האוניברסיטה העברית בירושלים
THE HEBREW UNIVERSITY OF JERUSALEM

High Field Pre-breakdown Acoustic Measurements

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Background

- One of the possible mechanisms for full BD initiation is the formation of a localized plastic deformation on the cathode surface
- Plastic event leading to the formation of such a protrusion is assumed to be linked with significant dislocation activity
- As of now, there is no direct observation of a stable population of such protrusions. One of possible explanation is that surface effects lead to protrusion smoothing
- By using a direct measurement of the dynamics population of dislocations in situ, while exposing a cathode to sub BD fields, we can measure possible plastic response in the cathode
- Correlation of such a “plastic” signal with modifications of the electrical signal from the gap can serve to identify the mechanism leading to BD formation

Acoustic emission

Acoustic signal is a unique identifier of plastic based pre BD mechanisms

Dislocation motion is correlated with significant acoustic signal, due to various effects:

- Glide + multiplication – interaction of elestic fields with obstacles
- Climb – production of point defects
- Pileups – generation of string elastic fields

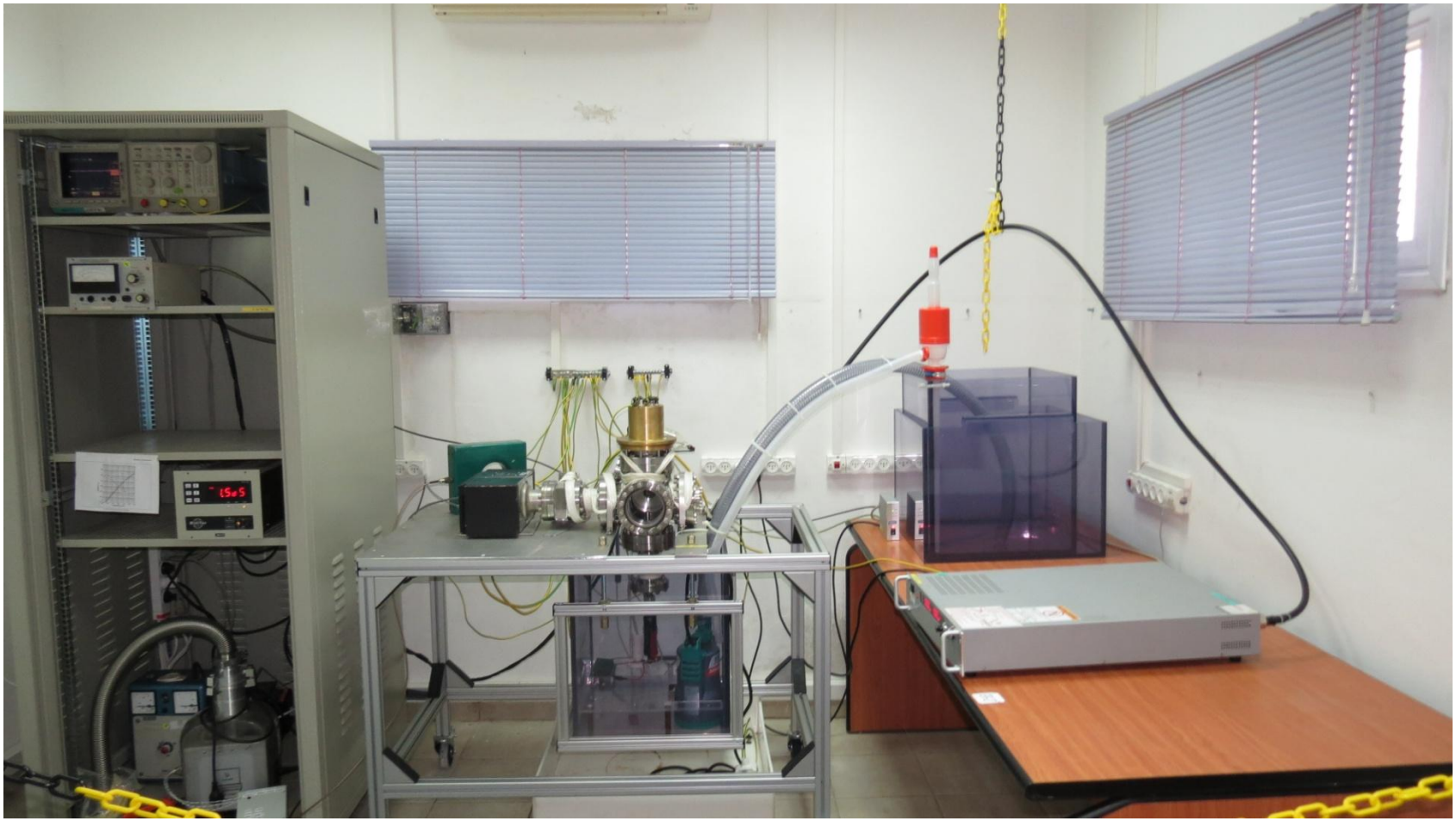
The acoustic signal contains two types of responses:

- Continuous – steady state response of dislocation population under constant drive conditions. E.g. glide under stress
- Discrete/burst – a sudden increase in mobile dislocation. E.g. twin formation, etc.

Objective of the experiment

- Measure an acoustic signal originating from the electrode surface
  - Look for continues signal or a set of discrete acoustic events
  - Measure the time and frequency distribution of such a signal
- If no signal found down to the limit of the BG → give bounds on the acoustic signal

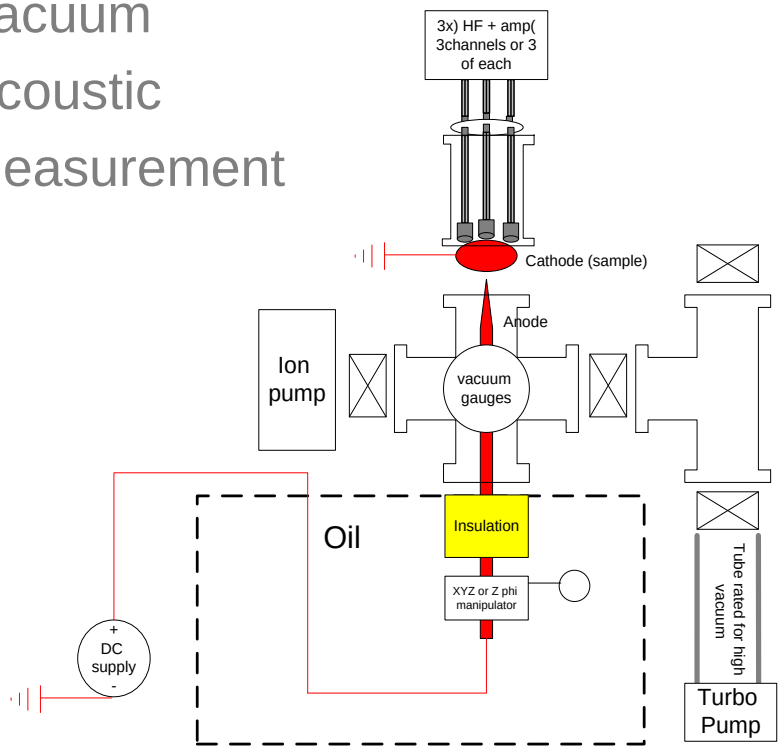
System setup

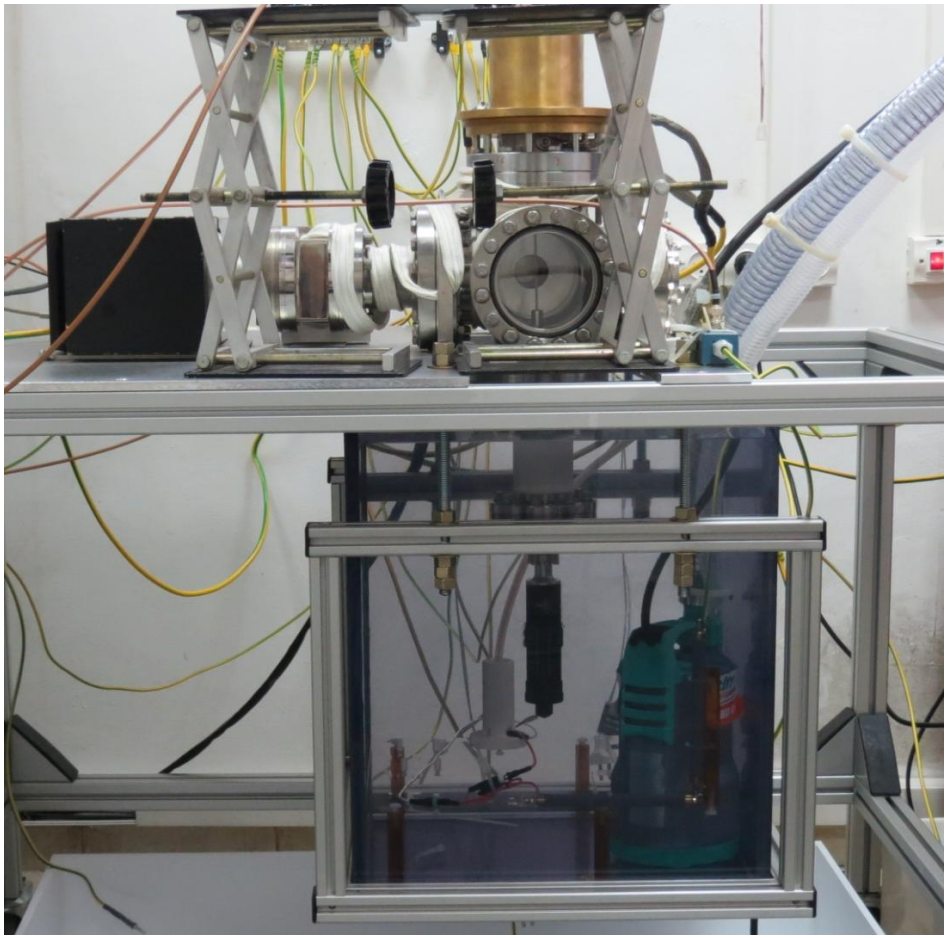


A closer look at the system

System designed For:

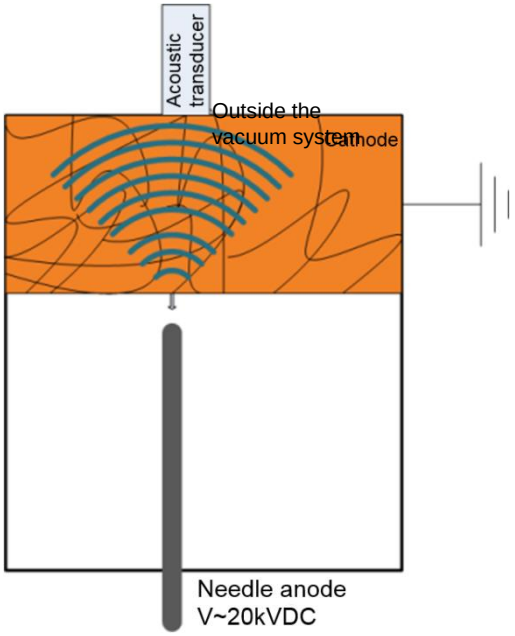
- High voltage
- Vacuum
- Acoustic measurement



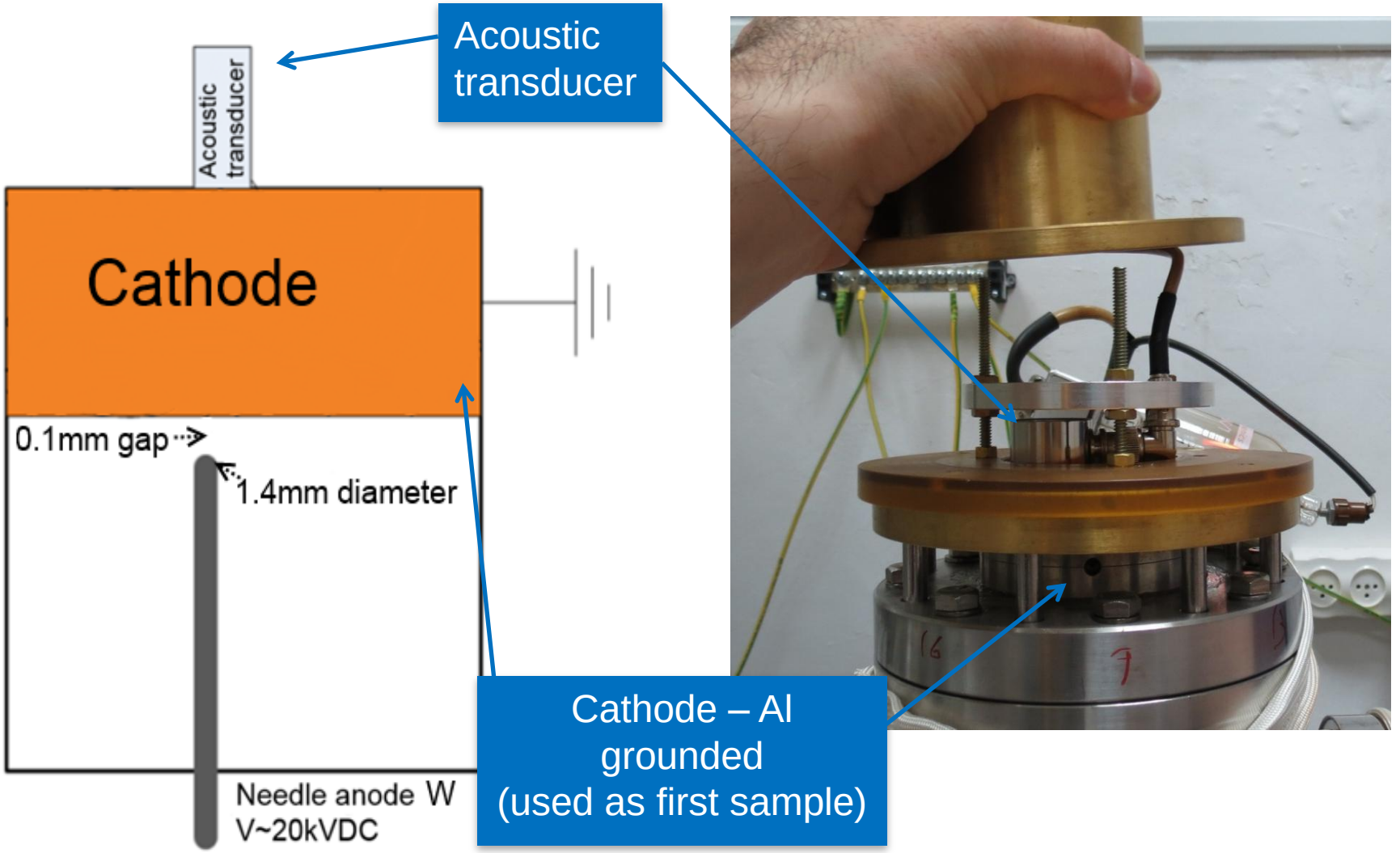


Experimental method

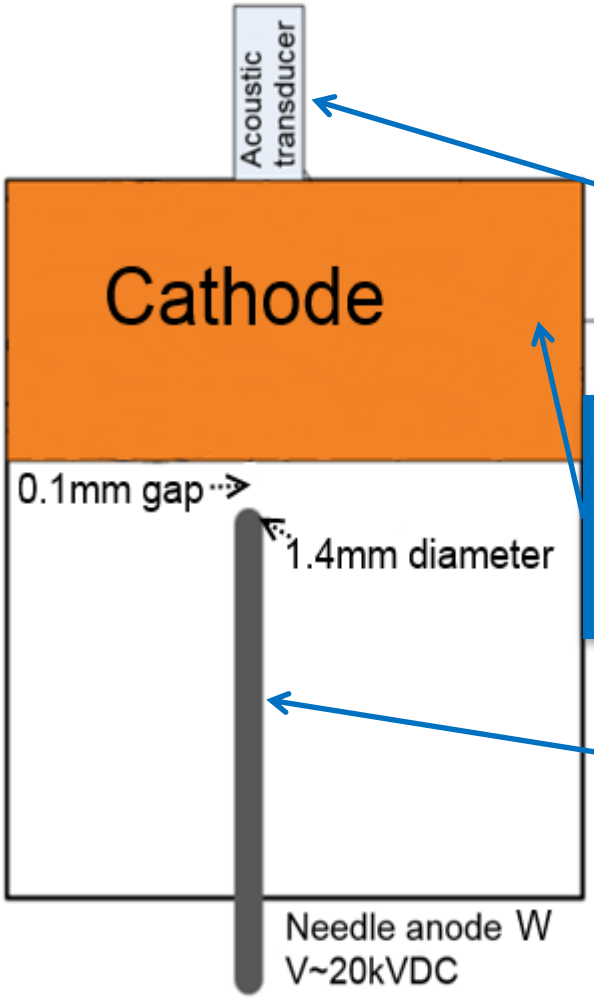
- A cathode is placed in a system with one side in vacuum and one side in the atmosphere
- cathode design – similar to DC FGS CERN system
- Currently, a machined and diamond polished Al cathode is installed
- The side in vacuum is exposed to high fields at sub-breakdown levels via a needle type W anode (circular 1.4mm diameter tip, 0.1 mm away from the sample)
- An acoustic transducer on the other side is placed on the cathode
- Measured freq range: ~100kHz to 1MHz. The signal is amplified by about 60dB



Main part of the system

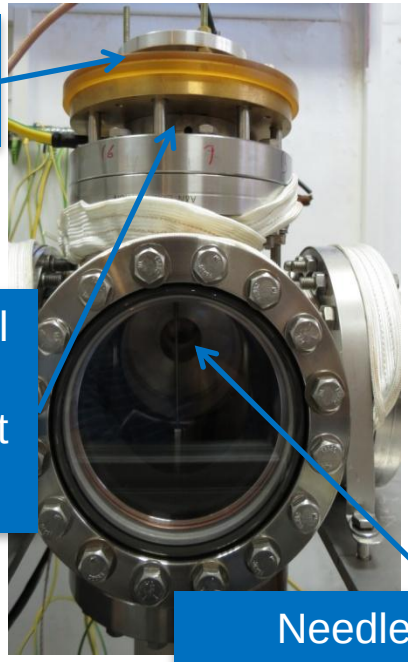


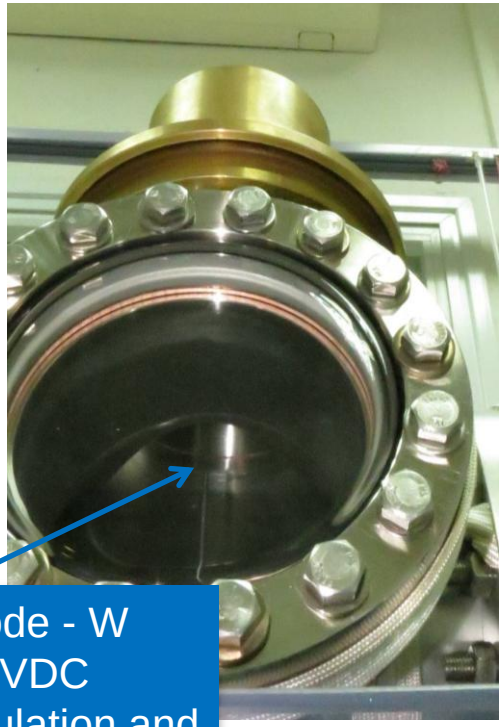
System setup



Acoustic transducer

Cathode – Al grounded (used as first sample)



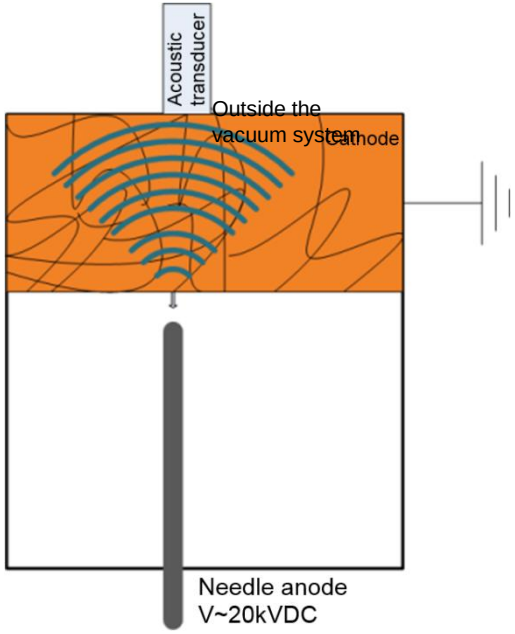


Needle anode - W
0 to 120 kVDC
(good for triangulation and cathode defects…)

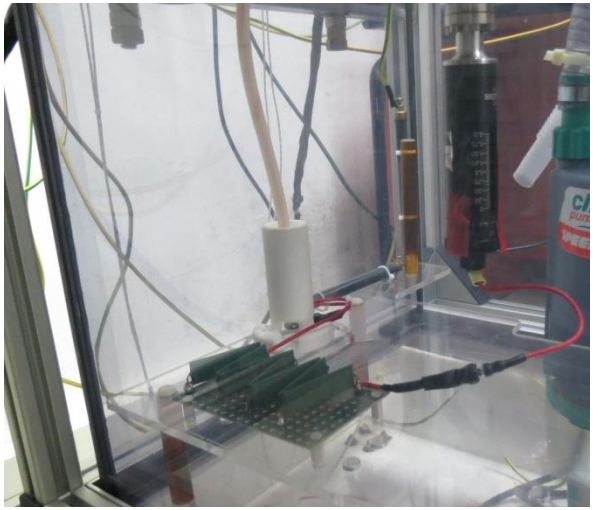
Experimental method

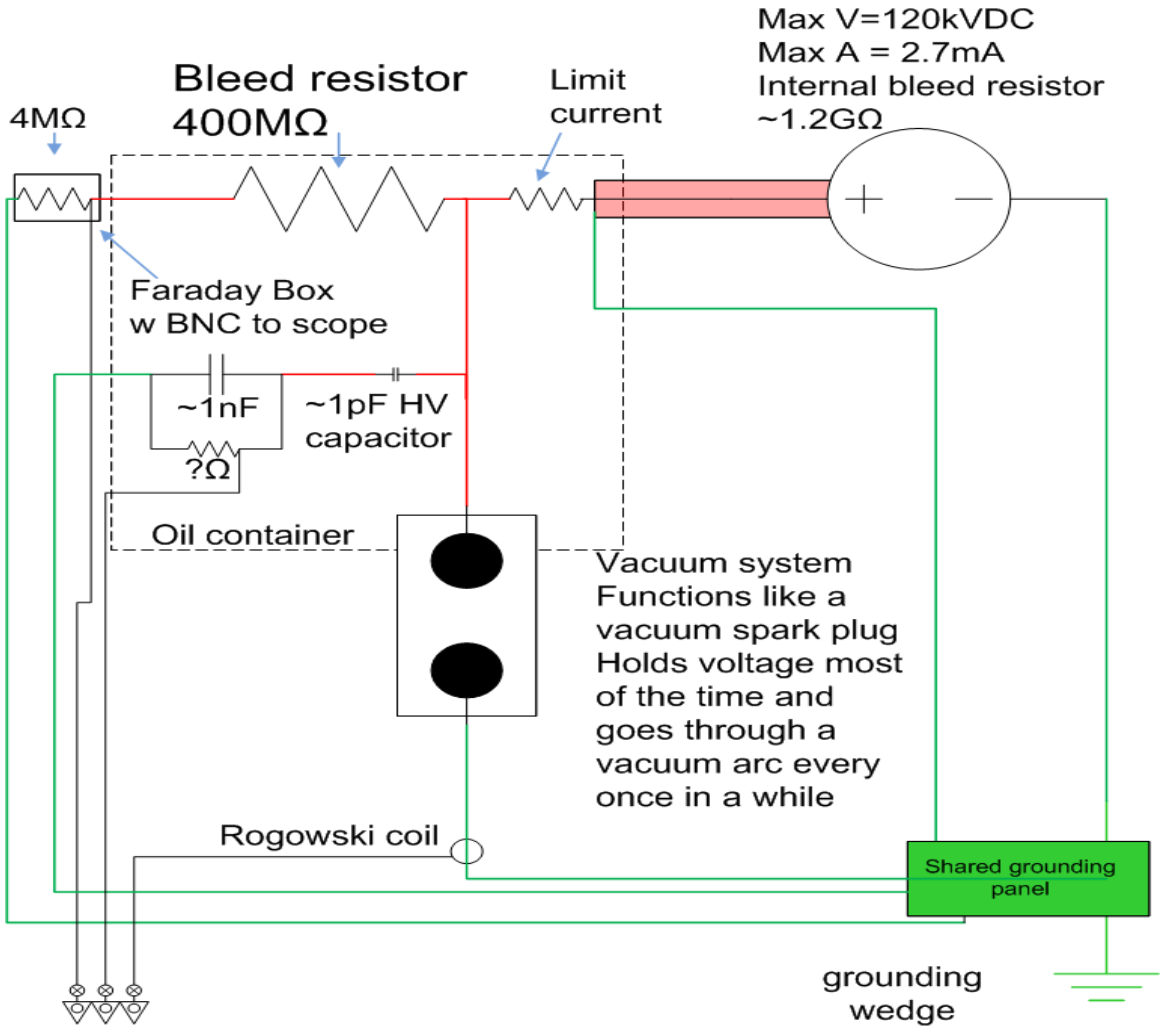
- The main aim is to identify whether we have pre-BD surface plastic activity.

  Therefore relative timing of any electrical activity and the acoustic signal is critical
- It is important to correlate various plasma electrical signals with their corresponding acoustic signal
- Specifically, we can identify if this correspondence changes upon conditioning

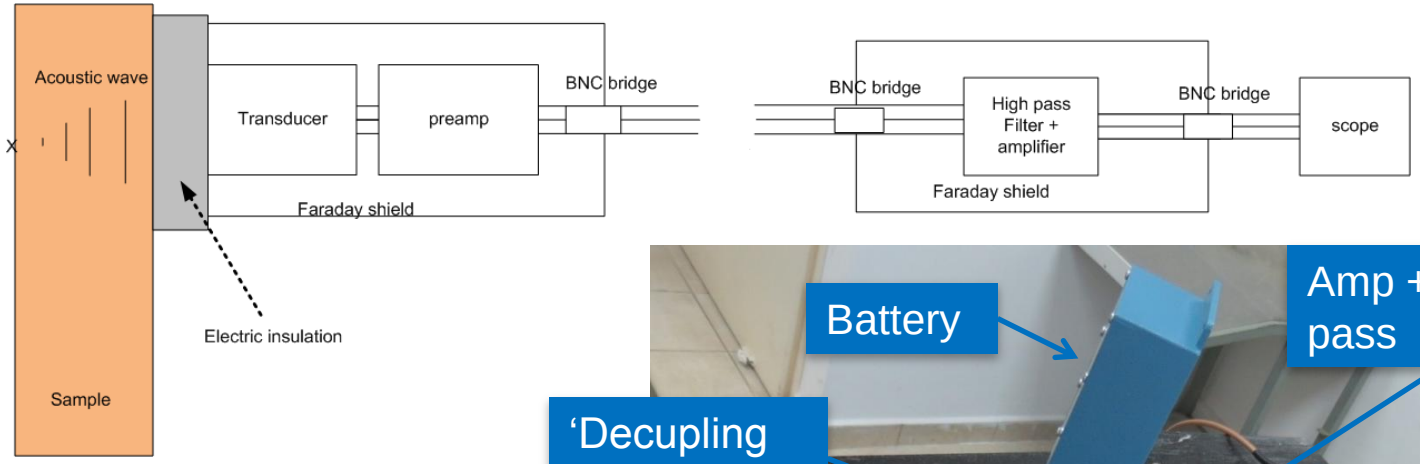


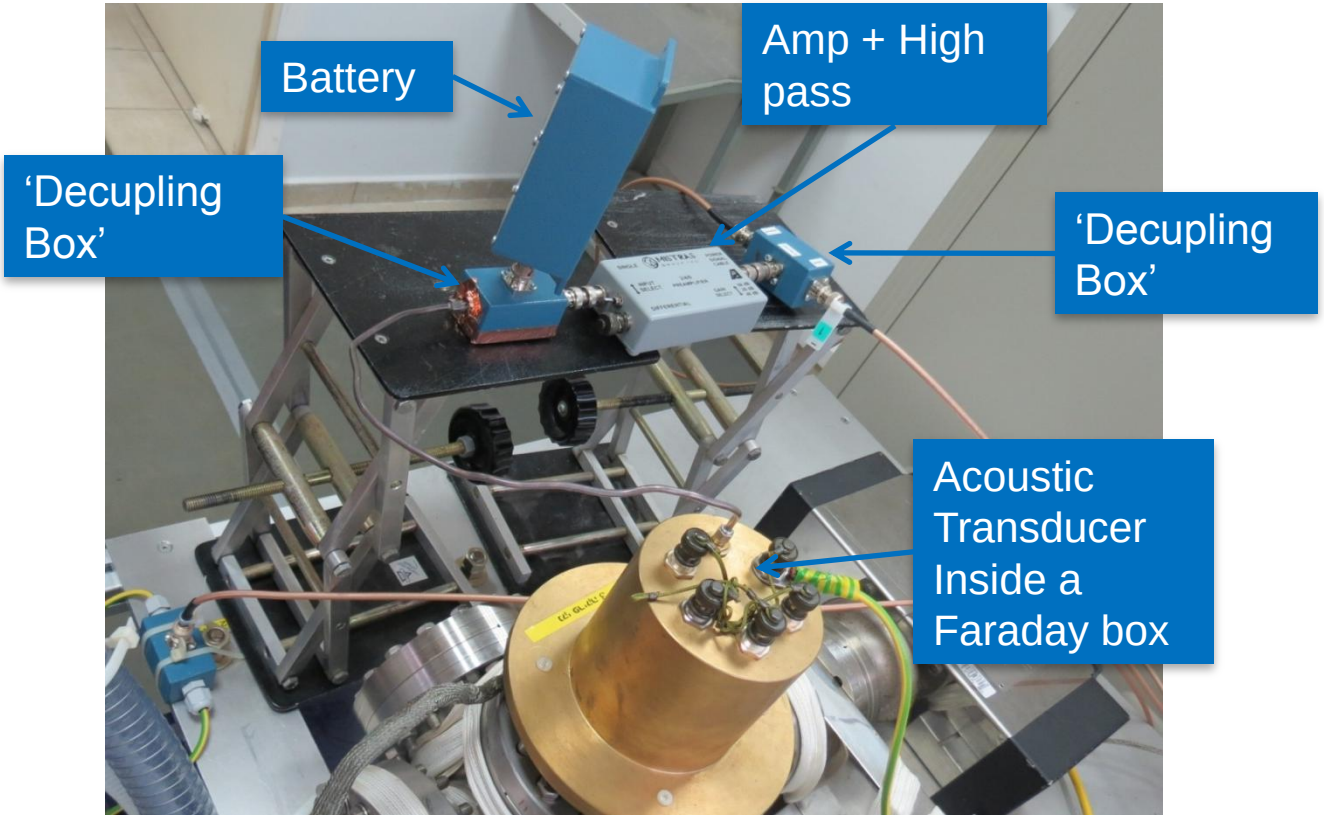
Electric system





Acoustic system

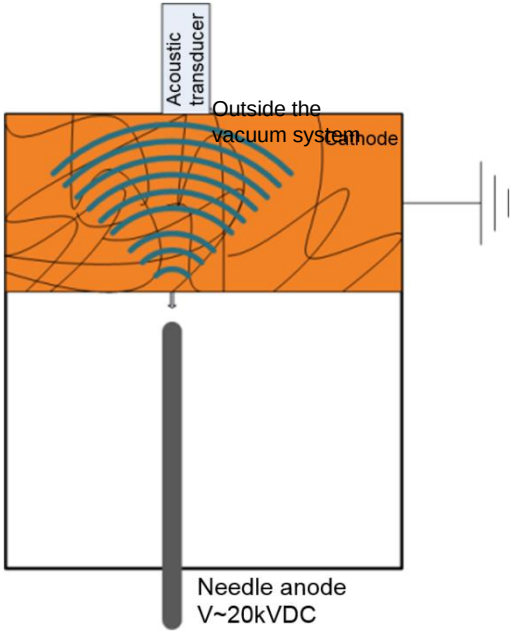




Types of signals

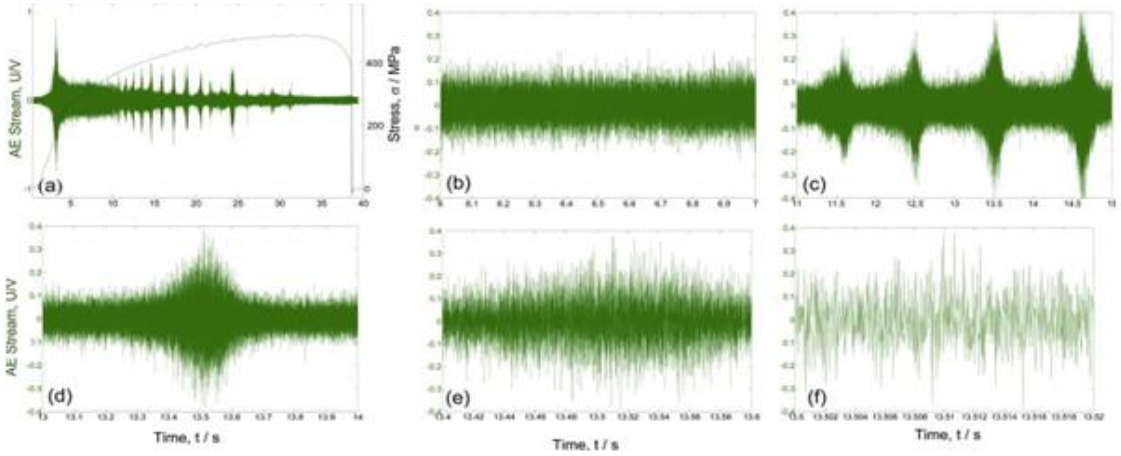
There are a few types of signals we would like to check:

1. Discrete acoustic events
2. A continues signal for high fields (a different frequency response from the BG). Could be with pre-breakdown
3. A continues signal before a breakdown



Previous work: Acoustic signals

strain stress experiments

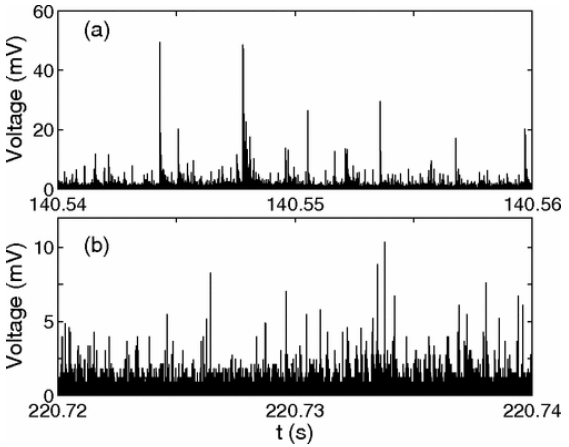


A. Vinogradov , A. Lazarev

Continuous acoustic emission during intermittent plastic flow in α-brass

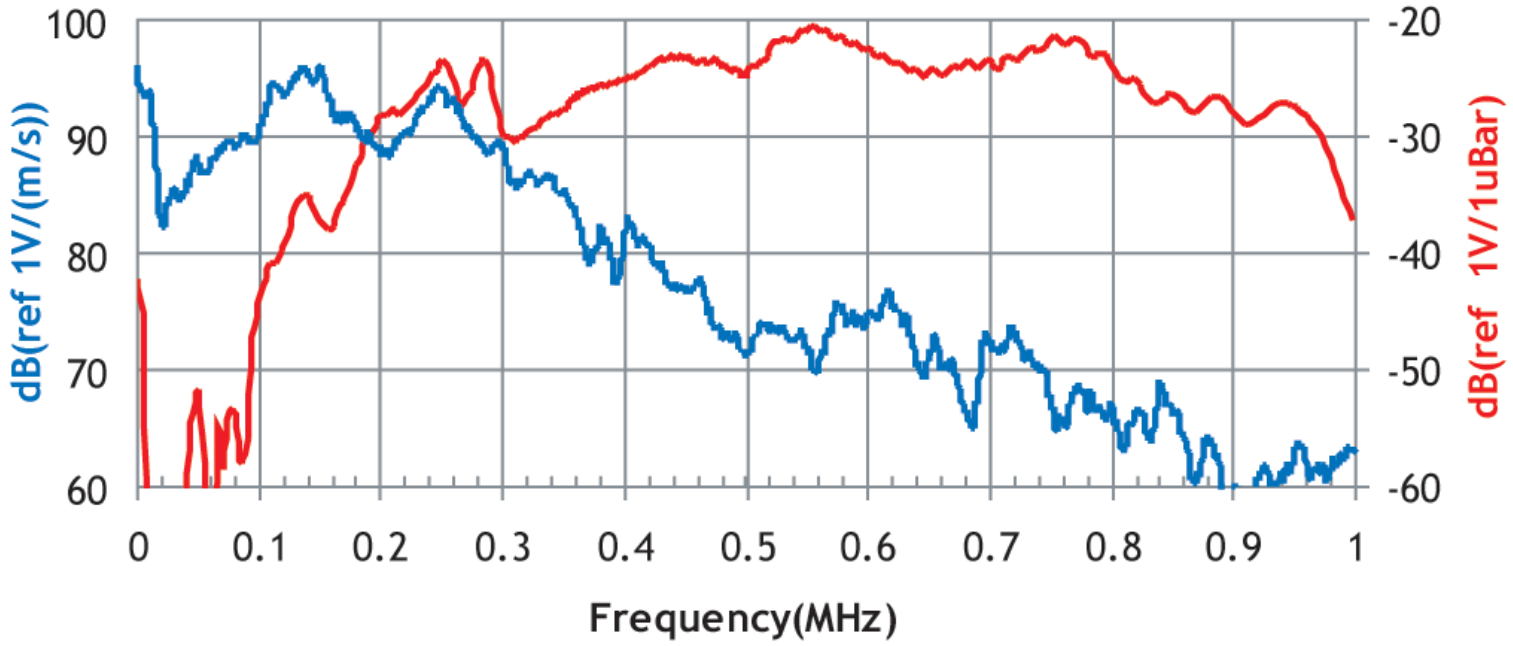
Scripta Materialia, Volume 66, Issue 10, 2012, 745 - 748

http://dx.doi.org/10.1016/j.scriptamat.2012.01.053

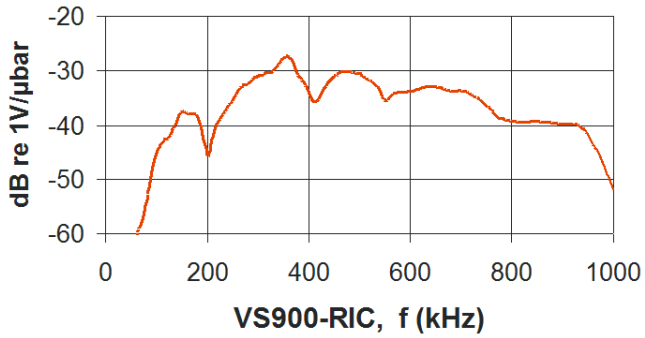


Lebyodkin, M. A. et al. Role of superposition of dislocation avalanches in the statistics of acoustic emission during plastic deformation. Phys. Rev. E 88, 042402 (2013)

Response of acoustic transducers



WDI



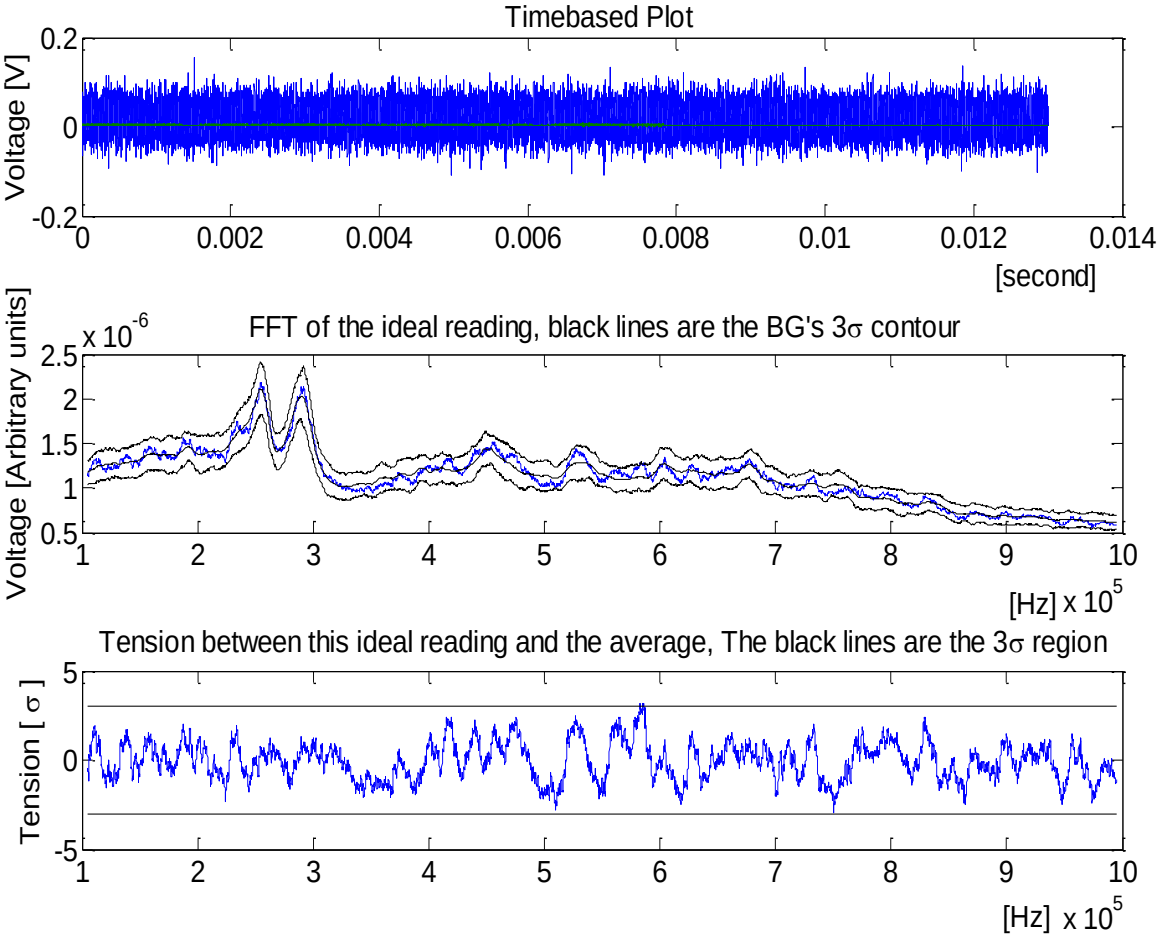
Background of acoustic signal

Idle acoustic measurements – no HV

In order to distinguish between ideal background and an acoustic signal:

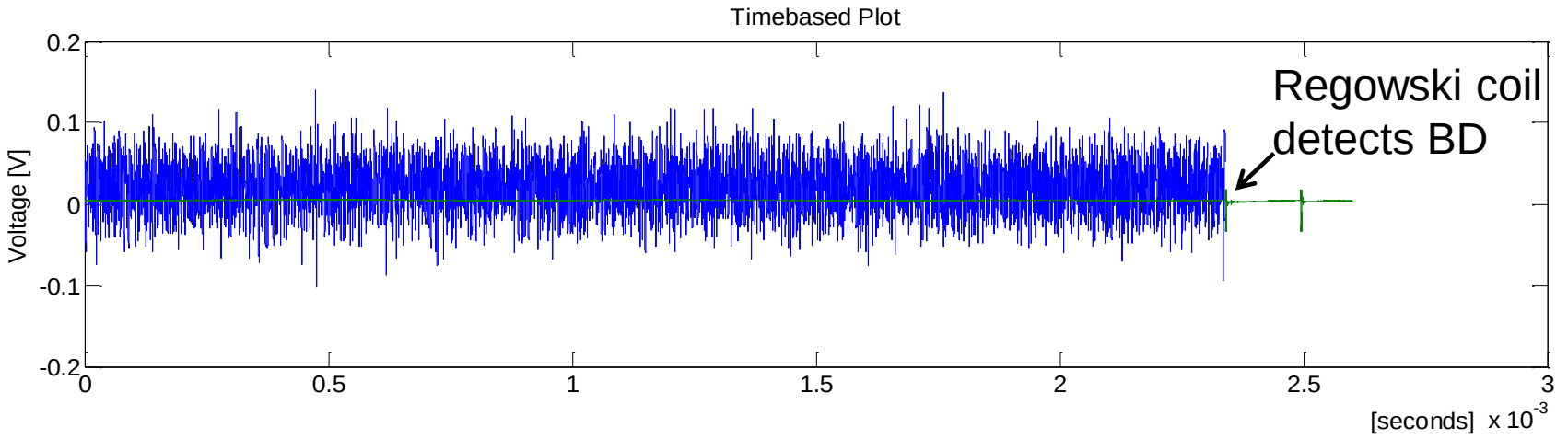
1. Took a sample set of ideal background.
2. Moving average of 10kHz
3. Normalized the amplitude
4. Found the mean and standard deviation of the sample

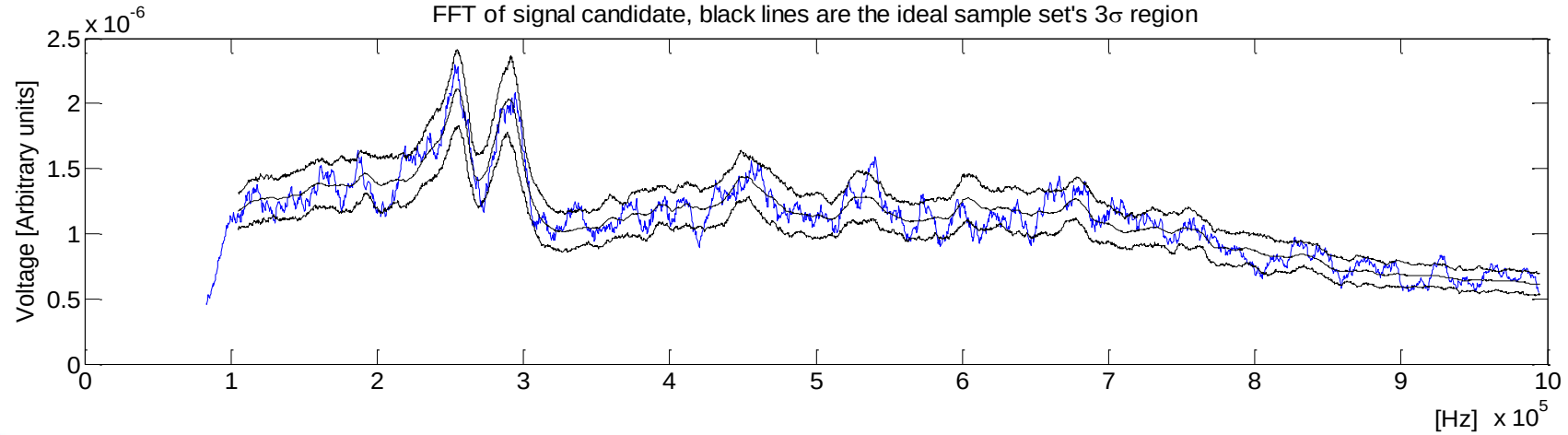
This sample is what we compare against candidate samples



Preliminary results (Al)

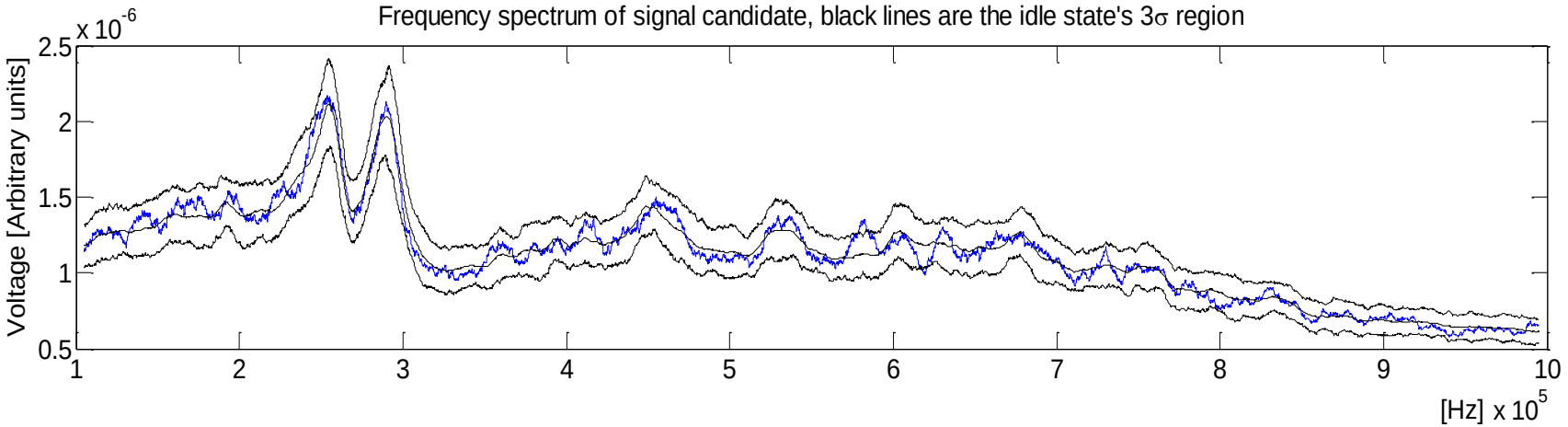
Just before a full breakdown

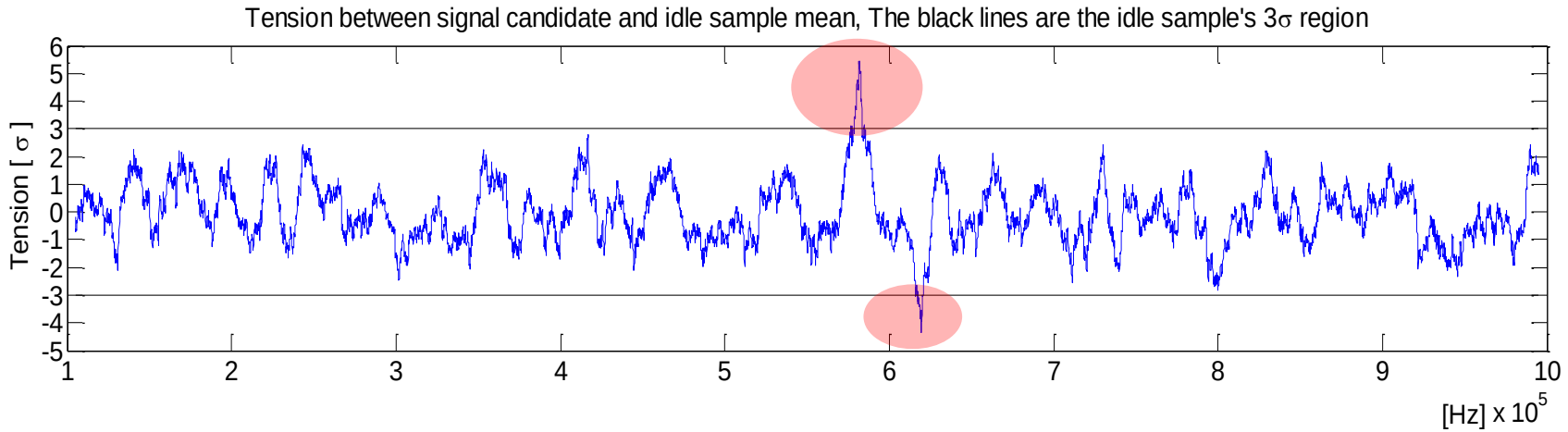




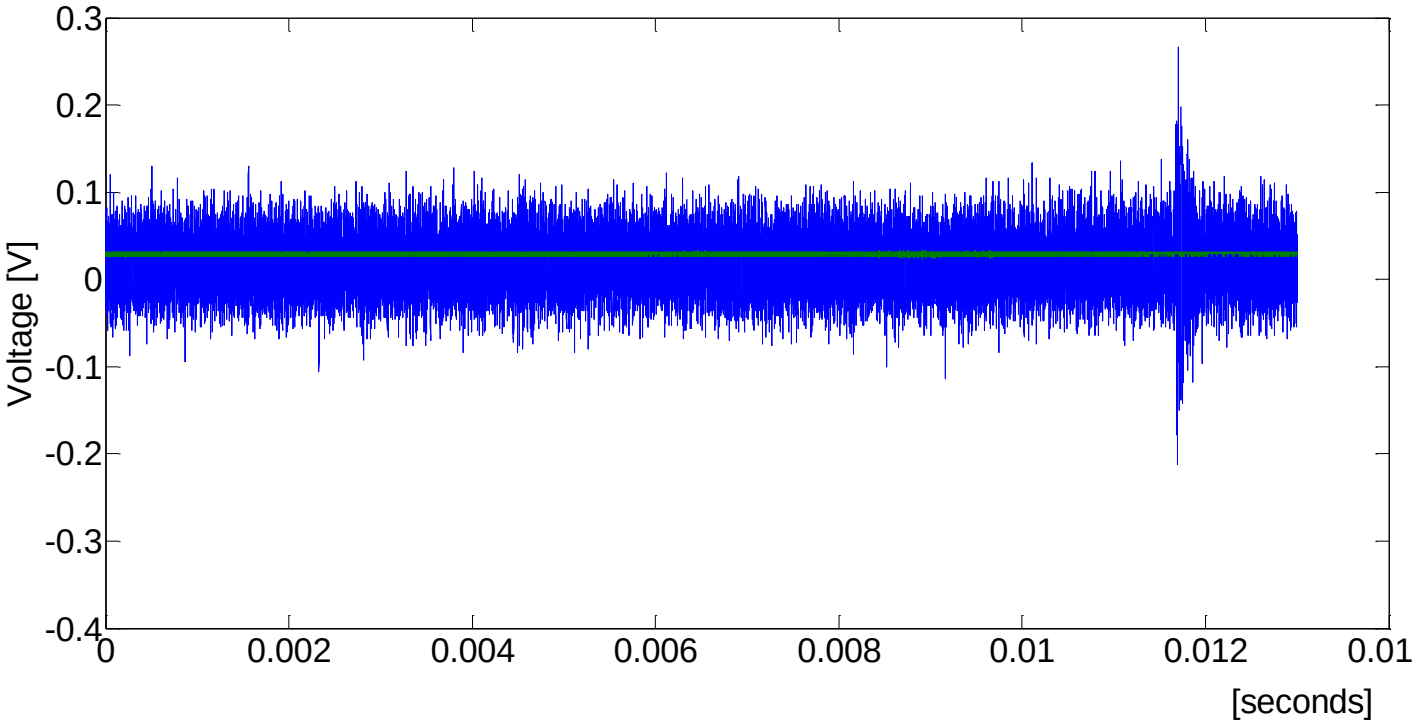
Preliminary results (Al)

pre-breakdown, I ≈ 30 [μA]





preliminary results - discreet

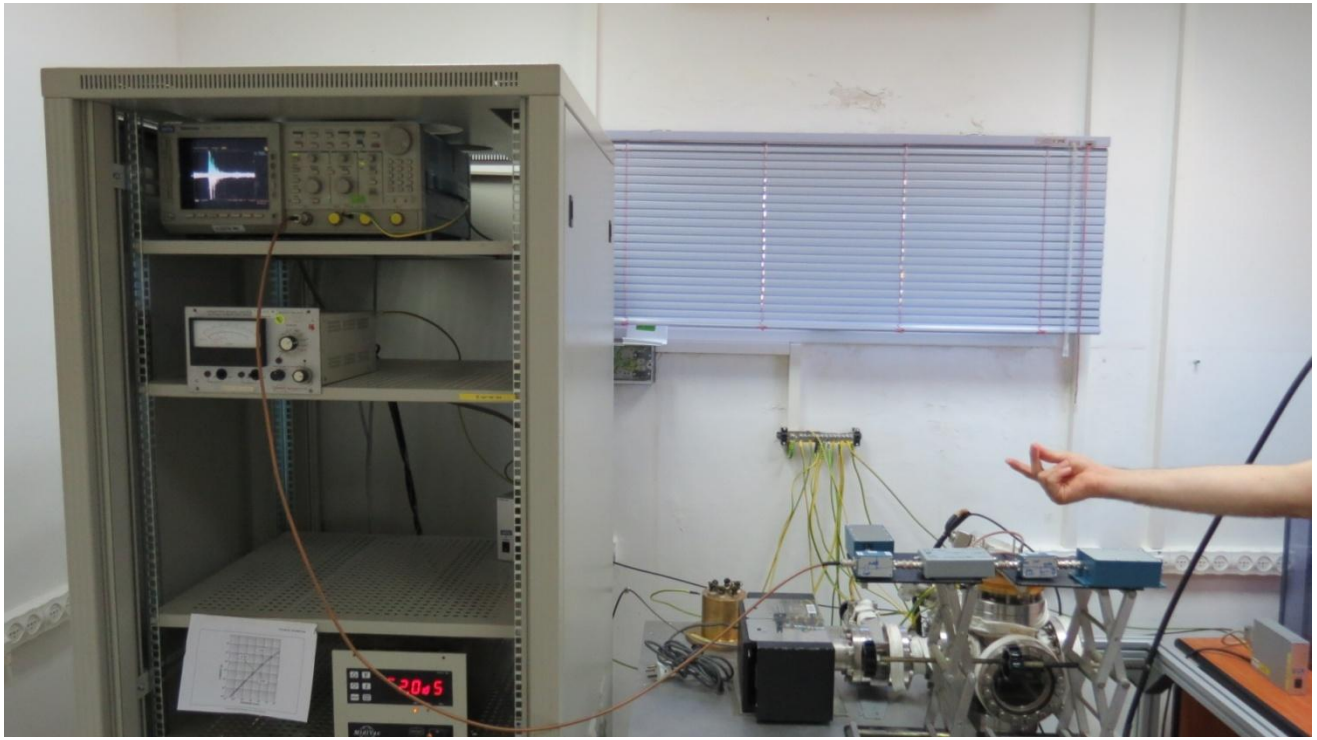


Further tests needed: Rate of discreet acoustic signals with correlation to the condition of the electric system, triangulation

Future work

- New system – need to complete various validity/sanity checks
- Detailed statistical analysis of candidate signals and background signal
- In case no signal is found, set lower bounds
- Make measurements on a fully conditioned sample
- Move to the copper sample given by CERN

Thank you



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