Central Laboratory Request System (CLRS – NA)

3252-2021 Nano Engine Valve Fracture

Test Status: Report Sent - Complete
Lead Coordinator: glafata4

Lab Number: US231121
Request Date: 11/28/2023
Prelim Due Dt: 12/4/2023
Report Due Dt: 12/22/2023

Contact Information

Requester/Record Holder Name:	Requester CDSID:	Requester Name:	Requester Phone Number:
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Matl. Eng. Contact Name:	**Matl. Eng. Contact CDSID:**	**Matl. Eng. Contact Phone#:**	**Request Submitted by:**
Hamilton, Joshua (J.)	jhami139	1-313-8157917	Hamilton, Joshua (J.)

Program Information

GPID (Global Product Identifier):	GPID Description:	GSDB Code:
QLT14	Quality Engine	E304C

Please add additional information as needed:

Test Request Details

Request Title:			Proposed Completion Date:
2021 Nano Engine Valve Fracture			12/1/2023
Reason for Test:	**Section Supervisor:**	**Stop testing upon failure?**	**CPSC Code:**
Warranty Issue Greater Than 12 MIS	Metallurgy & Mechanical	No	030901

Sample Information

Sample Name	Qty	Sample Identification	Ford Part Number	Material Specification	Supplier or Source
Intake Valve	2	10 & 12	JT4E-6507-AB	SAE J775 K14072	Eaton

Test Procedure and Reporting Details

Describe Procedure/Specific testing requirements and Additional Sample Information

Examine the fractured intake valves. Locate the fracture origin. Section the parts through the fracture origin and check for grinder burn in the keeper grooves. Perform hardness traverse on the valve tips.

VIN: 1FTEW1EP9M[redacted] Valve 12 fractured at 26,938 miles
VIN: 1FMEE5EP5M[redacted]; Valve 10 fractured at 2,869 miles

Would you like to attach Document as a procedure?
No

Attachment Description		Attachments:	
Report check all that apply	Email Data Only: No	E-Mail a Formal Report: Yes	E-mail Preliminary Results: No

Additional comments:

Central Laboratory
15000 Century Drive
Dearborn, MI 48120-1267

Report US231121

December 22, 2023

To:	J. Hamilton (JHAMI139)	(313) 815-7917
Record Holder:	P. Adam (PADAM6)	(313) 580-3971
From:	G. LaFata (GLAFATA4)	(313) 322-7340

Subject: 2021 Nano Engine Valve Fracture

GPID:	QLT14
Part Number:	JT4E-6507-AB
Specification:	SAE J775 K14072
Supplier:	Eaton

Received: Two (2) fractured intake valves (identified as Intake Valve 10 & Intake Valve 12) were received on November 28, 2023.

Object: Perform fracture analysis on the fractured intake valves to identify the fracture type and locate the origin. Section through the fracture origin and evaluate microstructure in the keeper grooves for evidence of grinding burn. Perform microindentation hardness at the valve tip at the core, keeper grooves and surface.

Conclusion: Both intake valves appear to have initiated characteristic of bending fatigue and propagated across approximately 80% in this mode and then transitioning to a ductile overload final fracture. Over tempering and retransformation products were observed in multiple locations along the keeper grooves. Microindentation hardness testing was performed below the keeper grooves, surface and within the core. The hardness in several regions near the grooves and core traverse exceeded the hardness specification per Ford Drawing JT4E-6507-AB. Please refer to the Data and Analysis section for further details.

Data and Analysis:

Sample Identification

The fractured intake valves are from warranty return vehicles. Valve 10 (VIN: 1FMEE5EP5M[redacted]) fractured at 2,869 miles. Valve 12 (VIN: 1FTEW1EP9M[redacted]) fractured at 26,938 miles.

Fracture Analysis
(Visual Examination and Scanning Electron Microscopy (SEM))

The fractured intake valves were photographed upon being received showing the fracture at the third keeper groove from the tip at the root (Figures 1 – 4). Both fractures exhibit a point containing one or more ratchet marks which beach marks radiate from, characteristic of bending fatigue. This region propagated approximately 80% of the cross-section where the fracture transitions to a rougher textured region, suggestive of an overload final fracture (Figures 5 – 6). The fracture propagation of Intake Valve 10 arrested at about a third of the cross-section and then continues to propagate at a different angle, suggesting that the loading of the valve tip changed at this point. The fracture surface was further examined using a scanning electron microscope (SEM). Fatigue striations were observed at the initiation and in all the regions of beach marks, confirming a fatigue fracture mode initiation for both intake valves (Figures 7, 9,10). Micro-void coalescence (ductile dimples) was observed within the rougher textured final fracture region on both samples, confirming a ductile overload final fracture (Figures 8, 11). No evidence identifying the presence of a preexisting crack at the initiation was observed.

Metallographic Analysis
(ASTM E3, E407)

Valve 10 was selected for metallographic analysis due to the similarities in the fractures. The tip of Intake Valve 10 was longitudinally sectioned through the apparent fracture initiation site. The section was prepared for metallographic analysis in accordance with ASTM E3. The cross-section was etched with Vilella's etchant to reveal the microstructure in accordance with ASTM E407. Over tempering and retransformation products were observed in multiple locations along the keeper grooves as indicated in Figure 12. Retransformation products were observed near the root of the first and second keeper grooves from the tip (Figures 13 – 14). Representative micrographs of retransformation products present within the keeper groove at the corner near the major diameter are shown in Figures 15 – 16. The overall microstructure appears to be predominately tempered martensite (Figure 17).

Microindentation Hardness[1], HV 500 gf
(ASTM E384, E140)

Microindentation hardness readings were made on the polished metallographic cross-section of Intake Valve 10 in the area shown in Illustration A. Microindentation hardness was performed with a Vickers pyramidal indenter using a 500 gf load in accordance with ASTM E384. Vickers values were converted to Rockwell C in accordance with ASTM E140. The core traverse was performed from the tip of the valve stem at 1 mm intervals. Hardness measurements were also taken 1 mm below each of the keeper grooves and along the tip, on the top and bottom sides as detailed in Illustration A. The hardness in several locations near the grooves and core traverse exceeded the hardness specification per Ford Drawing JT4E-6507-AB. The drawing specifies a hardness of 50 – 57 HRC past the keeper grooves, 17.3 – 21.3 mm deep from the tip which applies to all of the areas tested in this report, and 40 – 50 HRC for the remaining valve body. The hardness results are shown in Tables 1 – 2.

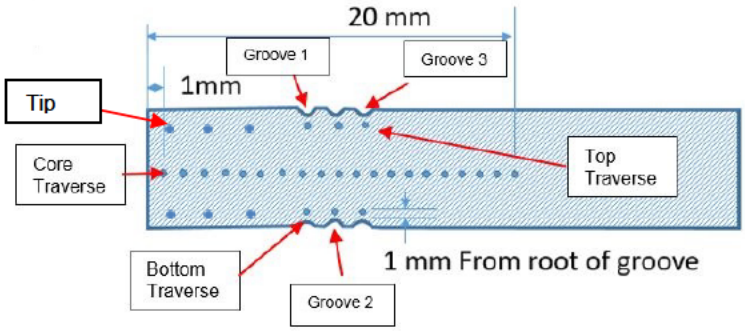


Illustration A: Hardness measurement locations.

Sample	Location	Hardness, $HRC_{VICKERS}$	
		Top	Bottom
Intake Valve 10	Groove 1	59_{664}*	59_{664}*
	Groove 2	58_{659}*	58_{643}*
	Groove 3	59_{664}*	57_{630}
	Tip 1	60_{689}*	59_{675}*
	Tip 2	58_{653}*	59_{678}*
	Tip 3	58_{661}*	58_{659}*
Specification		50 - 57	

* - *Indicates out of specification condition.*

Table 1: Keeper groove and tip hardness, $HRC_{VICKERS}$.

[1] Statement of Precision and Bias: The accuracy of HV500 gf readings has been confirmed with a standard test block in accordance with ASTM E384. The error has been determined to be -2.2%. The variability, with 95% confidence (±2σ), is ±3.1% when the average of 80 readings was compared to the published average for that block.

Microindentation Hardness (continued)

Sample	Core Indents from Tip, mm	Hardness, $HRC_{VICKERS}$
Intake Valve 10	1	56_{609}
	2	56_{611}
	3	56_{611}
	4	56_{618}
	5	56_{618}
	6	56_{618}
	7	56_{618}
	8	56_{621}
	9	57_{623}
	10	57_{630}
	11	58_{646}*
	12	58_{659}*
	13	58_{654}*
	14	58_{653}*
	15	58_{661}*
	16	58_{651}*
Specification		50 - 57

* - *Indicates out of specification condition.*

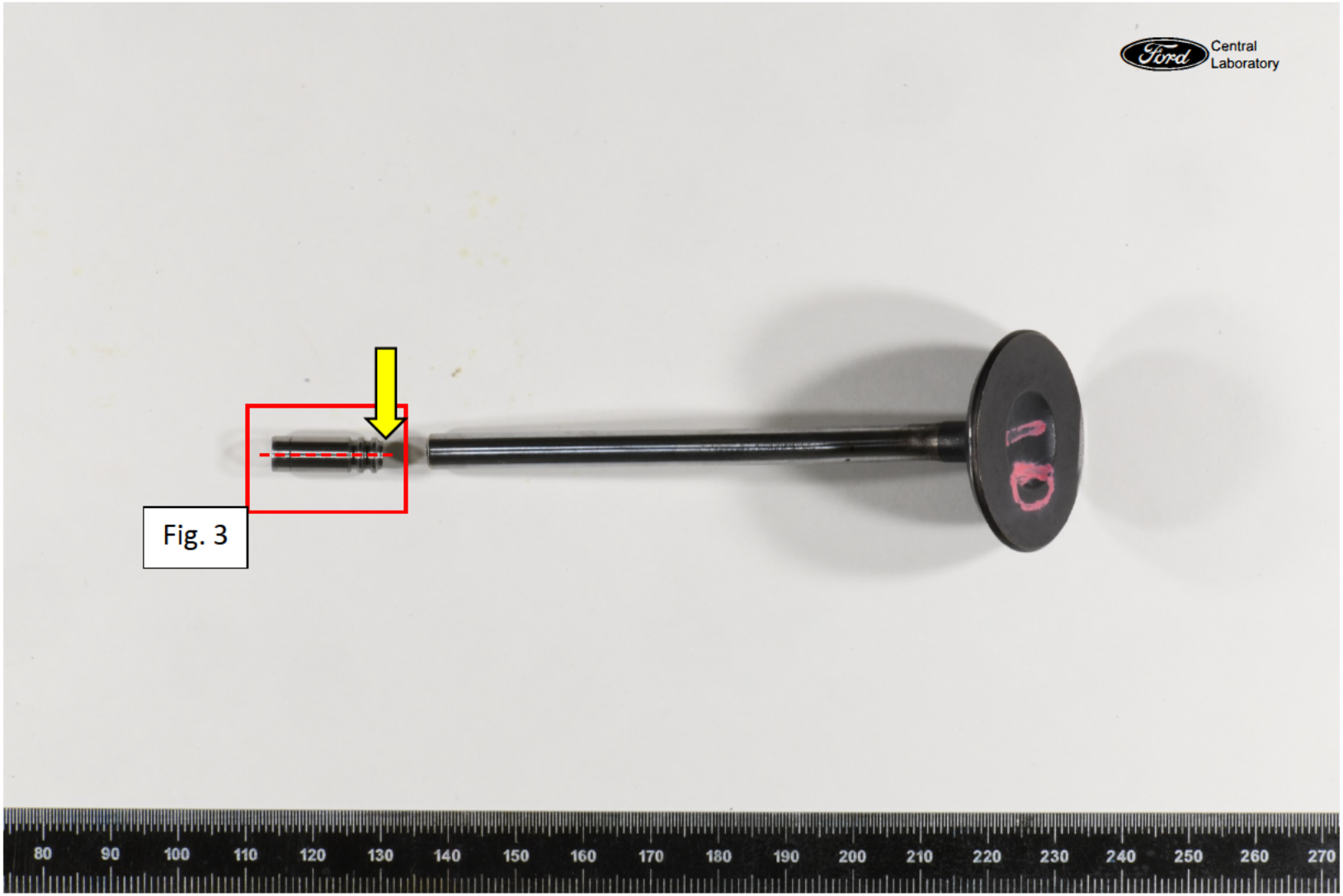
Table 2: Core hardness traverse, $HRC_{VICKERS}$.

Contributor(s): M. Krug, K Qiu (Sample Preparation, Fracture Analysis)

Concur: [redacted]
Scott Wolfe, Supervisor
Metallurgy & Mechanical Testing

By: [redacted]
Garrett LaFata (GLAFATA4)
Metallurgical Engineer

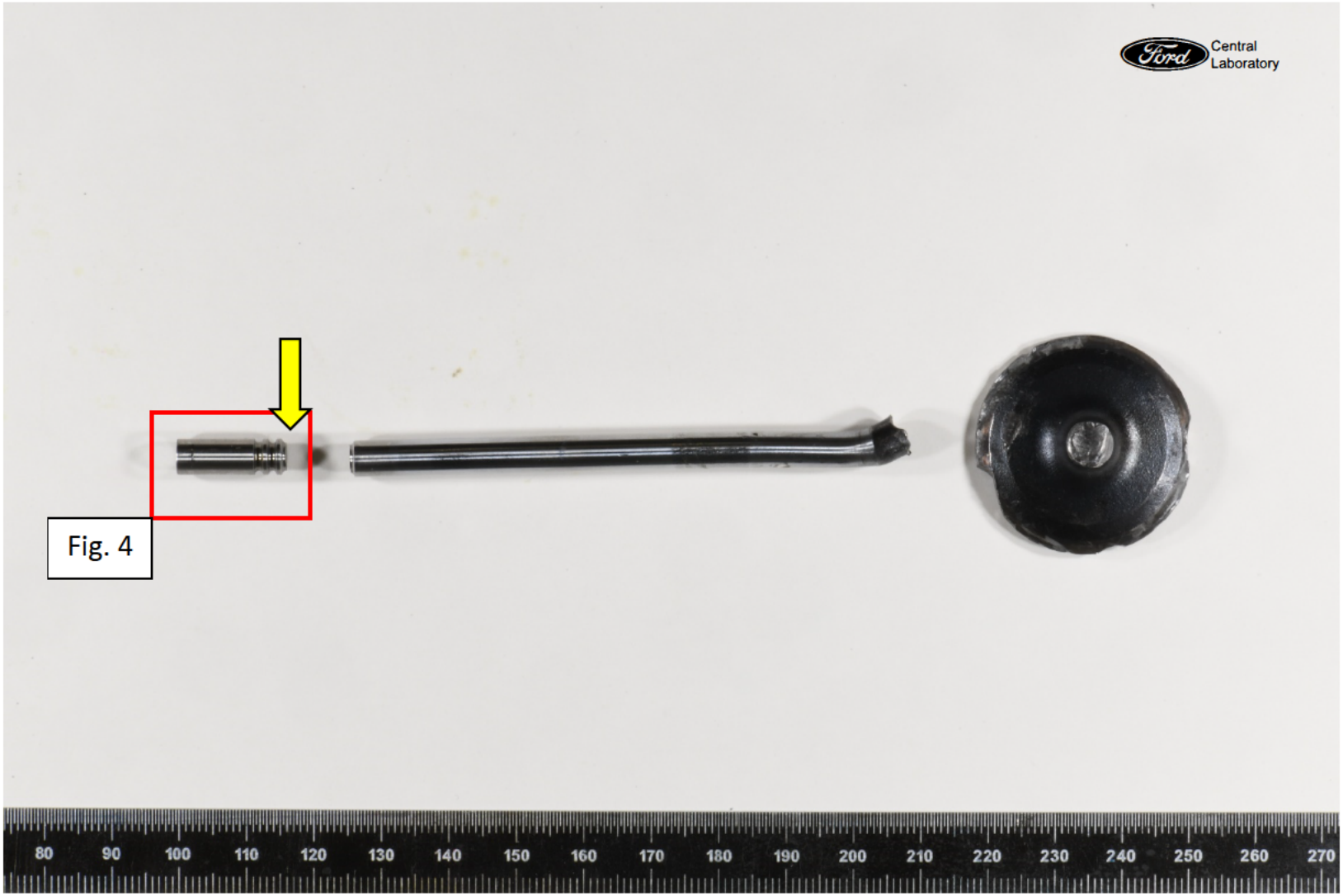
Enclosure(s): Figures 1 – 17 (17 Pages)



As-Received *Magnification: ~1.2X*

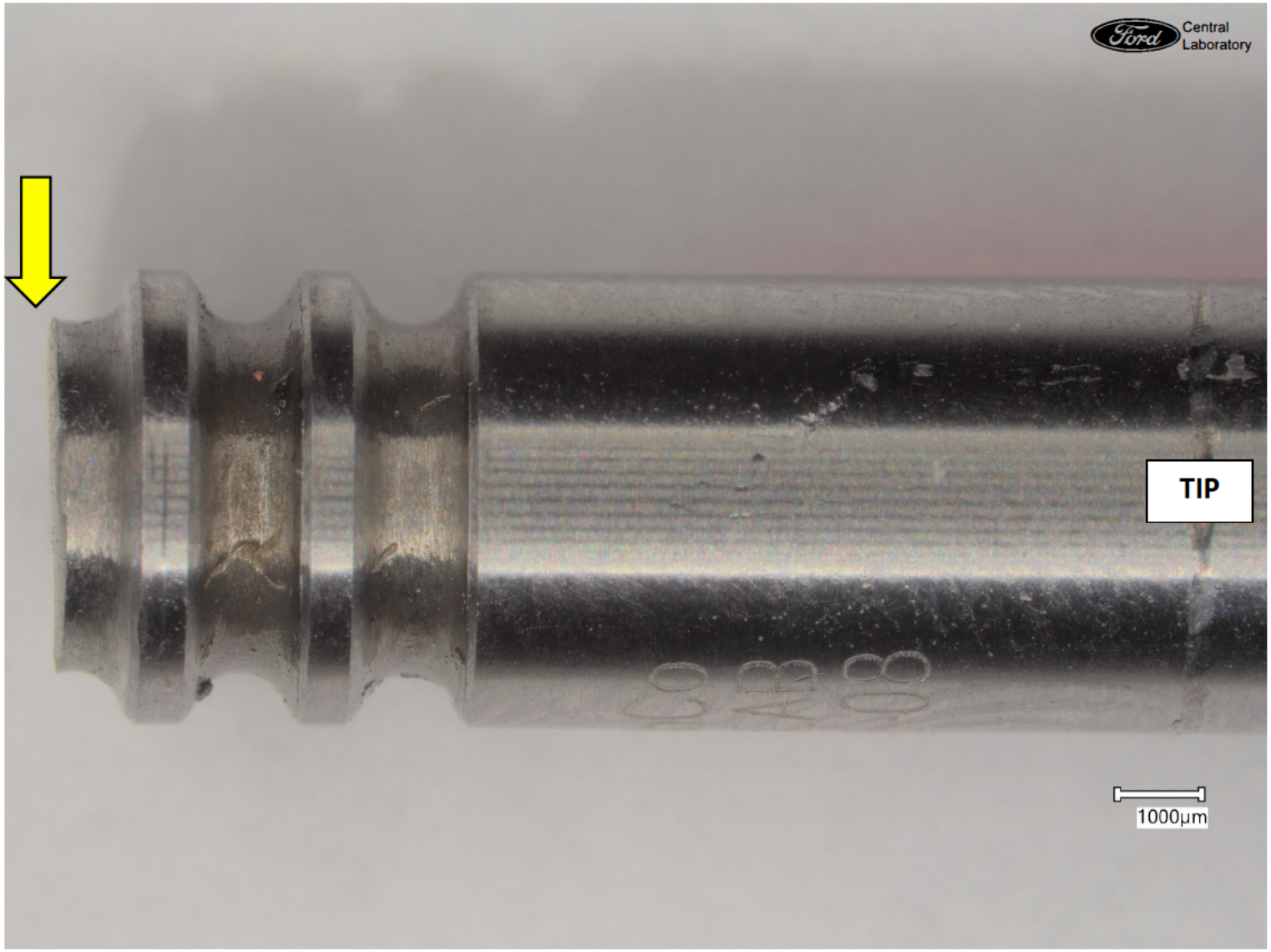
Figure 1: *Intake Valve – 10 – Overall view of the fractured intake valve. The fracture occurred at the third keeper groove from the tip as indicated by the yellow arrow. The red dotted line denotes the cross section location through the centerline.*

Note: Nominal magnifications given for photomicrographs.



As-Received *Magnification: ~1.2X*

Figure 2: *Intake Valve – 12 – Overall view of the fractured intake valve. The fracture occurred at the third keeper groove from the tip as indicated by the yellow arrow.*

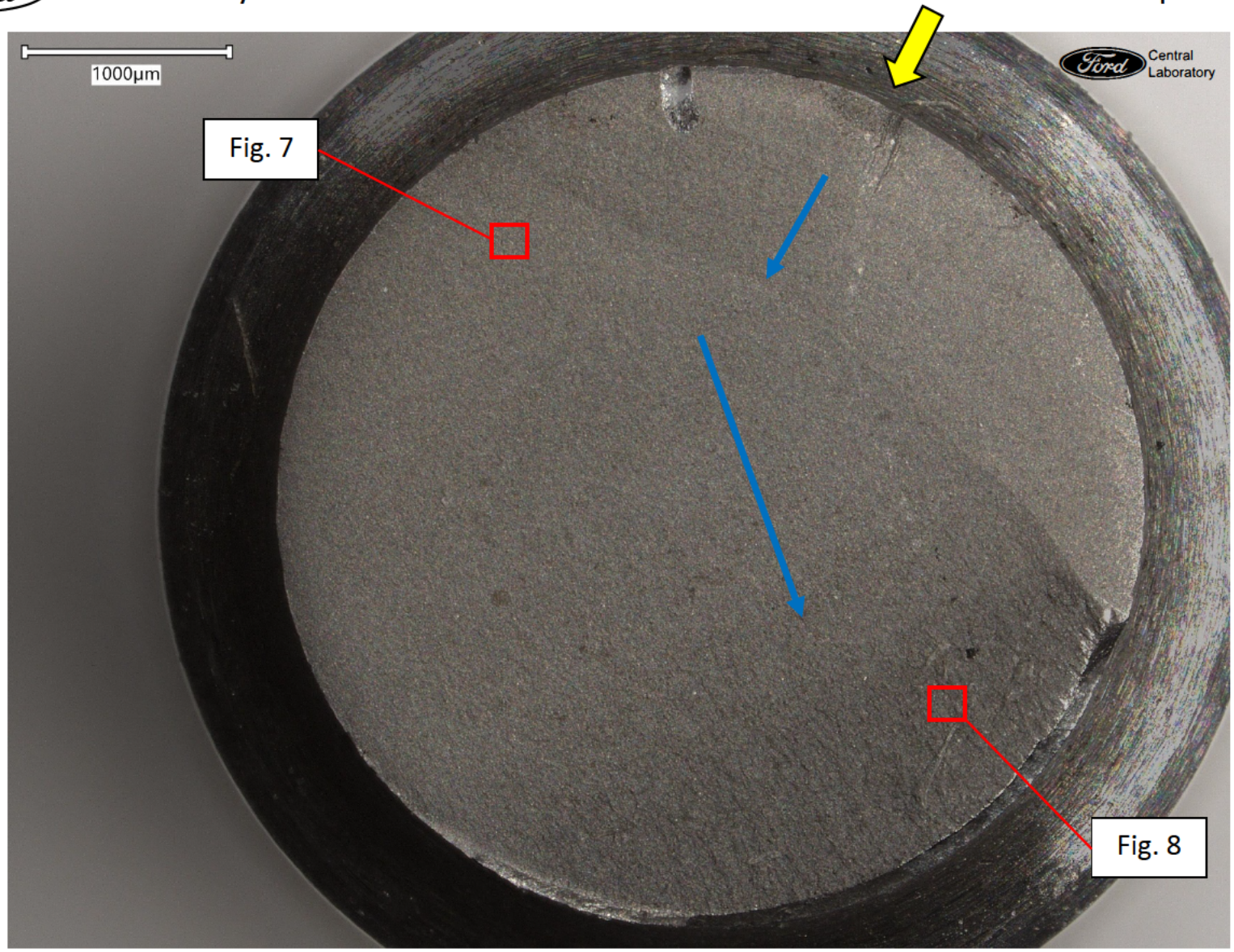


As-Received *Magnification: ~15X*

Figure 3: *Intake Valve – 10 – Magnified view of Figure 1 showing the fracture at the third keeper groove from the tip, indicated by the yellow arrow.*

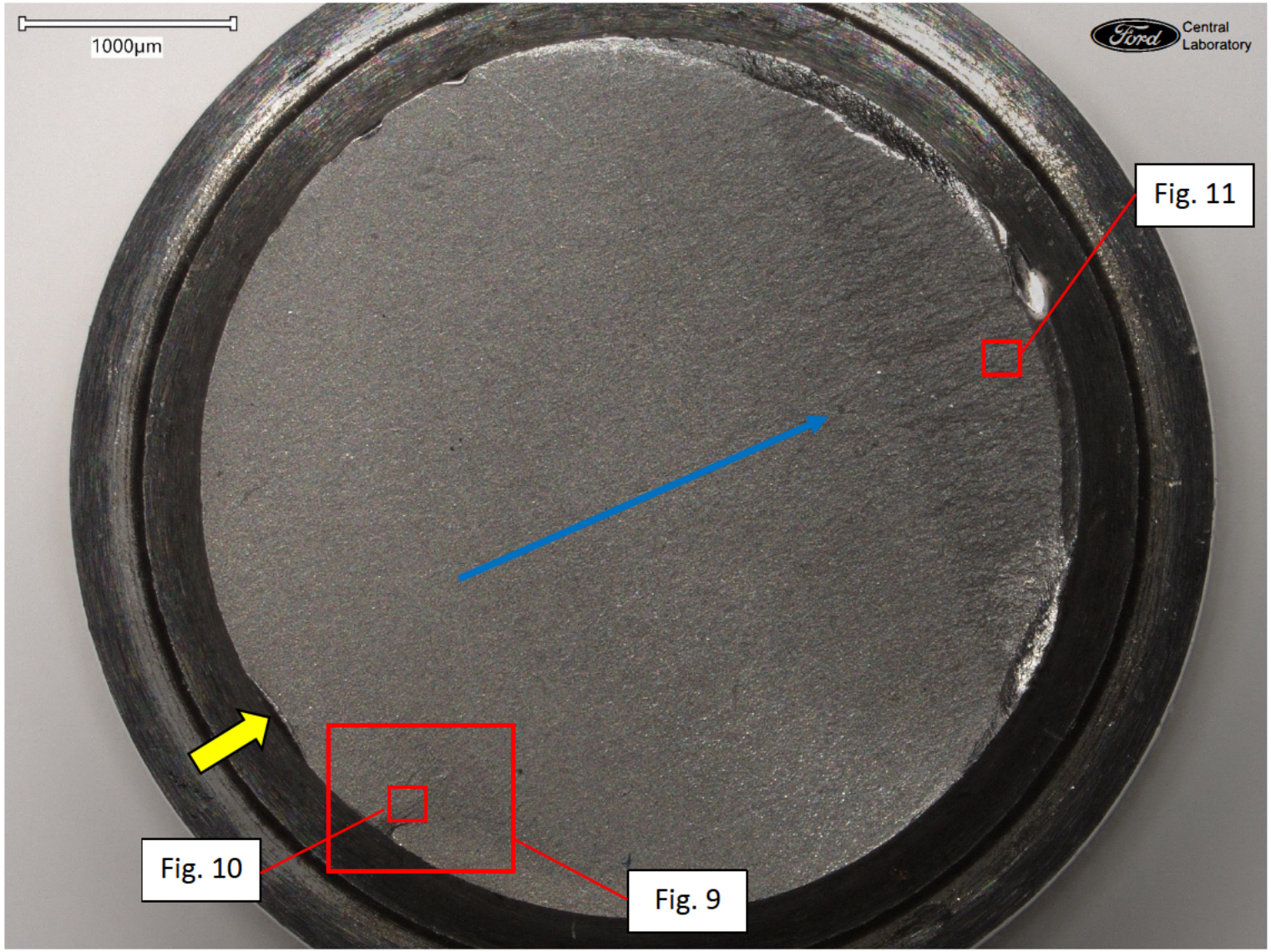
As-Received *Magnification: ~15X*

Figure 4: *Intake Valve – 12 – Magnified view of Figure 2 showing the fracture at the third keeper groove from the tip, indicated by the yellow arrow.*



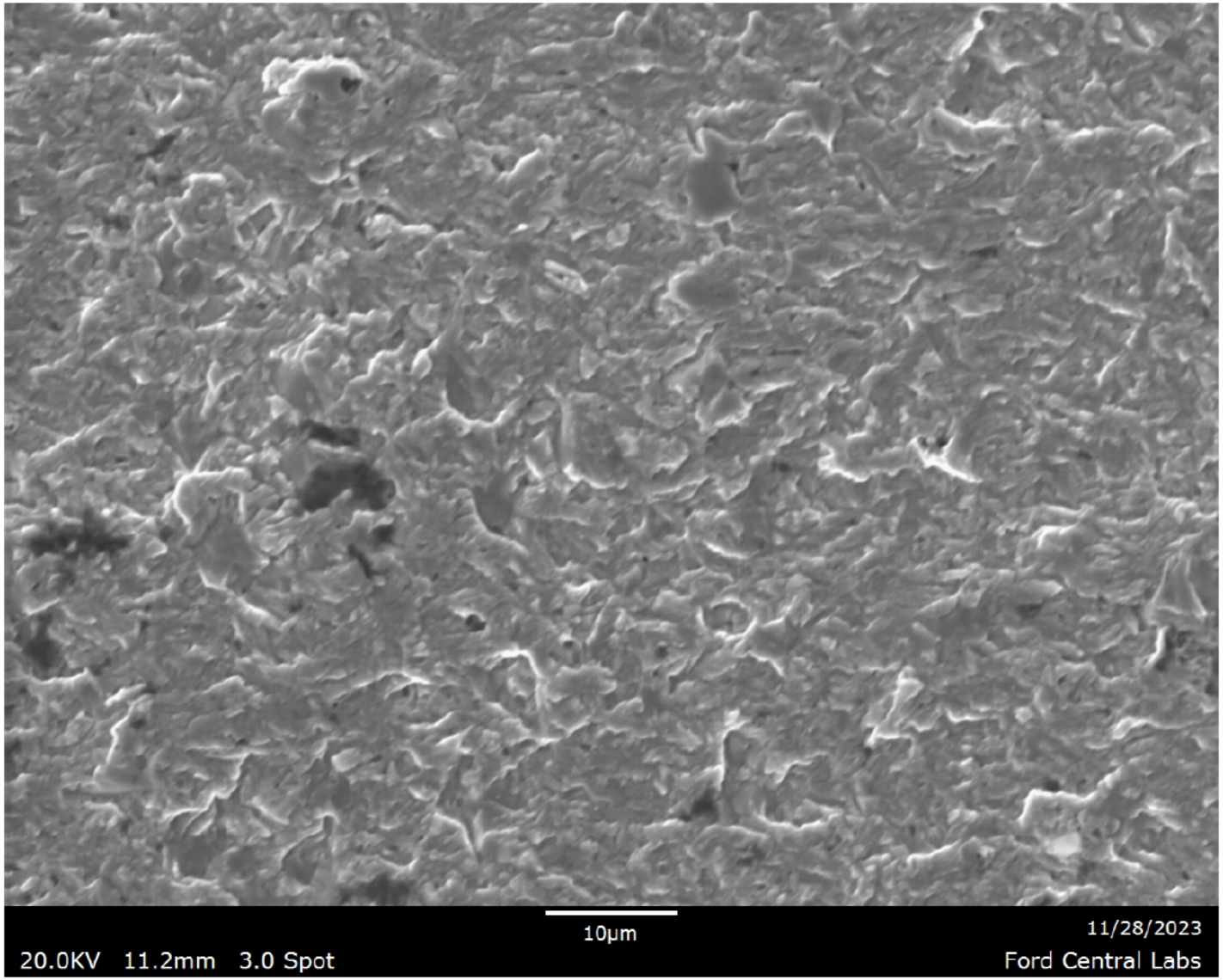
As-Received *Magnification: ~36X*

Figure 5: *Intake Valve – 10 – View of the fracture surface. The yellow arrow indicates the likely fracture initiation site. The blue arrows denote the fatigue propagation direction which suggests that the loading of the valve tip changed after propagating about a third of the cross-section.*



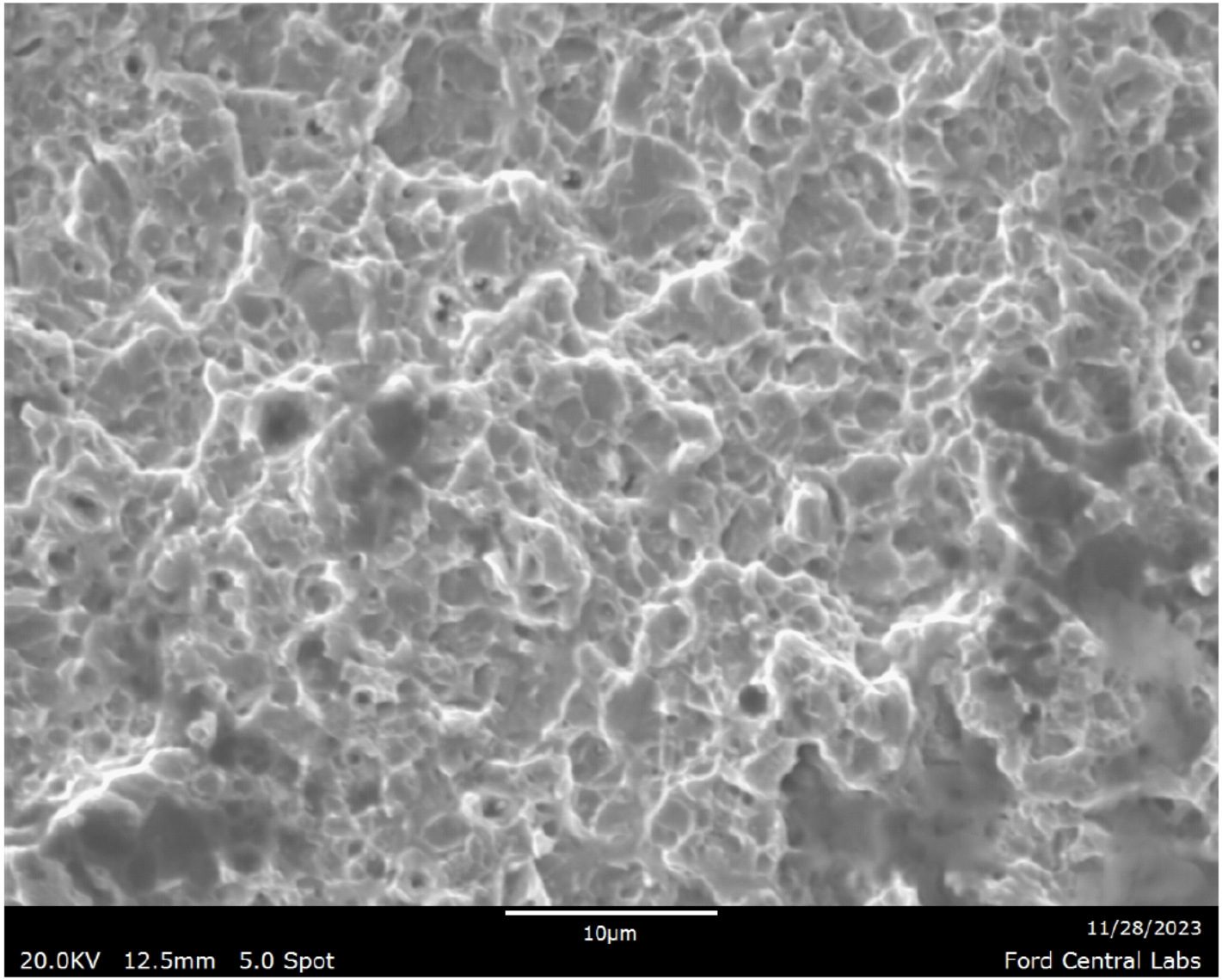
As-Received *Magnification: ~36X*

Figure 6: *Intake Valve – 12 – View of the fracture surface. The yellow arrow indicates the likely fracture initiation site. The blue arrow denotes the fatigue propagation direction.*



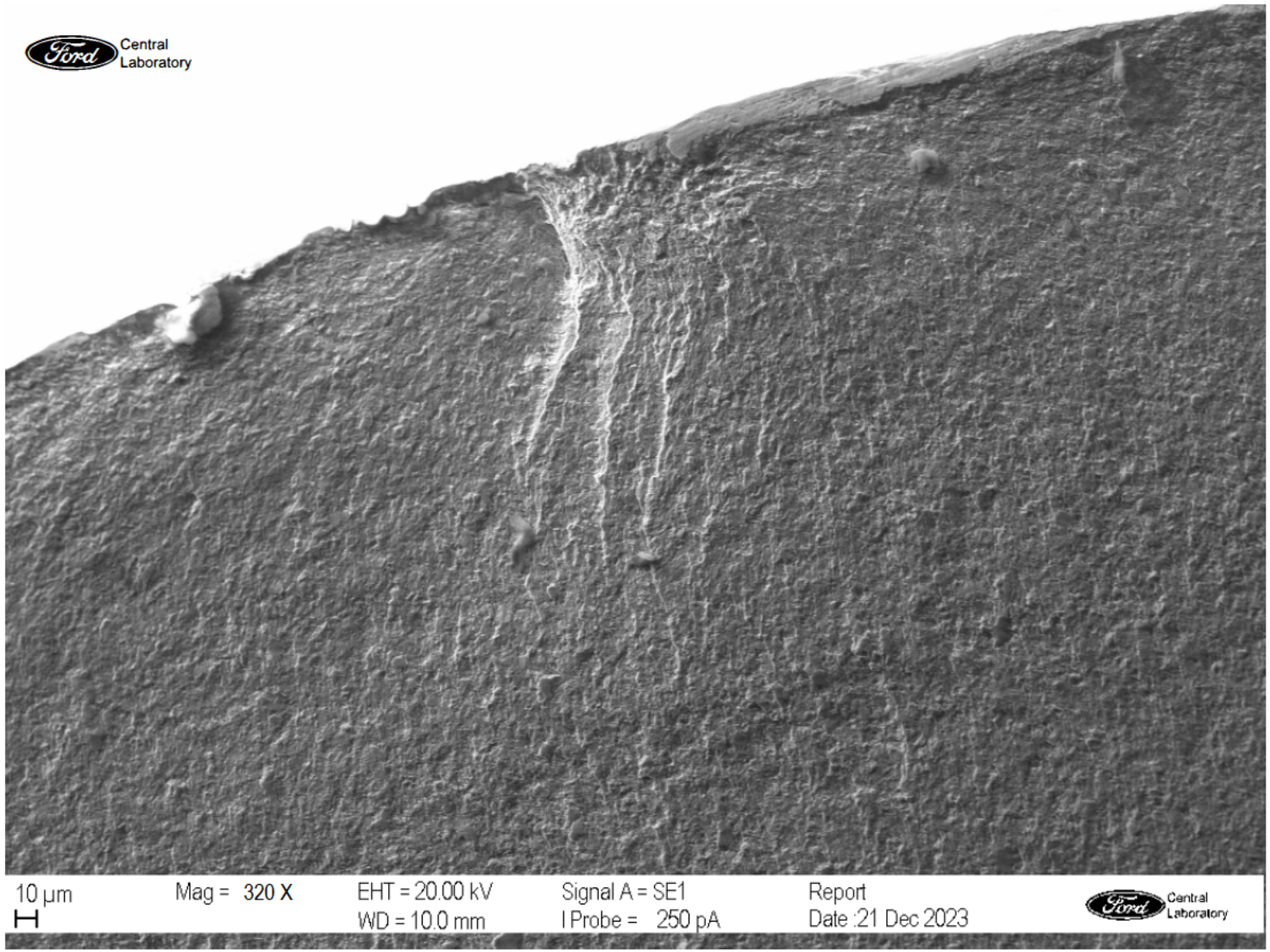
Secondary Electron *Magnification: ~2000X*

Figure 7: *Intake Valve – 10 – Magnified SEM view of Figure 5 showing fatigue striations.*



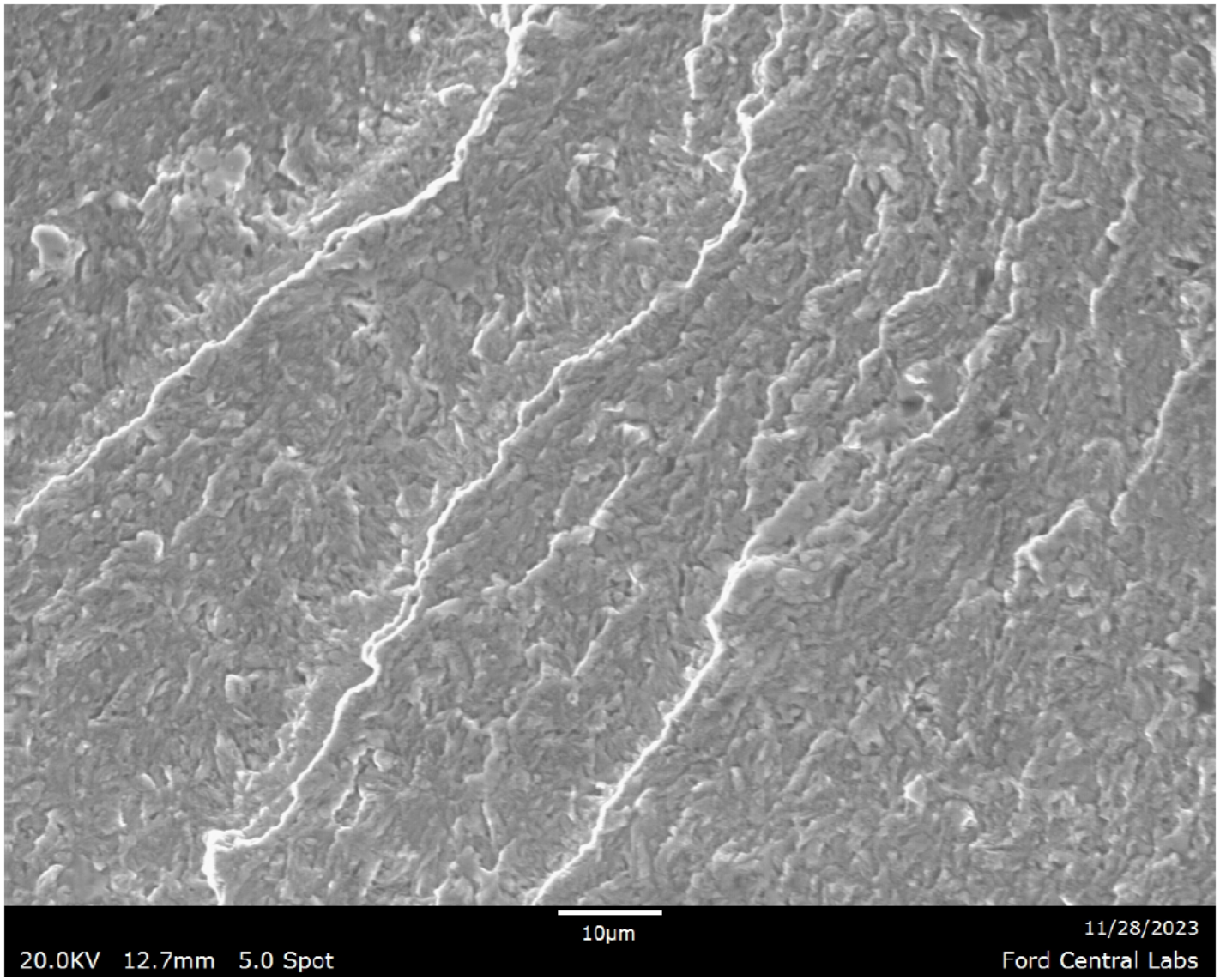
Secondary Electron *Magnification: ~3232X*

Figure 8: *Intake Valve – 10 – Magnified SEM view of Figure 5 showing Micro-void coalescence (ductile dimples) in the final fracture region.*



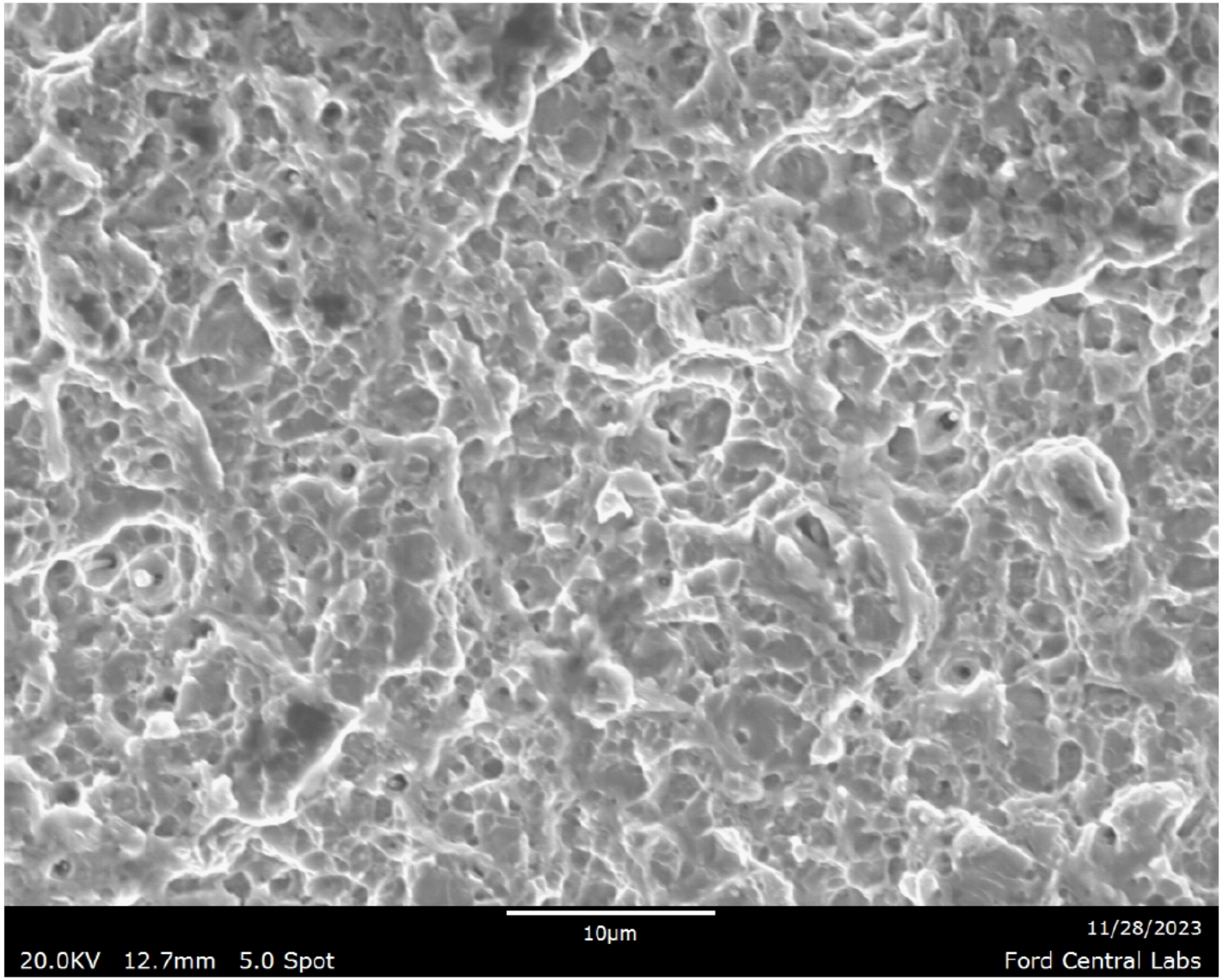
Secondary Electron *Magnification: 320X*

Figure 9: *Intake Valve - 12 - Magnified SEM view of Figure 6 showing the initiation region.*



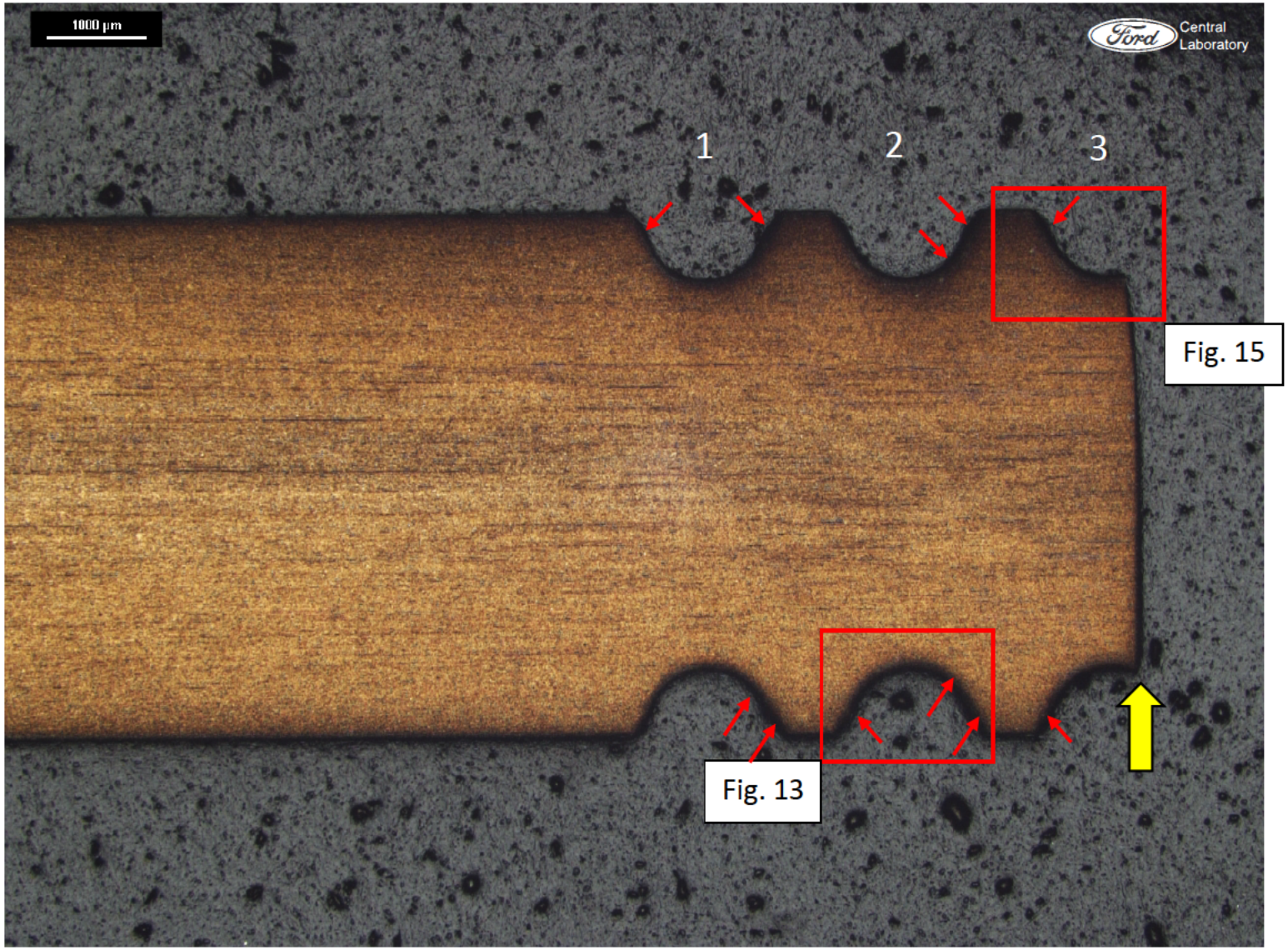
Secondary Electron *Magnification: ~1600X*

Figure 10: *Intake Valve – 12 – Magnified SEM view of Figure 6 showing fatigue striations.*



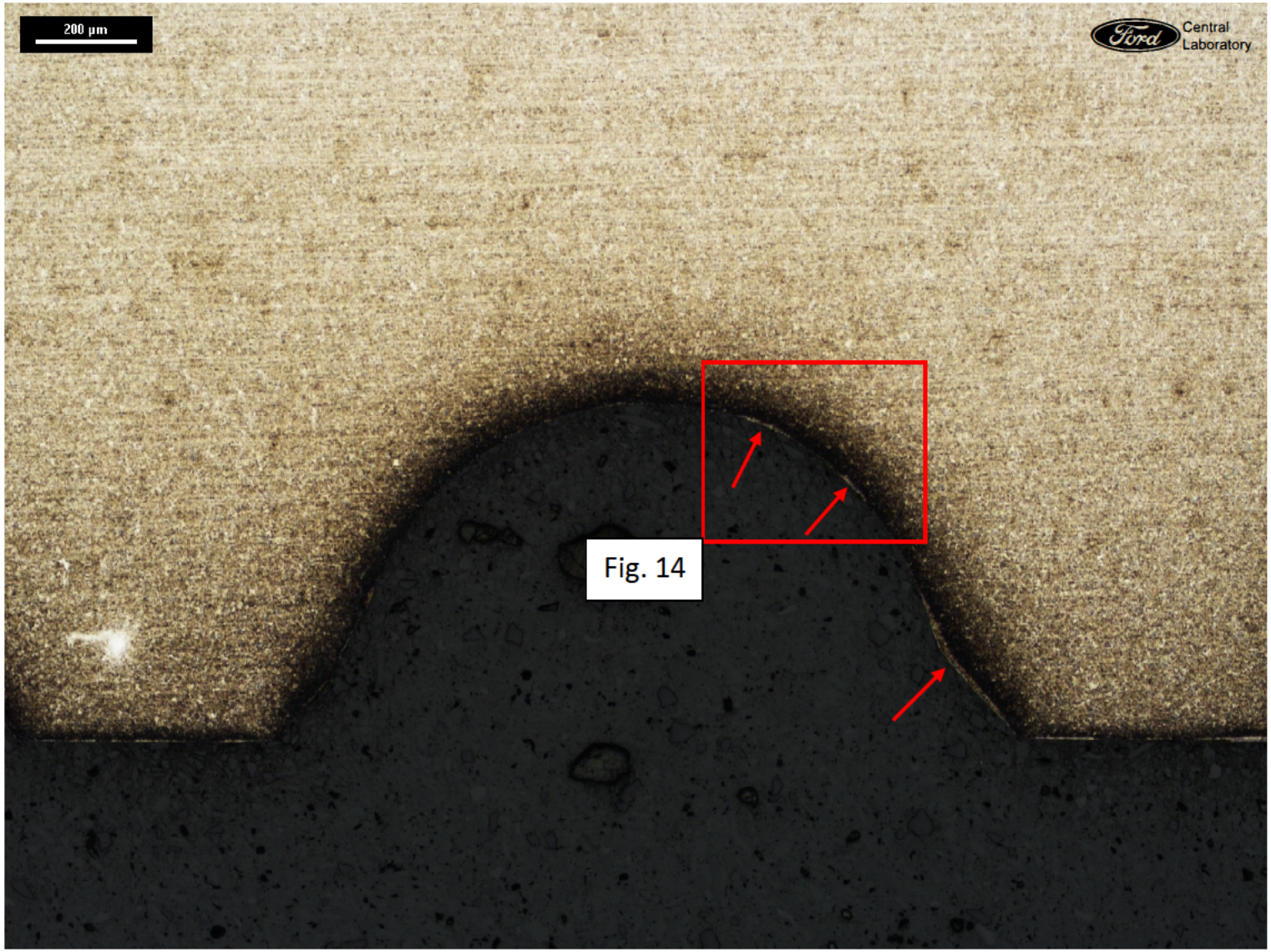
Secondary Electron *Magnification: ~3184X*

Figure 11: *Intake Valve – 12 – Magnified SEM view of Figure 6 showing Micro-void coalescence (ductile dimples) in the final fracture region.*



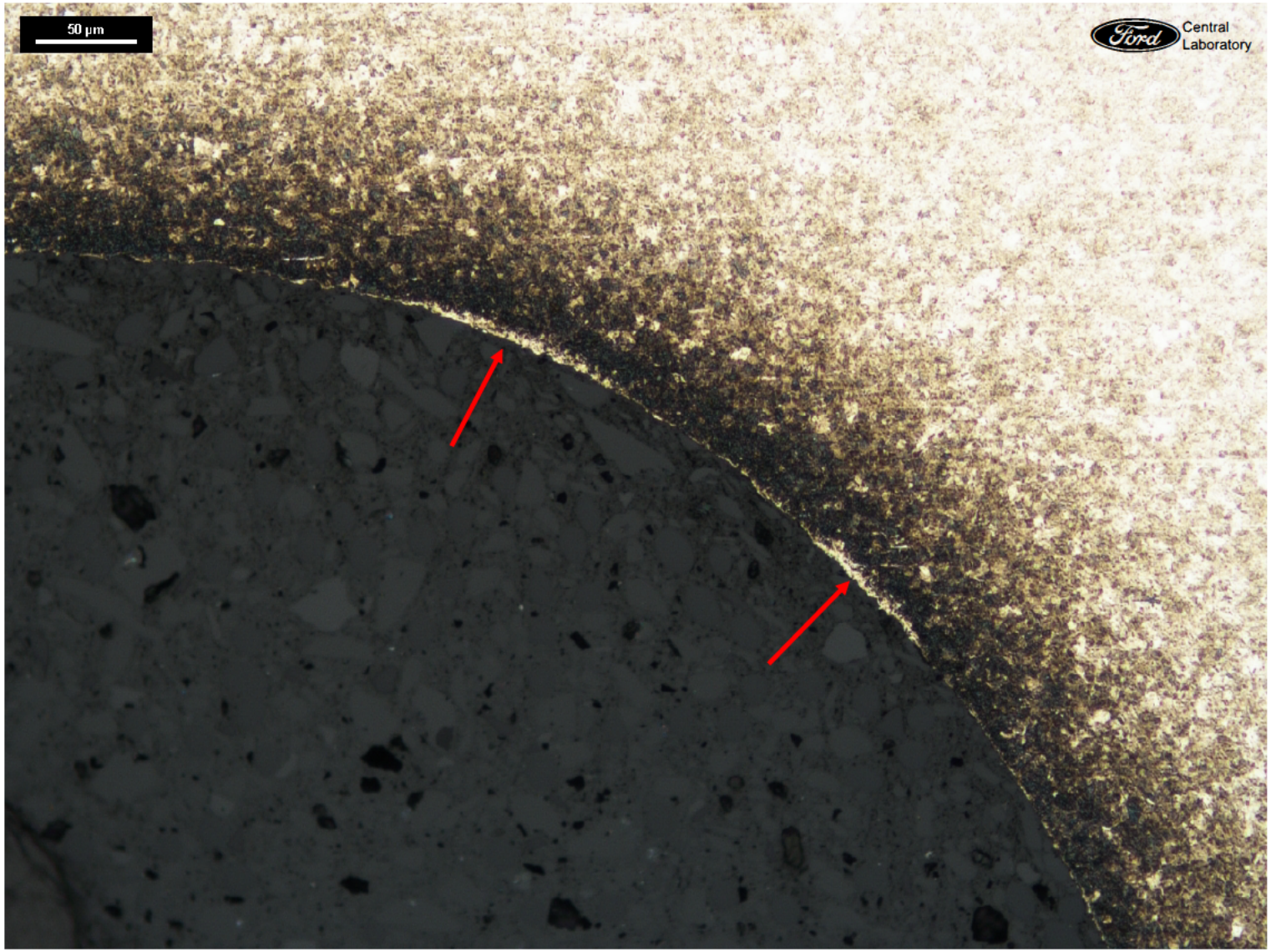
Vilella's Etchant *Magnification: ~16X*

Figure 12: *Intake Valve – 10 – Overall cross-sectional view of the fractured valve head showing areas of interest. The red arrows denote the locations where retransformation products were observed. The yellow arrow indicates the fracture initiation site.*



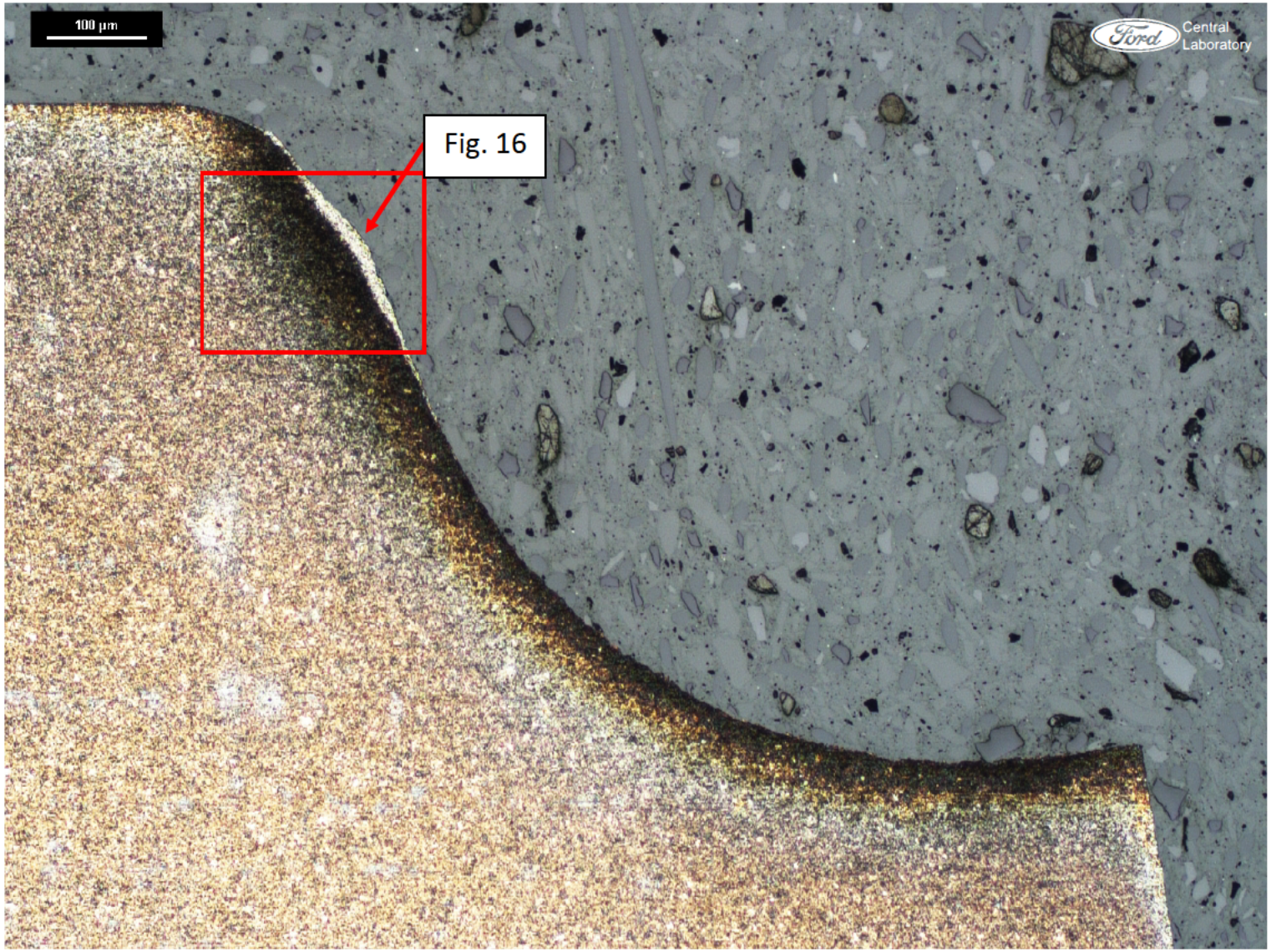
Vilella's Etchant *Magnification: ~80X*

Figure 13: *Intake Valve – 10 – Magnified cross-sectional view of Figure 12 showing over tempering (dark phase) and retransformation products (white phase) indicated by the red arrows.*



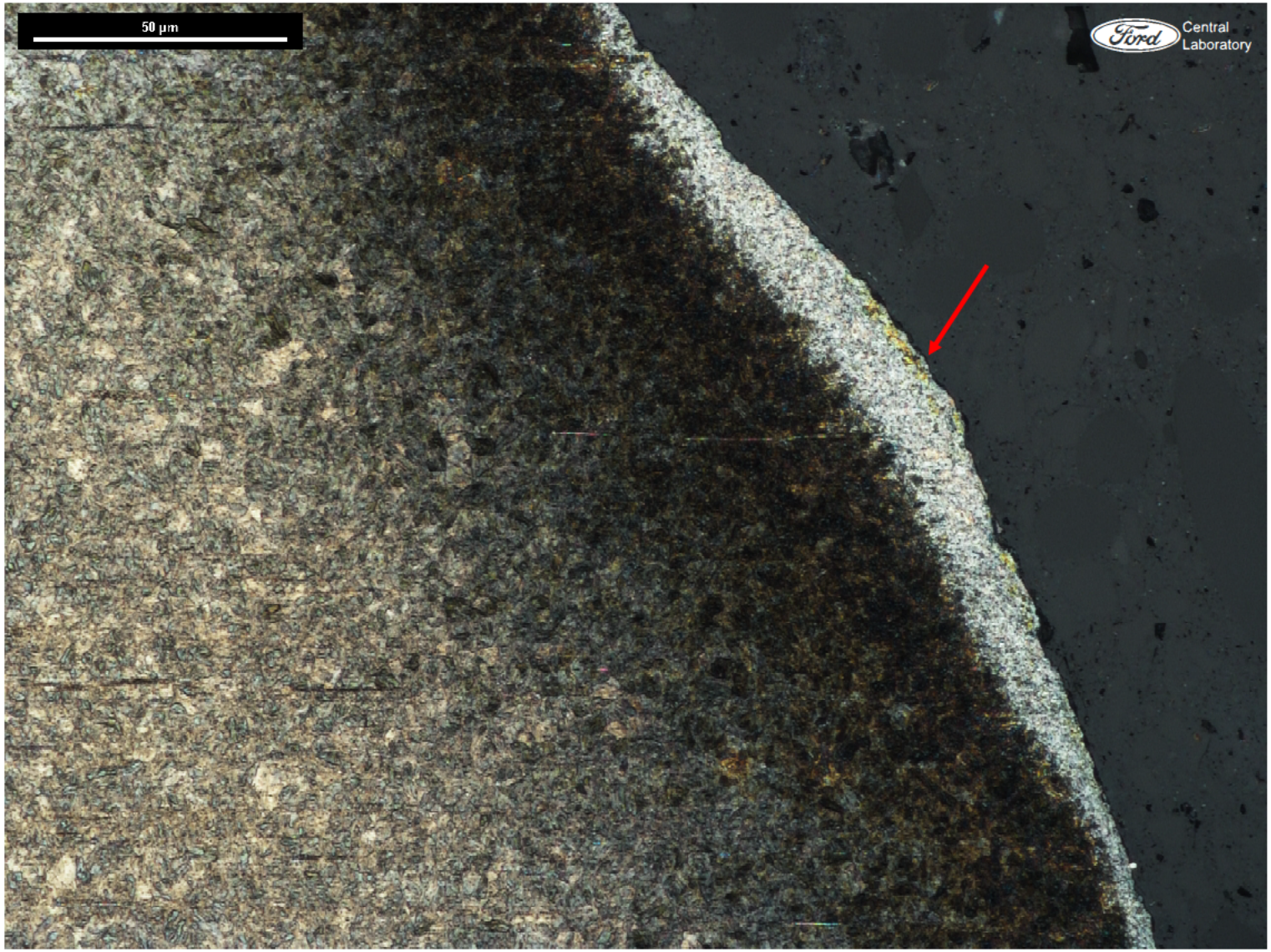
Vilella's Etchant *Magnification: ~320X*

Figure 14: *Intake Valve – 10 – Magnified cross-sectional view of Figure 12 showing retransformation products (white phase) within the keeper groove, indicated by the red arrows.*



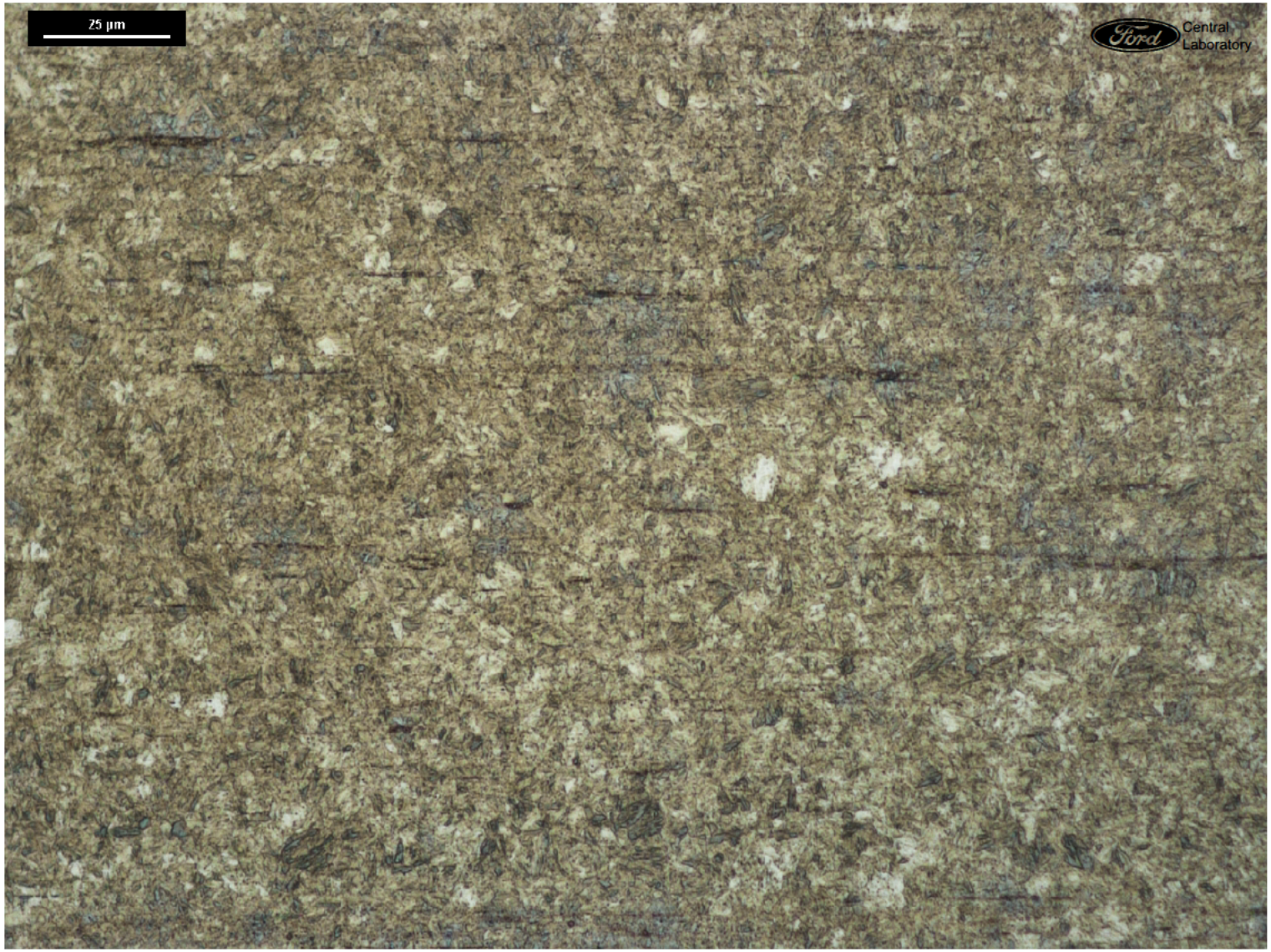
Vilella's Etchant *Magnification: ~160X*

Figure 15: *Intake Valve – 10 – Magnified cross-sectional view of Figure 12 showing over tempering (dark phase) and retransformation products (white phase) indicated by the red arrow.*



Vilella's Etchant *Magnification: ~800X*

Figure 16: *Intake Valve – 10 – Magnified cross-sectional view of Figure 15 showing over tempering (dark phase) and retransformation products (white phase) indicated by the red arrow.*



Vilella's Etchant *Magnification: ~800X*

Figure 17: *Intake Valve – 10 – Representative cross-sectional view showing the core microstructure consisting of predominately tempered martensite.*