A Handheld Image Analysis System for Portable and Objective Print Quality Analysis

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Objectives

- **Expansion of Imaging (Concept of ICJ2007)**

  Measurement technology is critical to the advancement of the science and technology of imaging.

- **Democratization of Objective Image Quality Analysis**

  Our goal is to bridge the gap between sophisticated image analysis in the laboratory and the need for a practical tool for EVERYDAY USE by EVERYONE.

Requirements

- **Functional** – calibrated, accurate, predictive, utilizes international and industry standards, …
- **Easy-to-Use** – simple operation even for the most sophisticated analyses: quick response, easy reporting, with specialized expertise built-in.
- **Portable and Affordable** - compact, light weight, and low cost
- **Flexible** – meets diverse measurement needs
- **Upgradeable** – capable of staying with the state-of-the-art at all times

Challenges

From the laboratory …
(expensive, complex)

to portable, personal use
(low cost, easy-to-use)

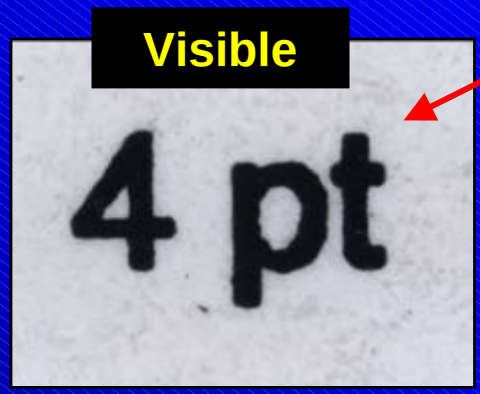
HOW?

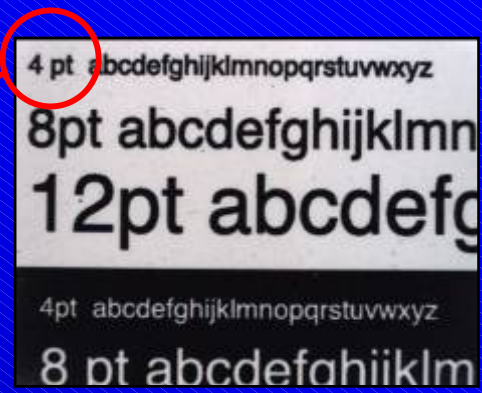
Hardware Solution

- **Compact design & light weight**
  - ~350g
- **USB 2.0 interface to PC**
  - No battery needed
- **Interchangeable optics:**
  - Different resolution & FOV
  - Different illumination geometry & spectral characteristics
- **Built-in calibration**
  - Grey level & spatial dimensions
- **Processing capabilities**

Optical Modules

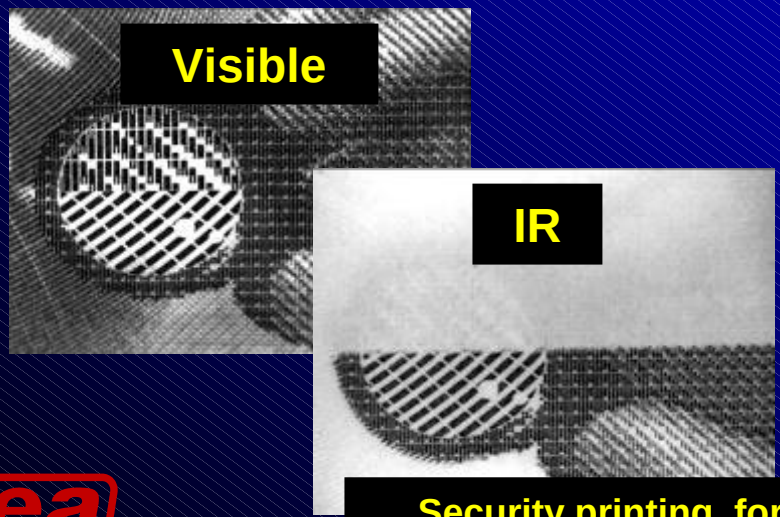
- Fixed focus
- Multiple resolution modules - Hi & Lo
- 45/0, coaxial, …
- Reflective & transmissive
- Visible, IR & UV

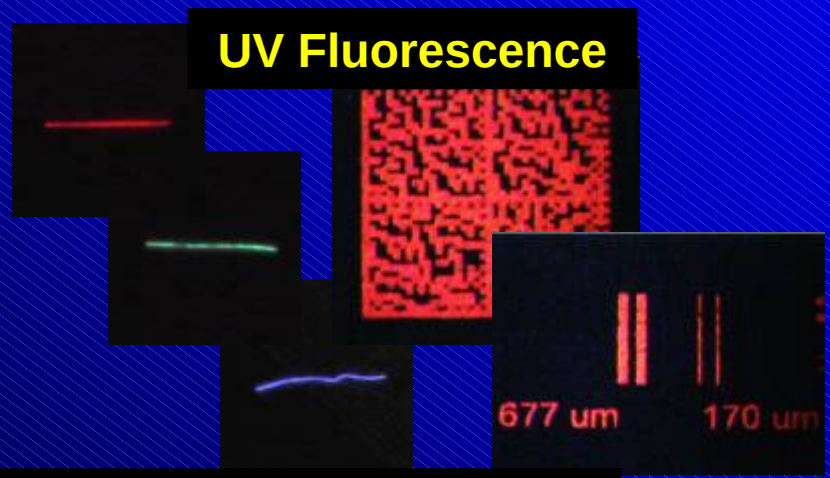




High Resolution
5 μm/pixel
3.2mm x 2.4mm

Low Resolution
37.5 μm/pixel
24mm x 18mm

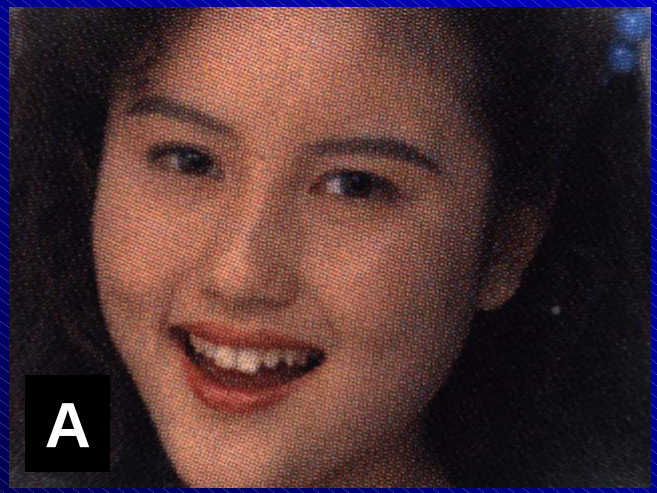


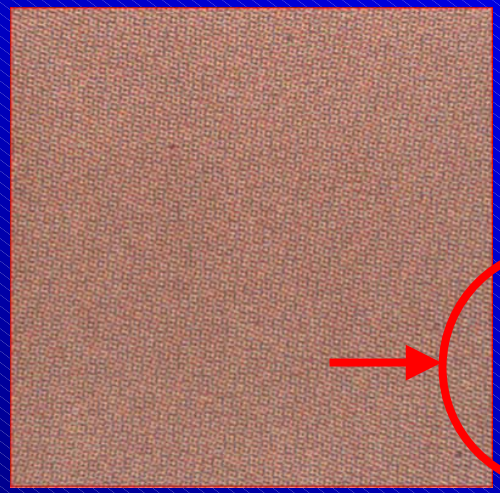


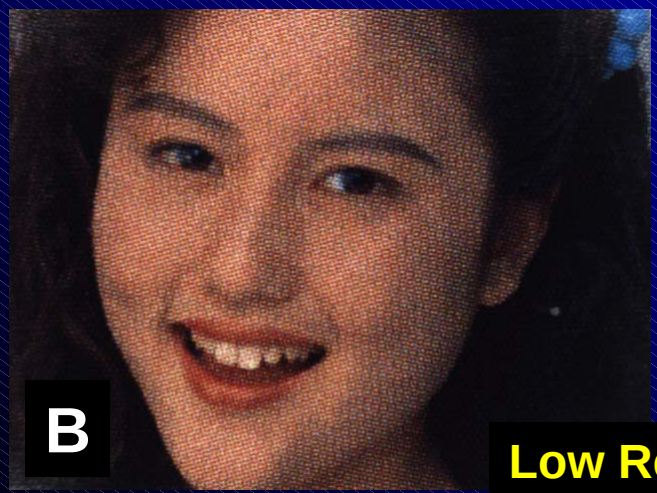
Security printing, forensic and other novel applications

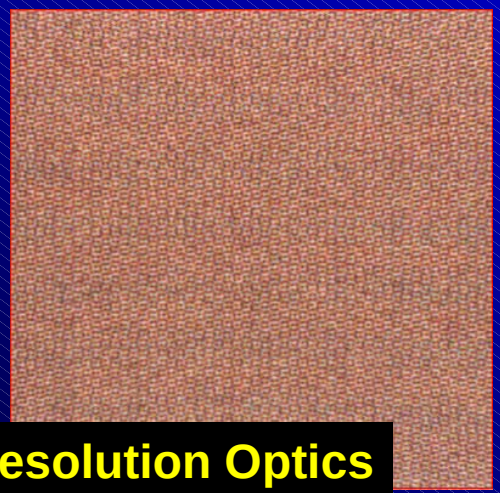
Why Different Magnifications (1)

To improve correlation with human perception:





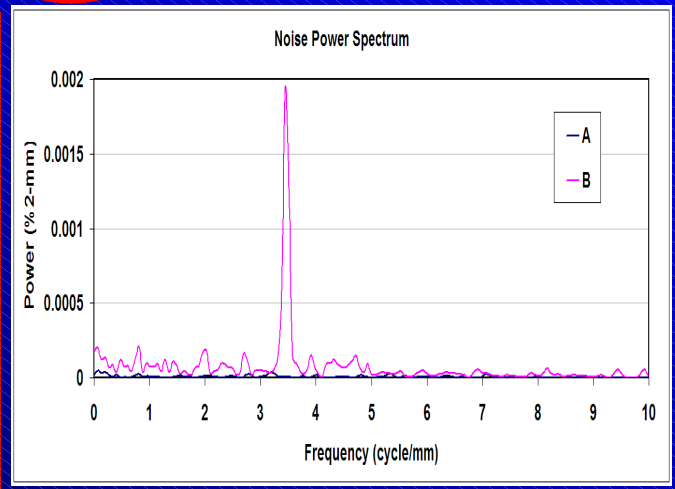




Illuminant	D65
Observer	2°
Grain Tile Size [µm]*	37.5
Mottle Tile Size [µm]*	299.6

*ISO-13660

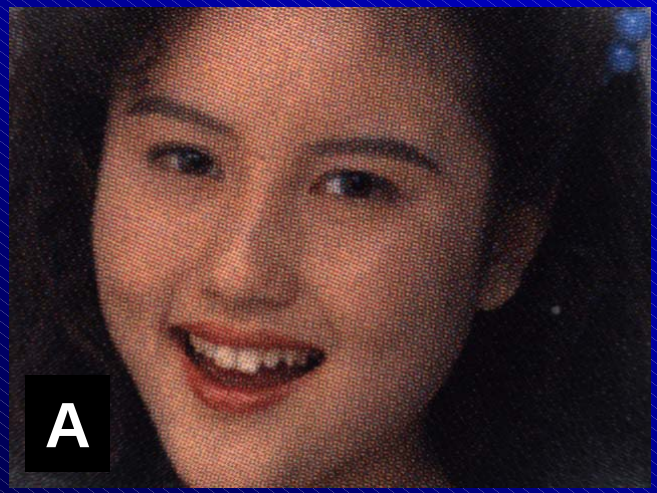
	Metric	A	B
Average	L*	72.7	73.2
	a*	10.2	11.8
	b*	17.2	20.3
Graininess	L*	7.68	8.70
	a*	13.20	13.75
	b*	10.29	12.78
Mottle	L*	1.17	1.46
	a*	1.13	1.33
	b*	1.22	1.80

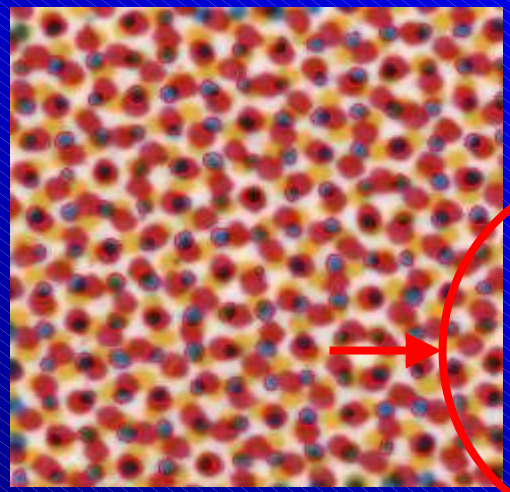


Low Resolution Optics
Large Field of View

Why Different Magnifications (2)

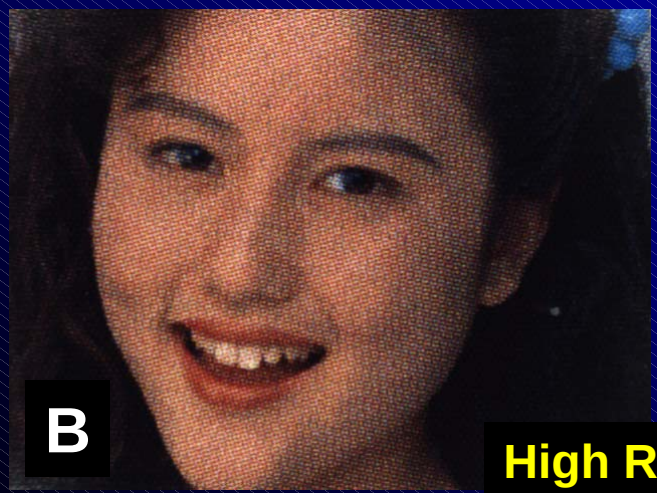
To provide machine diagnostic information:

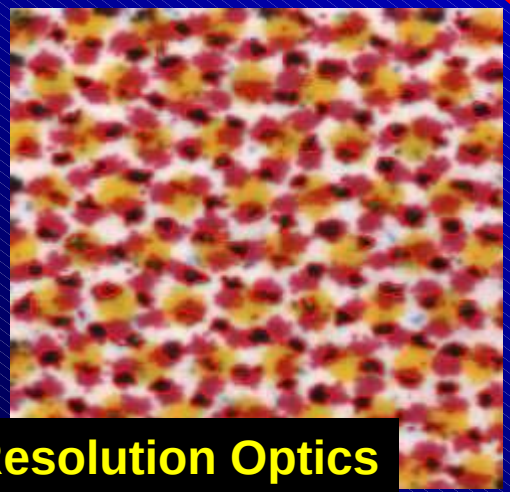


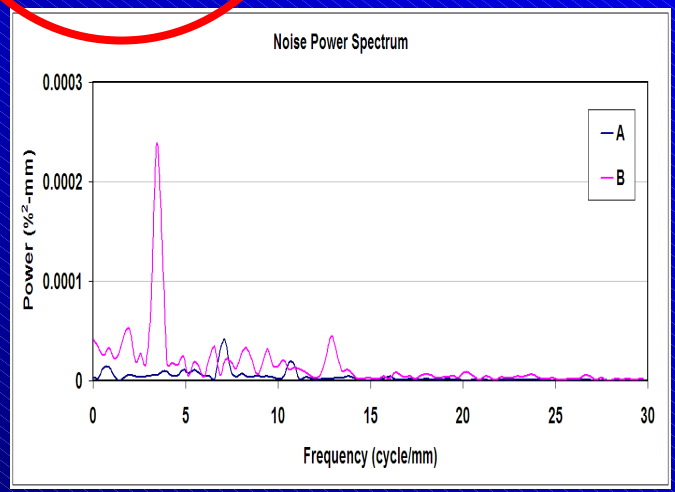


	A	B
Ruling (lpi)	178.9	168.7
Dot Percent (%)	22.8	19.7

	Mean		Stdev	
Dot Metrices	A	B	A	B
Area (mm²)	0.005	0.005	0.001	0.002
Diameter (mm)	0.078	0.077	0.007	0.014
Perimeter (mm)	0.247	0.270	0.024	0.076
BoxRatio	0.963	0.747	0.143	0.183
Circularity	1.013	1.221	0.045	0.317







High Resolution Optics
Small Field of View

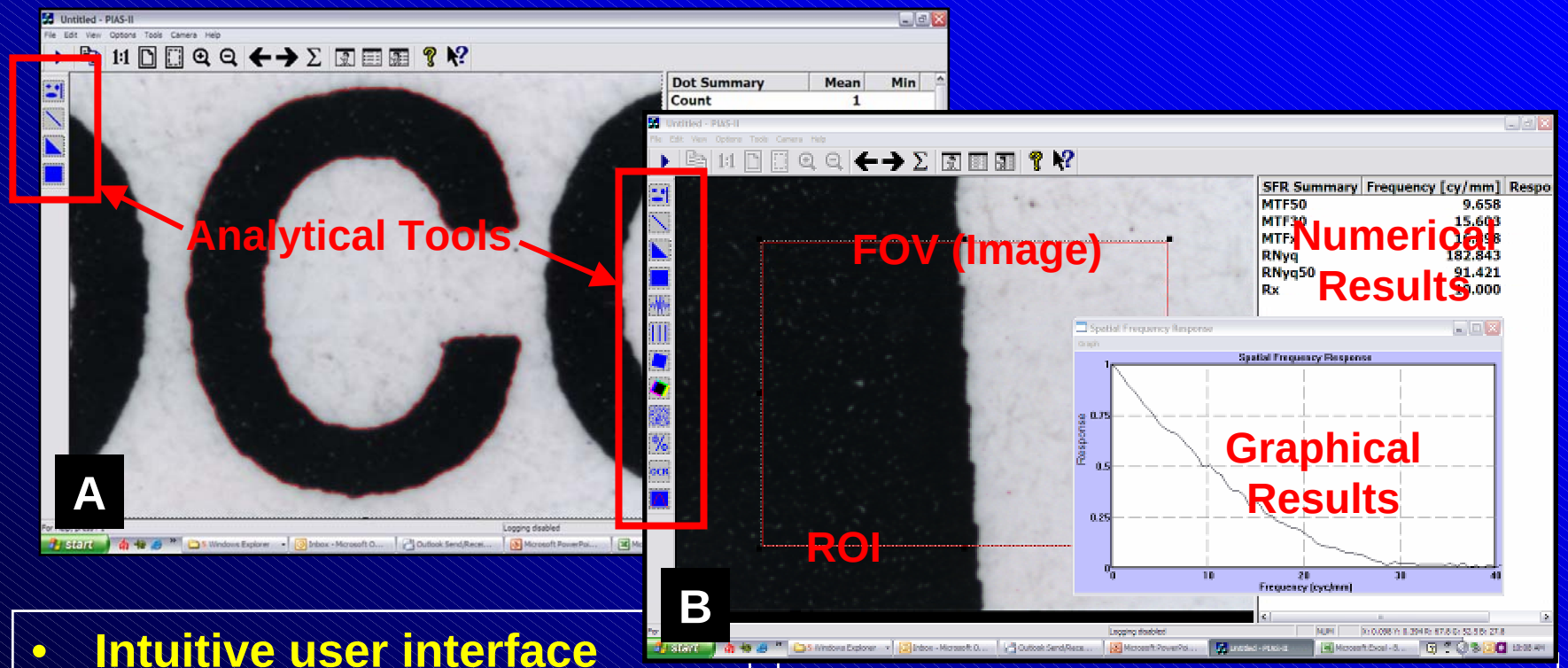
Calibration (1)

- **Grey level (Reflectance and Density)**
  - Use a test chart with calibrated CMYK tone scales (traceable)
  - Obtain camera RGB values
  - Obtain correlation between camera RGB and calibrated reflectance % (CMYK)
  - Convert reflectance % to optical density (for Status A, T, DIN and DIN NB)
- **Color (L*a*b*)**
  - Use a test chart with known sRGB values
  - Convert camera RGB to sRGB
  - Convert sRGB to L*a*b*

Calibration (2)

- **Spatial Dimensions (x and y)**
  - Use a calibrated (traceable), precision Ronchi ruling (chrome on glass)
  - Obtain x and y resolution in μm/pixel

Software Solution



- Intuitive user interface
- Analysis in real time or on saved images
- Mostly “one-click” to obtain useful results

- Efficient data & image interface to Excel or database
- Expandable analysis toolbox, e.g. A - basic, B - advanced

Analysis Toolbox (1)

- Dot quality (dot gain, dot shape and placement)
- Line and edge quality (width, blurriness, raggedness, contrast, fill and darkness – ISO13660)
- Text quality (stroke quality, fidelity, uniformity)
- Color adjacency and inter-color bleed
- Image noise (graininess and mottle – ISO13660)
- Banding, streaking, … (NPS – Noise Power Spectrum)
- Inkjet satellites, toner background, voids, ghosting …

Analysis Toolbox (2)

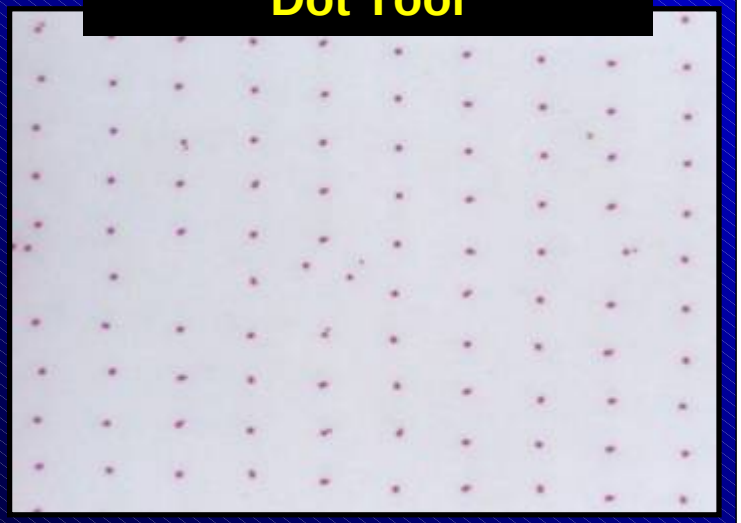
- Spatial Frequency Response (“slant edge” technique ISO12233) and Resolution
- Color registration error (“slant edge” technique)
- Profile and histogram tools
- Color channel viewing tools
- Density and color
- OCR (optical character recognition)
- Colorant % coverage
- Gloss and DOI

Applications

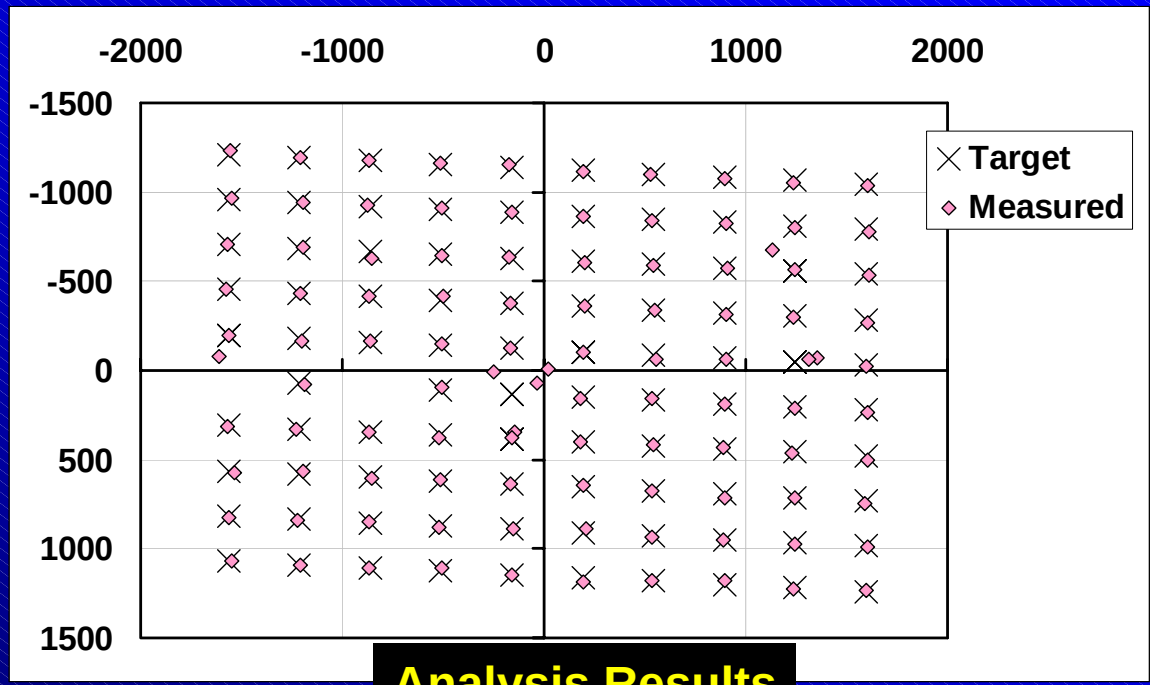
- **Engineering and Machine Diagnostics**
  - **(e.g, machine chatters, unsteady paper feed, inkjet printhead misfiring, laser scanner instability, thermal or LED printhead non-uniformity, …)**
- **Objective Image Quality vs. Perceptual Quality**
  - **Tone and color reproduction**
  - **Sharpness and details**
  - **Image artifacts (defects)**
  - **Gloss and DOI (Distinction of Image)**

Application Example (1)
– Inkjet Print Head Diagnostics

High Resolution Optics Dot Tool



Jetting Pattern

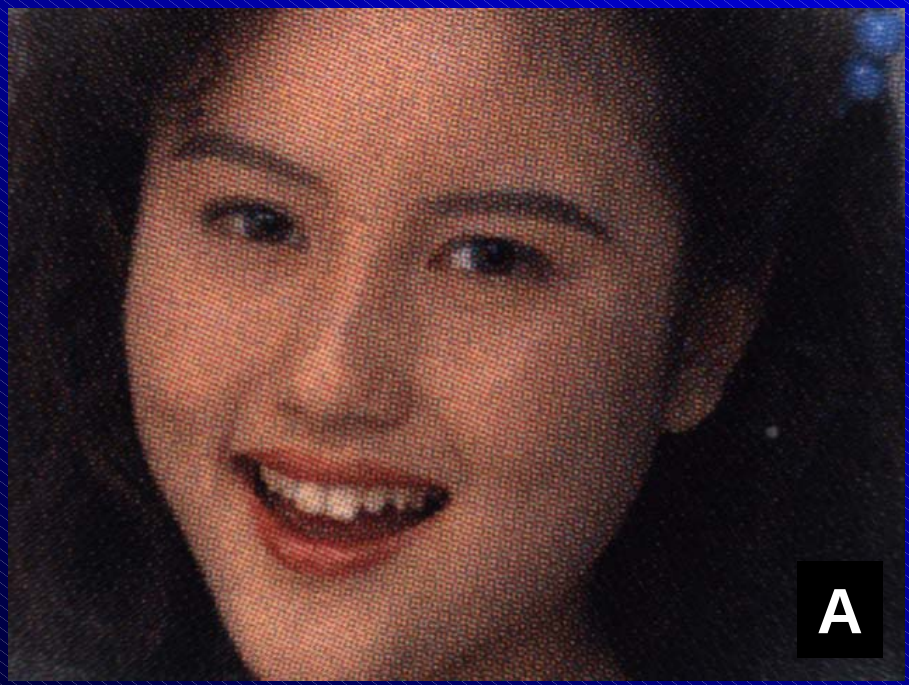


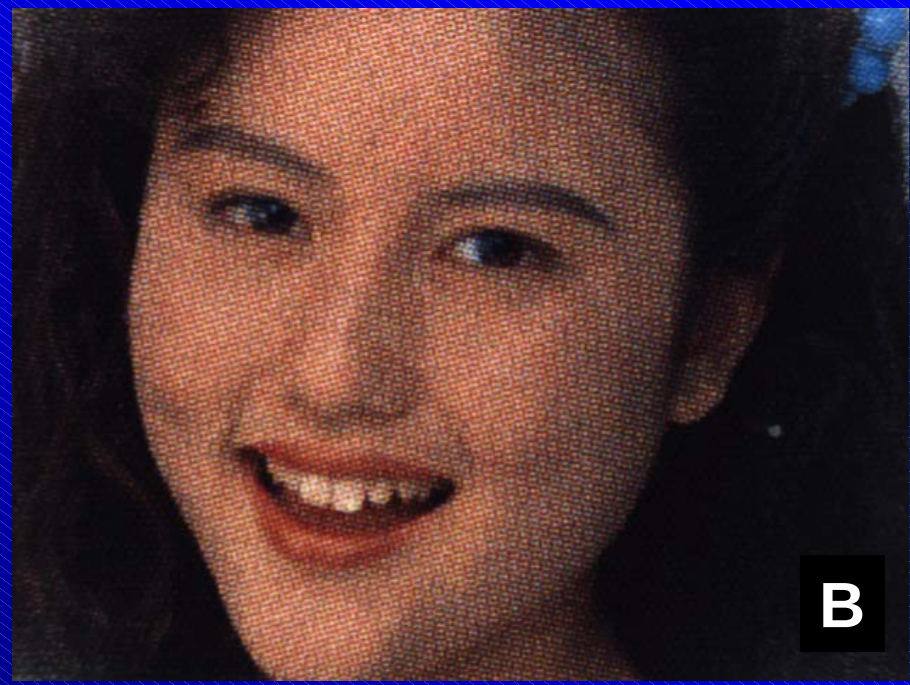
Analysis Results

Total Dots	104		Diameter, Mean (µm)	39.0
Missing Dots	2		Placement Error, Mean (µm)	20.7
Extra Dots	6		Diameter, Stdev (µm)	4.1
Spacing--Horizontal (µm)	351.3		Placement Error, Stdev (µm)	33.6
Spacing--Vertical (µm)	253.6			

Application Example (2a)

Printer Benchmarking, A vs B

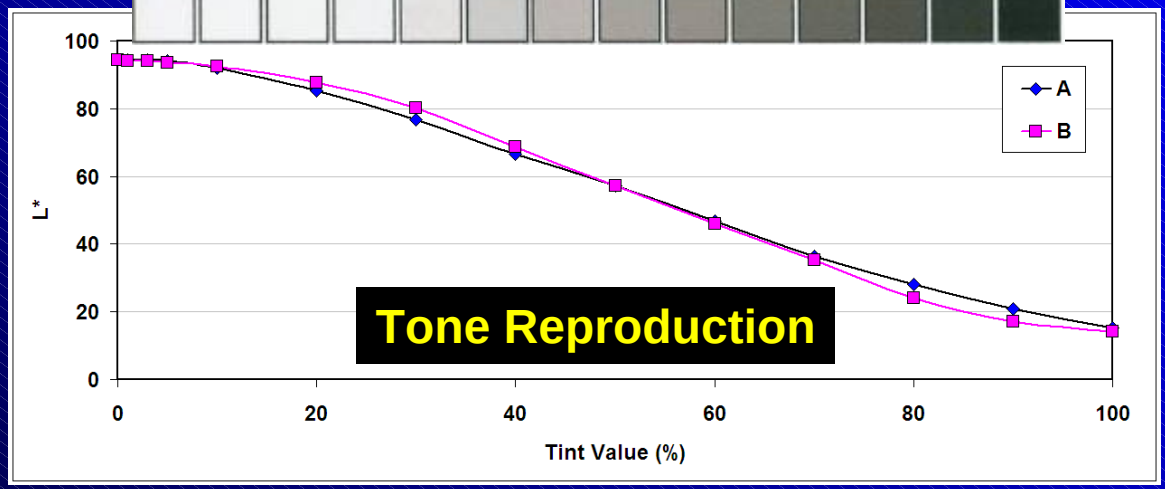


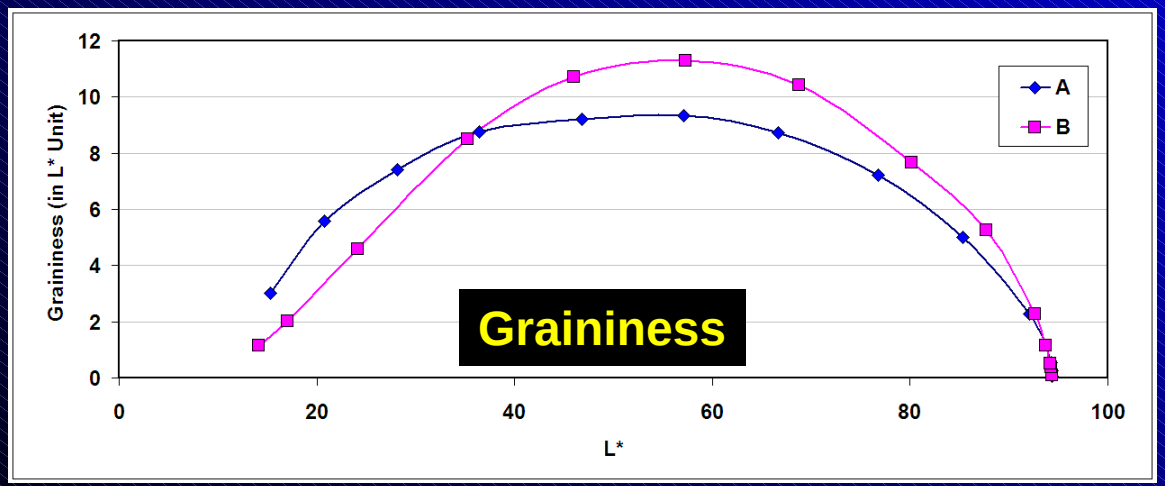


Two High Speed Color Electrophotographic Printers

Application Example (2b)

Tone Reproduction & Image Noise





Low Resolution Optics Area Tool

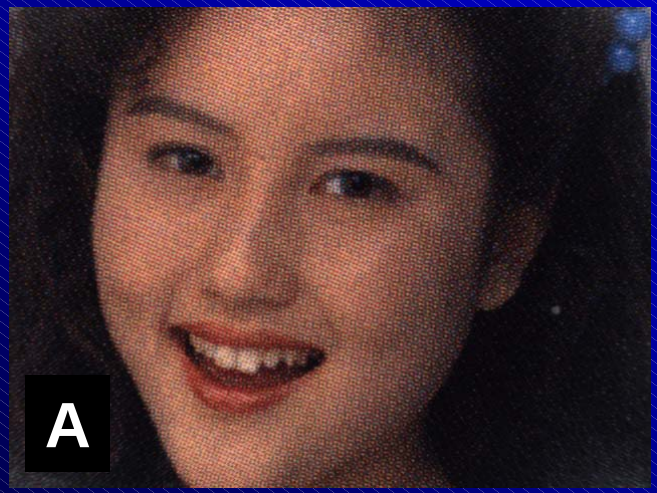
- "A" & "B" have similar tone reproduction
- Image noise mostly higher in "B" and is dependent on Lightness (L*)

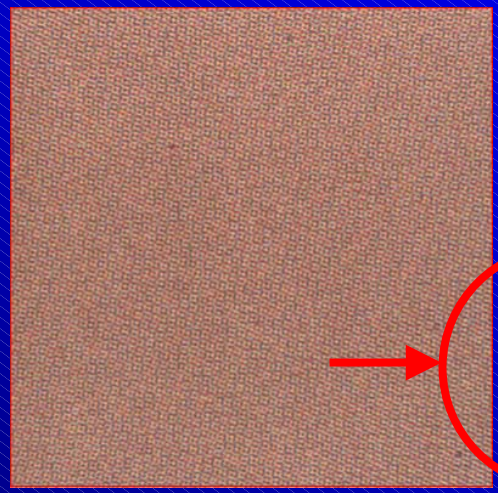
L*~30 ~55 ~85

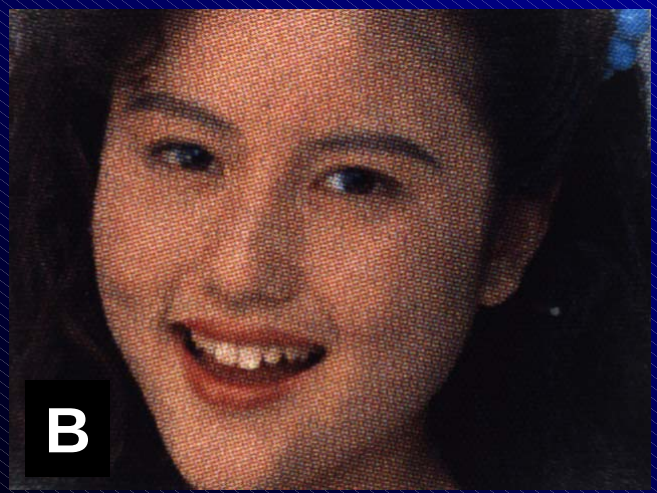
Application Example (2c)

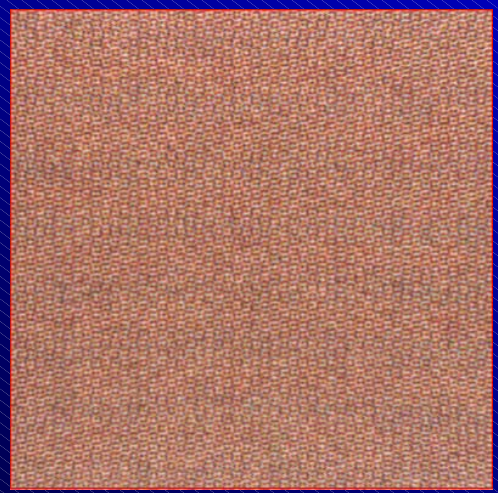
Image Noise: ISO13660 Graininess/Mottle & NPS Analysis

Low Resolution Optics









Illuminant	D65
Observer	2°
Grain Tile Size [µm]*	37.5
Mottle Tile Size [µm]*	299.6

**ISO-13660*

Area Tool

	Metric	A	B
Average	L*	72.7	73.2
	a*	10.2	11.8
	b*	17.2	20.3
Graininess	L*	7.68	8.70
	a*	13.20	13.75
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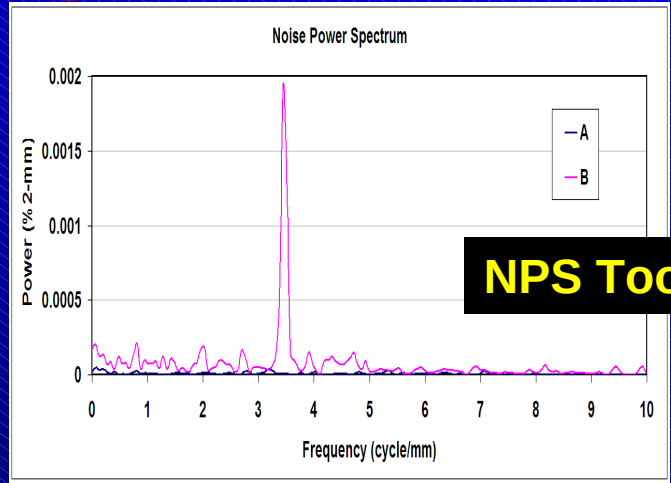
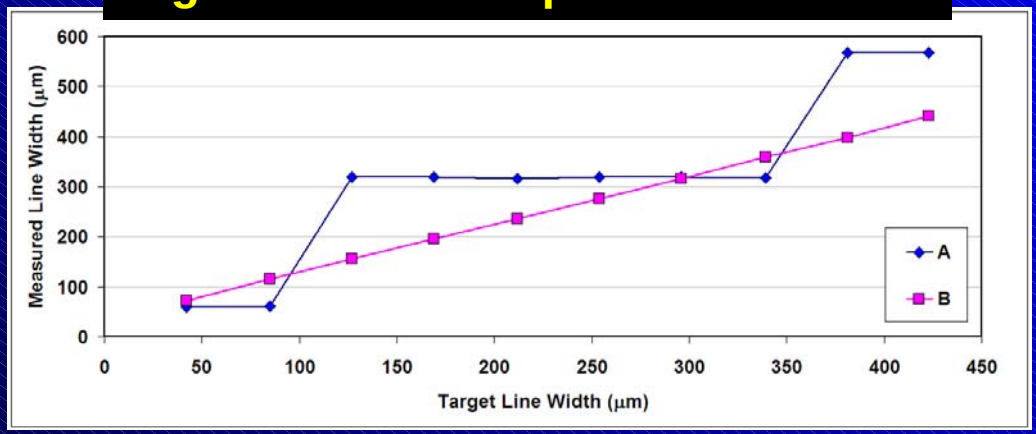


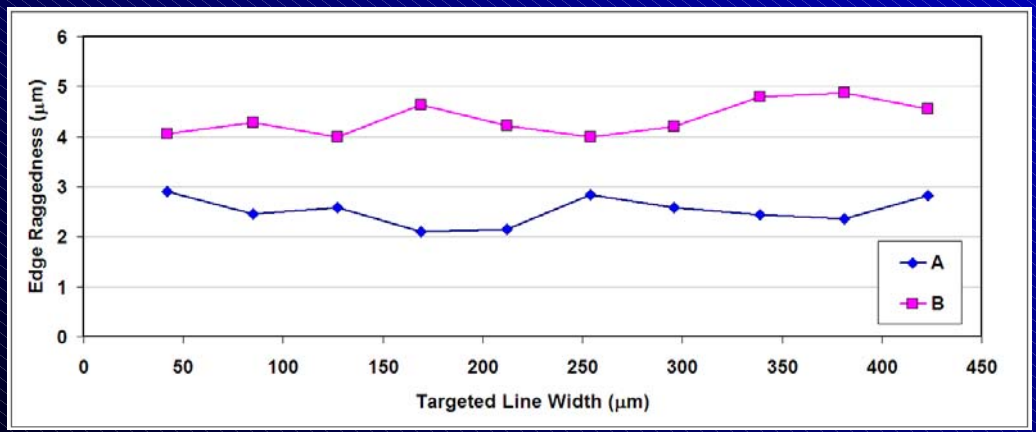
NPS Tool

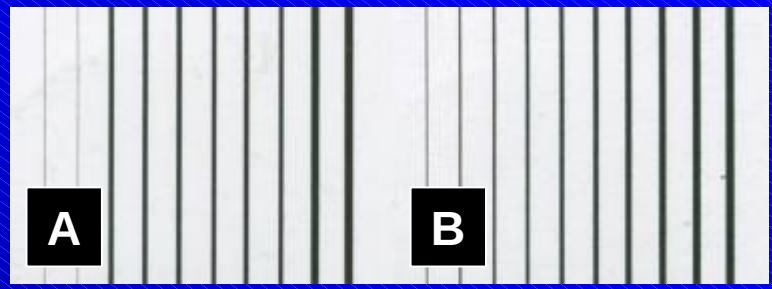
Application Example (2d)

Sharpness & Details: Line Quality (ISO13660)

High Resolution Optics – Line Tool



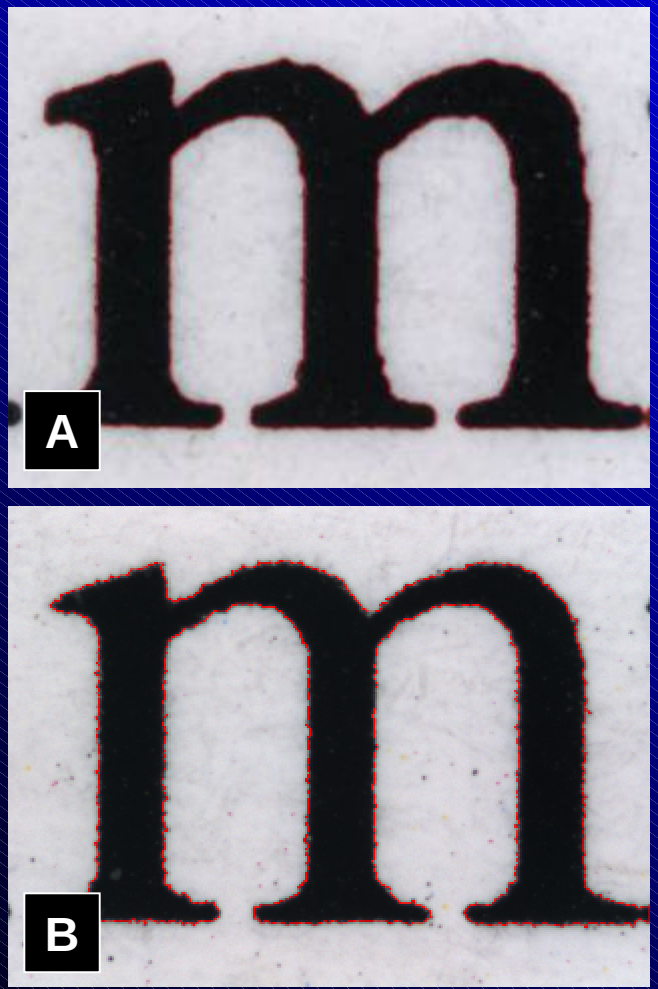




- "A" has significant problem in writing thin lines correctly.
- Edge raggedness difference is small and imperceptible.

Application Example (2e)

Text Quality – Dot & Line Tools



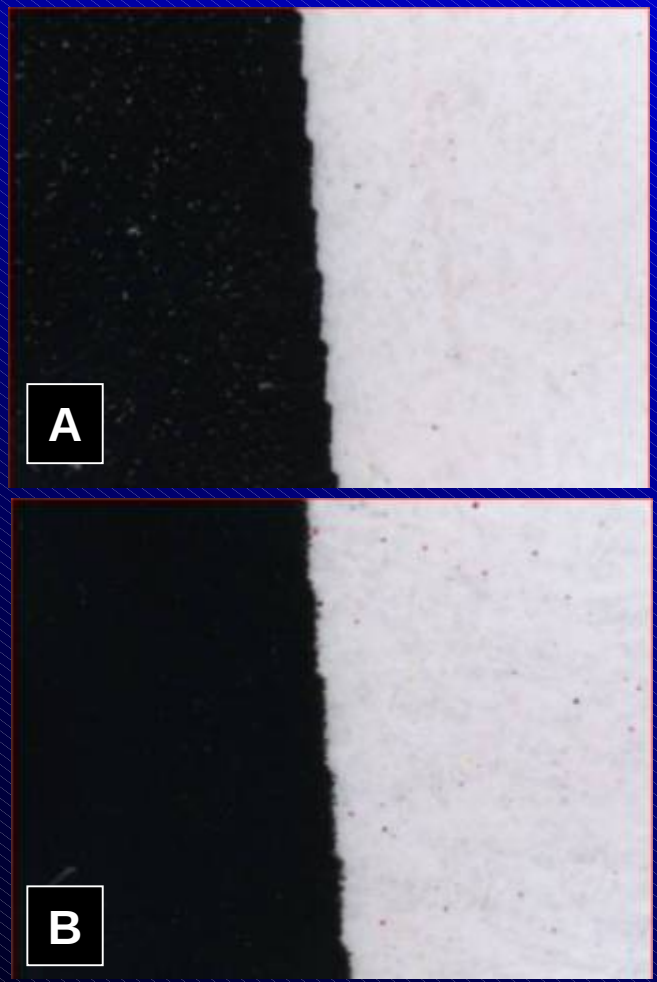
High Resolution Optics – Line Tool

Character Quality Attributes	A	B
Vertical Stroke Width (μm)	398.5	363.9
Stroke Darkness (OD)	1.07	1.06
Stroke Contrast	0.91	0.91
Edge Raggedness (μm)	4.03	3.61
Area (mm²)	3.17	2.75
Perimeter (mm)	20.62	22.12
Circularity	10.71	14.19

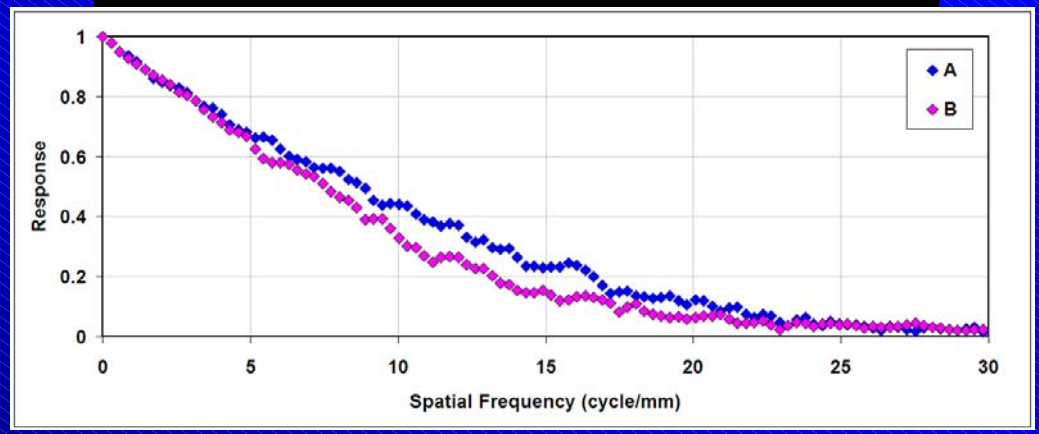
- "A" appears much bolder than "B" as indicated by Stroke Width & Character Area.
- Edge raggedness difference is small and imperceptible.

Application Example (2f)

Resolution & MTF (SFR Tool)



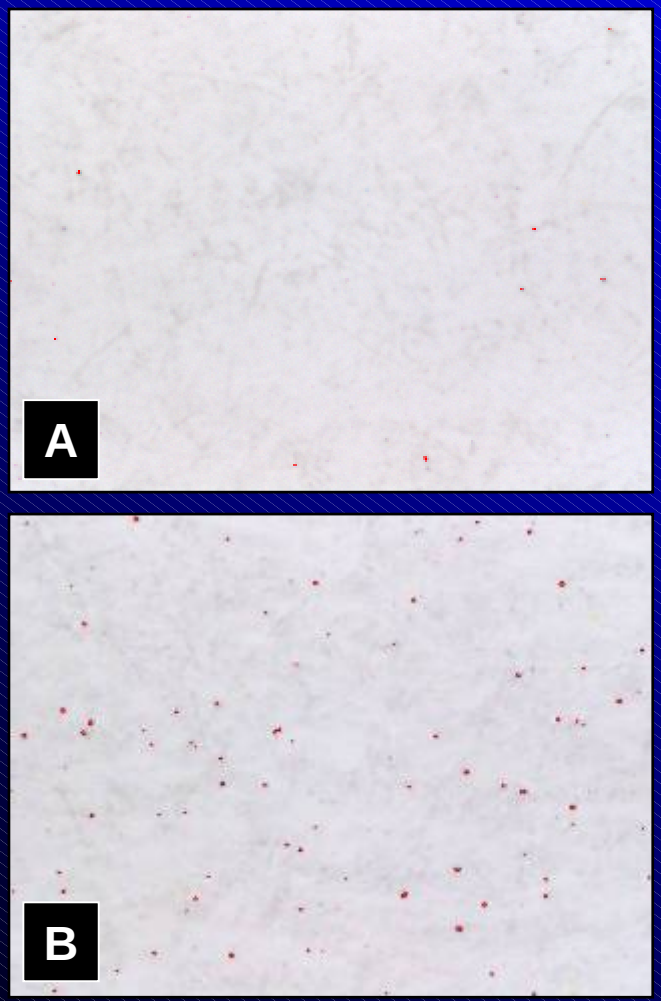
High Resolution Optics – SFR Tool



- The SFR tool (Slant Edge ISO12233) conveniently provides MTF information.
- "A" has slightly higher MTF than "B".

Application Example (2g)

Background Analysis



High Resolution Optics – Background Tool

Background Metrics	A	B
Count	18	118
Area (µm²)	278.0	363.1
Diameter (µm)	17.6	19.9
GS	1.36	4.54

- "GS" is a very useful metric for measuring Background, combining the role of number and size of particles.
- "A" is significantly better than "B"

Summary (1)

- Objective image quality analysis has advanced significantly in recent years; the challenge is that the technology is not readily available to most practicing imaging professionals.
- Our goal is simply to bridge this gap by developing a reliable image analysis tool for everyday use by everybody.
- This presentation summarizes our design approach and the hardware and software solutions of a second generation portable image analysis system.

Summary (2)

- The new tool provides a broad range of IQ analysis functions, and addresses the requirements of portability, flexibility, upgradeability, affordability, and most importantly, ease-of-use.
- We also place much emphasis on issues of calibration, reliability, and adaptation of international and industry standards.
- We hope our effort has made a contribution to the imaging industry, and towards the theme of “Expansion of Imaging” in ICJ2007.