Scratch and Dig Instrumentation Update

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Agenda

- Motivation
- Instrument approaches
- Polarization-based approach
- Intensity-based approach
- SavvyInspector results on various comparison standards

Motivation

- Most optics produced in the world today are made to a MIL-PRF-13830B scratch and dig specification
  - e.g. “80/50 Scratch-Dig”
  - Based on inspector evaluation of “visibility”
  - Methods of evaluation vary in lighting, angles, an interpretation
  - Subjectivity of test is the killer
- Surface imperfections by far the most cited cause of optics rejection
  - Almost all are cosmetic or workmanship specifications only
- The confusion about surface imperfections costs our industry tens of millions of dollars each year
  - MRB decisions
  - Returned optics
  - Reworked optics
  - Overmanufactured parts

Conventional visibility inspection is performed by a skilled operator under controlled lighting conditions

- The trained human eye is quite good (repeatable) in making accurate side by side comparisons.
- Disagreements from inspector to inspector and shop to shop due to differences in:
  - Training
  - Interpretation
  - Illumination
  - Visibility of comparison standards.

Photo from "taking variability out of scratch inspection", presentation to OEOSC by Ari B. Siletz

- Due to geometry, reflectivity of optics, most inspections actually done in reflection rather than transmission, as shown.

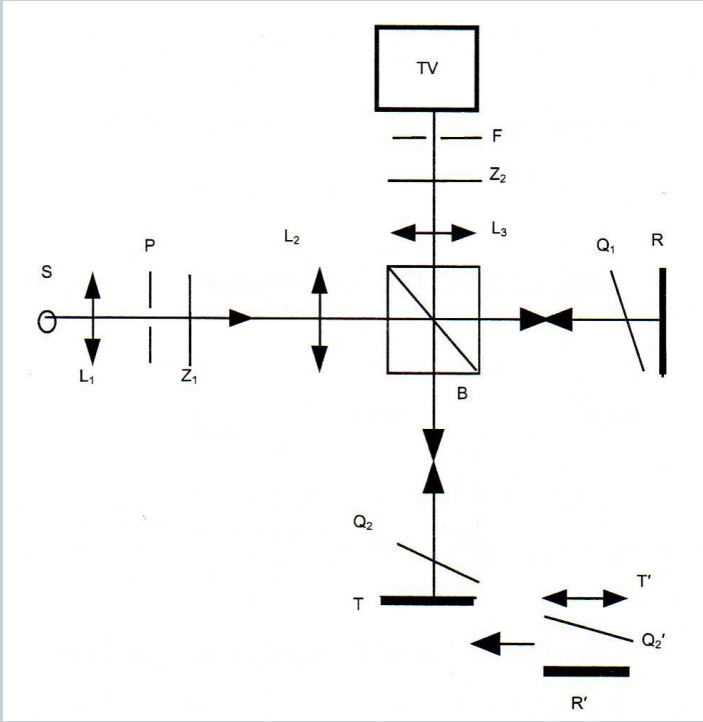
Instrument approaches

- Polarization approach
  - Index brightness using a polarizer-analyzer approach
  - Match "brightness" of sample to reference arm and correlate angle of analyzer to measurement standards
- Scatterometry approach
  - Index brightness using digital camera with fixed gain and integration time through image processing software
  - Match "brightness" of sample to pre-recorded brightness levels of measurement standards

Both methods require careful attention to illumination and detection angular spectra

Polarization based Visibility Measurement

- First proposed by Lionel Baker to the Brittish MOD circa 1991
- Instrument "commercialized" by SIRA
  - One sold to the US Army; now at Picatinny
  - One returned to the funder (MOD), then given to Pyser-SGI for safe keeping
  - No other units have been located.
  - According to the Army, the instrument has problems
    - Extremely subjective, since the user determines when the two scratches are of equal brightness
    - Only really works if all scratches are about the same width
    - Does not correlate well with visual measurements

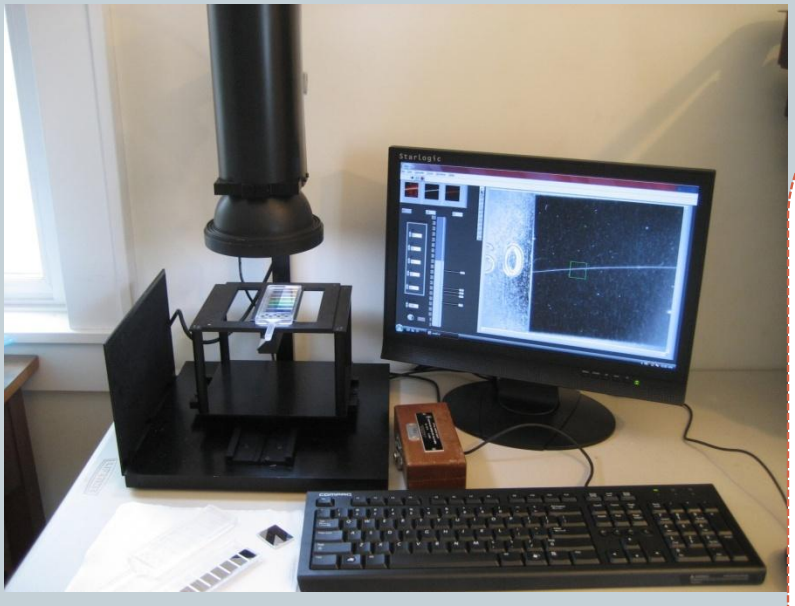


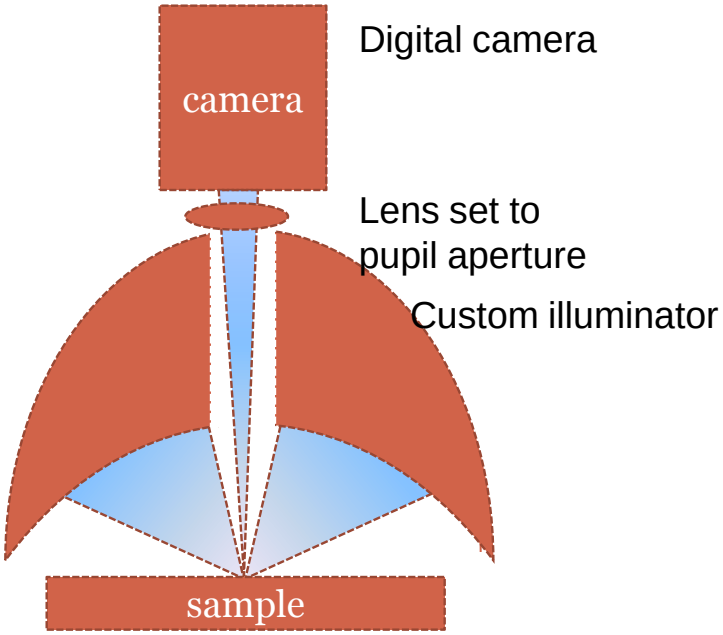
- Same instrument was documented in 2004 in Baker's book "Metrics for High-Quality Specular Surfaces"
  - Also described in ISO 14997 as the "micro image comparator" to convert ISO 10110-7 specifications to "Line-equivalent widths" and "Spot-equivalent diameters"

Scatterometry-based Visibility Measurement

- First proposed by Ari Siletz and Rich Beal in 2005
  - First instrument deployed at FLIR/Brysen for measurement of comparison standards
  - Project cancelled after initial testing
- New instrument design proposed by Dave Aikens and Ari Siletz in late 2007
  - Several design iterations required to match human visibility with measured brightness
  - Commercialized as "SavvyInspector™" in mid-2009
  - Army in the process of purchasing a system to replace SIRA tool
    - Intends to modify C7641866 to reflect SavvyInspector™ visibility readings for each scratch grade

The Model SIF-4 Savvy Inspector ™





The Savvy Inspector™ Software is the key to the inspection

Scratch window

Dig window

Scratch or dig value

Image field

Inspector window

Scratch standard visibility

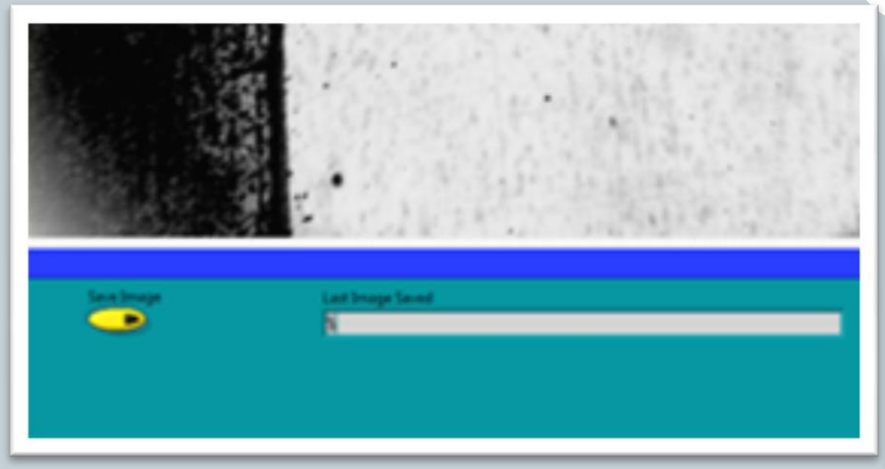
Scratch visibility bar

Active calibration file

Save image button

Saved image location

Inspection mode, continued



- Image files are saved to a folder with part information for future reference
- Values for scratches and digs entered into Savvy Accumulator spreadsheet for pass-fail determination

Scratch and Dig Accumulation Spreadsheet © 2009 Savvy Optics Corp

Part number	asdflkasdflkj
Serial number	123
Comment	this is a cool spreadsheet

Specification (e.g. 80-50) Scratch: 80 Dig: 50

Part diameter in mm: 25.0

allowed digs: 2
Allowed dig sum: 200 over part
Allowed concentration: 100 in 20 mm

Allowed max scratch total length: 6.25 in mm
Allowed total scrach accumulation: 80 if max scratch present
160 if no max scratch present

Concentration rule does not apply: N/A <-- leave this cell blank

Scratch inspection data

Scratches	Scratch grade	length in mm	relative length
Scratch #1	80	0	0.00
Scratch #2	60	0	0.00
Scratch #3	40	0	0.00
Scratch #4	20	0	0.00
Scratch #5	10	0	0.00
Scratch #6	0	0	0.00
Scratch #7	0	0	0.00
Scratch #8	0	0	0.00
Scratch #9	0	0	0.00
Scratch #10	0	0	0.00

Dig inspection data

Digs	Dig grade	within worst 20mm dia?
Dig #1	50	n
Dig #2	40	n
Dig #3	30	n
Dig #4	20	n
Dig #5	10	n
Dig #6	5	n
Dig #7	0	n
Dig #8	0	n
Dig #9	0	n
Other digs	0	n

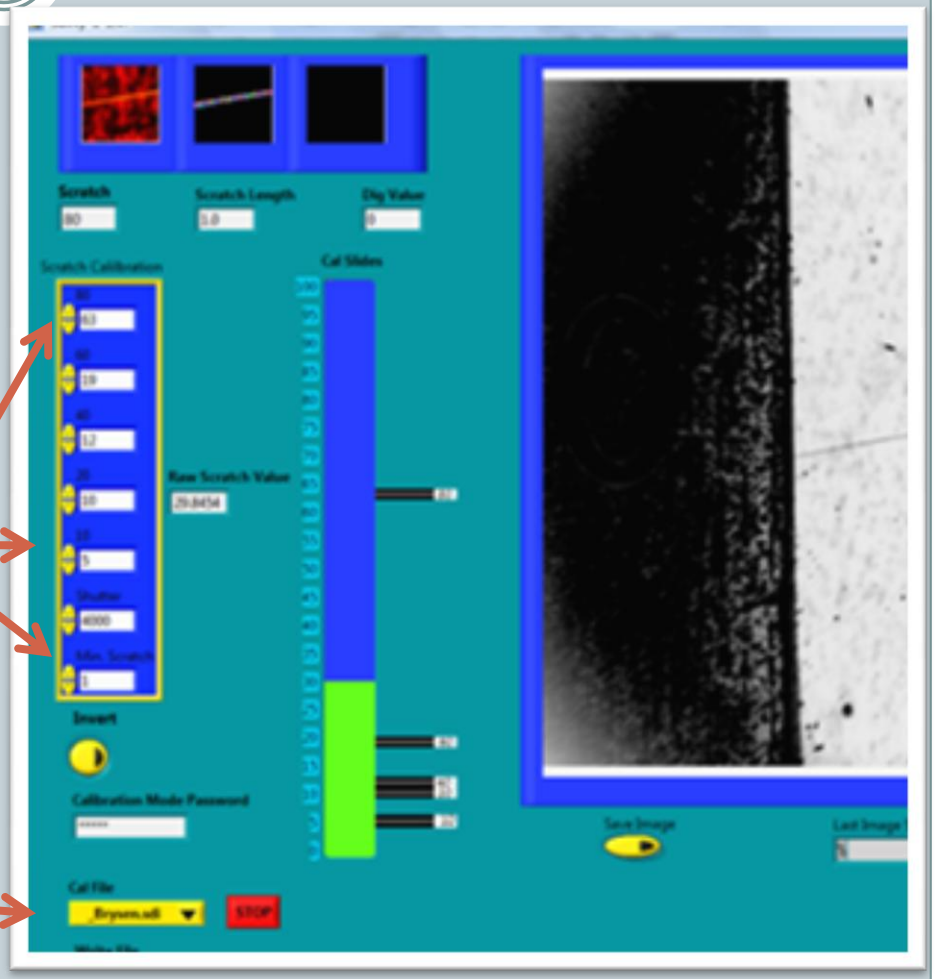
Max scratch	pass
Max scratch length	pass
Scratch Accumulation	pass
Concentration	pass
Scratch pass/fail overall	pass

Max dig	pass
Dig accumulation	pass
Dig concentration	pass
Dig pass/fail overall	pass

(user enters data in all cells marked in green:)

Calibration Mode

- User can enter calibration mode password to create new calibration files
- A comparison artifact of a given number (e.g. #20) is loaded, and the relative visibility is recorded here
- The calibration file is stored
- The new calibration appears on the calibration file pull-down menu



Summary

- Polarization based instruments seem to have fallen behind scatterometry
- Scatterometry based scratch visibility offers a path forward for the MIL-PRF-13830B visibility method
  - Correlates to visual observation
  - Quantifiable and documentable
- Army adoption of the SavvyInspector™ is in the works
  - Will remove confusion from various sets
- SavvyInspector™ demonstration at Booth 5202 on Thursday afternoon