Bruker

Webinar: XRF - Mining for Money

Bruker Webinar
XRF: Mining for Money

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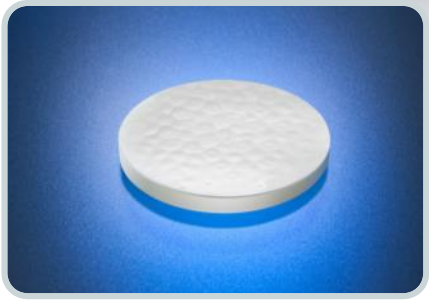


XRF: Mining for Money
Analytical Tasks in Mining Operations

- Exploration
  - Classification of mineral resources
- Process Control
  - Mining and Mine Planning
  - Mining Operations
  - Mineral Beneficiation
  - Grade Control
- Shipping
  - Grade verification along the supply chain
- Metal-Making
  - Process optimization
  - Final product control

XRF: Mining for Money
Why measure chemical composition?

Element concentrations are vital information in mining operations:

- **Exploration**
  - Value of resource is determined by total amount of elements of interest: Fe, Cu, Au, …
  - Hazardous elements will decrease commercial value
  - Distribution and other elements present will determine cost of mineral beneficiation
- **Mine operation**
  - Mine output is based on separation of high grades, low grades and waste
  - Process control will enable optimization steps to increase mine output and decrease production costs
- **Shipping**
  - Grade control and knowledge of penalty elements (P, Si in Fe ore)
  - Agreement between seller, buyer and involved contract labs will ease payment
- **Metal Production**
  - Accurate element concentrations will enable efficient production (dosing of coke in steelmaking)

XRF: Mining for Money
Chemical Analysis

- Qualitative and quantitative determinations of compounds or elements
- Elemental analysis is a process where a sample of some material (e.g., soil, drill cores, ores, tails, concentrates, raw and intermediate products) is analyzed for its elemental composition.
  - Organics - C-H-O, usually done by combustion
  - Inorganics - Beryllium (Be) to uranium (U) range
    Also referred to as “metals” analysis by different methods

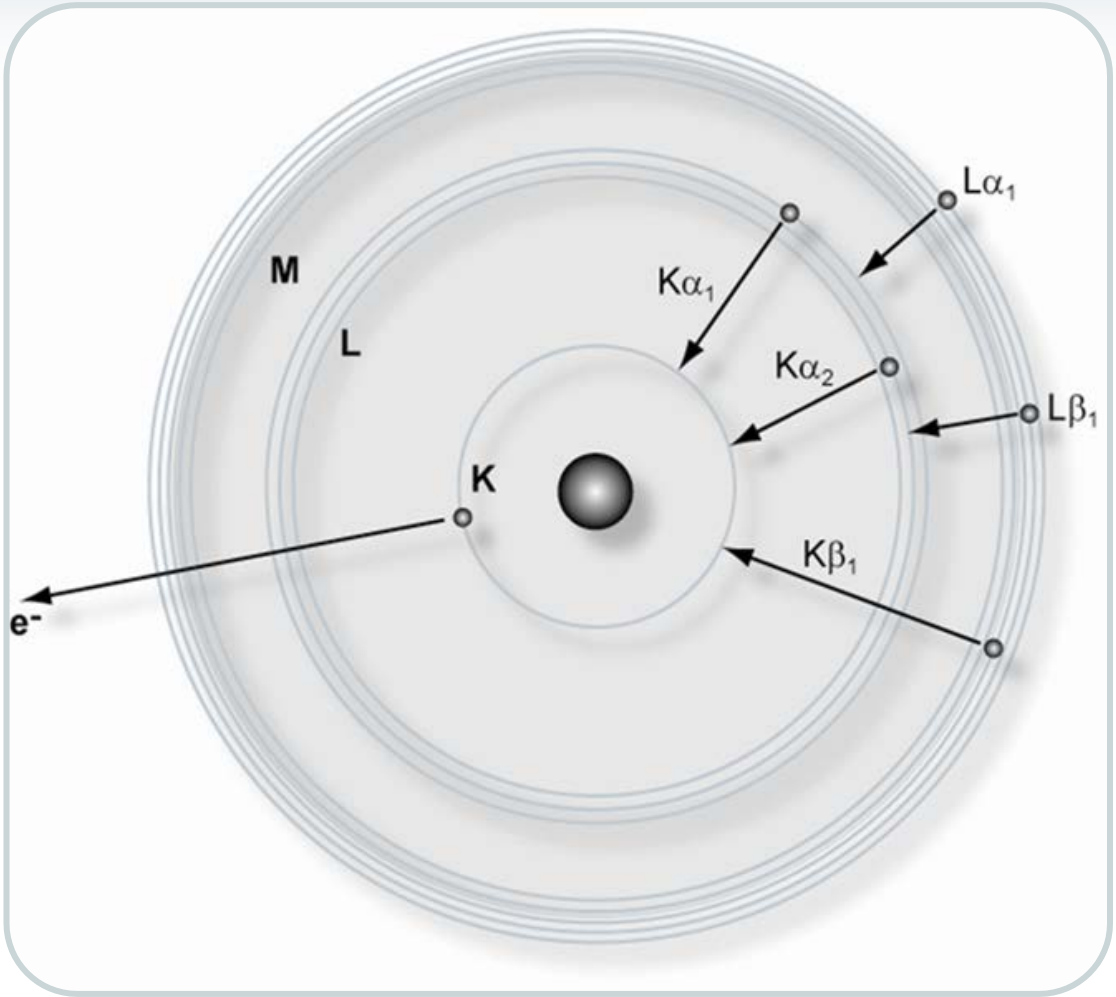
  - Each analytical method has based on its physical principle specific requirements and associated costs
  - It will deliver specific performance depending on the lab environment, skill of operators
    - Even under optimal circumstances there is a physical limit

MINING FOR MONEY – By selecting the best available method with the lowest total cost of operation will support excellence in mine operation and contribute financially

XRF: Mining for Money
Methods for elemental analysis

- Inorganic elemental analysis can be accomplished by a number of methods, including:
  - Optical spectroscopy
    - probes the outer electronic structure of atoms
    - Flame atomic absorption
    - Graphite furnace atomic absorption
    - Optical emission
  - X-ray fluorescence spectroscopy
    - probes the inner electronic structure of atoms

Origin of Characteristic X-rays
Inner Shell Electron Transitions

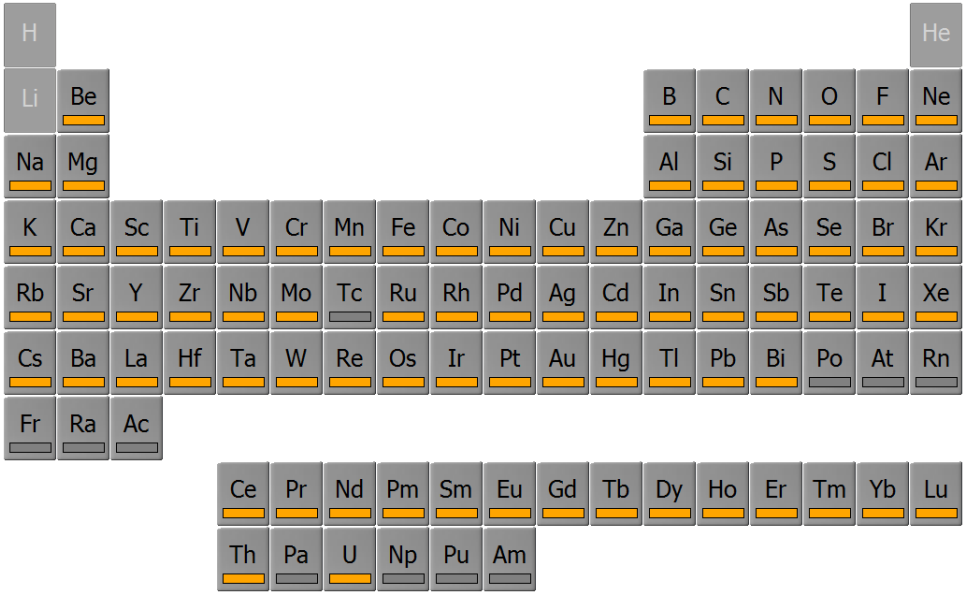


- An electron is expelled from an inner shell of its atom.
- An electron from a shell farther out falls into the vacancy.
- The energy difference is emitted as an X-ray photon with **a discrete wavelength characteristic of the emitting element.**
- These transitions are instantaneous (10^{-12} s).

X-ray Fluorescence Analysis (XRF)
Definition

X-ray fluorescence analysis (XRF) or X-ray spectrometry

- A method to do qualitative and quantitative analysis of the elemental composition by excitation of atoms and detection of their characteristic X-rays



- Elemental range
  - (Be) B to U
- Concentration range
  - ppm - 100 %

X-ray Fluorescence Analysis (XRF)
Capabilities

Samples measured as

- Liquids
  - directly
- Powders
  - directly
  - As pressed pellets
  - As fused beads
- Bulks
  - directly, after fitting into sample cups

Elemental Analysis Using Electromagnetic Radiation: Light

- Absorption of light (infrared/visible/ultraviolet)
  - AAS - Atomic Absorption Spectrometry
- Emission of light (infrared/visible/ultraviolet)
  - OES - Optical Emission Spectrometry
    - OES-Spark: metals
    - ICP-OES: dissolved/liquid samples
- Transitions of electrons between outer shells of the atom
- Energy of photons = energy of chemical bonding
- Usable spectra only for “free” atoms or ions
- Sample has to be evaporated

Elemental Analysis Using Electromagnetic Radiation: X-rays

- Emission of characteristic X-rays
  - XRF - X-ray Fluorescence Analysis
- Transitions of electrons between inner shells of the atom
- Energy of photons > energy of chemical binding
- Energy of characteristic X-rays independent of chemical binding
- Solid and liquid samples can be measured directly
- Non-destructive (for the sample)
- Only mechanical sample preparation or fusing



Comparison of Spectroscopic Techniques

Technique	Precision	Range	Sample Preparation	Materials	Cost
XRF	0.1%	PPM to 100%	5 to 15 min.	Inorganics	$35K to $200K
AAS ICP	3%	PPB to PPM	Need solutions – hrs to days	Inorganics	$35K to $200K
OES-Spark	1%	PPM to 5%	If conductive – easy	Inorganics	$35K to $200K
NMR	Qualitative	Organic – Imaging	Easy	Organics	$50K to $1M
NIR & FTIR	Qualitative	Organic – Functional	Easy	Organics	$35K to $100K

What Method to Use?

- The method used needs to be fit for purpose
- Select according to requirements for:
  - Accuracy
  - Precision
  - Cost of analysis
  - Speed of analysis
  - Regulatory purpose
  - Operator compatibility
  - Flexibility
  - Infrastructure needs
  - Cost of ownership

On your own!
Advantages of XRF

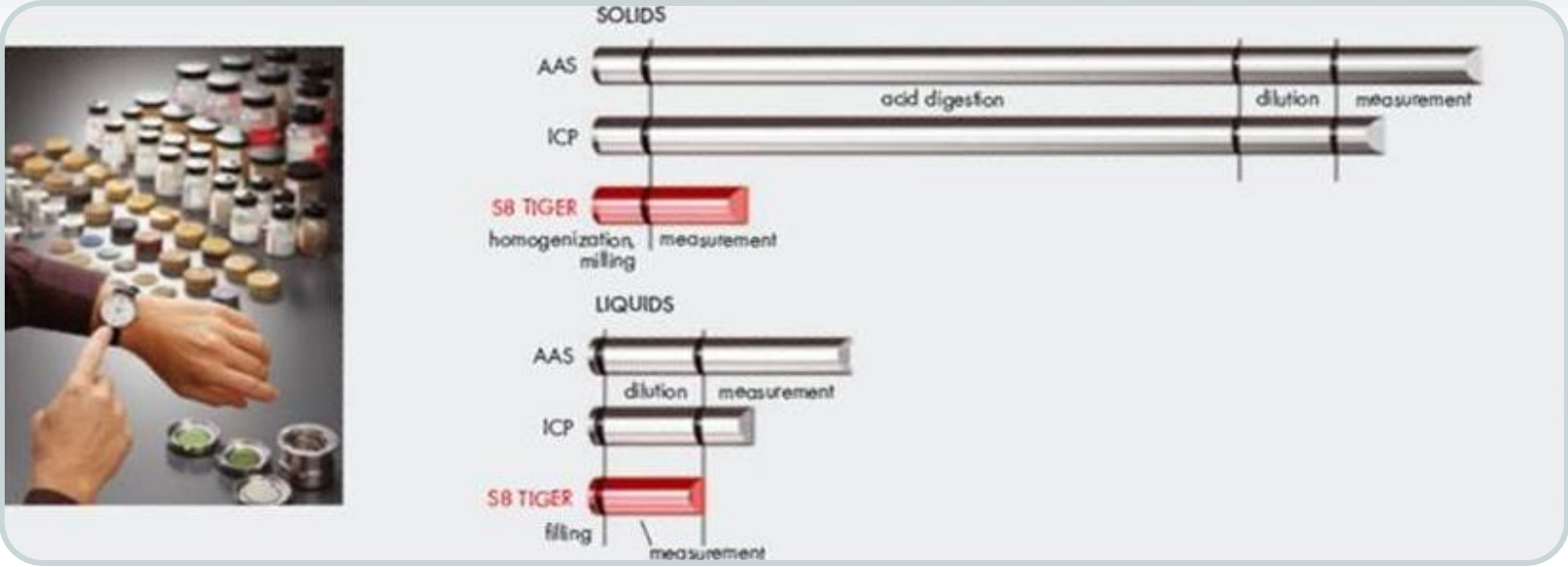
- Inherently non-destructive
- Simple and fast sample preparation
- Qualitative, semi-quantitative and quantitative analysis
- X-ray spectra are less complex than optical:
  - Typically 2 -3 lines versus 100s or 1000s of lines for ICP and AAS
- Environmentally clean and safe method
- Better precision
- Lab standardization
- Shorter learning curve
- Shorter analysis time
- Low analysis cost
- Standardless analysis

How XRF Solves Day-to-Day Industrial Challenges

The instrumentation for an analytical task must meet many different criteria:

- Time to result
- Instrument setup and calibration
- Cost of ownership
- Easy, fast sample preparation
- Safe investment for future applications
- Fit for purpose
- Experience and skill of laboratory employees
- Analytical performance

On your own!
Time to Result



Effective quality and process control requires the shortest time-to-result possible. This is the time needed from sampling to the final quantitative result. Any advantage results in:

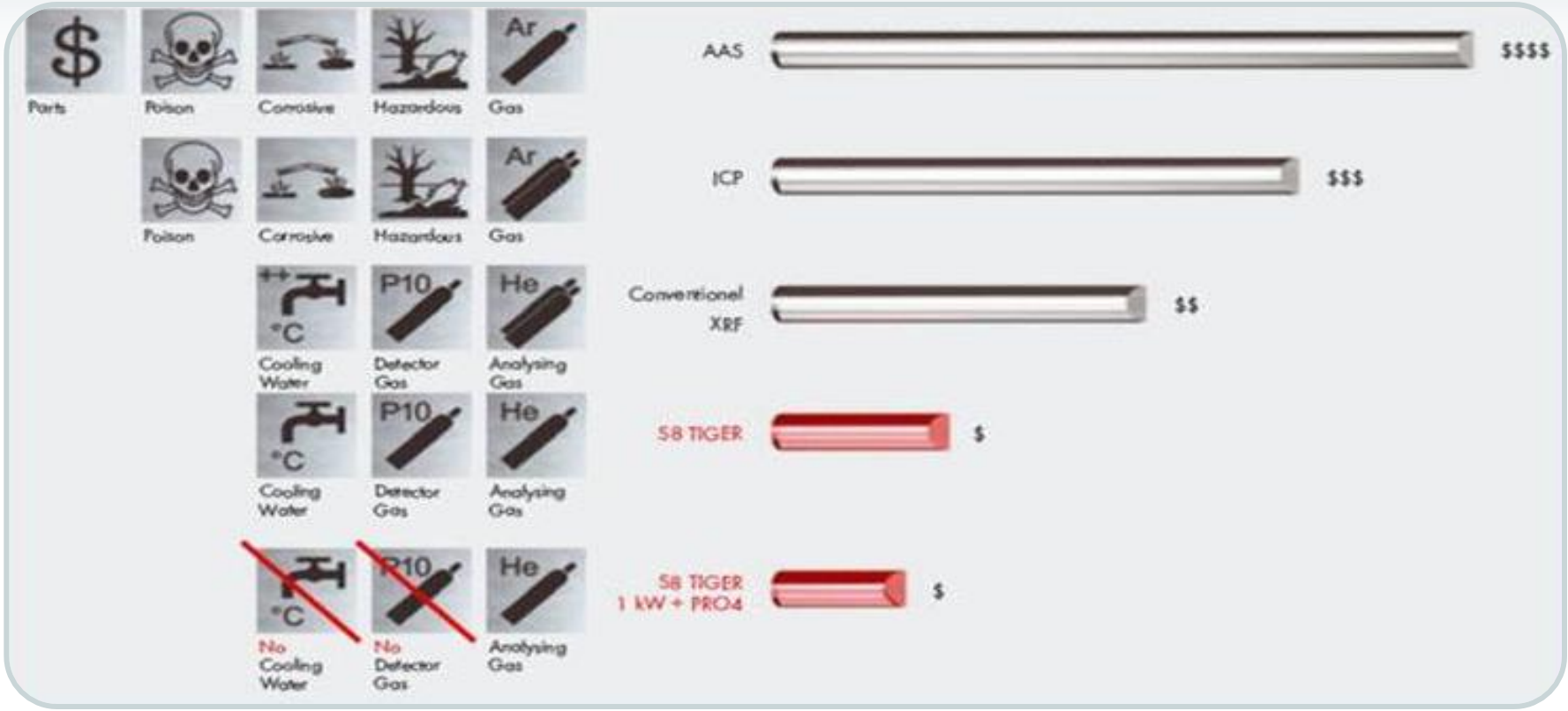
- Higher sample throughput
- Stable industrial processes due to immediate feedback
- Constant high product quality

Instrument Setup and Calibration
Daily Worktime

XRF minimizes instrument setup and calibration time. A simple one-time calibration based on your own standards is sufficient. After calibration, a stable drift correction sample is measured.

Modern XRF instrumentation, like the S8 TIGER, provide ready-made solutions (GEO-QUANT BASIC, ADVANCED and GEO-QUANT IRON ORE) and powerful tools for standardless analysis (QUANT EXPRESS).

A True Comparison of the Real
Cost of Ownership



The investment for the analytical instrument is only one part of the total cost of ownership. Expenses for laboratory equipment and consumables add to that cost. For example:

- Use of expensive accessories (AAS: graphite tubes)
- Consumption of noble gases (ICP: Argon)
- Need for hazardous chemicals (compliance with high-level safety regulations)
- Complicated sample preparation equipment (training and time)

Advantage XRF
Cost per sample

- Typical market prices for whole rock analysis at external labs:
  - By ICP ~ 60 USD*
  - By XRF ~ 40 USD*

- Typical cost per sample w/o labour:
  - ICP-OES ~ 40 USD*
  - ICP-MS ~ 30 USD*
    - plus sample preparation: acids, waste disposal, safety infrastructure, ...
  - XRF ~ 10 USD*

Comparison for a mid-size lab p.a.:

- ICP: Ar supply ~10.000 USD*
- XRF: usage for tubes ~ 4.000 USD*

*These are typical values and strongly depends on individual circumstances: local cost of goods, number of samples, model, working structure, infrastructure – sources can be found on the internet

Advantage XRF
Cost per sample

XRF

- Provides faster turn-around times due to little sample preparation
- Achieves savings on lab infrastructure compared to wet chem labs and lower costs for waste disposal
- Enables higher productivity due to shorter instrument warm-up times, no daily calibrations
- reduces cost for labor due to ease of use

- works typically in the ppm to 100 % range --> comparable for most elements to ICP methods
  - ppb values often only achieved for undiluted water

S8 TIGER Series 2
How a modern WDXRF supports mine operations!

- WDXRF spectrometer S8 TIGER Series 2, introduced in May 2017:
  - Analytical Speed (Time-to-result)
  - Precision
  - Accuracy

  Designed for highest count rates!

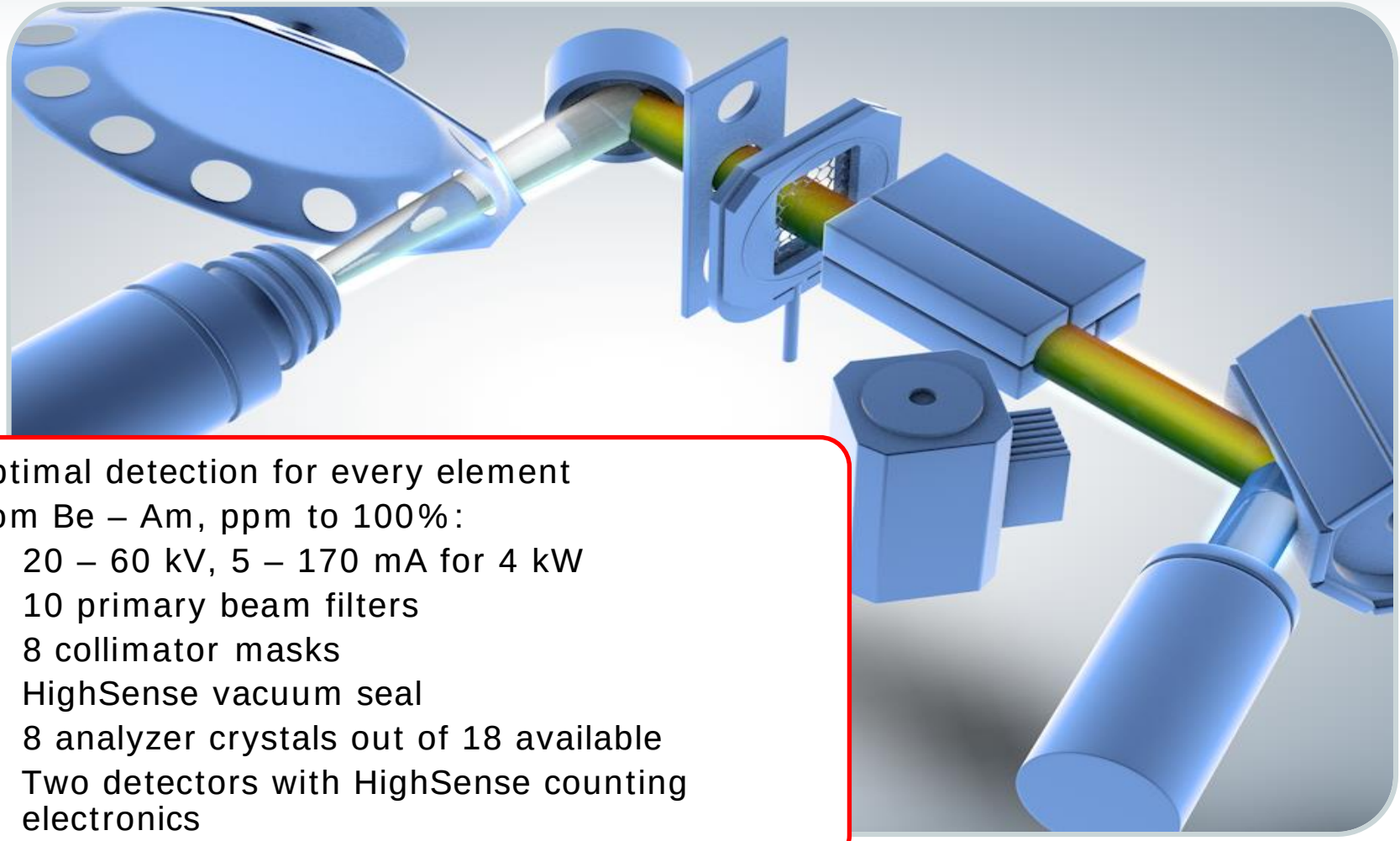
  Why are count rates so important?

  XRF precision is mainly determined by the instrument:

  Sample positioning, goiniometer drives, HV generator!

  and the counting statistical error

The All-New S8 TIGER Series 2 HighSense



Optimal detection for every element
from Be – Am, ppm to 100%:

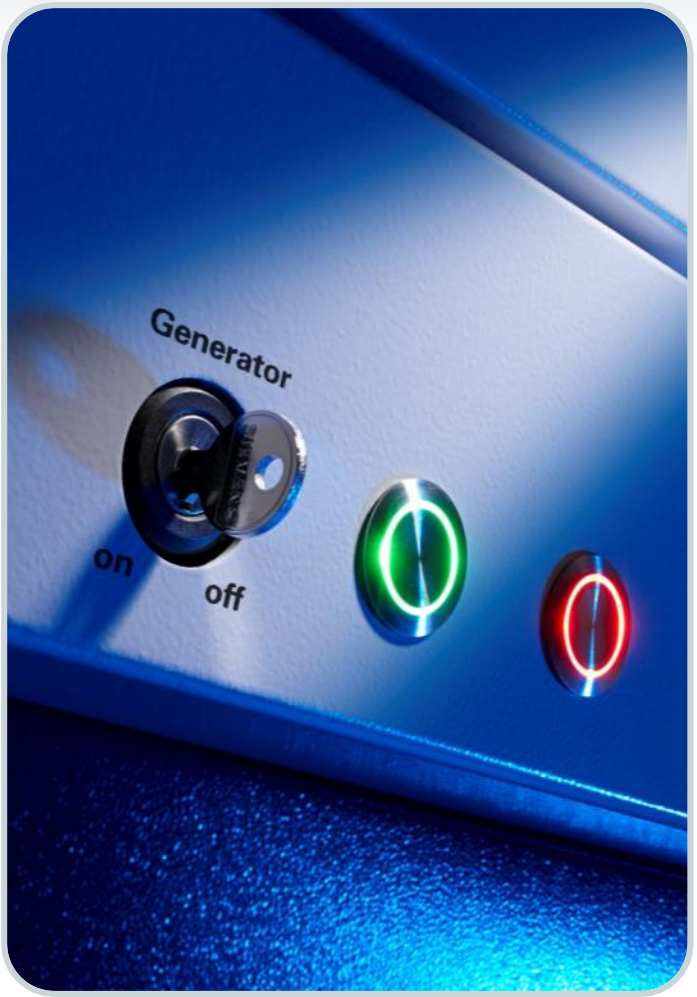
- 20 – 60 kV, 5 – 170 mA for 4 kW
- 10 primary beam filters
- 8 collimator masks
- HighSense vacuum seal
- 8 analyzer crystals out of 18 available
- Two detectors with HighSense counting electronics

The All-New S8 TIGER Series 2 HighSense: HV Generator

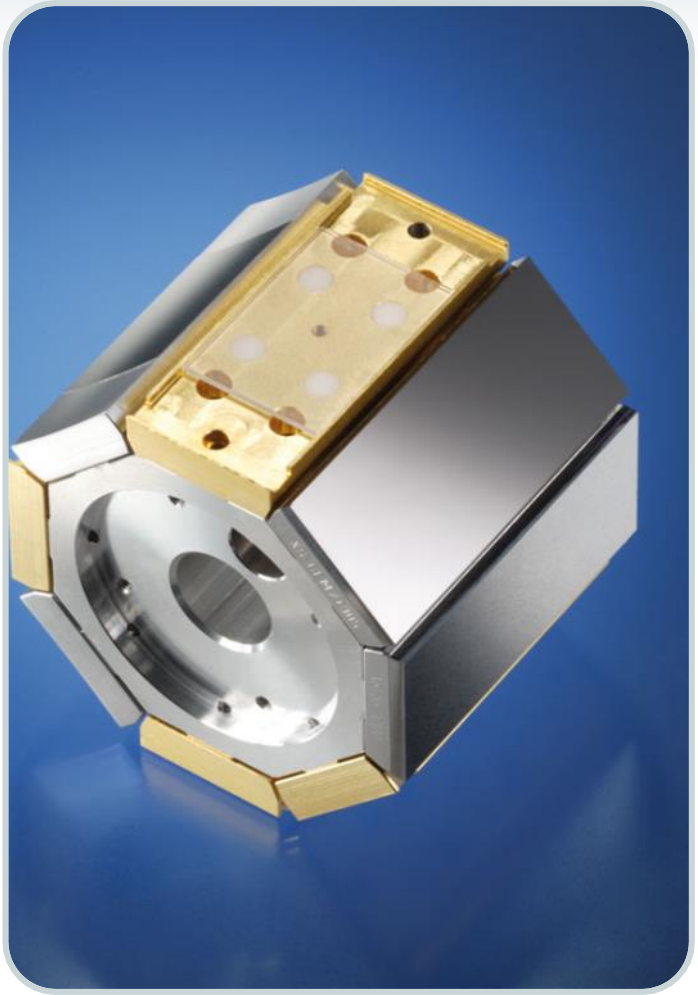
The **HighSense HV - generator** provides excellent:

- Analytical precision due to unrivalled output stability < +/- 0.00005
- Analytical flexibility with progressive instant voltage and current adjustment
- Closer control process and product quality
- Reduces user interactions on measurements due to DynaMatch, instant adjustment of current to element

- **Up to 170 mA** at full power,
  - Reduces background by more than 20% for better detection of light elements



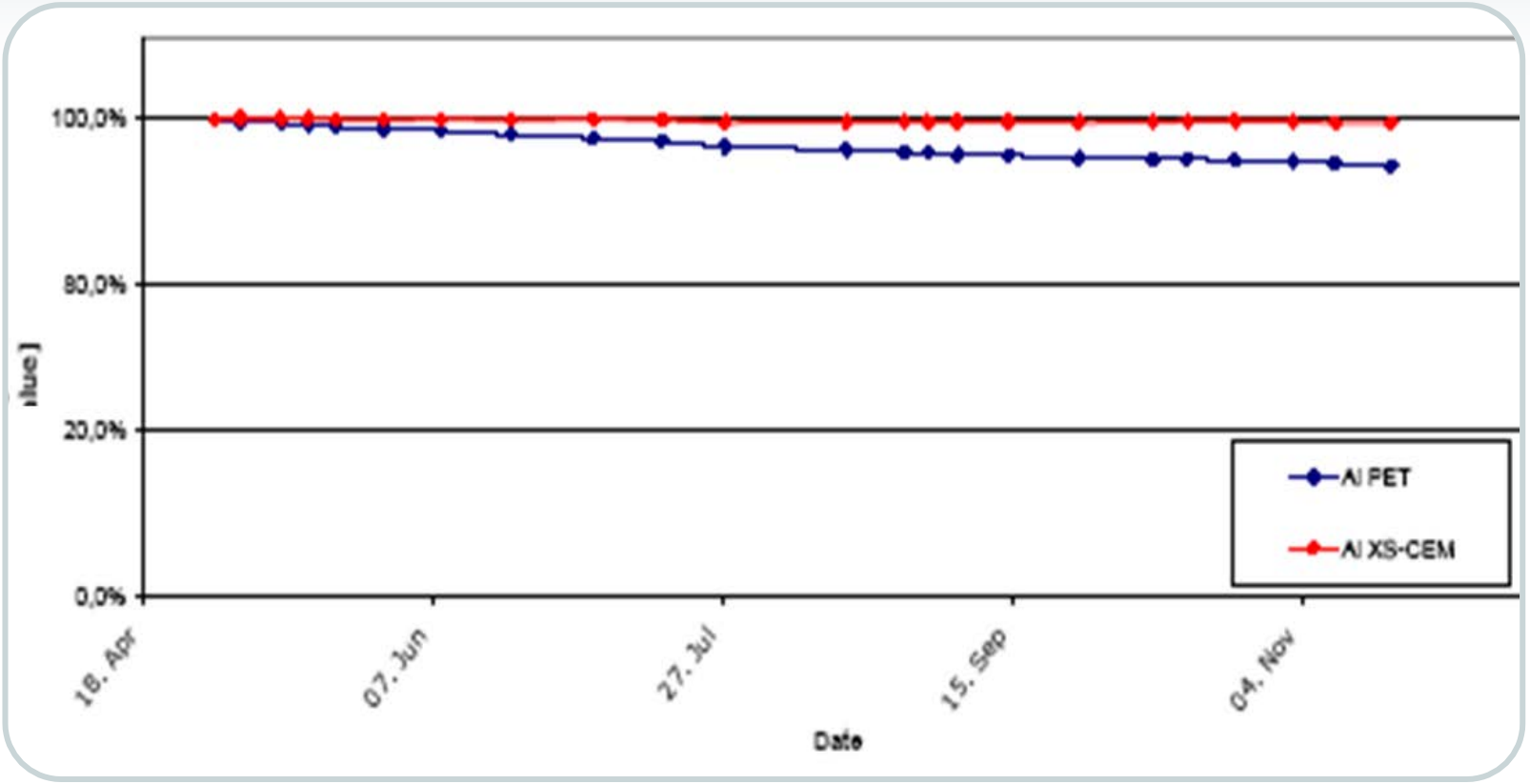
S8 TIGER
Analyser Crystals: XS-CEM



- Best long-term stability for the elements from Al – S
- No aging like organic crystals (PET)
- No long warm up periods

- Recommended for demanding applications of Al and Si : accurate, stable and precise
- Ideal for all applications in Cement, Minerals, Glass

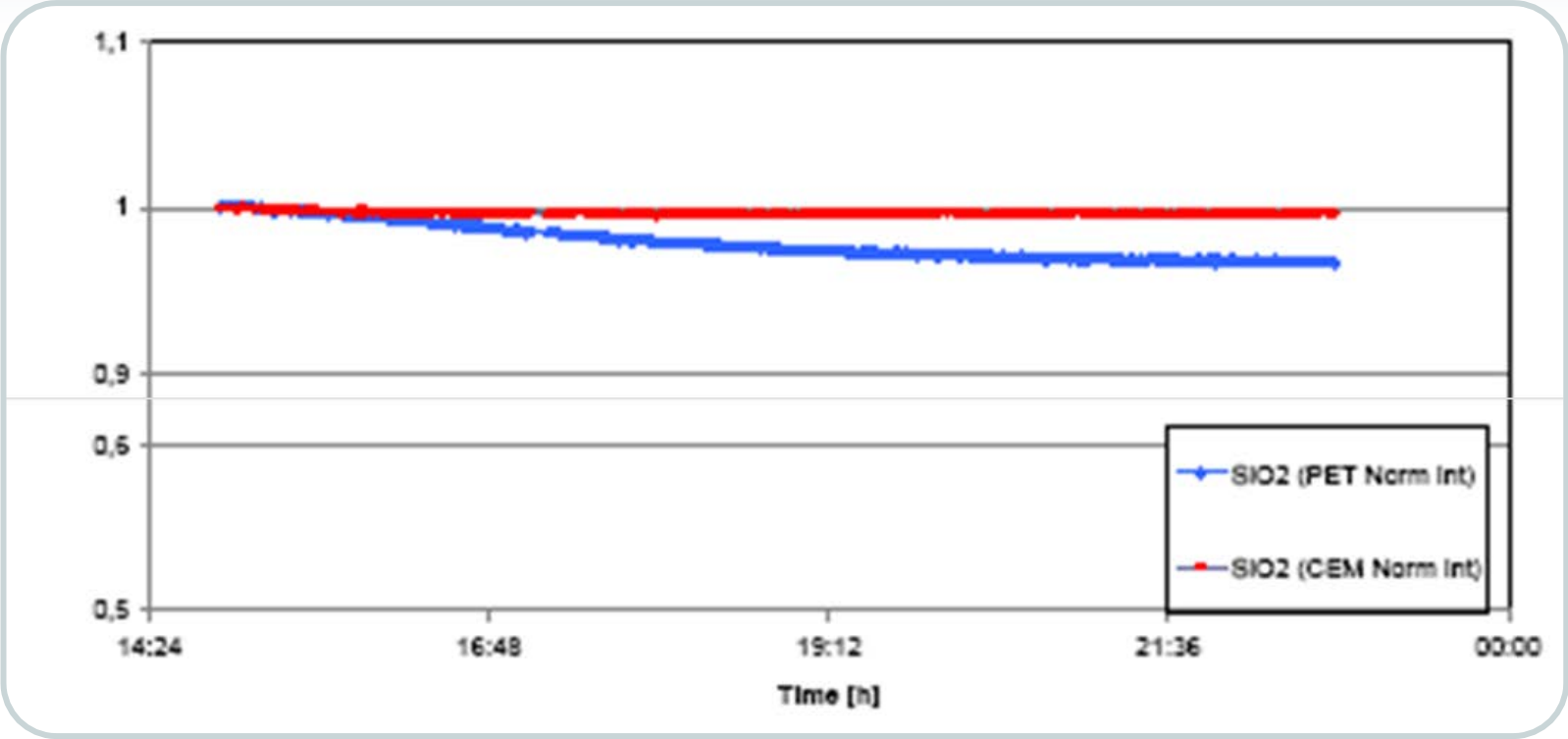
Analyzer Crystal: XS-CEM
Temperature independent



Temperature influence:

PET vs. XS-CEM under worst conditions: No climatisation, cold instrument after startup. The PET is stable after more than 5 h. The XS-CEM works immediately

Analyzer Crystals: XS-CEM
Long term stability: Practice at Kerneos



Long term stability:

XS-CEM vs PET: More than half a year no loss on intensity on the XS-CEM crystal

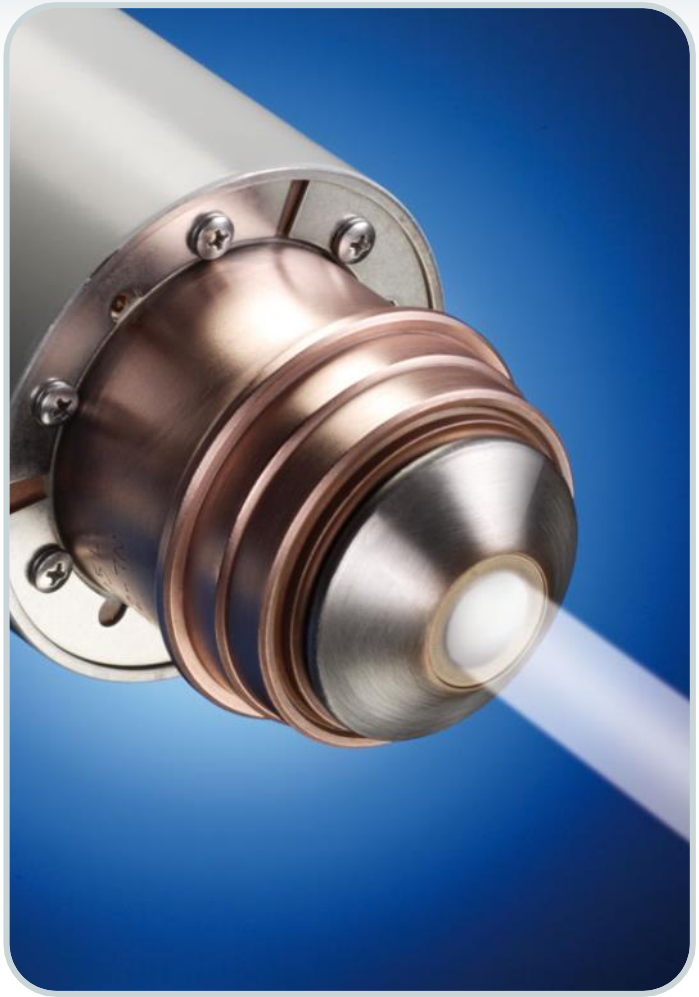
XRF: X-ray Fluorescence Analysis
Precision and Counting Statistics

Precision limited by counting statistical error

$$\Delta c / c = \text{SQRT}(N) / N = 1 / \text{SQRT}(N)$$

N =	100	SQRT (N) =	10	3*SQRT(N) / N =	30	%
N =	1000	SQRT (N) =	30	3*SQRT(N) / N =	10	%
N =	10 000	SQRT (N) =	100	3*SQRT(N) / N =	3	%
N =	100 000	SQRT (N) =	300	3*SQRT(N) / N =	1	%
N =	1000 000	SQRT (N) =	1000	3*SQRT(N) / N =	0.3	%
N =	10 000 000	SQRT (N) =	3000	3*SQRT(N) / N =	0.1	%

The All-New S8 TIGER Series 2
HighSense: X-ray tube



- **High Intensity X-ray tube**
  - Up to 4 kW
  - 75 µm tube window
- **HighSense X-ray tube 50 µm**
  - Up to 4 kW
  - 50 µm tube window
  - SampleCare protective coating
  - More than 15% plus for Be – Cl
- **HighSense X-ray tube 28 µm**
  - Up to 4 kW
  - 28 µm tube window
  - SampleCare protective coating
  - Plus 50% more intensity for ultra-light elements **B, C, N, F**
  - Plus 35% more intensity for light elements **Na - Cl**

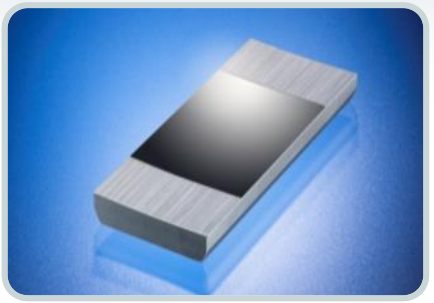
The All-New S8 TIGER Series 2
HighSense: Analyzer Crystals

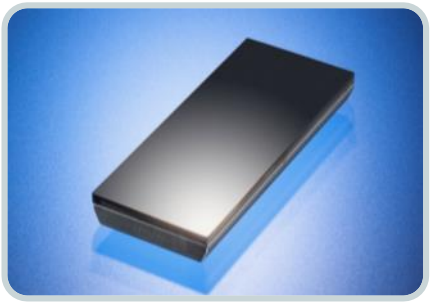
8 position crystal changer

- More than 18 different crystals available:

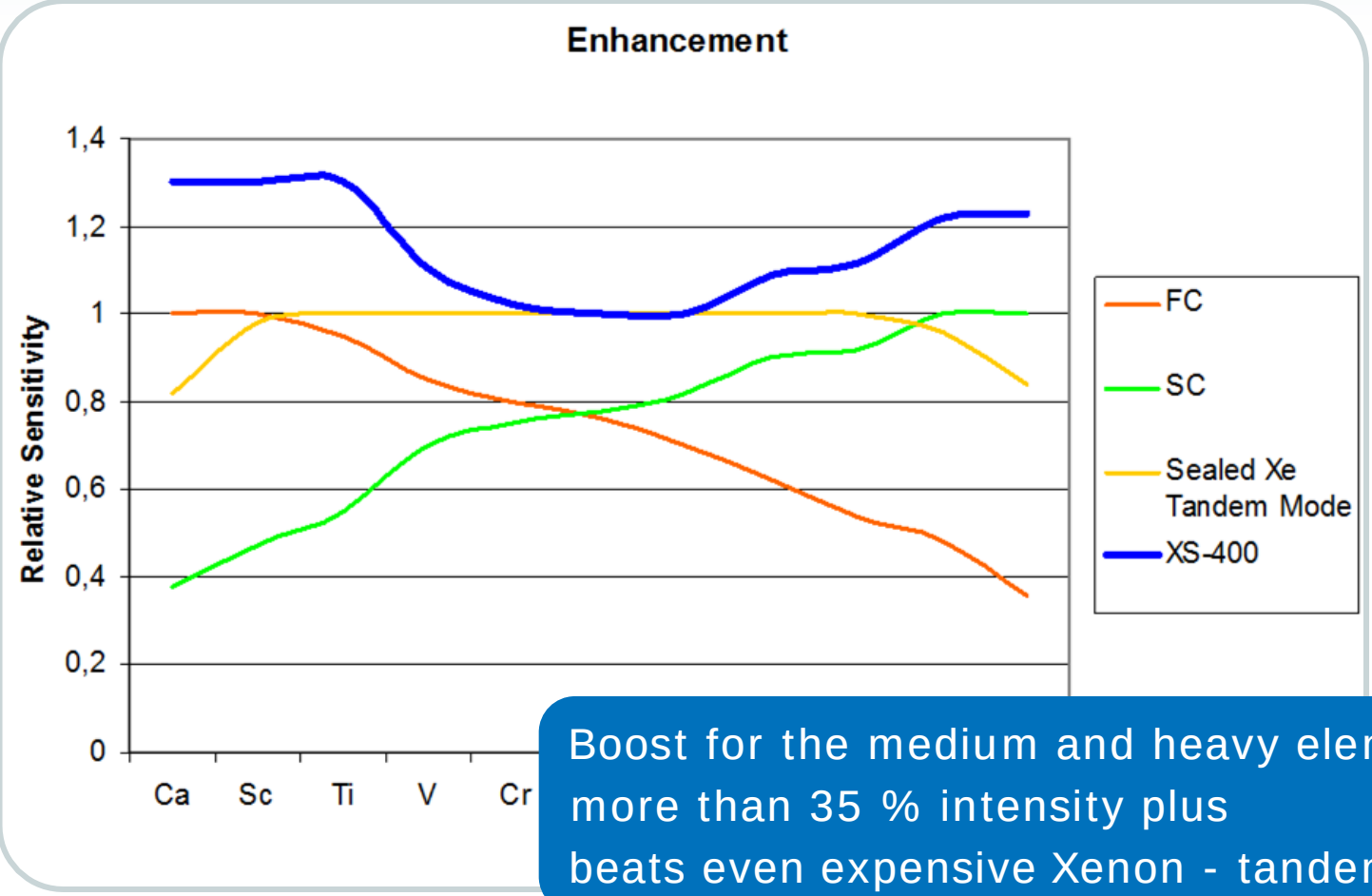
optimized **HighSense** crystals:

- XS-CEM: long-term stable, temperature independent
- XS-GE-C: plus 40% intensity for P, plus 20% intensity for S
- XS-PET-C: plus 20 % intensity for Al
- XS-B: plus 100% intensity for B
- XS-N-HS: plus 100% intensity for N
- XS-C: 30% reduced background for C
- XS-100 time optimized measurement
- 25% time savings
- XS-400 plus 35 % more intensity in the range of K to U





S8 TIGER
Competitive Advantage: XS-400



Boost for the medium and heavy element range,
more than 35 % intensity plus
beats even expensive Xenon - tandem detectors

The all-new S8 TIGER Series 2
HighSense: Counting Electronics

- **HighSense counting electronics**
  - Quick application setup with instant display of PHA scan
  - On-the-fly dead time correction with fast data processing
  - Advanced MCA technology
  - Up to 4 Mcps for both detectors
- Excellent detector linearity
  - FC: up to 2 Mio cps
  - SC: up to 2 Mio cps
  - DynaMatch: up to 13 Mio cps
  - Five times better than conventional WDX spectrometers
- Better analytical precision
- Faster measurements
- Easy application setup due to wide range calibration

The All-New S8 TIGER Series 2 HighSense: Counting Electronics

With the new features of S8 TIGER Series 2 our WDXRF will become the most competitive product in the market

- **Metals and Mining**
  - HighSense counting electronics with highest linear range enables
    - shorter measurement times in critical process control applications (steel, copper)
    - ISO 9516 compliant for iron ore applications
    - Easy setup due to wide range calibrations

WDXRF - Better No Turret Performance Test

Test	C.O.V. (actual)	Max. C.O.V. allowed	Alternate State		
				C.O.V. (actual)	Max. C.O.V. allowed
Stability	0.0307	0.0405			
Mounting & Loading	0.0245	0.0468			
Angular	0.0207	0.0468			
Collimator coarse	0.0360	0.0468	Collimator fine	0.0387	0.0476
Detector Scinti	0.0411	0.0468	Detector Flow	0.0277	0.0472
Crystal	0.0405	0.0468			
Beam Filter	0.0432	0.0468			
Mask	0.0378	0.0468	28mm	0.0303	0.0470
KV/mA	0.0357	0.0468	30 KV 135mA	0.0282	0.0457

High analytical precision:

- Sample mounting and loading through direct positioning
- High precision positioning with mechanical geared goniometer
- Quick and precise change and adjustment of X-ray excitation parameters

XRF: Mining for Money
Analytical Tasks in Mining Operations

- Exploration
  - Classification of mineral resources
  - The valuable elements are often not homogenously distributed, but enriched in special zones, bound in or to special minerals
  - This makes the mapping analysis of rocks so important to decide
    - Value of the minerals resource
    - Decision on later mineral beneficiation
    - e.g. decide for rock sorting, leaching or flotation
  - The bulk analysis might be similar in terms of concentration per ton, but in case of homogenous distribution the mine operation might become costly

S8 TIGER Series 2
Instrumental Setup for Precision

- Hardware enhancers for precision
  - Temperature and aging independend multilayer optcis for short and longterm stability
  - High precision generator for precise photon emission from X-ray tube
  - Direct loading for optimal precise sample positioning w/o drives
  - HighSense X-ray tube for constant photon emission
- Hardware booster for precision
  - HighSense X-ray tubes for additional excitation
  - Analyzer crystals for additional sensitivity (XS-400)
  - HighSense counting electronics for countrates up to 4 Mcps, 2 Mcps linear

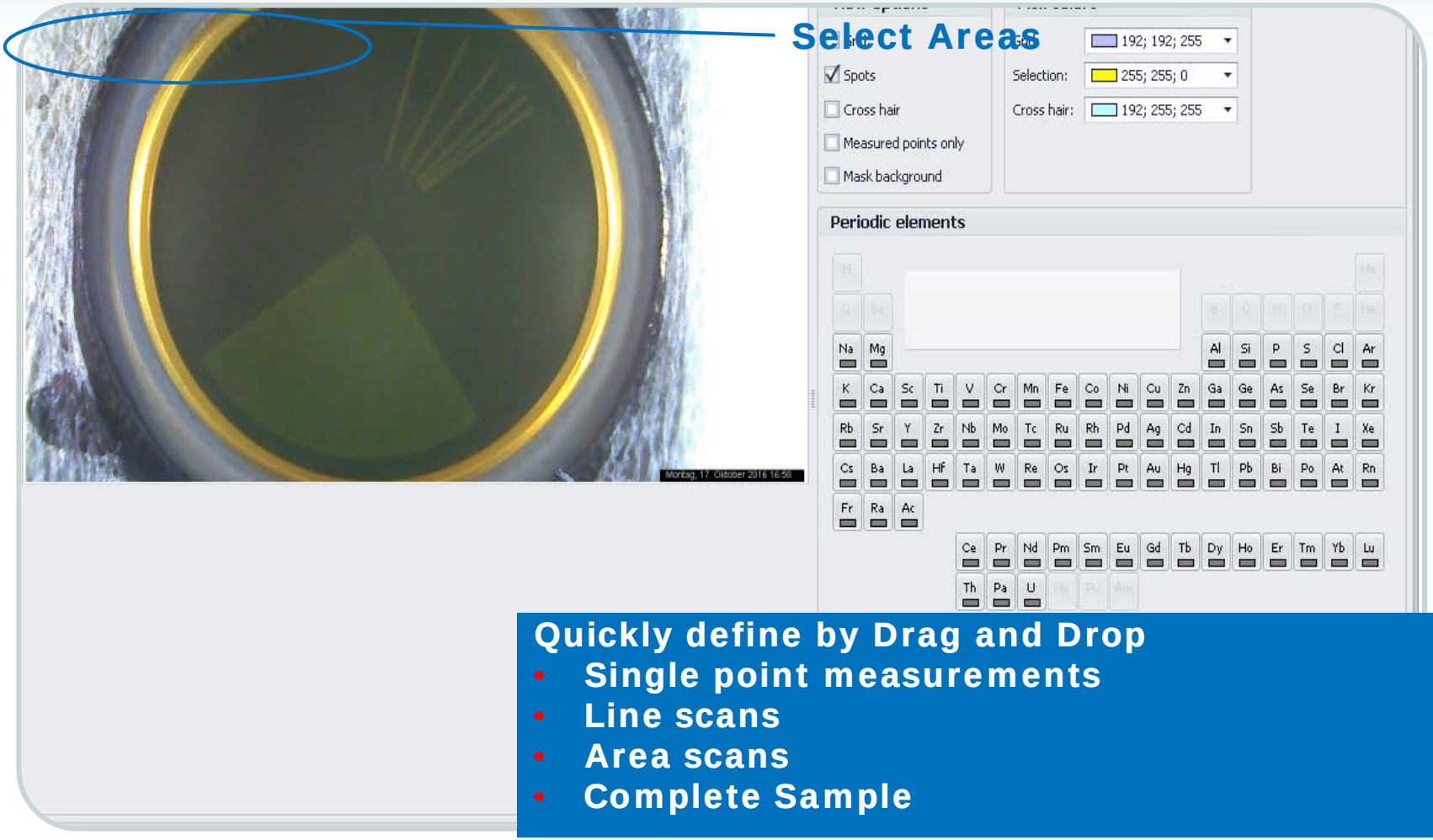
The All-New S8 TIGER Series 2 XRF²

XRF² on S8 TIGER Series 2 with HighSense beam path:

- 60 position loader incl 5 mapping positions
- HD camera station
- Bruker SW with mapping and reporting client
- Smallest mask size: **300 µm**
- Step size: **100 µm**

- Highest sensitivity with HighSense beam path and beam guide technology
  1. Shortest measurement times in WDXRF
  2. Best LLD‘s
  3. Best precision
  4. Smallest spot size
  5. Quick and easy application setup

The All-New S8 TIGER Series 2
XRF²

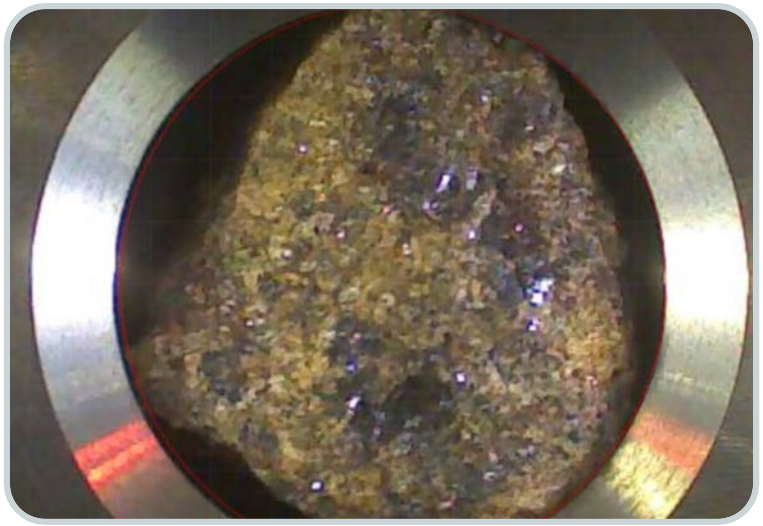


The All-New S8 TIGER Series 2 XRF^2 – Mining

- Coltan is known as conflict mineral, since the valuable resources in DRC have financed warlords and lengthen the civil war in Africa
  - New resources are explored
  - Being independend from China
  - Safe supply chain for future production of electronics (mobiles)
  - Nb and Ta, but also other elements are of interest

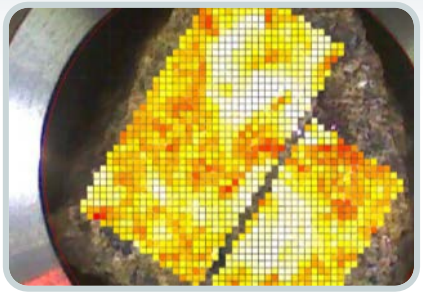
The All-New S8 TIGER Series 2
XRF² - Small spot analysis and mapping

- Element distribution in minerals
  - Ca containing limestone as host rock
  - Fe inclusions
  - Ta widely distributed in the rocks in smaller granules

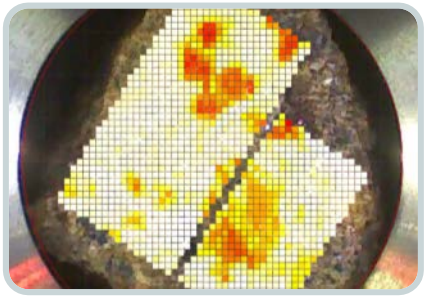


Coltan
Canada

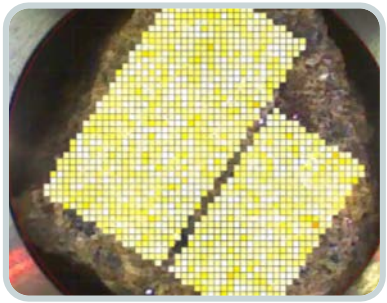
CaO



Fe



Ta



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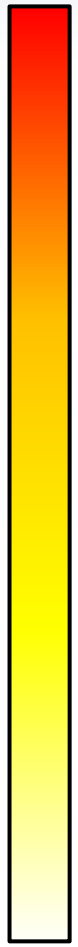

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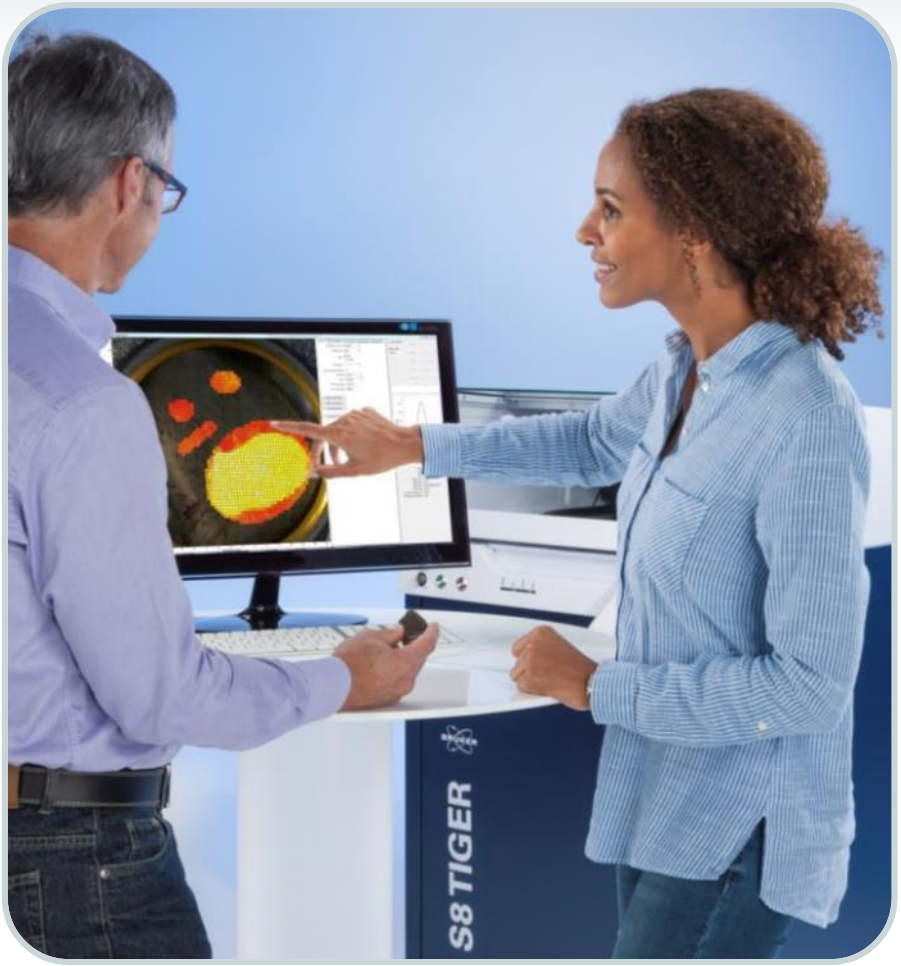
The All-New S8 TIGER Series 2
XRF²

- **Smallest mask size**
  - **0.3 mm** mask for high resolution mapping
  - **Highest sensitivity** with HighSense beam path and beam guide technology
  - **10 times higher** sensitivity than conventional WDXRF
  - Outperforming EDXRF based systems w/o optics at light and heavy elements plus resolution
- Small spots for single particles
- Area scans for full mapping

- This extra tool can save millions of dollars investing in worthless mining land!



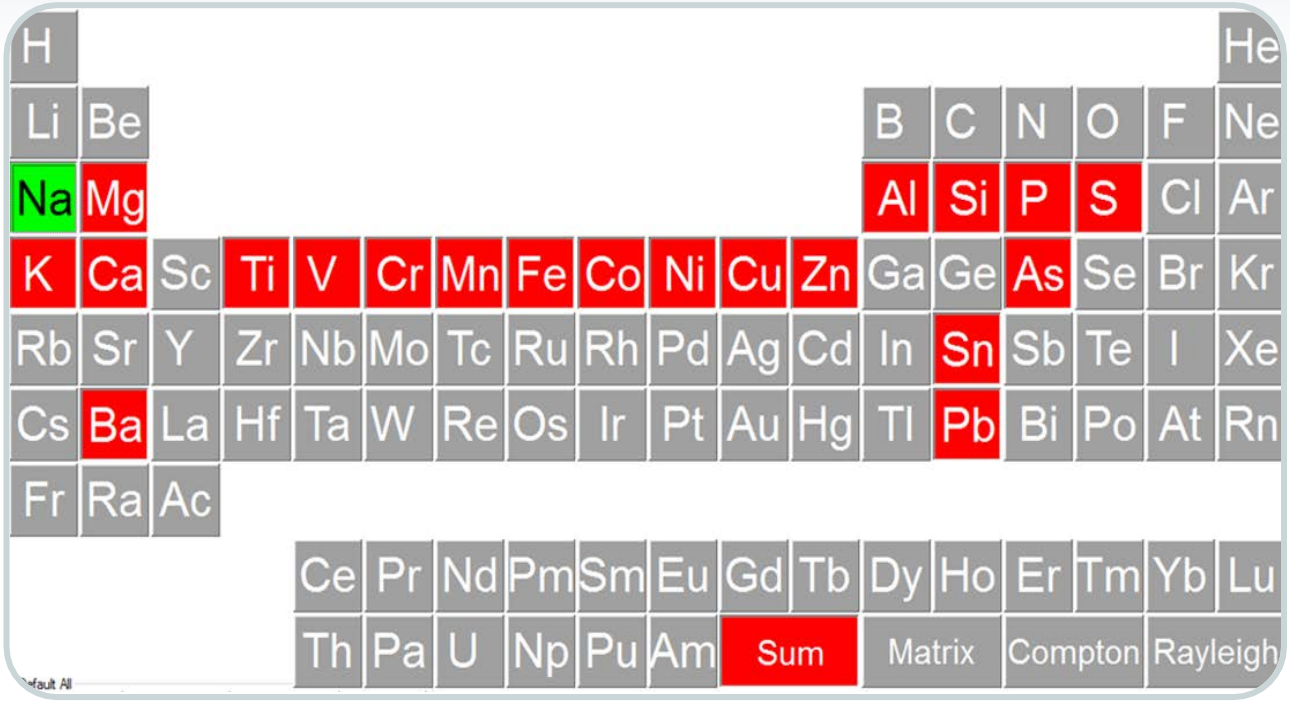
Analytical Excellence with S8 TIGER Series 2

Industry Solutions

GEO-QUANT Iron Ore
Norm-Compliant Analysis of Iron Ore

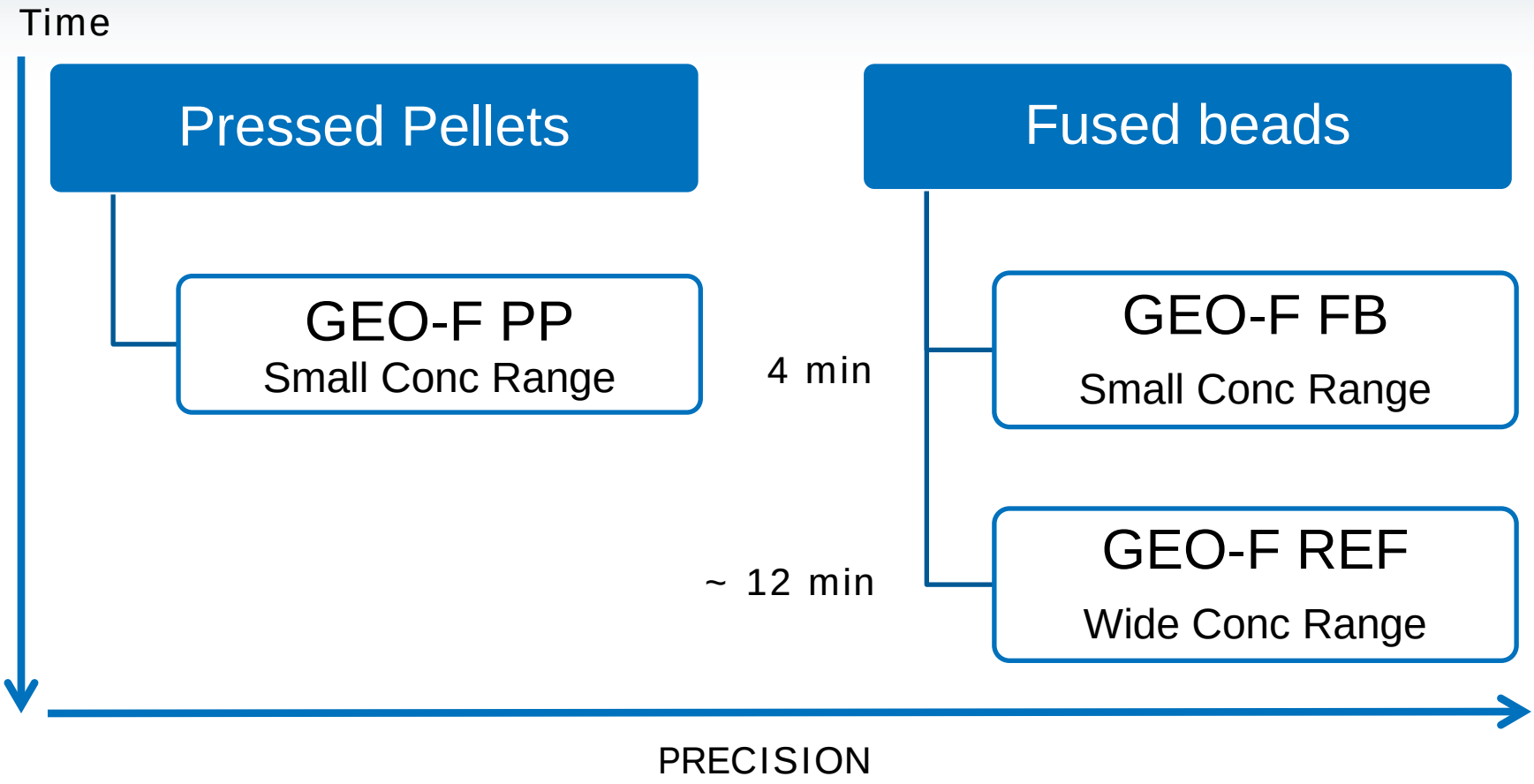
- The solution package for iron ore analysis (Grade control and process control
- Including methods for pressed pellets in process control applications
- Including methods for fused beads for grade control
- Recipes for all common fusion equipment vendors
- Norm compliant to ISO 9516
- Based on
  - variable alphas
  - loss eliminated alphas (alternatively acc. to ISO 9516)

GEO-QUANT Iron Ore
Norm-Compliant Analysis of Iron Ore



21 elements, including Na
(not required for ISO 9516)

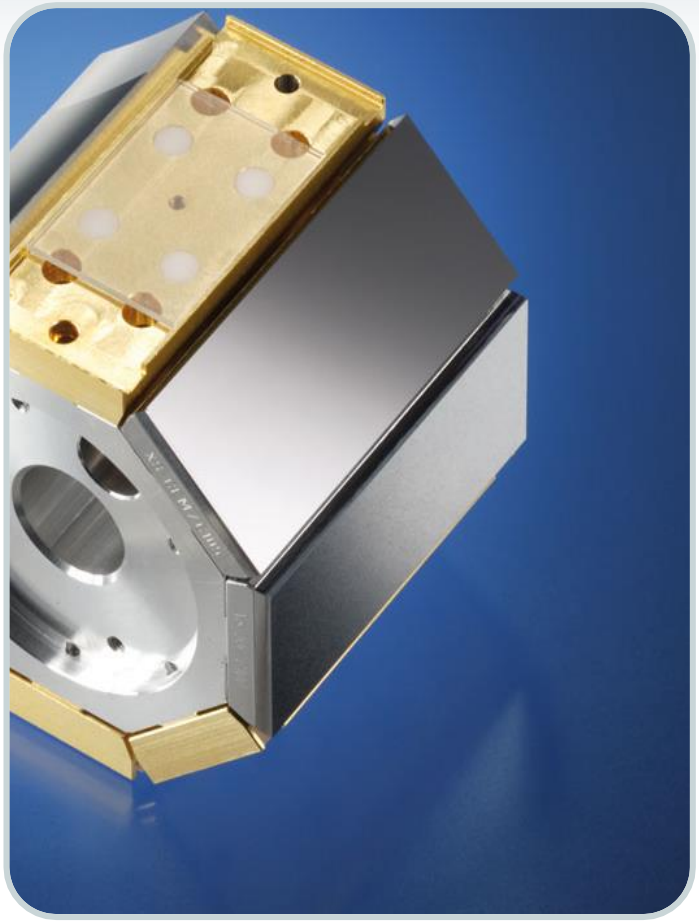
GEO-QUANT Iron Ore Measurement Strategy



GEO-QUANT Iron Ore Hardware

- GEO-QUANT Iron Ore contains
  - 14 reference materials
  - Evaluation samples
  - Drift correction samples
  - User Manual
  - Preparation Manual
- GEO-QUANT Iron Ore works best with
  - LIF 220 crystals
  - XS-100 crystal

GEO-QUANT Iron Ore XS-100



The XS-100 is a synthetic multilayer:

- covers the elemental range from F to Cl
- increased sensitivity compared to the XS-CEM
- enhanced long term stability compared to the PET
- Stable, independent from temperature changes

- Advantages:
  - Time optimzed measurement from F to Cl in one run without crystal change
  - Sample throughput and analyzing speed
  - Shared background positions, less background measurements

GEO-QUANT Iron Ore
Application Range – Precision Test

	MIN	MAX	MEAN	ST.DEV	%RSD
Na2O (%)	0.096	0.096	0.096	0.000	0.15%
MgO (%)	38.994	39.213	39.092	0.059	0.15%
Al2O3 (%)	44.673	44.820	44.751	0.041	0.09%
SiO2 (%)	94.534	94.819	94.664	0.090	0.10%
P2O5 (%)	5.217	5.237	5.225	0.005	0.10%
SO3 (%)	38.003	38.153	38.092	0.052	0.14%
K2O (%)	3.634	3.651	3.640	0.006	0.16%
CaO (%)	6.271	6.299	6.289	0.008	0.12%
TiO2 (%)	14.782	14.856	14.832	0.026	0.17%
V2O5 (%)	5.449	5.483	5.466	0.011	0.20%
Cr2O3 (%)	5.097	5.126	5.112	0.009	0.17%
Mn3O4 (%)	5.205	5.225	5.211	0.007	0.13%
Fe2O3 (%)	92.561	92.844	92.668	0.092	0.10%
CoO (%)	4.283	4.293	4.290	0.003	0.07%
NiO (%)	1.492	1.496	1.494	0.001	0.08%
CuO (%)	1.989	1.995	1.992	0.002	0.10%
ZnO (%)	3.574	3.587	3.578	0.004	0.11%
As2O3 (%)	1.415	1.420	1.417	0.002	0.13%
SnO2 (%)	2.014	2.035	2.023	0.007	0.32%
BaO (%)	5.105	5.152	5.129	0.018	0.35%
PbO (%)	4.338	4.361	4.351	0.007	0.17%

- Covers the ISO 9516 application range
- Includes low grade materials
- Precision in the 0.1% range
- Enables close monitoring of material grades and defines commercial value

GEO-QUANT Iron Ore Accuracy

	MIN	MAX	MEAN	CERT	ST.DEV
Na2O (%)	0.073	0.074	0.073	0.860	0.000
MgO (%)	1.736	1.759	1.747	1.625	0.007
Al2O3 (%)	2.209	2.230	2.220	2.240	0.006
SiO2 (%)	11.498	11.572	11.541	11.900	0.026
P2O5 (%)	0.215	0.234	0.223	0.162	0.006
K2O (%)	0.626	0.631	0.628	0.557	0.002
CaO (%)	1.523	1.540	1.531	1.655	0.005
TiO2 (%)	0.457	0.465	0.461	0.544	0.003
V2O5 (%)	0.113	0.118	0.115	0.182	0.002
Fe2O3 (%)	81.462	81.899	81.729	81.616	0.138
CoO (%)	0.133	0.1			
NiO (%)	0.074	0.0			
CuO (%)	0.063	0.0			
ZnO (%)	0.008	0.0			

- Accuracy test with CRM NIST 690
- Excellent performance
- Passing ISO 9516

- Precision and accuracy at 0.1% level

- Bulk carriers with 100.000 tons load carrying this high grade ore with 81.616 tons of iron a value of 8,3 Mio USD

0.1 % less precision or accuracy will cost more than 8.000 USD

Iron Ore
Rapid Grade Control

- Rapid control of element concentration
- Quality check
  - at the mining site
  - at shipping stations

Narrow concentration range

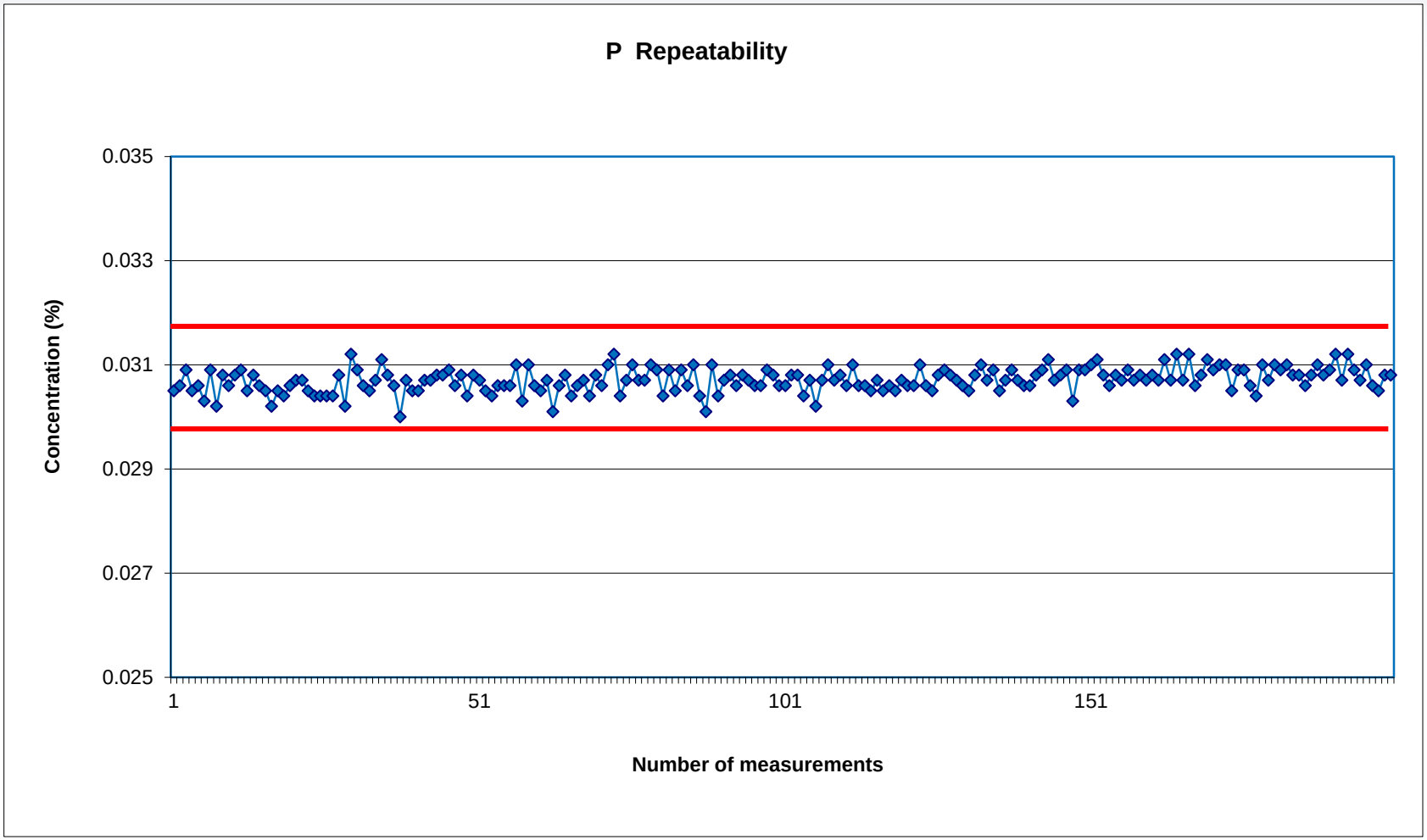
similar matrix allows pressed pellet preparation

- Quickest sample preparation:
- Crushing, Milling, Pressing with cellulose as binder (15 g sample plus 2 g binder)
- Maximum 60 s measurement time

- A quick feedback on production will ensure that no commercially intersted value is lost or energy and water (valuable resources) spent on waste rocks) – in iron ore a value of 63 USD per ton

- A higher preciosn enables better cut-off levels with higher accuracy

SEC: Precision Test on P in one week
200 measurements: 0.031 +/- 0.001



Coke and Coal
Precision at trace level

Lab Report XRF 115

S8 TIGER

Quality control of anode cokes – trace analysis by WDXRF (acc. to ISO 12980, ASTM D 6379 and YS/T 63.16)

Coke and Coal

Grade Control – Ash Concentration

Repro test – S8 TIGER

Sample	Na (ppm)	Mg (ppm)	Al (ppm)	Si (ppm)	P (ppm)	S (%)	Cl (ppm)	K (ppm)	Ca (ppm)	Ti (ppm)	Cr (ppm)	Mn (ppm)	Fe (ppm)	Ni (ppm)	Zn (ppm)	Pb (ppm)	C (%)
B404_F	36	6	43	80	21	0.57	241	13	66	11	9	6	127	3	570	449	99.2577
B404_F	36	5	48	75	21	0.57	244	14	66	10	9	6	127	3	568	449	99.2588
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
B404_F	36	5	45	83	21	0.57	241	14	66	10	9	7	126	3	570	449	99.2595
B404_F	36	5	43	83	21	0.58	243	14	66	10	9	6	128	4	570	451	99.2552
Average	**36.0**	**5.2**	**45.4**	**78.8**	**21.1**	**0.57**	**241.5**	**13.8**	**65.7**	**9.9**	**9.0**	**6.0**	**127.0**	**3.4**	**569.3**	**448.8**	**99.2579**
Std.Dev.	**0.0**	**0.4**	**1.5**	**12.0**	**0.3**	**0.00**	**1.7**	**0.6**	**0.5**	**0.7**	**0.0**	**0.6**	**0.8**	**0.5**	**0.8**	**1.1**	**0.0025**
Rel.Std.Dev.	**0.00**	**7.69**	**3.30**	**15.29**	**1.42**	**0.85**	**0.72**	**4.35**	**0.70**	**7.07**	**0.00**	**10.54**	**0.61**	**14.41**	**0.14**	**0.24**	**0.00**

The S8 TIGER provides very high accuracy paired with ultimate precision, directly analyzed from a pressed pellets within 5 minutes after sample arrival

- Major ash elements in the low ppm range within less than 1 ppm precision
- S and C (as rest to 100%) below 1 % relative
- With a price of actual 95 USD per ton for high grades the XRF analysis enables to exploit the maximum value

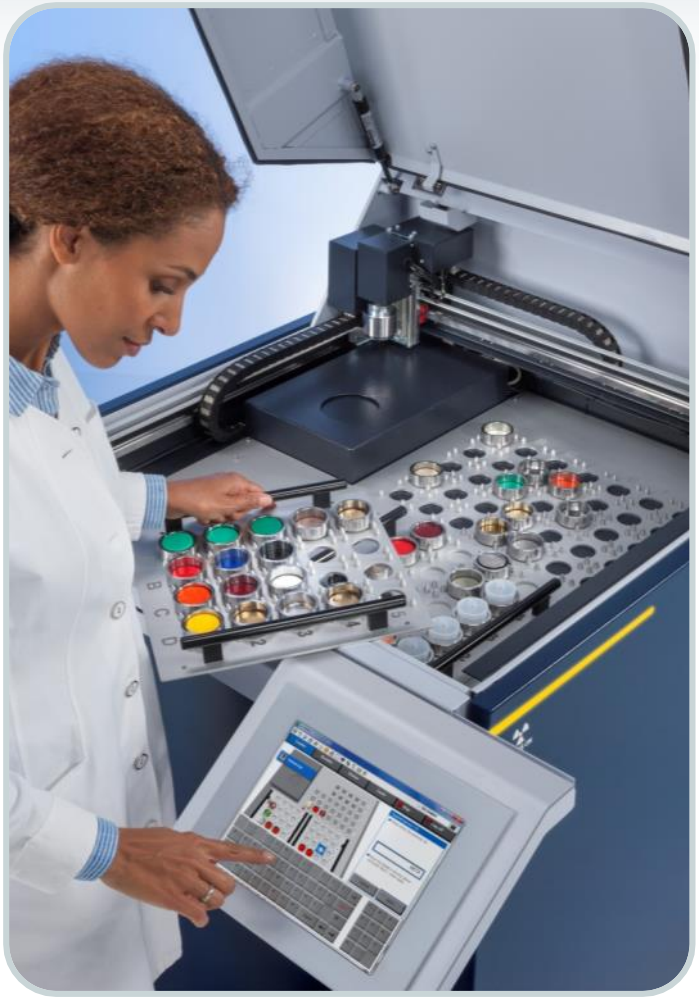
The All-New S8 TIGER Series 2

EZ Ergo

The All-New S8 TIGER Series 2
EZ Ergo: EasyLoad™

- Important criteria for instruments in industrial labs are:
  - Ease-of operation - > failsafe
  - Instrument uptime -> throughput
  - Cost of operation

- Most ergonomic instrument operation in the market:
  - Quick loading of sample with EasyLoad with sample trays
  - 75 Positions sample magazine
  - Easy and safe access of all sample positions due to open design of the magazine
  - Island mode: No pc, keyboard and display required for routine operations with TouchControl



The All-New S8 TIGER Series 2
EZ Ergo: TouchControl™

- Easiest operation due to intuitive touch screen interface: **Three steps to accurate results**
  1. Select sample position and application
  2. Enter sample ID
  3. Press “Measure”
- No operator training required
- Standalone operation in tough environments (no PC): Island Mode
- Unmatched Data Safety: Routine analysis is separated from advanced tasks like calibration, evaluation, and extended reporting
- Online language switch with huge selection

The All-New S8 TIGER Series 2
Evolution in Reliability

S8 TIGER Series 2: Evolution of Reliability and Robustness

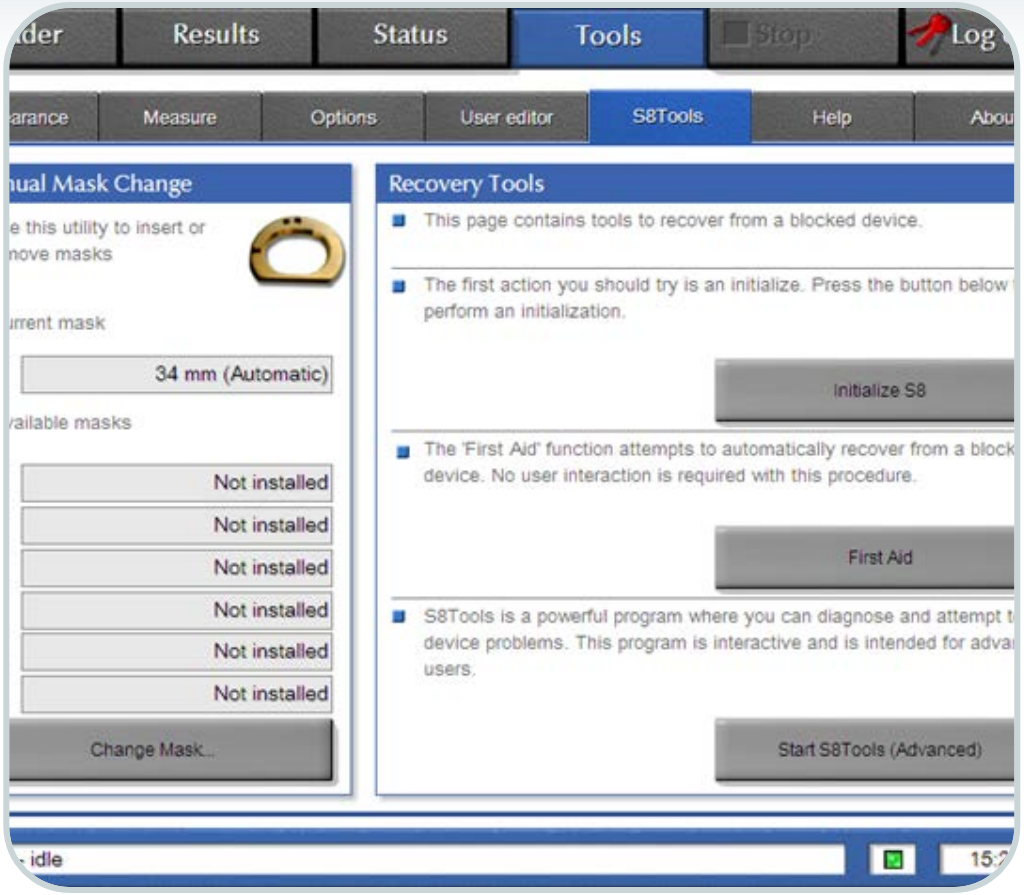
- Based on proven S8 TIGER Series 1 technology
- Major technology upgrades to state-of-the-art to enhance instrument uptime

- S8 Tools software with constant monitoring of more than 1200 parameters
  - Quick system setup
  - Automatic system recovery
  - Service tags
  - Extended service remote functionality
  - Remote access
  - FIRST AID button for system recovery

The All-New S8 TIGER Series 2
Robustness – Reliability: S8 TOOLS

For maximum uptime in TouchControl and for the connected PC (remote):

- Full system control of all functions, incl. drives, controls, sensors
- Complete continuous system self diagnosis
- First aid functionality with automatic system recovery
- Full service and maintenance access via telephone, TCP/IP, WEBEX,...



Analytical Excellence with S8 TIGER Series 2 Industry Solutions

- Bruker industry specific solutions provides
  - Dedicated analytical performance
  - Optimal utilization of S8 TIGER series 2 capabilities
  - Norm-compliant analysis folling international standards, such as ASTM, ISO, EN, DIN
  - Based on certified reference samples
  - Includes validation samples to complete quickly and easily ISO audits
  - Includes drift correction samples for life time maintenance of applications

- Enables
  - Quick system setup
  - Time savings
  - Costs savings on reference materials
  - No learning curve

The All-New S8 TIGER Series 2
GEO-QUANT Basic and GEO-QUANT Advanced

- GEO-QUANT Basic for raw materials, minerals:
  - 14 Elements: Na, Mg, Al, Si, P, S, K, Ca, Ti, Cr, Mn, Fe, Zn, Sr
  - 20 CRM, 4 CRM for validation QC Standards, 3 DC Glass Monitors
- GEO-QUANT Advanced for geology, ceramics, glass
  - 21 Elements: Na, Mg, Al, Si, P, S, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Sr, Zr, Hf, Ba, Pb
  - 32 standards, 5 CRM for validation

S8 TIGER
GEO-QUANT BASIC

Reference calibration based on more than 20 certified reference materials:

- for 11 elements as oxides: Na_2O, MgO, Al_2O_3, SiO_2, P_2O_5, SO_3, K_2O, CaO, TiO2 MnO, Fe_2O_3
- matrix correction based on variable alpha model
- measurement time:

  6 min for the default program S8 TIGER 4 K
- optimized sample preparation procedure as fused beads

- For optimum results of P and S:

  XS-GE-C

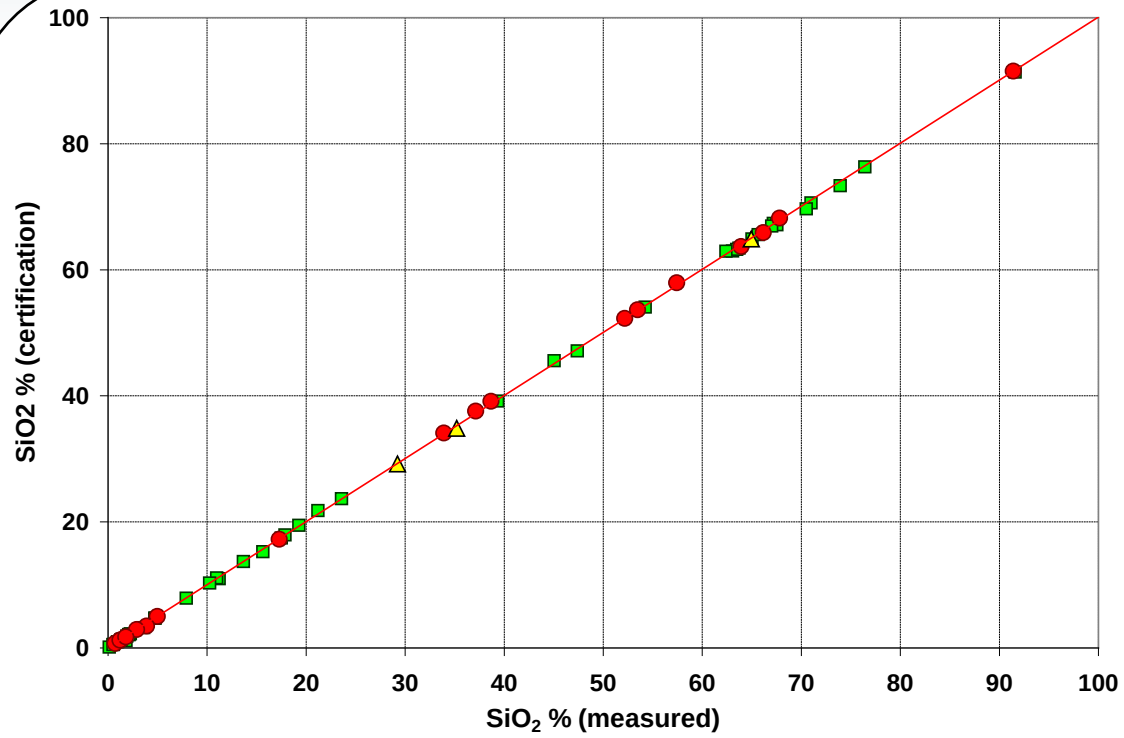
GEO-QUANT BASIC
Accurate and Precise

Element	Low range [%]	High range [%]
Na_2O	0.01	11.30
MgO	0.01	95.77
Al_2O_3	0.04	90.80
SiO_2	0.41	99.88
P_2O_5	0.01	19.34
SO_3	0.05	54.38
K_2O	0.01	15.36
CaO	0.01	97.88
TiO_2	0.01	7.79
MnO	0.01	0.88
Fe_2O_3	0.01	39.08

Wide calibration ranges

- Close to 100 % for most of the elements
- best practice: based on fusion sample preparation for accurate results
- enhanced evaluation based on unique matrix correction with the variable alpha model
- intelligent measurement strategy for high sample throughput and shortest time-to-results

GEO-QUANT BASIC
The perfect match



Evaluation of the accuracy for a wide range of international reference materials
(Acceptance test samples included shown in yellow)

GEO-QUANT BASIC
Turn-Key Solution for the S8 TIGER

The complete solution for
the process and quality control
by XRF for general oxides:

- Geological materials
- Industrial Minerals
- Ceramics, Refractories, Glass

Including:

- 20 standard reference materials
- 3 acceptance test samples
- 3 glass drift monitor samples
- Operators manual
- Sample preparation manual
- Material safety data sheets

Analytical Excellence with S8 TIGER Series 2 Industry Solutions

The All-New S8 TIGER Series 2
Mining for Money

- WDXRF instruments can cut costs per sample typically by more than a factor of three compared to ICP
  - plus additonal
    - savings for infrastructure
    - learning curve of operators
    - costs for waste disposal
- Higher accurracy and precision compared to other methods leads easily to savings of more than 8 kUSD per shipment of iron ore
- Current Bruker WDXRF technology with S8 TIGER Series 2 is combining high analytical precision with ergoniomic instrument operation and a flawless startup in the production lab.

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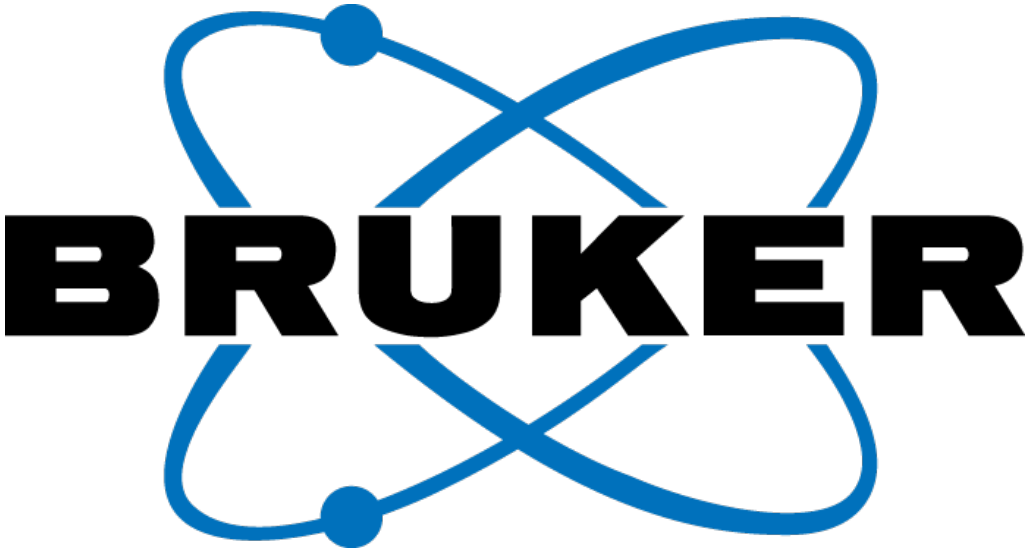

Innovation with Integrity