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# Multi-channel impedance spectroscopy for optimizing fuel cell operation

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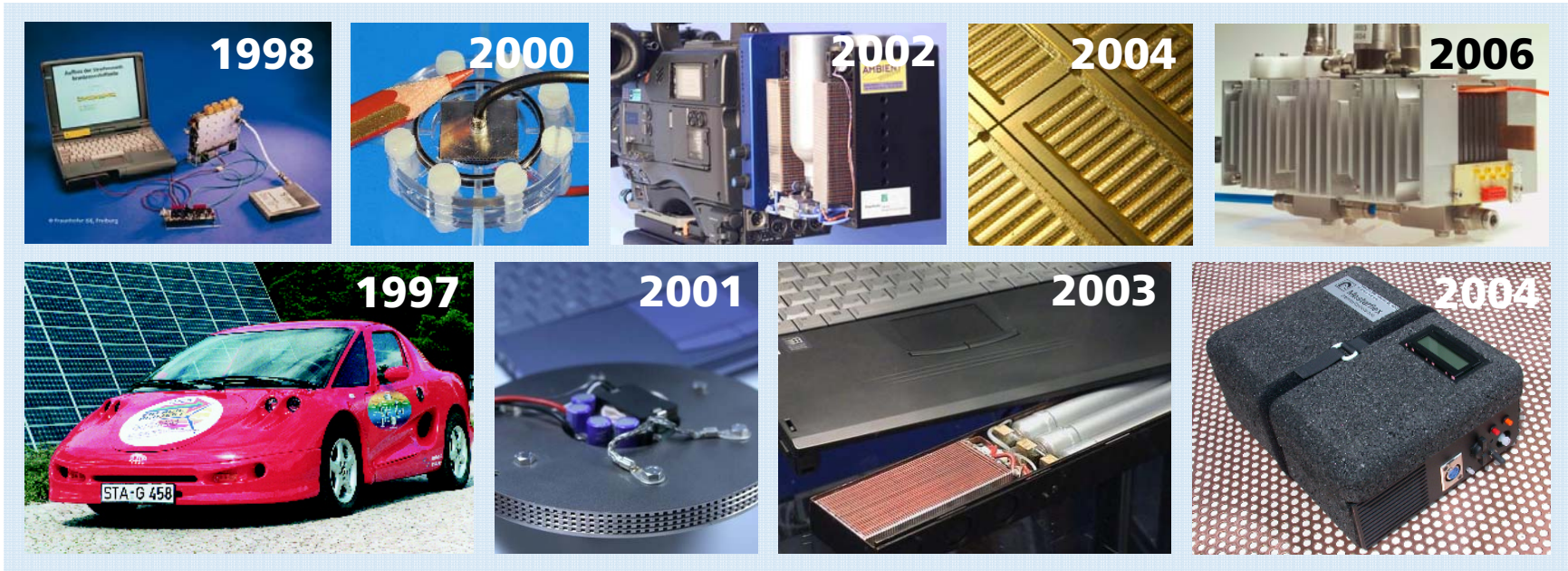
# Agenda

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- Fuel Cell Systems @ Fraunhofer ISE
- Test stand for multi-channel impedance spectroscopy
- Outcomes



# We are dedicated to fuel cells since the early 1990s.



# We comprise a lot of competences.

- 1992 begin of activities on hydrogen and fuel cells
- Ca. 2 Mio. € budget (2009)
- 7 engineers, 3 doctoral scientists, 4 doctoral students, ca. 15 students
- To our equipment belong:
  - 50 channel impedance spectroscopy
  - ICP-MS (Inductively Coupled Plasma – Mass Spectroscopy)
  - ESEM with EDX (Environmental Scanning Electron Microscope with Energy Dispersive X-Ray Spectroscopy)
  - Climate chamber
  - Several fuel cell test stands for micro and portable PEM fuel cells (NT- and HT-PEMFC) up to 5 kW<sub>el</sub> power

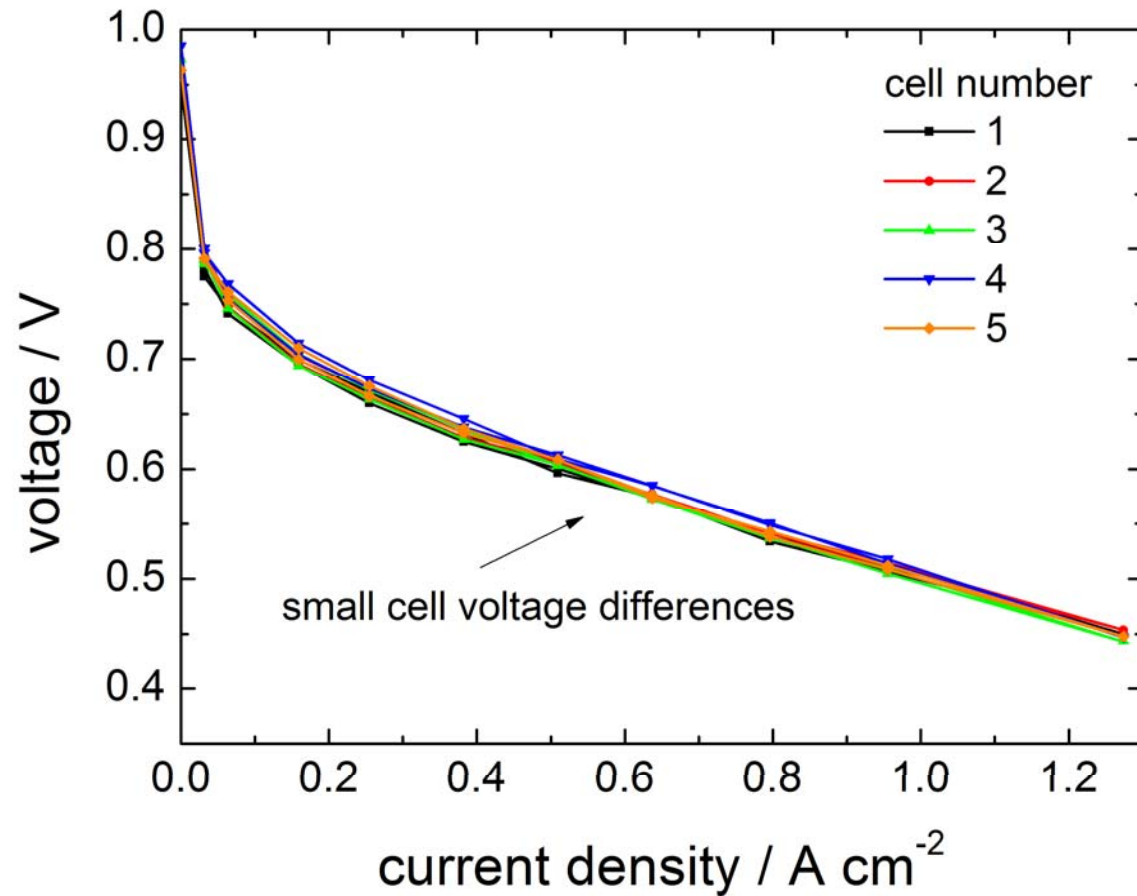
# PEM fuel cells are our profession.

- Planar, air breathing micro fuel cells (PEMFC, DMFC, DEFC) from 100 mW<sub>el</sub> to 10 W<sub>el</sub>
- Portable fuel cells (NT- & HT-PEMFC) for operation with hydrogen and reformat from 10 W<sub>el</sub> to 1 kW<sub>el</sub>
- System technology for membrane fuel cells from 100 mW<sub>el</sub> to 5 kW<sub>el</sub>

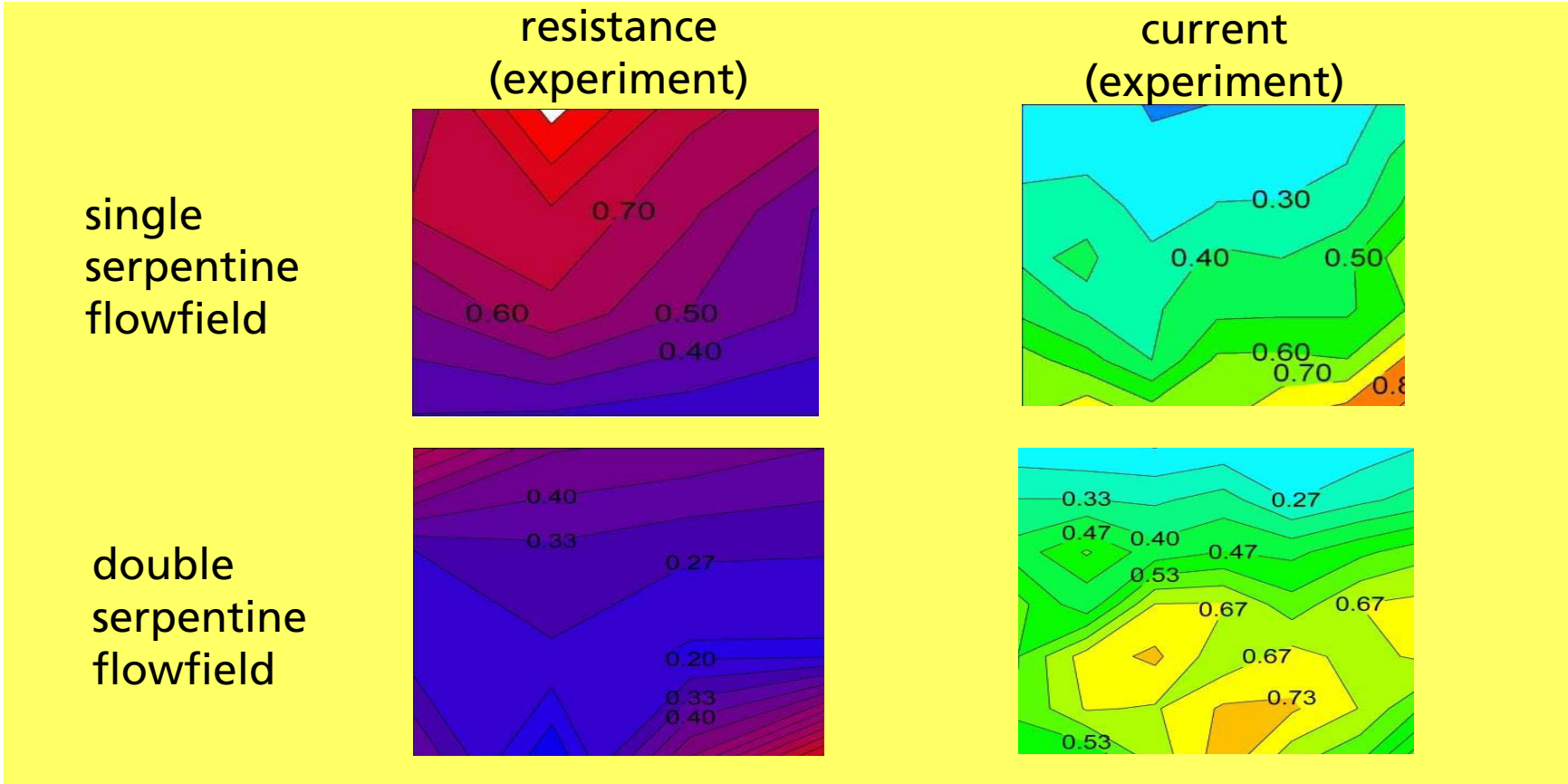


# Homogeneous conditions have to be realised.

- design improvement
- well-chosen operating conditions
- ingenious start/stop strategies

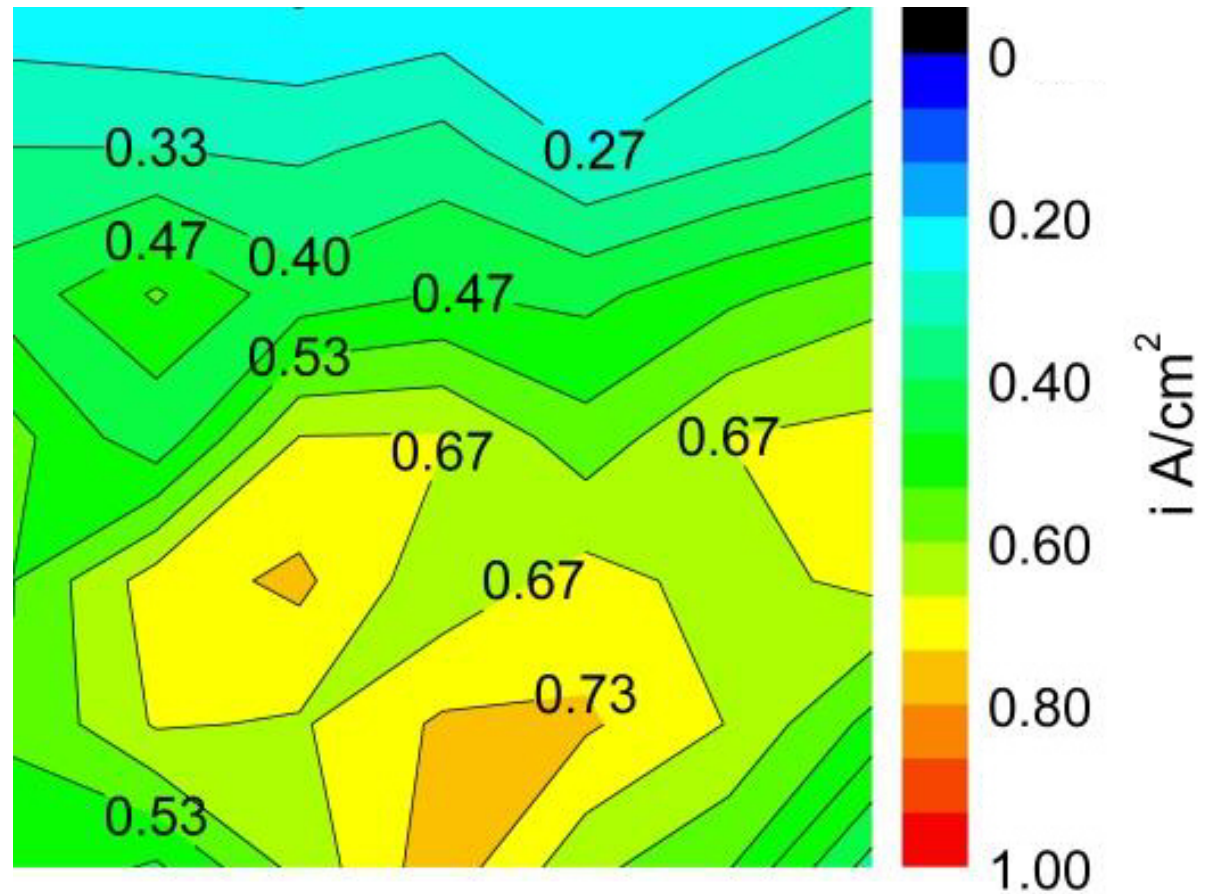


# Local effects are influenced by design, material and control strategies.

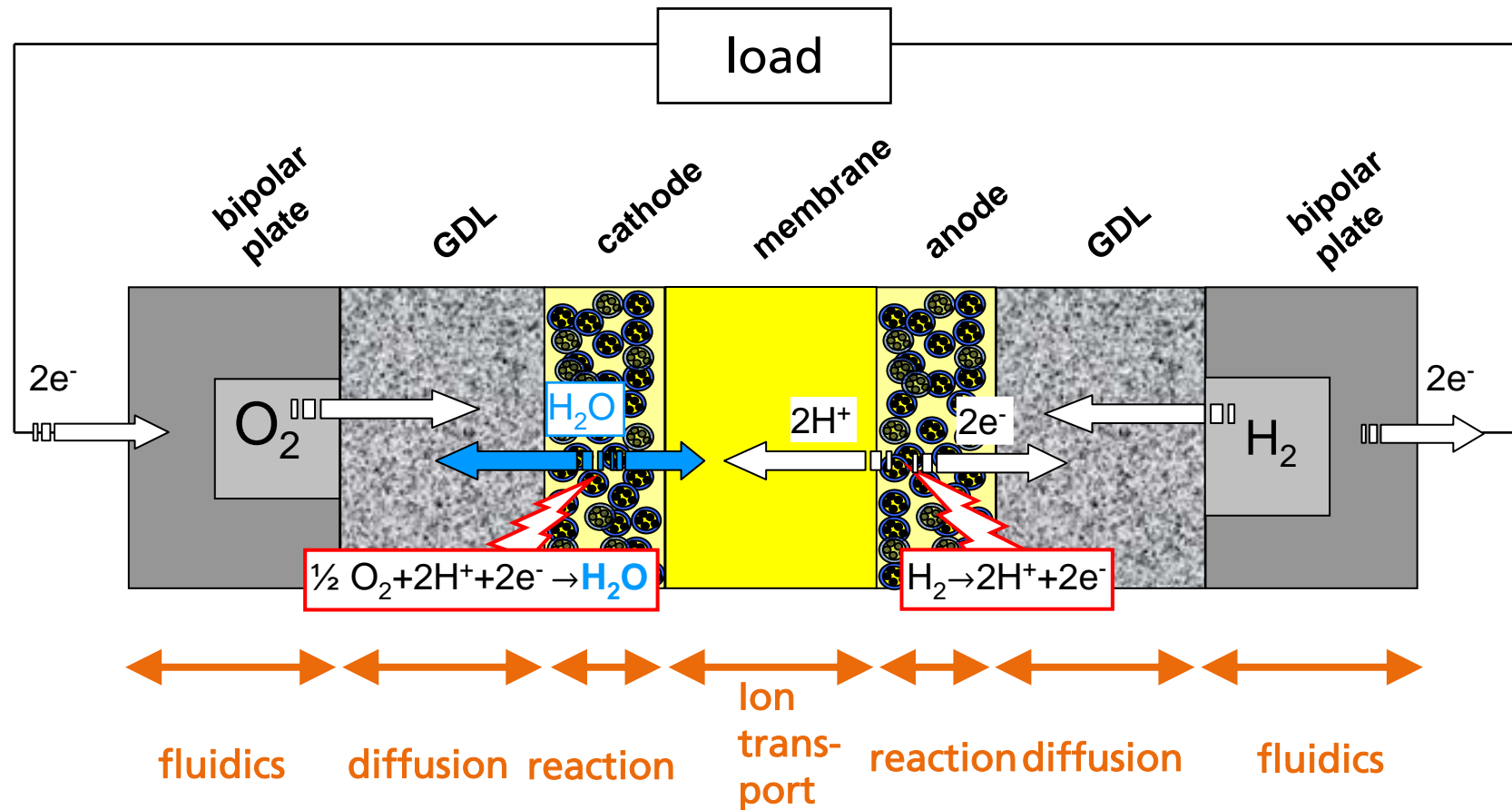


# Inhomogeneous conditions lead to performance loss and accelerated degradation.

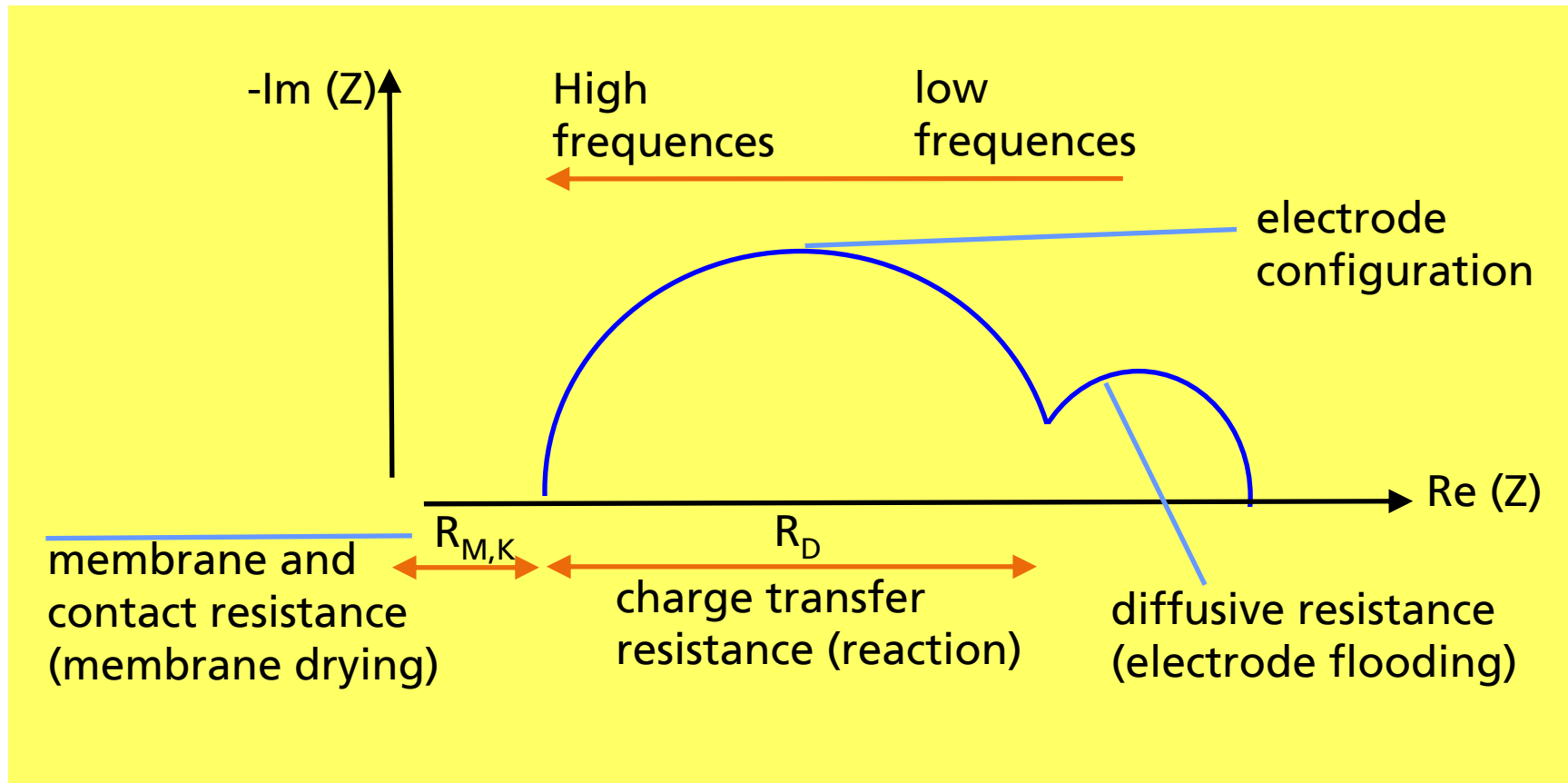
- educt concentrations
- temperature distribution
- contact resistances
- humidification



For optimization of fuel cell design and control, understanding the different processes is viable.



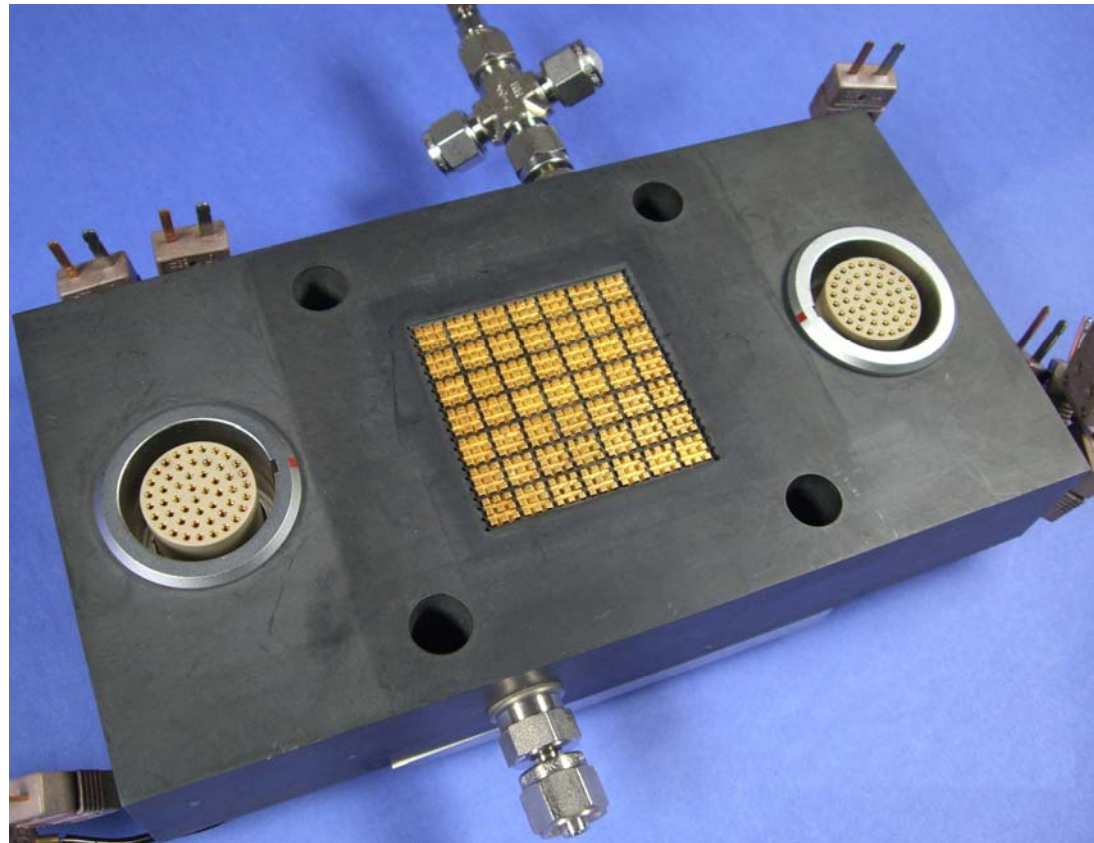
Impedance enables the separation of the processes by analysing effects at different frequencies.



# Fraunhofer ISE segmented test fuel cell for spatially resolved fuel cell characterisation.

Investigation of local

- current production
- potential distribution
- membrane conductivity
- temperature distribution



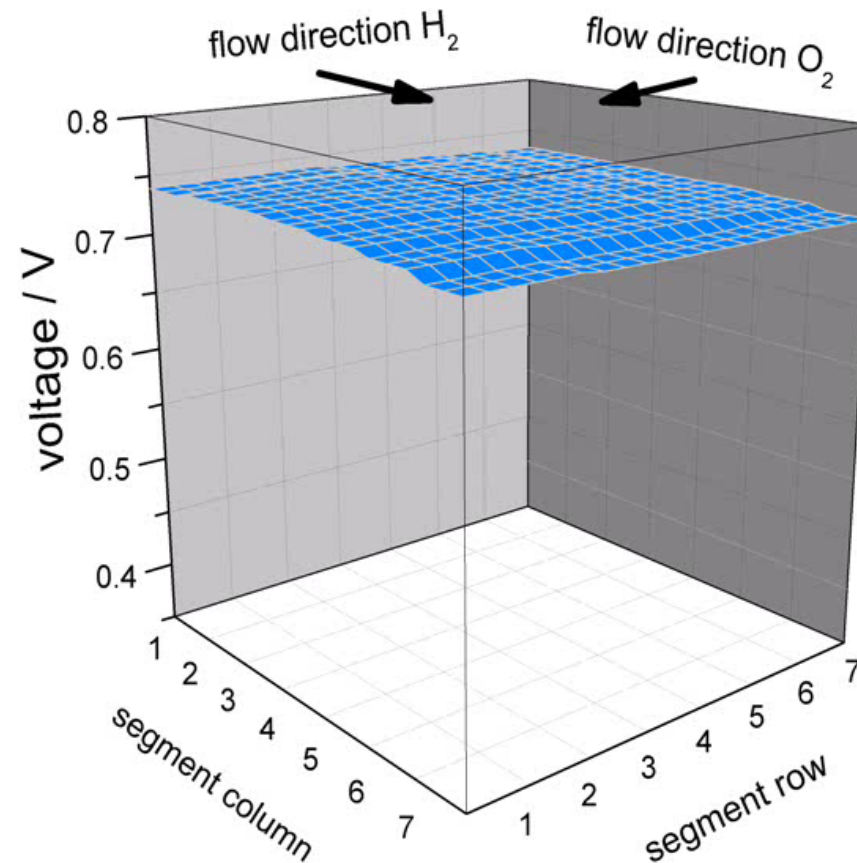
# 50 channel impedance spectroscopy for analysing single cell performance.

- 50 fully synchronized potentiostats
- combined with 50 FRAs
- operates in four quadrants:
  - current range:  $\pm 5$  A/pstat
  - voltage range: +4/-1 V
- frequency range: 10 kHz - 0.1 Hz
- noise optimized lock-in FRA
- ultra-low inductive cabling



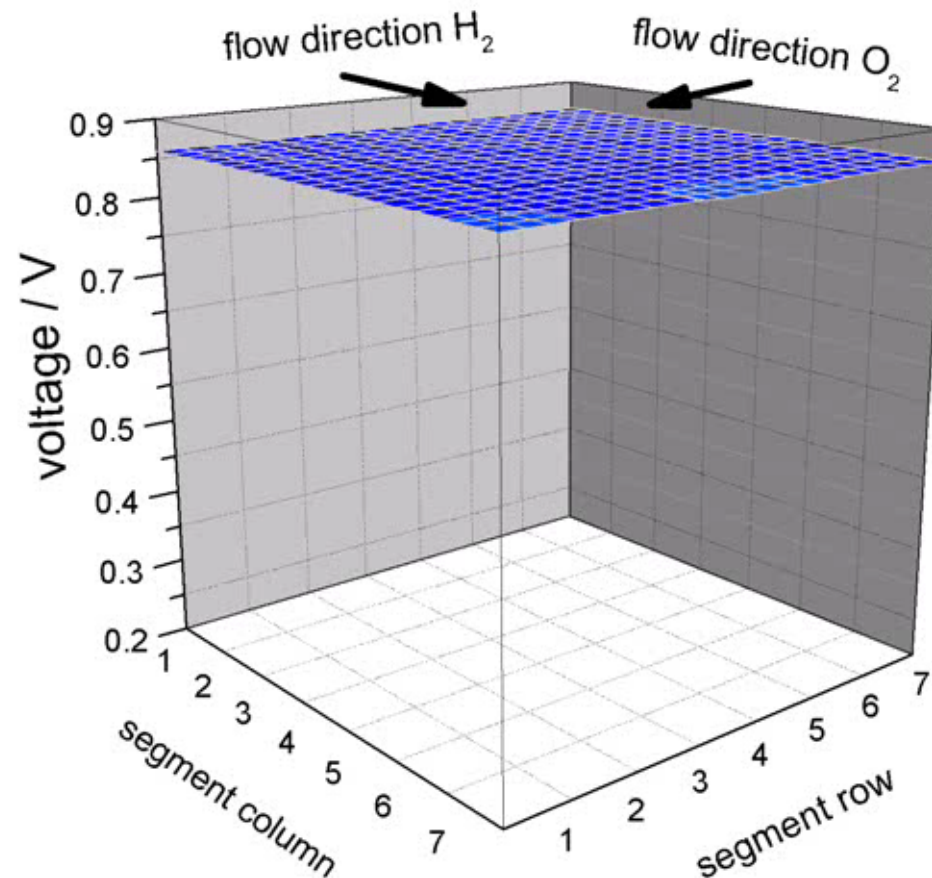
# Impact of fuel starvation on cell potential distribution

- hydrogen flow reduced from 200 to 50 ml/min
- 50 mA/segment
- temperature: 60°C
- oxygen flow: 300 ml/min



# Potential distribution for different applied load current

- Current increased stepwise from 15 to 750 mA
- temperature 60°C
- oxygen flow: 300 ml/min
- hydrogen flow: 100 ml/min

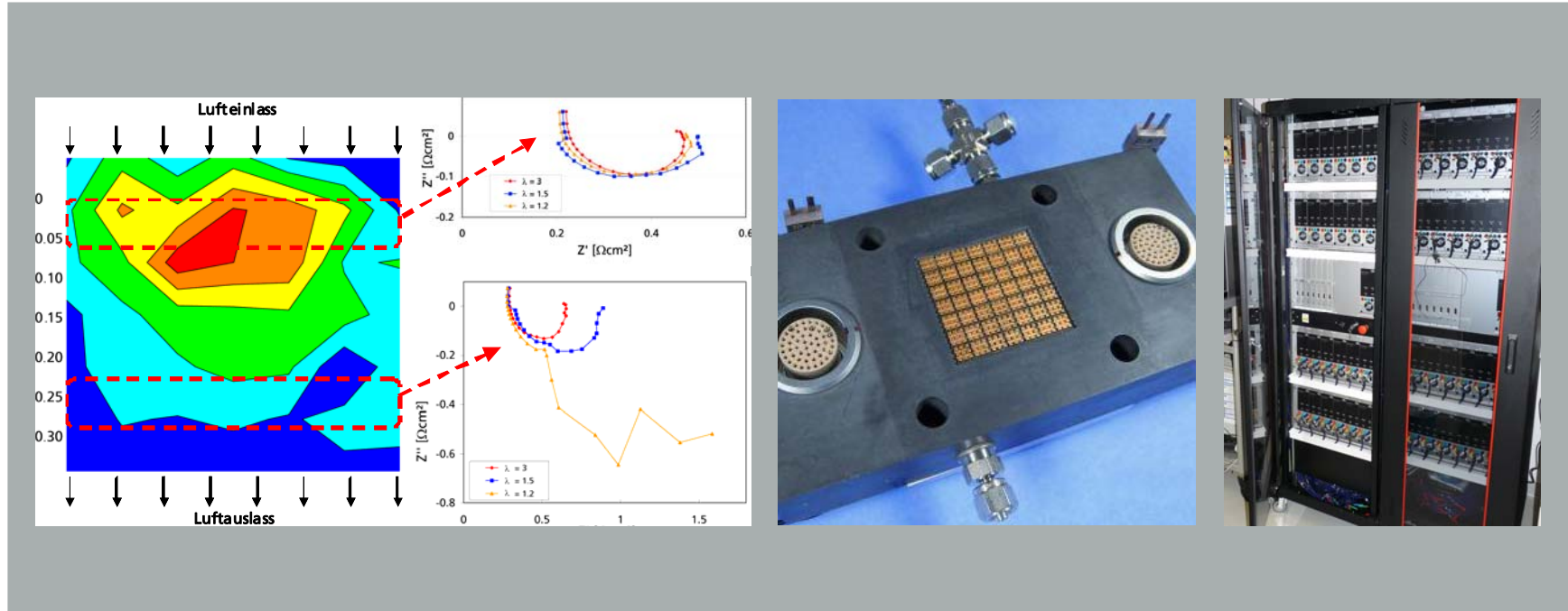


# 50 channel impedance spectroscopy for analysing fuel cell stack performance.

- electronic load
  - voltage: 0 - 40 V
  - current: 100A
- combined with 50 FRAs
- frequency range: 10 kHz - 0.1 Hz
- noise optimized lock-in FRA
- ultra-low inductive cabling



# Fraunhofer ISE offers in-depth analysis of fuel cells and stacks by 50-channel impedance spectroscopy.



# ... and what can we do for you?

