

The world of Micro-XRF – A non-destructive method to reveal details in different fields of applications



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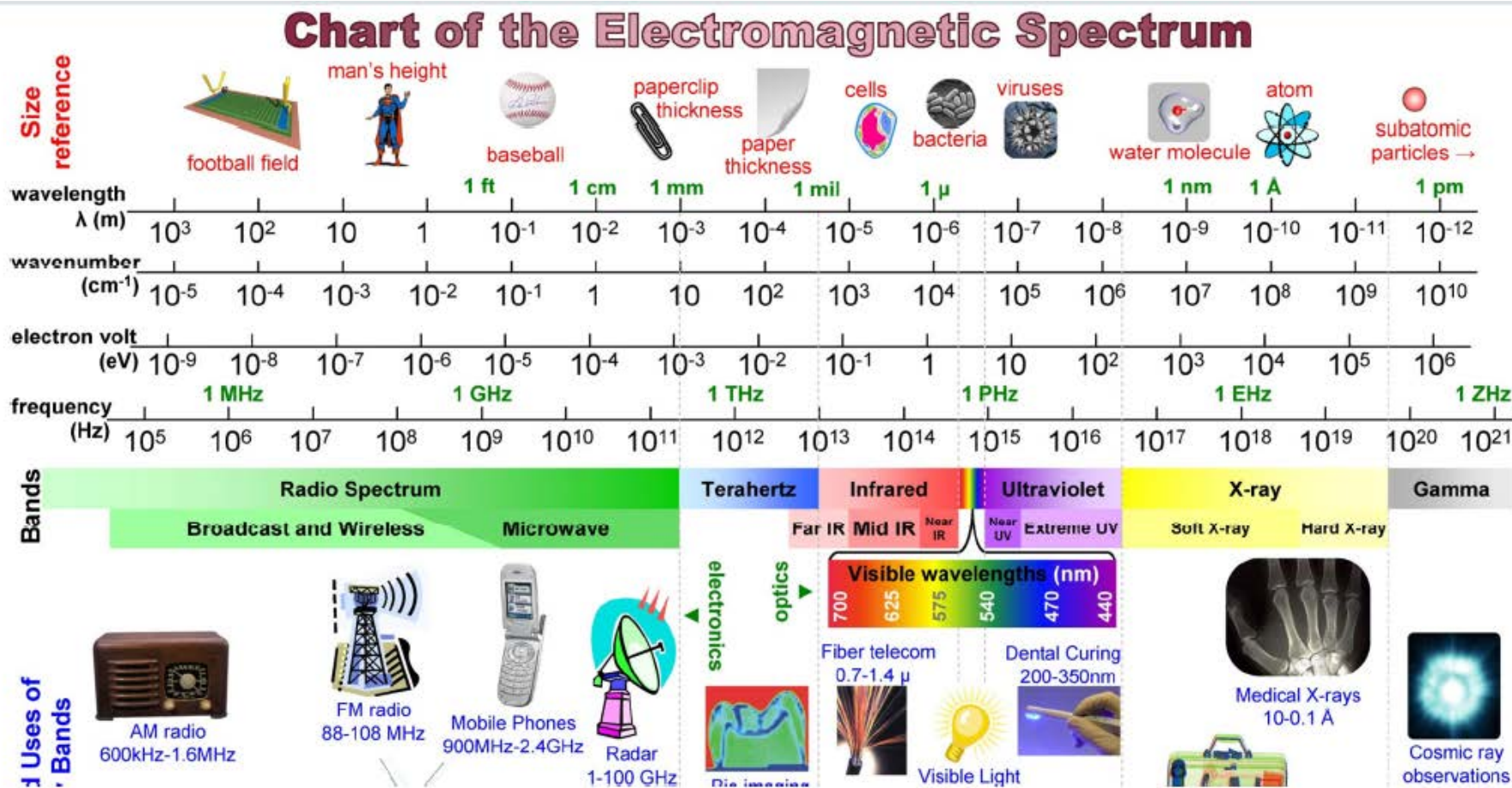
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Falk Reinhardt, Application Specialist
Max Bügler, Application Specialist

YFlash[®]
Technology

Micro-XRF

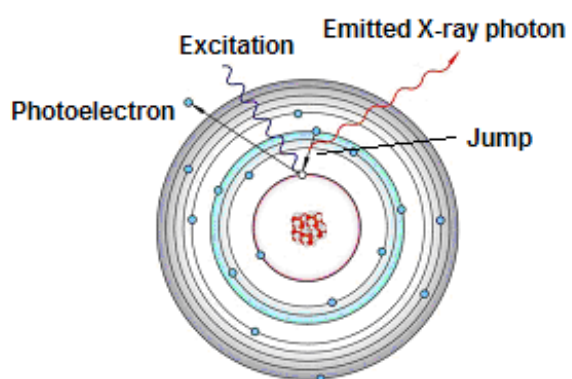
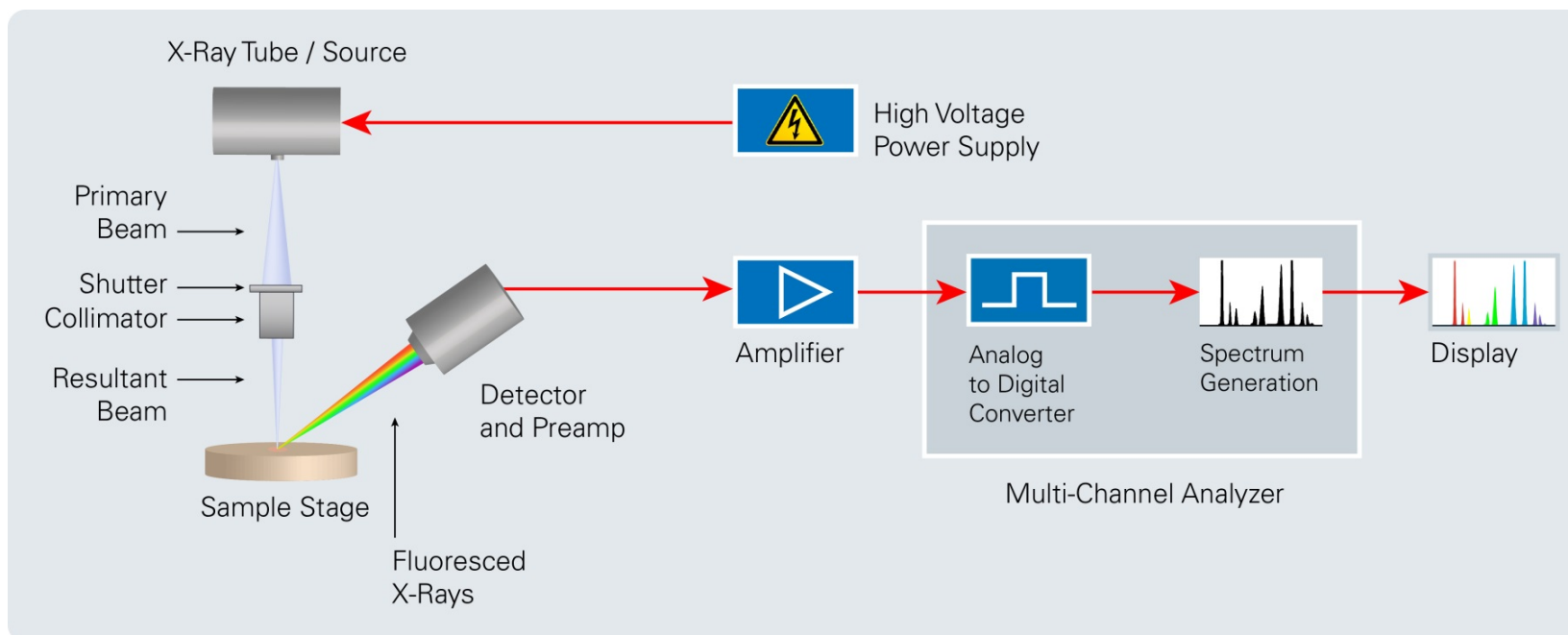


Introduction to Micro-XRF



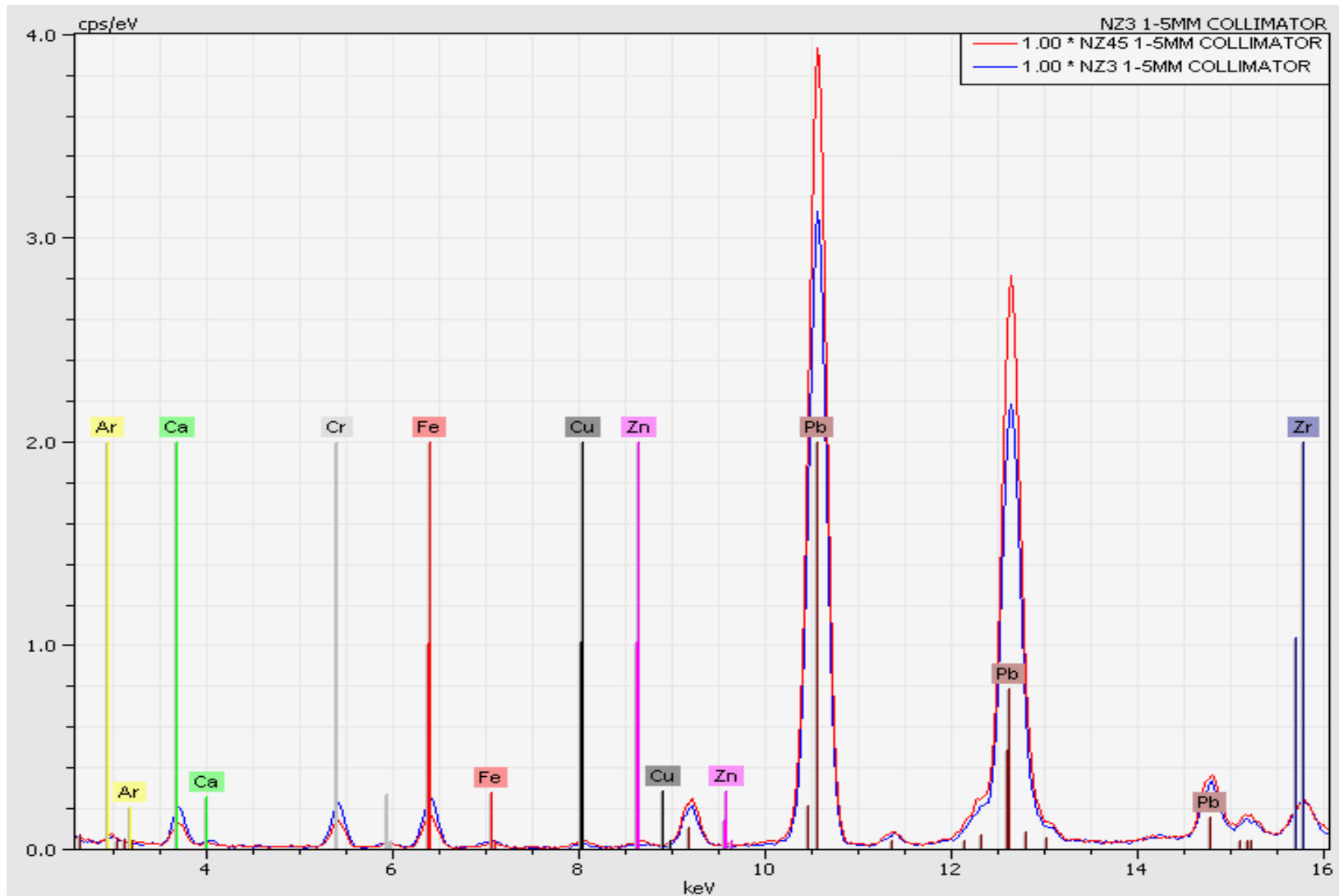
Introduction to Micro-XRF

Basic layout



- Excitation of an atom by high energetic radiation
- Generation of a vacancy
- Fill up this vacancy by outer electrons
- Emission of a characteristic X-ray photon
- Fluorescence yield depends on atomic number (low for low atomic number and vice versa)

Comparison of NZ45 and NZ23, 1.5mm Collimator

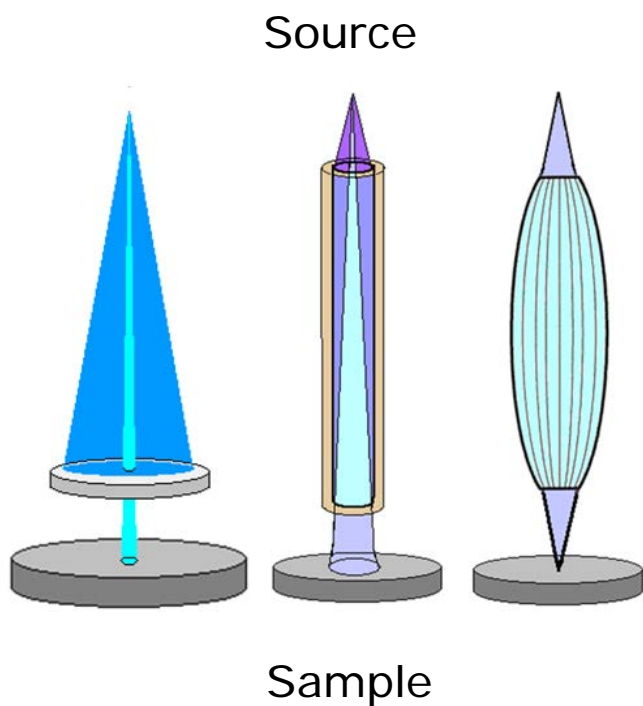


Introduction to Micro-XRF

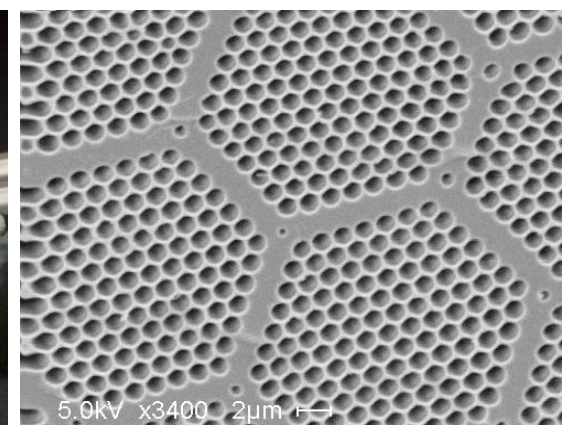
Benefit of capillary optics



Comparison of collimator and focusing device



Optic	∅ Input / mm	Captured angle / sr	Transmission / %	Brilliance / norm for area
Colli	1	$7 \cdot 10^{-5}$	100	1
Monocap	0.3	$6 \cdot 10^{-5}$	≈ 85	≈ 10
Polycap	3	$2 \cdot 10^{-3}$	≈ 10	≈ 5000



Resolution 20µm
Resolution 1µm



Introduction to Micro-XRF

Detectable elements in vacuum and air



	I	II	IIIa	IVa	Va	VIa	VIIa	VIIIa	Ia	IIa	III	IV	V	VI	VII	VIII		
1	1 H															2 He		
2	3 Li	4 Be									5 B	6 C	7 N	8 O	9 F	10 Ne		
3	11 Na	12 Mg									13 Al	14 Si	15 P	16 S	17 Cl	18 Ar		
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	89**	104 (Ku)	105 (Ns)													
			*Lanthanide															
6			58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu		
			**Actinide															
7			90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr		

- Not available
- Not possible
- Only in vacuum (with M4)
- In air

Instrument design



Instrument versions

M1 ORA

M1 Mistral



Small unit in particular for jewelry analysis

Larger unit for different applications also coating analysis, RoHs

Instrument design M4 Tornado



Unique features

- Large, vacuum tight sample chamber
- Fast X-Y-Z-stage for distribution analysis "on the fly"
- Two optical microscopes for sample view with different magnifications
- Small spot size ($< 20\mu\text{m}$) and high excitation intensity due to capillary optics

Applications - Forensics

Analysis of banknotes



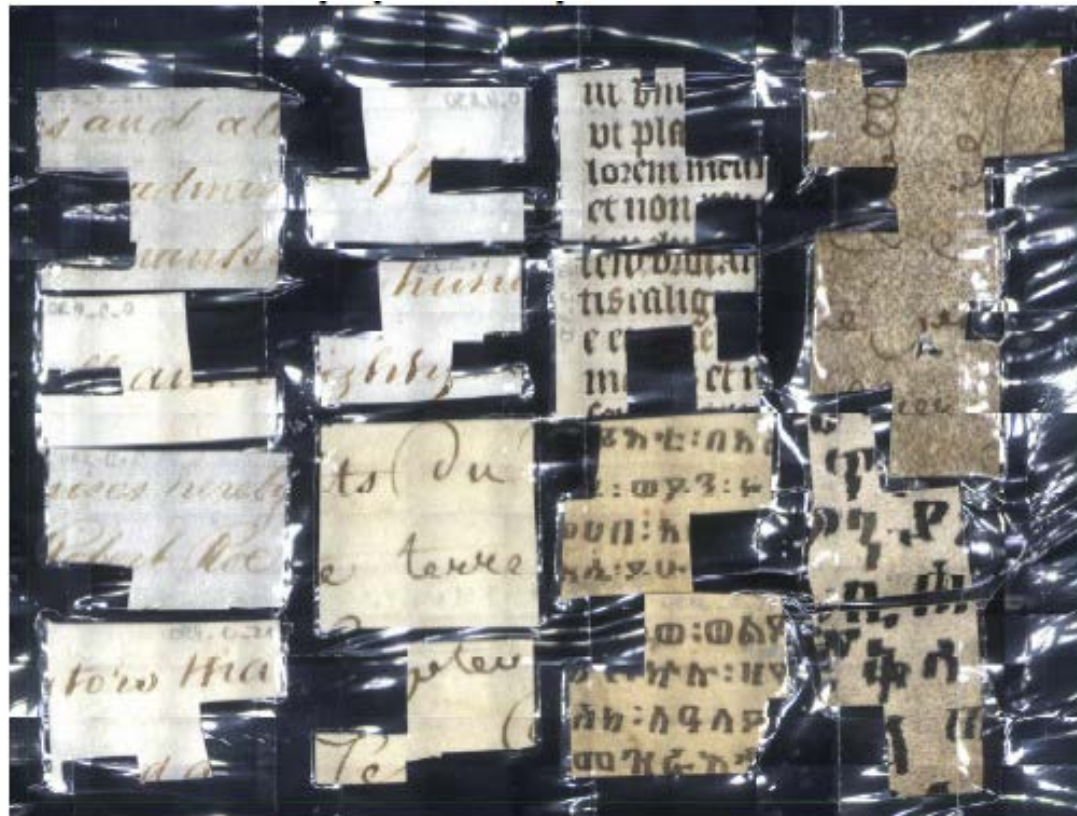
Applications - Forensics

Analysis of banknotes



Applications - Forensics

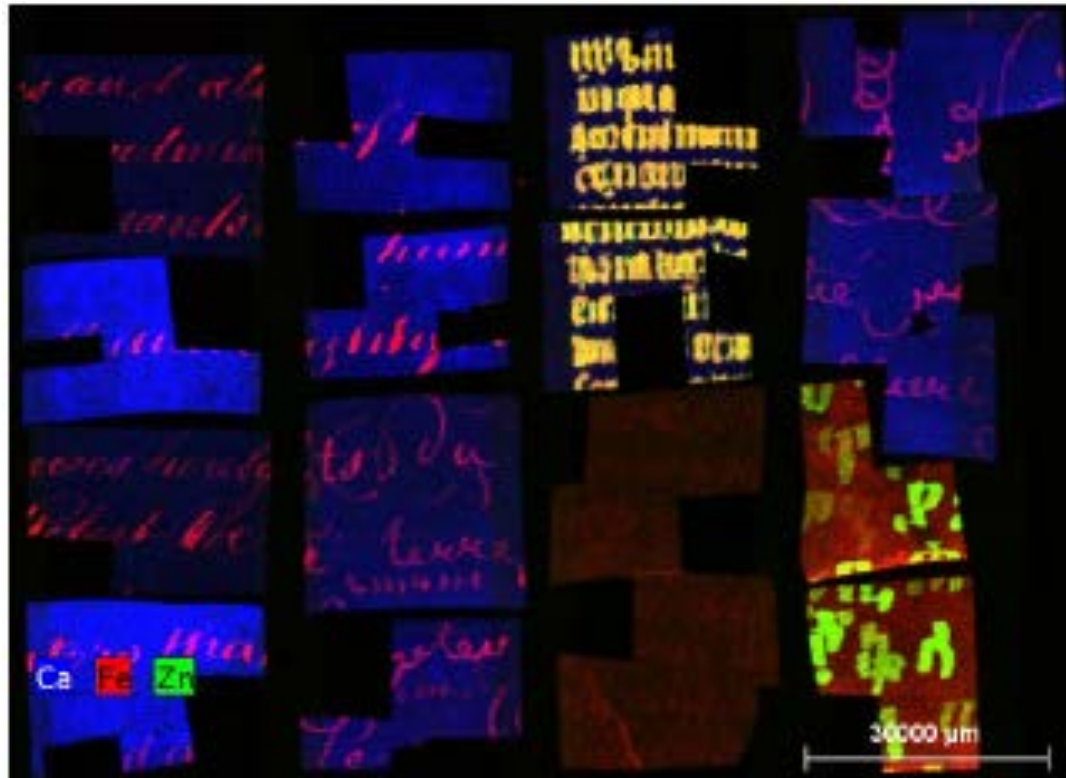
Analysis of ink



Collection of different types of paper and inks were scanned

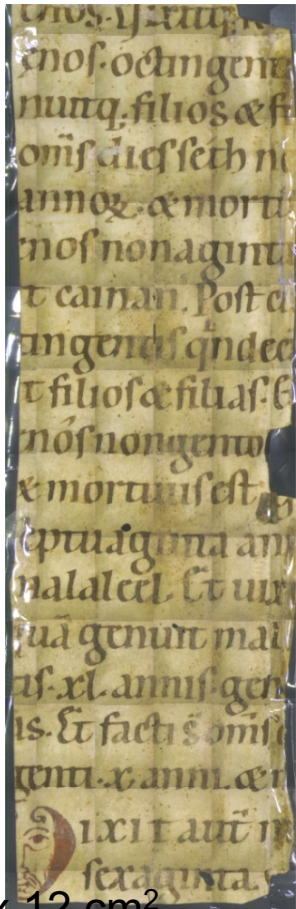
Applications - Forensics

Analysis of inks

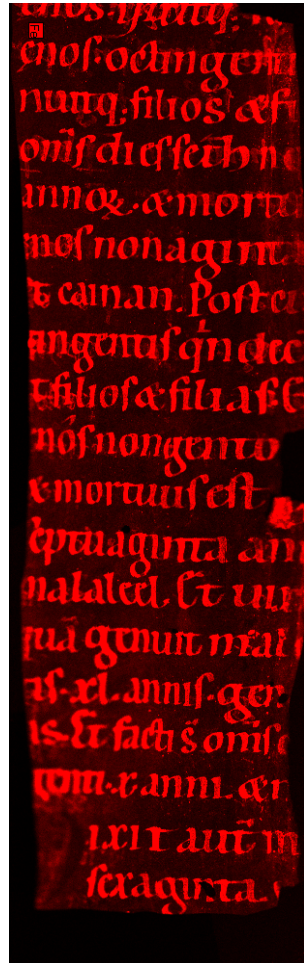


Applications - Archeometry

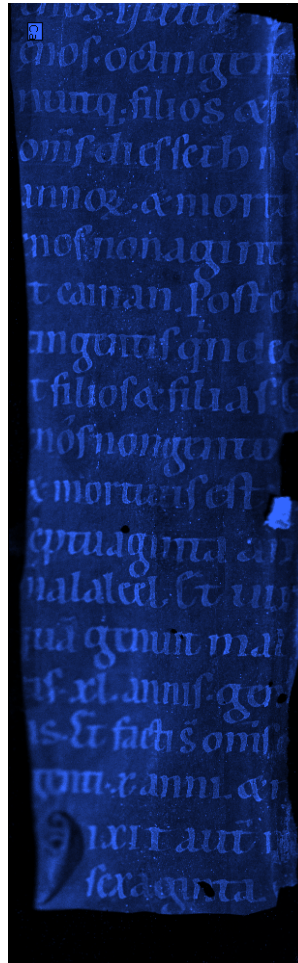
Analysis of historic documents



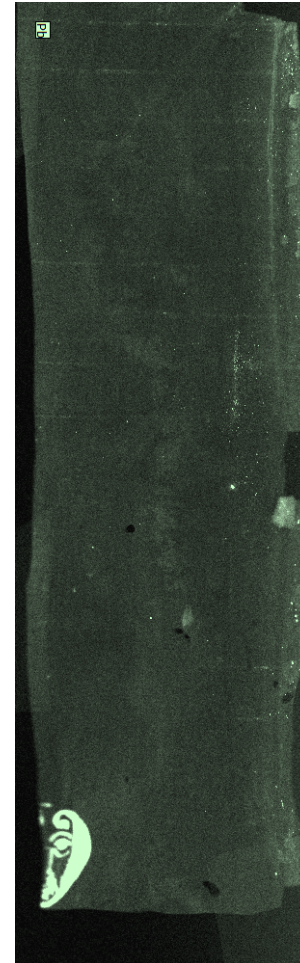
4 x 12 cm²,
300 x 800 Pixel,
100 ms/Pixel



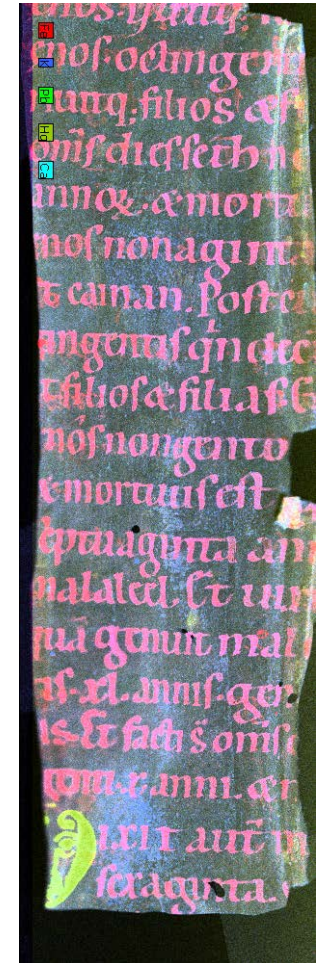
Fe



Ca



Pb



K, Ca, Fe, Hg, Pb

Applications - Archeometry

Analysis of documents - Fe-intensity as 3D profile



Fe-intensity
as 3D profile

Micro XRF - Other applications

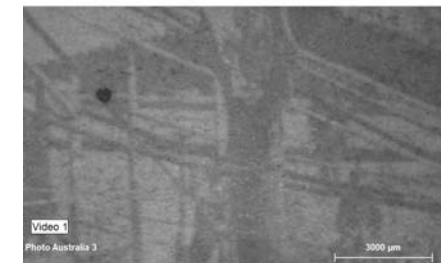
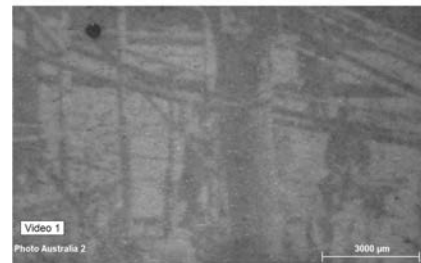
Reconstruction of faded photographs



Photo: 7.5 cm x 7.5 cm

Fade image, details are still recognizable ...

Reconstruction of the picture from the Ag-L intensity



50 µm step size
260 pixel x 160 pixel



25 µm step size
520 pixel x 320 pixel

Other applications

Reconstruction of faded photographs



Photo: 7.5 cm x 7.5 cm

Scan-step size: 22 μm

4 Scans with
1800 pixel x 1800 pixel
13 Mpixel image

Reveal of hidden details

Rembrandt 190.5 x 280.5 cm



This is Rembrandt's first and only corporate group portrait. The *Syndics* stands out for its exceptionally large format and more than life-sized figures. All eyes of the sampling officials – who assessed the quality of dyed cloth – are turned to us and one figure even rises from his chair as if to acknowledge our presence. Because of the low vantage point, the table seems to jut out of the picture.



Rembrandt and/or studio, *The Syndics of the Amsterdam Drapers' Guild*, known as the 'Sampling Officials', 1662, canvas, 190.5 x 280.5 cm, Rijksmuseum NL

Reveal of hidden details
Rembrandt 190.5 x 280.5 cm



Reveal of hidden details
Rembrandt 190.5 x 280.5 cm



Reveal of hidden details
Rembrandt 190.5 x 280.5 cm



Micro-XRF

Conclusion



- Non destructive method which requires minimal to no sample preparation
- Optical microscope and XYZ stage allows precise navigation to area of interest
- Fast mapping down to 1ms/pixel and high spatial resolution of 5000x5000 pixel allows high resolution elemental mapping and line-scans
- Allows distributional analysis (elements and phases)
- Improve detection limits (10x or better) compared to SEM/EDS
- Greater penetration depth than SEM/EDS
- Vacuum or air analysis, allowing liquids to be analyzed