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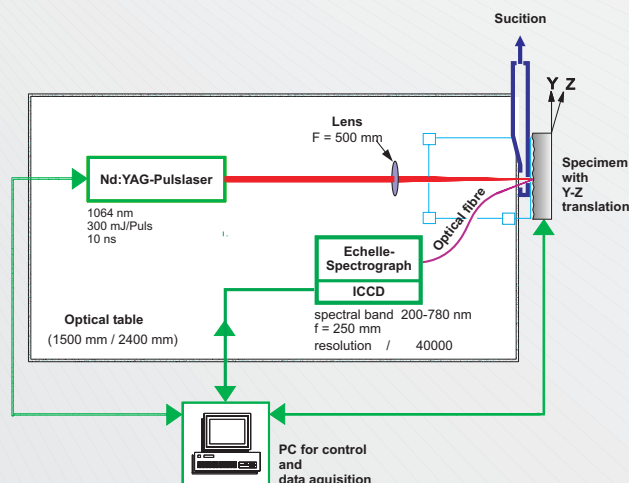
Our aim is the application of LIBS as a simple, quasi on-line method for the non-destructive testing of concrete. Concrete is naturally inhomogeneous. Therefore we must take into account the local variation of the element composition using a statistical analysis. Depending on how much cement and aggregate is measured with each laser pulse, a scan on the surface of a concrete specimen produces a distribution of points in the Rankin diagram which is used to characterise the concrete.

Component	PZ	EPZ	HOZ	TrZ	ÖZ	TEZ	FA
CaO	61 - 69	52 - 66	43 - 60	43 - 58	53 - 58	23 - 41	3 - 6
SiO ₂	18 - 24	19 - 26	23 - 32	25 - 28	19 - 21	1 - 7	44 - 50
Al ₂ O ₃ + TiO ₂	4 - 8	4 - 10	6 - 14	6 - 9	5 - 7	51 - 69	25 - 29
Fe ₂ O ₃ (FeO)	1 - 4	1 - 4	0.5 - 3	2.5 - 3.5	3 - 6	1.5 - 0.5	7 - 14
Mn ₂ O ₃ (MnO)	0 - 0.5	0 - 1	0.1 - 2.5	0.1 - 0.3	0.1 - 0.2	0 - 0.1	-
MgO	0.5 - 4	0.5 - 5	1 - 9.5	1 - 3	1.5 - 2.5	0.3 - 1.5	1 - 3
SO ₃	2 - 3.5	2 - 4	1 - 4.5	2 - 3	2.5 - 3.5	0.1 - 0.7	0.5 - 5

Chemical composition of some cements in % weight (PZ : portland cement, EPZ : iron-portland cement, HOZ : blastfurnace cement, TrZ : trass cement, ÖZ : oil-shale cement, TEZ : aluminous cement, FA : fly ash)

Experimental

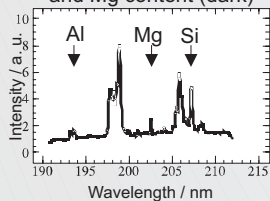
The main components of concrete are aggregates (size: < 1 mm - several mm), cement and air pores. A typical cement/aggregate ratio is 1/7. A differentiation between concretes made of different cement types is complicated by the natural variation of the element content in the base material (Table). With each laser pulse, a varying ratio of cement and small aggregates or - when hitting a larger aggregate - only the aggregate composition is detected. Therefore we recorded a representative number of linescans (see left), each containing about 100 single point measurements. For each point the Ca, Si, Al, Fe and Mg content was measured and the oxid content was calculated. Those values are then rendered in a Rankin diagram.



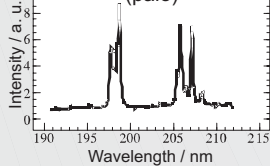
Results

The results in the right column are obtained on different cement and concrete specimens. The wide straggling of the values (see 3-5) are caused by the material and not by LIBS. Clockwise along the sides of the triangles, the density functions for the elements are shown. They provide an additional criterion for the characterisation of concrete. The position of the reference specimens are marked by an *.

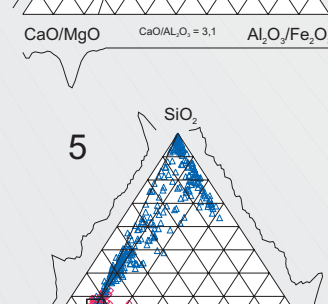
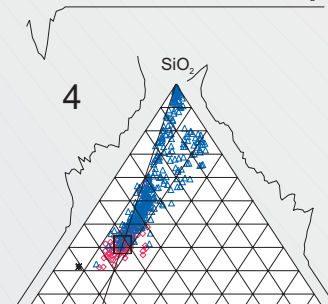
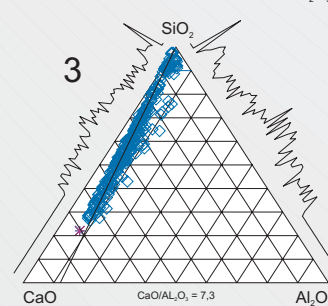
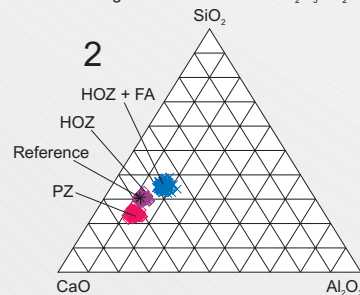
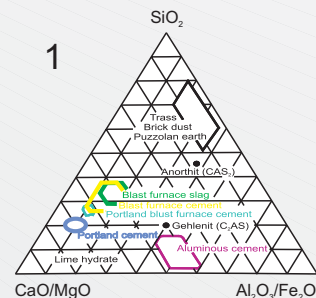
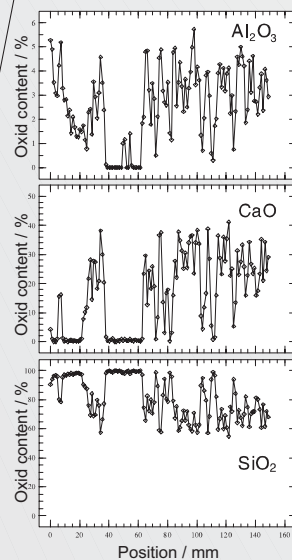
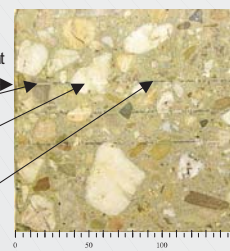
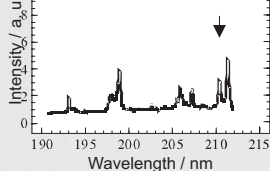
Silica aggregate with Al and Mg content (dark)



Normal silica aggregate (pale)



Cementmatrix



- 1 Rankin Diagramm for various cement types
- 2 Results of different cement specimens (each 127 measurements). Cements used: Portland cement (PZ), furnace blast slag cement (HOZ) and furnace blast slag cement containing 30% fly ash (HOZ+FA)
- 3 Results from a cutted concrete surface. The distribution of the points along a line is caused by the ratio cement/aggregate in the evaporated material.
- 4 Comparison of LIBS results from a casted surface (red) and a cutted surface (blue) of a concrete (furnace blast slag cement) specimen; aggregates contain additional Al₂O₃/Fe₂O₃ content.
- 5 like 4 but concrete made from Portland cement

Conclusion

LIBS can be used to characterise concrete. We can identify the type of cement and the type of aggregates in the concrete. A new detection devices (Echelle Spectrograph) enables the simultaneous measurement of spectral lines of all dominant elements.