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)

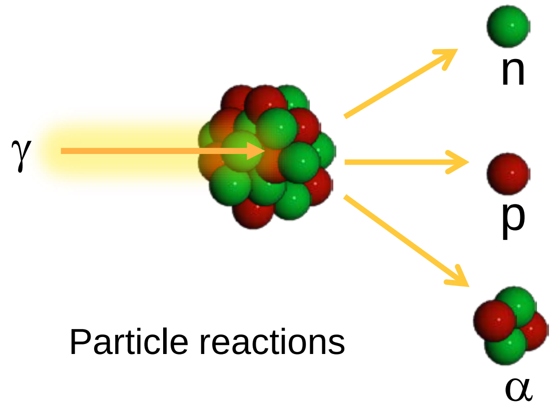
Extensive
sample prep

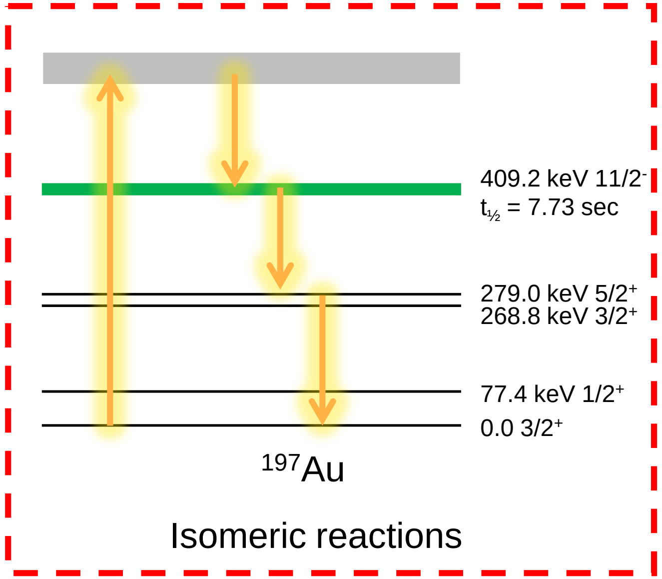
Skilled labour
requirements

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





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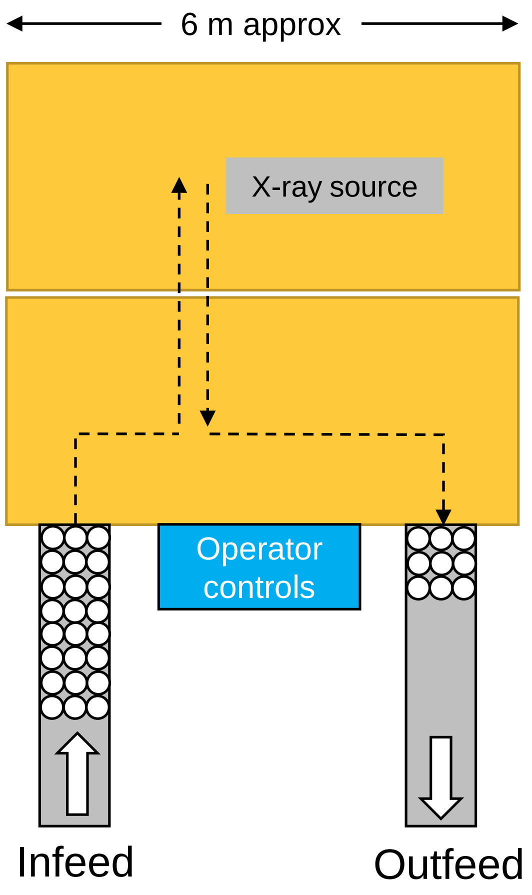
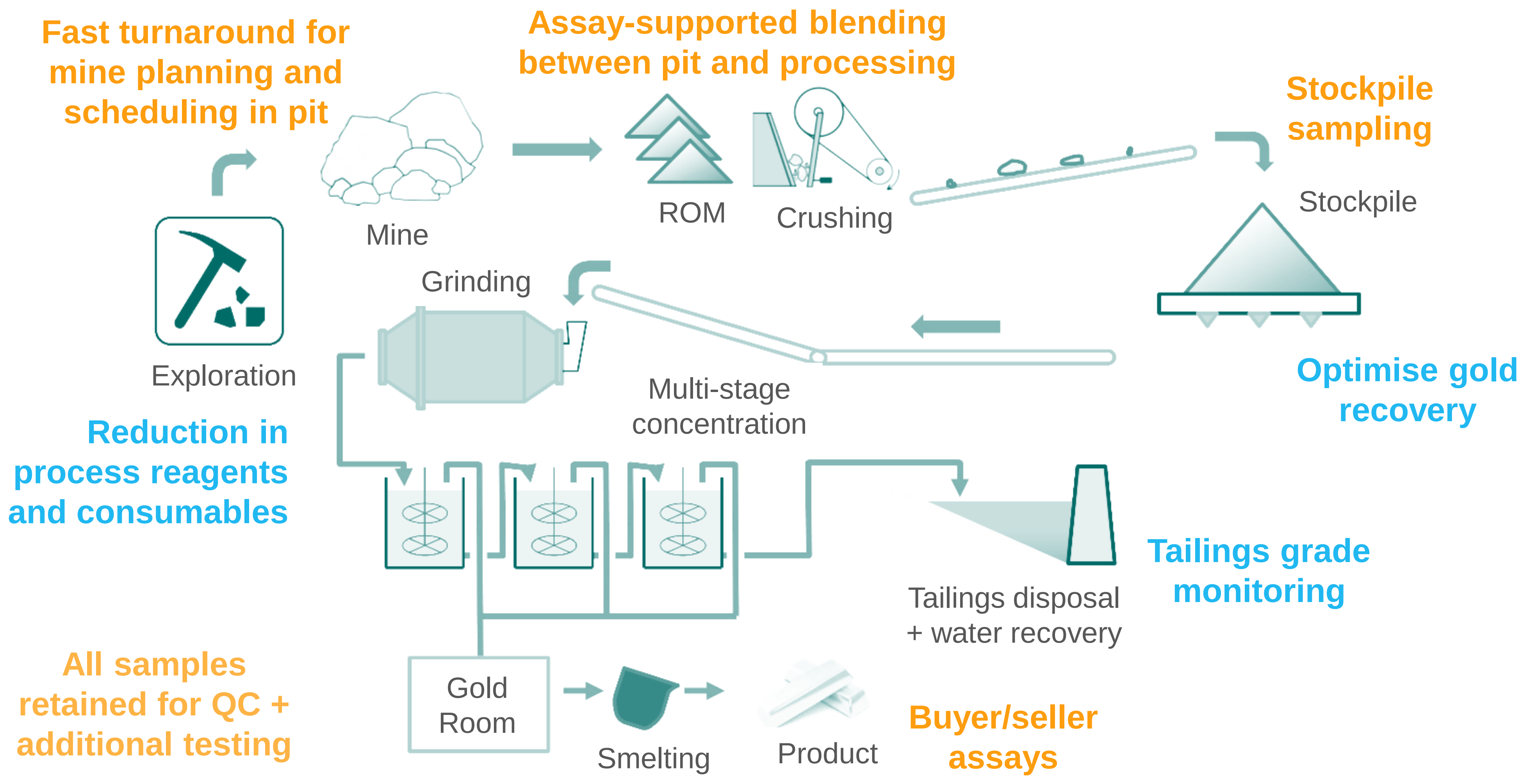
Safety and operator requirements



- 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



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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

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Performance

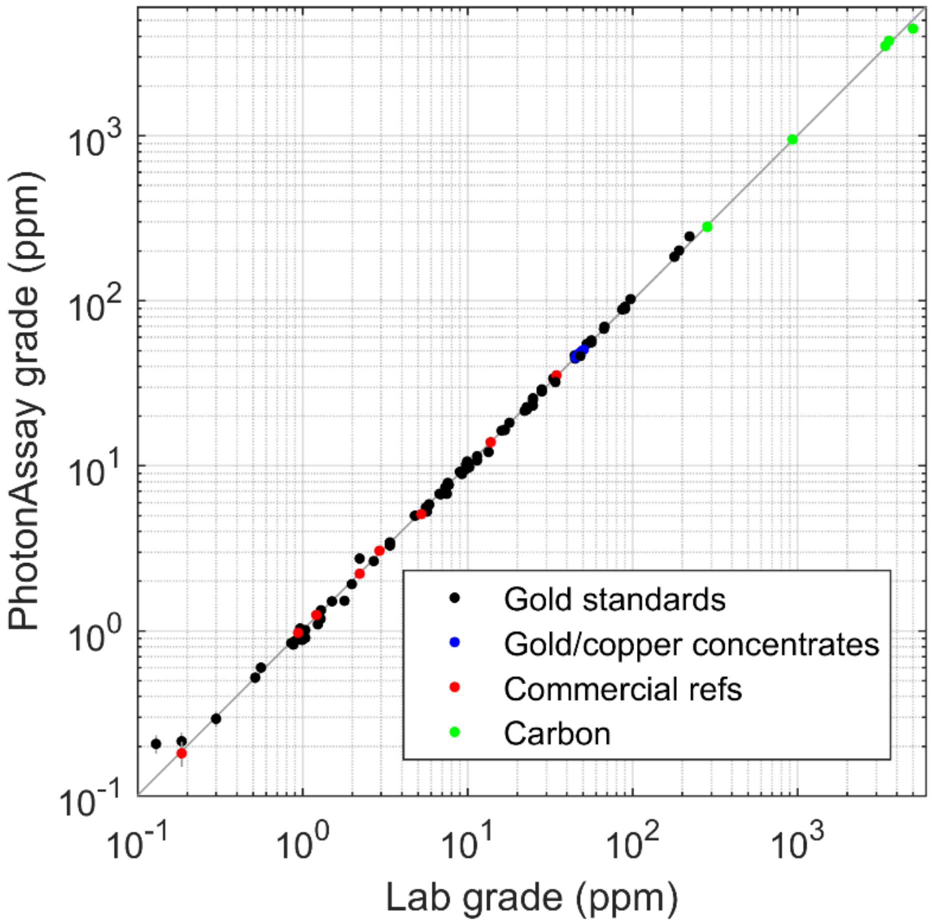
- PhotonAssay more accurate than fire assay above 1ppm, similar accuracy below
- Round-robin, inter-lab comparison of CRMs, 150-180 laboratories, outliers removed

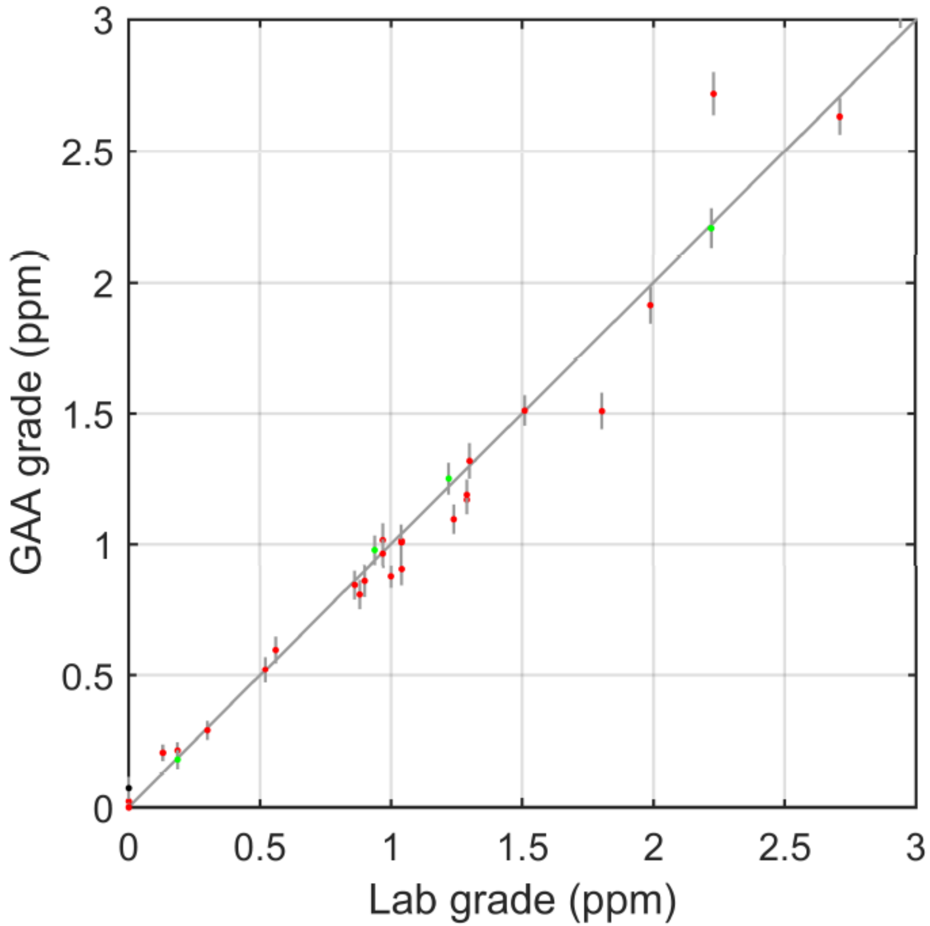
Parameter	Results to date (lab prototype)	Final system (under construction)	Fire assay	Aqua regia
Throughput	6 samples/h*	80 samples/h*		
Det. limit (3σ)	60-75 ppb*	< 30 ppb*	1 ppb (ICP finish) 10 ppb (AAS finish) 3 ppm (gravimetric)	1-20 ppb, depending on finish
Accuracy @ 0.1 ppm	35% (0.035 ppm)	15% (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





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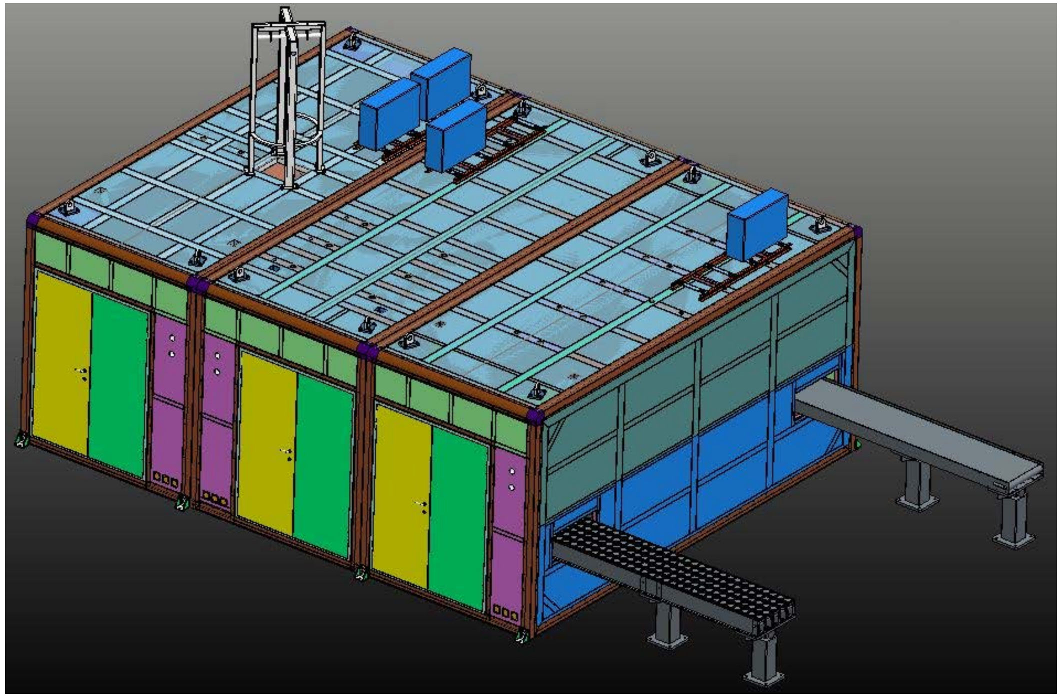
Equipment footprint

- Compact and relocatable
- Not a hand-held device



Design Phase: 2016-2017

Manufacturing Phase: August 2017

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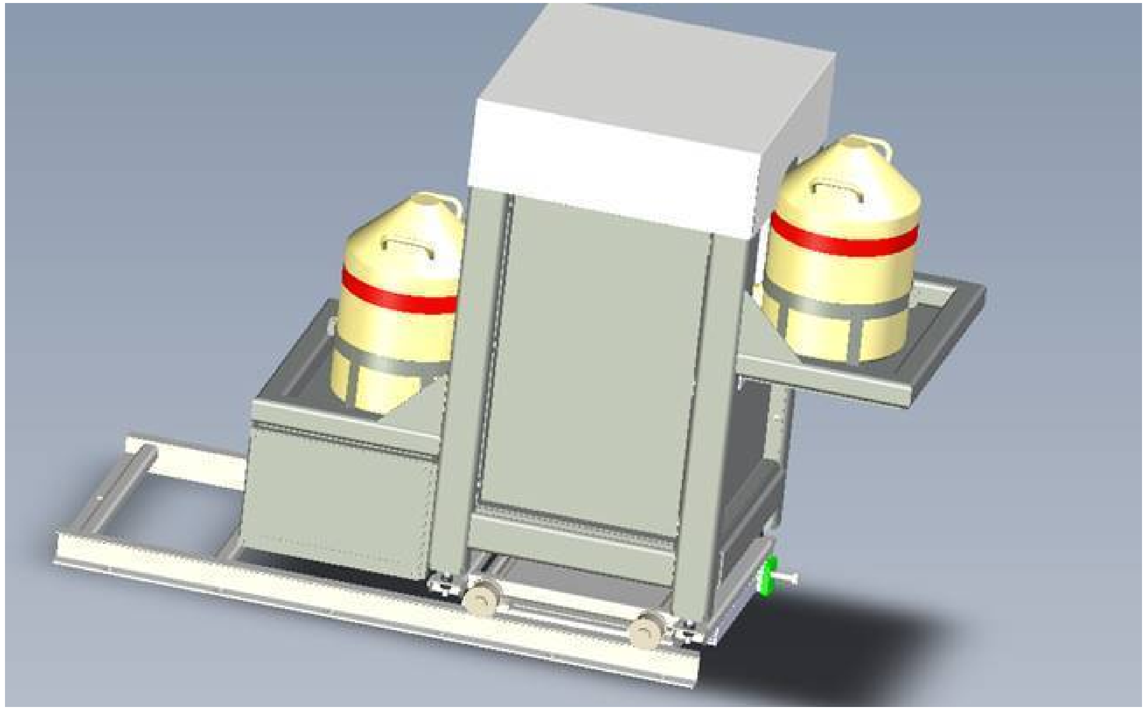
Engineering development

Manufacturing Phase: August 2017



Design Phase: 2016-2017

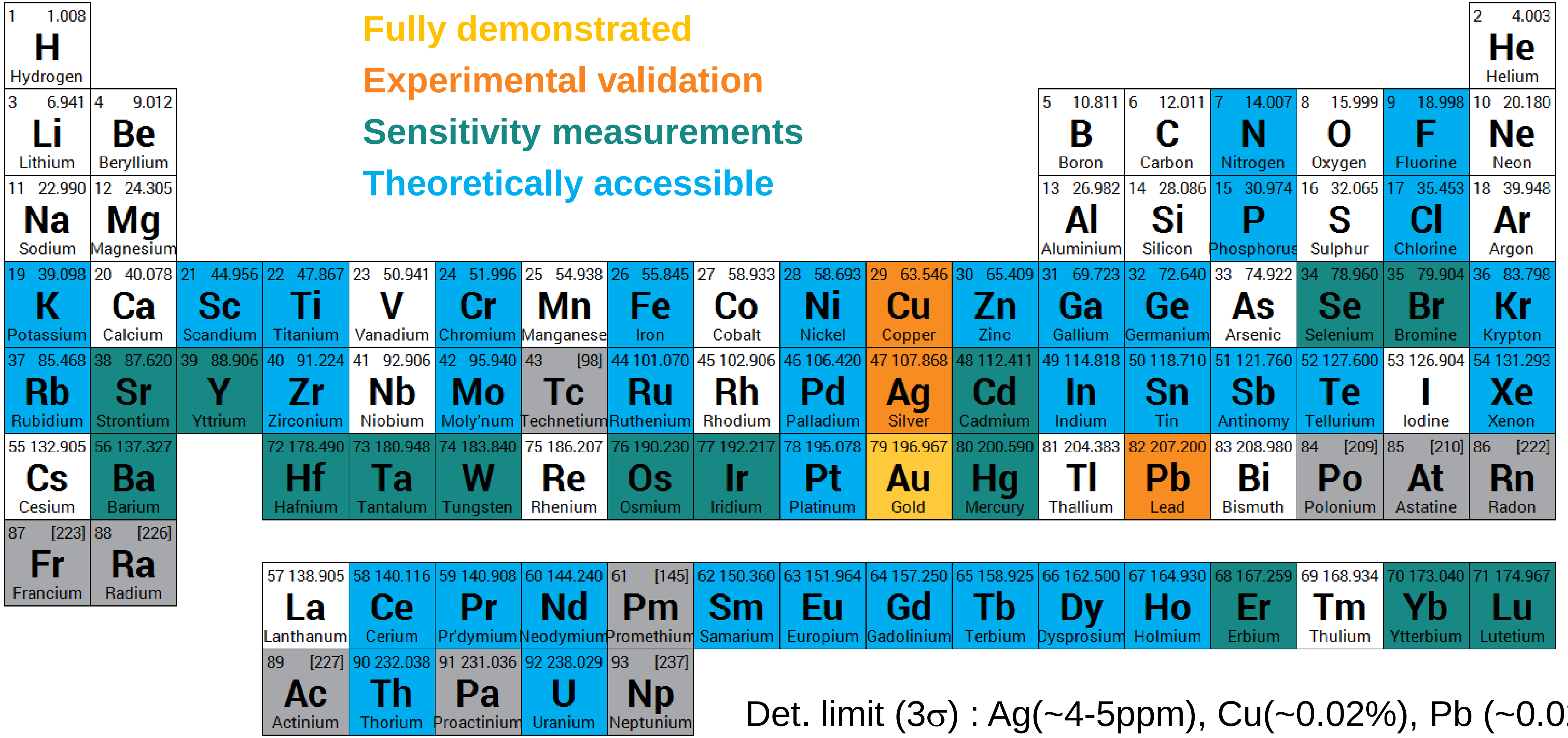
Max and on-site units

- 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 equivelant
  - 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



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

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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

Commercialising a best in class gold assay method:

- Fast analysis
- High accuracy and precision
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- Large sample size
- Insensitive to sample matrix
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- Application to different elements

Applications:

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

Thank you

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