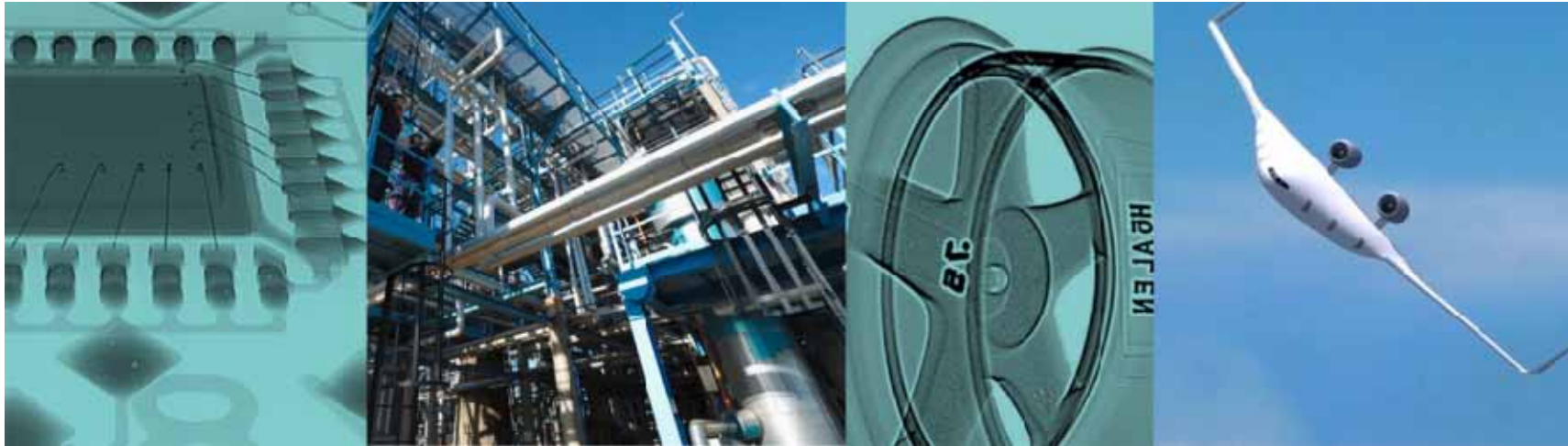


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Ankiros 11-14 November 2010

## APPROACH TO AUTOMATIC X-RAY IMAGE ENHANCEMENT



Frank Herold, Malte Kurfiss and Peter Kramm

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# Outline

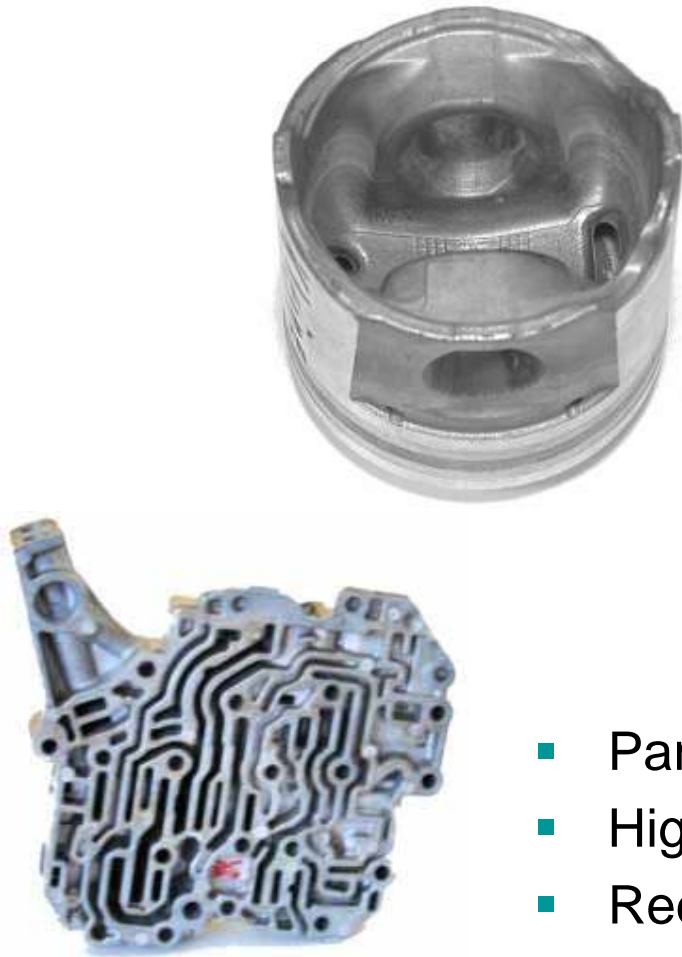
---

- Why automating X-ray
- X-ray parameters
- Choice of detector
- Automated image qualification
- HDR

---

## Why Automating X-Ray?

---

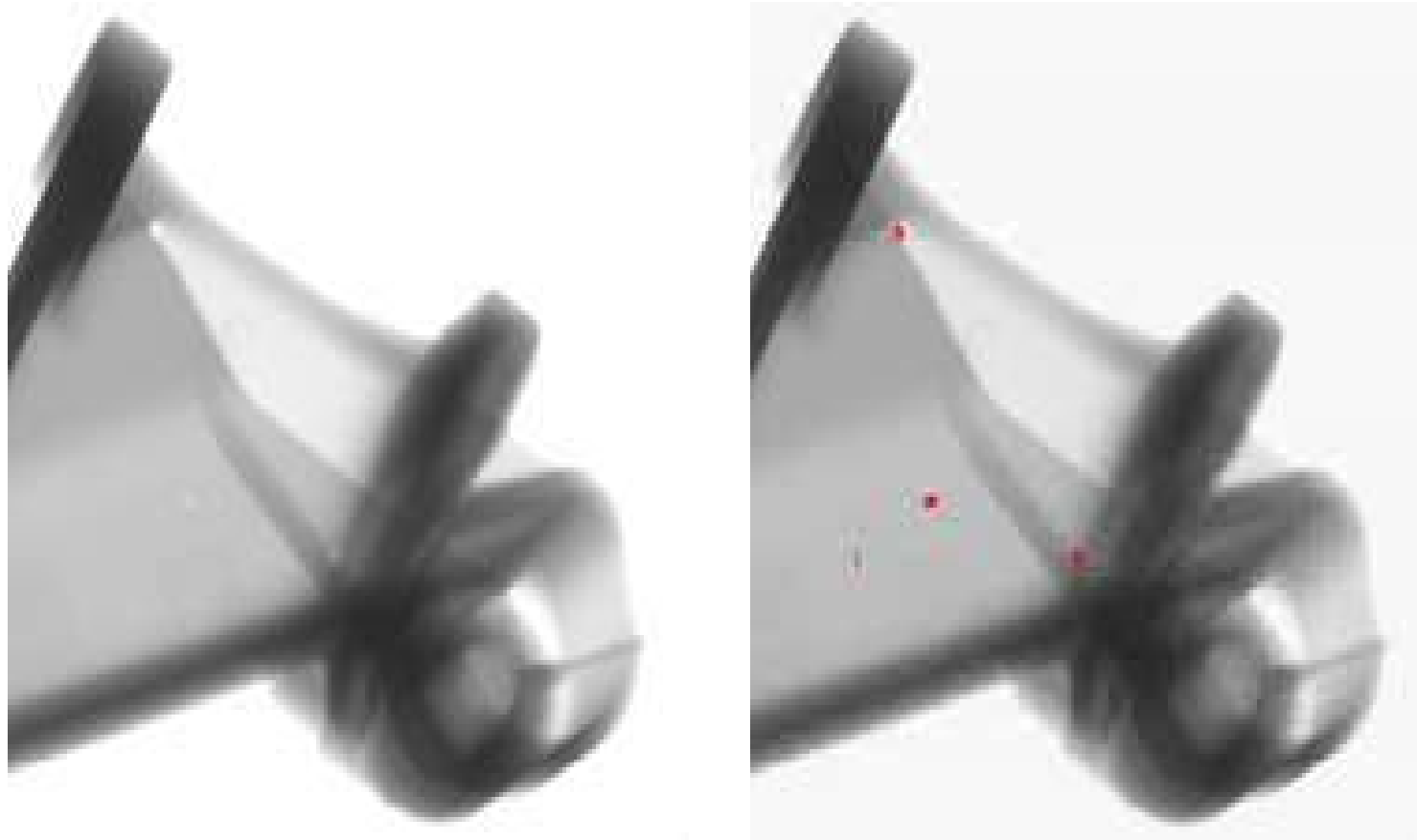


- Parts with complicated structure
- High demands in quality
- Reducing inspection time

---

## What is Visual X-Ray Inspection?

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Voids of a few hundred  $\mu\text{m}$

---

# Outline

---

- Why automating X-ray
- X-ray parameters
- Choice of detector
- Automated image qualification
- HDR

---

# Key-Parameters

---

- X-Ray source
  - X-Ray parameter (kV, mA)
- Detector
  - Spatial <> contrast resolution
  - SNR ~ CNR
- Visualization



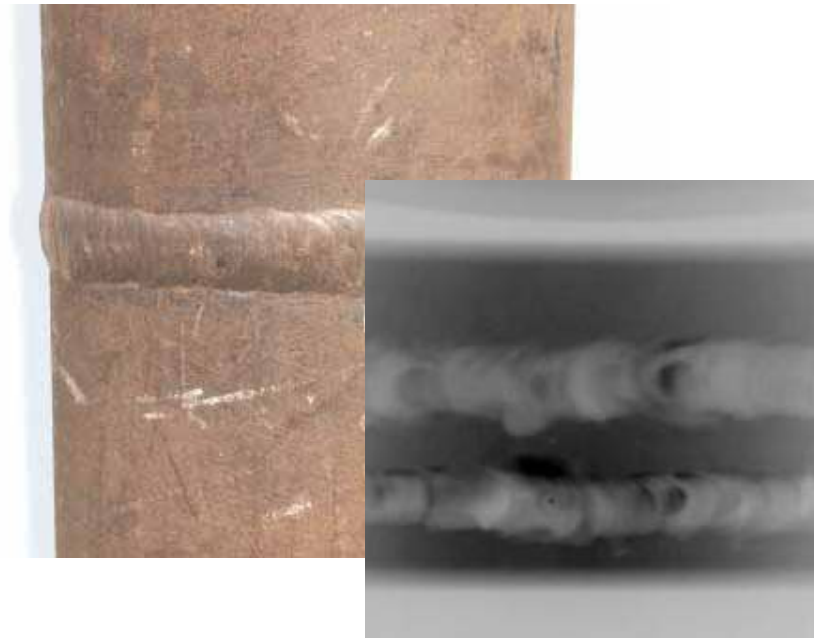
---

# X-Ray Source for film technique

---



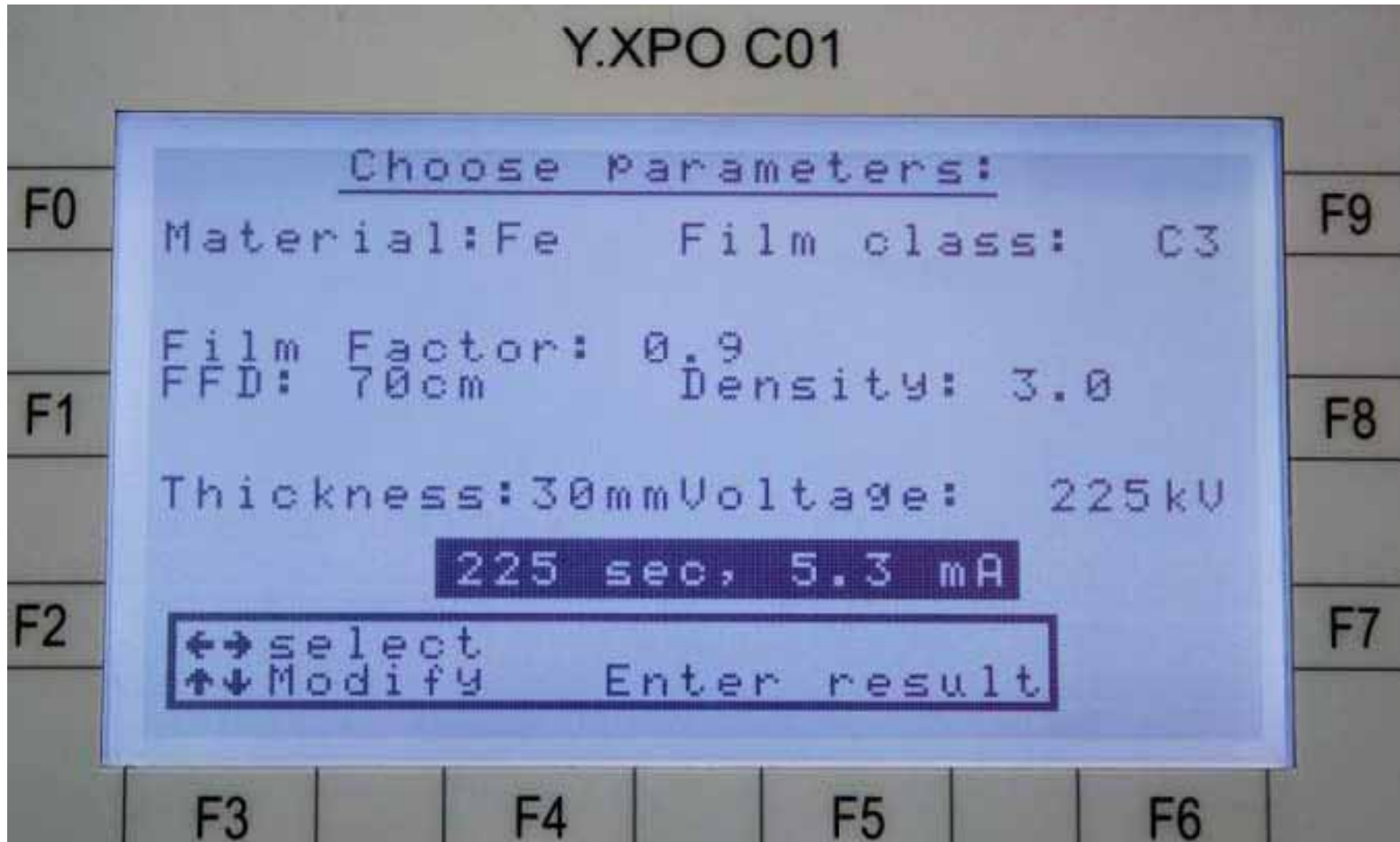
Double-wall exposure  
2 x 15 mm Fe



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# Exposure calculator

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---

# X-Ray Source

---

How to obtain a maximum of information

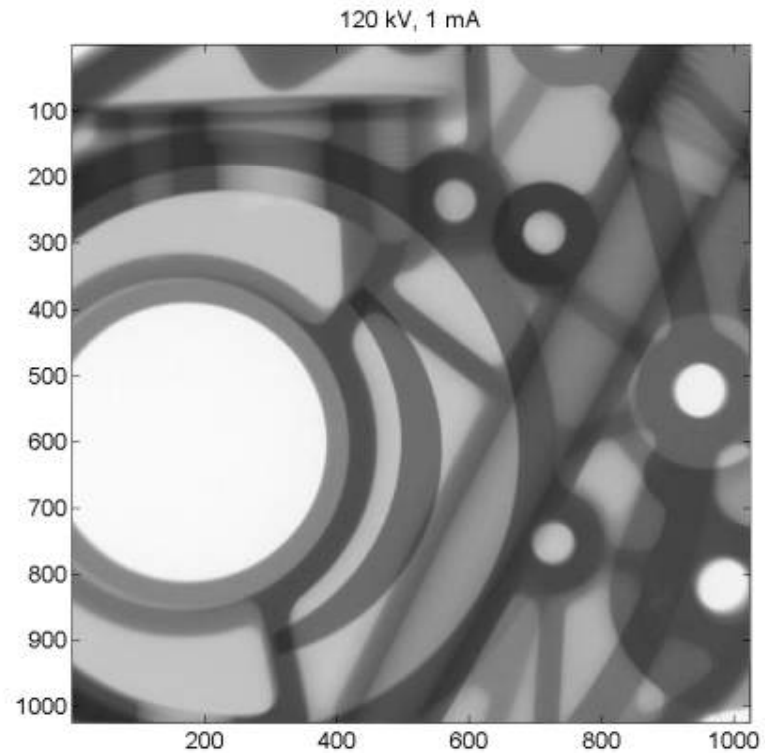
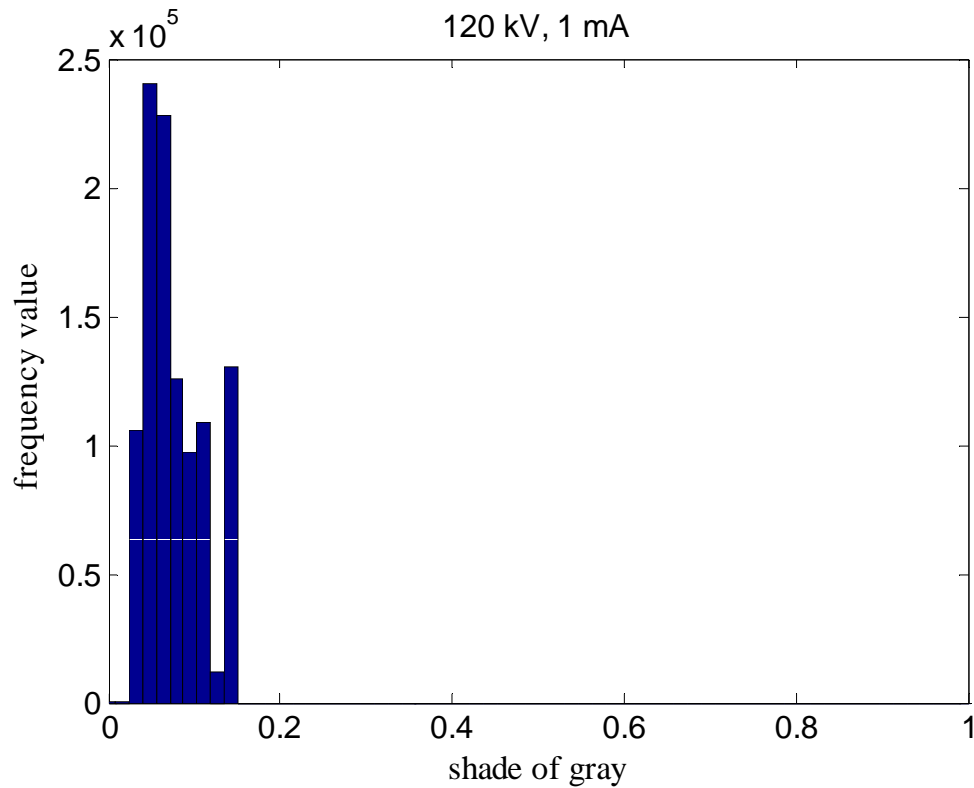


more gray values translates  
into more depth information



# X-Ray Source

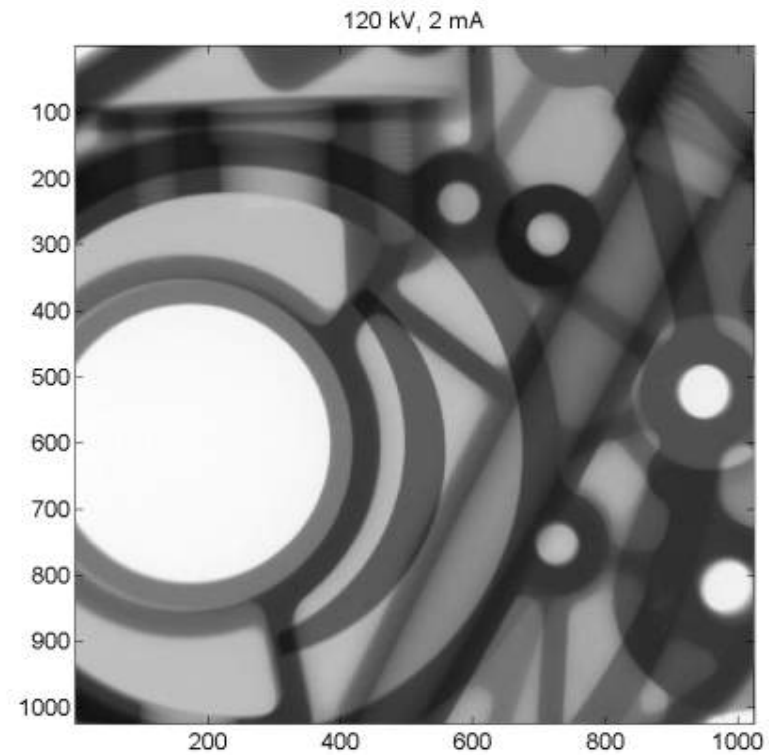
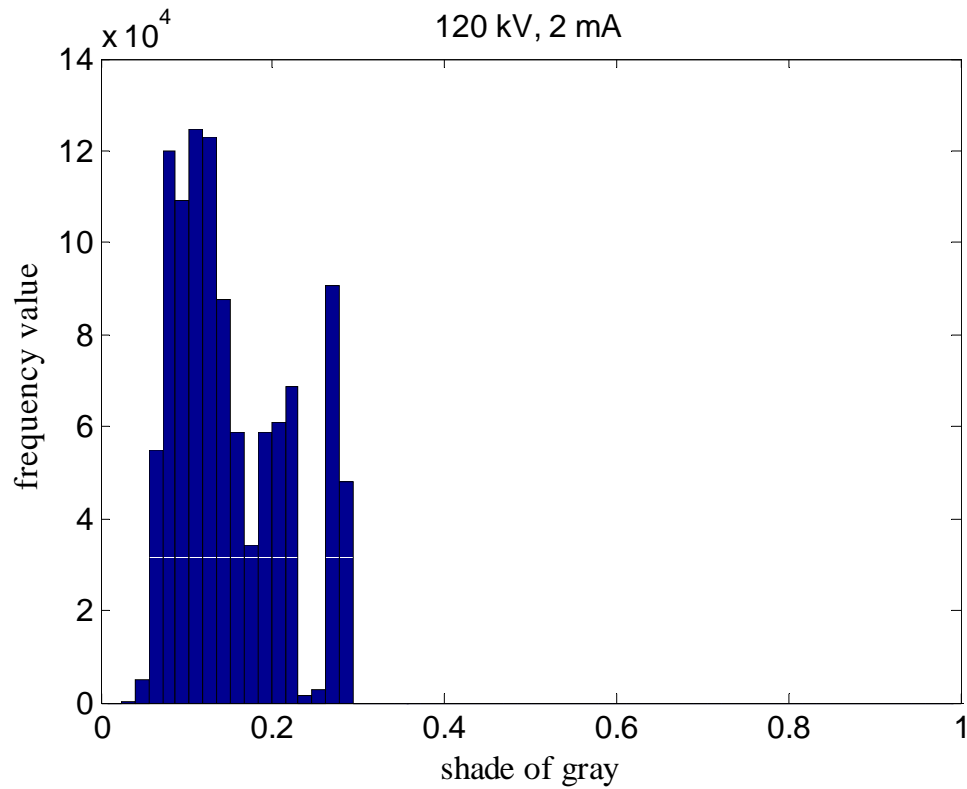
(Automatic adjustment of X-Ray current)



↔ ~ 100 gray values

# X-Ray Source

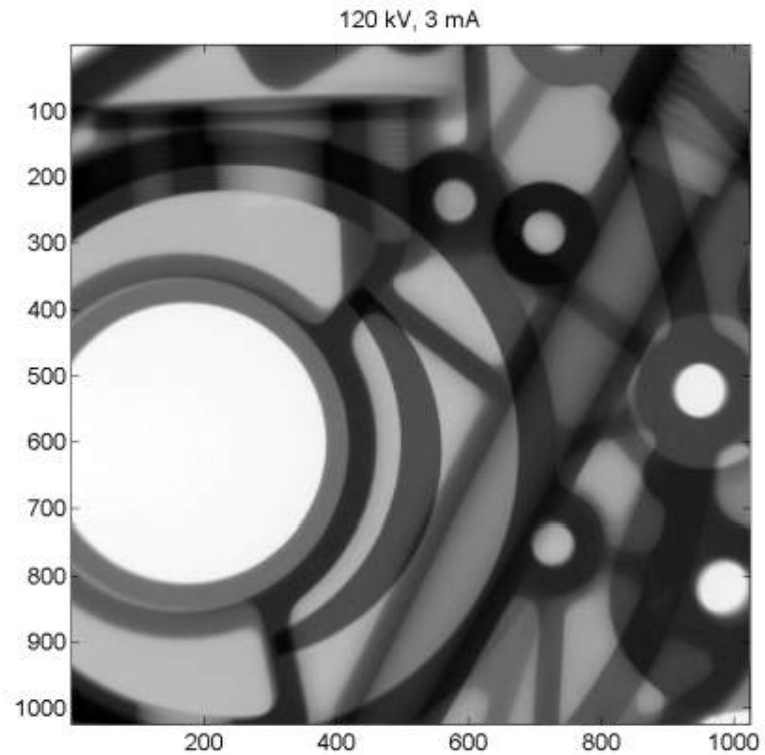
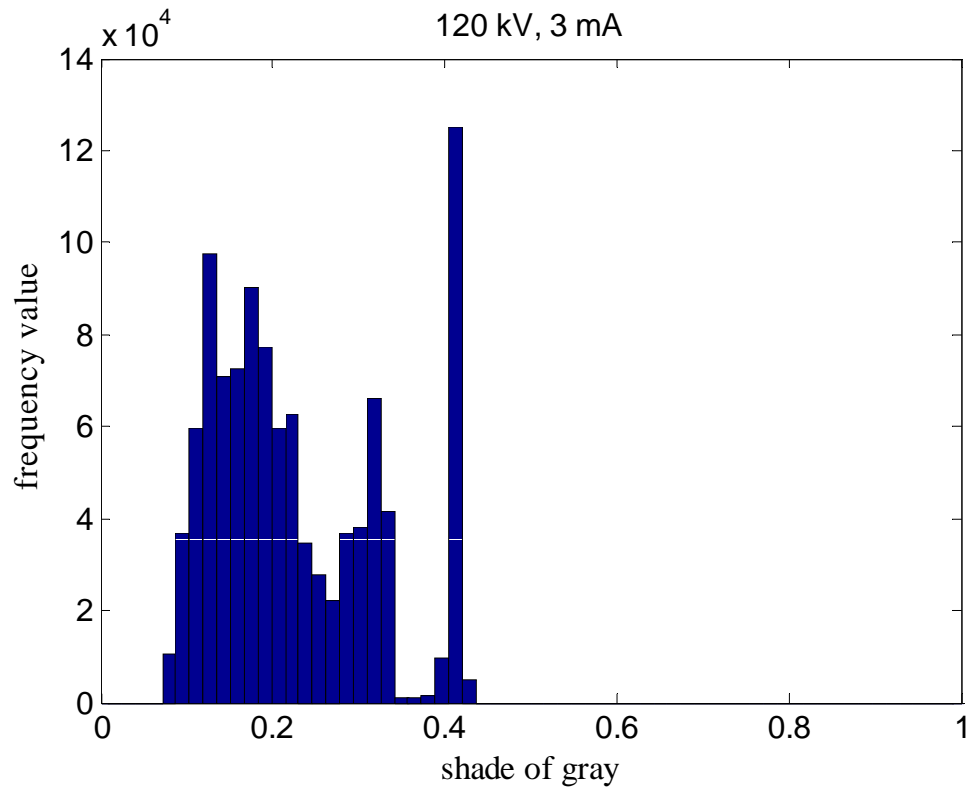
(Automatic adjustment of X-Ray current)



↔ ~ 500 gray values

# X-Ray Source

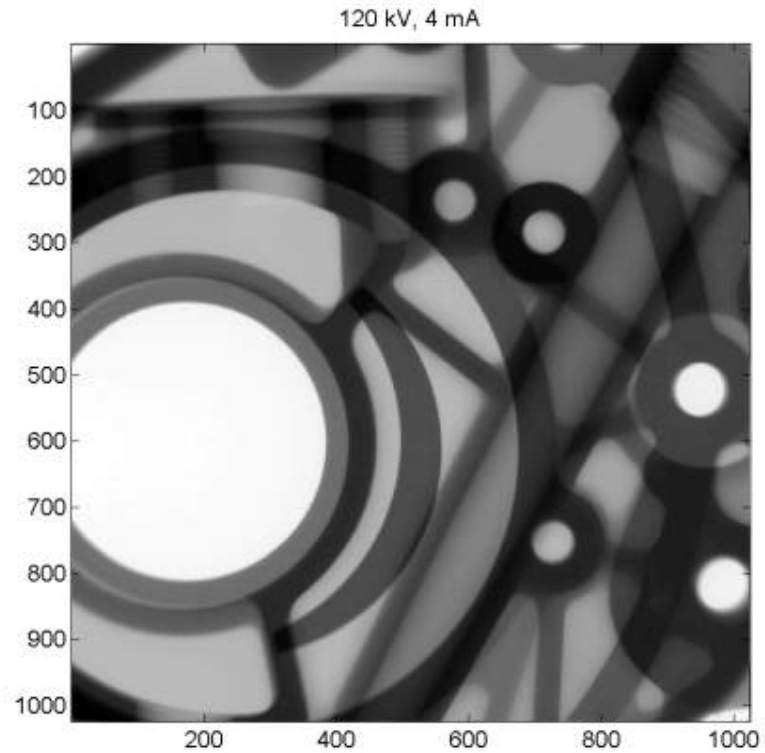
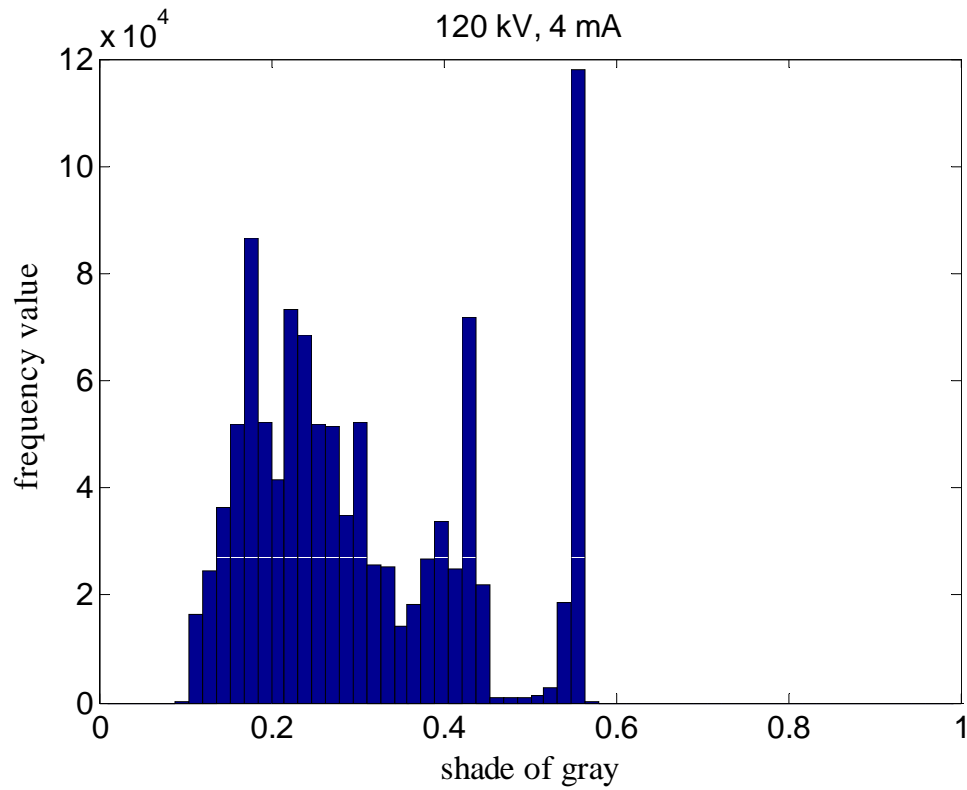
(Automatic adjustment of X-Ray current)



~ 1.000 gray values

# X-Ray Source

(Automatic adjustment of X-Ray current)



~ 5.000 gray values

---

# Outline

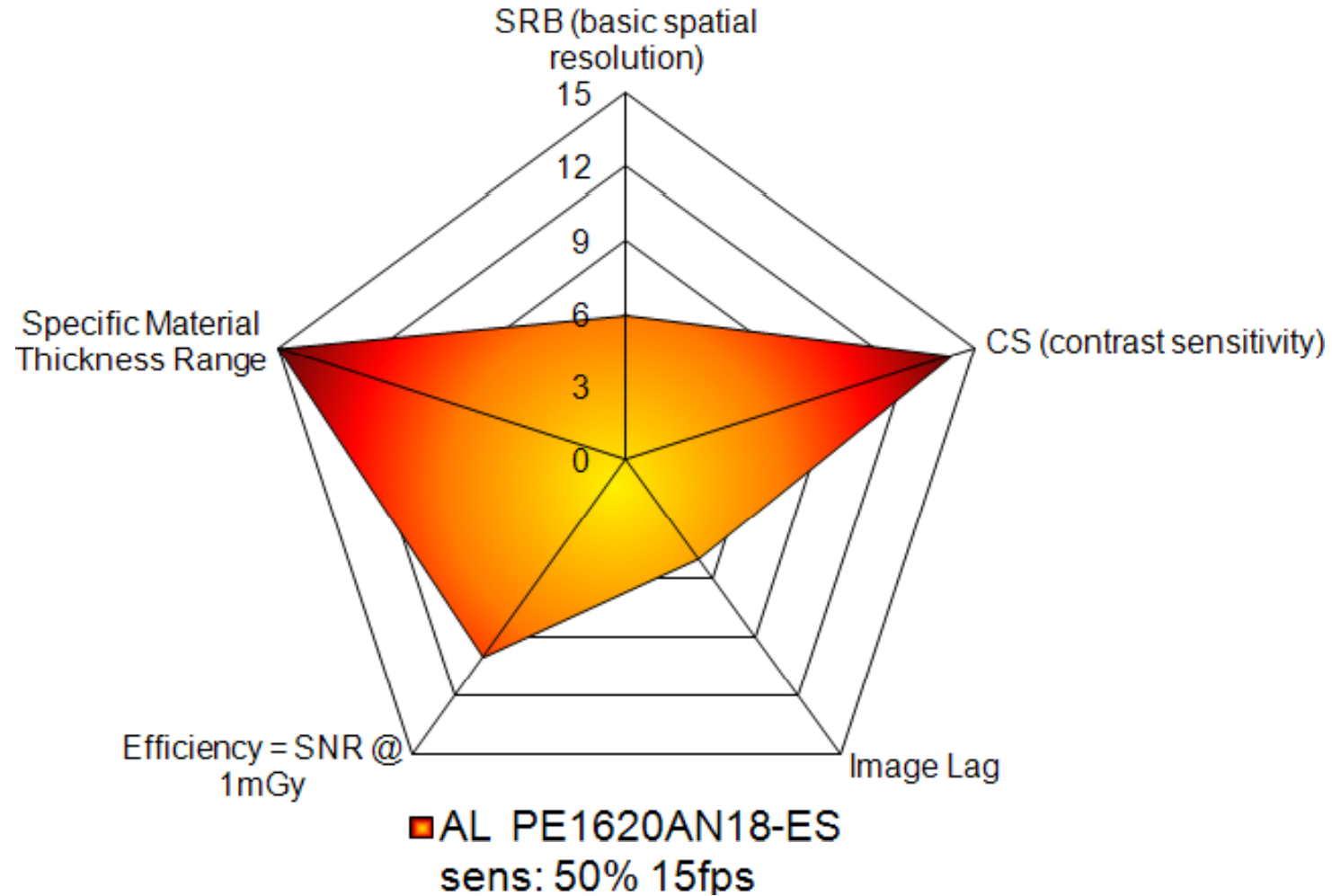
---

- Why automating X-ray
- X-ray parameters
- Choice of detector
- Automated image qualification
- HDR

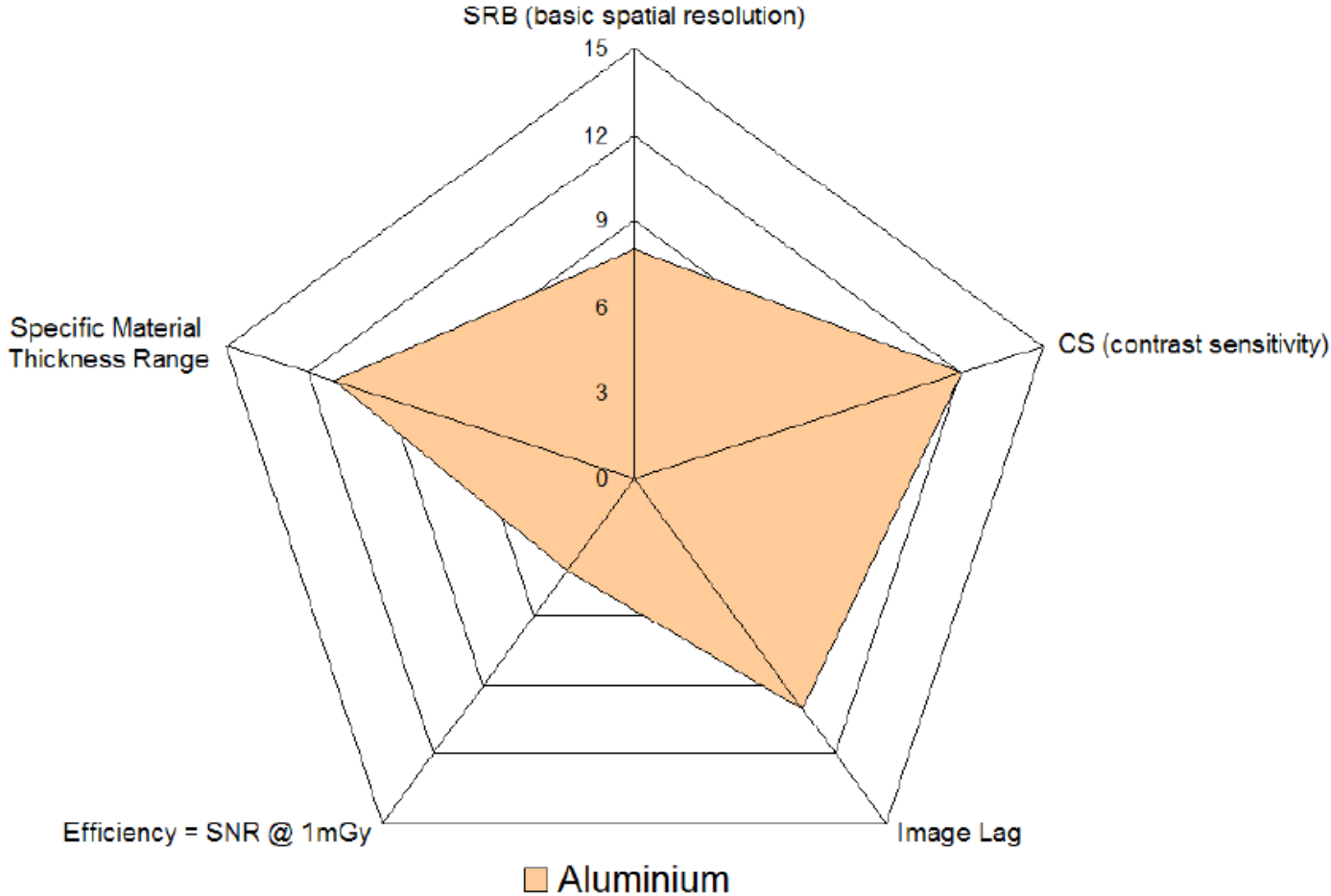
---

# Choice of Detectors

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# Choice of Detectors



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# Outline

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- Why automating X-ray
- X-ray parameters
- Choice of detector
- Automated image qualification
- HDR

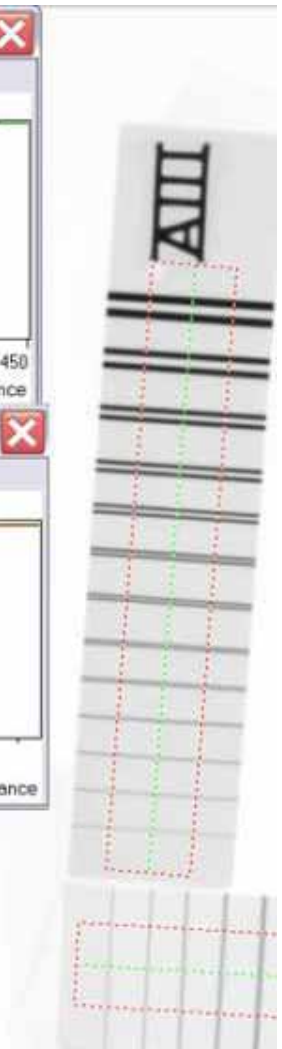
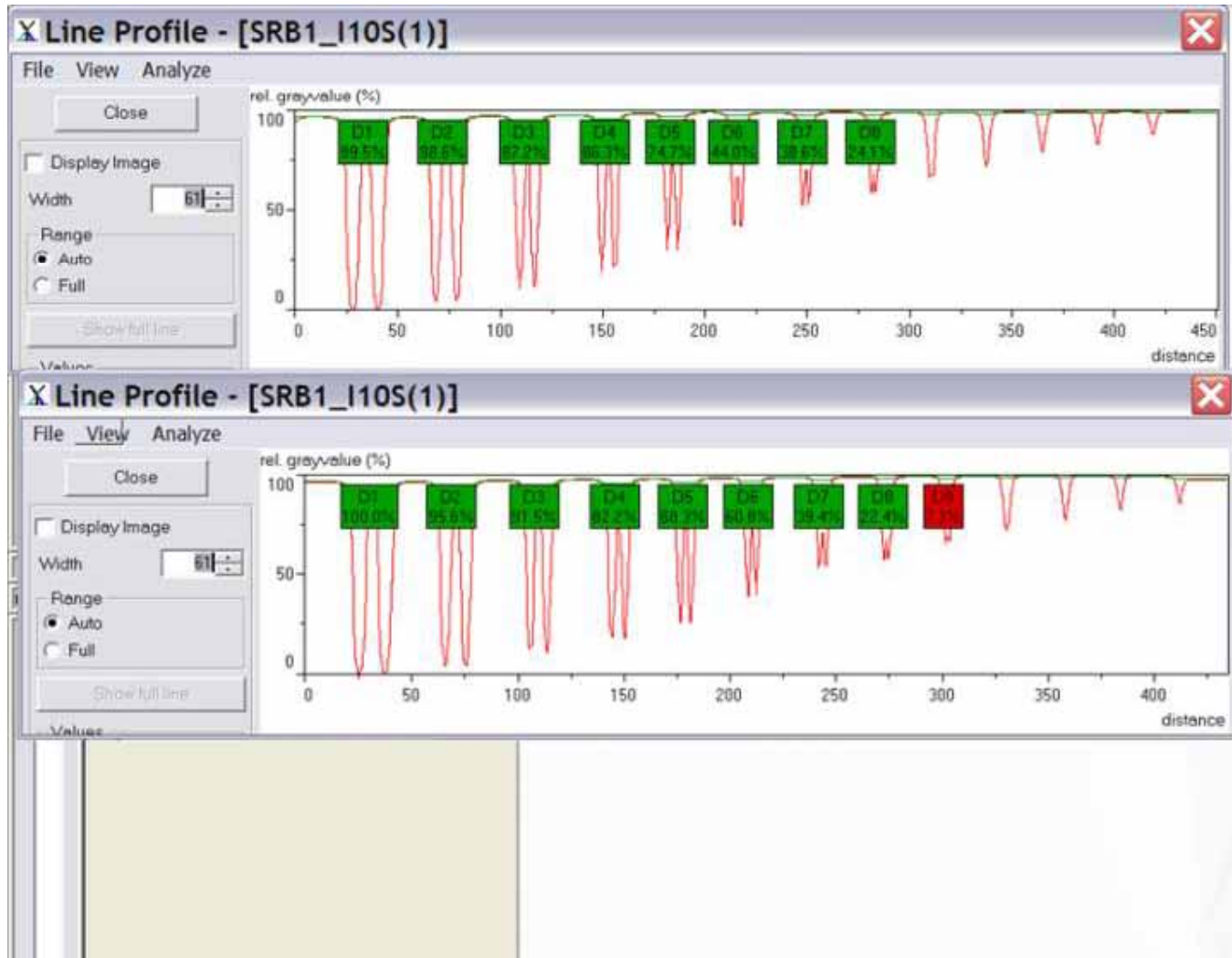
---

# Detector

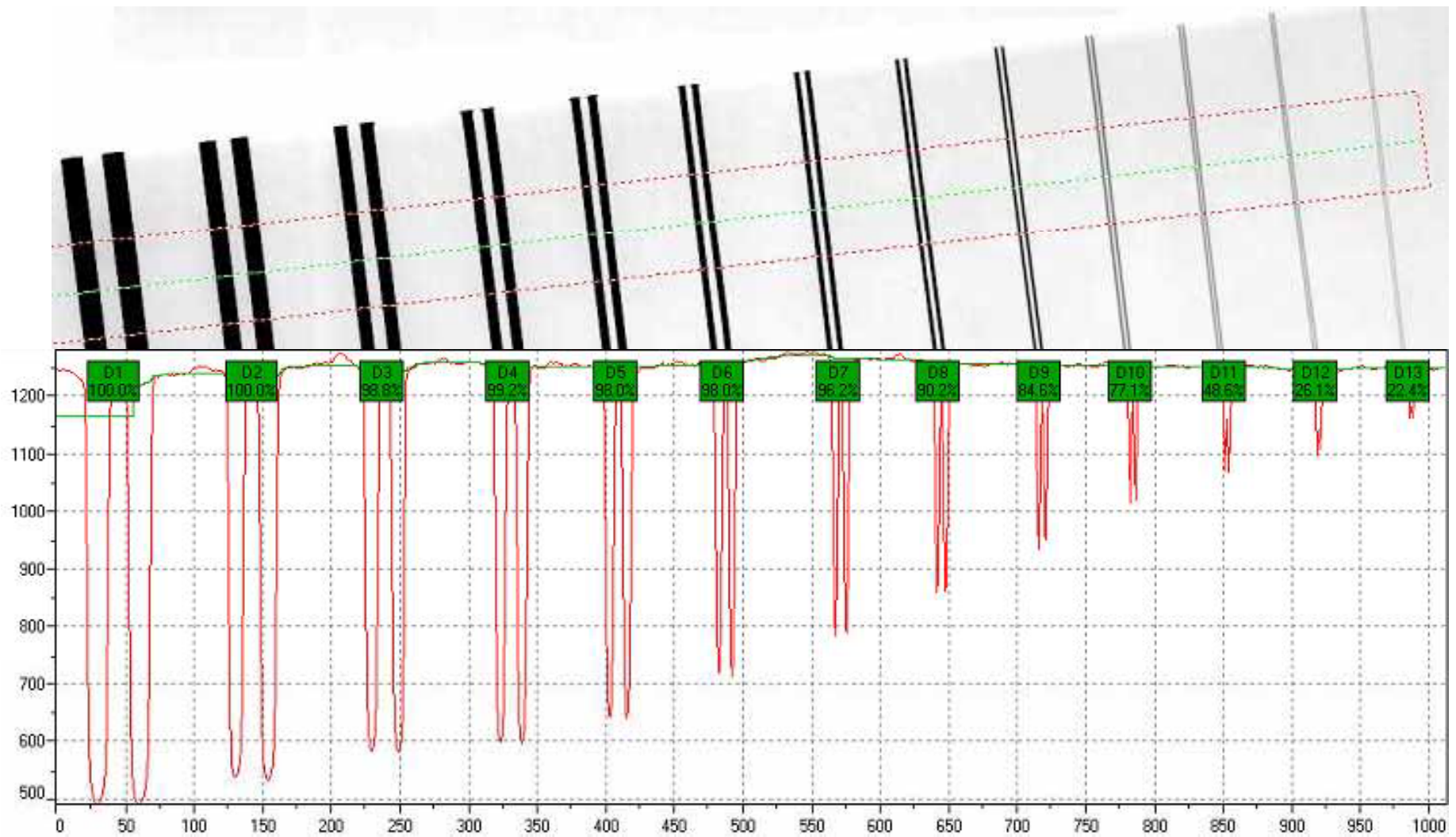
---

## Tool

- Duplex Wire
- 4T, 2T and one hole
- Automated calibration



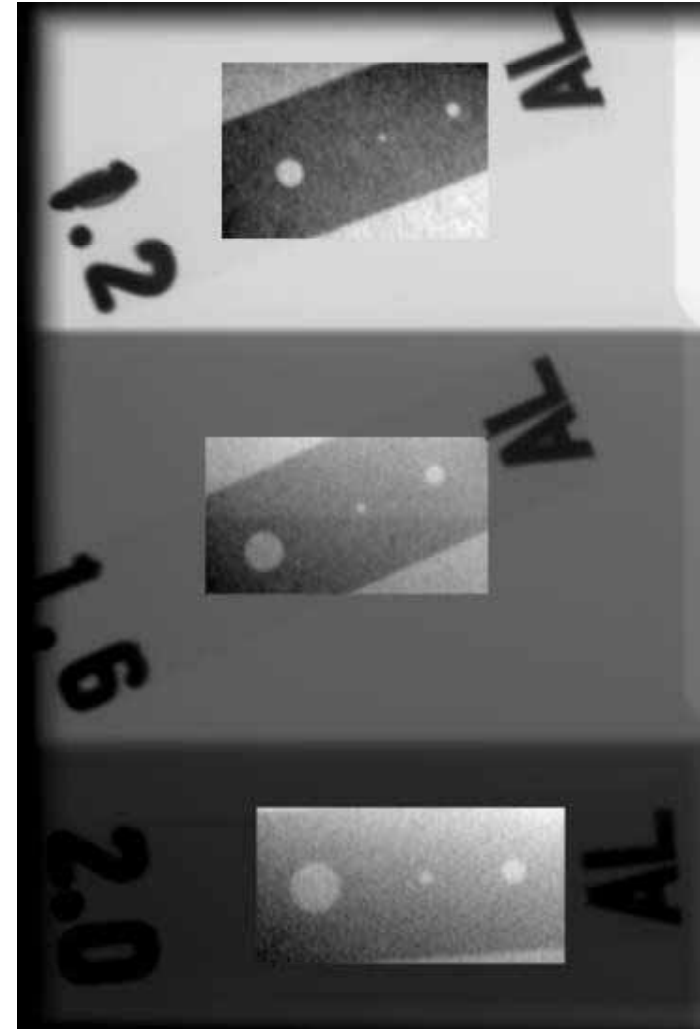
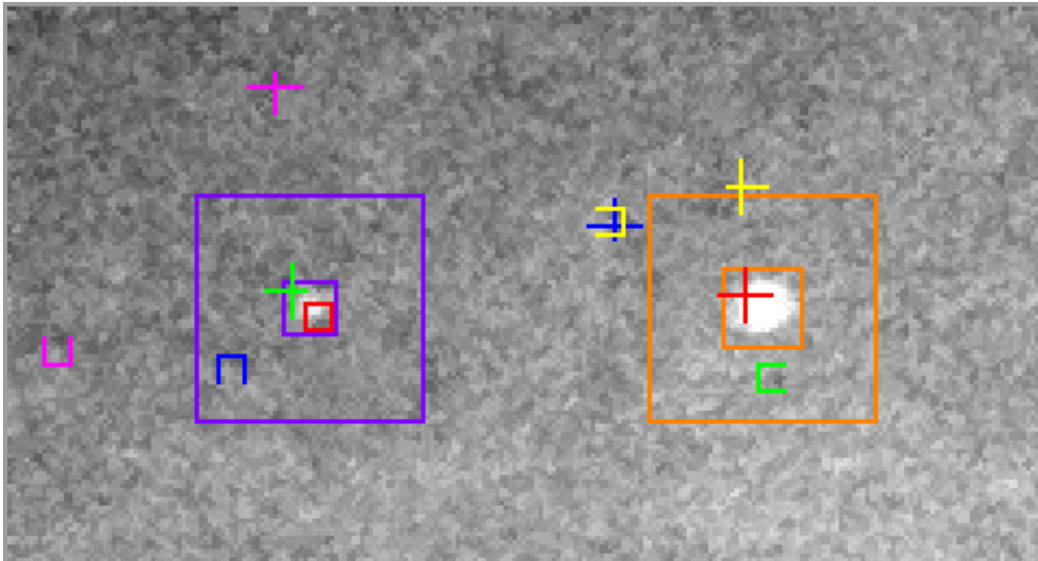
# Detector (Duplex Wire EN-642-5)



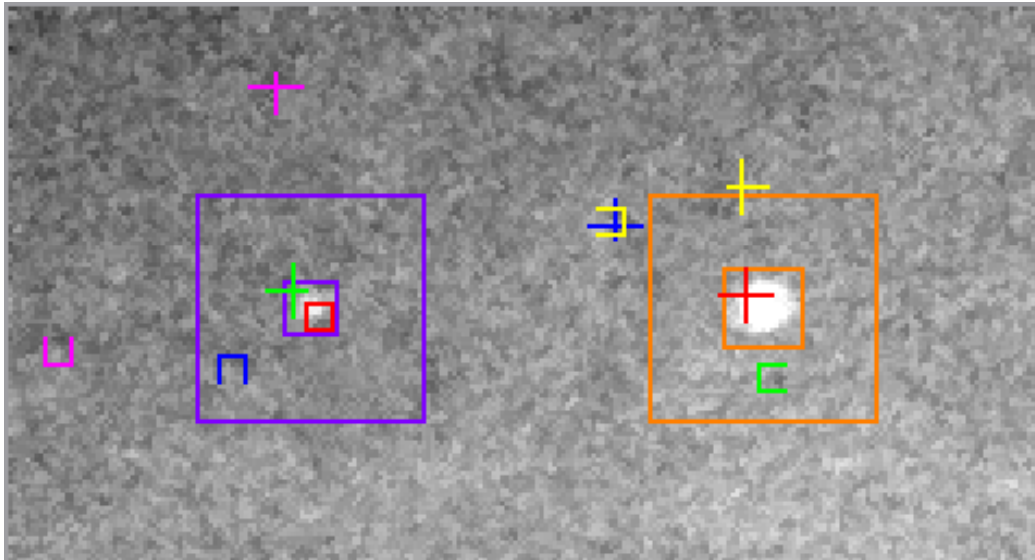
---

# Detector (Penetrameter ASTM E 1025 / E 1742)

---



# Detector (Penetrameter ASTM E 1025 / E 1742)



Minimal signal to noise ratios for window size			
2T	<input type="text" value="13"/>	1T	<input type="text" value="6"/>
	<input type="text" value="129"/>		<input type="text" value="200"/>
	<input type="text" value="237"/>		<input type="text" value="366"/>
	<input type="text" value="453"/>		<input type="text" value="373"/>
	<input type="text" value="454"/>		<input type="text" value="374"/>
	<input type="text" value="471"/>		<input type="text" value="376"/>
Mean	<input type="text" value="597.6"/>	Mean	<input type="text" value="662.2"/>
SNR Dist	<input type="text" value="256"/>	SNR Dist	<input type="text" value="87"/>
GBV	<input type="text" value="9.1"/>	GBV	<input type="text" value="6.4"/>
Result	<input type="text" value="OK"/>	Result	<input type="text" value="OK"/>

---

# Outline

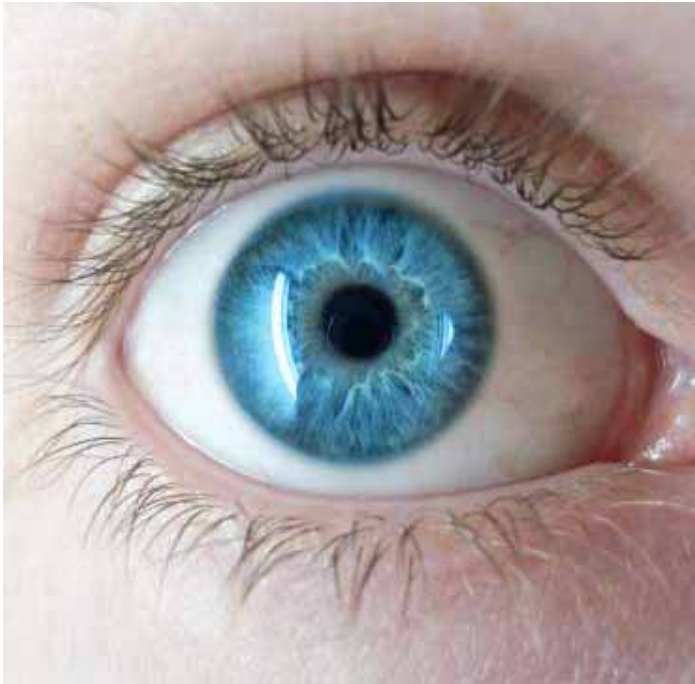
---

- Why automating X-ray
- X-ray parameters
- Choice of detector
- Automated image qualification
- HDR

---

# The Human Eye

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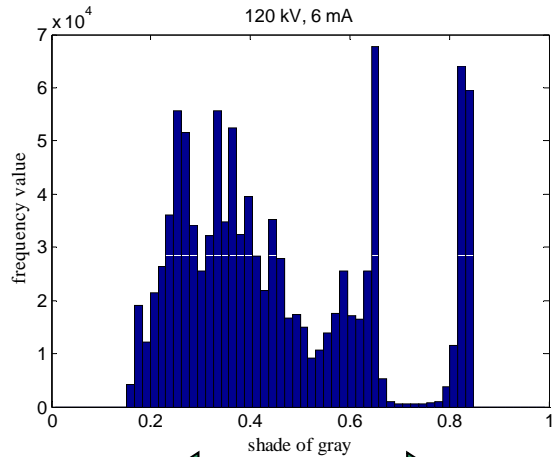
- Field of view  $180^{\circ} \times 130^{\circ}$
- About 16 million colors
- But only 60-80 grey values!

---

# High Dynamic Radioscopy

---

Original Image 40.000 grey values  
More information than the human eye can distinguish



~ 40.000 gray values

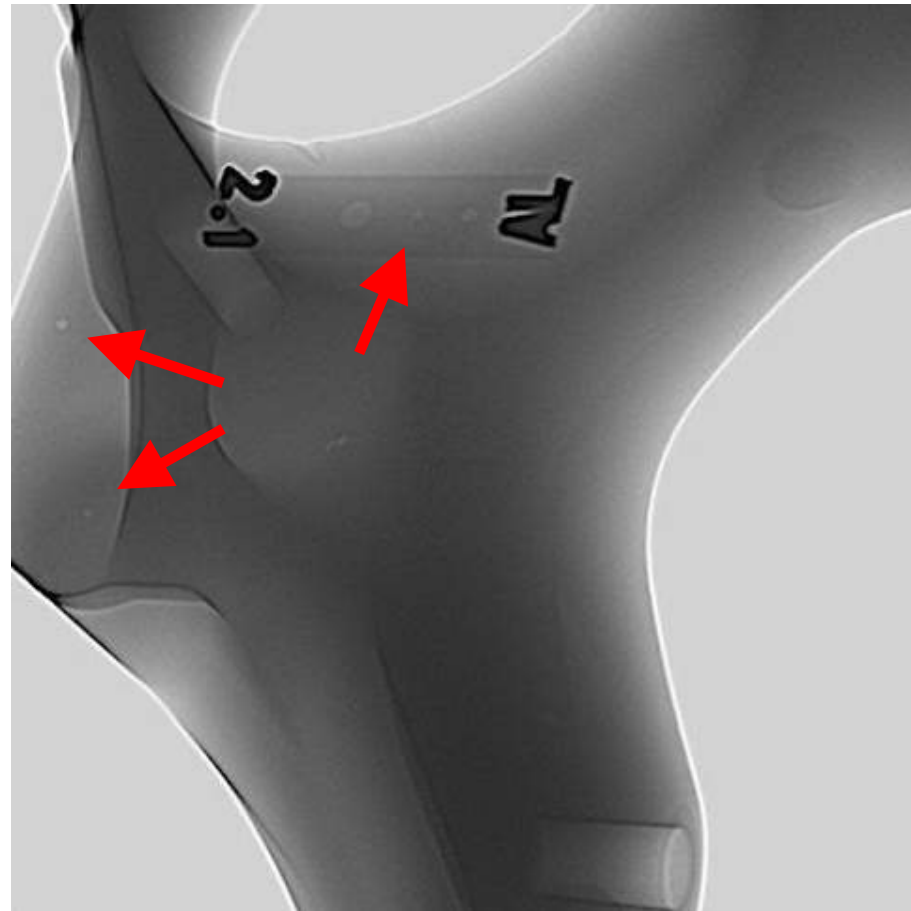
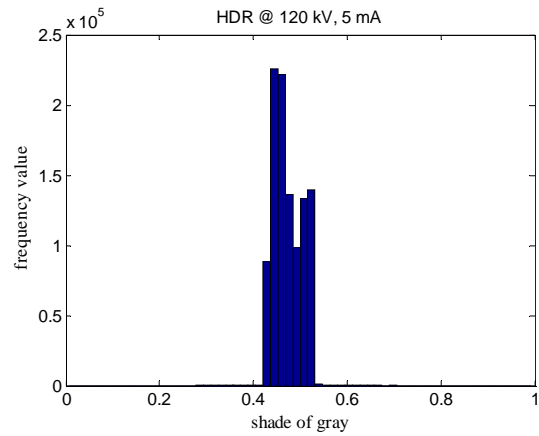


---

# High Dynamic Radioscopy

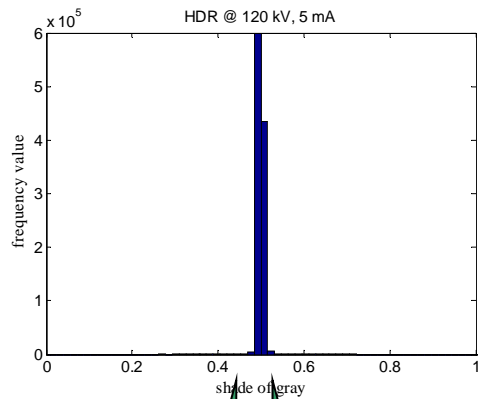
(Compression of image information)

---

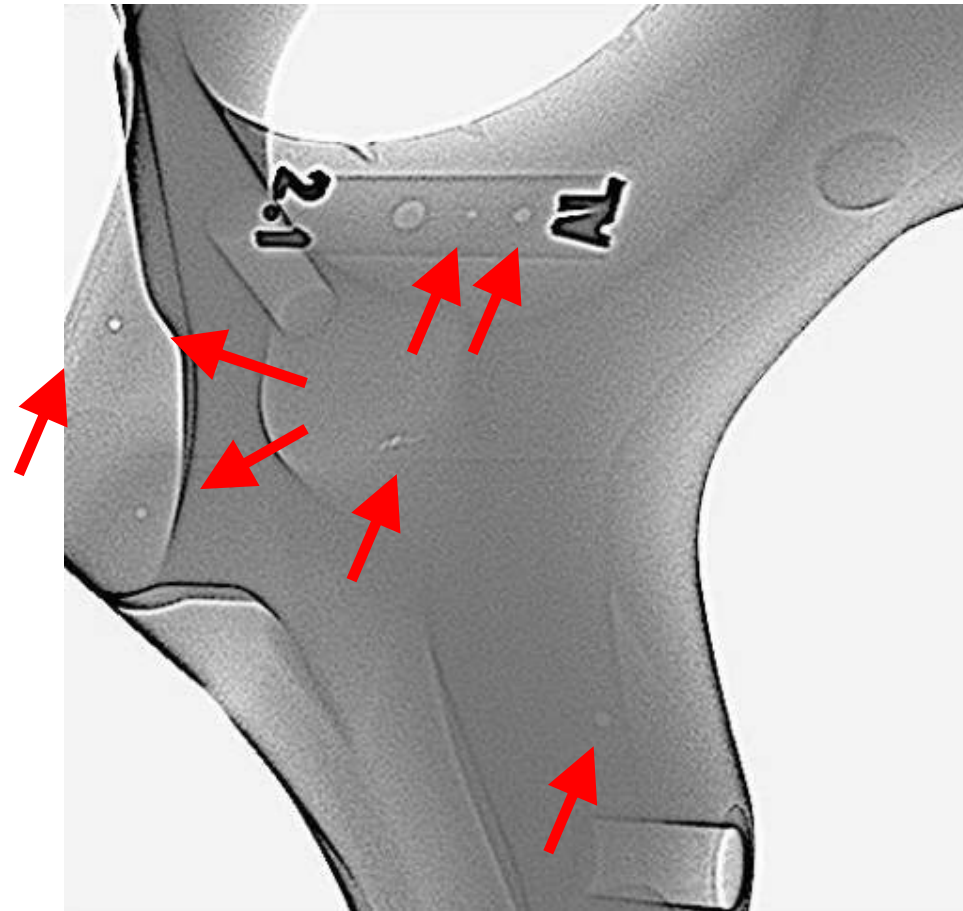


# High Dynamic Radioscopy

(Compression of image information)



60-80 gray values



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## Conclusion

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- Visual X-Ray inspection is still future-orientated:
  - Starting with the proper choice of X-Ray tube
  - Choosing an appropriate X-Ray detector
  - Using intelligent Image Processing Software

⇒ **To overcome limitations of the human's eye**

- Automating means
  - Objective, reproducible decisions
  - Fast, i.e. no manual parameter adjustment

⇒ **Human inspector can concentrate on NDT**

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# Any Questions?

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- References for further Reading

- [1] K. Bavendiek, U. Heike, "HDR Hoch Dynamik Radioskopie", DGzFP Jahrestagung 2009, Münster, Germany.
- [2] K. Bavendiek, "Film, CR, and Flat Panel Detectors for BAM 5 Reference Weld", ASTM Conference, Reno (NV), June 2005.
- [3] K. Bavendiek, U. Zscherpel, U. Ewert: "Digital Detector Arrays (DDA) for X-Ray Micro Imaging", IEEE Workshop on X-Ray Micro Imaging of Materials, Devices, and Organisms, October 2008, Dresden, Germany.
- [4] K. Bavendiek, "Erweiterung der visuellen Röntgenprüfung durch effizientere digitale Technologien: Mit HDR schneller und sicherer zum Ziel", MP Materials Testing, Volume 52, 2010, Carl Hanser Verlag, München, Germany, ISSN: 0025-5300.
- [5] K. Bavendiek, U. Heike, F. Herold, "Automated Defect Recognition in Industrial Applications", International Workshop on Imaging NDE, April 2007, Kalpakkam, India.
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- [8] R. Gonzalez, R. Woods, "Digital Image Processing", 2nd edition, Prentice Hall, Pearson Education, Upper Saddle River, New Jersey, 2002, ISBN: 0-201-18075-8.
- [9] F. Herold, S. Frantz, K. Bavendiek, R. Grigat, "Building Blocks of Third-Generation Automatic Defect Recognition System", 9th European Conference on NDT, September 2006, Berlin, Germany.
- [10] P. Soille, "Morphological Image Analysis", 2nd edition, Springer, Berlin, Germany, 2003, ISBN: 3-540-42988-3.

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**Thank you for your attention.**



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