



Development of PhotonAssay Non-Destructive, Rapid Assay of Gold and Other Metals

Chrysos Corporation

Chrysos PhotonAssay

Commercialising a best in class gold assay method:

- Fast analysis
- High accuracy and precision
- Low to zero sample preparation
- Large sample size
- Insensitive to sample matrix
- Chemical free
- Non-destructive analysis
- Application to different elements

Conventional assay techniques

- Fire-assay has been the standard method for many centuries
- Existing alternatives:
 - Aqua regia digest
 - Cyanidation
 - Neutron activation analysis



Turn-around time
Usually > 24 hours



Small sample
mass (10-50 g)



Extensive
sample prep



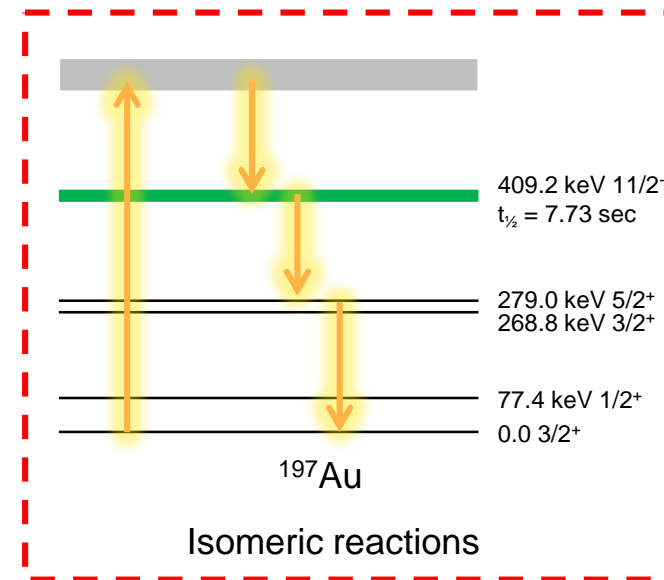
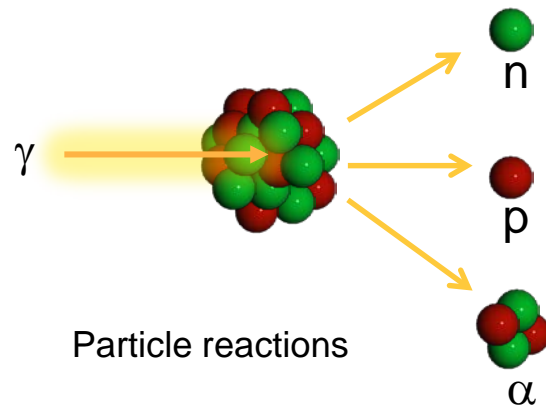
Skilled labour
requirements



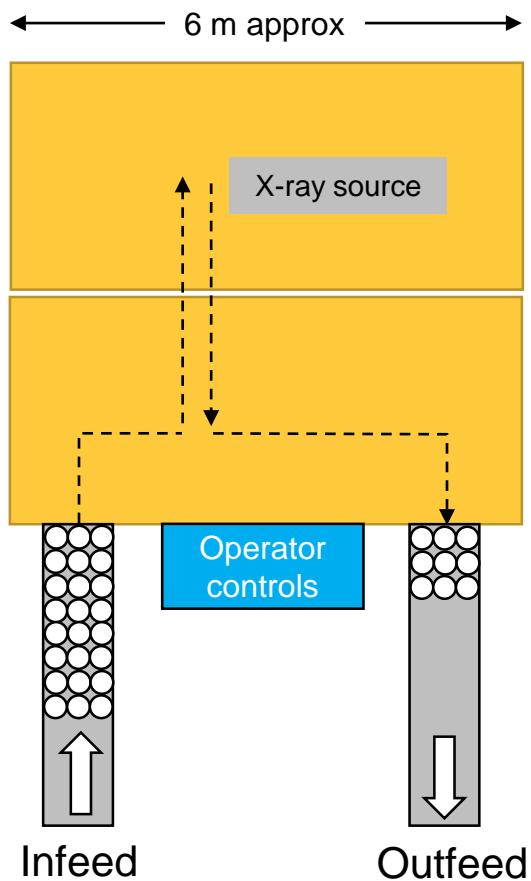
Hazardous
process

Gamma activation analysis (GAA)

- Use high-energy X-rays to induce reactions in target nuclei
- Measure resulting activity and relate to element concentration

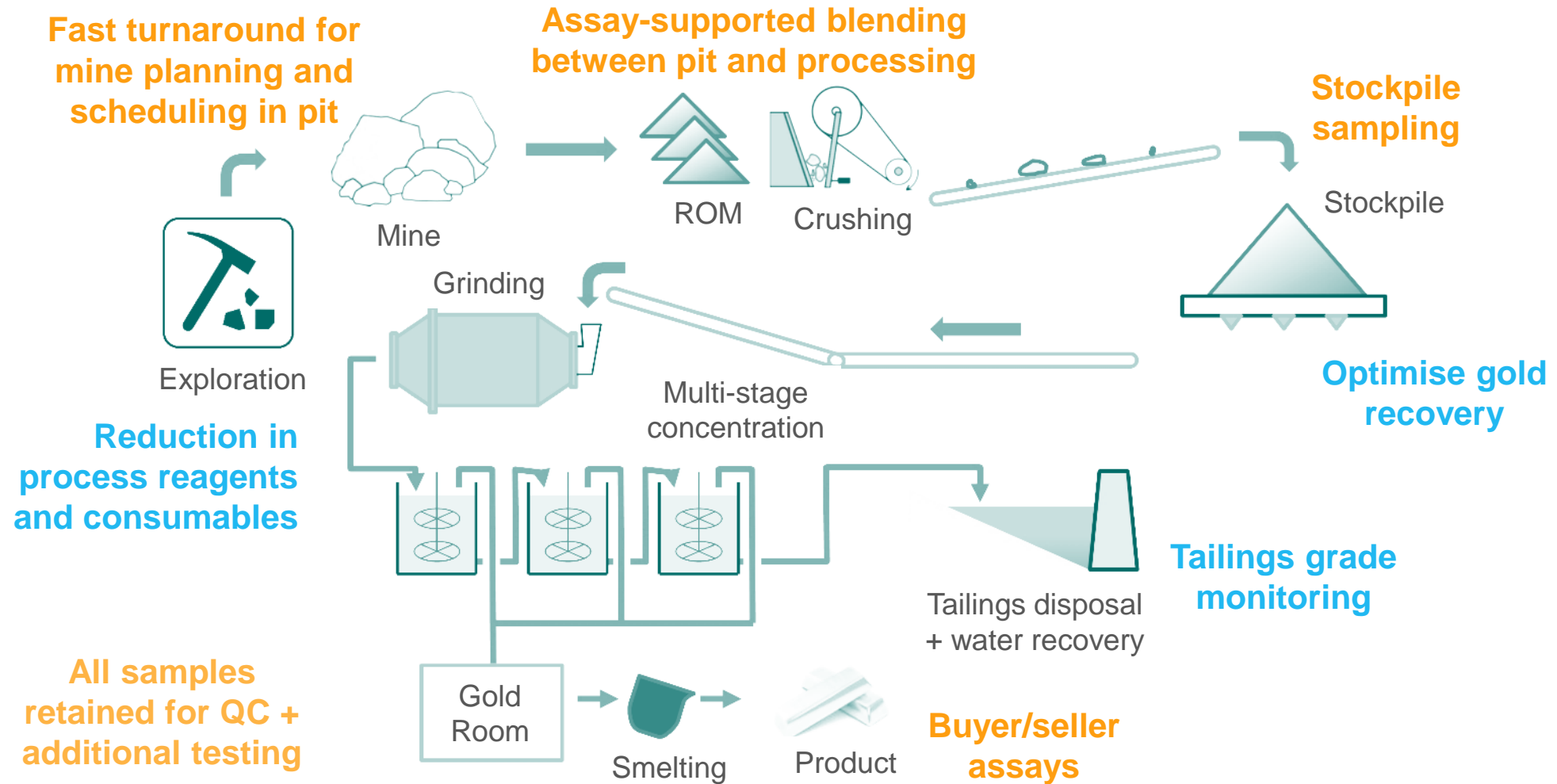


Safety and operator requirements



- Fully automated sample handling. Operator loads and unloads samples from outside unit
- Electronic X-ray source: no power, no radiation
- Equipment packaged as 'black box'. No operator access during routine use
- Radiation levels, interlocks etc in compliance with state and national regulations
- Samples can be safely handled, stored or disposed of after analysis
- Minimal opportunities for human error

Applications of rapid turn-around assay



PhotonAssay analysis characteristics

- Highly penetrating X-rays pass through entire sample
 - True bulk analysis of large samples
- Analysis is independent of physical, chemical or mineralogical form of sample
 - Tested on oxide and sulphide ores, concentrates, carbon pulps, polymetallic ores and direct testing of slurry samples
- Low or zero sample preparation required
 - Sample preparation typically accounts for 30-40% of total assay costs
- No direct interference from other elements
 - Highly elevated levels of U, Th and Ba raise detection limit, but this can be detected and reported for individual samples



Performance

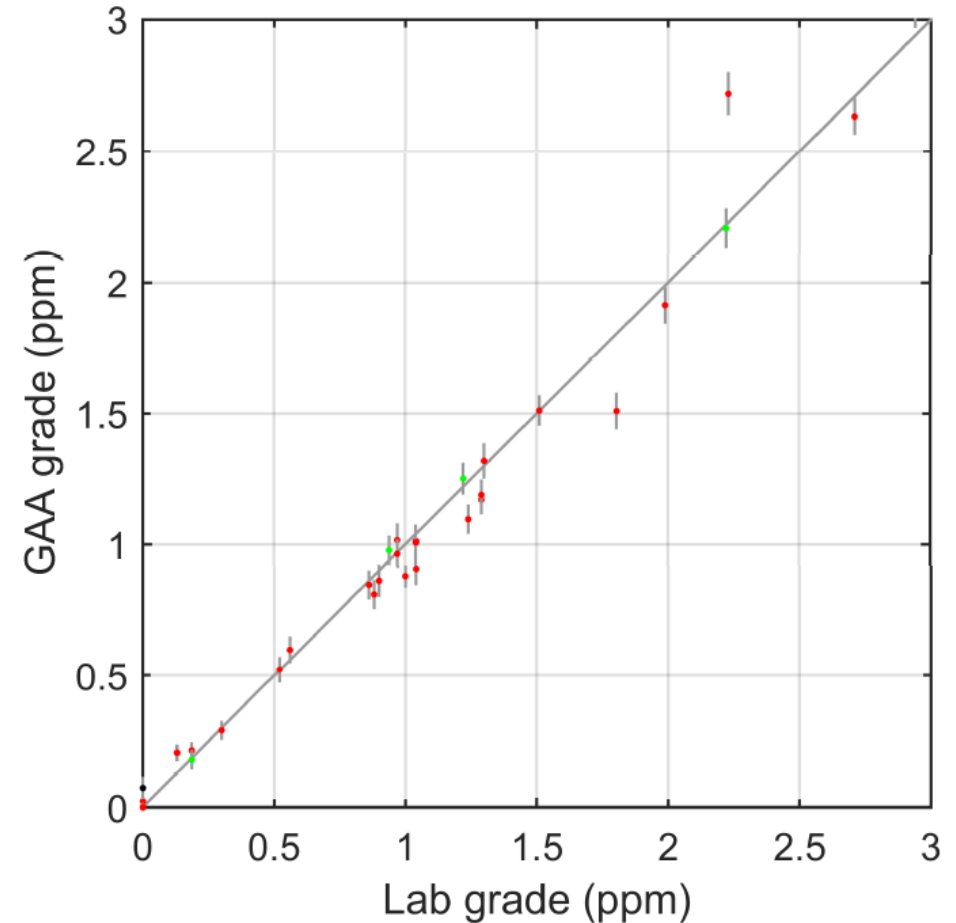
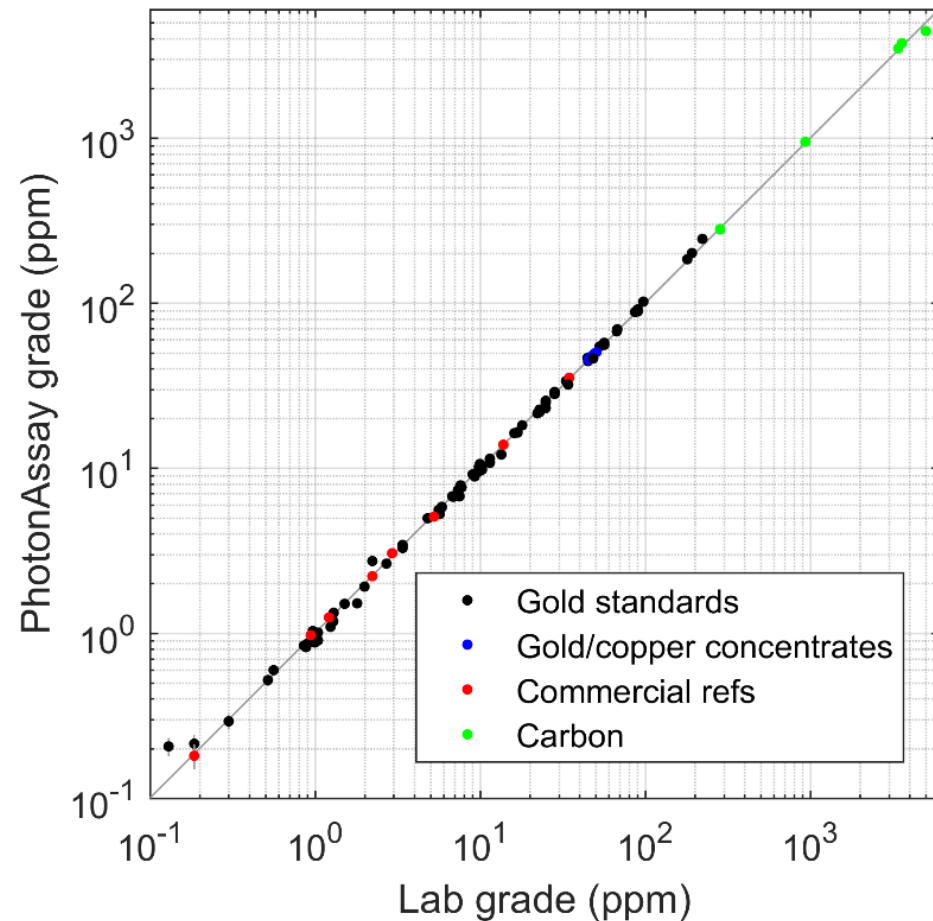
- PhotonAssay more accurate than fire assay above 1ppm, similar accuracy below
- Round-robin, inter-lab comparison of CRMs, 150-180 laboratories, outliers removed

Parameter	Results to date (lab prototype)	Final system (under construction)	Fire assay	Aqua regia
Throughput	6 samples/h*	80 samples/h*		
Det. limit (3 σ)	60-75 ppb*	< 30 ppb*	1 ppb (ICP finish) 10 ppb (AAS finish) 3 ppm (gravimetric)	1-20 ppb, depending on finish
Accuracy @ 0.1 ppm	35% (0.035 ppm)	15% (0.015 ppm)	10-12%	15%
Accuracy @ 0.3 ppm	15% (0.045 ppm)	7% (0.020 ppm)	5-6%	8-10%
Accuracy @ >1 ppm	Better than 5%	Better than 3%	3-4%	4-6%
Accuracy @ >30 ppm	< 1-2%	< 1%	2.5-3.5%	4-6%

* Throughput/sensitivity can be traded

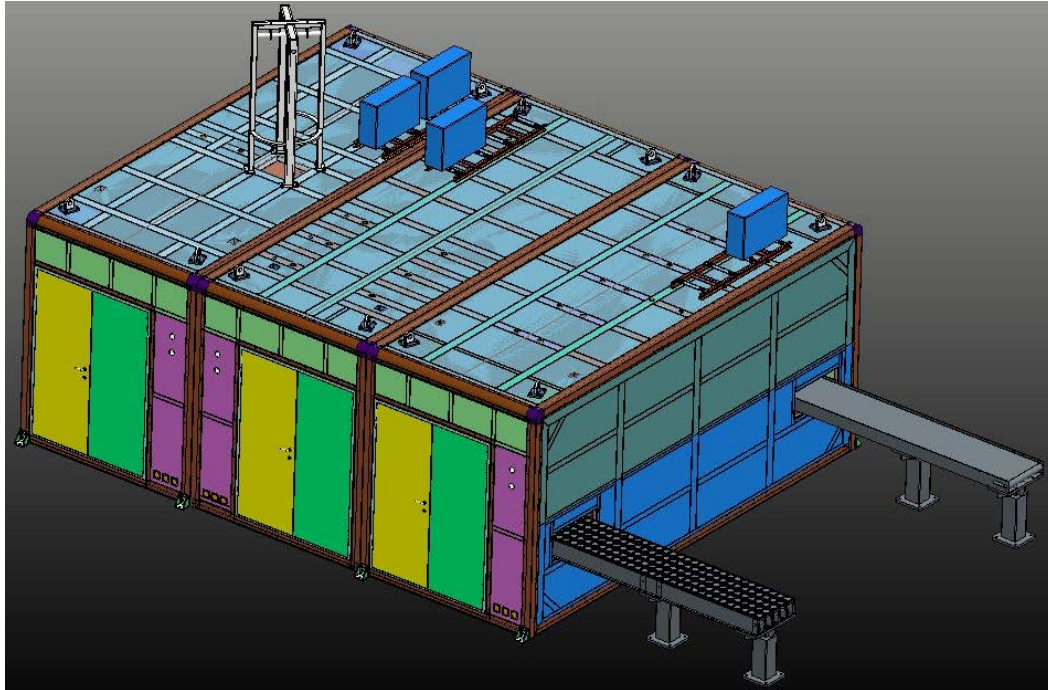
Fire assay comparison

- High correlation for samples run in test work at full scale <0.9% discrepancy



Equipment footprint

- Compact and relocatable
- Not a hand-held device

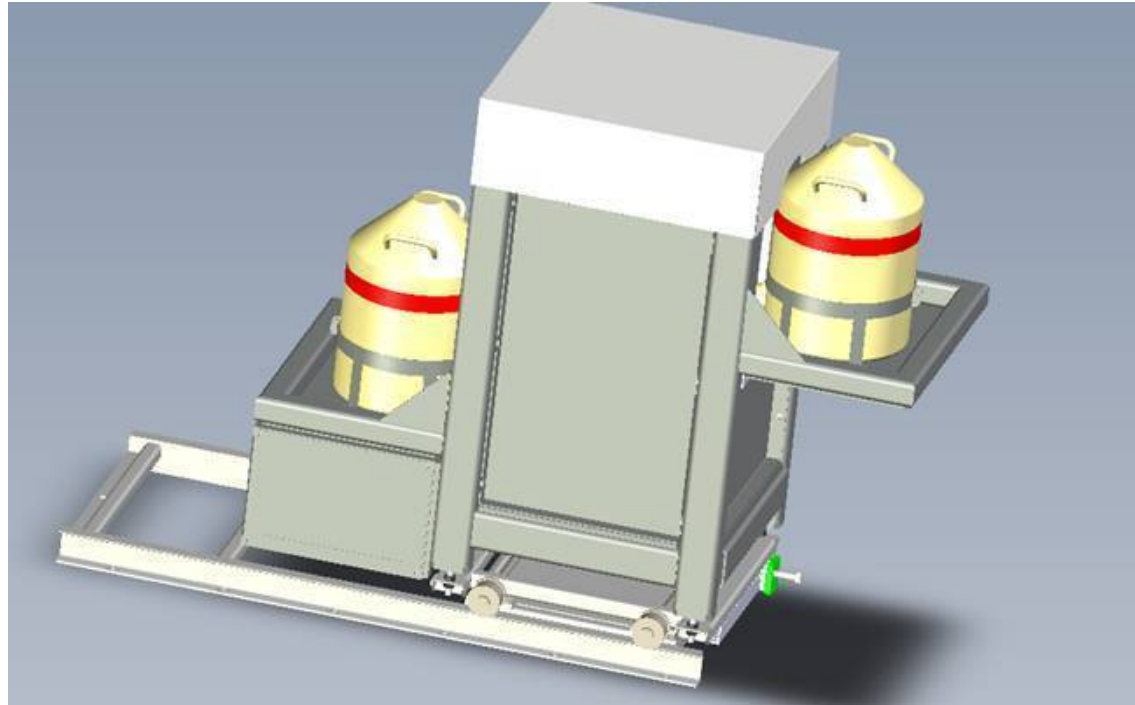


Design Phase: 2016-2017



Manufacturing Phase: August 2017

Engineering development



Design Phase: 2016-2017

Manufacturing Phase: August 2017



Max and on-site units

- Chrysos Max unit – from Dec 2017
 - Designed for fixed lab operations – ‘fire assay replacement’
 - High throughput (80 samples/hour at standard precision)
 - Flexible X-ray source to cover broad element suite
- Chrysos On-site unit – from mid-2018
 - Designed for rapid turn-around analysis for planning and control
 - Reduced power requirements and footprint
 - Throughput of 20-80 samples/hour at standard precision
- Operating model
 - Both units operate on fee-per-assay lease model
 - Pricing competitive with conventional assay

Accreditation and QA/QC

- NATA (National Association of Testing Authorities, Australia)
 - Work with existing NATA-accredited facility to undertake validation and develop new procedure specification
- JORC (Joint Ore Reserves Committee) NI 43-101 equivalent
 - Establish scientific reliability of PhotonAssay method through validation and reporting
- Quality assurance/quality control
 - Reference foil method ties analysis directly back to CRMs
 - Digital recording of all process steps
 - All samples can be retained in original form

Other elements

1 1.008 H Hydrogen																	2 4.003 He Helium																
3 6.941 Li Lithium	4 9.012 Be Beryllium																	5 10.811 B Boron	6 12.011 C Carbon	7 14.007 N Nitrogen	8 15.999 O Oxygen	9 18.998 F Fluorine	10 20.180 Ne Neon										
11 22.990 Na Sodium	12 24.305 Mg Magnesium																	13 26.982 Al Aluminium	14 28.086 Si Silicon	15 30.974 P Phosphorus	16 32.065 S Sulphur	17 35.453 Cl Chlorine	18 39.948 Ar Argon										
19 39.098 K Potassium	20 40.078 Ca Calcium	21 44.956 Sc Scandium	22 47.867 Ti Titanium	23 50.941 V Vanadium	24 51.996 Cr Chromium	25 54.938 Mn Manganese	26 55.845 Fe Iron	27 58.933 Co Cobalt	28 58.693 Ni Nickel	29 63.546 Cu Copper	30 65.409 Zn Zinc	31 69.723 Ga Gallium	32 72.640 Ge Germanium	33 74.922 As Arsenic	34 78.960 Se Selenium	35 79.904 Br Bromine	36 83.798 Kr Krypton																
37 85.468 Rb Rubidium	38 87.620 Sr Strontium	39 88.906 Y Yttrium	40 91.224 Zr Zirconium	41 92.906 Nb Niobium	42 95.940 Mo Molybdenum	43 [98] Tc Technetium	44 101.070 Ru Ruthenium	45 102.906 Rh Rhodium	46 106.420 Pd Palladium	47 107.868 Ag Silver	48 112.411 Cd Cadmium	49 114.818 In Indium	50 118.710 Sn Tin	51 121.760 Sb Antimony	52 127.600 Te Tellurium	53 126.904 I Iodine	54 131.293 Xe Xenon																
55 132.905 Cs Cesium	56 137.327 Ba Barium																	72 178.490 Hf Hafnium	73 180.948 Ta Tantalum	74 183.840 W Tungsten	75 186.207 Re Rhenium	76 190.230 Os Osmium	77 192.217 Ir Iridium	78 195.078 Pt Platinum	79 196.967 Au Gold	80 200.590 Hg Mercury	81 204.383 Tl Thallium	82 207.200 Pb Lead	83 208.980 Bi Bismuth	84 [209] Po Polonium	85 [210] At Astatine	86 [222] Rn Radon	
87 [223] Fr Francium	88 [226] Ra Radium																	57 138.905 La Lanthanum	58 140.116 Ce Cerium	59 140.908 Pr Praseodymium	60 144.240 Nd Neodymium	61 [145] Pm Promethium	62 150.360 Sm Samarium	63 151.964 Eu Europium	64 157.250 Gd Gadolinium	65 158.925 Tb Terbium	66 162.500 Dy Dysprosium	67 164.930 Ho Holmium	68 167.259 Er Erbium	69 168.934 Tm Thulium	70 173.040 Yb Ytterbium	71 174.967 Lu Lutetium	
																		89 [227] Ac Actinium	90 232.038 Th Thorium	91 231.036 Pa Protactinium	92 238.029 U Uranium	93 [237] Np Neptunium											

Fully demonstrated
 Experimental validation
 Sensitivity measurements
 Theoretically accessible

Det. limit (3σ) : Ag(~4-5ppm), Cu(~0.02%), Pb (~0.02%)

History and development challenges

History

- Discovery of basic physics of the X-ray activation process (1940s-1950s)
- Identification of X-ray activation as method for gold analysis (1960s)
- Establishment of assay lab(s) in the former Soviet Union (1970s-1990s)

**Limited subsequent
commercial development
Why?**

Challenges

- Improving sensitivity and accuracy
- Reducing equipment footprint and simplifying installation
- Understanding sample preparation needs
- Safety and compliance with licencing requirements
- Accreditation (JORC, NATA), quality assurance and quality control
- Cost effectiveness for end users

Summary

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Applications:

- Fire-assay replacement
- Mine planning/grade control
- Near real-time process monitoring
- Buyer/seller assays
- Other ...

Dirk Treasure

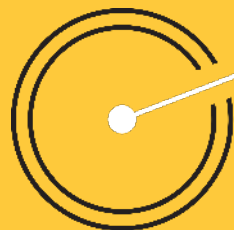
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Thank you



**CHRYSOS
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