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Radioactive Waste Management Conference  
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# **Remote Characterization of HLW using Laser-Induced Breakdown Spectroscopy**

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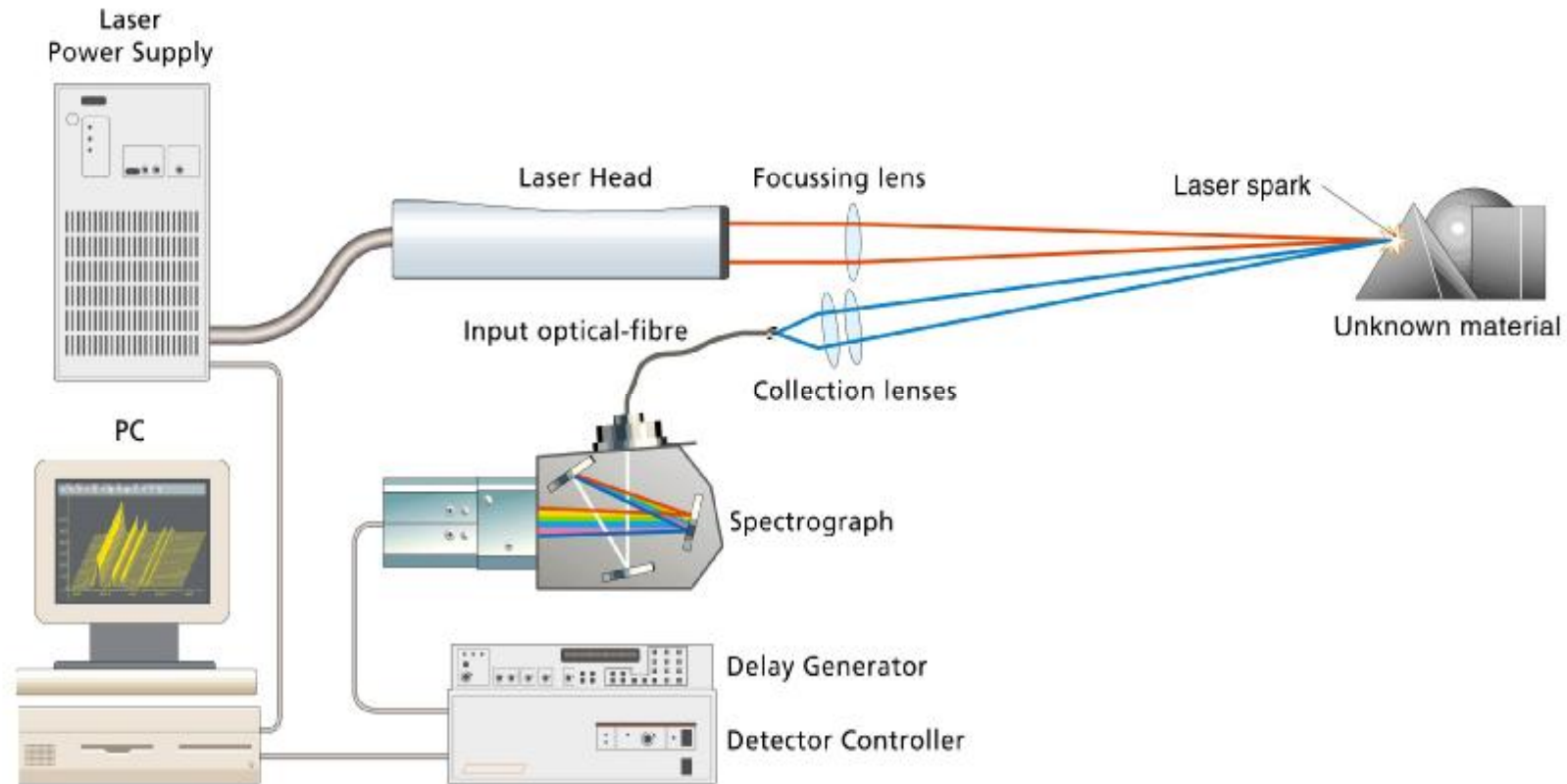


# Overview



- Introduction to Laser-Induced Breakdown Spectroscopy (LIBS)
- General types of LIBS instrument
- Qualitative measurements
  - Remote, non-invasive compositional analysis of surface contamination
  - In-situ detection of “fixed” surface contamination on vitrified HLW drums
- Quantitative measurements
  - In-situ measurements of calcine (fission-product) content of HLW residues
- Summary

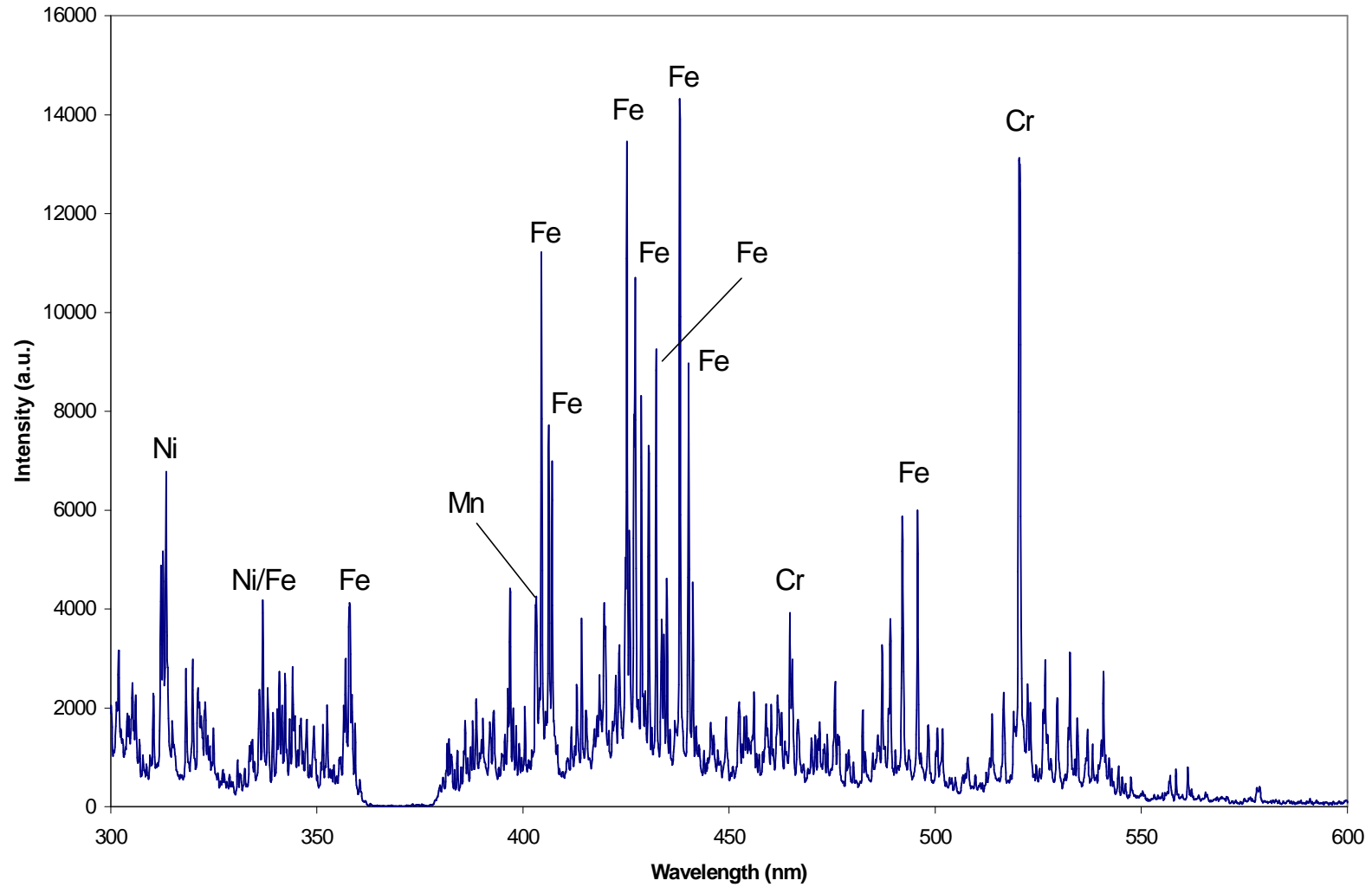
# Laser Induced Breakdown Spectroscopy (LIBS)



## Laser generated spark on a steel sample



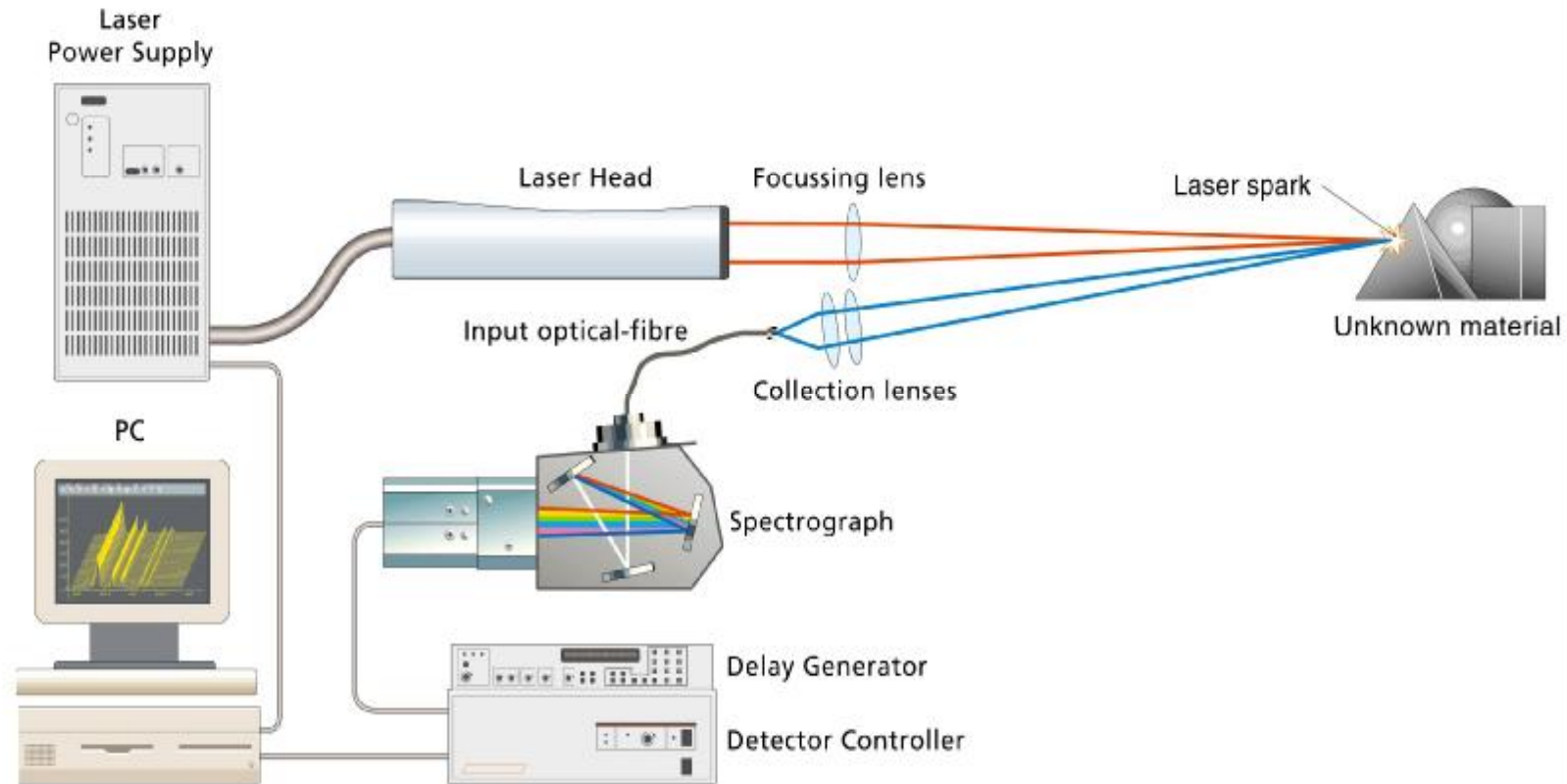
# 304 Stainless steel



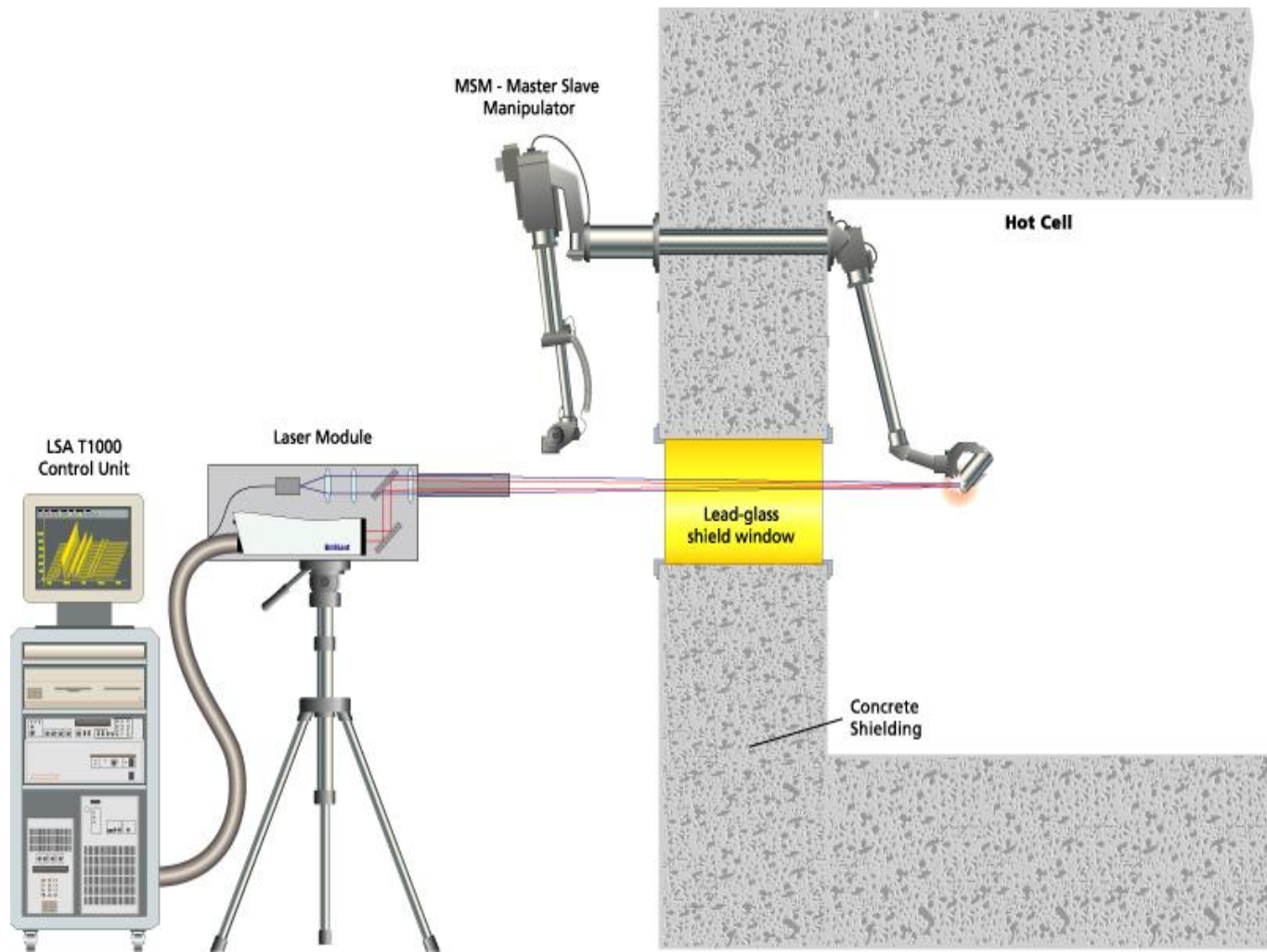


# General types of LIBS Instrument

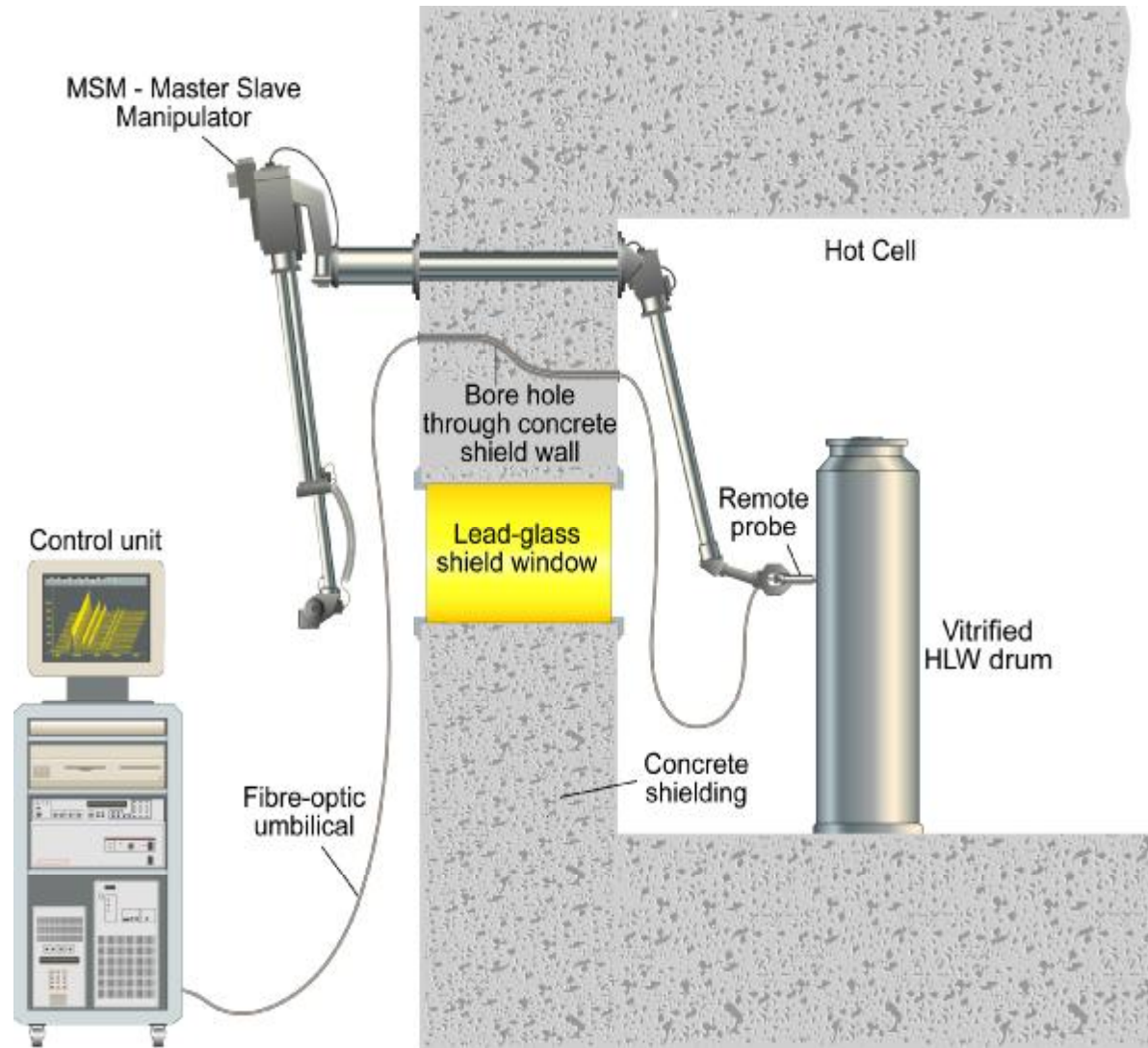
# Laser Induced Breakdown Spectroscopy (LIBS)



# Telescope LIBS instrument



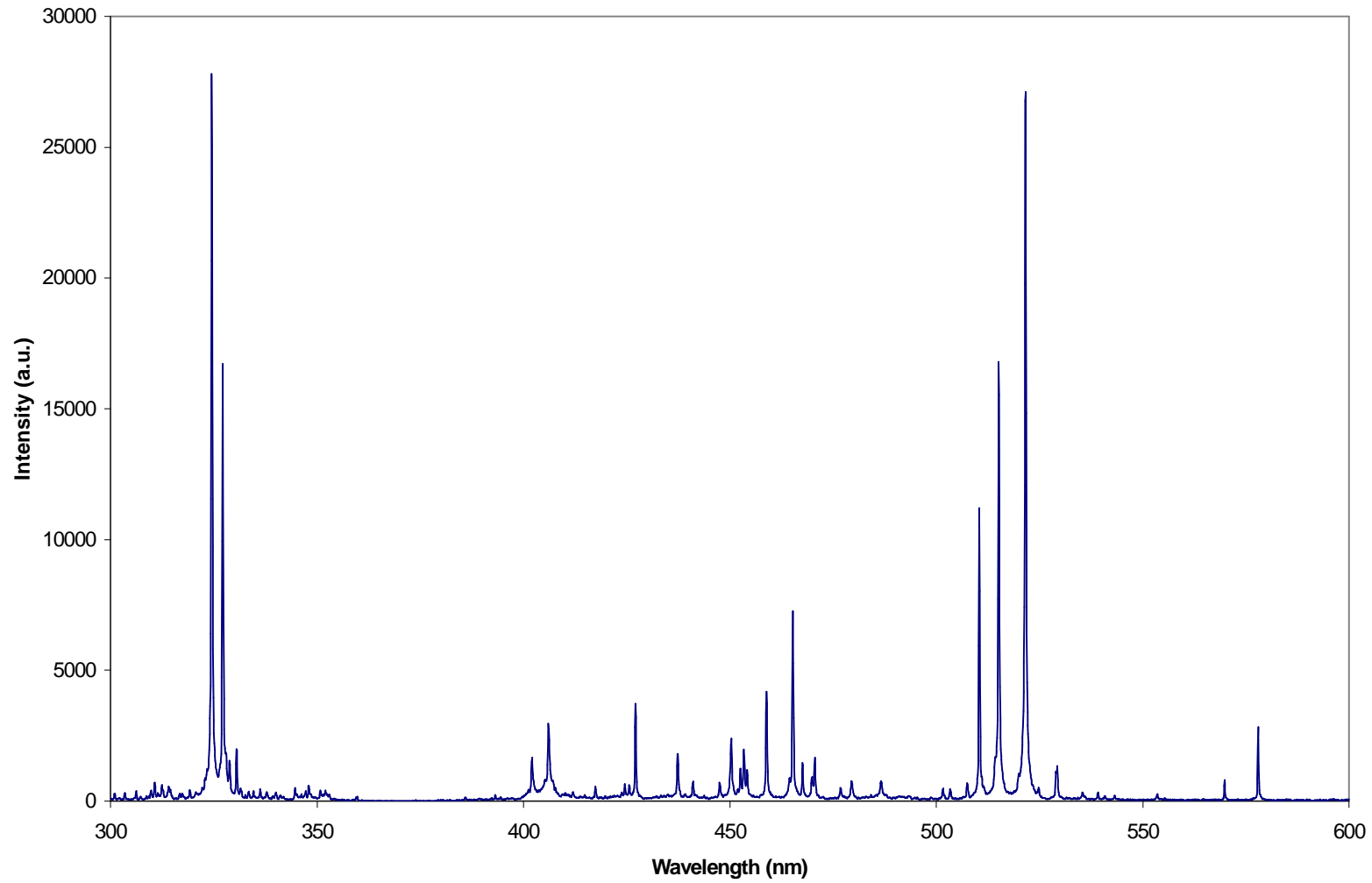
# Fibre-optic probe LIBS instrument





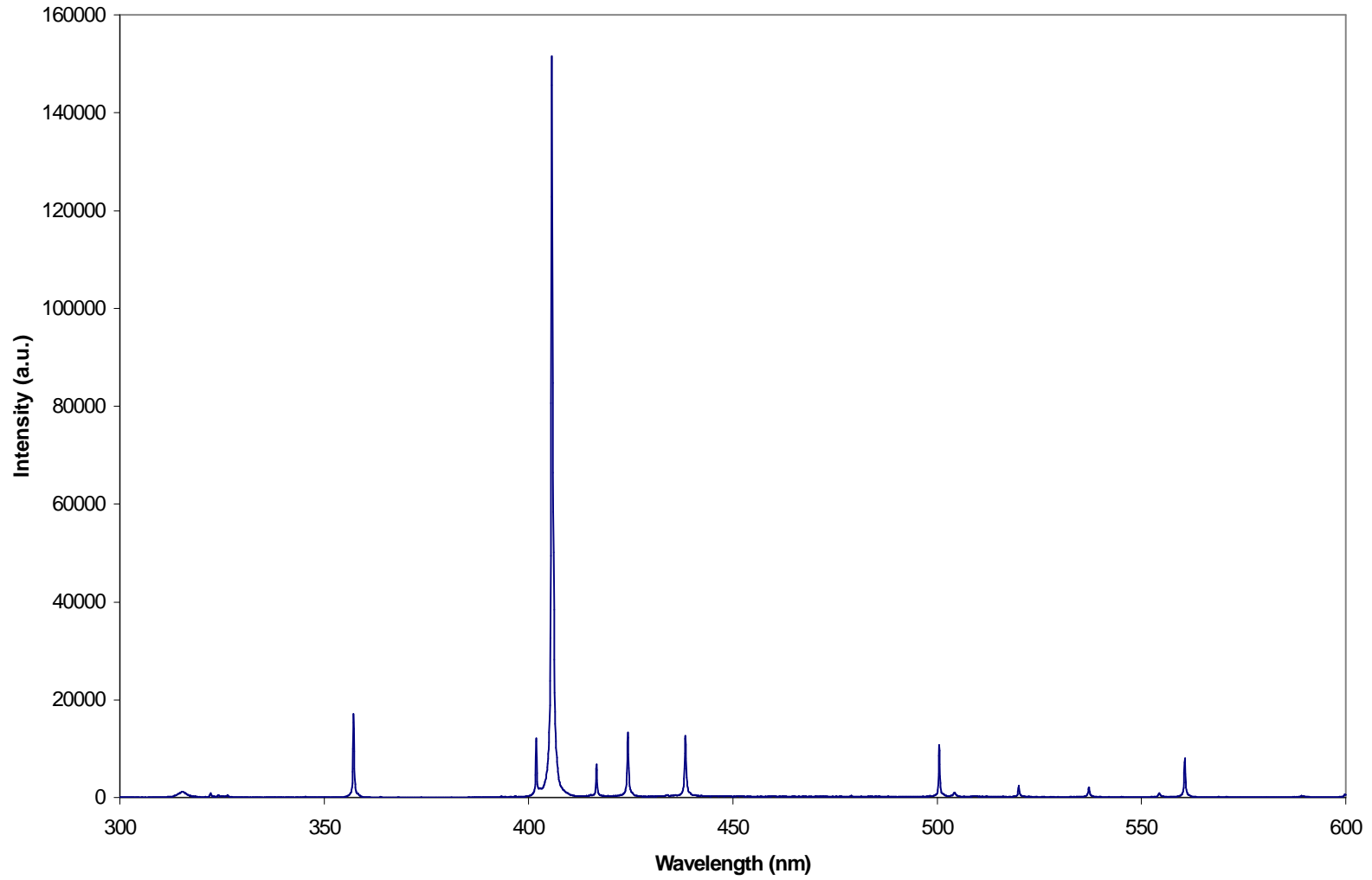
# Qualitative measurements by LIBS

# Copper

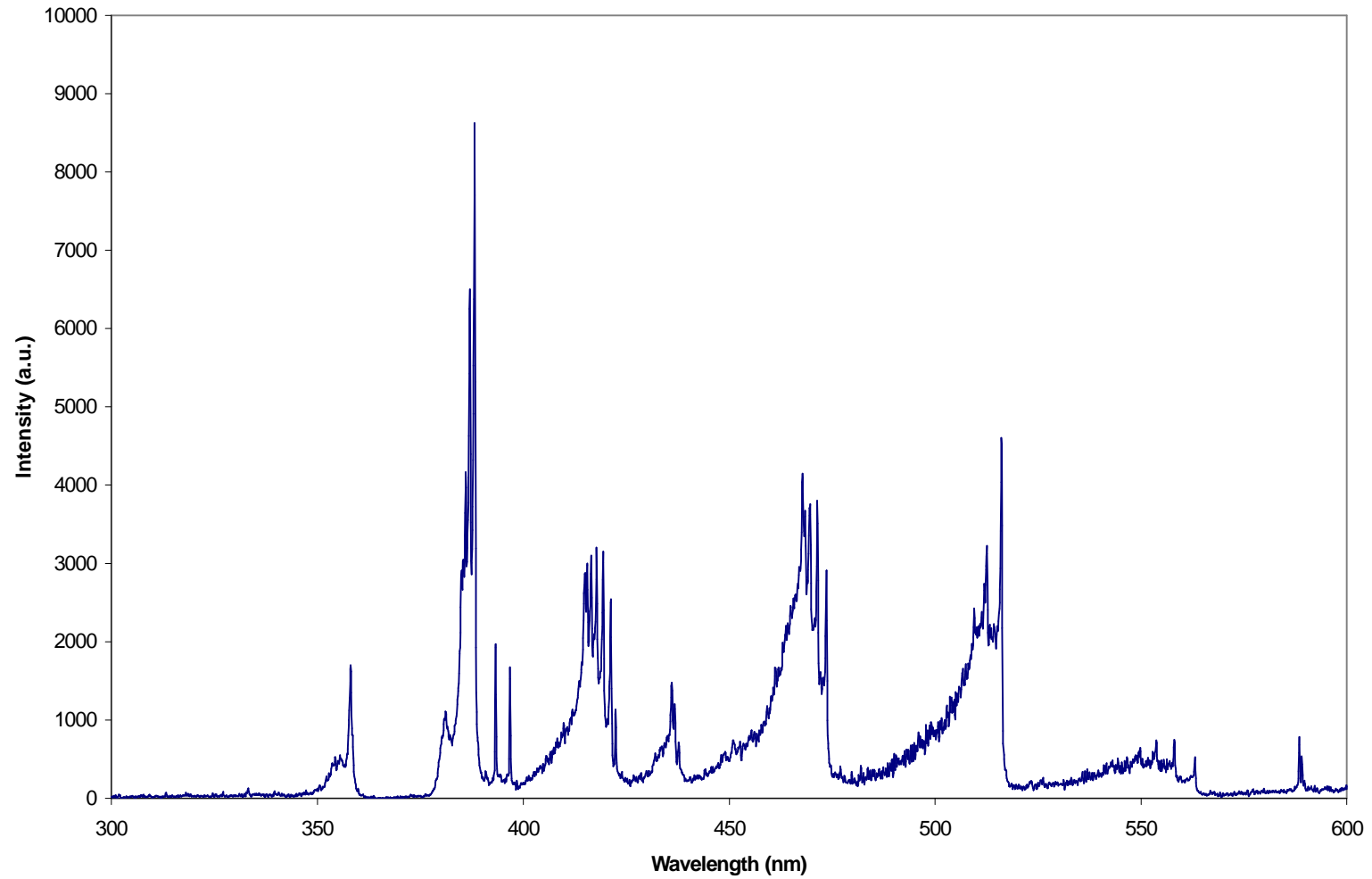


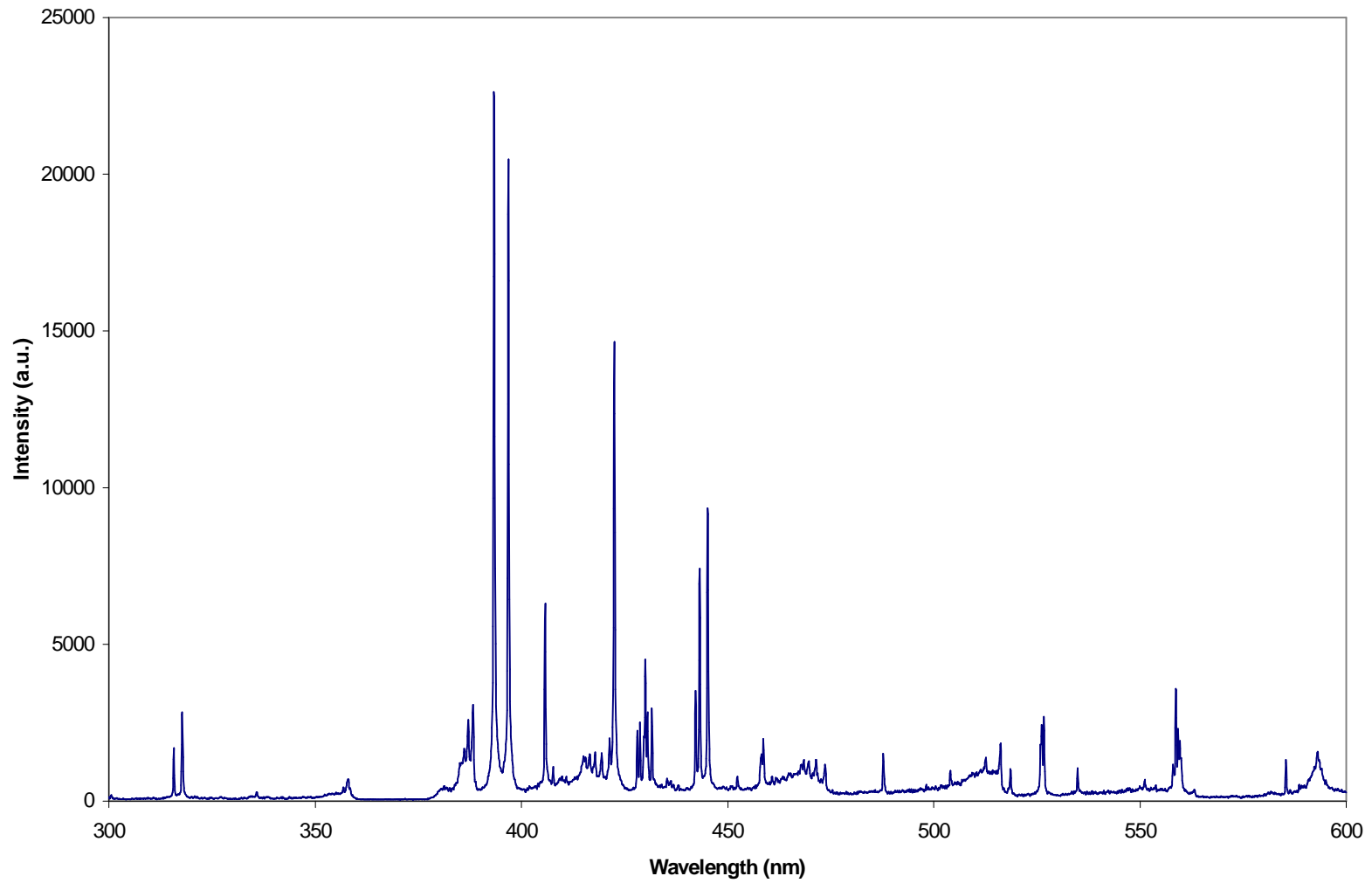


# Lead



# Graphite

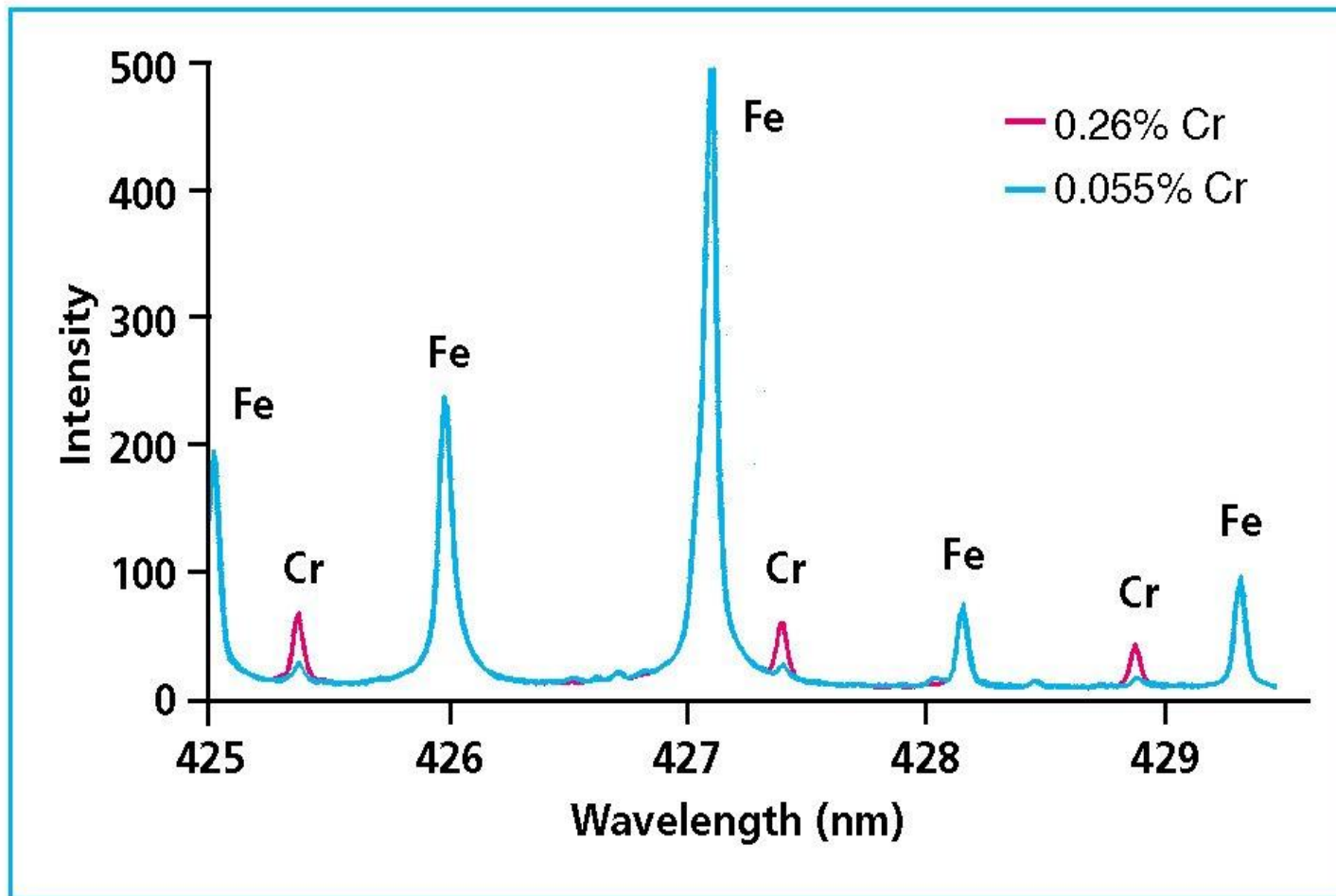






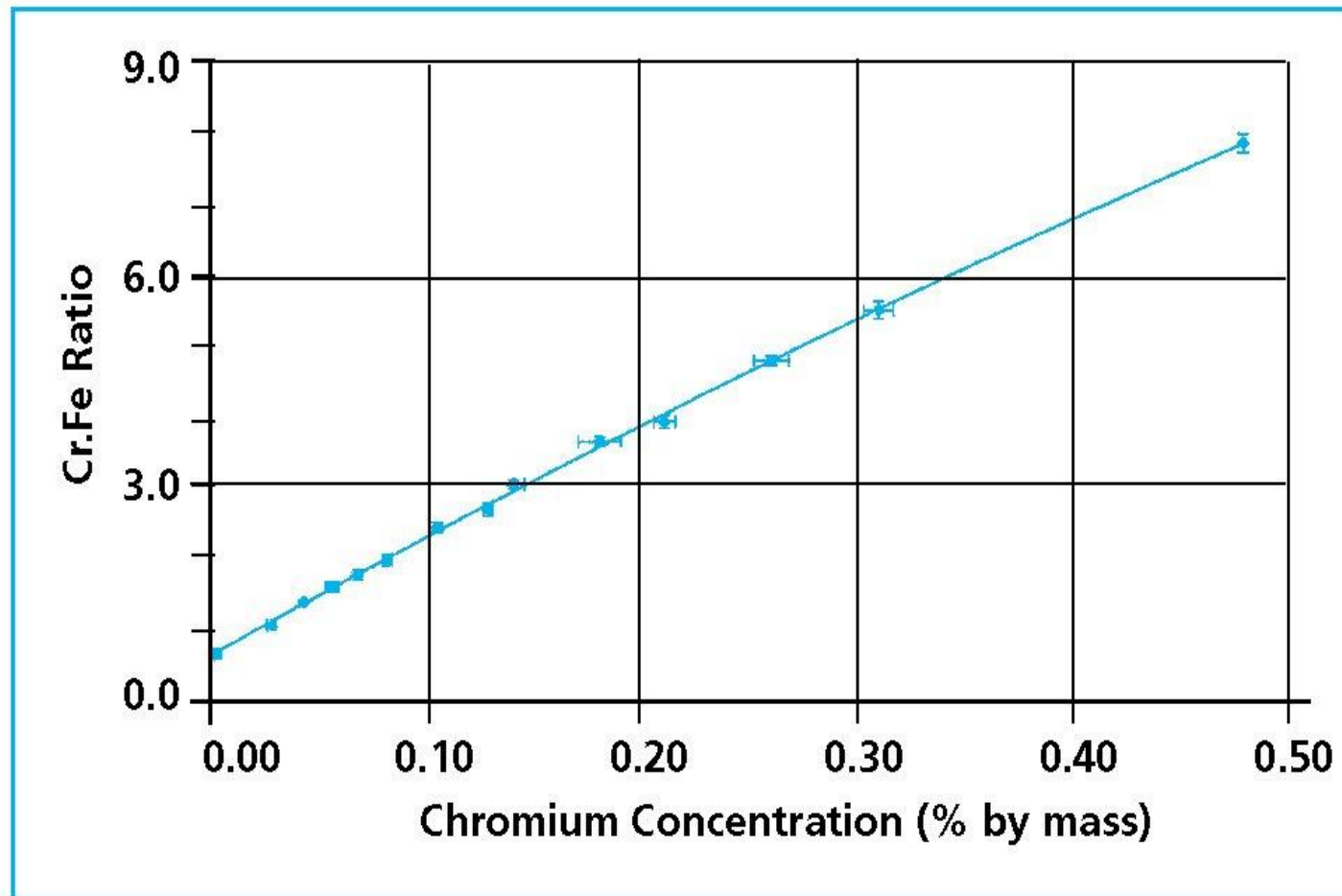
# Quantitative measurements by LIBS

# Quantitative measurements by LIBS



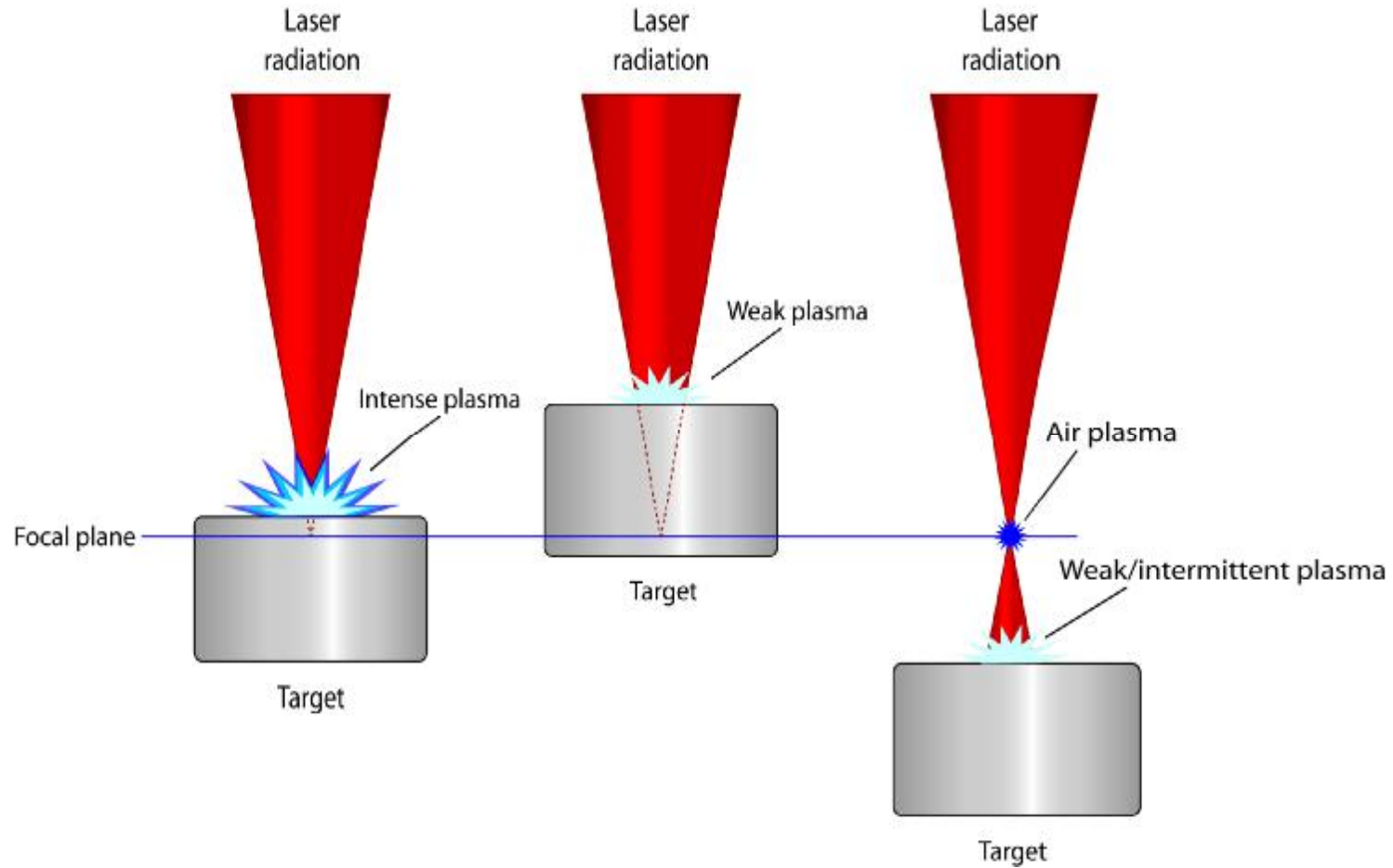
LIBS spectra obtained from steel showing Fe and Cr emission lines

# Quantitative measurements by LIBS



Chromium calibration curve using Internal Standardisation

# Effect of target position on plasma formation





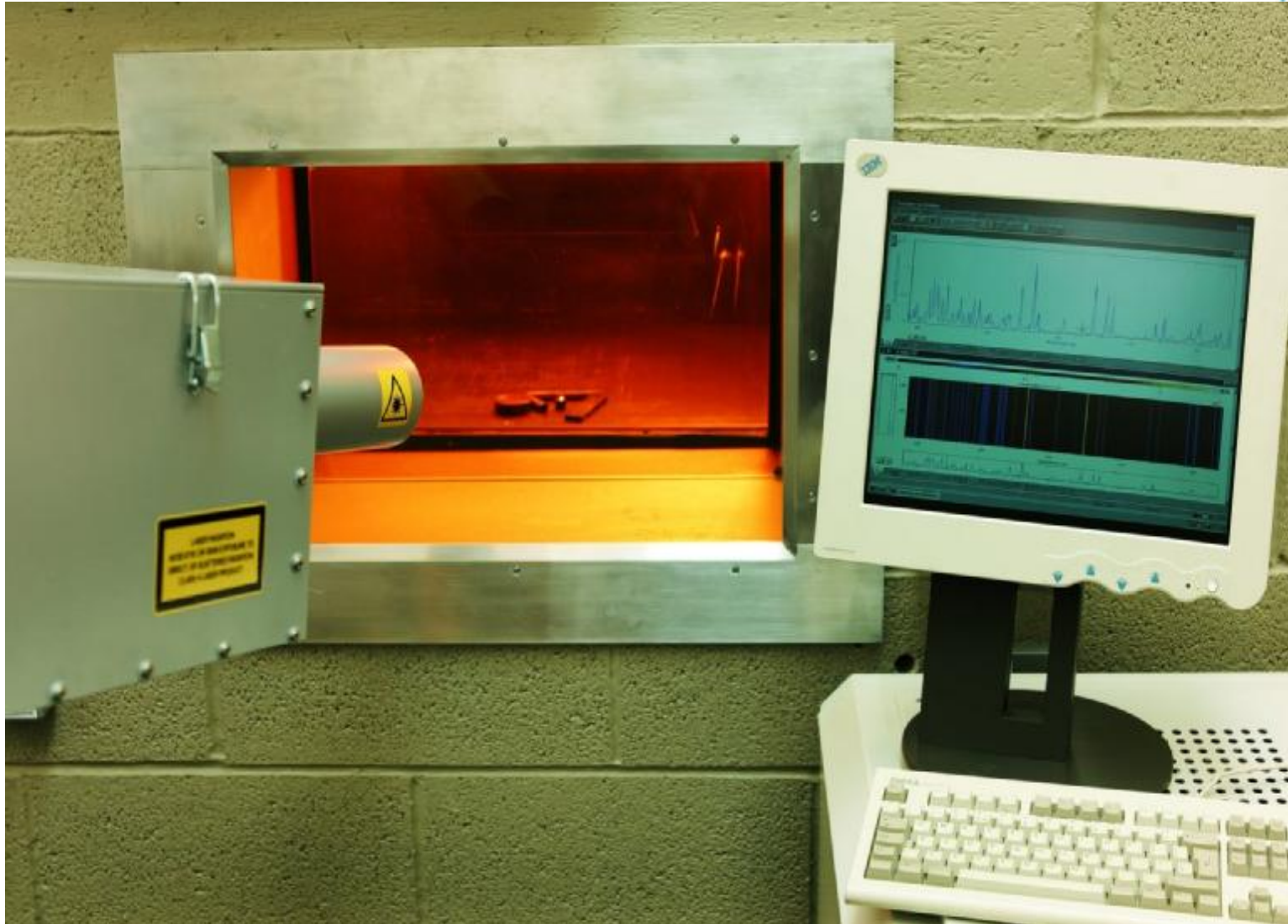
## Qualitative measurements by LIBS



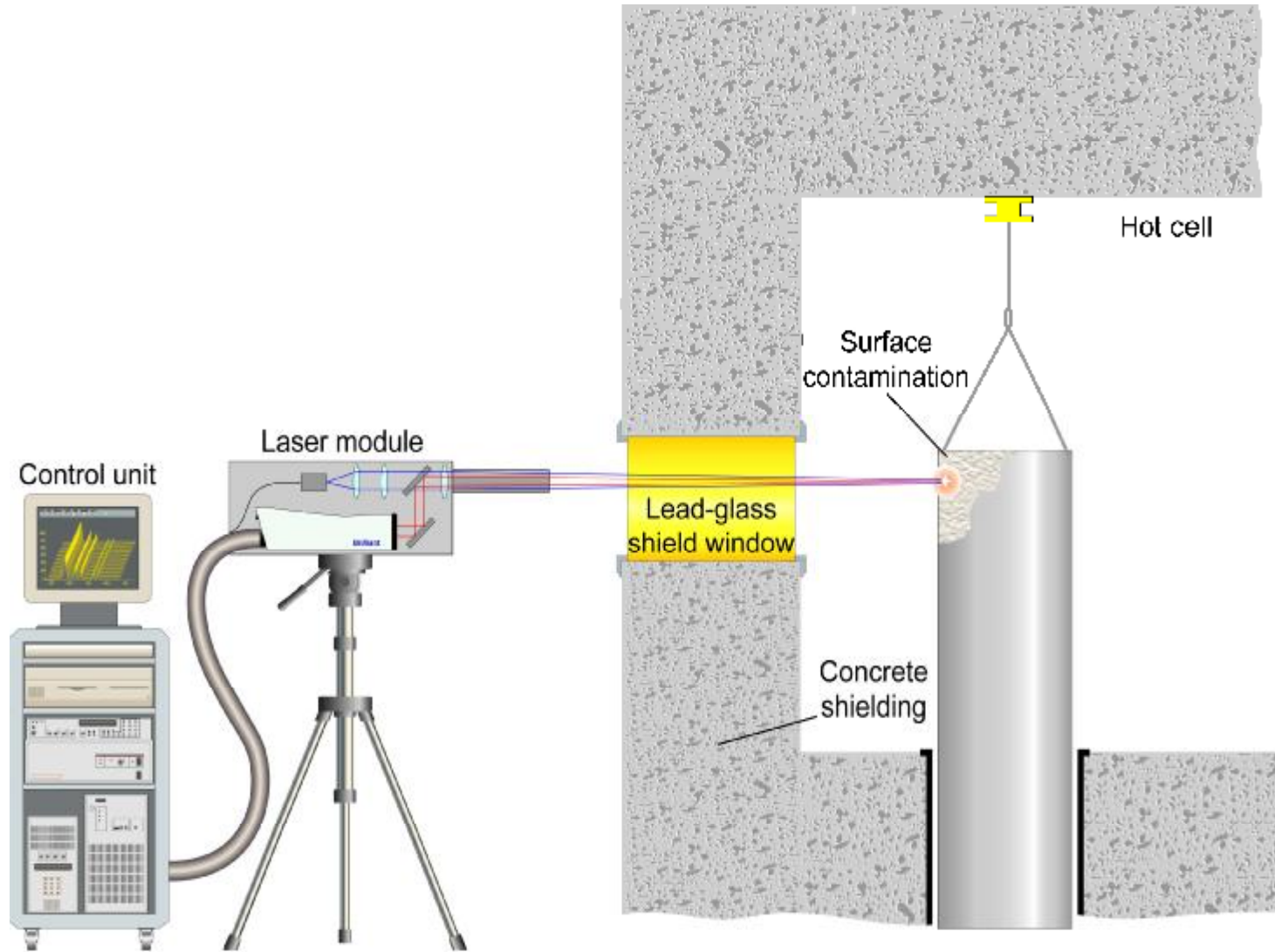
THORP spent-fuel reprocessing plant  
BNFL Sellafield, Cumbria, United Kingdom

**Remote, non-invasive compositional analysis  
of surface (gross) contamination**

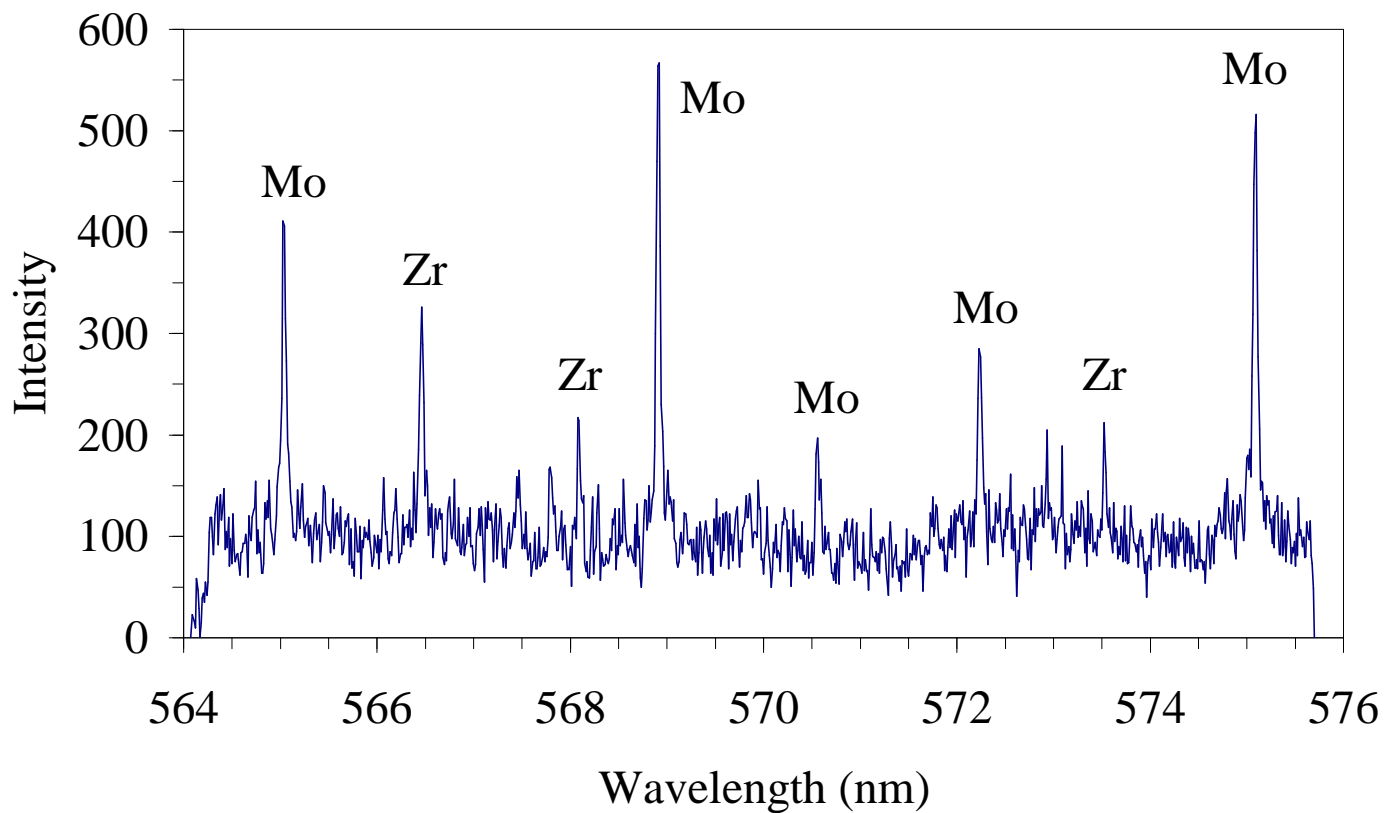
## ‘Through-Window’ deployment of a Telescope LIBS instrument



## Deployment of a telescope LIBS instrument at the Thorp spent-fuel reprocessing plant



# LIBS emission spectrum of contaminant material





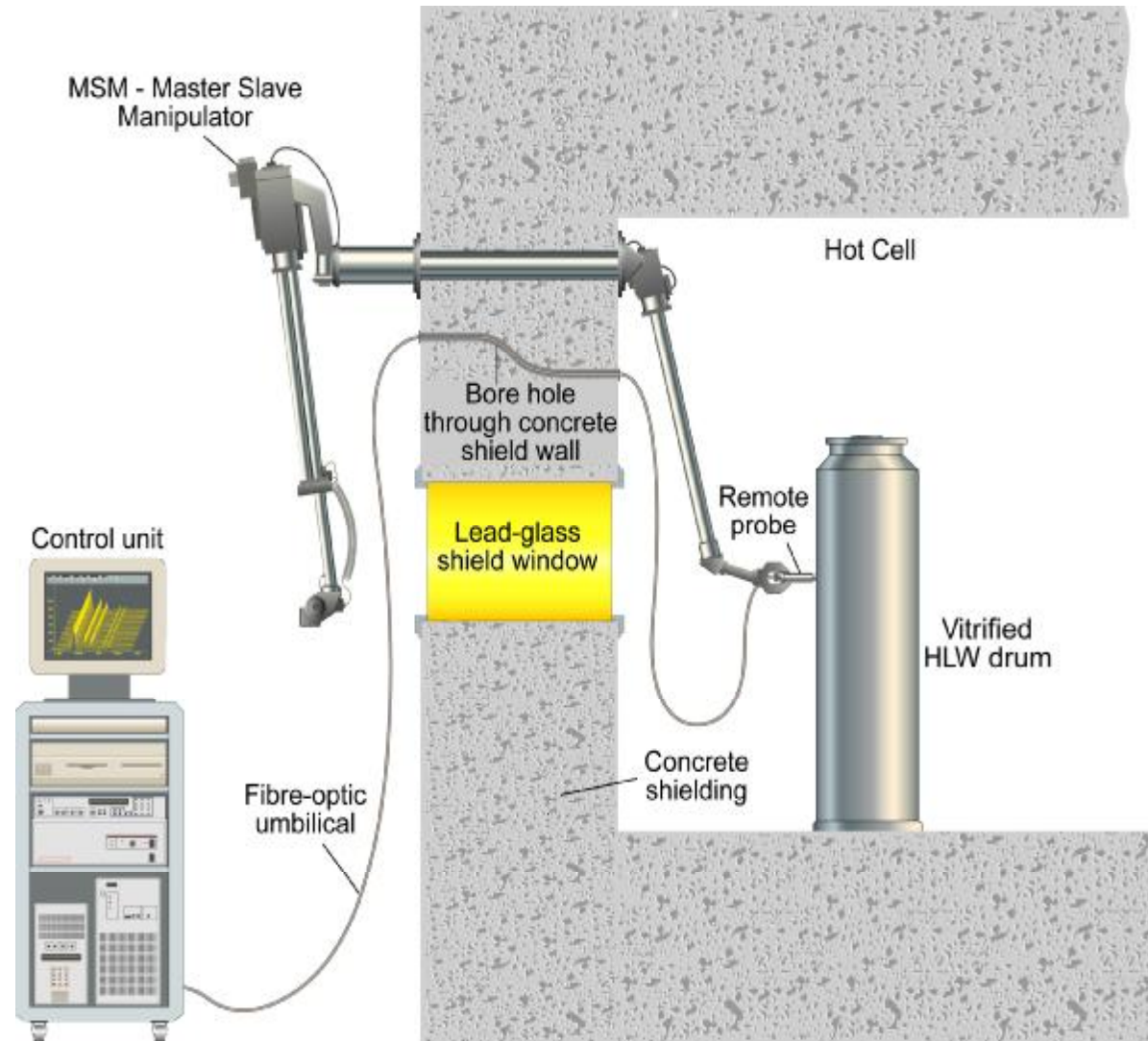
# Qualitative measurements by LIBS



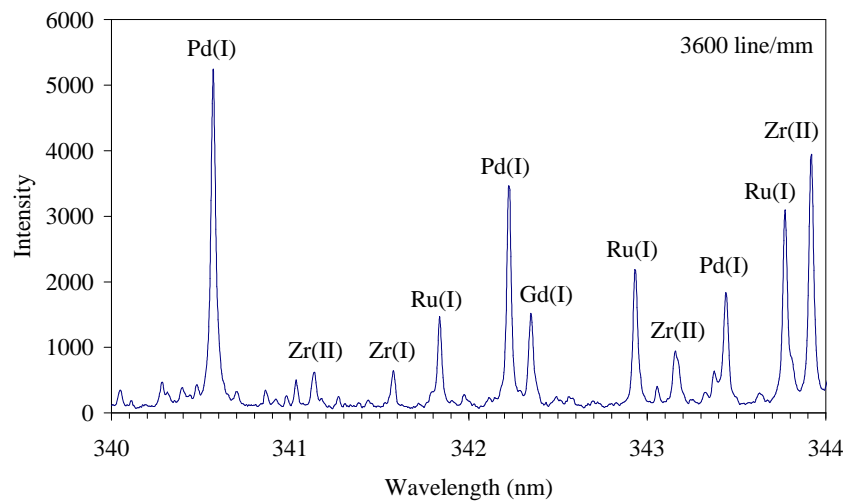
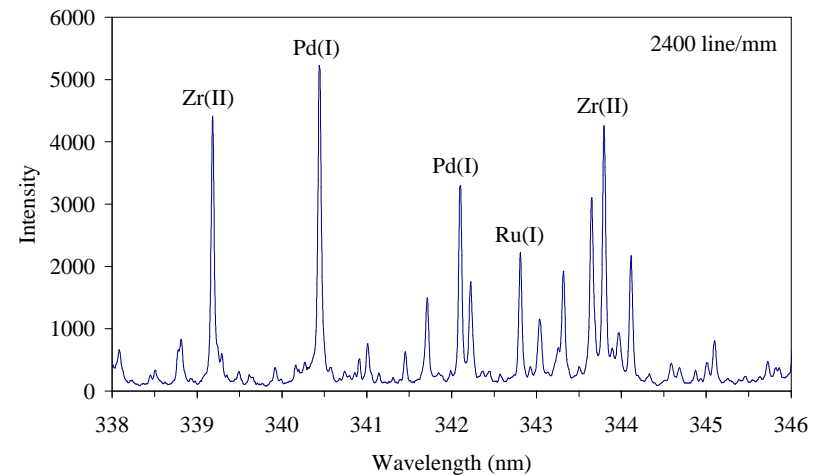
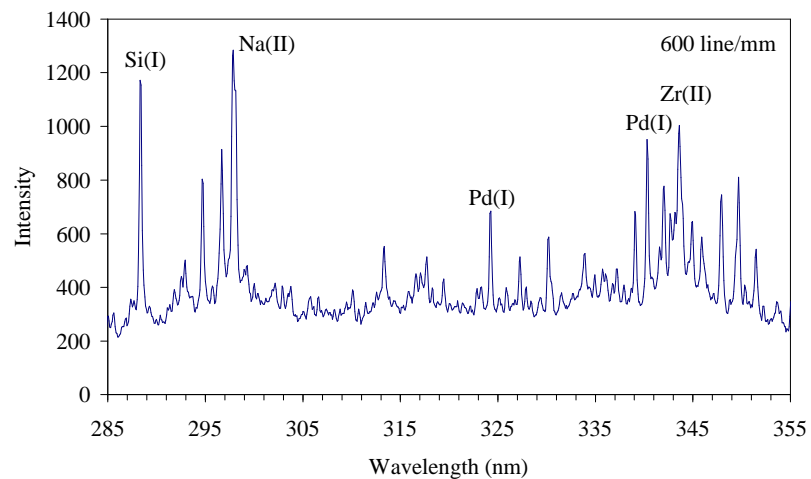
HLW Vitrification Plant  
BNFL Sellafield, Cumbria, United Kingdom

**In-situ detection of “fixed” surface  
contamination on HLW drums**

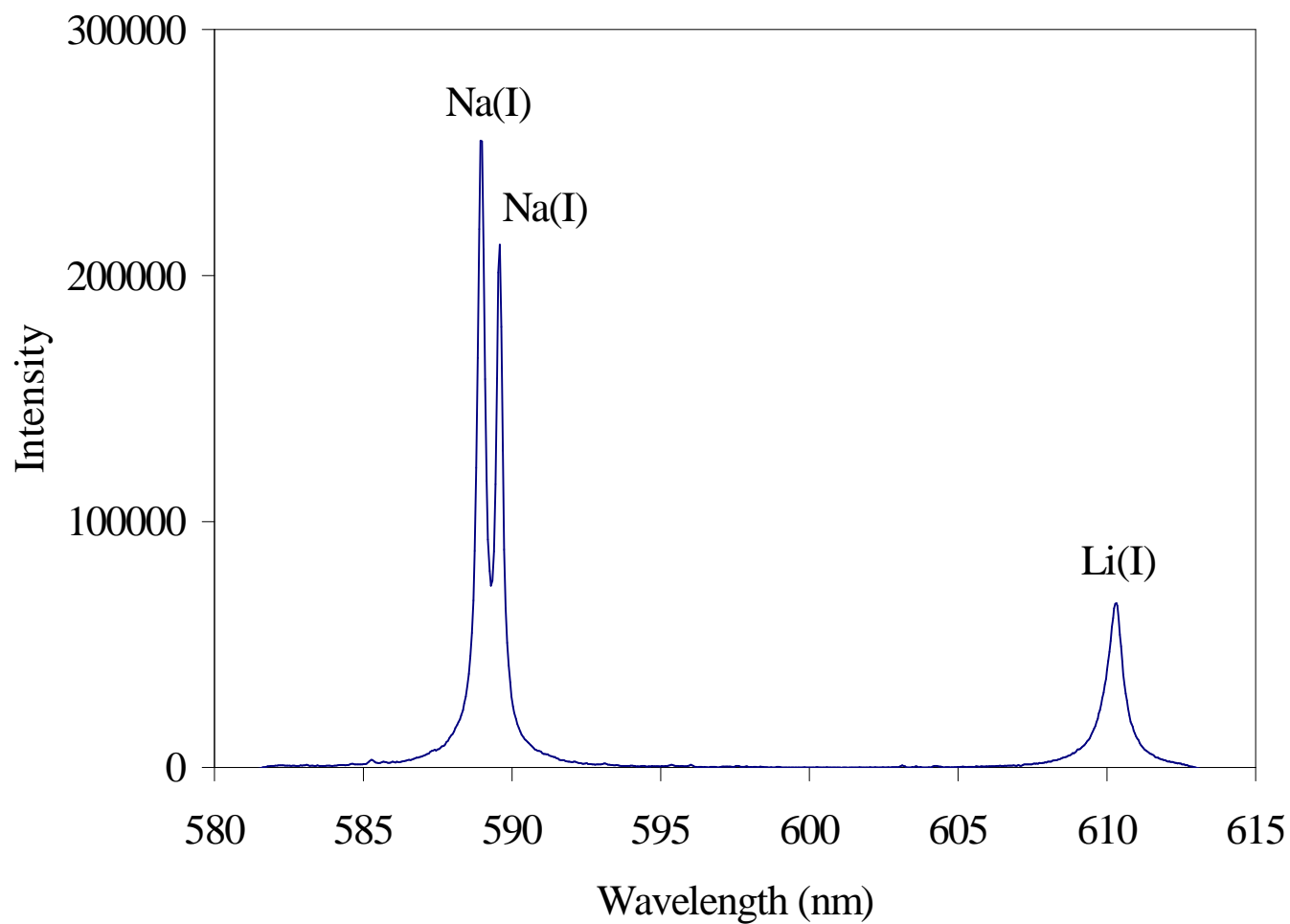
## Deployment of a fibre-optic LIBS instrument at a HLW vitrification plant



# LIBS emission spectra of vitrified HLW



## LIBS emission spectrum of vitrified HLW showing intense sodium (Na) and lithium (Li) atomic emission lines





# Quantitative measurements by LIBS



HLW Vitrification Plant  
BNFL Sellafield, Cumbria, United Kingdom

**In-situ measurement of the calcine (fission-product)  
content of HLW residues**



## **In-situ measurement of the calcine (fission-product) content of HLW residues**

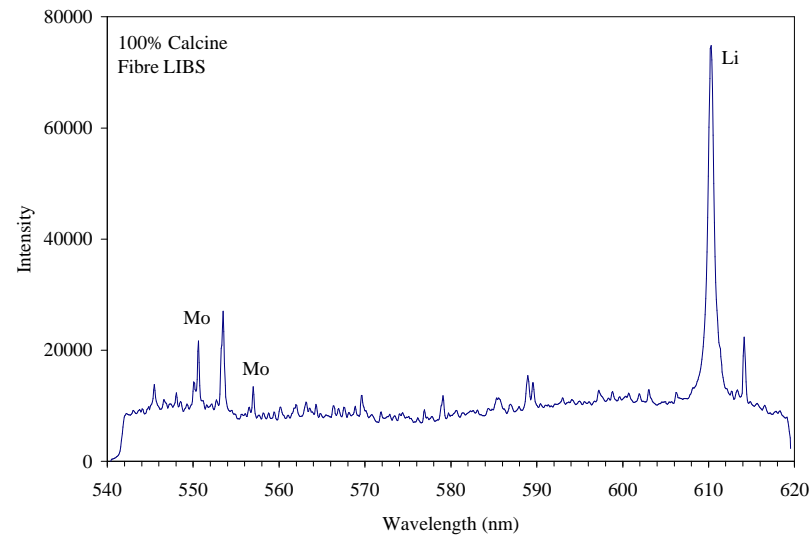
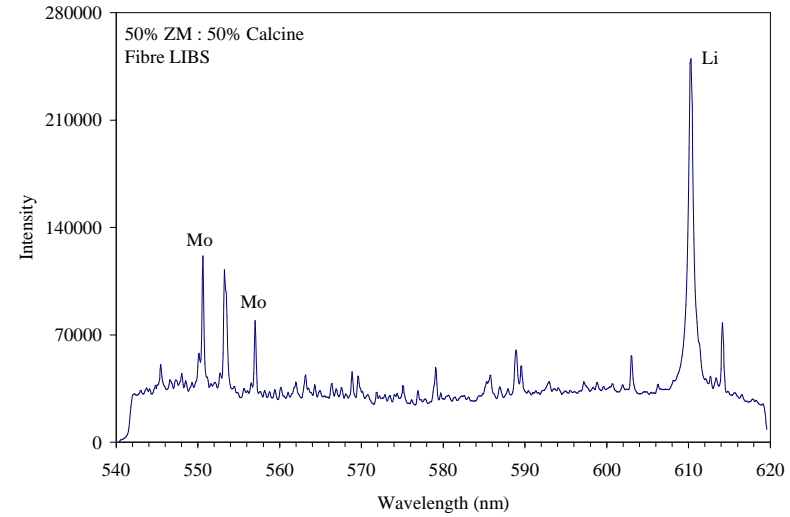
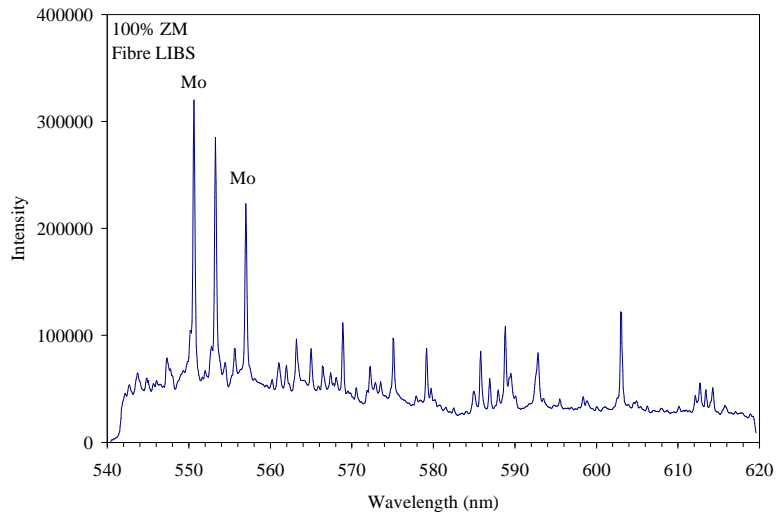


### **LIBS instrument calibration**

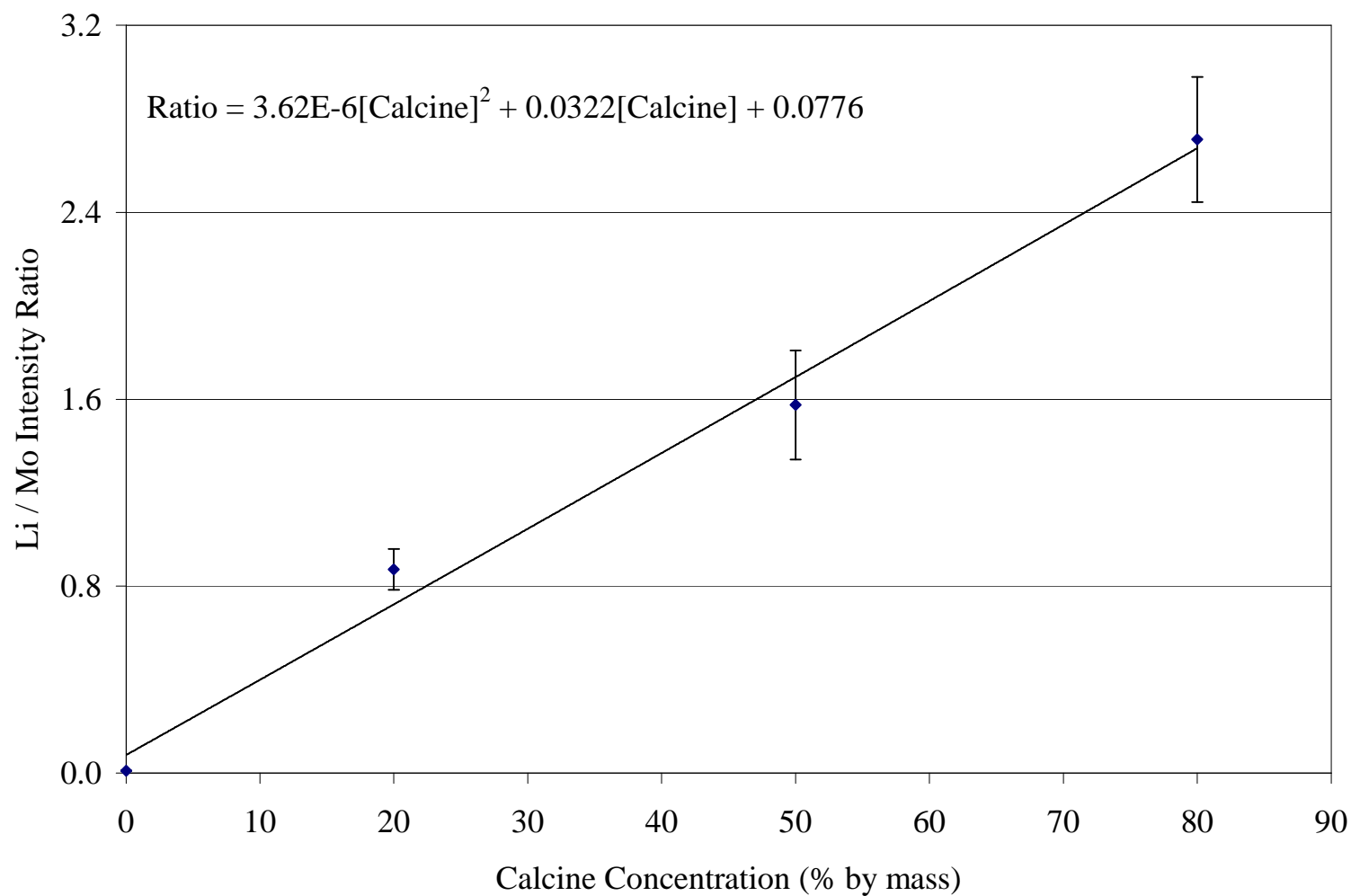
Lithium (Li) used as an indicator of calcine (fission-products)

Molybdenum (Mo) used as an indicator of the residue matrix material

# Calibration using inactive simulatates



## Calibration curve obtained using the fibre-optic probe LIBS instrument





## Summary



- LIBS is able to remotely characterize the elemental composition of virtually any material (solids, liquids and gases)
- Non-invasive or remote probe methods of deployment
- Essentially non-destructive
- No sample preparation necessary
- Can be deployed in hostile environments including very high radiation areas (e.g. HLW plants)
- Rapid deployment and rapid measurements
- Qualitative, semi-quantitative and quantitative measurements

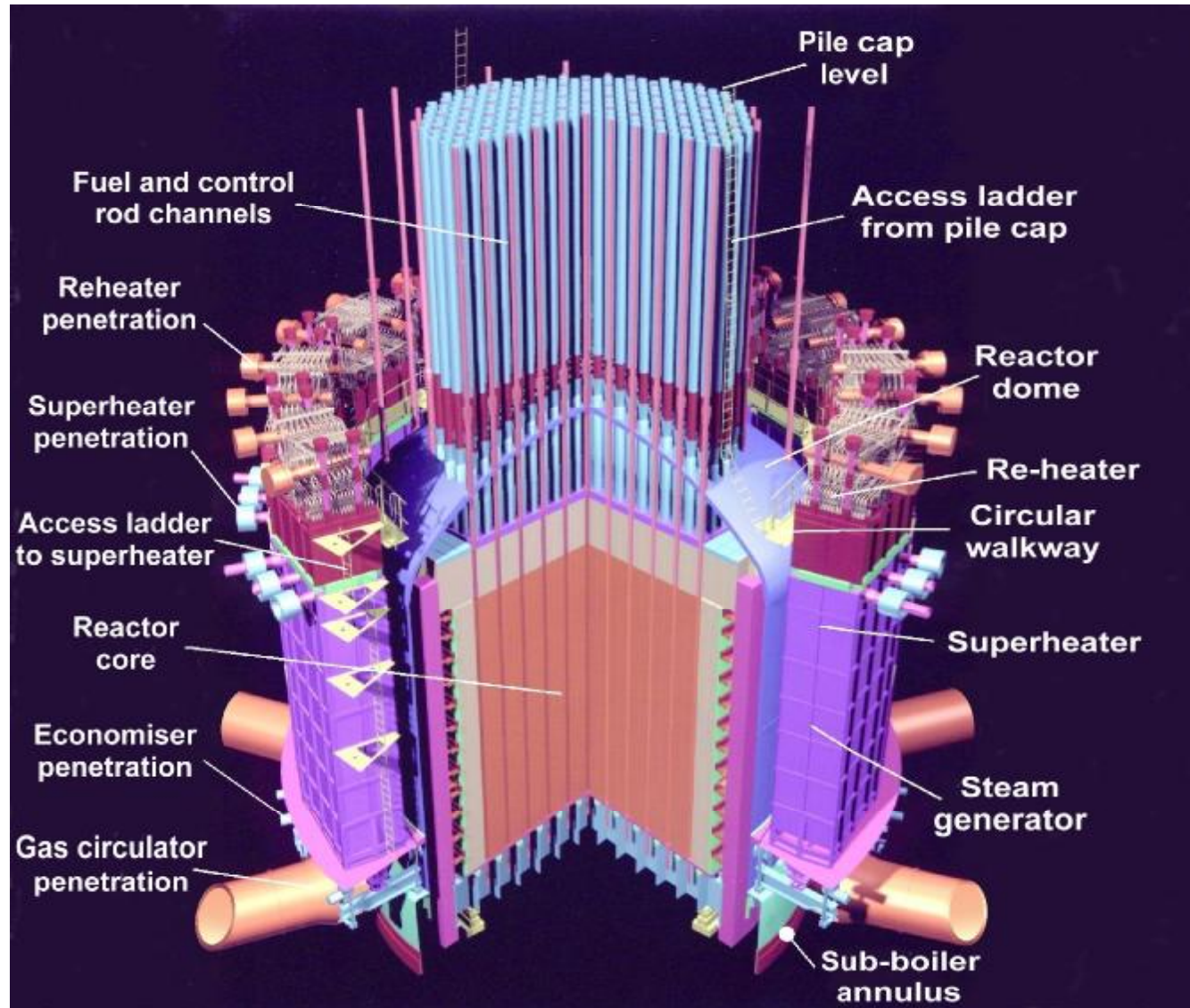


## Examples of other nuclear applications of LIBS undertaken by Applied Photonics Ltd

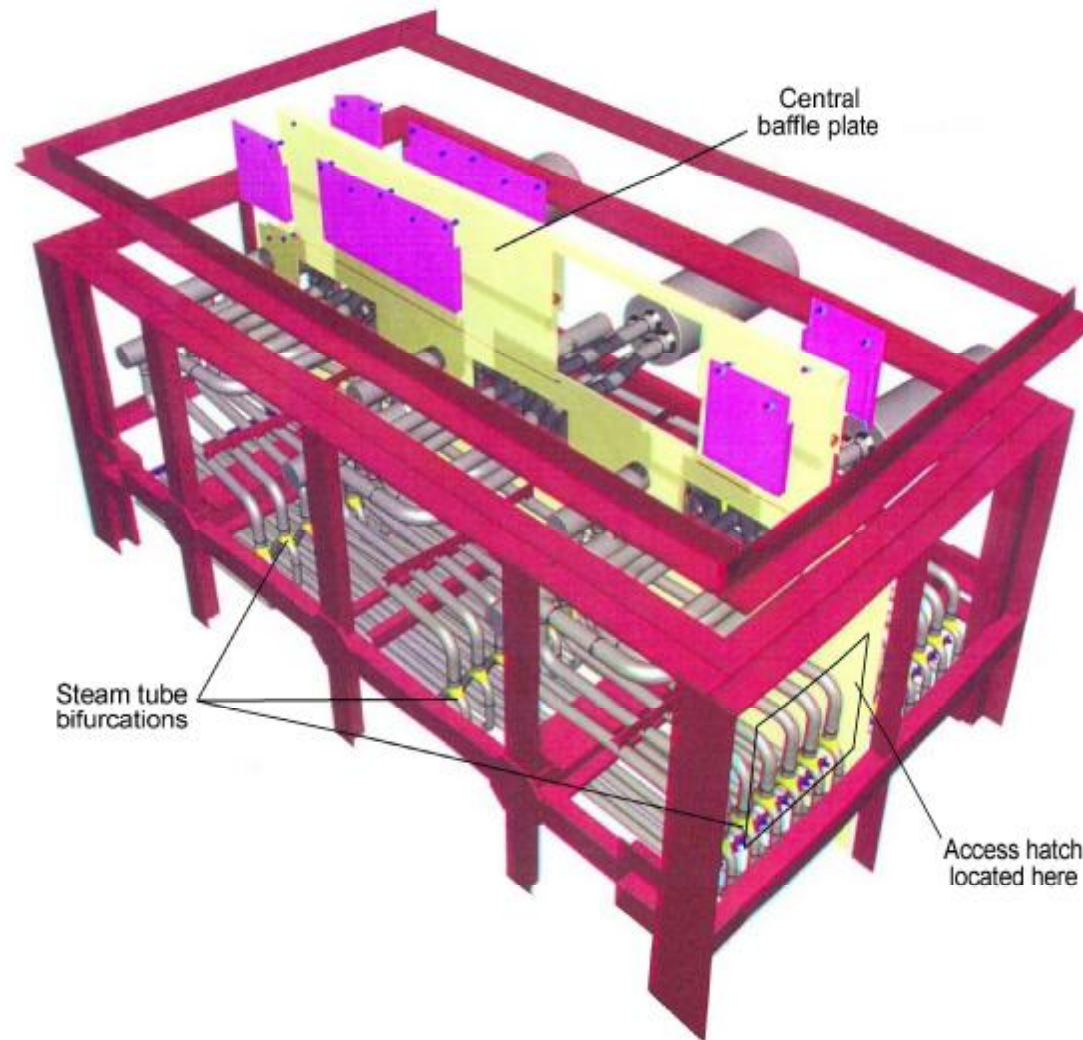


- Fibre-optic LIBS instrument used for in-situ compositional analysis of superheater steam tube bifurcations within the pressure vessel of an Advanced Gas-Cooled Reactor (AGR) nuclear power station. The instrument used a 75 metre fibre-optic umbilical connected to a remote probe which was manually deployed within the reactor pressure vessel. The instrument was used to measure the copper content of the 316H stainless steel superheater tubes as part of an inspection campaign to locate tubes manufactured from a certain type of steel.
- 30 metre umbilical fibre-optic probe LIBS instrument used to measure the chromium content of economiser tubes within the Sub-Boiler Annulus (SBA) of an AGR reactor pressure vessel. The instrument was used as part of an inspection campaign to identify tubes manufactured from steel containing less than ~0.1% chromium (these tubes being at increased risk of damage through the effects of erosion-corrosion).
- Telescope LIBS instrument used to identify reinforcing bars and cooling water tubes within the concrete pressure vessel of Wylfa (Magnox) nuclear power station.

## Fibre-optic probe LIBS instrument used to analyse the composition of superheater tubing within the pressure vessel of an AGR nuclear power station



## CAD view of an AGR superheater showing location of superheater steam tube bifurcations



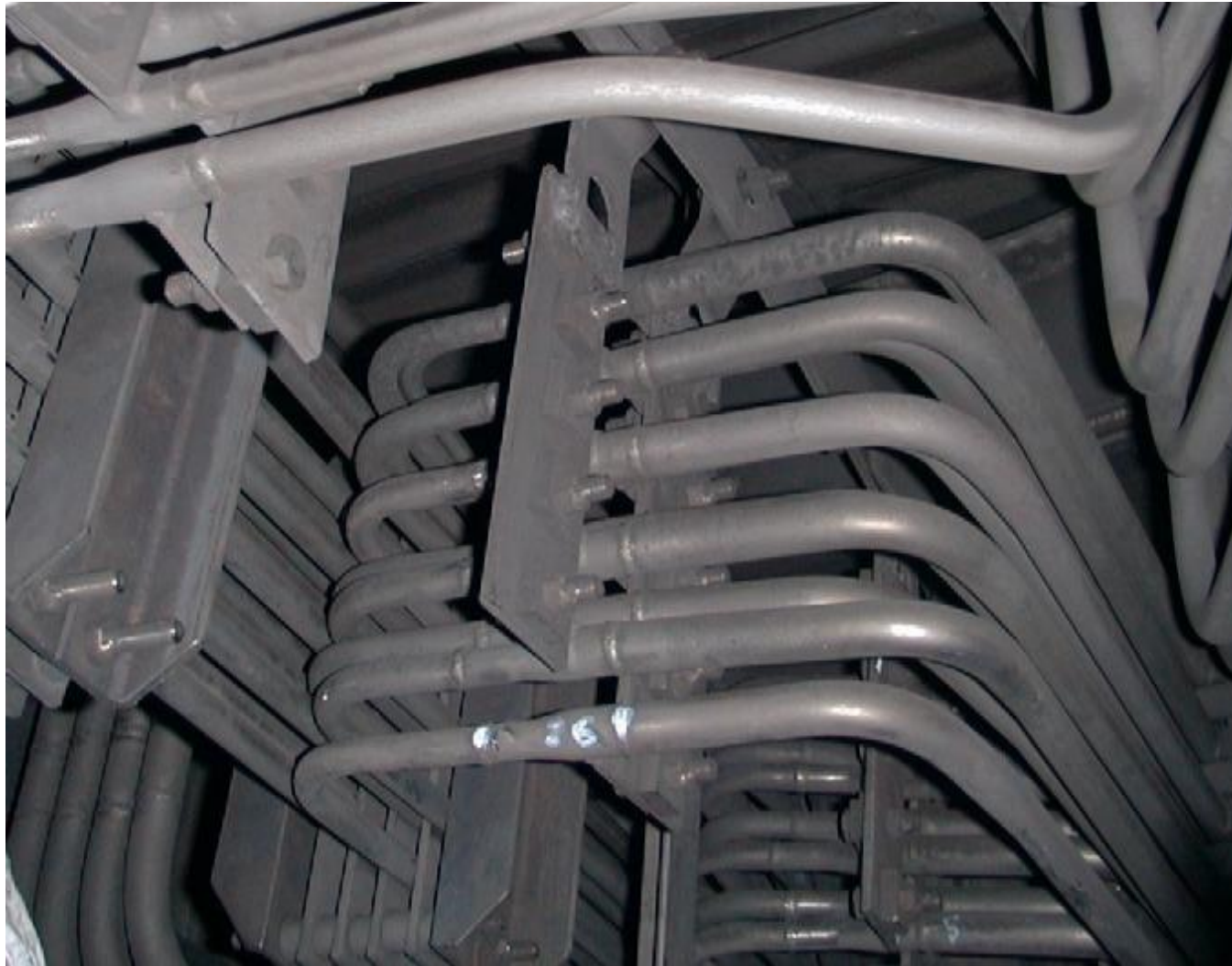


## Deployment of the remote probe of the fibre-optic LIBS instrument within an AGR superheater





**Fibre-optic probe LIBS instrument used to measure the chromium content of economiser tubes within the Sub-Boiler Annulus of an AGR reactor pressure vessel**





## Deployment of the remote probe of the fibre-optic LIBS instrument within the Sub-Boiler Annulus of an AGR reactor pressure vessel

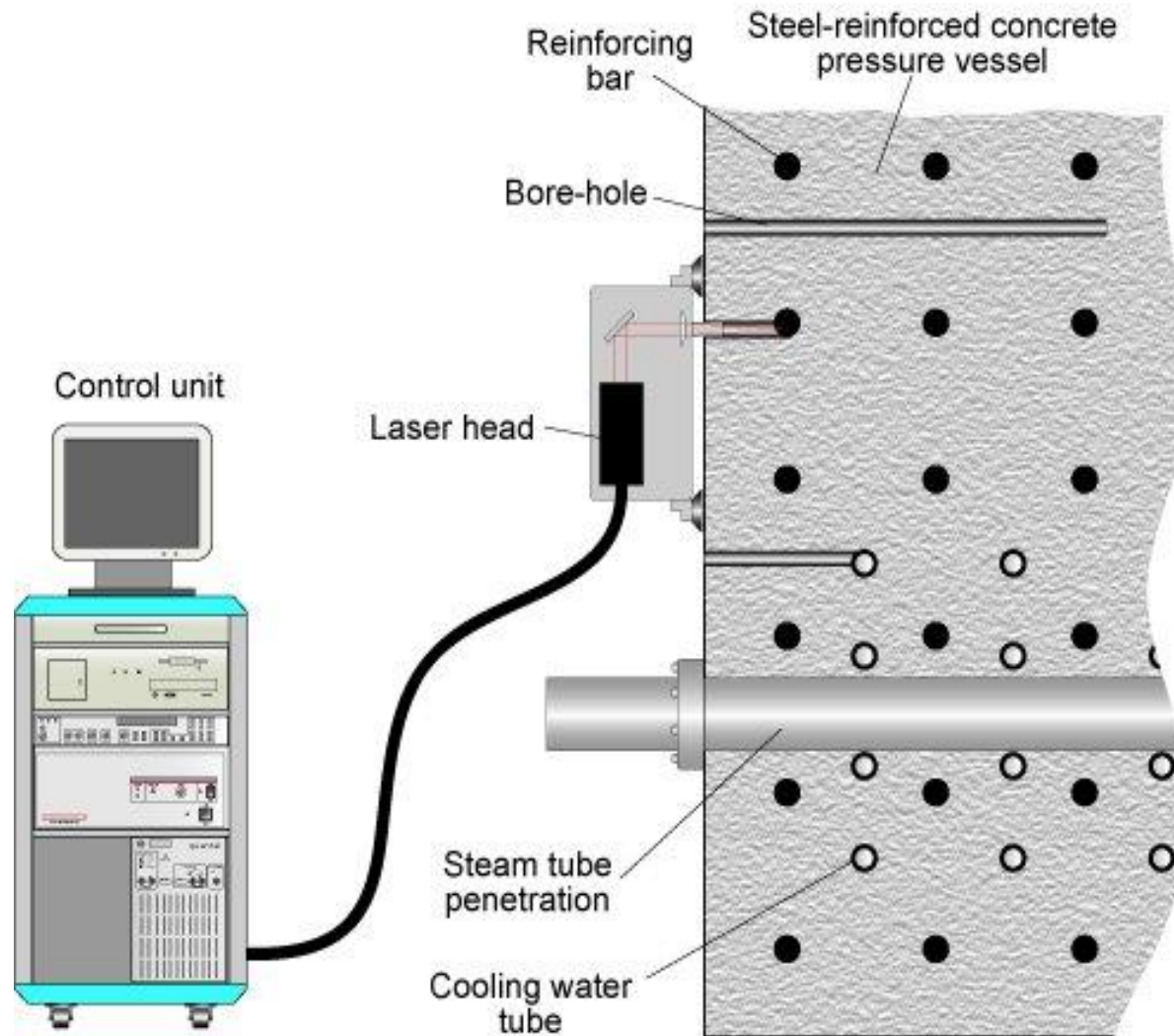




## Wylfa (Magnox) nuclear power station Anglesey, North Wales, UK



## Telescope LIBS instrument used at Wylfa Power station to distinguish reinforcing bars from cooling water tubes within the concrete pressure vessel wall of the reactor



## Deployment of the LIBS instrument at Wylfa nuclear power station

