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Compact setup for standoff laser induced breakdown spectroscopy of radioactive material

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Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

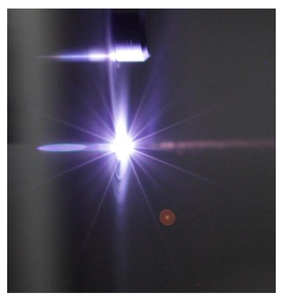
Objective

- Investigation of contaminated areas
- Detection of specific elements, like nuclear fission products
- Standoff detection to prevent direct contact to hazardous materials
- Compactness allows for handheld operation
- Remote control using a small robot or an unmanned aerial vehicle

LIBS

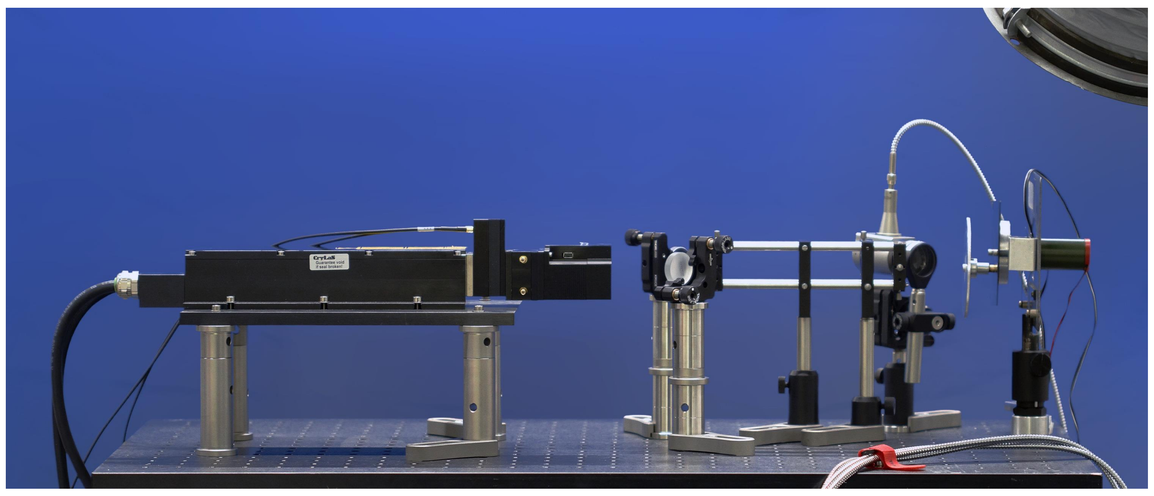
- Laser pulses are focused onto sample to provide high energy density needed to create plasma

Plasma = electrical neutral medium of unbound positive (ions) and negative (electrons) particles sometimes called the 4th state of matter



- After switching off the laser radiation the plasma relaxes and ions and electrons recombine
- Afterwards excited atoms and ions remain and emit element specific radiation in the optical spectral region
- The optical radiation is spectrally analyzed and chemical composition and/or relative quantities can be extracted

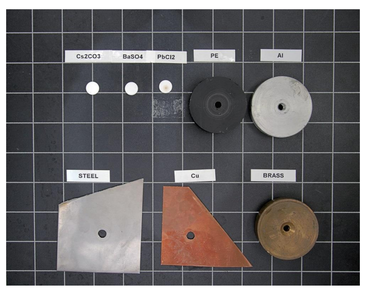
Experimental Setup



System Parameters	
Laser system	Crylas FTSS 355-300
Laser pulse energy	< 300 µJ
Repetition rate	20 Hz
Focus diameter	Few micrometer
Collection optics diameter	1‘‘
Spectrometer	Avantis multichannel
Standoff distance	5 cm
Acquisition time (100 spectra)	< 10 sec

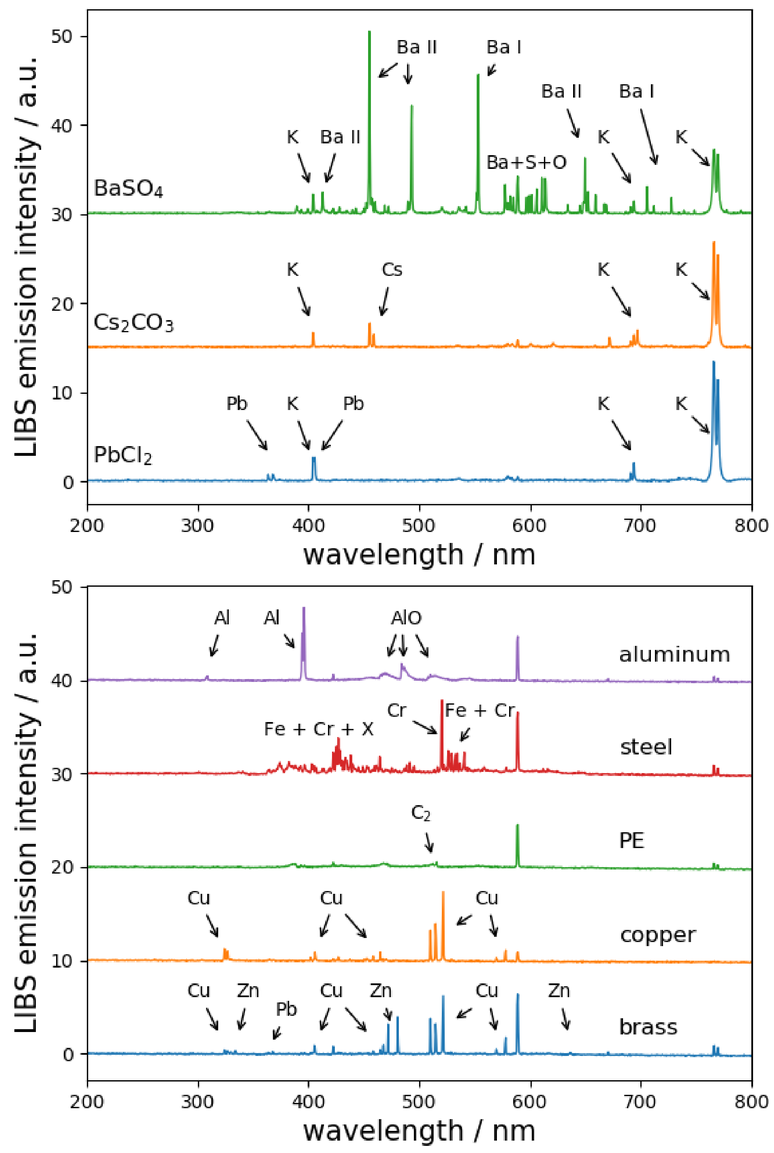
Sample Preparation

- $PbCl_2$, Cs_2CO_3 and $BaSO_4$ powders serve as source for Pb, Cs, Ba as nuclear fission products
- Powders were mixed with KBr in mortar and pressed under vacuum with a weight of 10 tons resulting in pellets of 1 cm diameter
- For metal and PE samples no preparation was needed

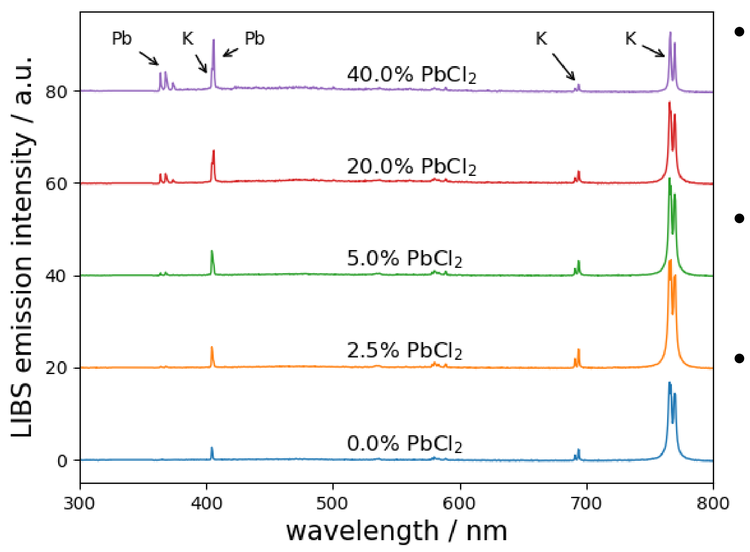


Qualitative LIBS Analysis

- Spectra of salts containing nuclear fission products and different background materials (metal and PE) are compared
- Despite for steel no interference of the dominant peaks of the nuclear fission products and other samples
- Advanced algorithms considering peak heights and positions should still be able to detect small contents of nuclear fission products in steel
- Small lead content could be detected in brass sample

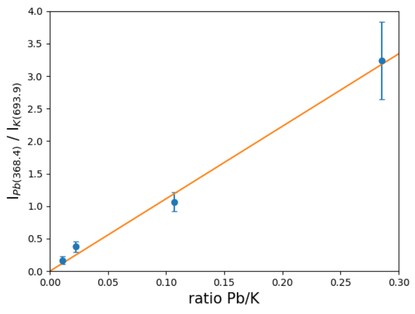


Quantitative LIBS Analysis



- LIBS spectra were acquired for different mass percentage of $PbCl_2$ in KBr samples
- peaks around 360 nm growing for higher amounts of $PbCl_2$
- In first approach lead could be detected at 2.5 % (appr. 4000 ppm)

From the ratio of the peak heights for the lead peak around 368.4 nm and the potassium peak around 693.9 nm a calibration curve was extracted (see figure on the right).
This could be used to determine relative quantities of lead.



Outlook

- Implementation of different self optimizing algorithms i.e. artificial neural networks or support vector machines to automatically distinguish between spectra acquired for different samples
- More advanced algorithms can be used for quantitative analysis of different materials
- Double pulse LIBS can be used to enhance sensitivity
- Determination of relevant spectral range for high resolution spectra to resolve isotope shift

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