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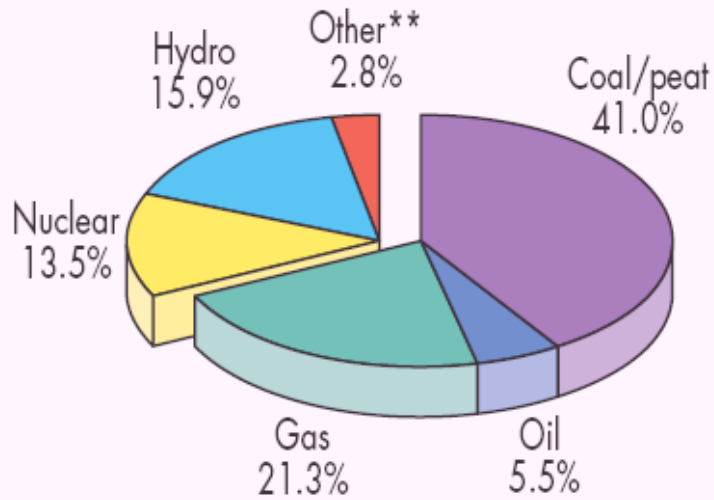


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Elemental analysis of coal by means of the Laser Induced Breakdown Spectroscopy (LIBS) technique

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Why coal analysis?



2008 fuel shares of electricity generation

Coal characteristics do have a direct impact on the operation of industrial boilers.

Coal is the combustion fuel most widely used for electricity generation in the world.



Influence of coal composition on boilers



Existing solutions

Real time coal elemental analysis is presently carried out by means of:

- ➡ *PGNAA (Prompt Gamma Neutron Activation Analysis)*
- ➡ *XRF (X Ray Fluorescence)*
- ➡ *PFTNA (Pulsed Fast Thermal Neutron Analysis)*



PGNAA Station

Drawbacks

- *Cumbersome apparatuses*
- *Need of a radioactive source*
- *Ionizing radiations*

Proposed solution ➡ *LIBS*

Proposed solution

Coal elemental analysis by means of LIBS



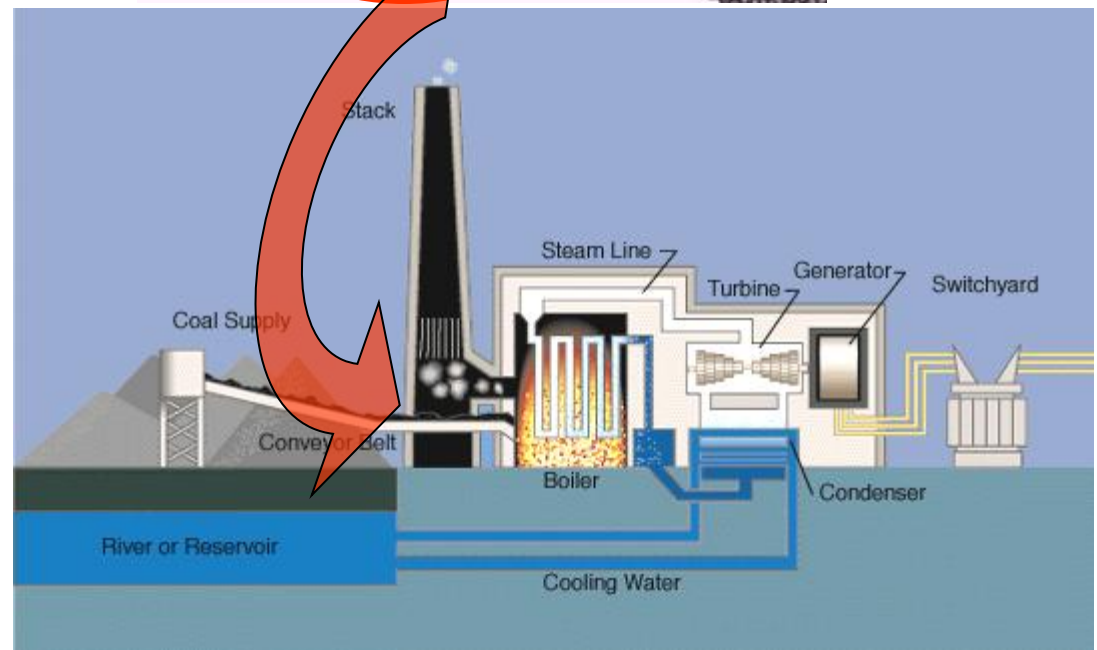
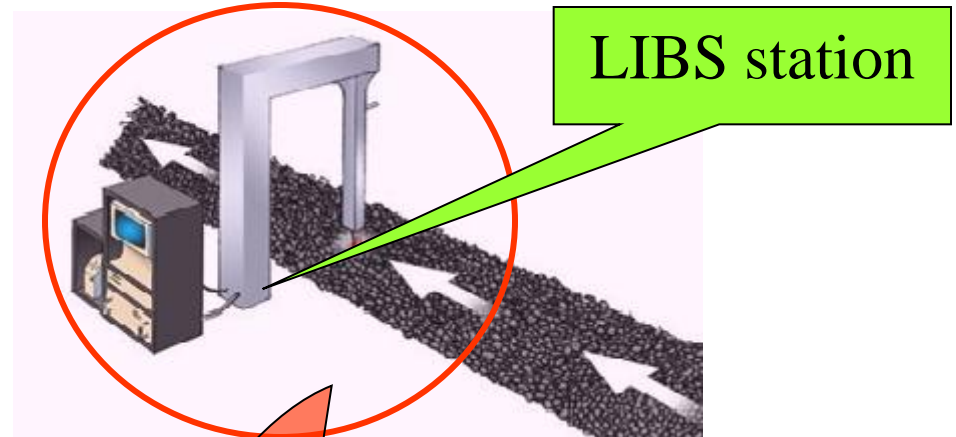
Determination of combustion parameters by means of neural network techniques



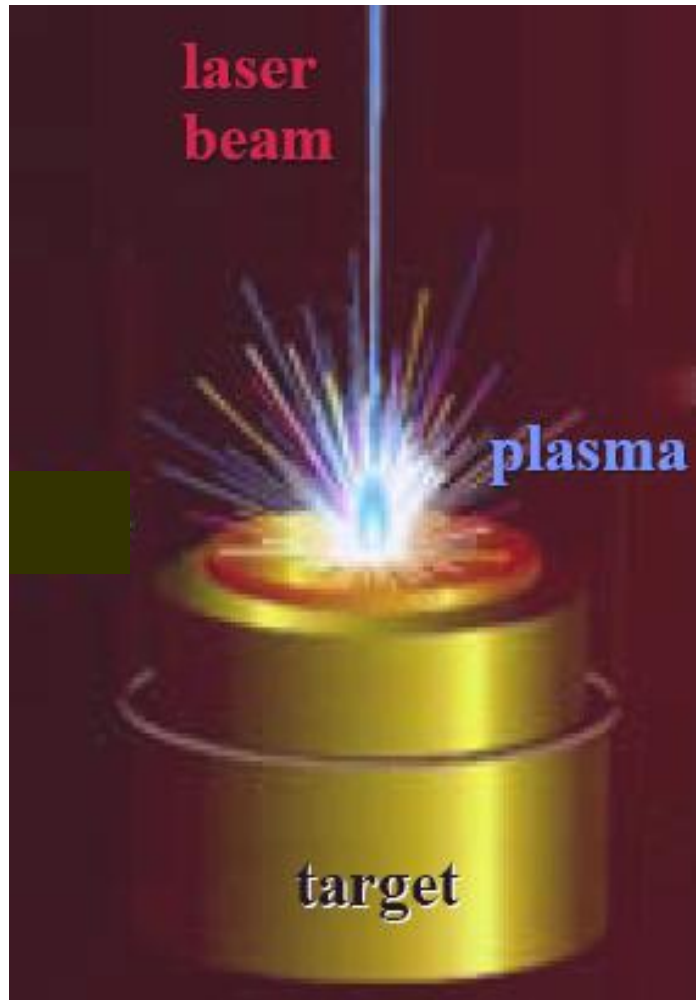
Control of the combustion process



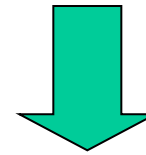
Optimization of boiler operations



LIBS Technique: principle of operation

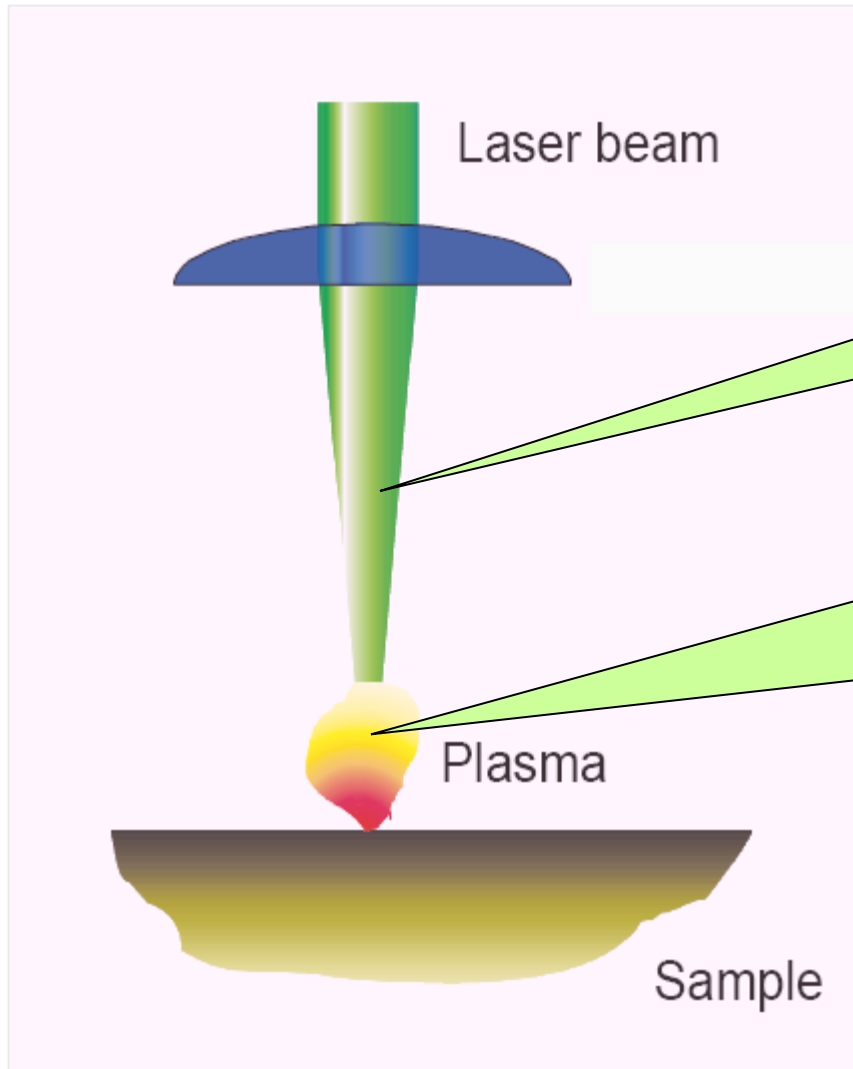


Laser Induced Breakdown Spectroscopy (LIBS) is a laser based non intrusive Emission Spectroscopy Technique



- *A pulsed laser beam is focused on the test point to produce a spark*
- *The spark generates a plasma that excites atomic elements in the focal volume*
- *Atomic emission from the plasma is collected and spectrally analyzed*
- *From the intensities of the atomic emission lines it is possible to determine the concentration of the atomic species*

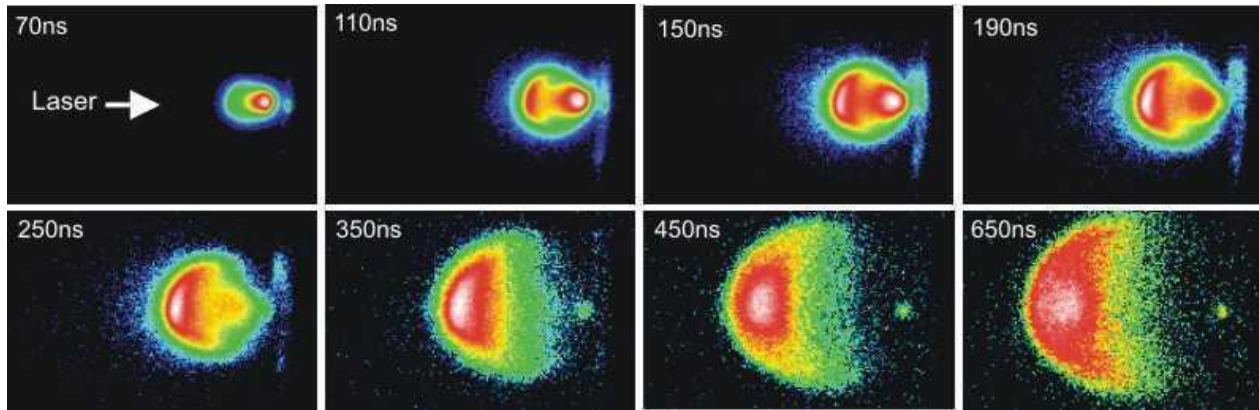
LIBS Technique: typical parameters



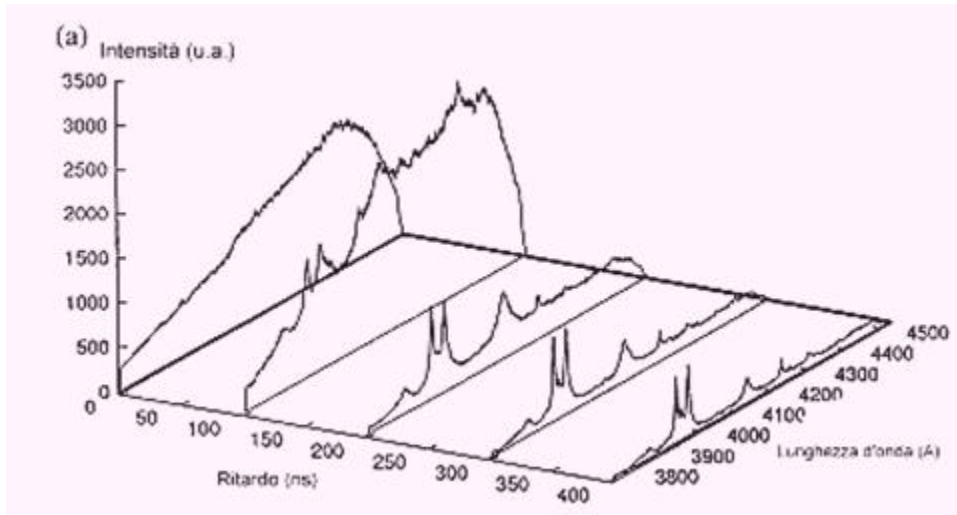
- ☀ *Pulse Energy: 10 – 1000 mJ*
- ☀ *Pulse Duration: 5 – 50 ns*
- ☀ *Wavelength: UV, VIS, IR*

- ☀ *Irradiance: 10–100 GW/cm²*
- ☀ *Initial Temperature: $\approx 10^7$ °C*
- ☀ *Electronic Density: 10^{16} - 10^{20} cm⁻³*
- ☀ *Electric Field: $\approx 10^8$ V/cm*

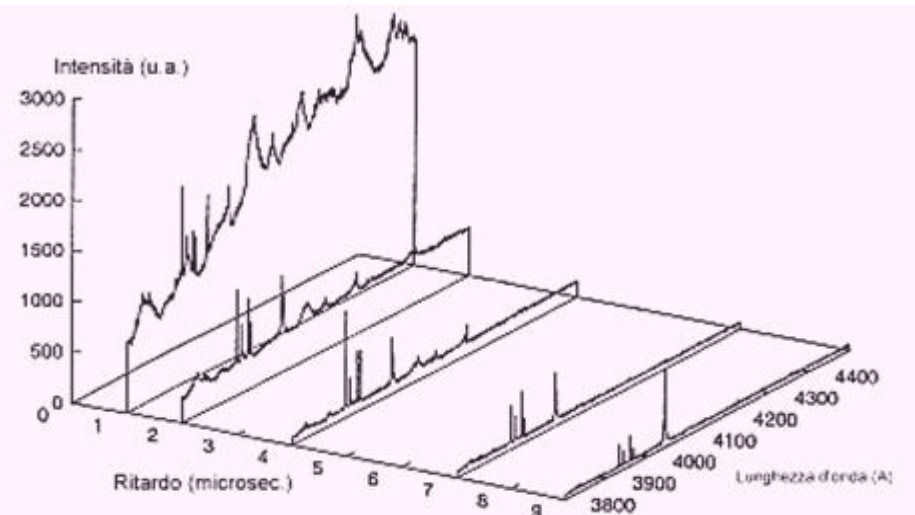
LIBS Technique: temporal evolution



ICCD photographs of visible emission from laser-produced Si plasma at 5 GW cm⁻² average laser intensity and 500 mTorr He background gas.

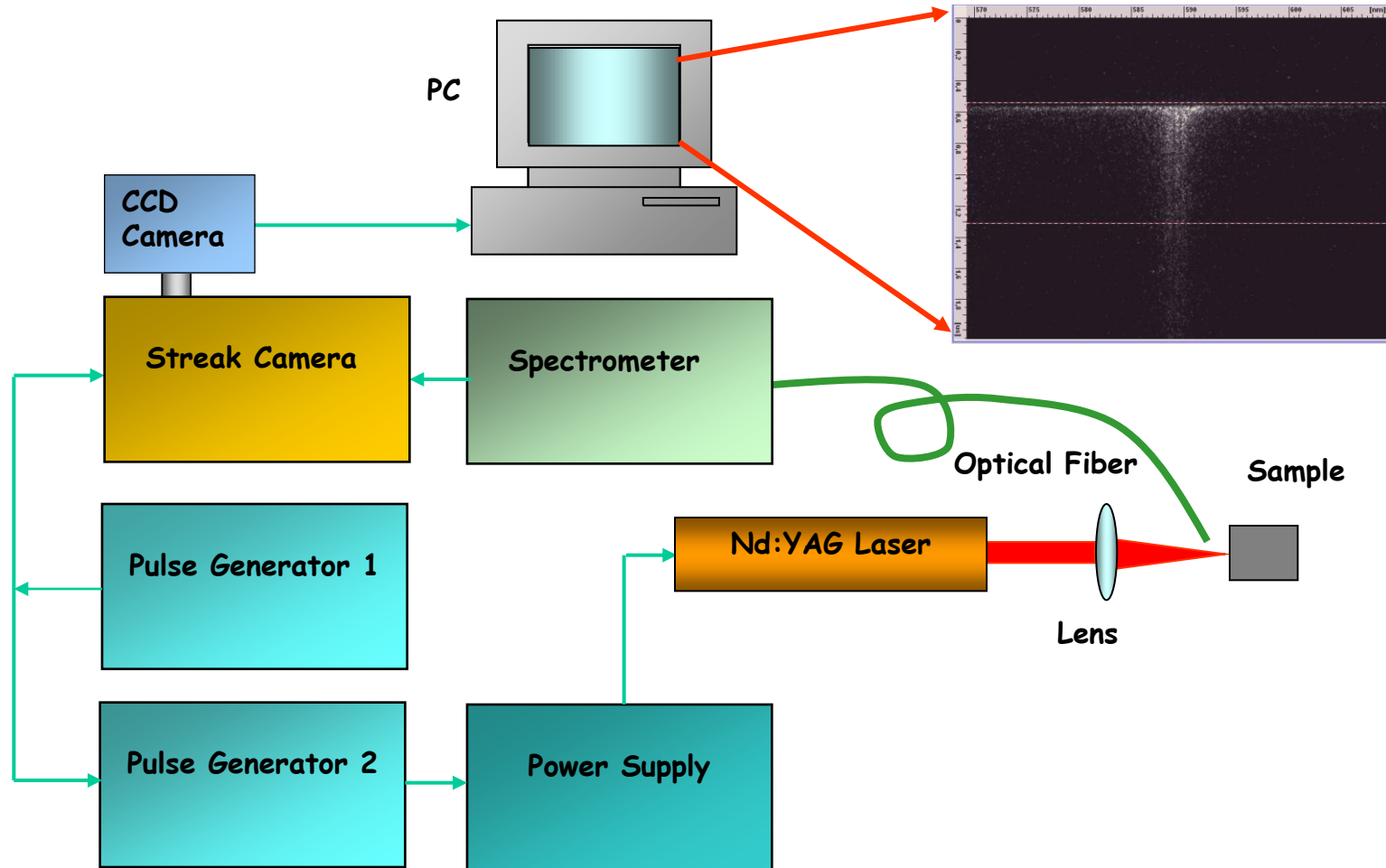


Laser pulse @ λ = 308 nm



Laser pulse @ λ = 1064 nm

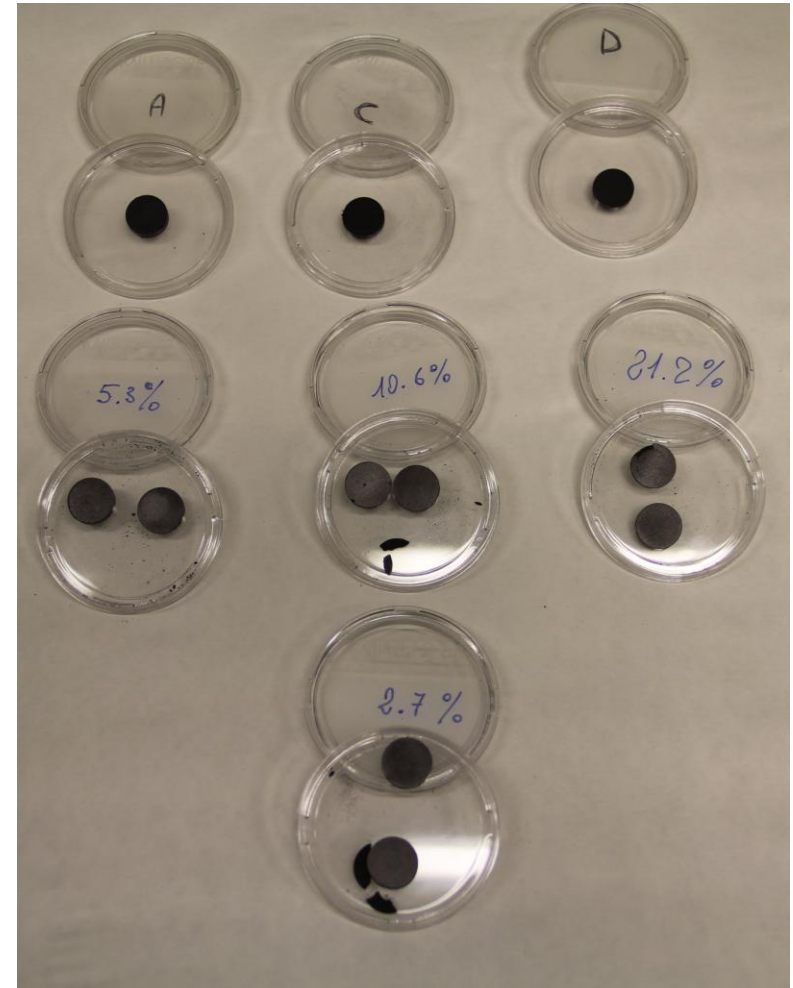
Experimental apparatus



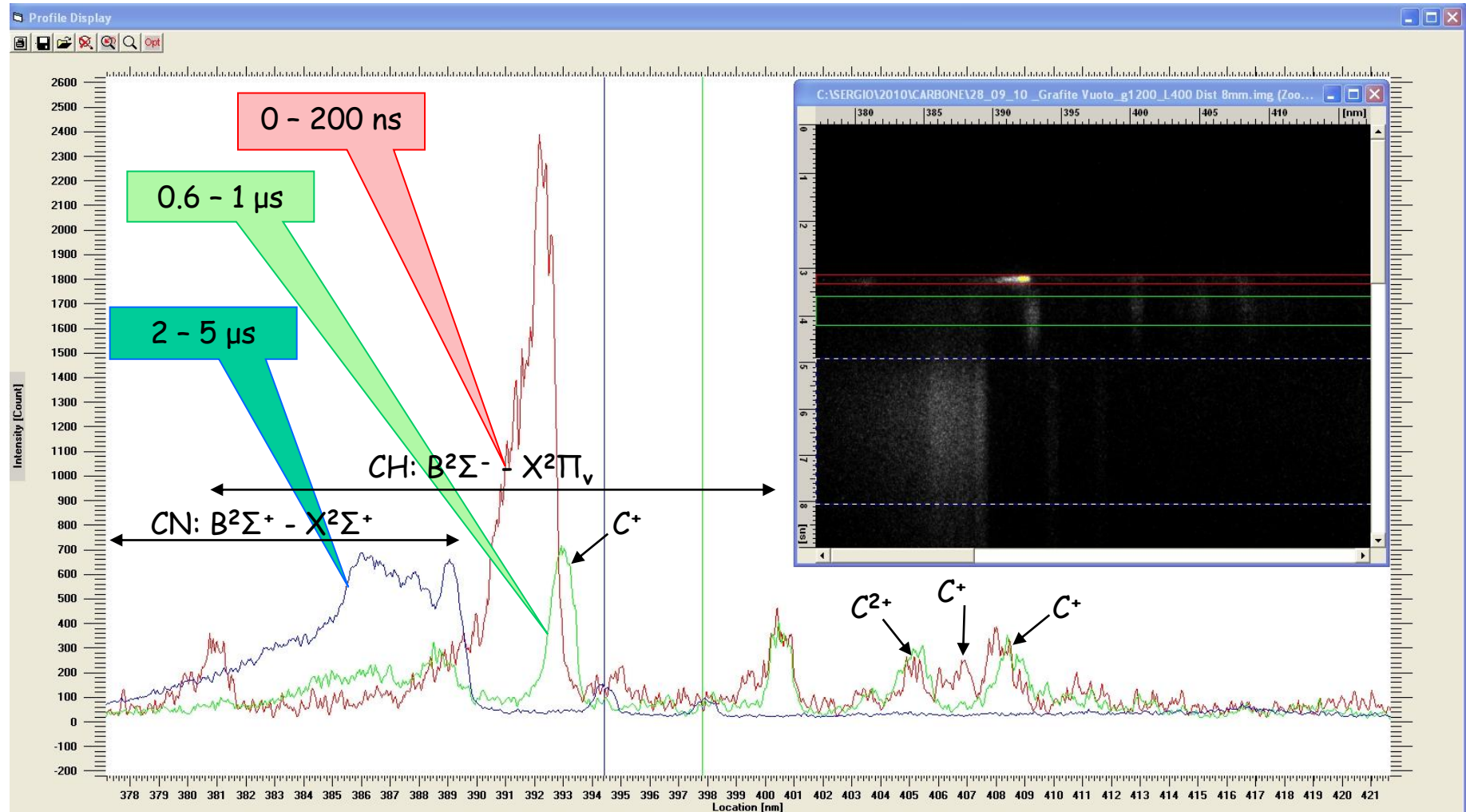
Preliminary measurements

Measurements have been carried out on:

- ② *Pure graphite*
- ② *Compressed pellets made by a mixture of Graphite and Alumina powders*
- ② *Coal samples*

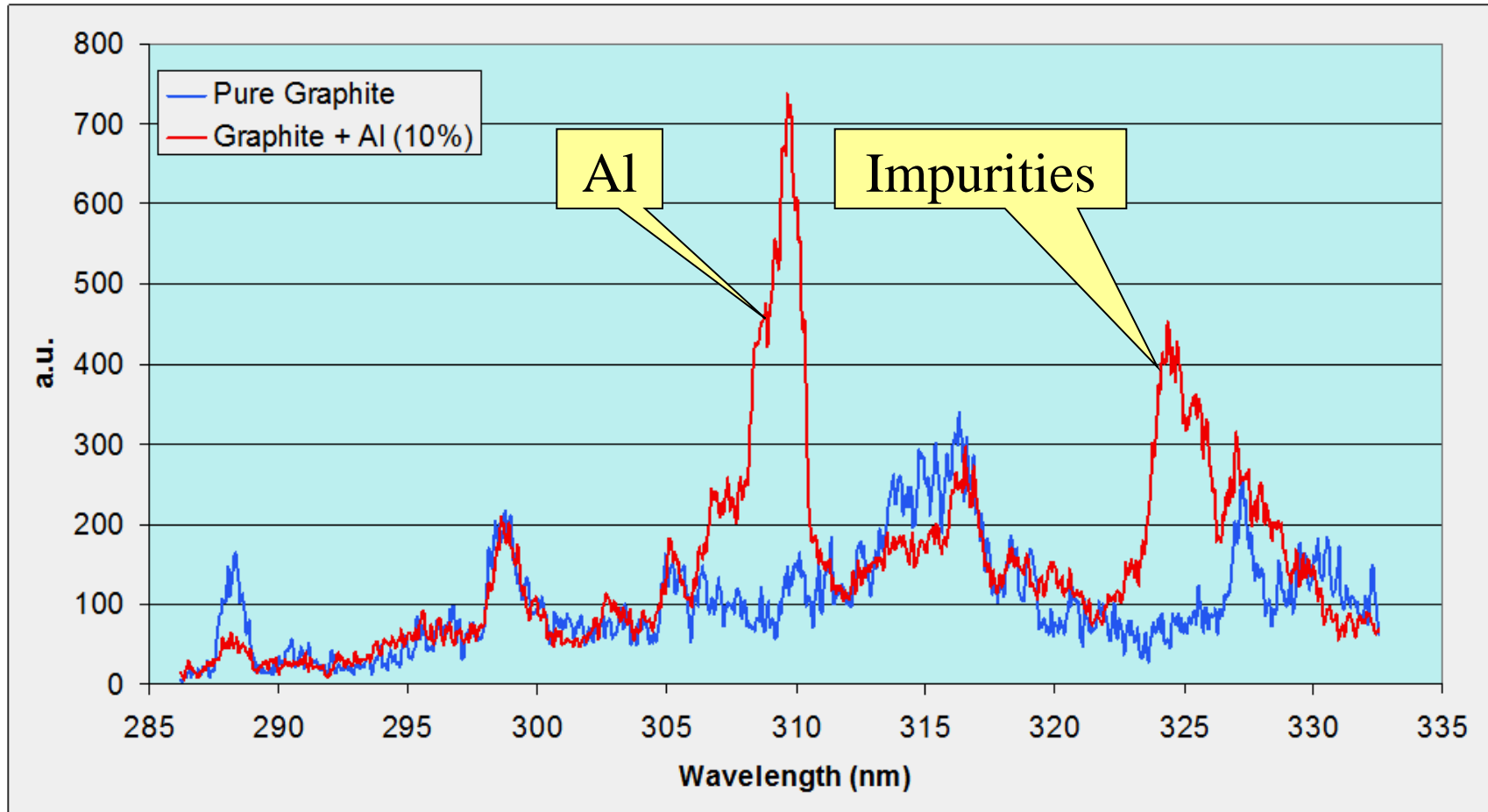


Measurements on graphite samples



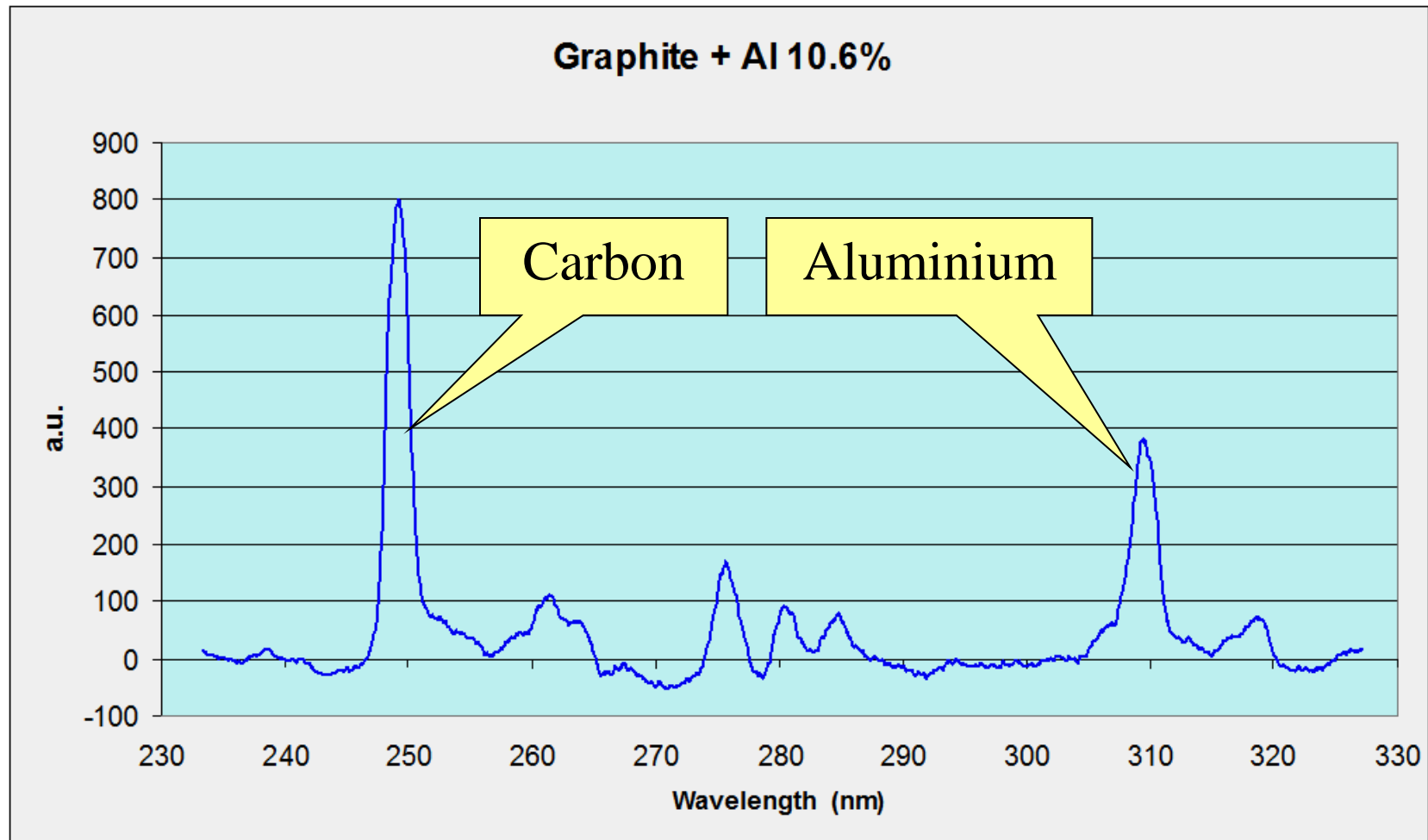
● *Measurements on a graphite sample @ different delays*

Measurements on Graphite +Alumina pellets



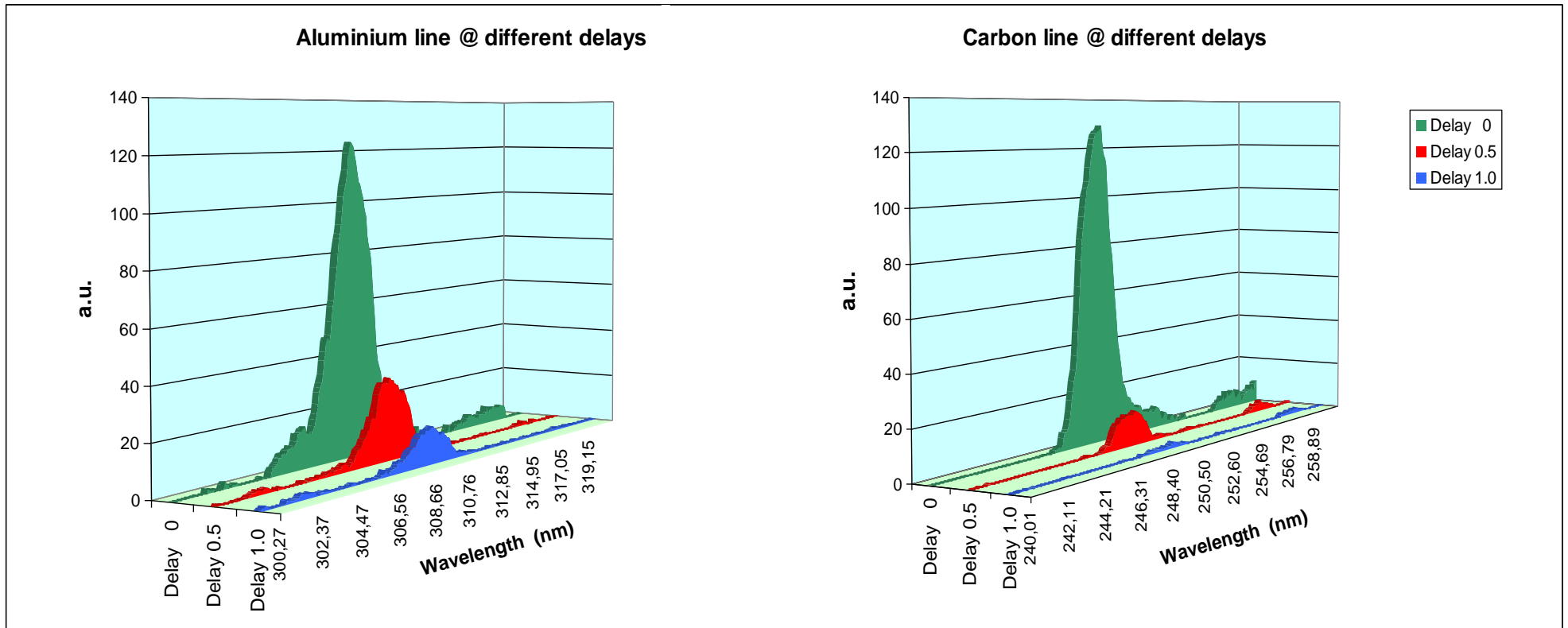
● *The Aluminium line can easily be identified in the graphite spectrum*

Preliminary evaluation of concentration



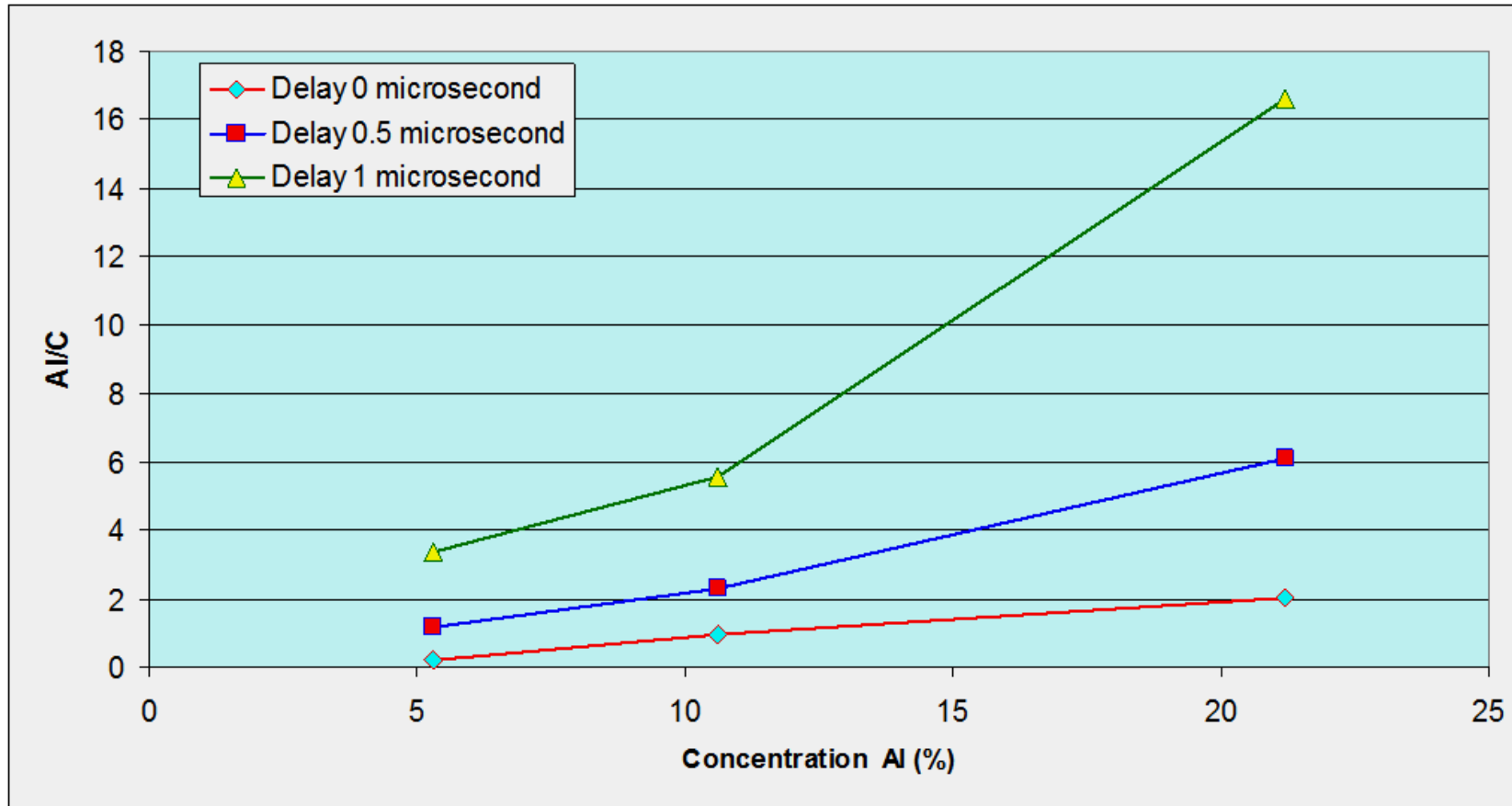
- *Aluminium concentration can be expressed in terms of Al/C ratio*

Line intensity evolution as a function of time



● *Carbon line decreases more rapidly than the Aluminium line*

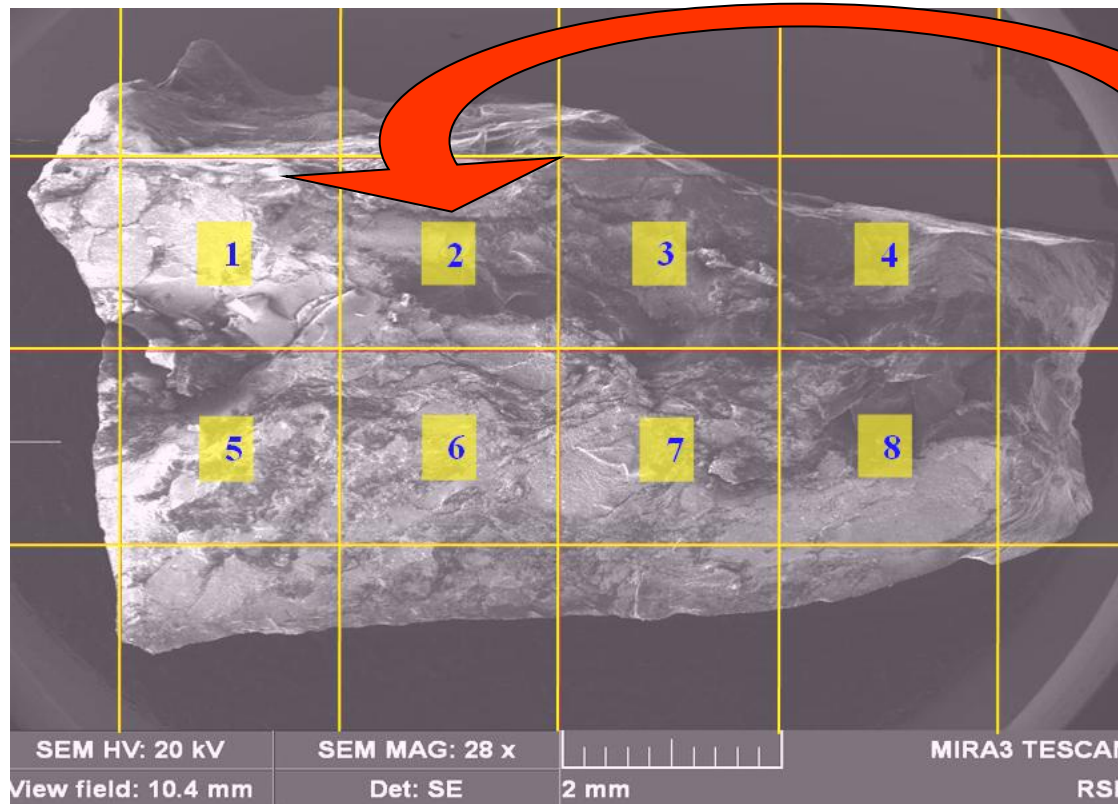
Preliminary evaluation of concentration



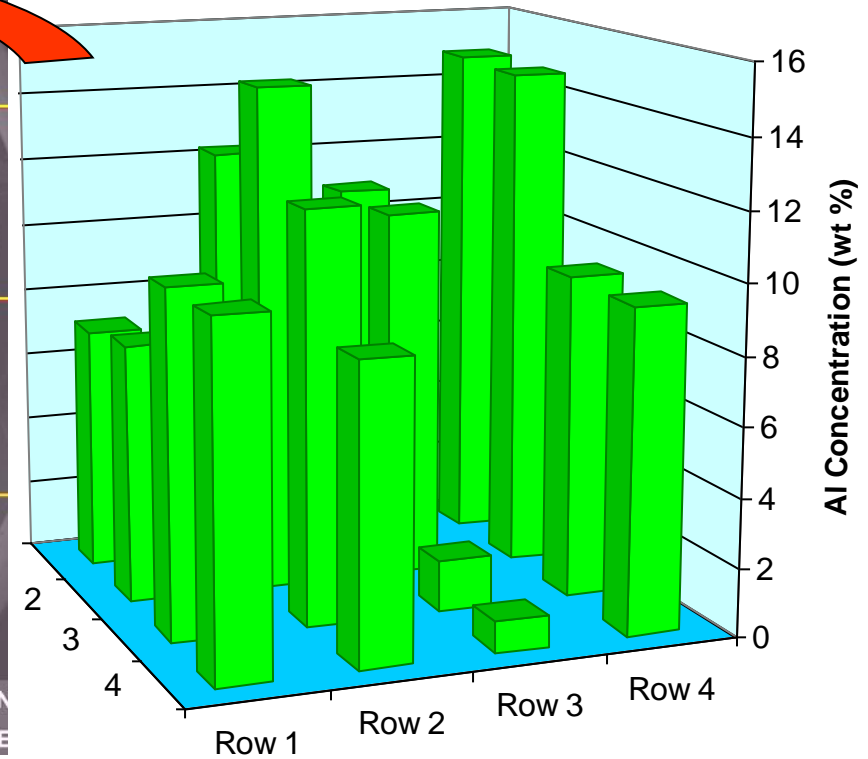
● *A/C ratio measured at different delays*

Preliminary measurements on coal

SEM measurements



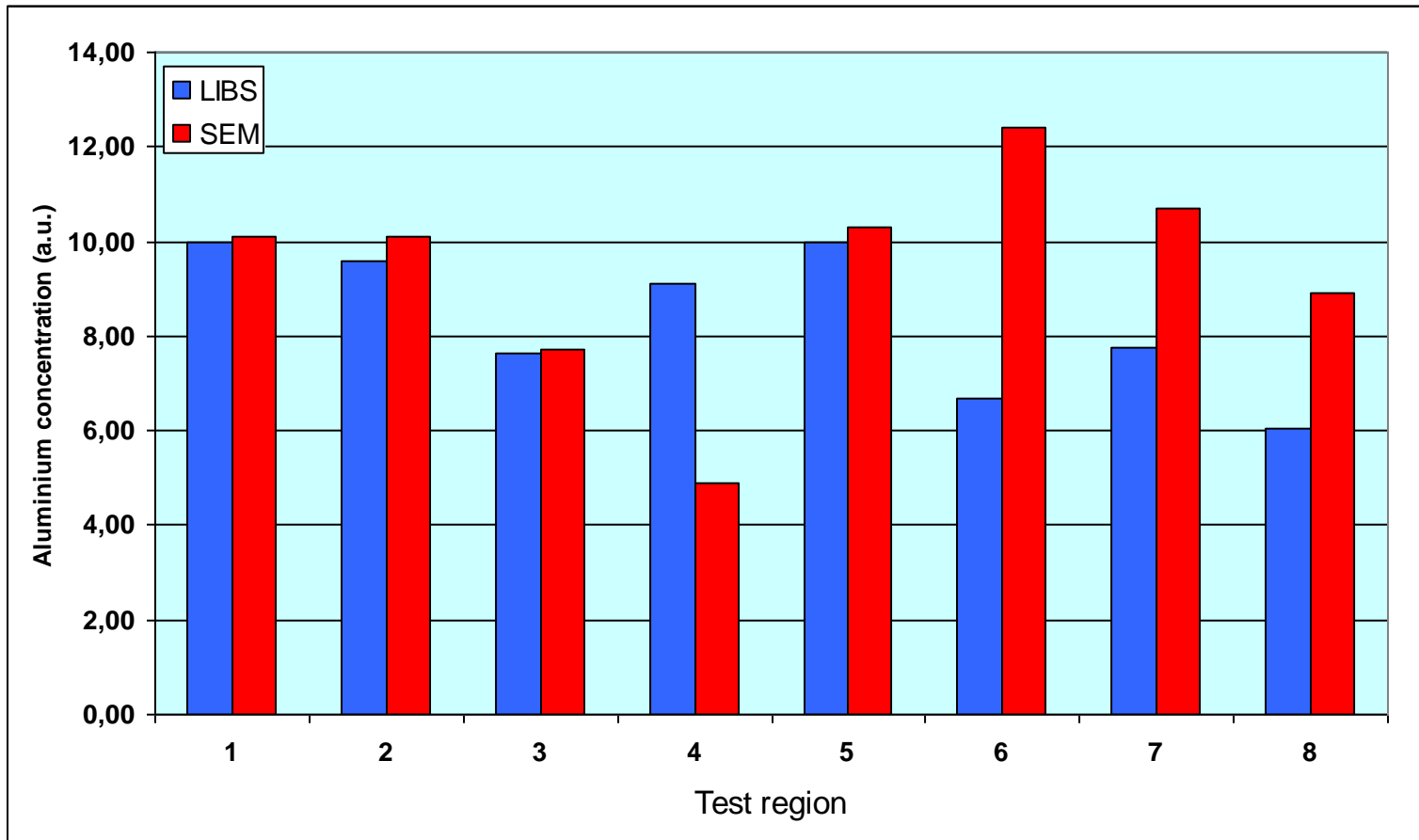
Al Concentration in Q2



- *Measurements carried out on a coal sample by means of SEM show that the sample composition is extremely non-homogeneous*

Preliminary measurements on coal

Comparison SEM - LIBS measurements



- *Taking into account the strong non-homogeneity of the sample and the poor quality of SEM data, the agreement between the two measurements is acceptable.*

Conclusions

- *Experimental activity has been carried out to check whether the LIBS technique can be used for the elemental analysis of coal.*
- *Preliminary measurements on properly prepared samples show a good sensitivity of the technique and the possibility of utilizing samples with known concentration for a calibration procedure.*
- *Future activity will mainly be concerned to the determination of a calibration procedure for a quantitative measurement of the elements of interest (i.e. Al, Ti, Fe, Mg, Si).*
- *Quantitative measurements on coal samples will be used in connection with neural network techniques to determine the composition of the coal ash and relate the composition measurements to ash slagging potential.*