New high-resolution optical 3D surface metrology methods for bullet and cartridge case identification

AFTE 2017 - 17th May 2017
Denver

SUMMARY

- Motivation

- Traditional and New 3D methods

  1. Bullets

  2. Cartridge cases

- Conclusions

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MOTIVATION

Surface metrology experts

- + 15 years
- + 600 systems worldwide

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MOTIVATION

Surface metrology experts + Firearms & tool marks community

- Objective Identification (AFTE 2016)
- Optimize 3D measurements (AFTE 2017)

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TRADITIONAL 3D METHODS
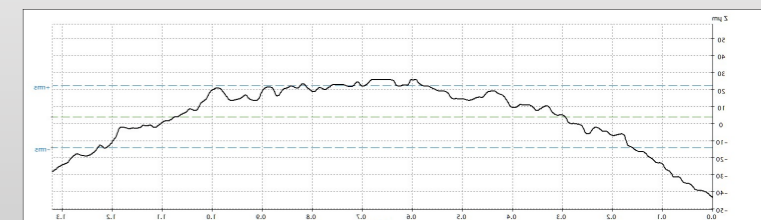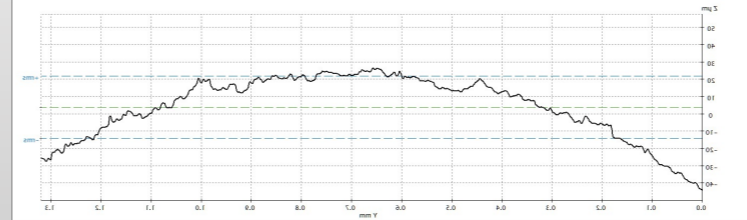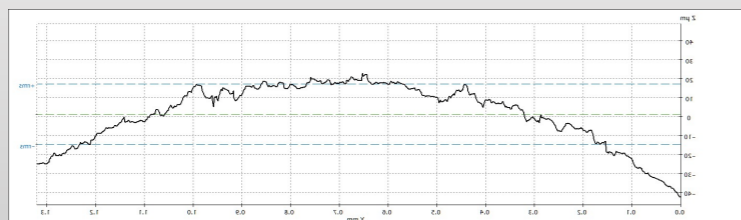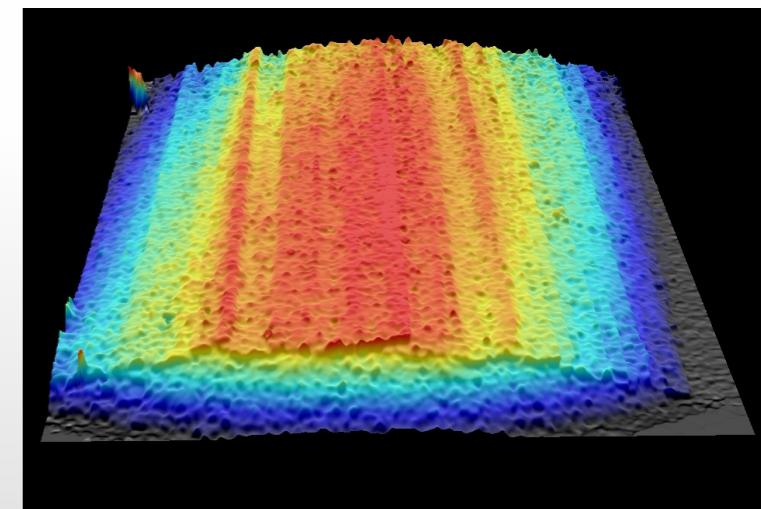
CSI
Interferometry

Confocal

Focus Variation

TRADITIONAL 3D METHODS

	CSI Interferometry	Confocal	Focus Variation
Rough samples	★	★ ★	★ ★ ★
Smooth samples	★ ★ ★	★ ★ ★	—
Micro-scale features (XY/Z)	★ ★ ★	★ ★ ★	★ ★
Nano-scale features (Z)	★ ★ ★	★ ★	—
High local slopes (>20º)	★	★ ★	★ ★ ★
Speed	★	★ ★	★ ★ ★

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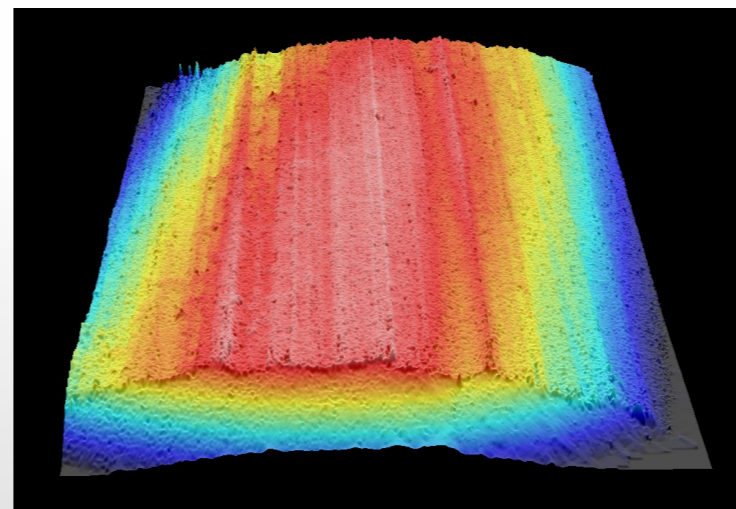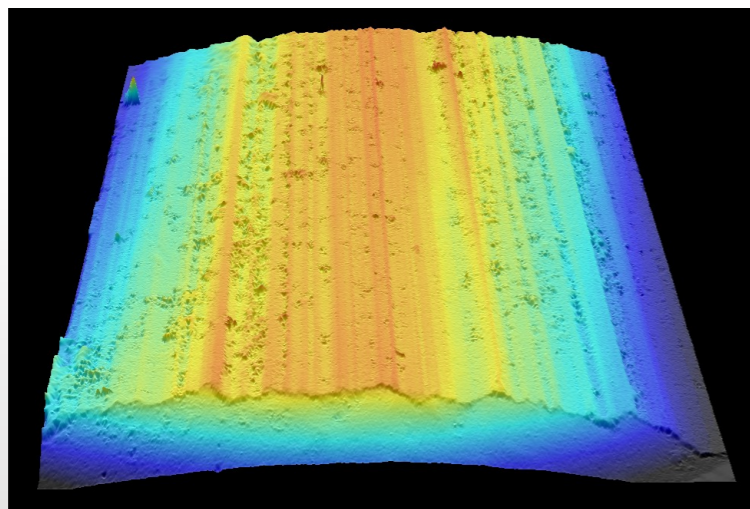
TRADITIONAL 3D METHODS

	CSI Interferometry	Confocal	Focus Variation
Rough samples	★	★★	★★★
Smooth samples	★★★	★★★	—
Micro-scale features (XY/Z)	★★★	★★★	★★
Nano-scale features (Z)	★★★	★★	—
High local slopes vs NA	★	★★	★★★
Speed	★	★★	★★★

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NEW 3D METHODS

	CSI Interferometry	NEW **Continuous** Confocal	NEW **Confocal Fusion**	Focus Variation
Rough samples	★	★ ★	★ ★ ★	★ ★ ★
Smooth samples	★ ★ ★	★ ★ ★	★ ★ ★	—
Micro-scale features (XY/Z)	★ ★ ★	★ ★ ★	★ ★ ★	★ ★
Nano-scale features (Z)	★ ★ ★	★ ★	★ ★ ★	—
High local slopes (>20º)	★	★ ★	★ ★ ★	★ ★ ★
Speed	★	3x ★ ★ ★ faster	★ ★ ★	★ ★ ★

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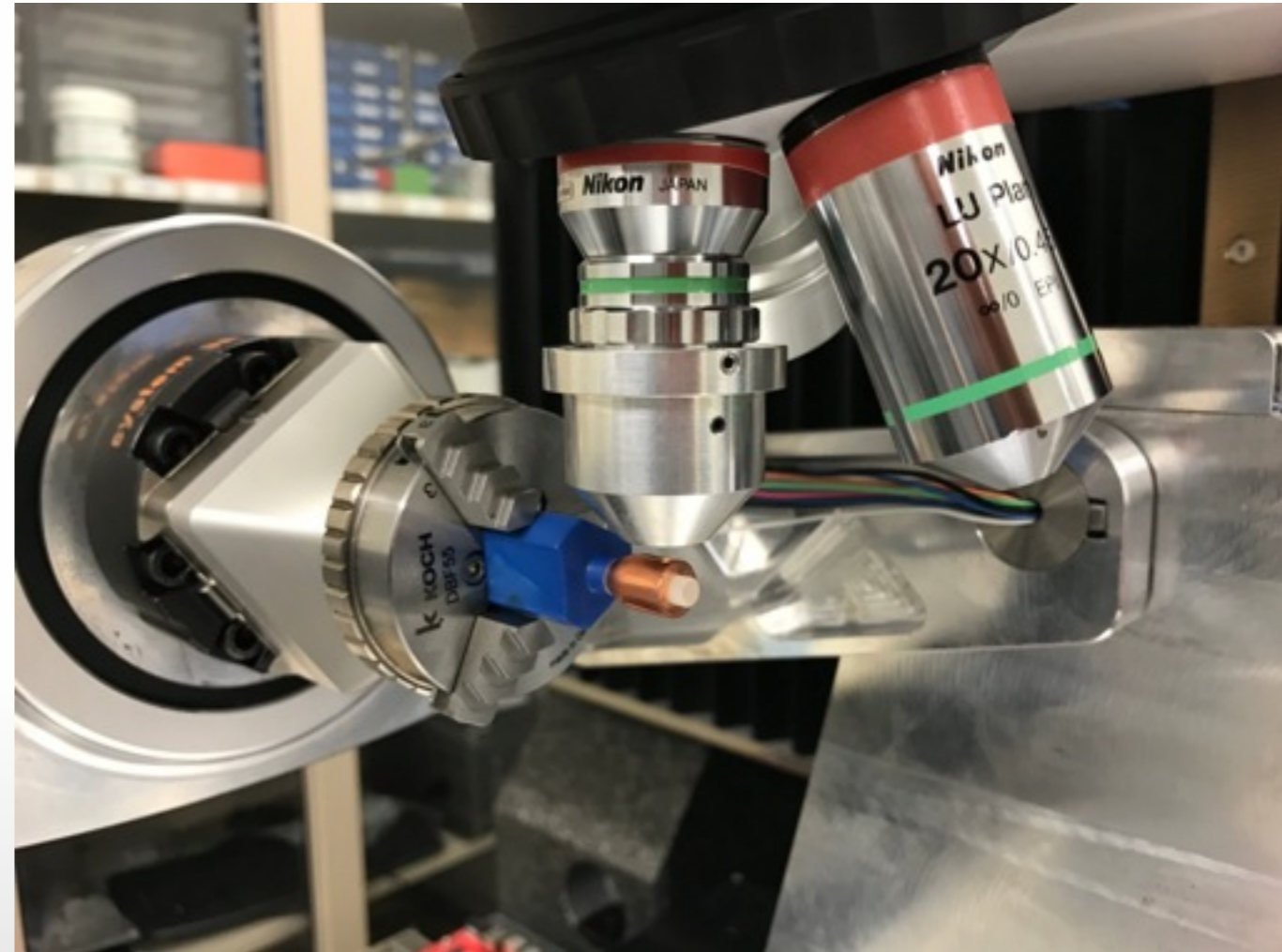# NEW 3D METHODS / BULLETS

NIST SRM 2460

Four 3D methods:

- CSI

- Confocal (C)

- Continuous Confocal (CC)

- Focus Variation (FV)

20X objective:

- NA 0.45 (EPI) & 0.4 (DI)

- Pixel size 0.65 micrometers

Z scan range 190 micrometers

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NEW 3D METHODS / BULLETS

Sensofar's objective identification methodology (AFTE 2016)

- IC surface extraction for each technique

- IC created from NIST SRM 2460 virtual profiles (contact stylus profiler)
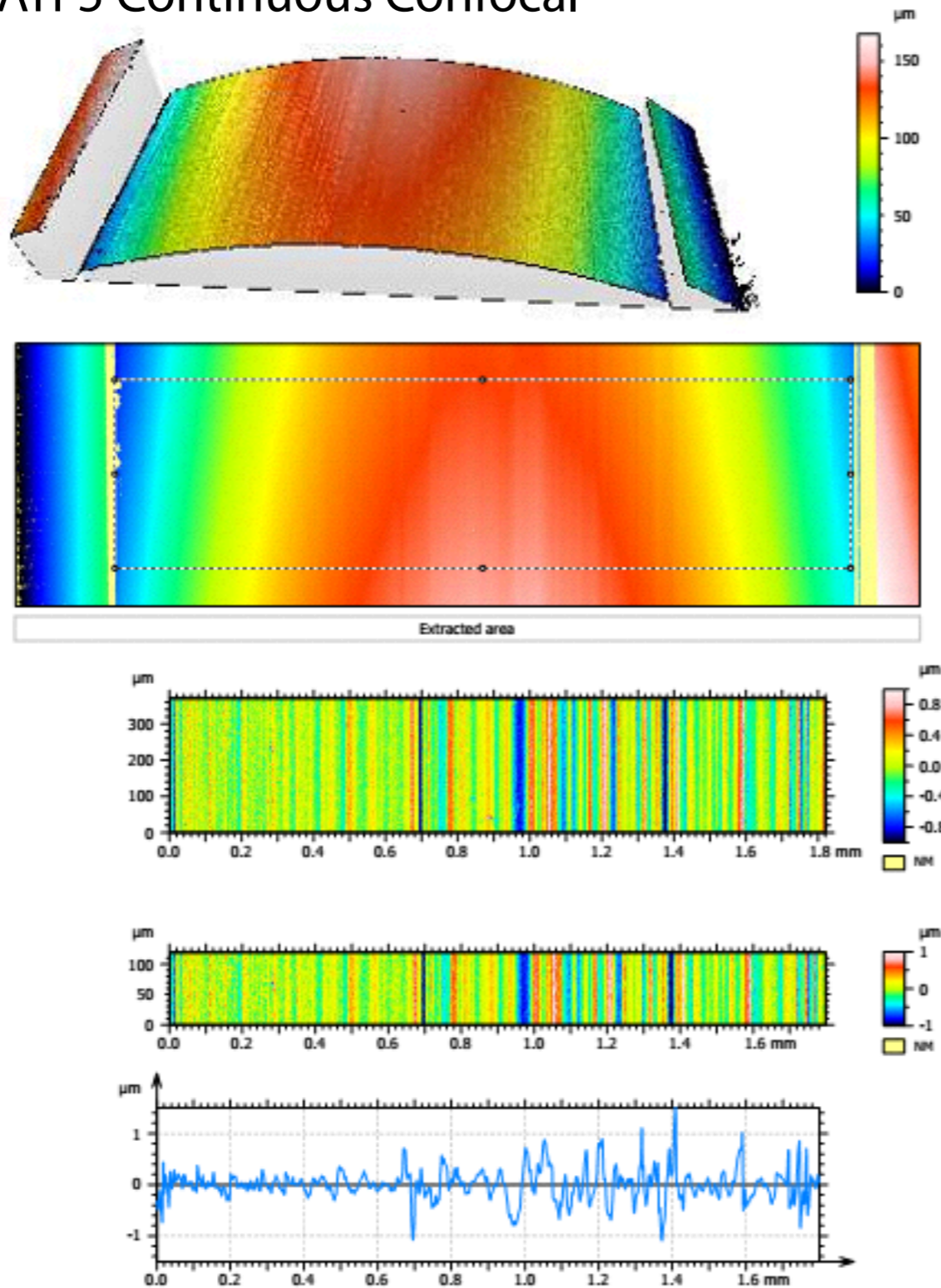
1. Land surface measurements

2. IC extraction

3. IC comparison (CCF_{max})

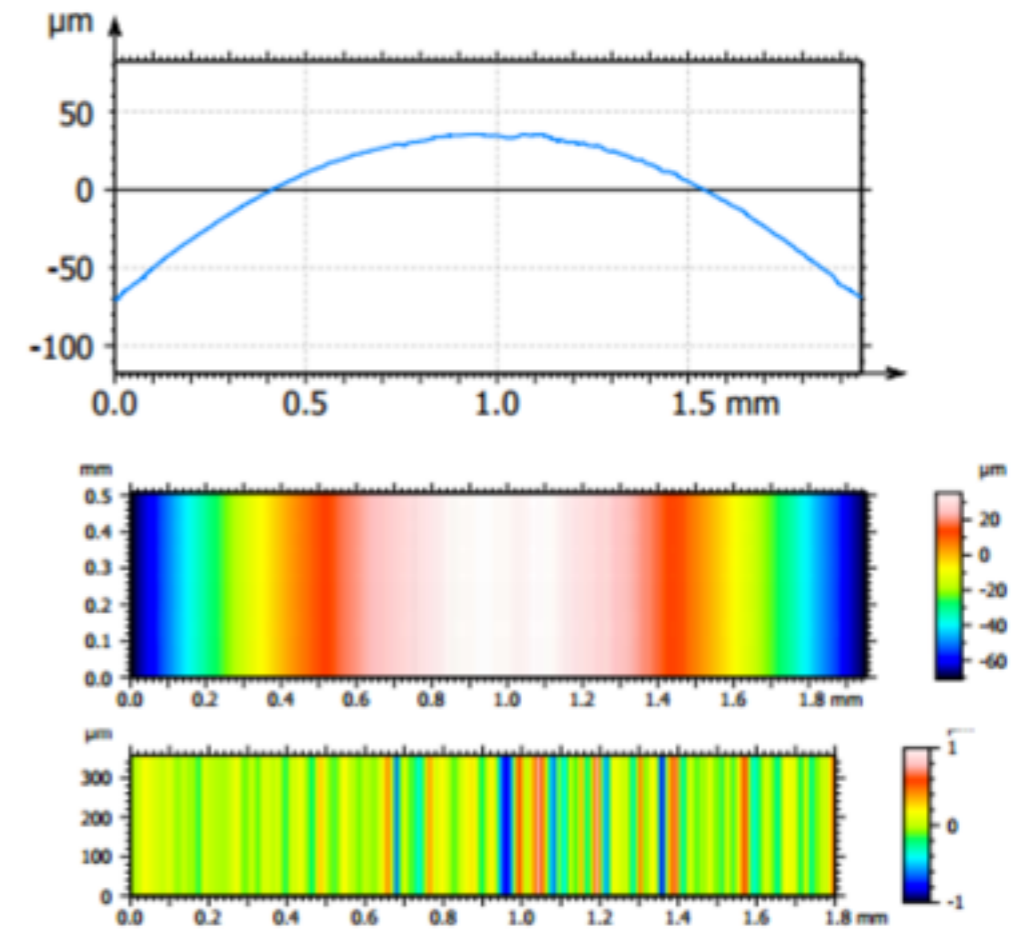4. Bullet comparisons: new automated comparison score: **Sequence Average Maximum (SAM)**

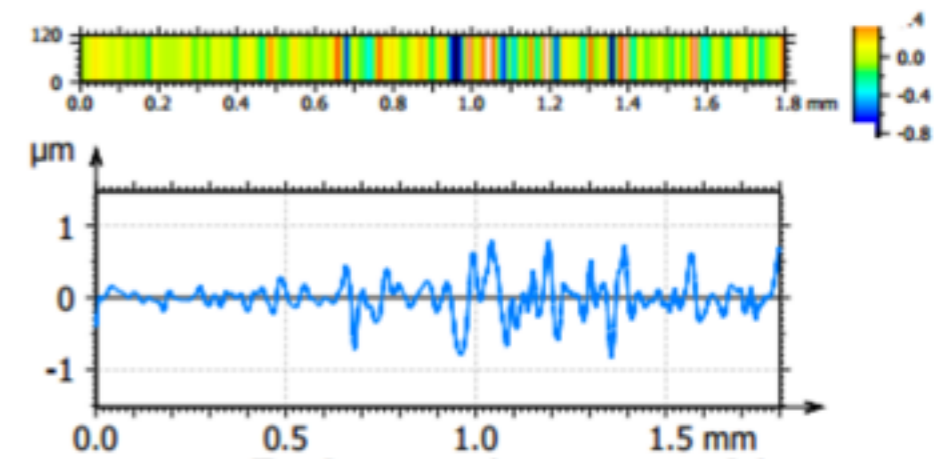5. Top N list analysis

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NEW 3D METHODS / BULLETS

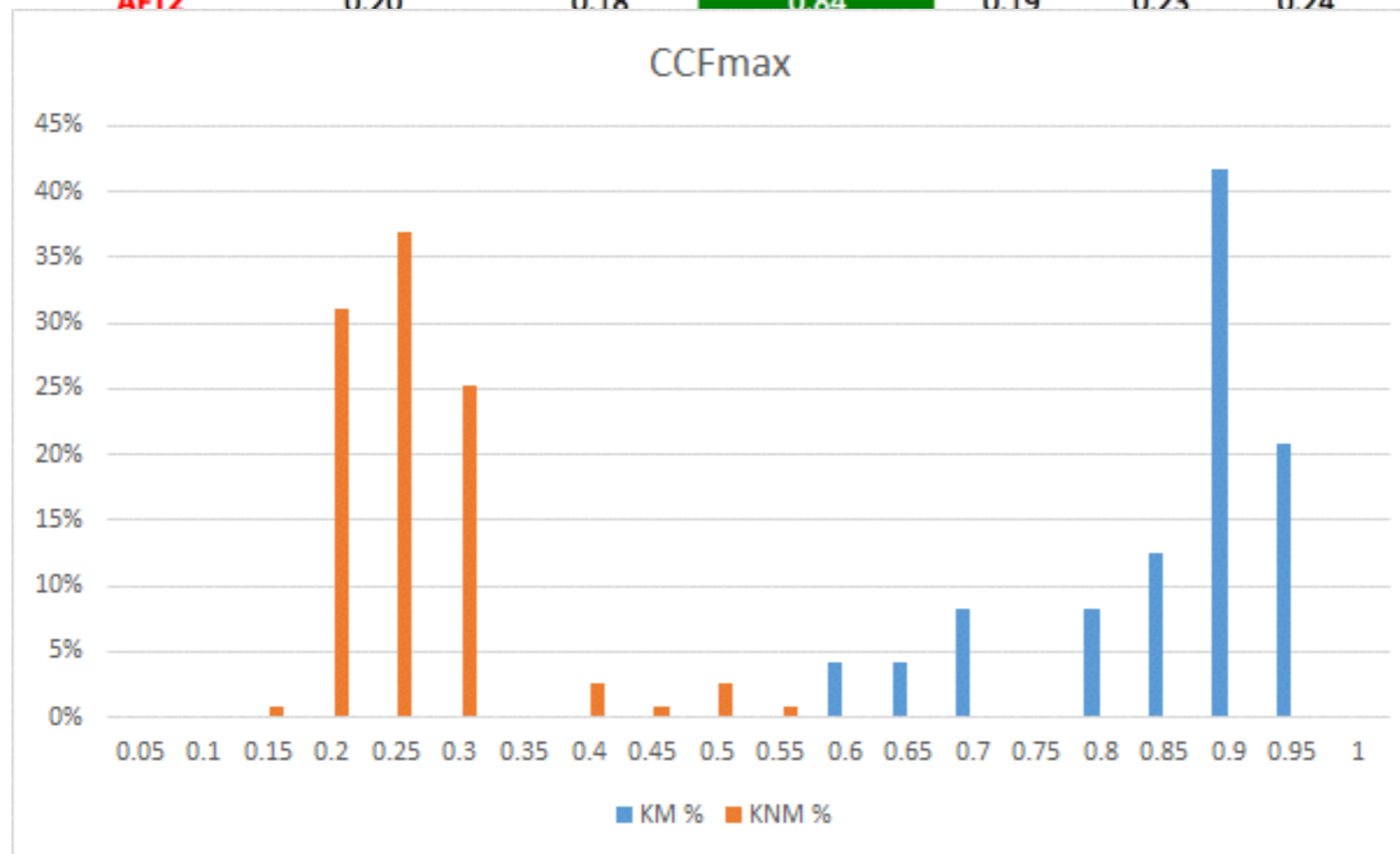ATF5 Continuous Confocal

ATF5 Virtual Profile

NIST SRM2460 AFT5 IC surface

NEW 3D METHODS / BULLETS

Comparison of KM CCF$_{max}$ for different techniques for all NIST SRM 2460 LEA

CSI	AFT5	AFT4	AFT2	FBI3	FBI2	FBI1
ATF5	0.91	0.19	0.23	0.18	0.25	0.25
AFT4	0.18	0.87	0.17	0.17	0.14	0.20
AFT2	0.20	0.18	0.84	0.19	0.23	0.24

KM CCF$_{max}$

average = 0.83

KNM CCF$_{max}$

average = 0.24

	AFT5	AFT4	AFT2	FBI3	FBI2	FBI1
AFT5	0.85	0.23	0.25	0.25	0.28	0.27
AFT4	0.19	0.86	0.22	0.20	0.18	0.24
AFT2	0.22	0.21	0.79	0.18	0.25	0.26
FBI3	0.17	0.19	0.20	0.58	0.24	0.22
FBI2	0.29	0.22	0.30	0.26	0.91	0.49
FBI1	0.22	0.25	0.26	0.19	0.39	0.89

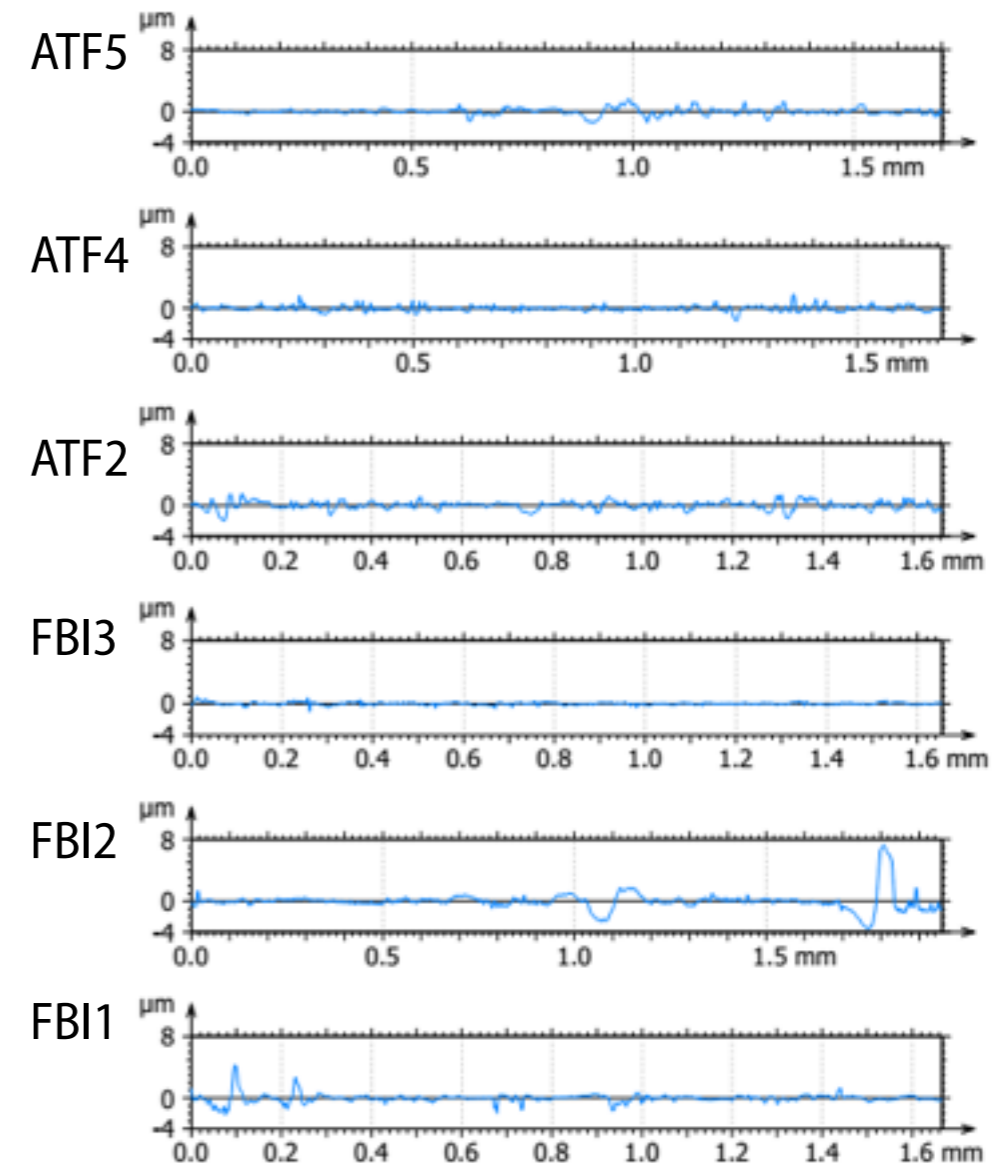SENSOFAR

NEW 3D METHODS / BULLETS

Comparison of KM CCF_{max} for different techniques for all NIST SRM 2460 LEA
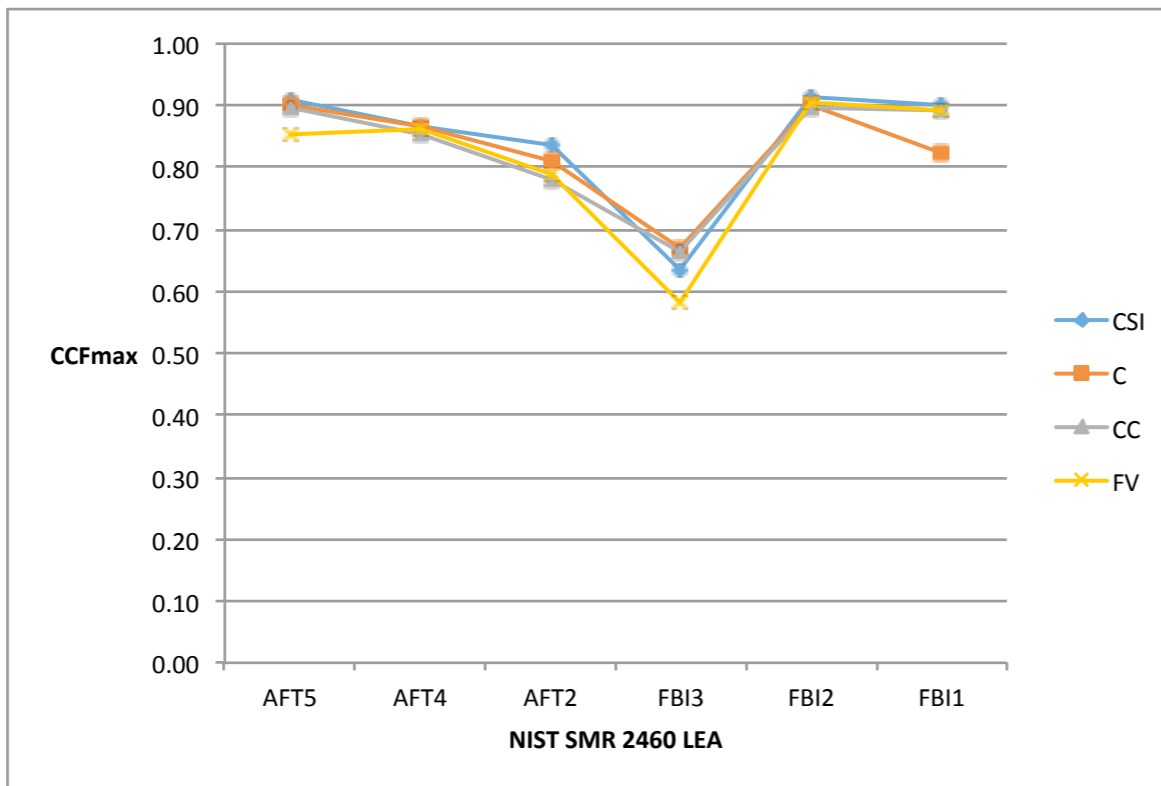
Good agreement

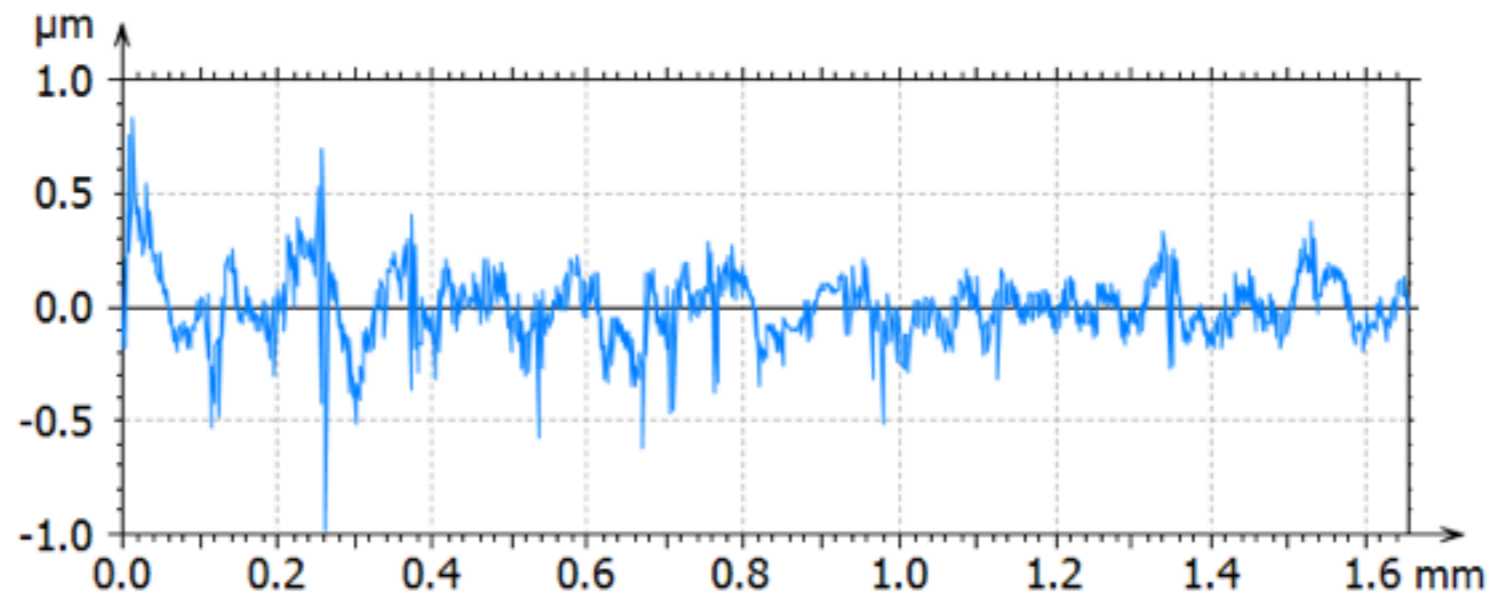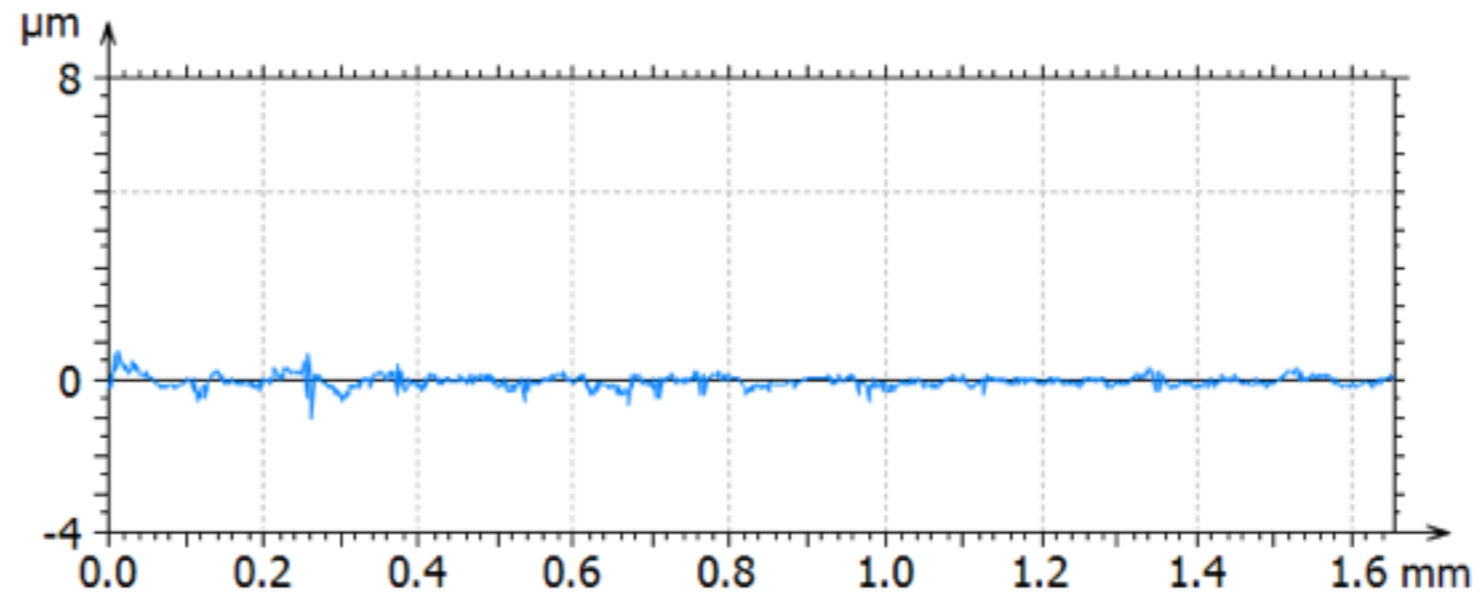Better Z resolution = higher CCF_{max}

Weakest mark has lower CCF_{max}

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NEW 3D METHODS / BULLETS

Z resolution

FBI3

NEW 3D METHODS / BULLETS

Z resolution

FBI3

PV 500 nm
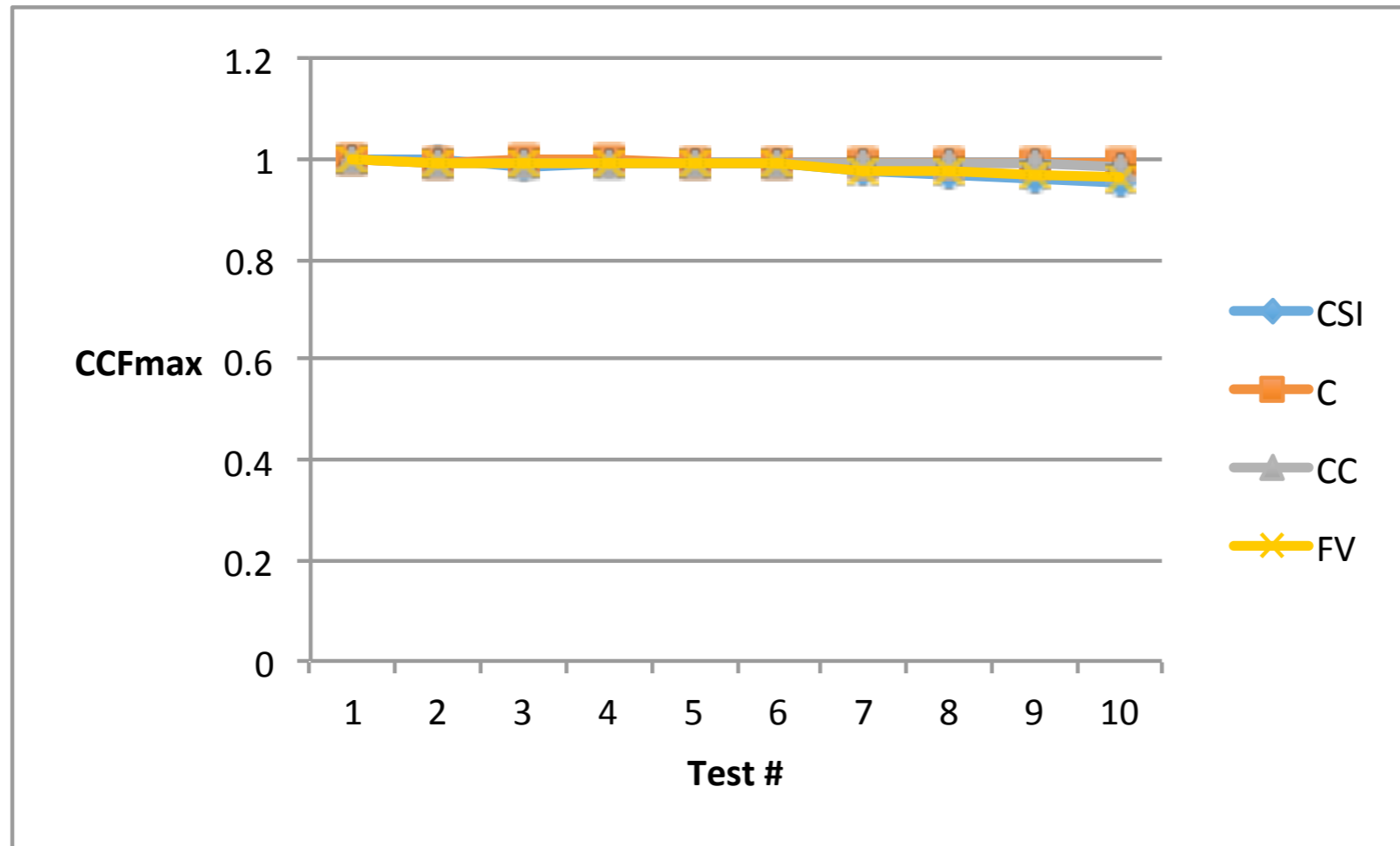
Z resolution
50 nm

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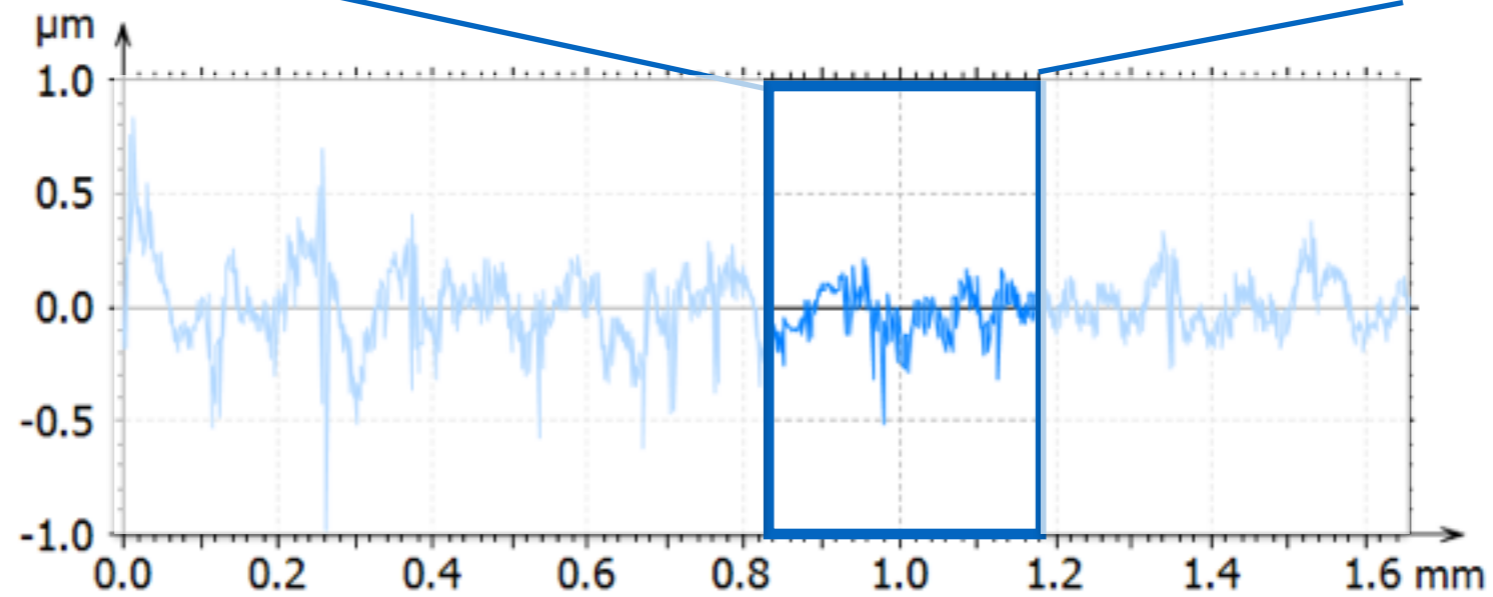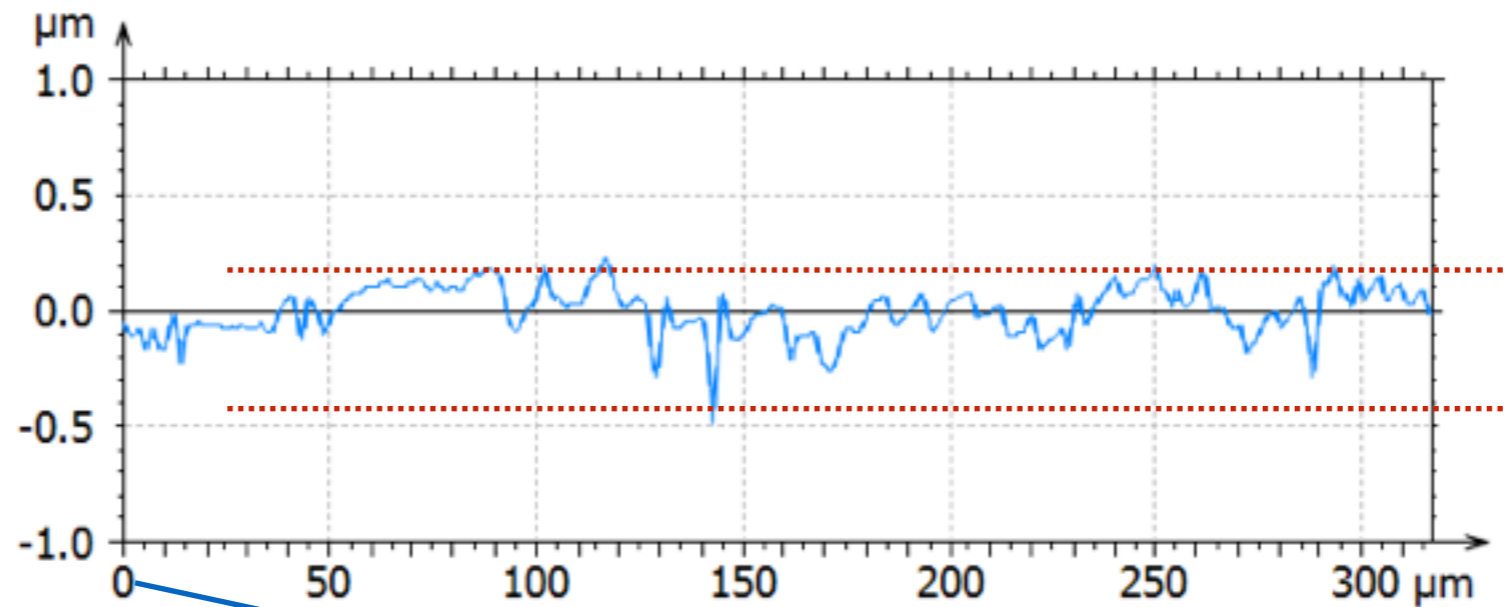
NEW 3D METHODS / BULLETS

Repeatability test on NIST SRM 2460 LEA ATF5

1 LEA

FV: 47 s
CC: 50 s
C: 3 m 40 s x4
CSI: 9m 54 s x10

	CSI	C	CC	FV
Average	0.982	0.993	0.991	0.986
std	0.011	0.001	0.003	0.009
std %	1.15%	0.13%	0.29%	0.92%

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NEW 3D METHODS / BULLETS

Phoenix PD blind test **successfully solved** using
S neox, Continuous Confocal, 20X & SAM score

- 8 guns (3 test fires)

- 10 unkowns

SAM scores for Phoenix PD blind test

|	Unk #9	Unk #10
1-A9-B1	0	0.29
1-A9-B2	0	0.30
1-A9-B3	9	0.30
1-C8-B1	0	0.32
1-C8-B2	2	0.33
1-C8-B3	0	0.30
1-F6-B1	1	0.32
1-F6-B2	9	0.33
1-F6-B3	8	0.32
1-L5-B1	9	0.29
1-L5-B2	9	0.29
1-L5-B3	8	0.29
1-M2-B1	2	0.29
1-M2-B2	1	0.31
1-M2-B3	3	0.30
1-P7-B1	8	0.28
1-P7-B2	0	0.29
1-P7-B3	2	0.28
1-R3-B1	2	0.30
1-R3-B2	9	0.29
1-R3-B3	0	0.29
1-U10-B1	0	0.33
1-U10-B2	0	0.34
1-U10-B3	8	0.35

■ KM ■ KNM
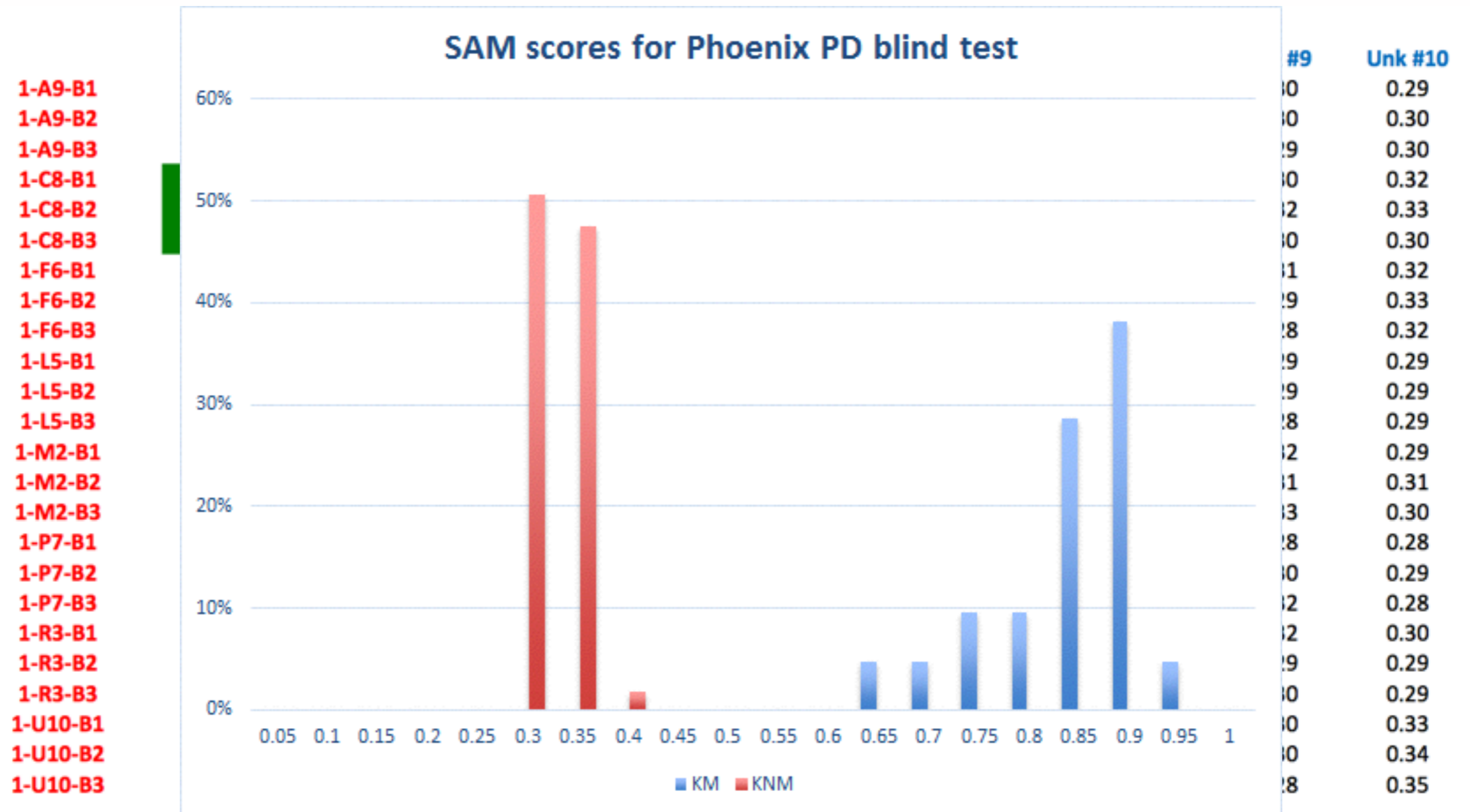
NEW 3D METHODS / BULLETS

A subset of this study solved by 3 examiners at Guardia Civil (Barcelona) using Virtual Microscopy SensoCOMP

- 3 Ruger guns (3 test fires)
- 2 unkowns
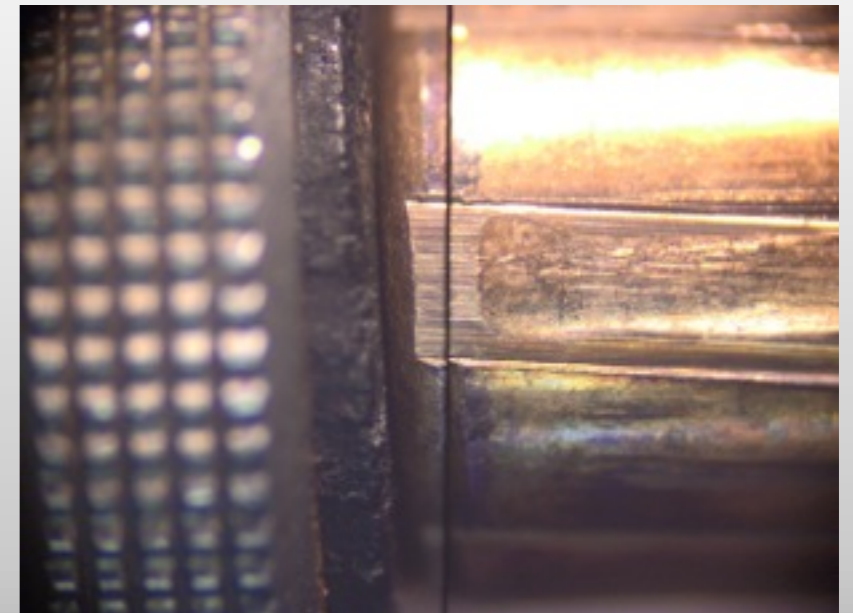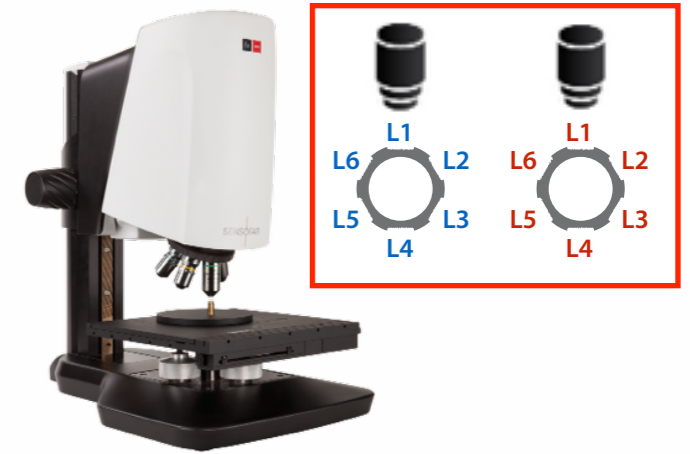
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NEW 3D METHODS / CARTRIDGES

Three Glock S&W 40

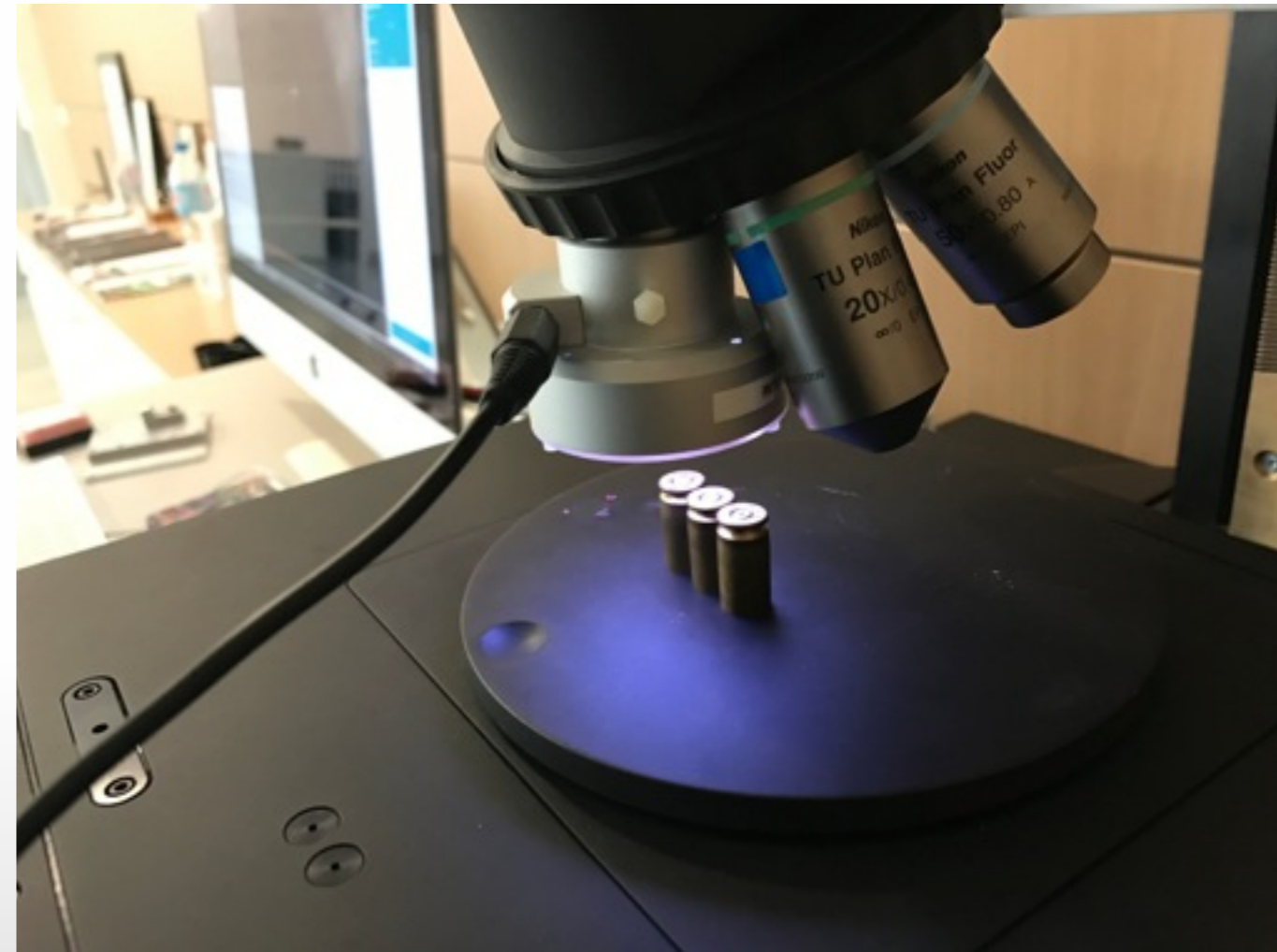Two 3D measurement methods:

- Continuous Confocal (CC)
- Focus Variation (FV)

10X objective:

- NA 0.3
- 1.3 micrometers pixel

Z scan range 600 micrometers (firing ping included)
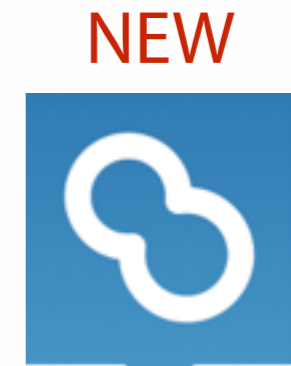
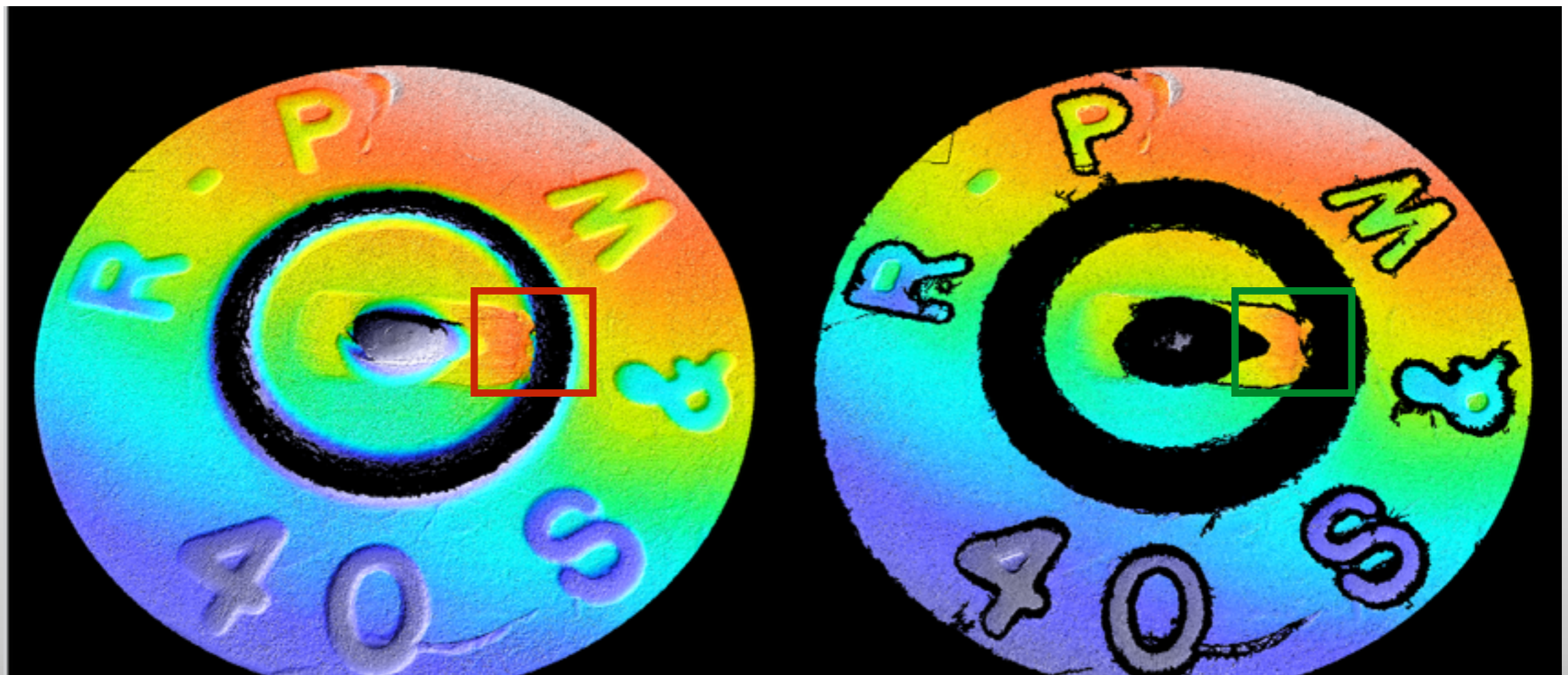Virtual Microscopy comparison

NEW 3D METHODS / CARTRIDGES
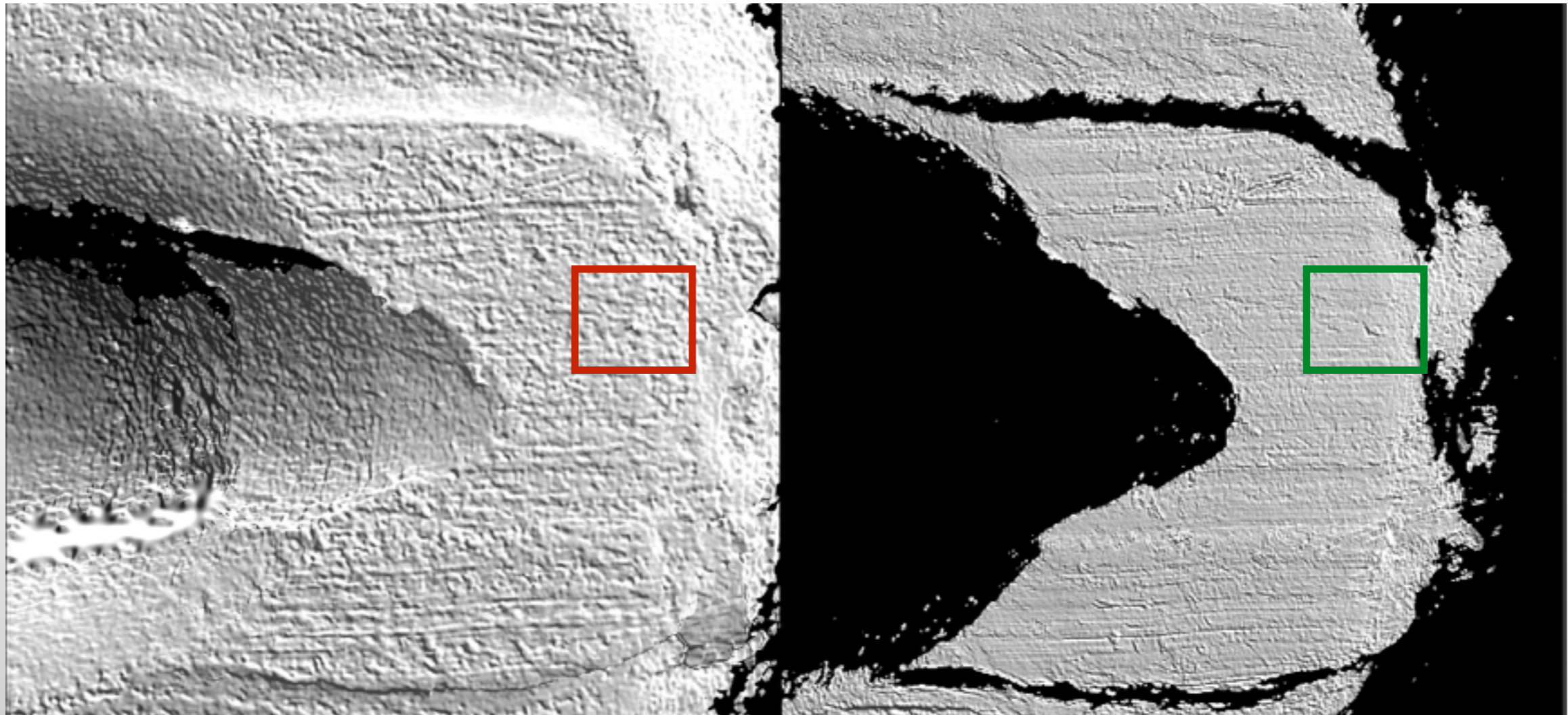
Focus Variation

full < 10 m

breech face < 2 m

Continuous
Confocal
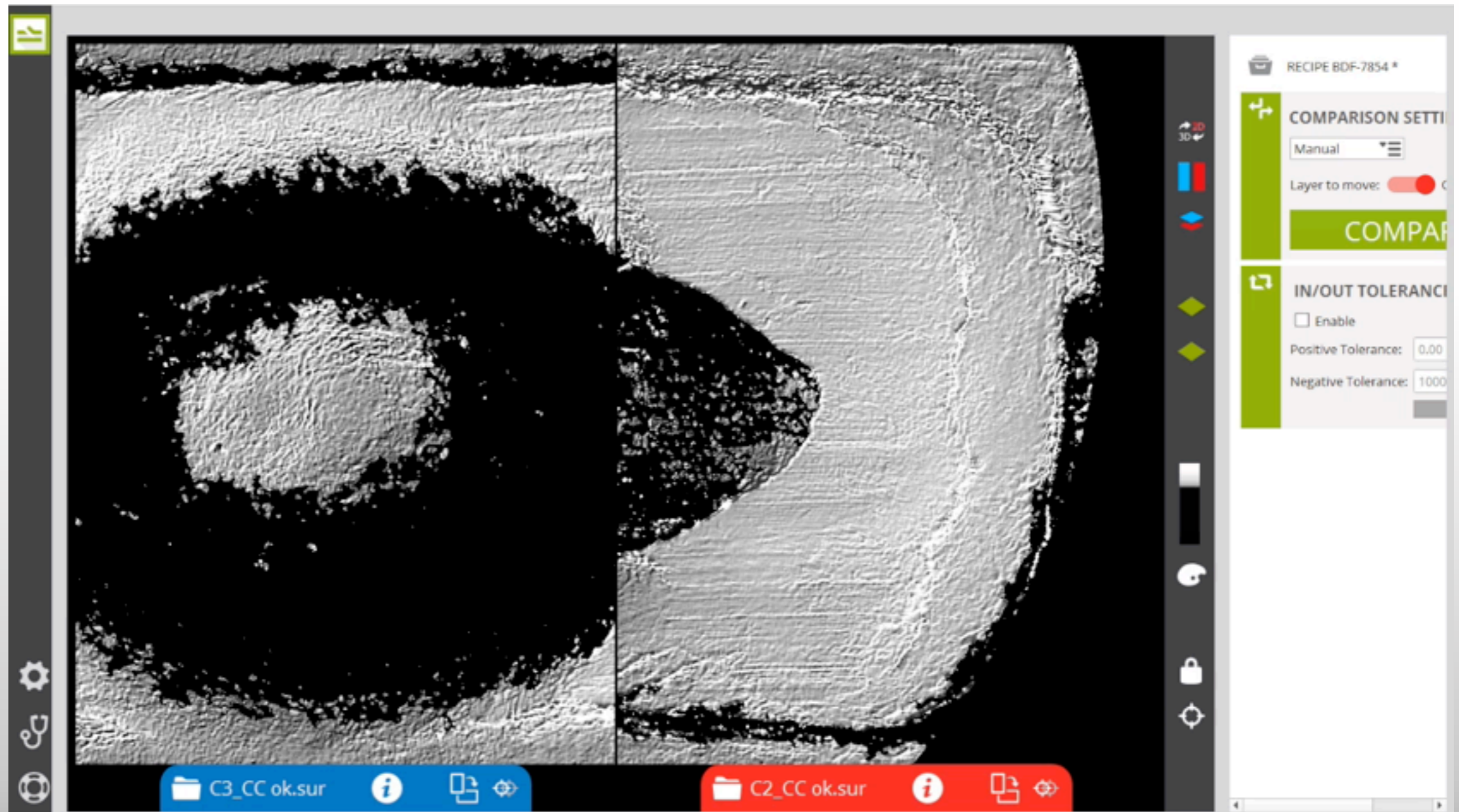
NEW 3D METHODS / CARTRIDGES

Visual comparison of **Focus Variation vs Continuous Confocal** on the aperture shear

NEW 3D METHODS / CARTRIDGES

Visual comparison of **two different cartridges fired with same firearm**
SensoCOMP Virtual Microscopy (VM) software tool

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CONCLUSIONS

1. Two new high-resolution optical 3D surface metrology methods have been presented and compared to existing methods using Sensofar S neox system

2. **Continuous Confocal** offers the **best performance at 3x speed**

   Validation tests using CCF_{max}, SAM and VM
   - NIST SRM 2460 bullet
   - Phoenix PD blind test bullets
   - Glock S&W 40 cartridge cases

3. **Confocal Fusion** shows promise for **cartridge case** 3D measurements

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Acknowledgments

- Roger Artigas & Pol Martinez @ Sensofar

- Erich Smith @ FBI

- Antonio Garrido, Miguel Ángel and Sara @ Guardia Civil

- Tylor Klep @ Phoenix PD

Announcements

- Examiners at invited to test these new techniques at Iowa State University

- Examiners are invited to solve the Phoenix PD study using Virtual Microscopy

Thank you for your attention!

Bill Henderson

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Sensofar Tech SL & CD6-UPC

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