Spectroscopic analysis of DC breakdowns

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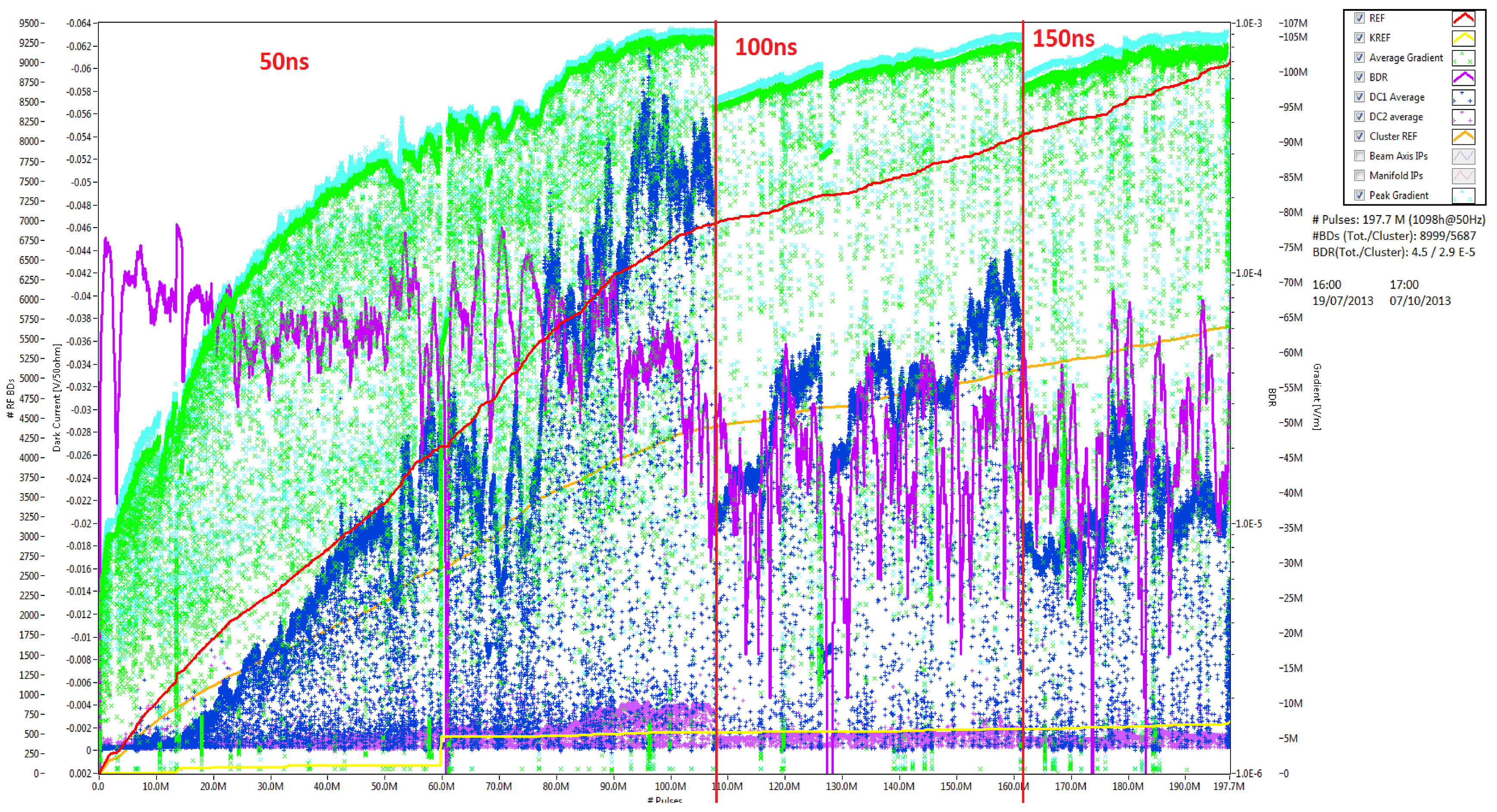
Motivation and importance

Electrical breakdowns in vacuum is one of a urgent problem of accelerator constructions. Such breakdowns are a main performance limitation in TeV colliders, with accelerating gradients above 100 MV/m. With such field RF breakdown are likely occur and disrupt the accelerated beam. Investigation RF breakdowns takes more time (including for conditioning process) and resources.



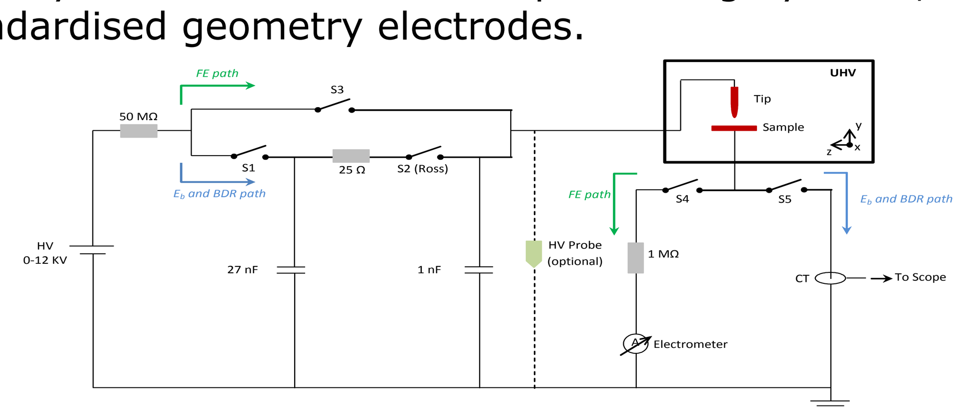
Results of RF breakdown studies [courtesy of B. Woolley]

For understanding this phenomena in the RF case, we first need to study them in DC. Optical spectroscopy is a strong noncontact method for breakdown investigation. It is used in combination with the DC system in order to study breakdown plasma and surface physics and to support theoretical modelling of breakdowns. Nowadays simulations use actively for studying the properties of vacuum arc discharges. For the moment, only electrons, neutral copper and Cu^{1+} taken into account during modelling in Particle-in-Cell code. Finding other kind of particles and understanding they influence to breakdown mechanism will produce a new results in RF breakdown simulations.

Experimental setup

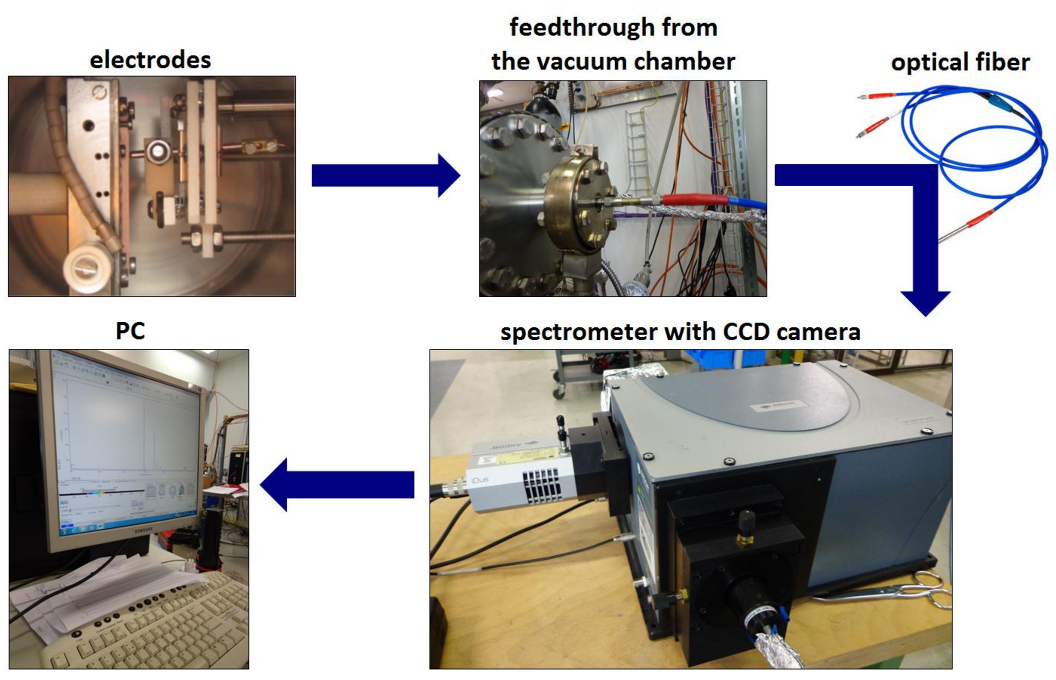
Setup for optical spectroscopy of DC breakdowns based on DC-spark system, which provides a cheap, fast, easier than RF tests and effective apparatus for breakdown studies at CERN. The main parts of DC-spark system are: vacuum and positioning systems, high-voltage switching electronics and standardised geometry electrodes.

Experimental conditions:
Electrodes material - copper
Gap distance – 20 μm
Pressure – $9 \times 10^{-9} mbar$
Applied voltage – 8 kV



Circuit schematics DC-spark system

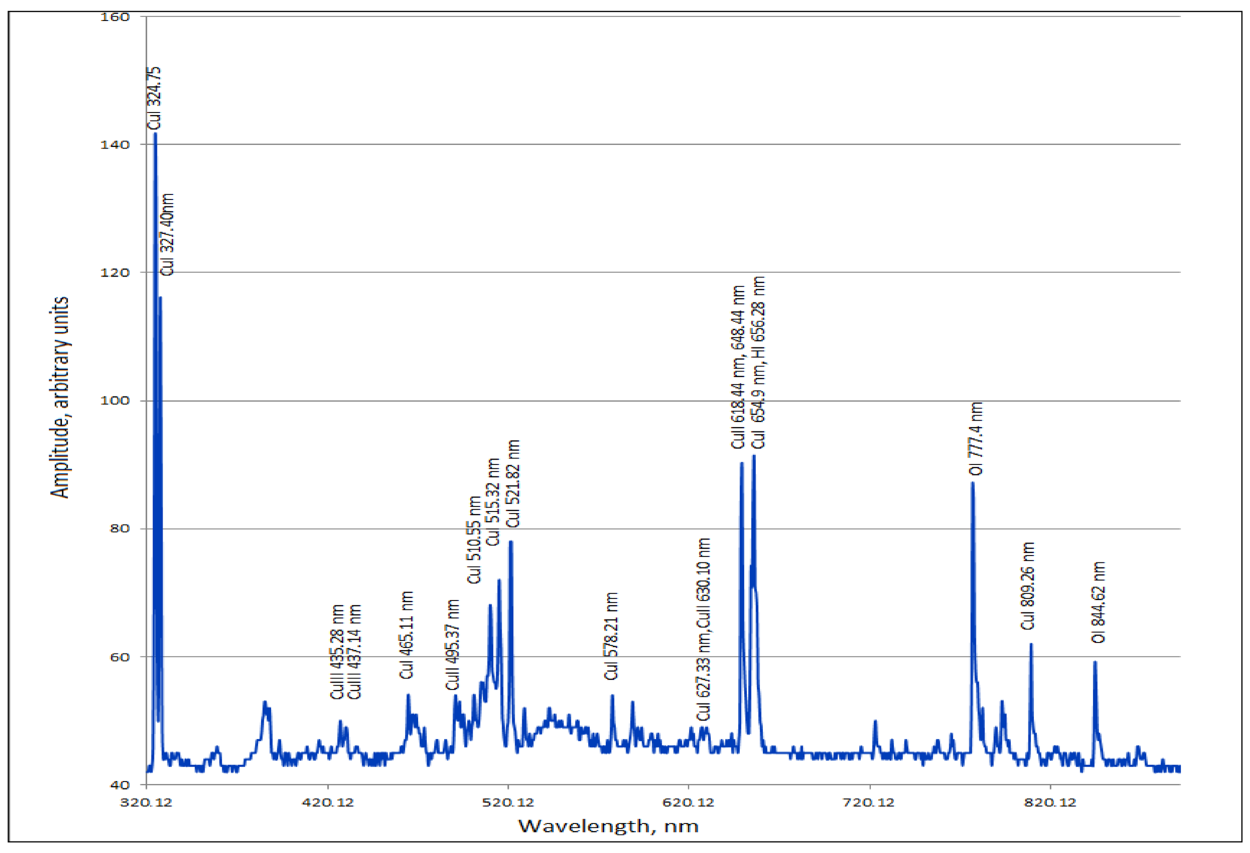
DC-spark system at CERN



The scheme of setup for optical spectroscopy of breakdowns

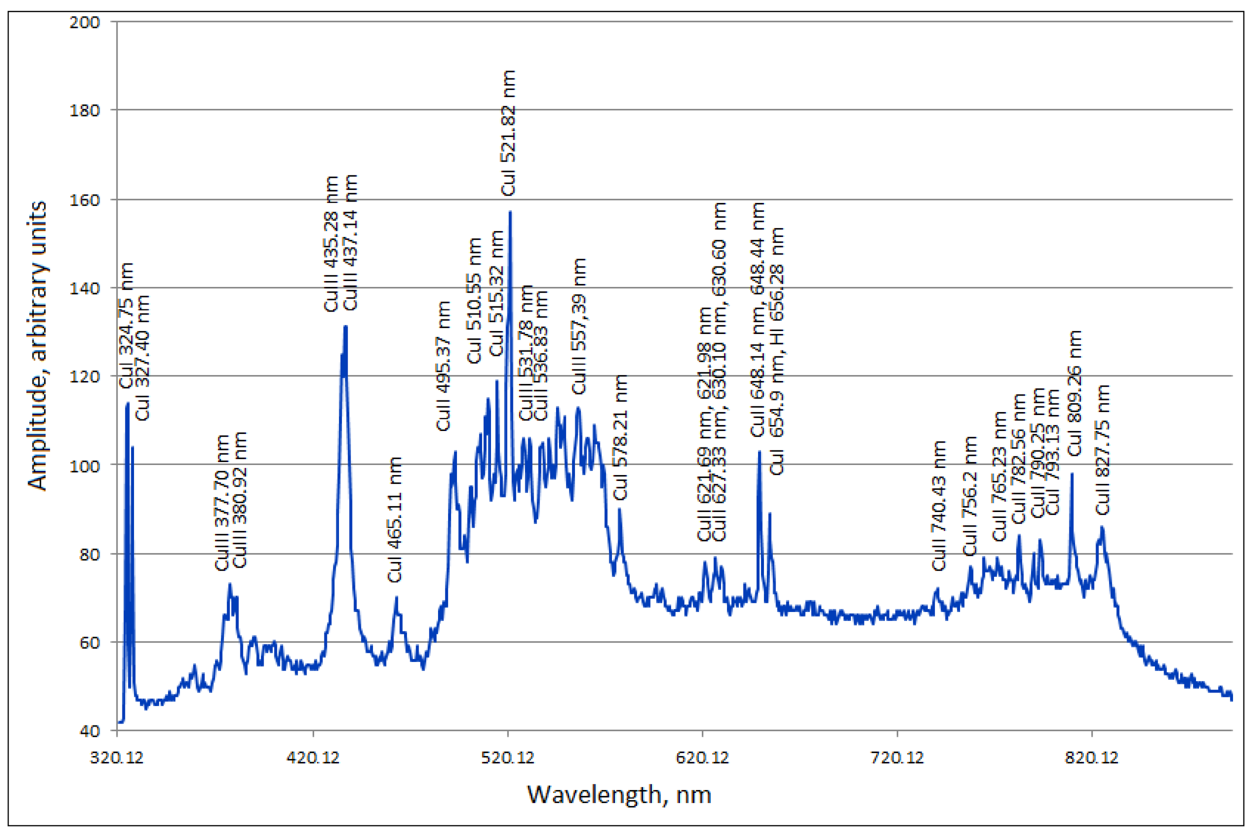
Specifications for optical spectroscopy parts			
Optical fiber	bandpass, nm	400-2100	
CCD camera	active pixels	1024×255	
	pixel size, um	26×26	
Spectrometer	grating, l/mm	150	1200
	resolution, nm	0.88	0.1
	bandpass, nm	600	67

Results



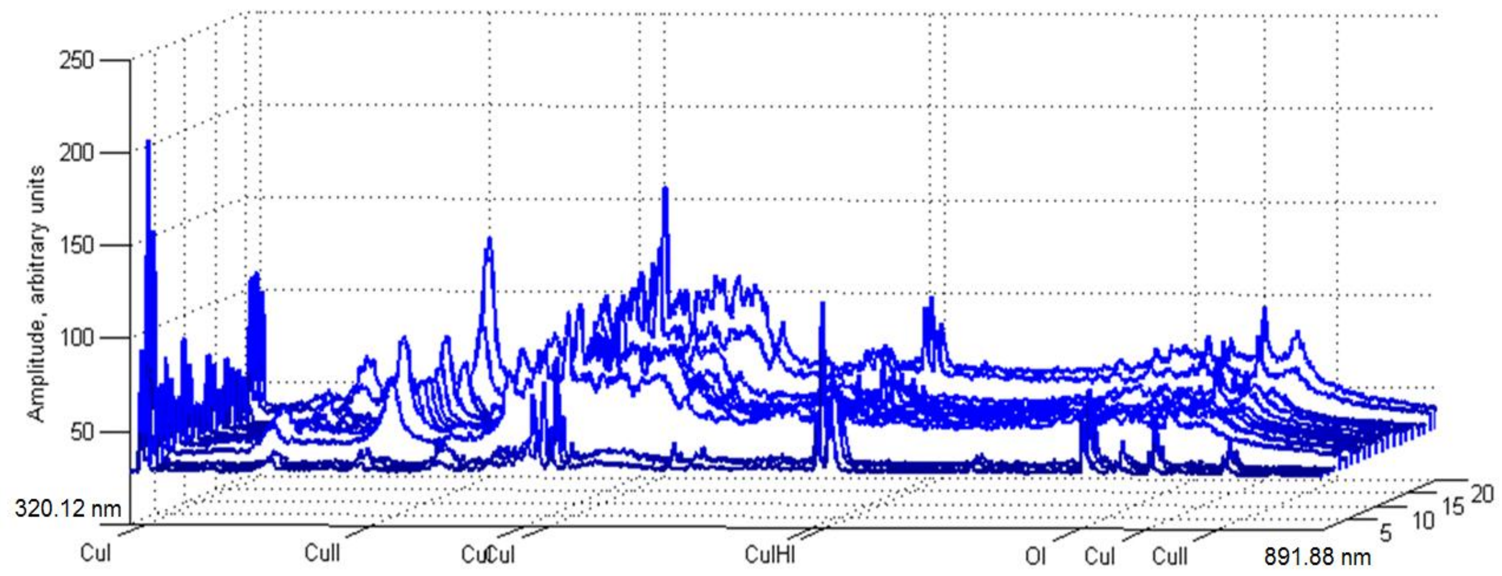
The spectrum of the first breakdown

After analysis of emission spectra of breakdowns lines of neutral atom of Cu (CuI), Cu^{+} (CuII) and Cu^{2+} (CuIII) were founded. In additional the emission lines of gas impurities (oxygen (777.4 nm, 844.63 nm) and hydrogen (656.3 nm)) were observed.



The spectrum of 20th breakdown

A comparison of several consecutive breakdowns showed differences between fist 3-4 breakdowns and others. Such The difference in the spectra of the first breakdowns can be explained by destruction of the oxide layer by the sparks, which is a result of adsorption on the copper surface of the elements that are situated at the atmosphere.



A comparison of the optical spectra for 20 consecutive breakdowns

Future plans

- Take more statistics for improving results:
  - investigate more spots;
  - check reproductively of results after re-oxidize of surface.
- Time-resolved spectroscopy of breakdown to give information about line development during breakdown.
- Look for Cu^{2+} lines and study they development during breakdown.
- To find the way to make a parameter calculation of breakdown plasmas (temperature, density, etc.).
  These are potentially benchmarks for future models and simulations.

References

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