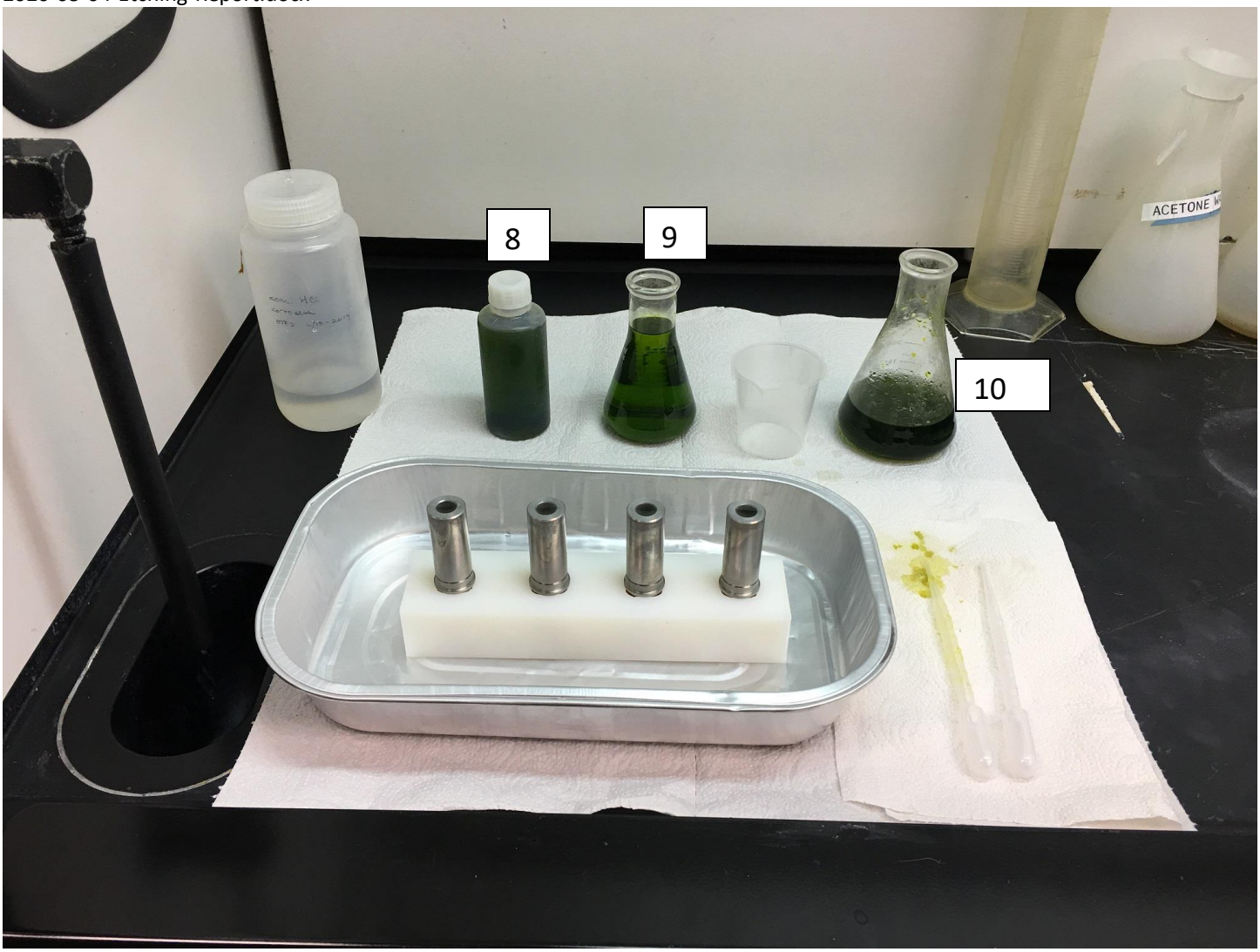


Fig 4. Typical etching laboratory setup. Note the color of waste concentrated Hydrochloric acid in containers:
8: Dark-green, dirty hydrochloric acid
9: Lighter, clean green hydrochloric acid
10: Dark green hydrochloric acid
Note: if etching is producing acid that is too dark-green and dirty like seen in items 8 and 10, reduce etching time on subsequent days.

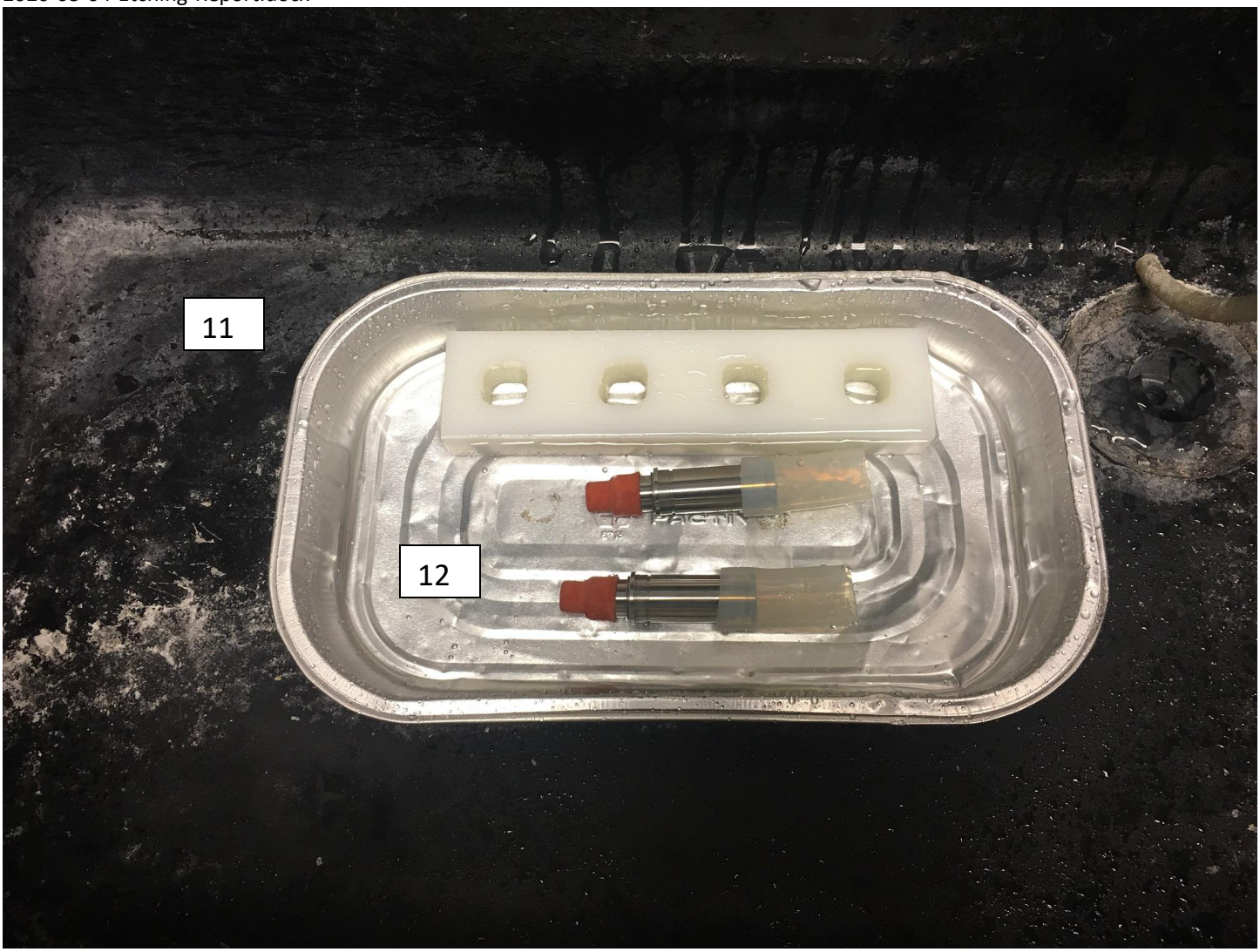


Fig 5. Typical washing and disassembly setup
11: Laboratory sink
12: De-ionized water, to cover the Fiber Optic Penetrator etching assemblies completely
Note: be extremely careful taking apart each Fiber Optic Penetrator etching assembly. The best way is to take them apart while full covered by the water. That way any residual acid is immediately being dissolved by the water.

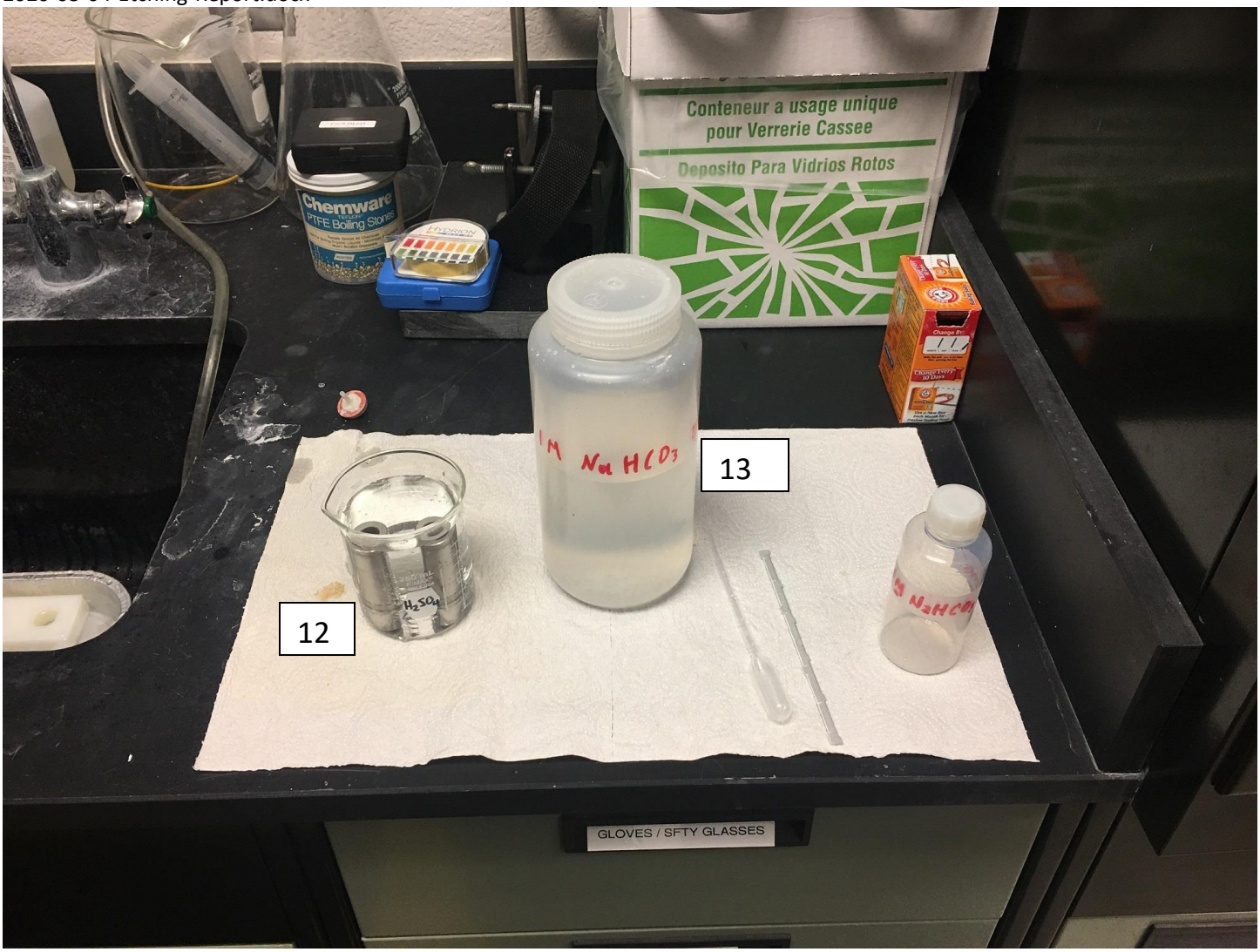


Fig 6. Typical acid-neutralizing setup
12: Beaker to hold penetrators and sodium bicarbonate
13: Sodium Bicarbonate (NaHCO3) 1M solution to neutralize acid

Fig 7. Typical washing setup

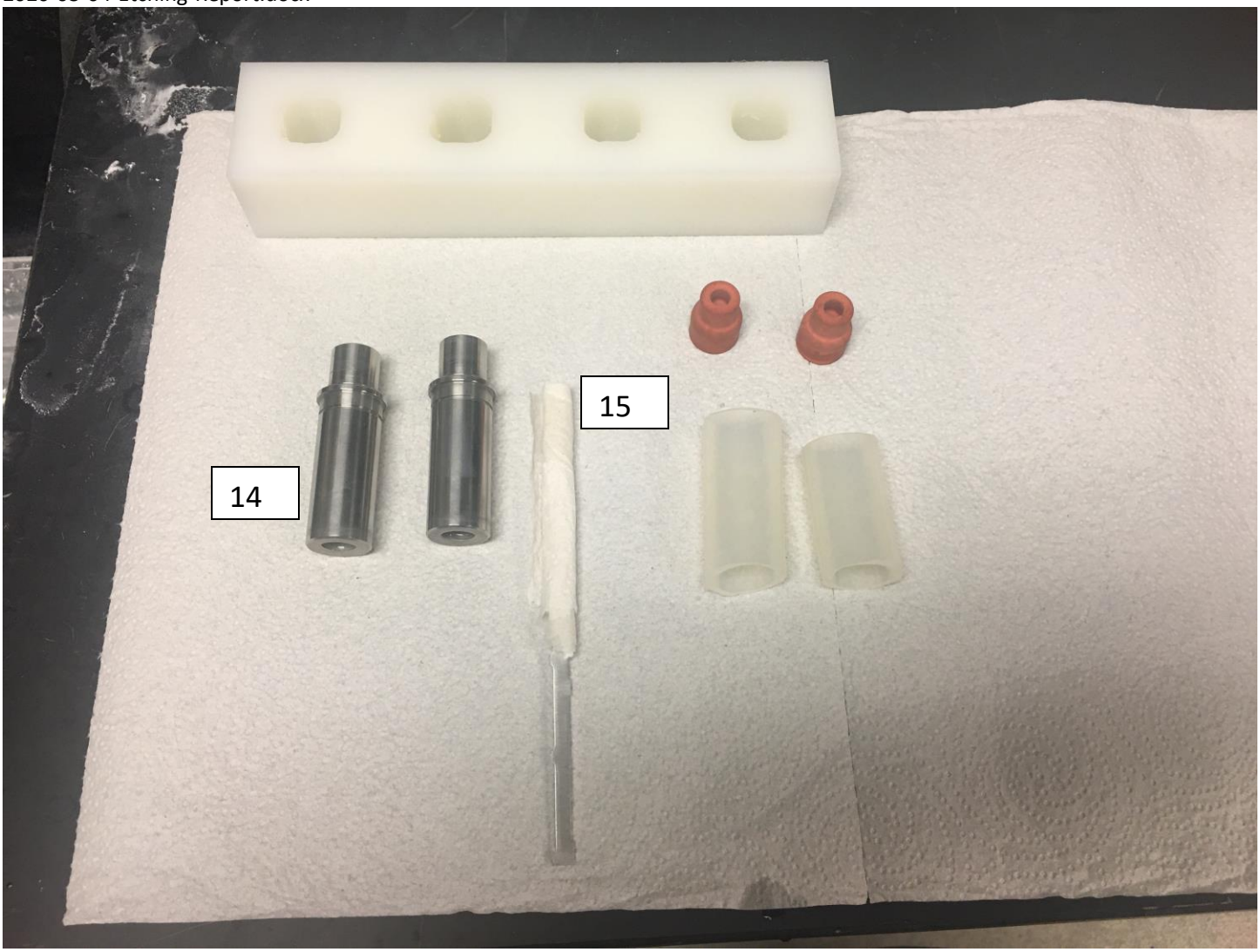


Fig 8. Typical drying setup
14: Fiber Optic Penetrator
15: Cleaning rod with a paper tissue wrapped around it, to clean and dry inside the Fiber Optic Penetrator

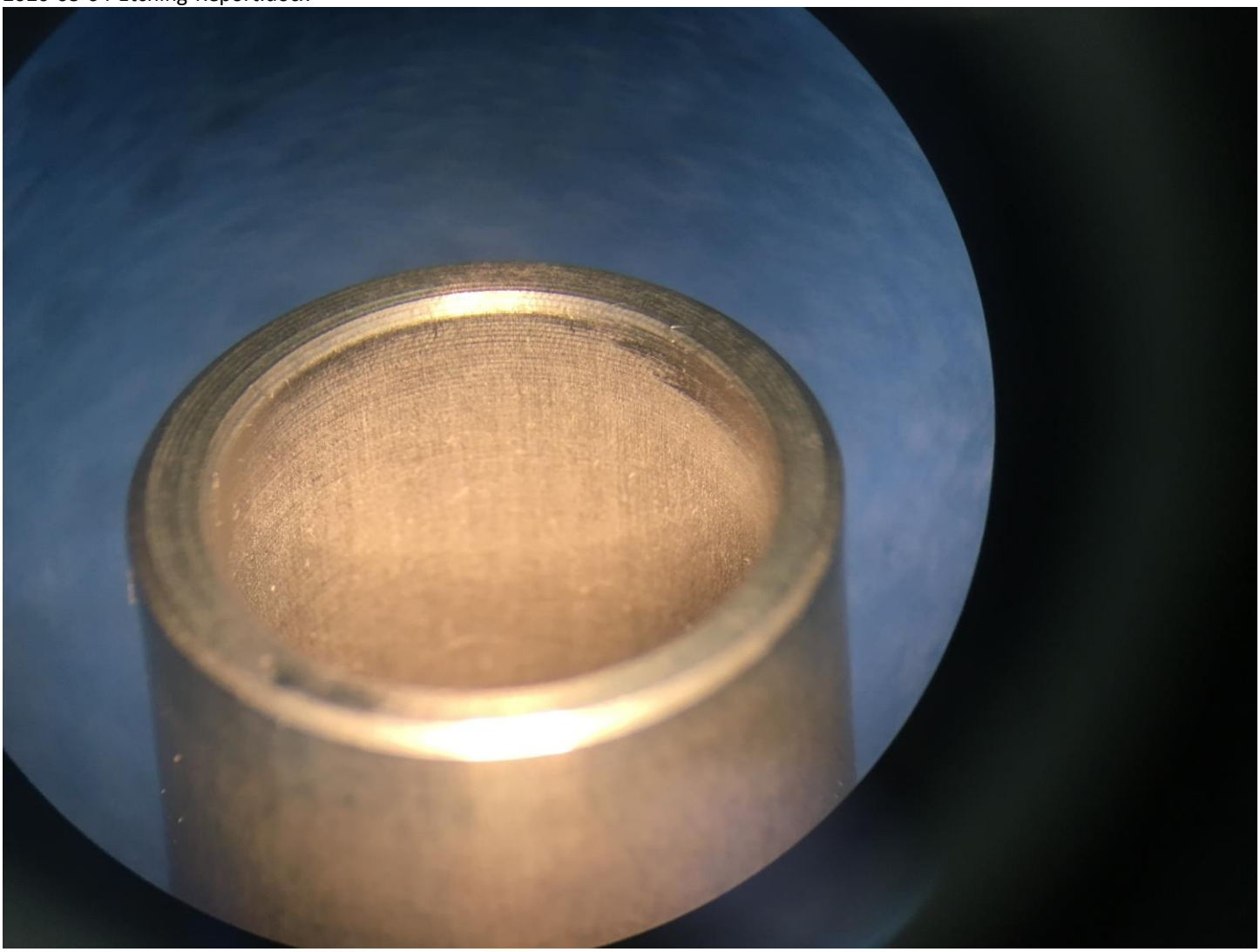


Fig 9. Typical etching of sufficient quality

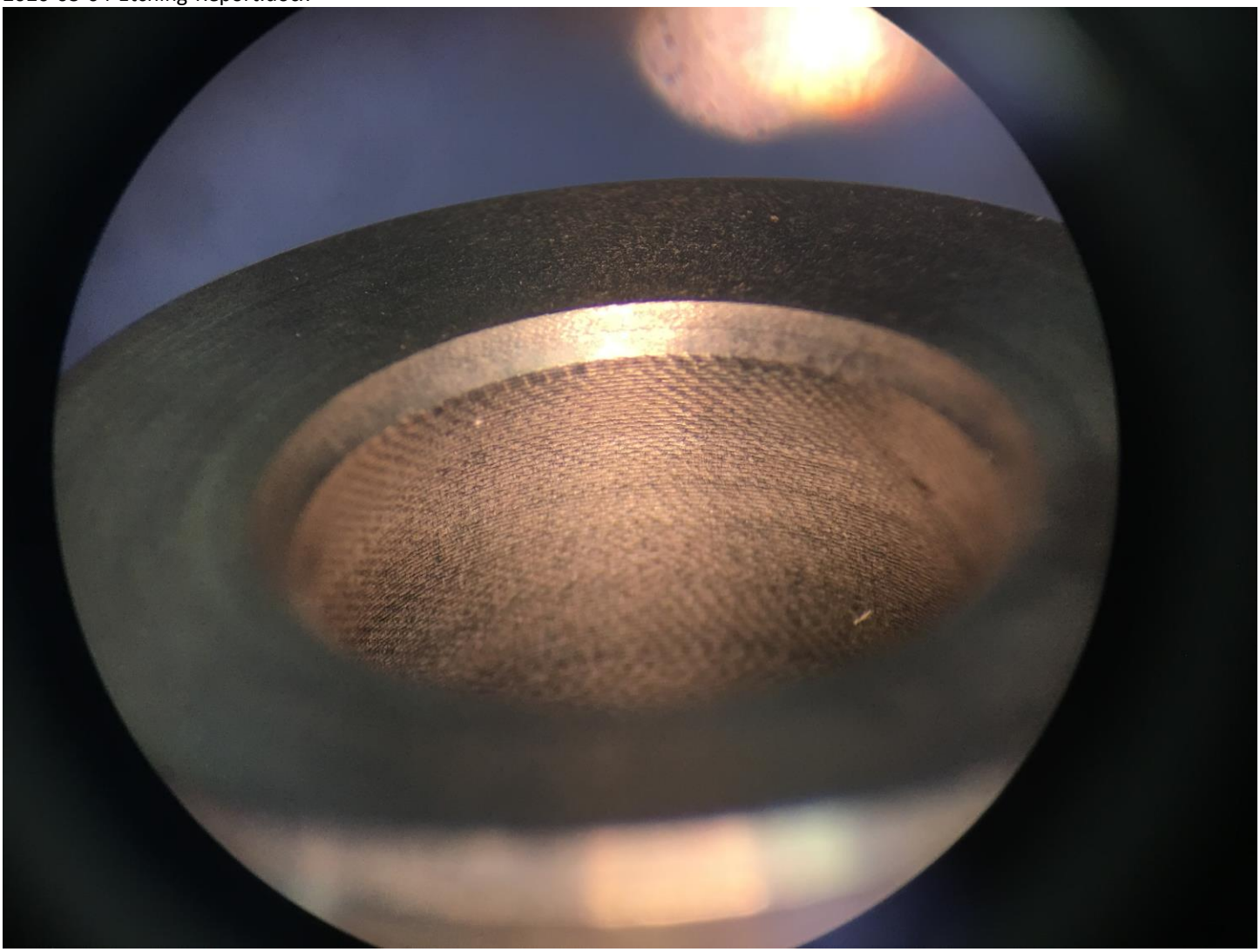


Fig 10. Typical insufficient etching

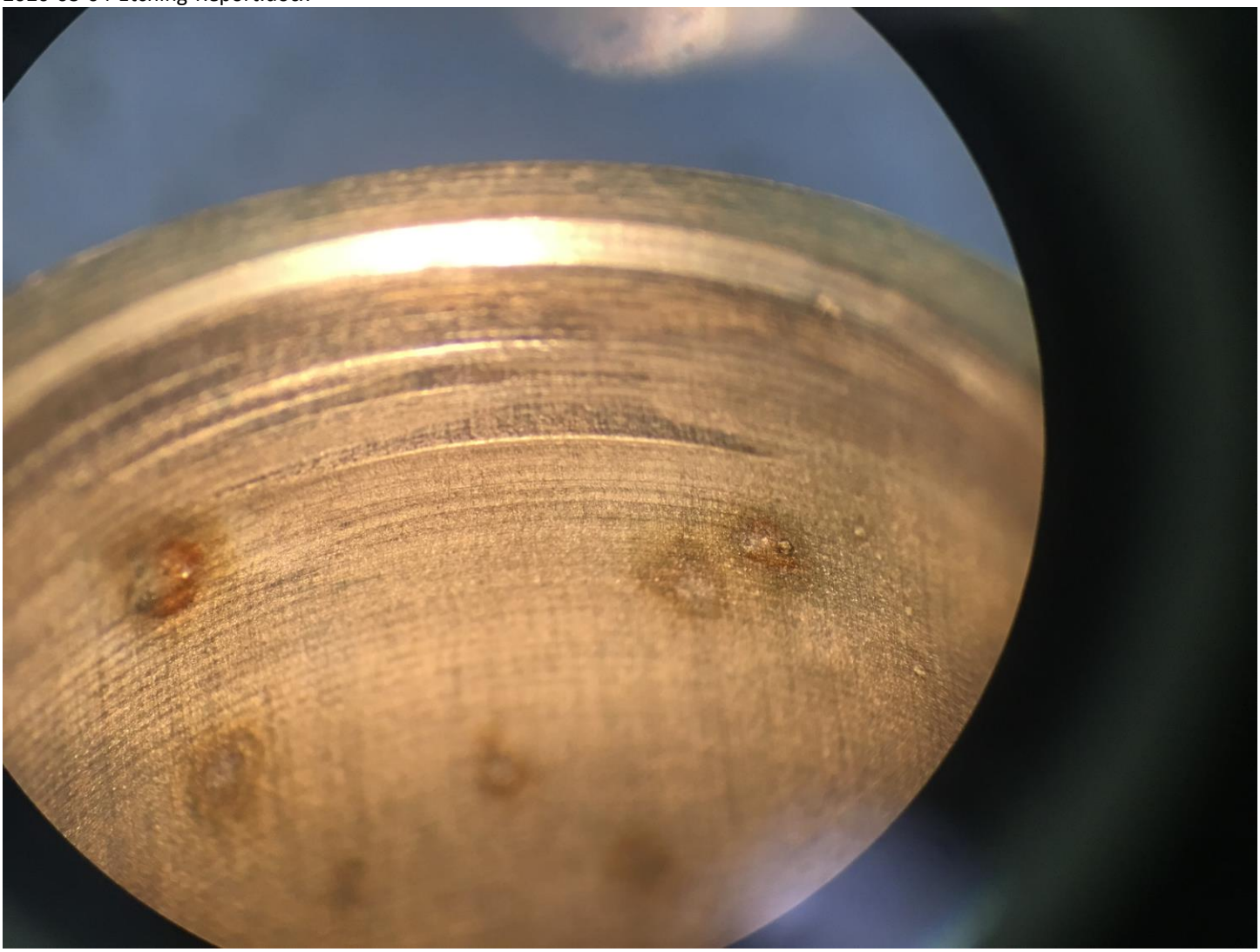


Fig 11. Typical issue with corrosion spots due to insufficient neutralization of acid after etching

Project: 901809.00 DeepPIV/ Deep Sea Bioinspiration
Author: Aaron Schnittger (ME Tech);
Editing: Denis Klimov (EE)
Rev(09/16/2020): initial draft text release with pictures
Rev(09/29/2020): input from Joost Daniels incorporated; reference to pressure and continuity testing added
Rev(10/12/2020): photo 7 added (View of potted penetrator assemblies)

Instructions for making sea going Optical Fiber (OF) cables for Deep PIV

This document will outline the procedure for making penetrating optical fiber cables.

1. Summary/ Basic Steps:
    a. Etch penetrators **See Denis (**2020-03-04-Etching-Report.docx**)
    b. Clean component pieces with acetone. Use sprayer as needed. Prime optical fiber and strain relief ends.
    c. Set-up inserts in the jig and fix in bench top vice.
    d. Assemble dummy, insert, strain relief, and fiber
    e. Fill insert with hard Loctite E-60NC
    f. Mix and de-gas Devcon Flexane 80 Liquid 15800 then pot connector with soft urethane.
    g. Fill inside of internal side of insert with Devcon Flexane 80 and place strain relief tubing into correct position using guide (jig).
    h. Connectorize ends of cable
    i. Check continuity, power through the cable, pressure test

2. Required parts:
    a. Single mode optical fiber 9um/125 (Coastal Connection). 2’ for test and 25-27’ for final product.
    b. Etched dummy connectors (MIN-K-DSP) from SeaConn/Brantner. These are used to dummy off MIN-K series bulkhead connectors.
    c. 316 stainless steel inserts with two 0.04” holes for fiber pass through.
    d. Potting compounds: Hard two part epoxy-Loctite E-60NC with applicator, Devcon Flexane 80 Liquid 15800, and FL-20 primer (Devcon).
    e. 0.125” Tygon tubing for strain relief. 0.1875 Tygon tubing for epoxy application.
    f. Jig function: (**Figure 4**)
        i. To hold two penetrators and associated fibers and strain relieve tubing so they could be tilted for potting
        ii. To hold fibers and strain relieve tubing parallel to the axis of penetrator, and centered at the penetrator opening, and at the correct depth
        iii. This jig was purpose-built for this project and kept together with other parts in the project box.
    g. Misc- Acetone, emery cloth, masking tape, thin gauge wire, nitrile gloves, etc.
3. Clean components using acetone.
    a. Clean the optical fiber jacketing with acetone either spray or dunk and wipe with a kimwipe. Approx. 1’ of both ends.
    b. Clean abraded end of 1.25” by 0.125” tygon tube strain reliefs (2 per) with acetone. (Dip in acetone) Clean fill tube of 2.5” by 0.1875” tygon tube (1 per) with acetone (take special care to clean inside of tubing).
    c. 316 stainless steel dummies should be held with 0.4” bore facing down and cleaned by spraying acetone up into the bore and allowing the acetone to drip out. This will ensure that the bores will be free of contaminates (**Figure 1**).
    d. Allow 10 minutes of drying time before moving on to next step.

Handle Components with clean gloved hands only

4. Priming the OF PVC jacketing
    a. Using Devcon’s FL-20 in a fume hood apply one coat of primer to the section of fiber that will be potted inside of the 316 stainless steel bore.
    b. Let the primer dry for 1 hour, but re-prime if the fiber has not been potted by 2 hours after first coat.

5. Set-up components in jig (Dummies and strain relief). Using wire fix the clean brass and isolators in the proper position ** See **Figures 2, 3, 4**
6. Insert the two OF in the 0.04" holes of the stainless steel dummy bore(s) ** See **Figure 2**
    a. Route the fibers through brass (2), isolators (4), and strain reliefs (in holder).
7. Hard epoxy Application
    a. Purge the epoxy applicator tip of excess air bubbles. ** See **Figure 5**
    b. Fill dummy bore with Loctite E-60NC using clean 0.1875" tubing to approx. 0.9" (**Figure 6**)
        i. Note: make a mark on the 2.5" tubing at 0.9" to help with filling to appropriate level.
        ii. Note: move the strain relief jig slightly over to improve access.
    c. Pull fibers down slightly to ensure that the epoxy flows through 0.04" holes.
    ** See **Figure 8**
    d. Align fibers in the dummy bore making sure that the fibers run parallel/ centered and minimize any slack using masking tape on either side of the dummy.
    See **Figure 4**
    e. Allow 2-3 days for curing.
8. Urethane top layer application ** See **Figures 7, 9**
    a. Re-prime, using FL-20, fibers and the submerged end of strain relief.
    b. Allow 1 hour to cure.
    c. Mix 50cc of Devcon Flexane 80 and de-gas in vacuum housing.
    d. Apply urethane using a small spoon to the remaining 0.9" of the bore.
        i. Note: minimize trapping air during fill.
    e. Position strain reliefs and holder in the final position.
    f. Allow 2-3 days for curing.
9. Assemble the potted components for testing
    a. Install greased O-rings.
        i. Note: pay special attention to keep O-rings clean.
    b. Install Brass, isolators, and snap rings into the bulkheads
10. Pressure test
    a. For example of pressure testing procedure, refer to **"2019-04-16-Prototype-Test-2"**
11. Continuity test
    a. This is a test for light transmitting continuity.
    b. Quick test could be conducted using flashlight or similar light source illuminating one side of the fiber, and visually observing the light on the other side.
    c. More advanced test could be conducted using fiber optic illuminator, microscope, and several pieced of plastic with holes drilled to hold fibers. For instance, this would allow comparative evaluation of light transmission between two or more fibers; if visually light intensity on output of fibers are about equal, there is a decent chance of intact fiber; while damaged optical fiber typically results in quite dim output (see **"2019-04-16-Prototype-Test-2")**

Figure 1: Acetone sprayed into bore

Figure 2: Insert optical fibers

Figure 3: Assemble strain relieve tubes to the aluminum support plate

Figure 4: Pre-assembled jig

Figure 5: Purging tip

Figure 6: Fill dummy bore with Loctite E-60NC

Figure 7: View of potted penetrator assemblies

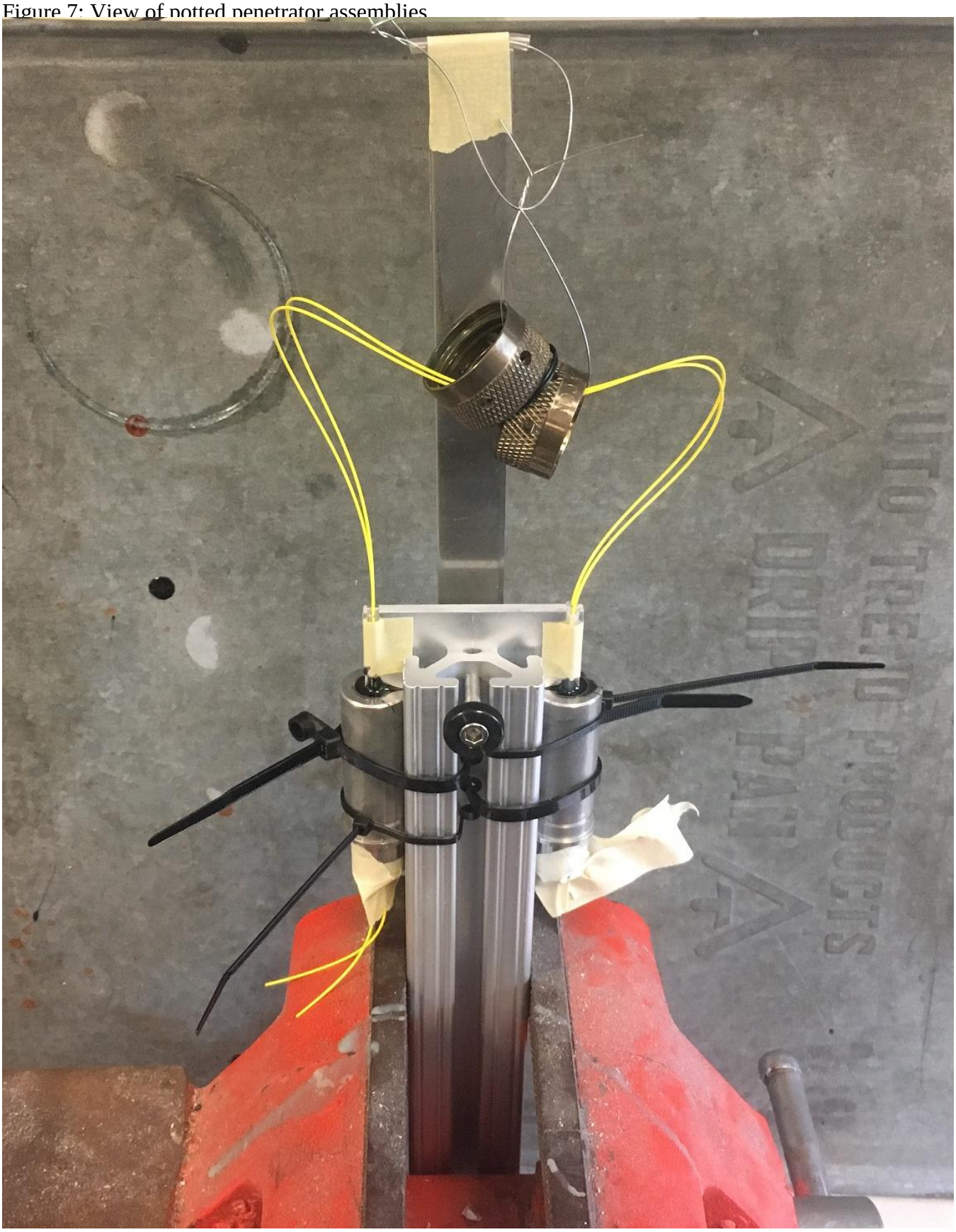
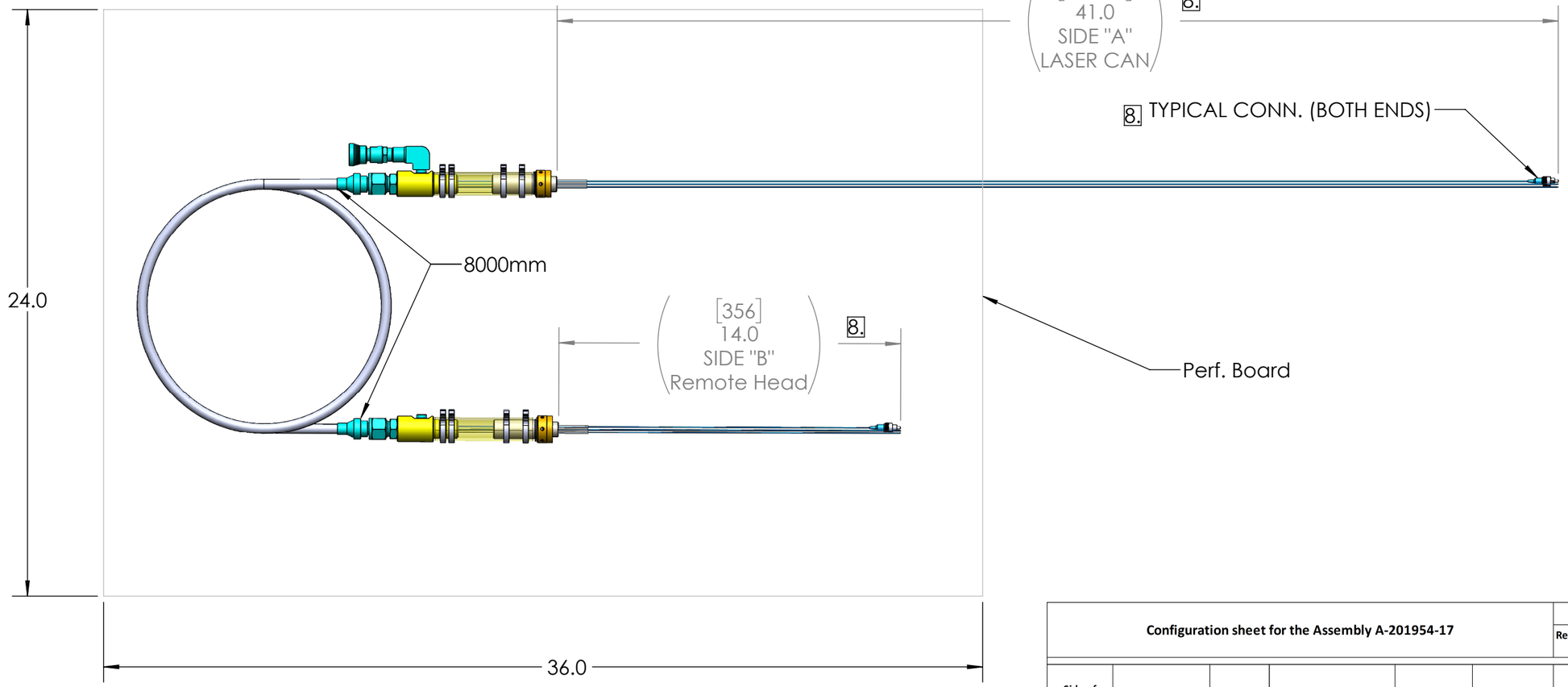


Figure 8: Reference to ensuring epoxy flows through 0.04” holes

Figure 9: Urethane top layer application

REVISIONS			
REV.	DESCRIPTION	DATE	APPROVED
	INITIAL RELEASE	X/XX/00	J.E.



Configuration sheet for the Assembly A-201954-17

Date:	6/15/2018
Revision: Letter for Mechanical + Number for Configuration	RevA-0

Side of assembly description (refer to Drawing A-201954-17)	Fiber model	Number of fibers in the assembly	Optical connector termination	End-Cap	Number of connectors to be terminated	Fiber labels	Fiber length from end face of penetrator to the tip of optical connector (refer to Drawing A-201954-17)			
							Length, Initial termination for new assembly		Length, minimum acceptable	
							inch	mm	inch	mm
Side A	SMF-28; 1550nm SM Fiber; 9 um core; 900 um PVC jacket	4	S-FUnkFUnk-9/125/0.9	300 +/-30um Long End-Cap	2	A-1; A-2	41.0	1041	39.0	991
Side B		4	S-FUnkFUnk-9/125/0.9	300 +/-30um Long End-Cap	2	B-1; B-2	14.0	356	12.0	305

Note: termination specification code	
	S = Single Mode
	F = FC connector
	U = UPC (Ultra Physical Contact)
	N = Narrow Key
	k = Cap (optical end-cap)
	9/125 = Core, um / Cladding, um
	0.9 = Fiber patch OD, mm

8. NOTE CONFIGURATION TABLE.
7. PROJECT LIBRARY:\901506 DeepPIV\ME Drawings\FiberConnections

NOTES: (CONT. FROM TITLE BLOCK)

BILL OF MATERIALS

Shop / Q.C.		UNLESS OTHERWISE SPECIFIED TOLERANCES ARE:				APPROVALS	DATE
Inspector		1 PLACE DIM ±1/16	2 PLACE DIM ±.02	3 PLACE DIM ±.005	ANGLES ±1°	DRAWN J. ERICKSON	12/12/17
Shop Foreman		1. DIMENSIONS ARE IN INCHES				ENGINEER J. ERICKSON	12/12/17
Engineer		2. DIMENSION LIMITS HELD AFTER PLATING.				CHECKED	
NEXT ASSY Description	NEXT ASSY Number	3. REMOVE BURRS AND SHARP EDGES .015 MAX.				PROJECT NO.	901506
		4. MACHINED FILLET RADII .0150-.030.				PROJECT	DEEP PIV
		5. MACHINED DIAMETERS ON A COMMON CENTERLINE CONCENTRIC WITHIN .005					
		6. PERPENDICULARITY & PARALLELISM OF MACHINED SURFACES .002 PER INCH, MAX .012 INCHES FOR SINGLE SURFACE.					
Application		DO NOT SCALE DRAWING				WEIGHT	5.974 lb.

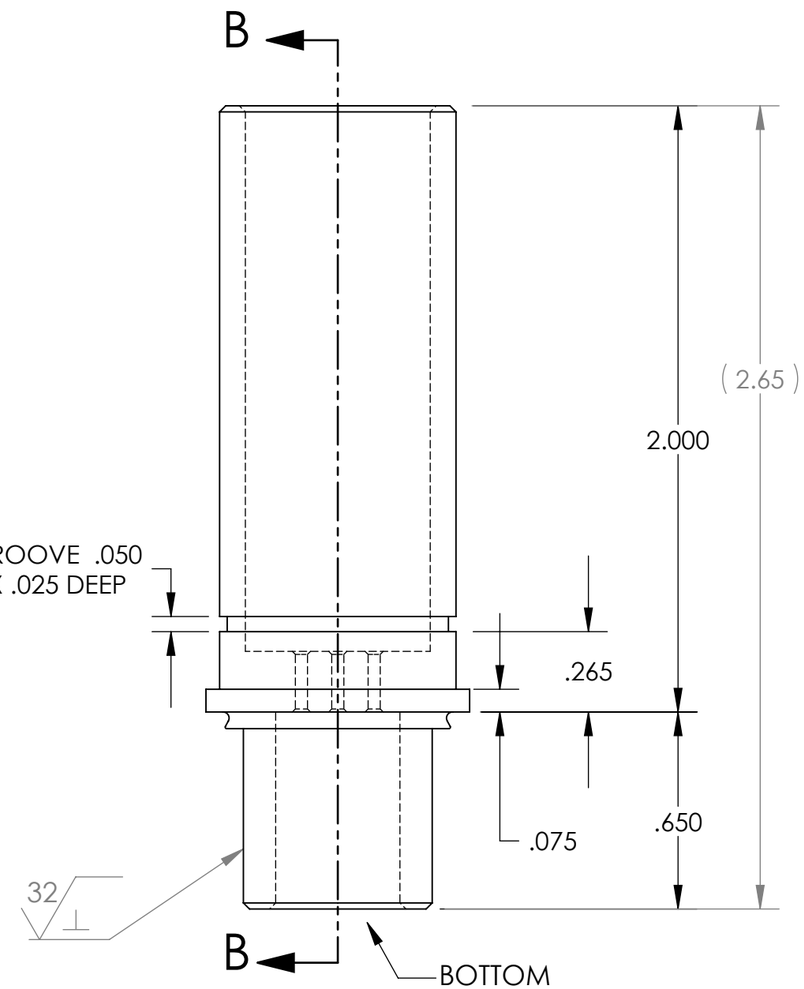
Monterey Bay Aquarium Research Institute
MBARI
7700 Sandholdt RD.
Moss Landing, CA 95039
PH: (831) 775-1700

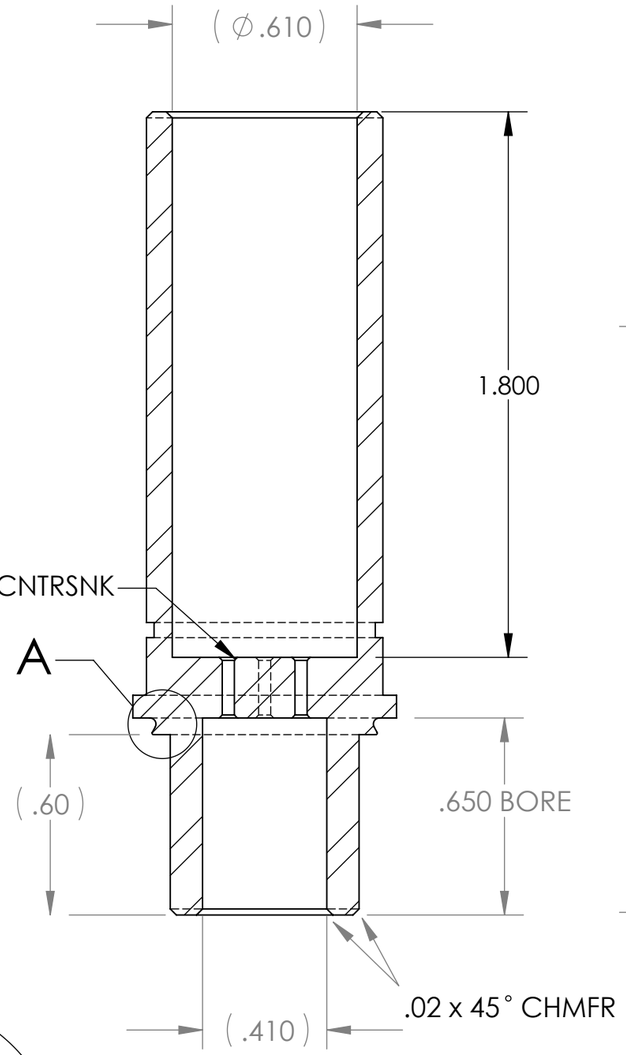
PIV COHERENT LASER
PBOF Fiber Assembly

SIZE	DWG. NO.	REV.
B	A-201954-17.DWG	
SCALE 1:24	CAD FILE: MECH ENG ON TORNADO	SHEET 4 OF 4

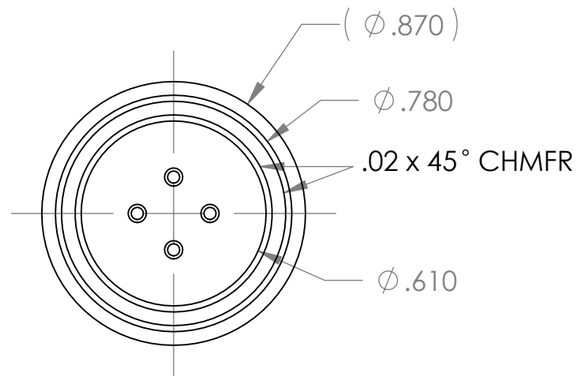
REVISIONS			
REV.	DESCRIPTION	DATE	APPROVED
	INITIAL RELEASE	5/25/04	

REVISIONS				
ff	REV.	DESCRIPTION	DATE	APPROVED
B1	A	CHG Fiber Hole Dia. frm .062 to .040	9/21/2018	J.E.

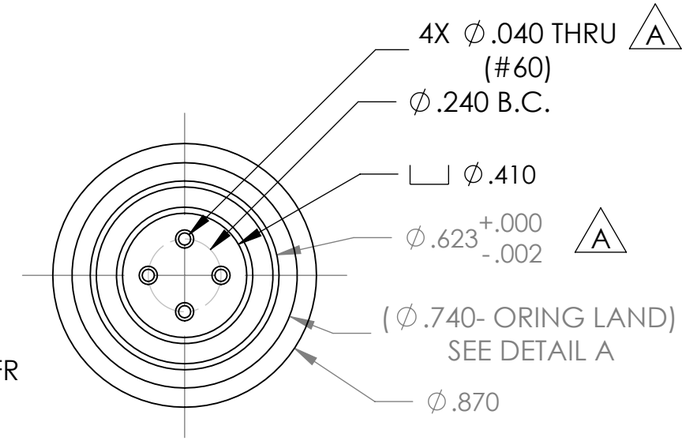




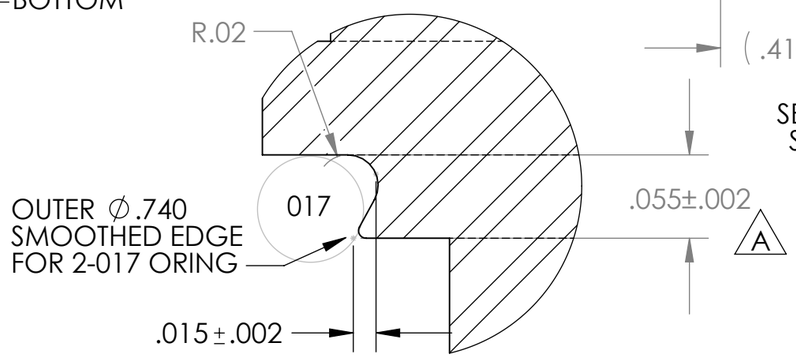
SECTION B-B
SCALE 2 : 1



TOP



BOTTOM VIEW



DETAIL A
SCALE 10 : 1

8. Mates to MinK-FCR

7. PROJECT LIBRARY:\901506 DeepPIV\ ME Drawings\FiberConnections\Test

ITEM NO.	QTY	PART NO.	DESCRIPTION	MATERIAL SPECIFICATION
			FIBER OPTIC PENETRATION FOR LRS/DORISS	316 SS

BILL OF MATERIALS

UNLESS OTHERWISE SPECIFIED TOLERANCES ARE:

1 PLACE DIM ±1/16	2 PLACE DIM ±.02	3 PLACE DIM ±.005	ANGLES ±1°

1. DIMENSIONS ARE IN INCHES
2. DIMENSION LIMITS HELD AFTER PLATING.
3. REMOVE BURRS AND SHARP EDGES .015 MAX.
4. MACHINED FILLET RADII .0150-.030.
5. MACHINED DIAMETERS ON A COMMON CENTERLINE CONCENTRIC WITHIN .OO5
6. PERPENDICULARITY & PARALLELISM OF MACHINED SURFACES .002 PER INCH, MAX .012 INCHES FOR SINGLE SURFACE.

DO NOT SCALE DRAWING

APPROVALS	DATE
DRAWN J. Erickson	10/10/18
ENGINEER J.Erickson	X/XX/XX
CHECKED	
PROJECT NO. 901506	
PROJECT PIV	
WEIGHT	

Monterey Bay Aquarium Research Institute
MBARI
7700 Sandholdt RD.
Moss Landing, CA 95039
PH: (831) 775-1700

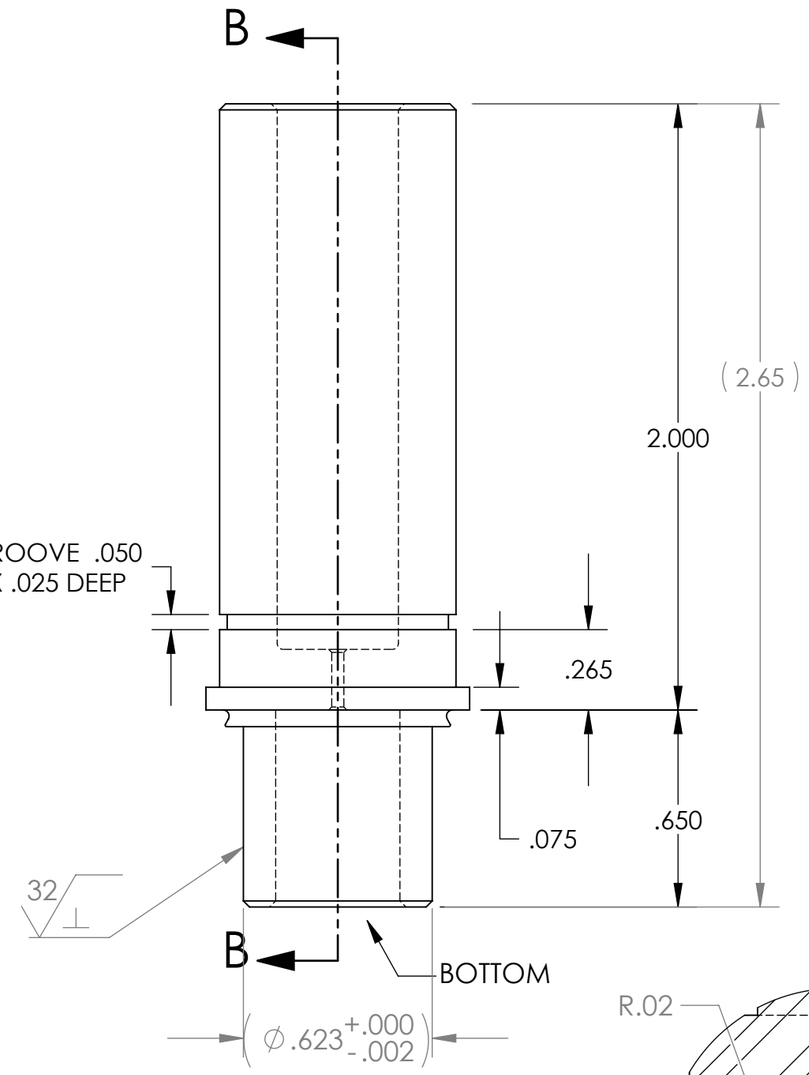
FIBER OPTIC CABLE PLUG

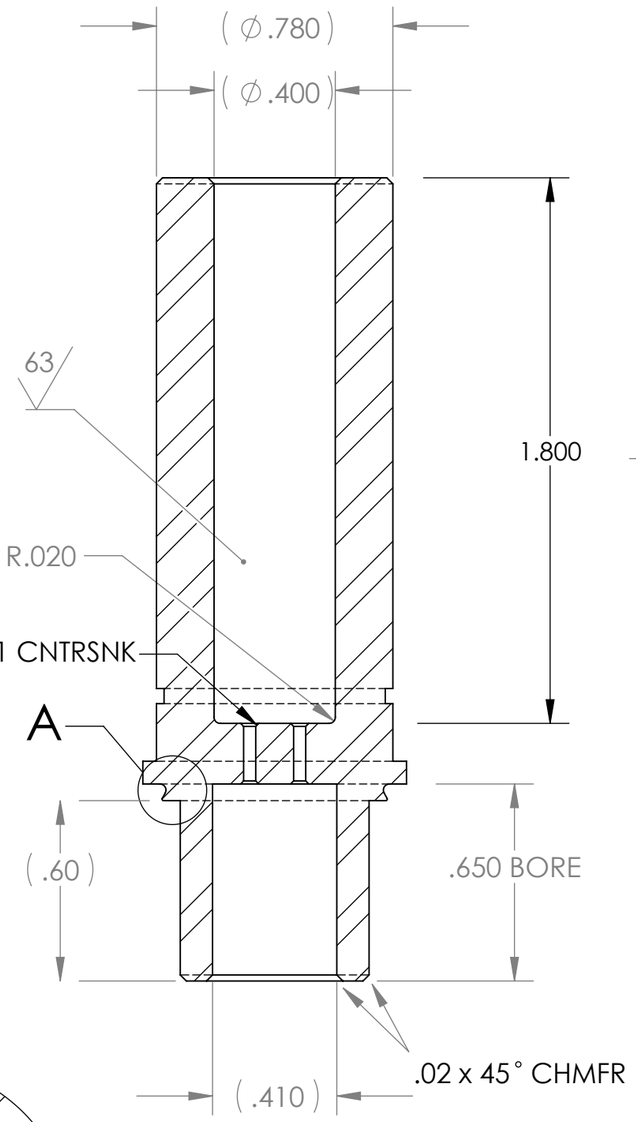
NEXT ASSY	USED ON
APPLICATION	

SIZE	DWG. NO.	REV.
B	P-1002444-18	A
SCALE 1:1	CAD FILE:	SHEET 1 OF 1

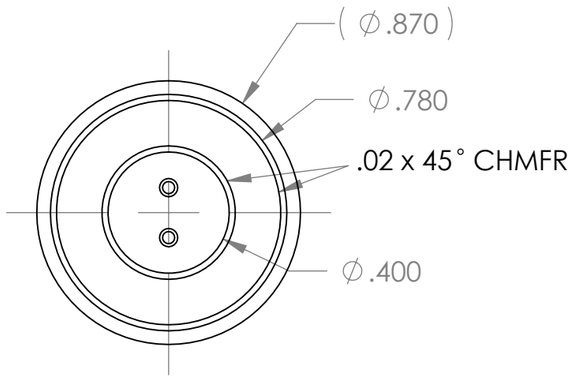
REVISIONS			
REV.	DESCRIPTION	DATE	APPROVED
	INITIAL RELEASE	5/25/04	

ff	REV.	DESCRIPTION	DATE	APPROVED
B1	A	CHG Fiber Hole Dia. frm .062 to .040	9/21/2018	J.E.
A1, B1	B	CHG No.of FIBER HOLES 0 2 CHG B.C. to .165 frm .240	4/25/2019	J.E.

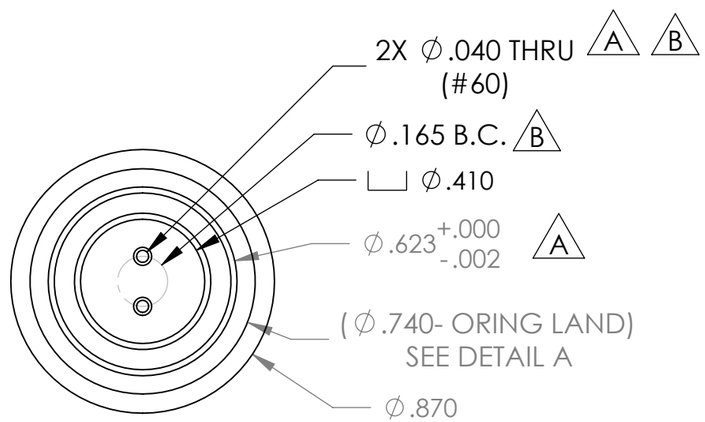




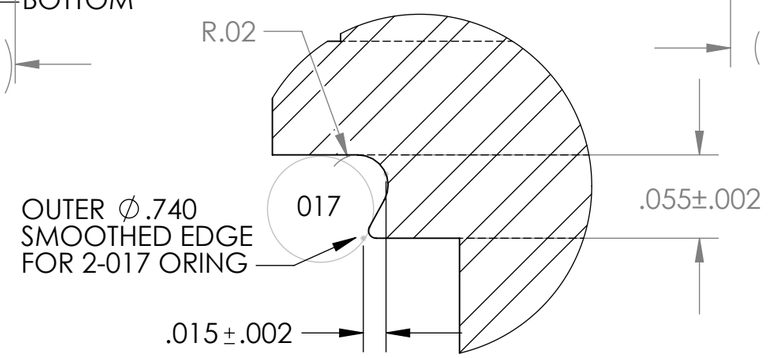
SECTION B-B
SCALE 2 : 1



TOP



BOTTOM VIEW



DETAIL A
SCALE 10 : 1

8. Mates to MinK-FCR

7. PROJECT LIBRARY:\901506 DeepPIV\ ME Drawings\FiberConnections\Test

ITEM NO.	QTY	PART NO.	DESCRIPTION	MATERIAL SPECIFICATION
			FIBER OPTIC PENETRATION FOR LRS/DORISS	316 SS

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APPROVALS	DATE
DRAWN J. Erickson	10/10/18
ENGINEER J.Erickson	X/XX/XX
CHECKED	
PROJECT NO. 901506	
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WEIGHT	

NEXT ASSY	USED ON
APPLICATION	

Monterey Bay Aquarium Research Institute
MBARI
7700 Sandholdt RD.
Moss Landing, CA 95039
PH: (831) 775-1700

FIBER OPTIC CABLE PLUG

SIZE	DWG. NO.	REV.
B	P-1002444-18	B
SCALE 1:1	CAD FILE:	SHEET 1 OF 1