Diagnostics for Breakdown Experiments RF & DC

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Motivation:

Diagnostics of breakdown events in DC and RF are complementary to the 'usual' structure tests and aim at answering the following questions:

1. What triggers a breakdown?
2. What happens during a breakdown?
3. New conditions after a breakdown (conditioning!)?
4. What limits the performance of a structure?

Goal: Constructive feedback to structure design and production!

What kind of diagnostics?

All diagnostics will be applied to RF and DC tests:

Are breakdowns in DC similar to breakdowns in RF?

Reproducible similarities would be extremely helpful in terms of time and costs:

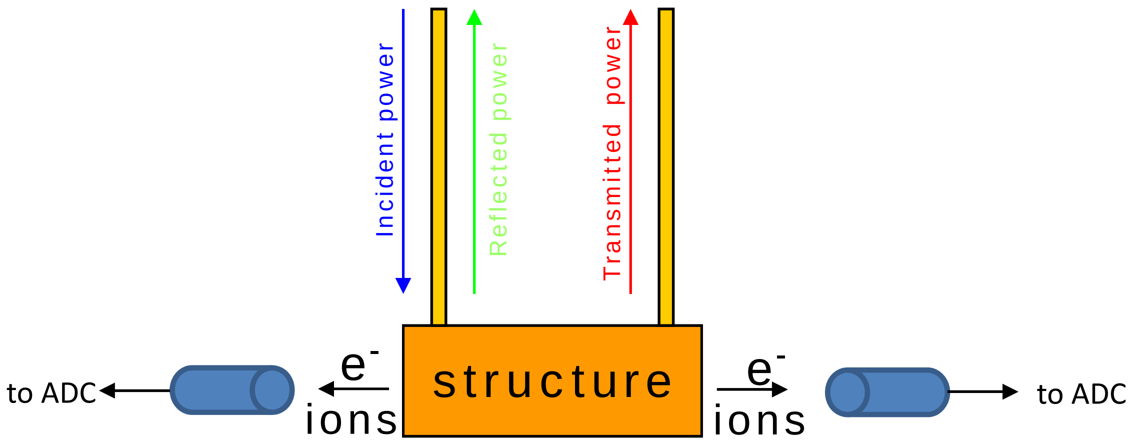
Parameter	**DC**	**RF**
Time of one test	days	months
Material cost of one test	A few CHF	Tens of kCHF
Preparation	1 day	1 week

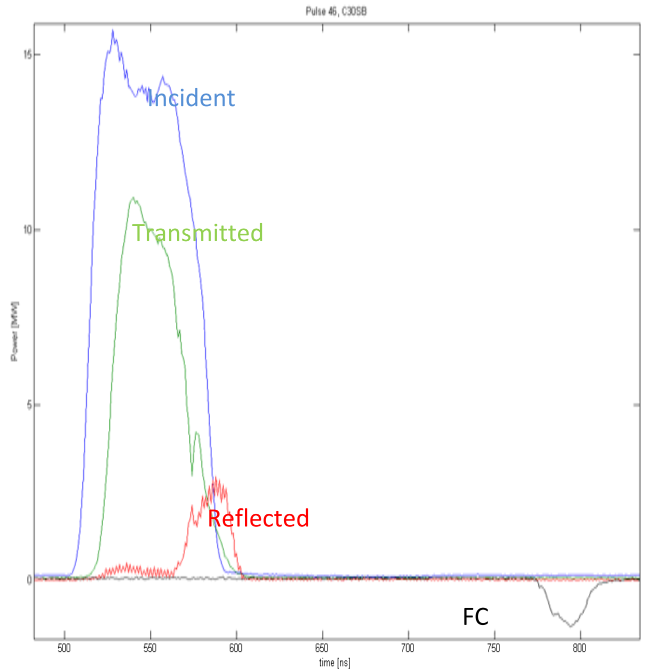
If yes, the 'easy' benchmarking of materials, surface treatment and production techniques in DC could be applied to RF structures!

Used and planned diagnostics in RF

- 'Standard' instrumentation:
  - RF signals from the structure for normal pulses and breakdown pulses, this includes the incident pulse, transmitted and reflected pulse
  - all signals calibrated and checked for consistency and stability

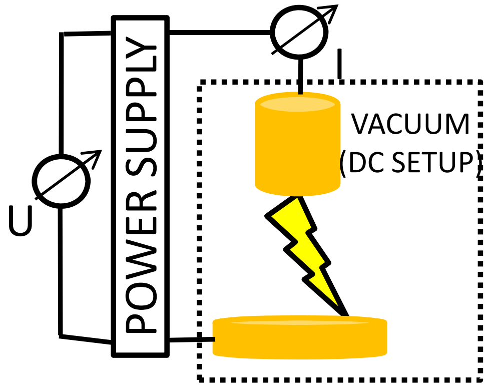
- Faraday cups at each end of the structure connected to fast ADCs





Used and planned diagnostics in DC

- 'Standard' instrumentation:
  - Current and voltage from the setup for normal pulses and breakdown pulses
  - Vacuum level and rest gas composition (mass spectrometer)



Which values can be compared with RF?

- Total power dissipated per breakdown (~0.5J)
- Breakdown-rate vs. gradient for different materials
- But: much smaller surface, no RF, completely different timing

Diagnostics applied to RF and DC

- Breakdowns are transient plasma phenomena after they have been triggered:

  → Light emission from IR to UV

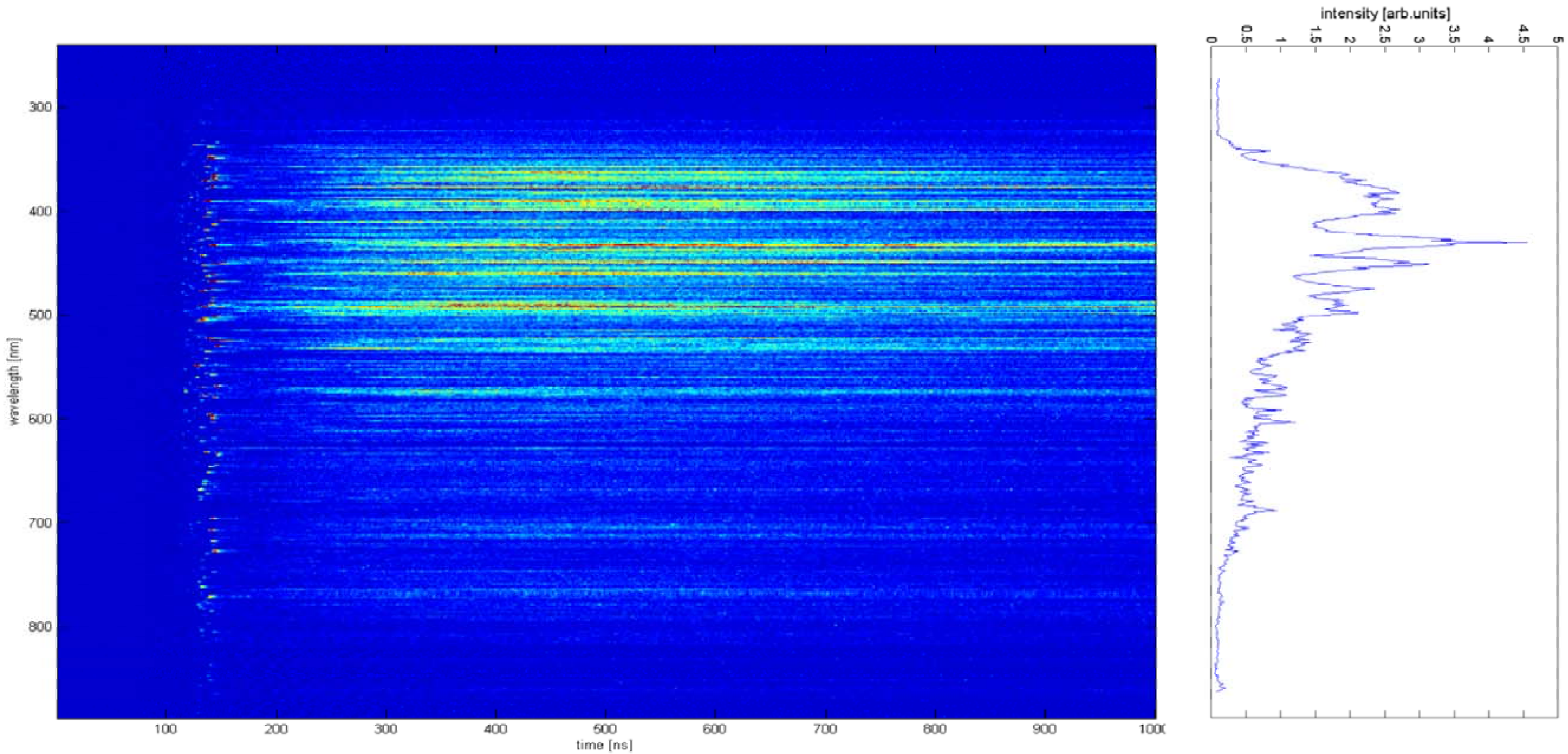
  → Time resolved spectroscopy will be applied to RF and DC

  → New system will arrive end of November 2008

Specs:

- 0.2nm resolution
- Gratings for overview and high resolution spectra
- Cooled CCD camera for integrated spectrum
- High-QE multialkali PMT for time-resolved spectroscopy at single lines
- Fully computer controlled

Diagnostics applied to RF and DC



Example: DC spectrum measured for Cu electrodes with existing setup

The new system will be able to record a full integrated spectrum and one time-resolved wavelength interval for each breakdown

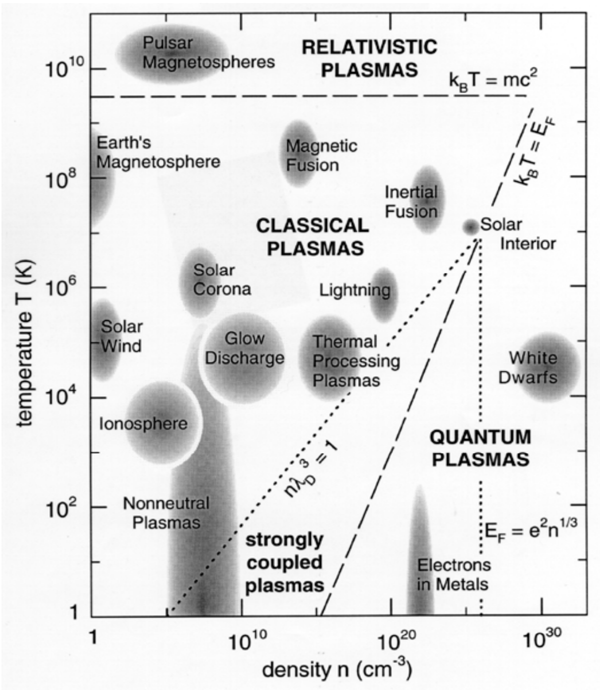
Diagnostics applied to RF and DC

Parameters measured with time resolved spectroscopy will be applied to RF and DC:

1. 'Classical' spectroscopy: What lines resp. elements are involved in the process? How do they develop in time? Any correlations to the conditioning-effect?
2. Is there a blackbody background? Does it change with time? Precursors???
3. Estimation of plasma parameters:

   Plasma temperature and density

Feedback to plasma simulations!



Diagnostics applied only to RF

- Electron and ion currents on faraday cup (many thanks to Uppsala)
- An immense flash of x-rays has been detected during a breakdown

These diagnostics will be upgraded:

- The energy distribution of electrons and ions will be measured with a magnetic spectrometer

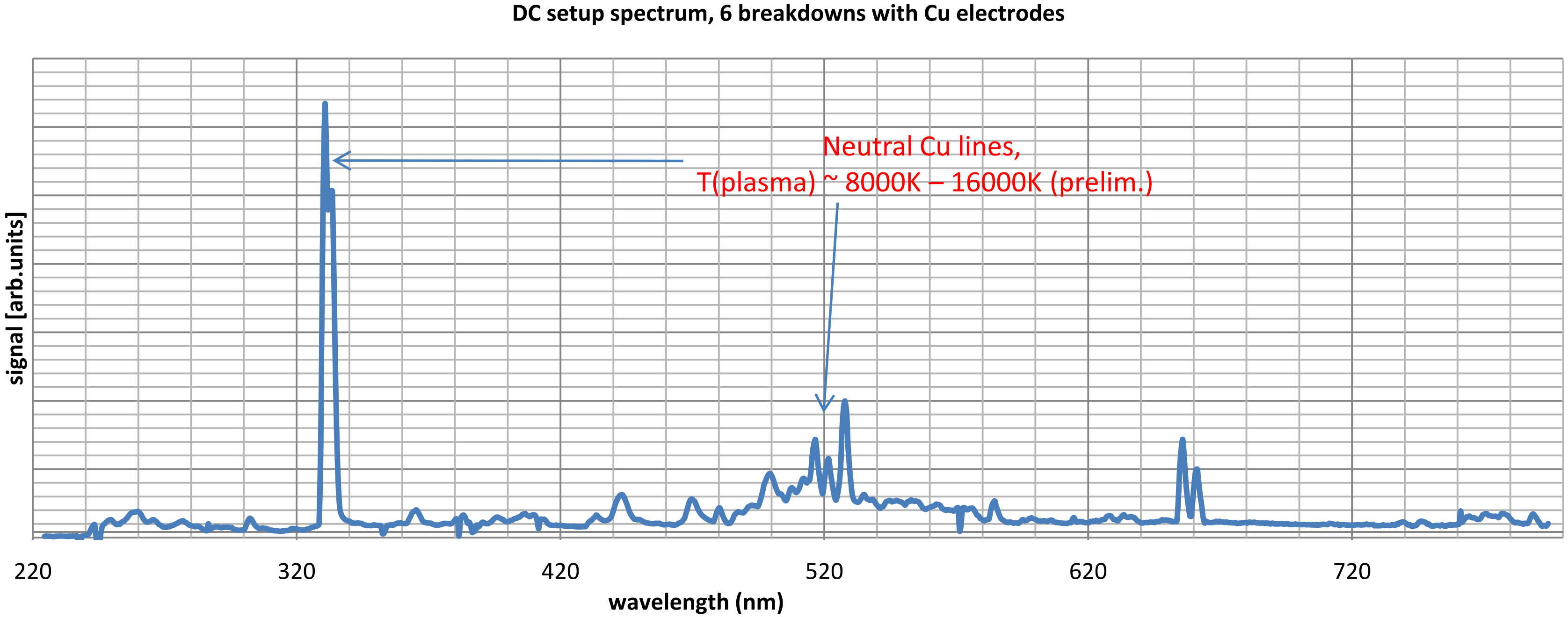
- Energy distribution of x-rays measured with a filter wheel

- Investigations are ongoing if the energy distribution of the x-rays can be measured within one shot resp. breakdown

- Upgrade of the single-line PMT to a 32-line PMT on the spectrometer

- 30GHz microwave plasma diagnostics in 12GHz system (to be designed…)

Preliminary results from DC



Demonstration of the capability of the new spectroscopy system like ordered:

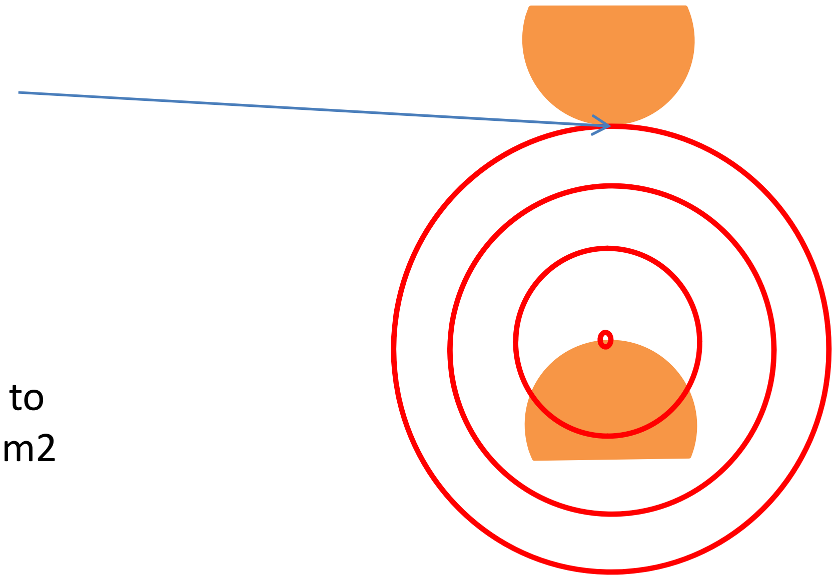
- Neutral copper lines can be clearly identified
- Two-line-method to estimate plasma temperature is easily applicable: ~1eV

Preliminary results from RF – where does the missing energy go?

Damage by ions from Coulomb explosion:

Measured by M.Johnson & R.Ruber with FC:
- ~10E10 ions per event on FC, 1/200 of solid angle ➔ 10E13 ions in Coulomb explosion
- Ion energies (ToF) ~100eV - 1keV or $2*10^{-17}$- 10^{-16}J per ion)

Estimation:
-Radial expansion of the coulomb explosion
- 4mm to next iris
➔5E11 ions/mm2 on the other side of the iris
➔~50uJ/mm2 of energy deposited
➔In 1ns, this is 10kW/mm2
➔Max. 1mJ in total



Seems that the ions cannot heat up the surface to melting point (pulsed surface heating is 7kW/mm2 for 68ns, ΔT is only 60K…)

But: One ion impact each 10x10atoms2, sputtering?

Preliminary results from RF – where does the missing energy go?

Energy carried by electrons:

Measured:

-High currents (5V in 50Ohms, 100mA) of electrons hit the FC in each BD event, X-rays are produced by these electrons

X-rays pass vacuum window and Al-foils

➔ at least 10keV to be detectable, for 10E13 electrons (from single charged ions), dissipated energy is around 20mJ

X-rays pass 14mm Cu and 5mm Fe (tank)

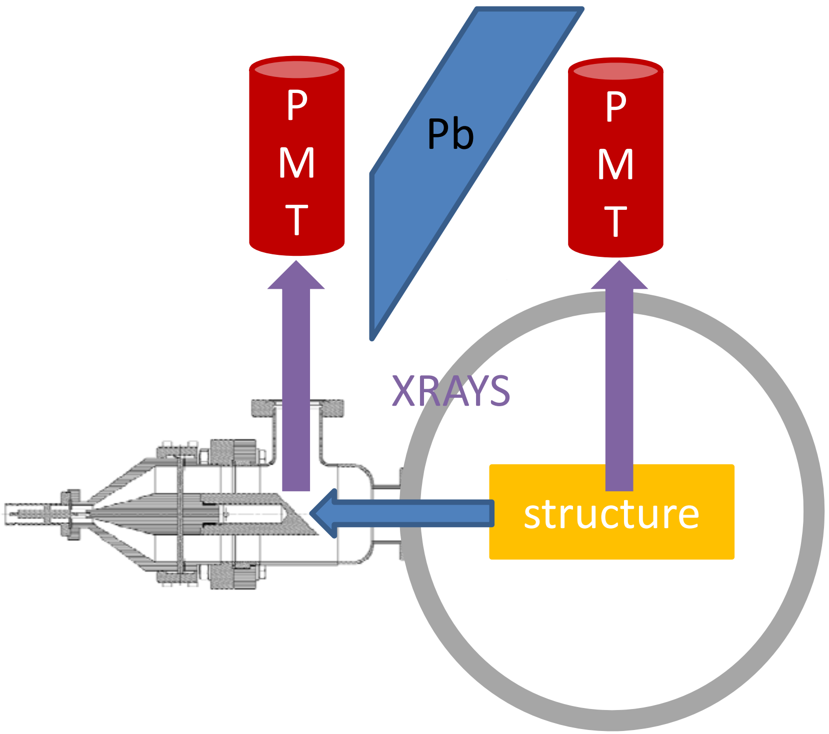
➔ at least 100keV to be detectable

In total: 10E13 electrons with 100keV carry

~200mJ

Estimations from surface field calculations: 400keV…

Remember: 500mJ missing RF energy!



Conclusion and Outlook

• Breakdown diagnostics will be used to discover the processes happening during a breakdown and possibly give information about its trigger mechanism and conditioning

• A proven similarity between RF and DC would be extremely helpful in benchmarking materials and processing techniques

• Breakdown diagnostics give direct feedback to plasma simulations

Used and planned diagnostics virtually cover all possible ways to get information about breakdowns and stable operation