Monitoring of Laser Ablation-Generated Acoustic Emission Signals

Location: Faculty of Science, Masaryk University, Laboratory of Atomic Spectrochemistry, Brno
Date: April 24, 2006
Equipment Used: DAKEL XEDO, AE 3.0 module, slot 12, AE sensor with ceramic plate
AE Monitored by: Ing. Miroslav Varner, Mgr. David Varner

Laser Ablation Experiment Overview

Acoustic emission (AE) monitoring has been performed as an integral part of the laser ablation experiment. A Quantel Brilliant pulse laser unit has been mounted on a special table featuring sample translation unit. The sample has been placed on the rear wall of test cell for inductively coupled plasma – optical emission spectroscopy (ICP/OES) or on the rear wall of circular aluminum frame for laser induced breakdown spectroscopy (LIBS). The laser ray hits a single point on the sample or creates specific patterns based on programmed translation unit setting. See Figure 1 for the experiment installation.

The AE monitoring was performed to find a relationship among its parameters (RMS, C1, C2, and PSD), pit depth, and element emission line intensity. It might be possible to use AE parameter changes for layer-to-layer transition indication. Also, the AE signal could be successfully used instead of internal reference element. The experimental verification is to be performed using sheet metal and ceramic tile samples.

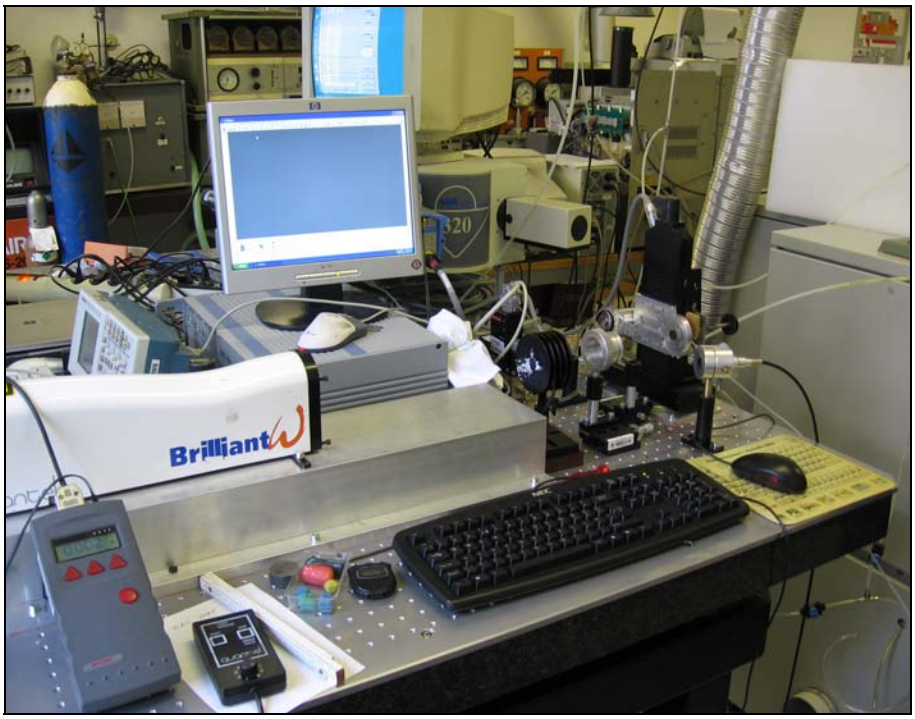

Figure 1: Experimental Installation for Laser Ablation. Photo by D. Varner

Acoustic Emission Monitoring

The actual AE monitoring was performed using two samples - ceramic tile fragment and steel cylinder. Green glazed tile Hob was manufactured by the Keramika Horní Bříza - Lasselsberger Group factory. The glaze thickness is approximately 0,3 mm. Under the glaze, there is a white porous ceramic matrix. Table 2 at the end of this report contains oxide contents based on analysis done by the manufacturer in 2004. The tiles have no longer been in production. The steel cylinder is a standard sample used with the Hilger optical emission spectrometer. Table 3 at the end of this report contains minor element amounts stated in weight percent.

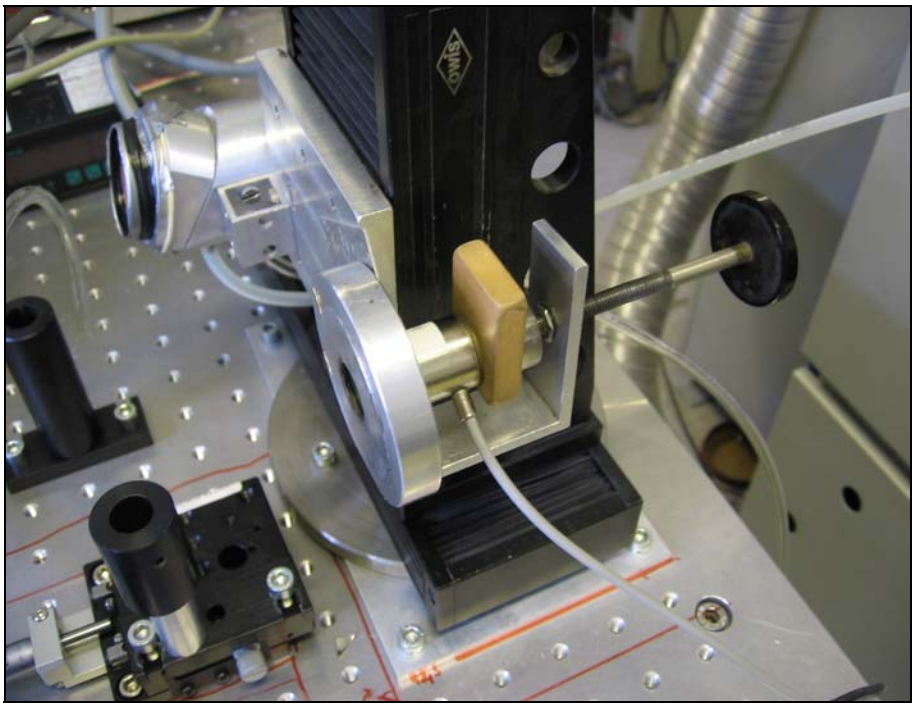

Figure 2: AE Sensor Placed on the Ceramic Tile Sample. Photo by D. Varner

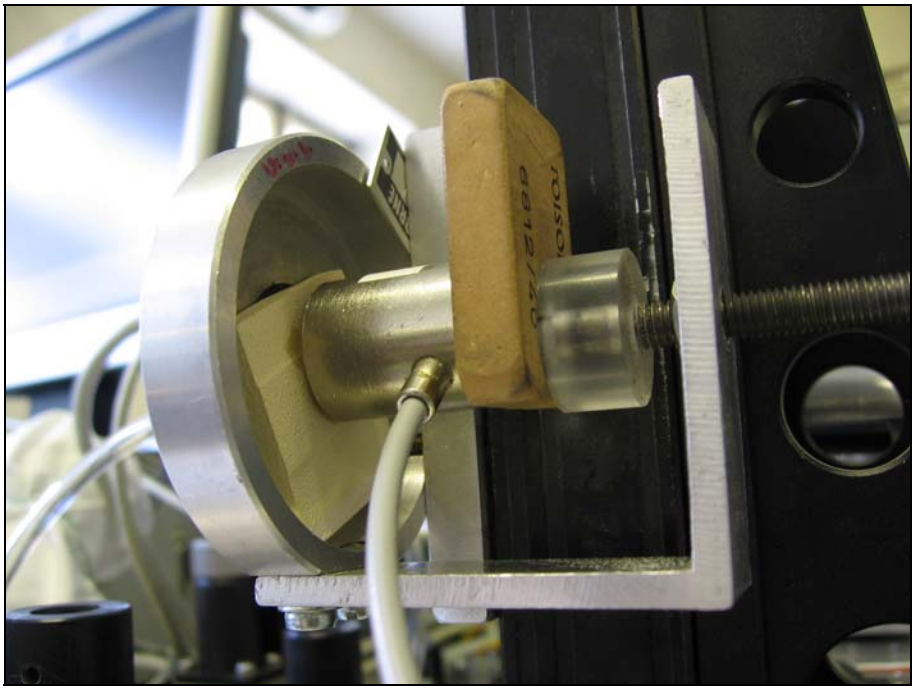

Figure 3: Detail of the AE Sensor Placed on the Ceramic Tile Sample. Photo by D. Varner

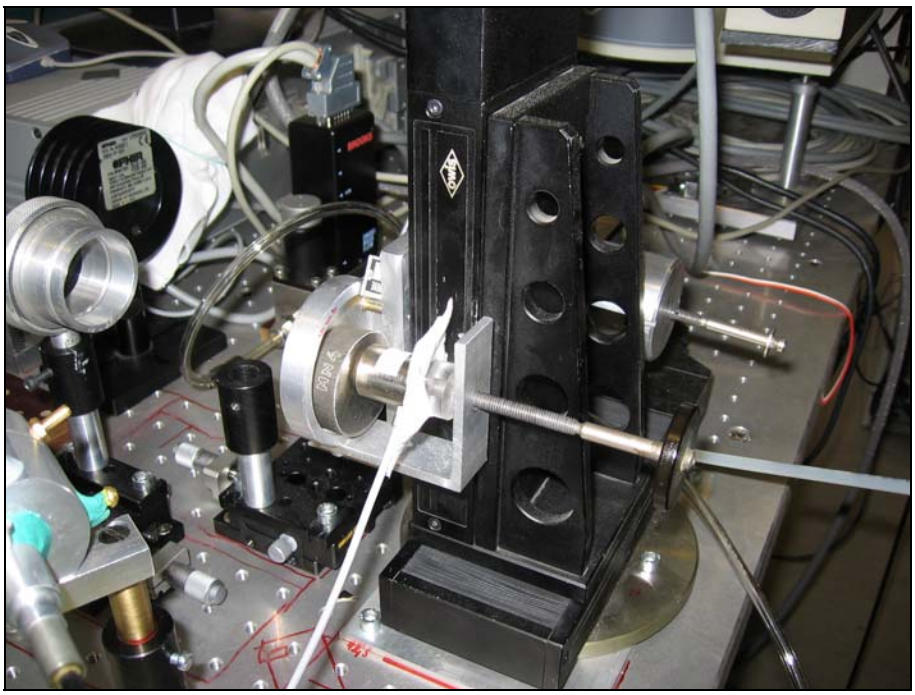

Figure 4: AE Sensor Placed on the Steel Cylinder Sample. Photo by D. Varner

The AE sensor was attached to the back of the sample using a fixing screw. Silicon paste was used to maintain acoustic link between the sample and the AE sensor. To reduce noise over the non-active surface of the AE sensor, we used a common eraser and placed it between the sensor and the fixing screw (see Figures 2, 3, and 4). AE signals generated during the laser beam operation were monitored and evaluated using XEDO device manufactured by the DAKEL ZD Rpety Company.

The AE monitoring parameters were set as follows: sample frequency 2MHz, gain 25dB, maximum range ± 2400 mV, count levels C1 = 245mV, C2 = 480mV, event threshold 725 mV, event end 245 mV, event-count dead time 3000 μs, saved event sample number 1500, pre-trigger 250 samples.

The evaluated quantities included RMS, C1/C2 level count, number of AE events, and power spectral density (PSD) of the AE event.

The laser has been triggered in two modes - manual and automatic. Manual mode featured pressing of a trigger button on the control panel. In automatic mode, the laser was fired with frequency of 10 Hz.

Results and Discussion

Total of 5 AE monitoring sessions were done. Table 1 lists individual data directories, session times, sample types, and laser trigger modes.

Data Directory	Session Time	Sample Type	Laser Trigger Mode
Laser_0427_1	16:09-16:10	ceramic	manual
Laser_0427_2	16:42-16:43	ceramic	automatic
Laser_0427_3	17:45-17:47	ceramic	manual
Laser_0427_4	17:49-17:50	ceramic	automatic
Laser_0427_5	18:08-18:10	steel 12050	automatic

Table 1: AE Monitoring Summary

RMS, C1, and C2 Values

Figures 5 to 10 show RMS of the AE signal and number of C1/C2 counts for individual monitoring sessions. Figure 8 illustrates detail of listed parameters values recorded shortly after the 2nd monitoring session's start.

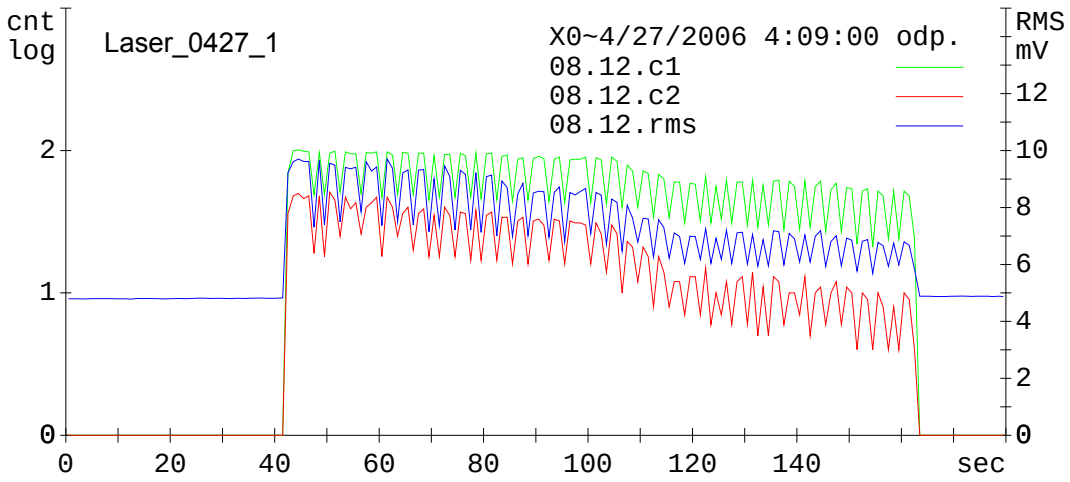

Figure 5: AE Monitoring Results (RMS, C1, C2)

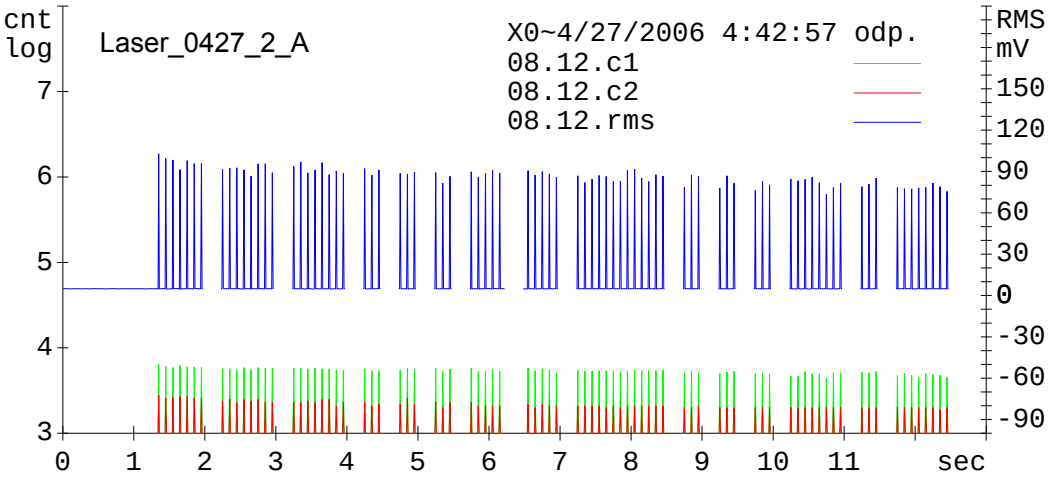

Figure 6: AE Monitoring Results (RMS, C1, C2)

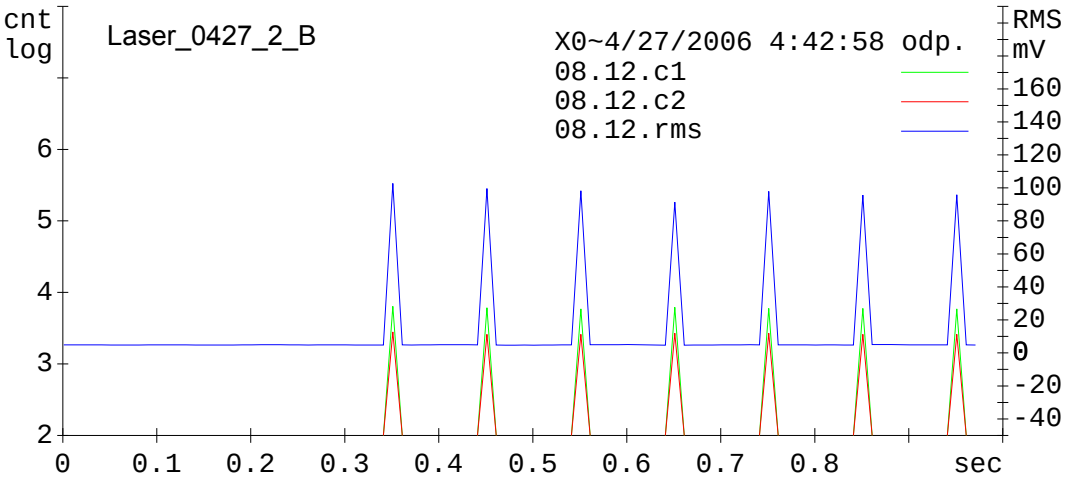

Figure 7: AE Monitoring Results (RMS, C1, C2)

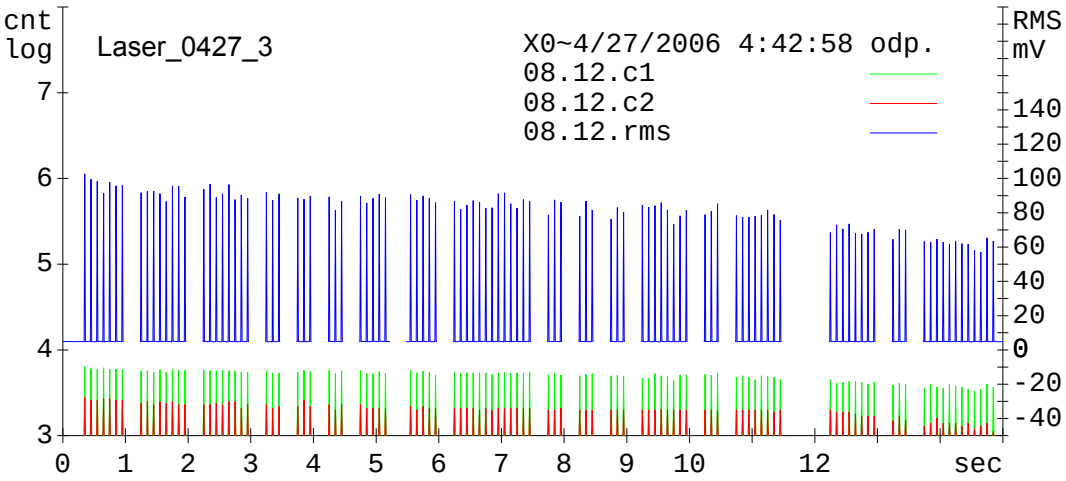

Figure 8: AE Monitoring Results (RMS, C1, C2)

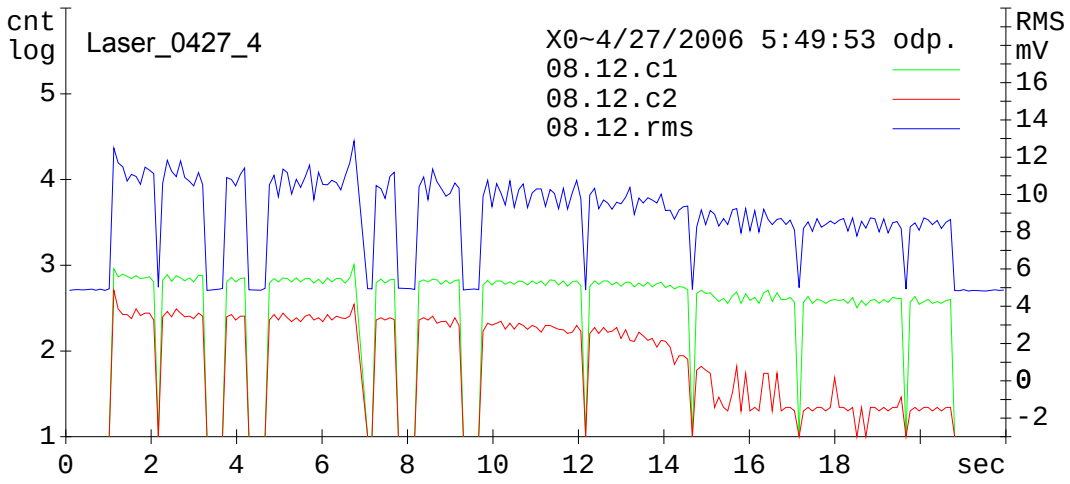

Figure 9: AE Monitoring Results (RMS, C1, C2))

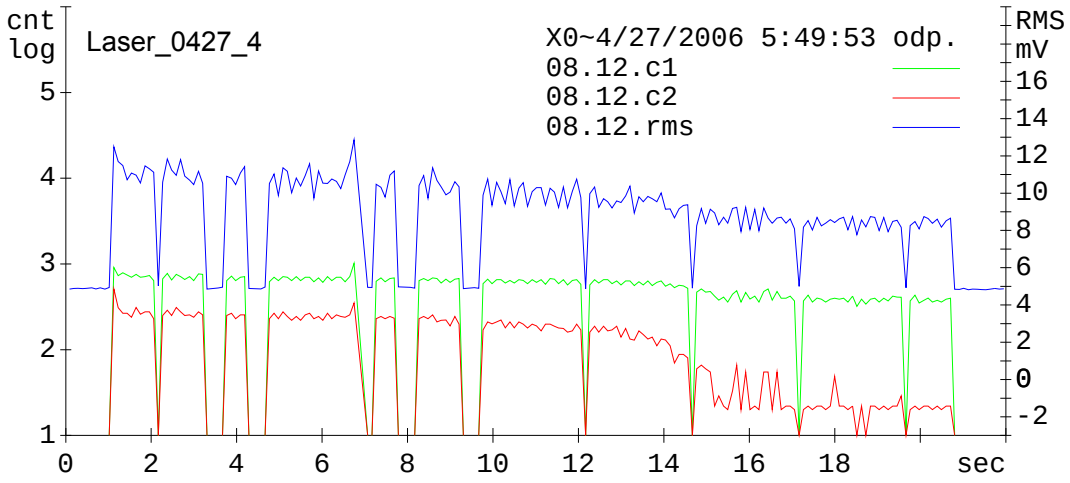

Figure 10: AE Monitoring Results (RMS, C1, C2)

The charts presented above prove that all the values (RMS, C1, and C2) show decreasing trend with increasing number of laser hit number.

PSD Values

Similar function can be seen with the PSD maximum - see the following charts. Left hand side charts show time dependent recordings of AE signals generated when the laser beam hit the sample; the rectangle indicates data used for the PSD calculation. Right hand charts show the actual PSD function. Note different value range of the Y axis. For demonstration purposes, the following functions have been chosen from the data acquired in the first session: 4 from initial phase, 4 from intermediate phase, and 4 from final phase. Individual chart headings include id label and monitoring time.

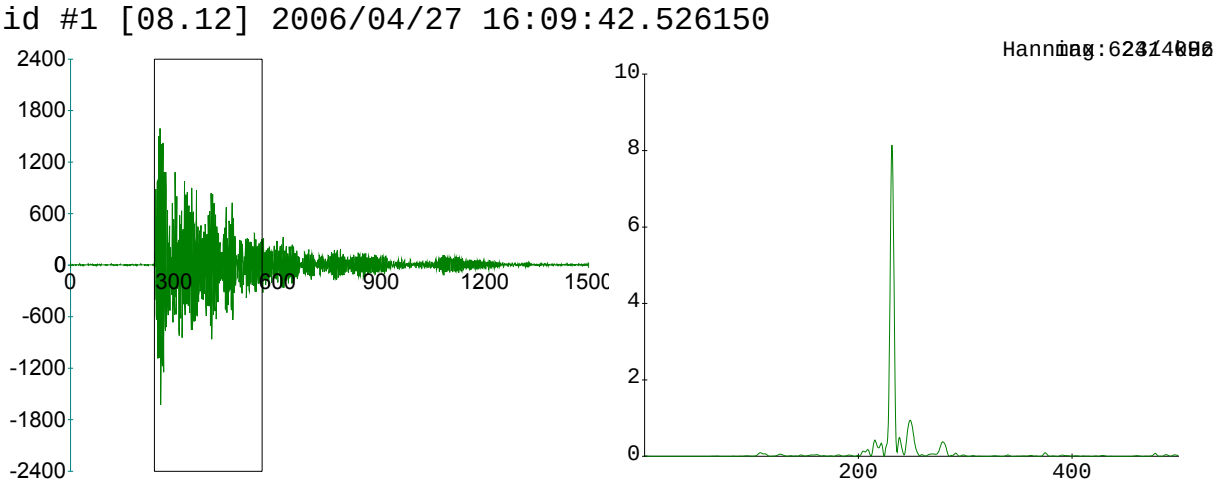

Figure 11: AE Monitoring Results (PSD)

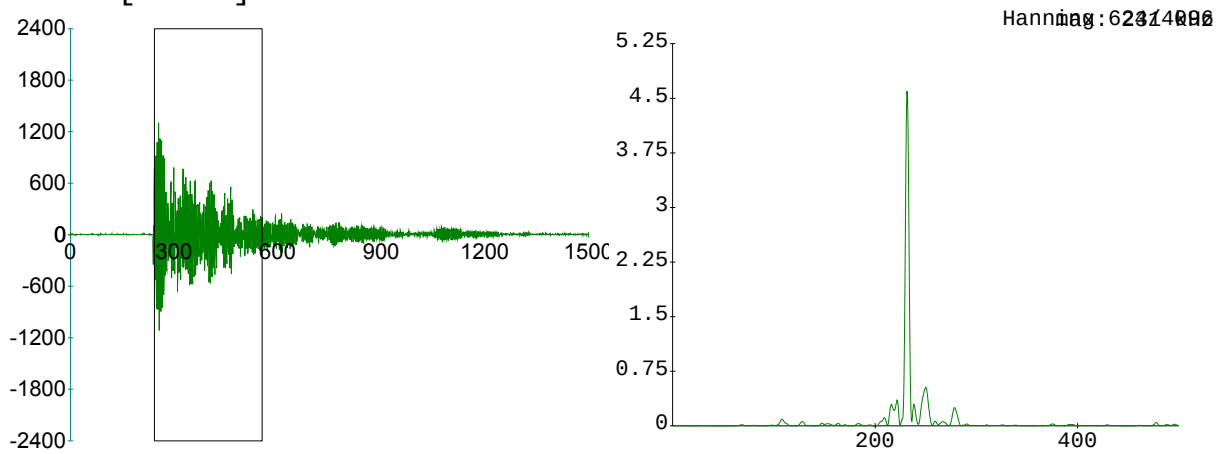

Figure 12: AE Monitoring Results (PSD)

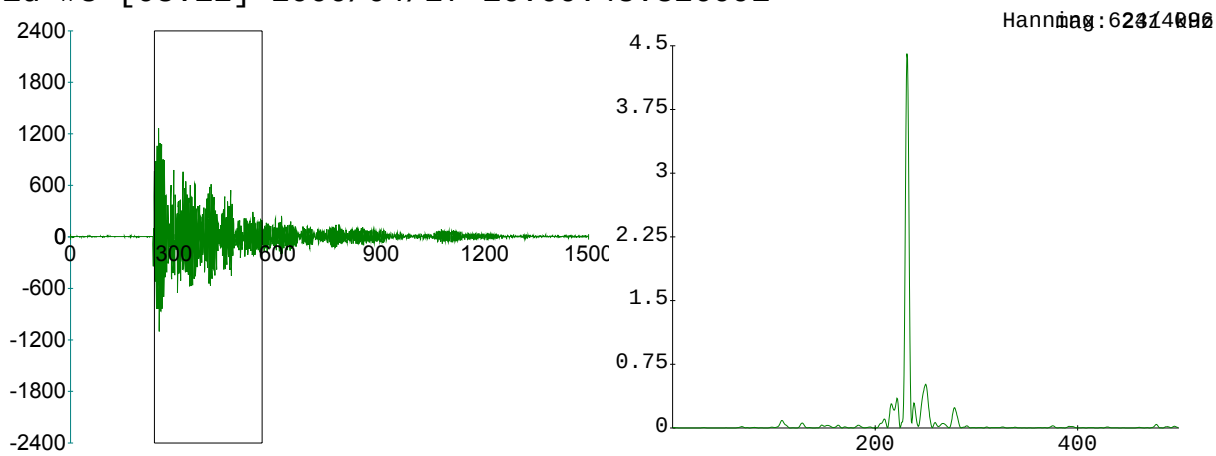

Figure 13: AE Monitoring Results (PSD)

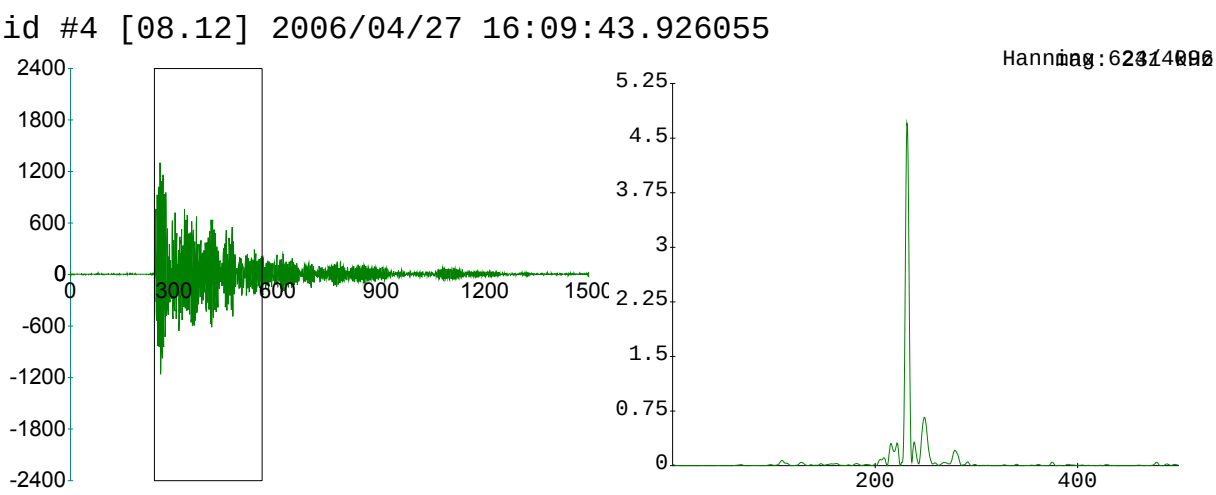

Figure 14: AE Monitoring Results (PSD)

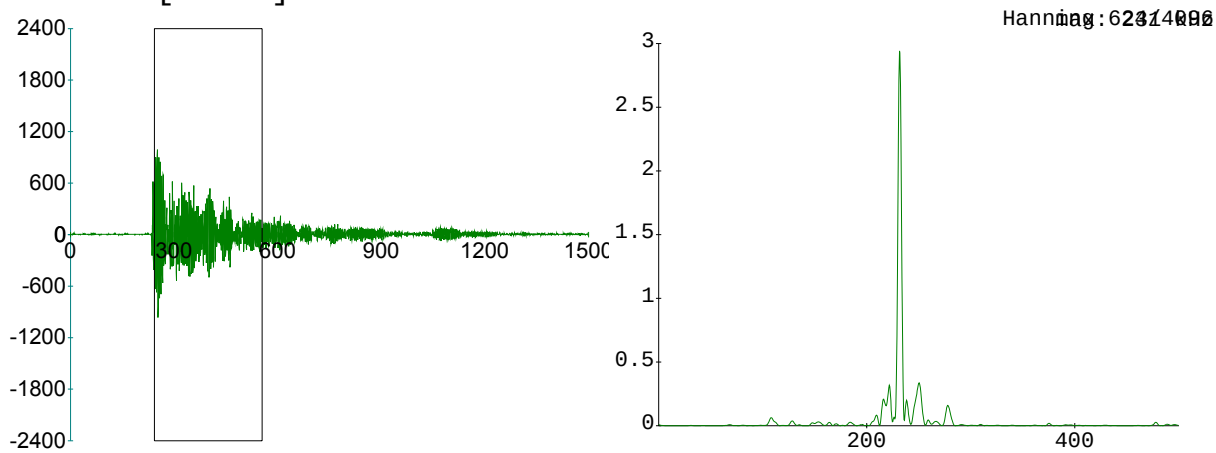

Figure 15: AE Monitoring Results (PSD)

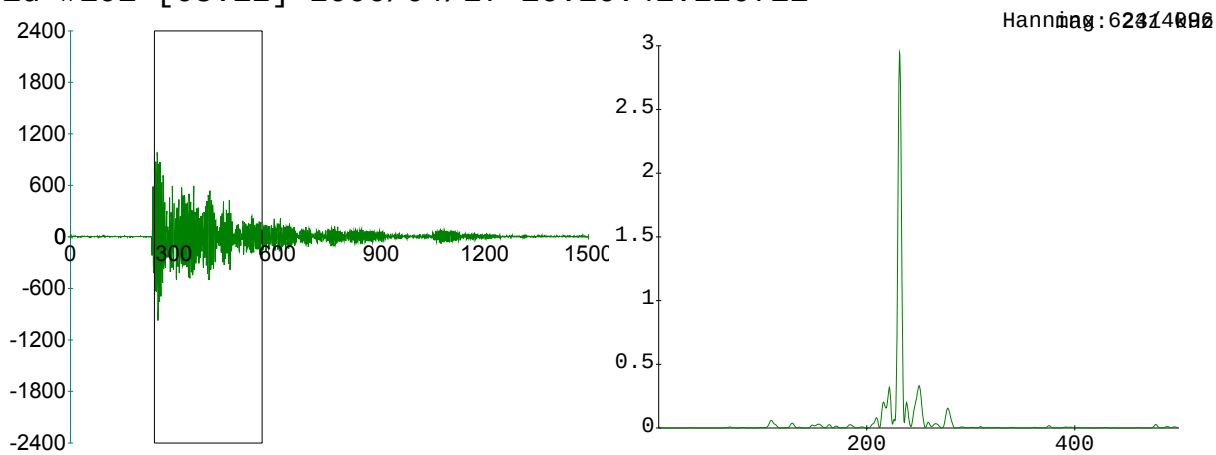

Figure 16: AE Monitoring Results (PSD)

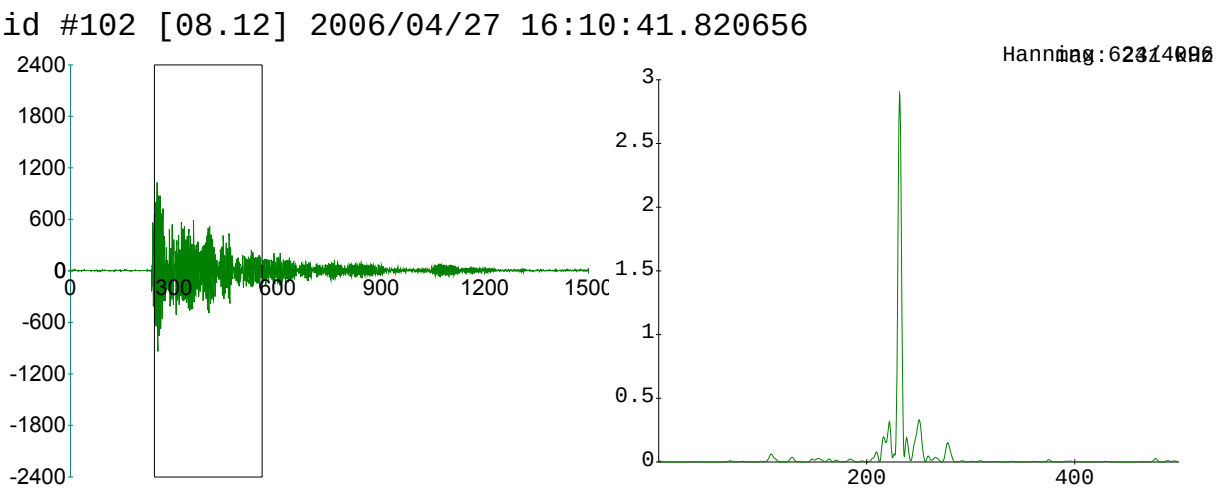

Figure 17: AE Monitoring Results (PSD)

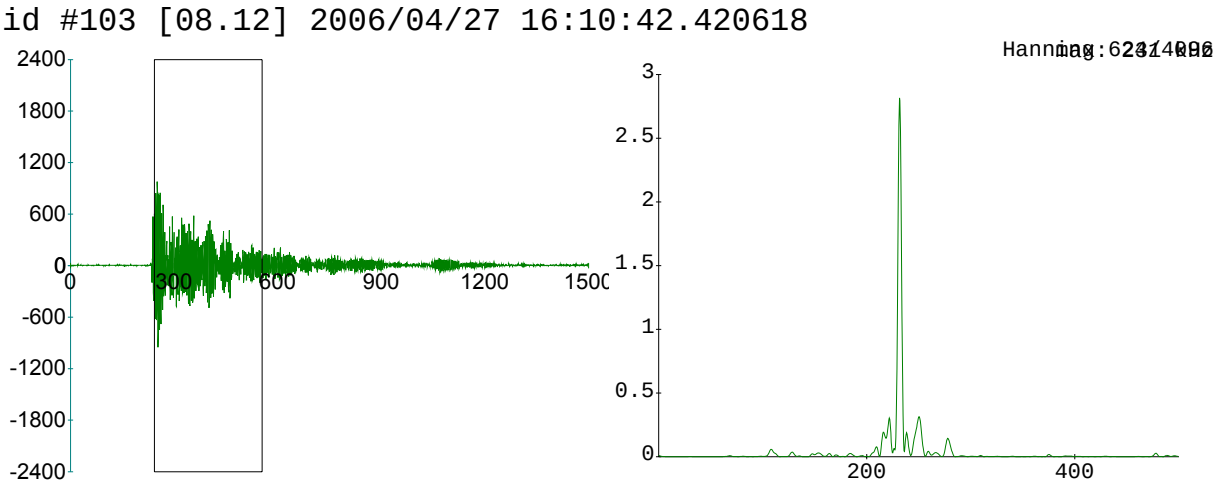

Figure 18: AE Monitoring Results (PSD)

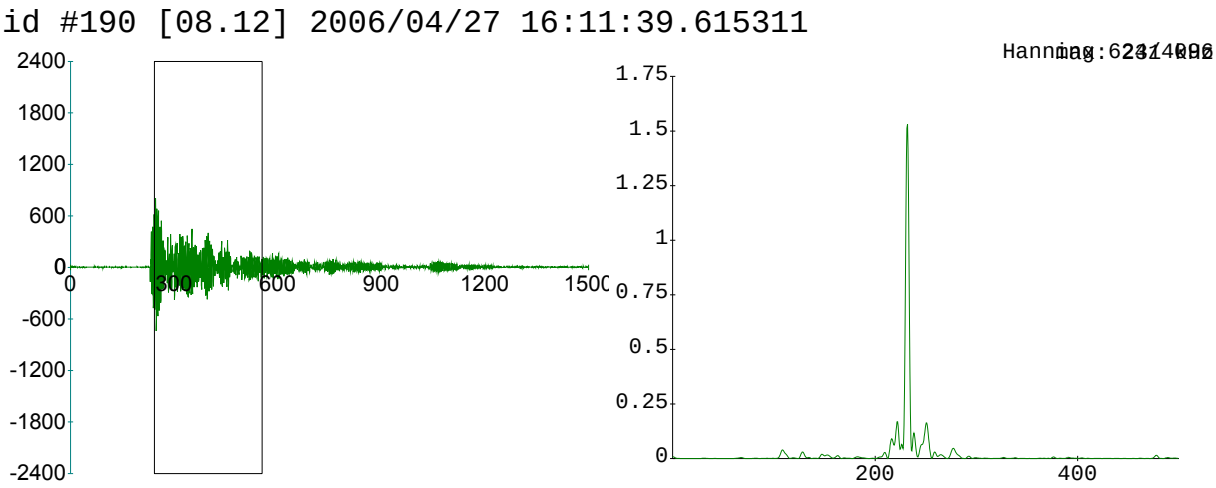

Figure 19: AE Monitoring Results (PSD)

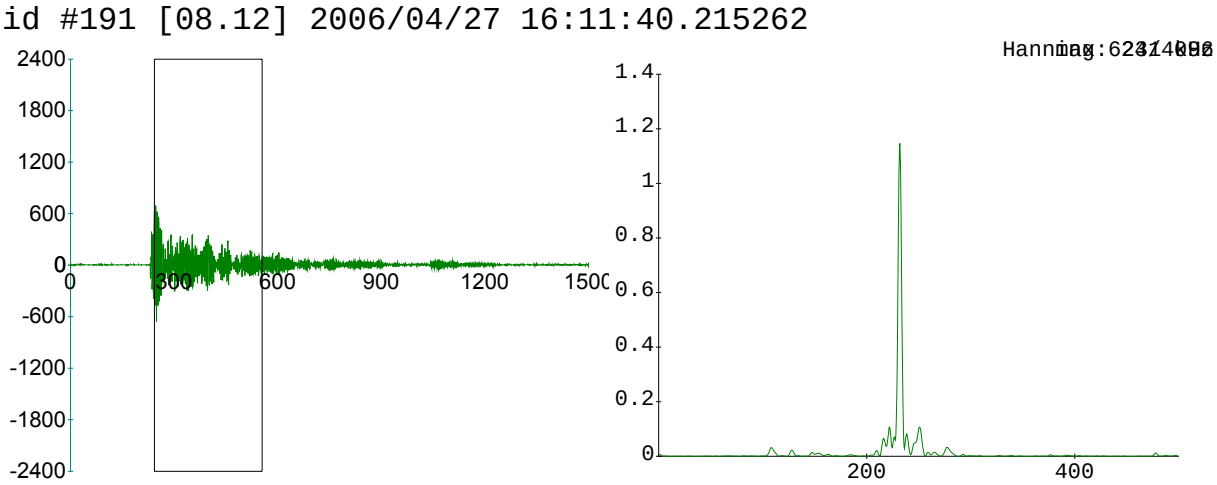

Figure 20: AE Monitoring Results (PSD)

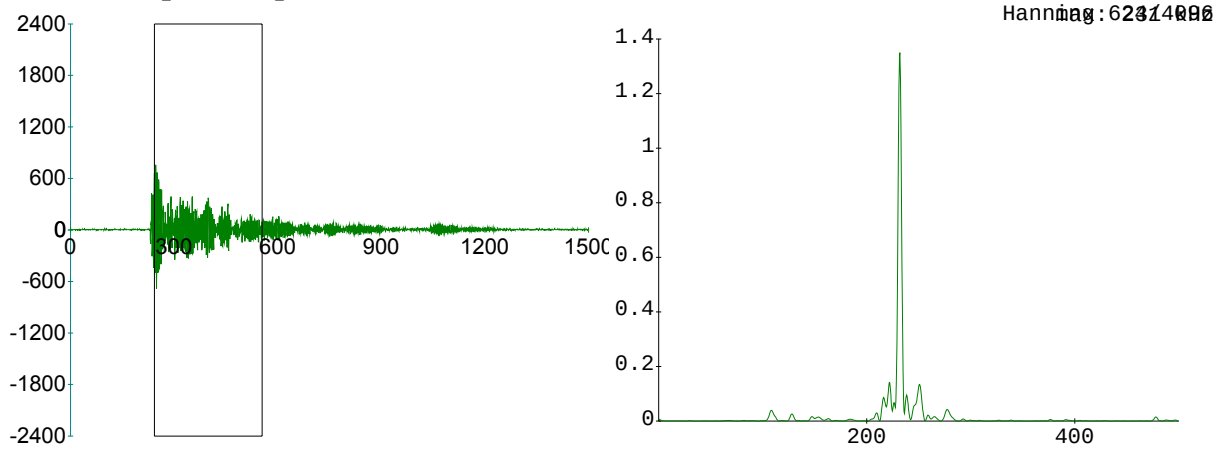

Figure 21: AE Monitoring Results (PSD)

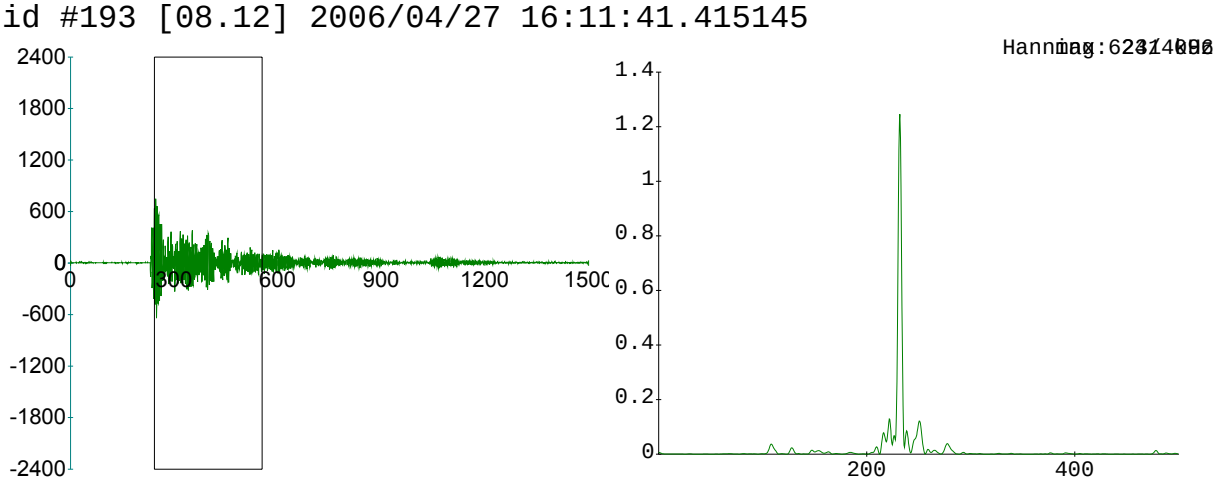

Figure 22: AE Monitoring Results (PSD)

Tables: Sample Composition Data

Glaze	L450 green
Oxides	wt. %
SiO_2	56.84
Al_2O_3	7.75
Fe_2O_3	0.35
TiO_2	0.09
CaO	6.03
MgO	0.54
K_2O	2.51
Na_2O	0.20
ZrO_2	0.22
ZnO	9.26
BaO	1.96
SrO	0.10
PbO	7.37
CuO	0.06
Cr_2O_3	6.18
CoO	0.37
NiO	0.14

Table 2: Oxides in Ceramic Tile Sample - Glaze

Matrix wt. %	Avg.	Min.	Max.
SiO_2	66.11	65.27	66.9
Al_2O_3	18.99	18.12	19.62
TiO_2	0.68	0.65	0.73
Fe_2O_3	1.23	1.18	1.32
CaO	9.79	9.35	10.31
MgO	1.49	1.35	1.62
Na_2O	0.29	0.24	0.35
K_2O	1.42	1.31	1.54

Table 2: Oxides in Ceramic Tile Sample - Matrix

Sample	C %	Si %	S %	P %	Mn %	Ni %	Cr %	Mo %	V %
MN 4	1,38	0,78	0,053	0,042	18,6	1,32	2,29	0,80	0,022

Table 3: - Minor Element Contents in Steel Cylinder Sample

References Cited:

Hrdlička, Aleš.: Monitoring of Acoustic Signals Generated during Laser Ablation, Information about the Experiment and Samples Used, PF MU, Brno, 2006

Report by: Mgr. David Varner

Brno May 19, 2006