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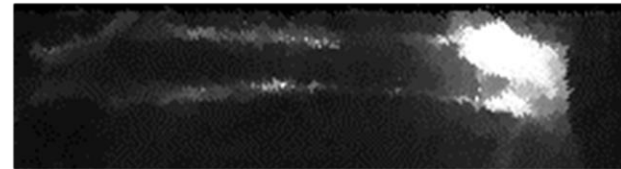
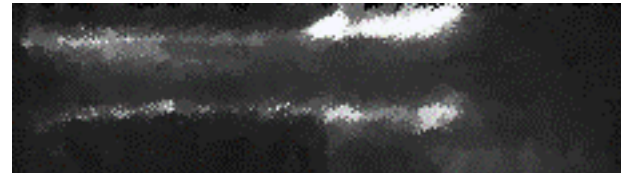
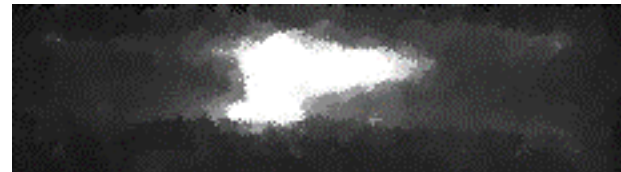
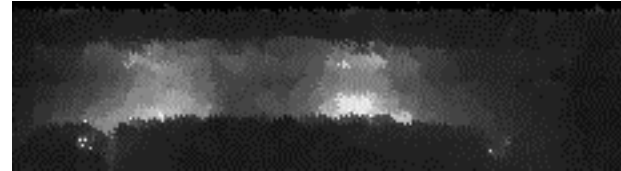


Processing of the radiation intensity distribution and electrical data of high-current vacuum arc between transversal magnetic field contacts for software-based evaluation

Benjamin Weber, Tobias Pieniak, Dietmar Gentsch

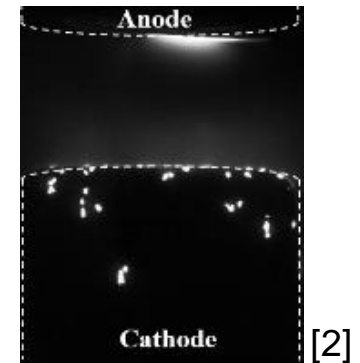
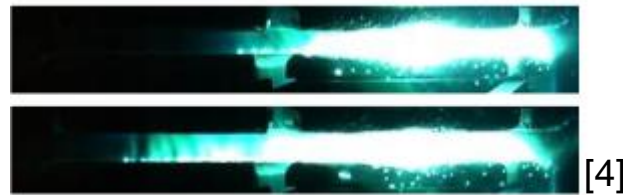
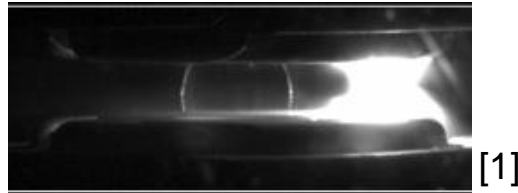
Agenda

- Introduction
- Test setup
- Measured data and video images
- Data preparation
- Data processing
- Conclusion and outlook



Introduction

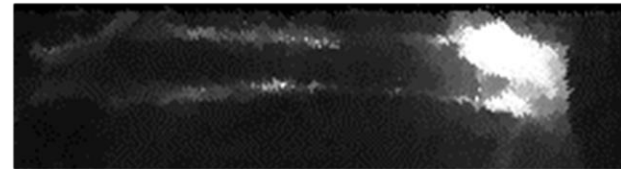
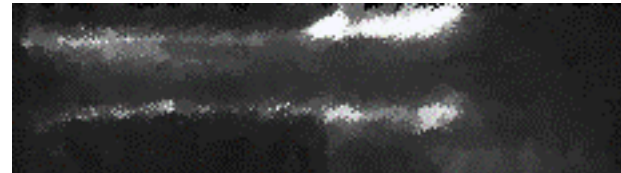
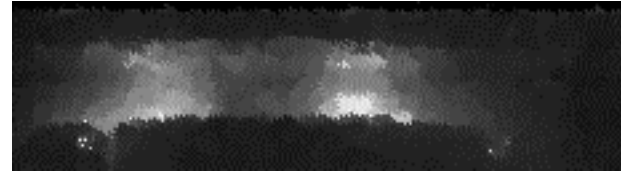
Evaluation of high-speed video images is a common method for vacuum arc investigation



- Every pixel records a intensity in range of the **sensors resolution**
- Manual evaluation is **time costly** and **observer-dependent**
- **Variable parameters** can change every evaluation
- ➔ Our goal is a **high reproducibility** and **effort reduction**

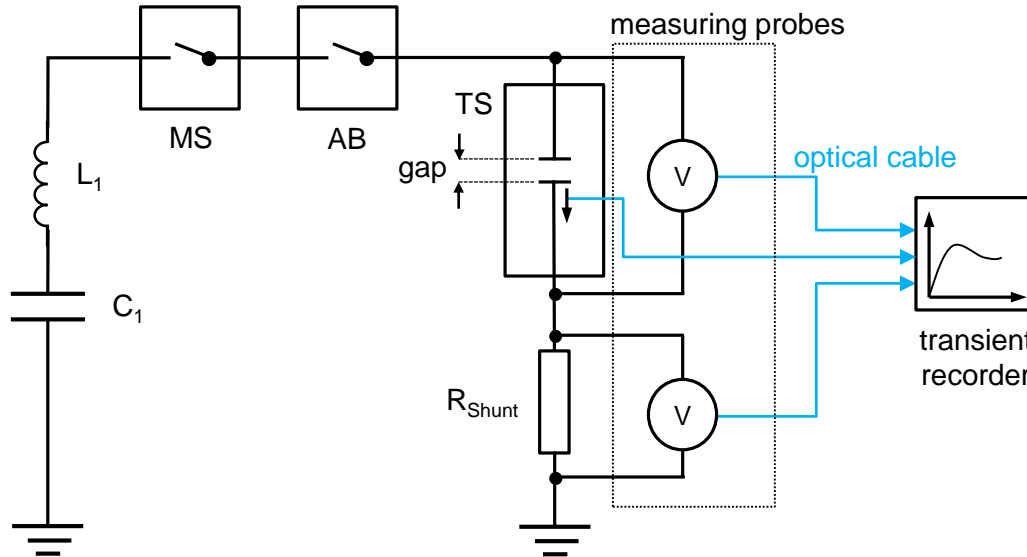
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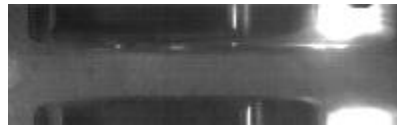
Test setup

High-current circuit for breaking operations



C_1 : High-current capacity
 L_1 : Coil (for 50 Hz half-wave)
 MS: Making switch
 AB: Axillary breaker
 TS: Test switch

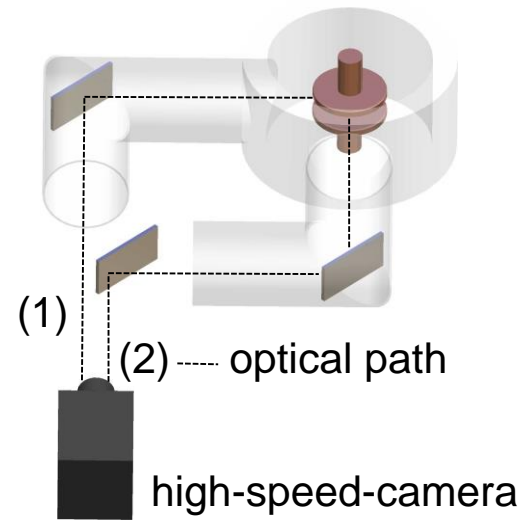
Camera perspectives: (1)



(2)

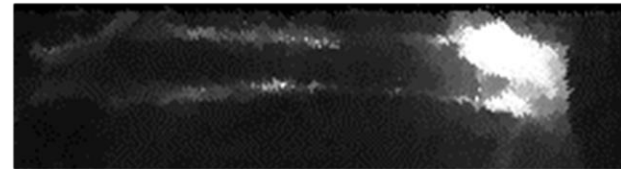
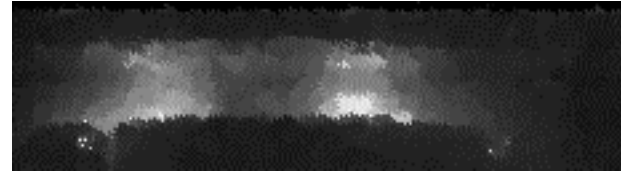


Swichting chamber



Agenda

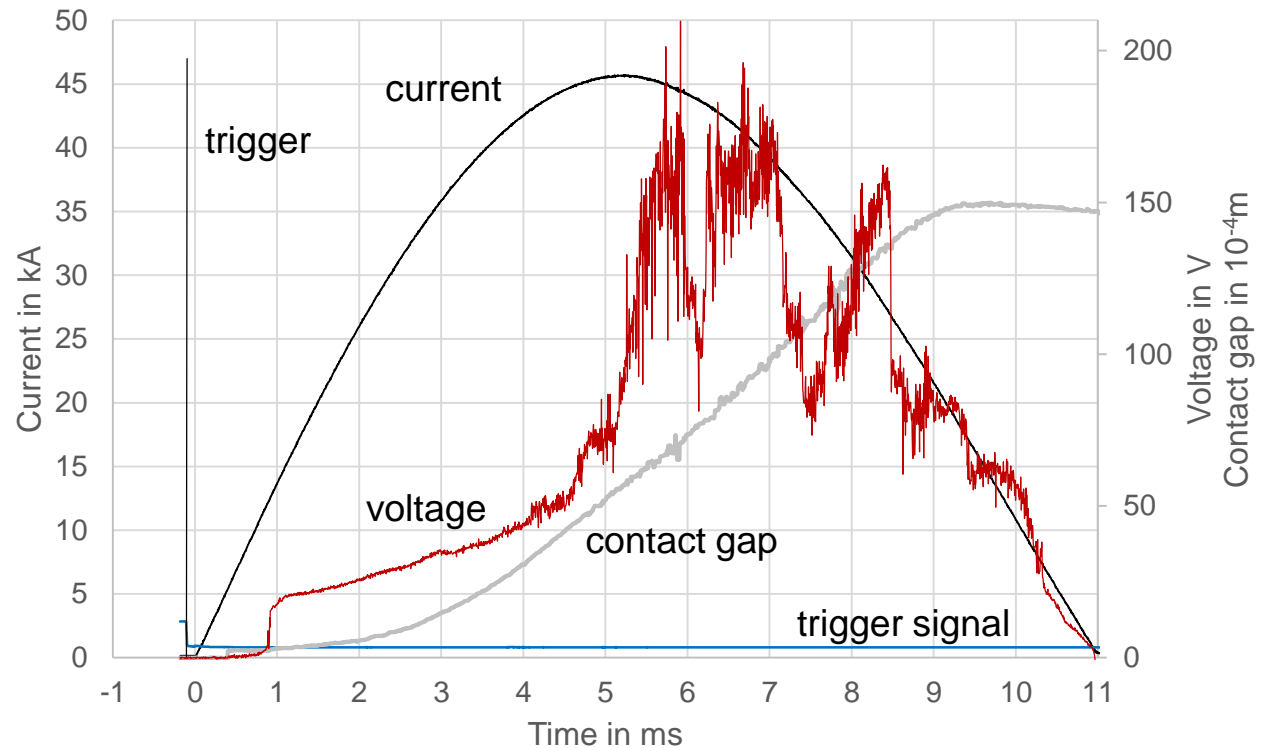
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Measured data and video images

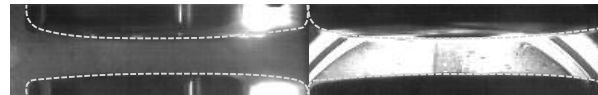
- 31,5 kA breaking operation
- recorded electrical data and video file
- contact separation at 0,75 ms
- 38500 Hz recording frequency
- trigger signal for temporal allocation

→ Focus on arc behavior



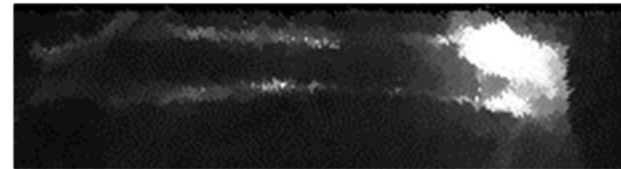
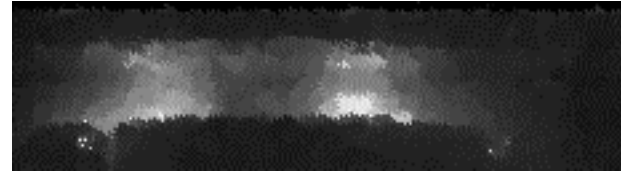
Camera perspectives:

Breaking operation:



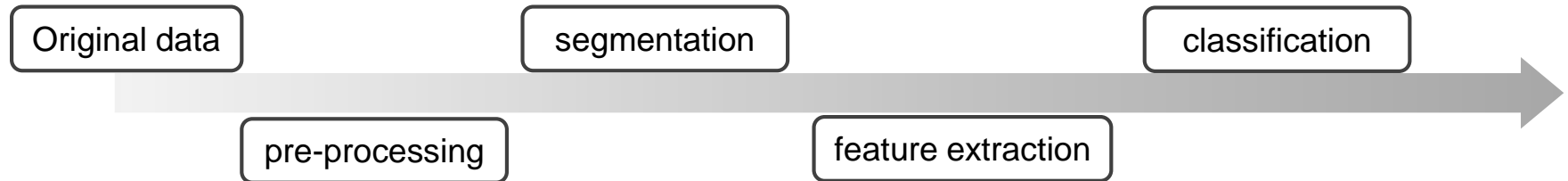
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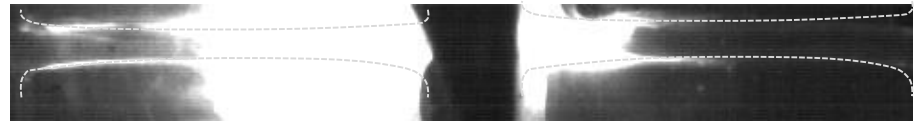
Data preparation

Steps of an software-based evaluation



What is recorded and can it be recognized by an algorithm?

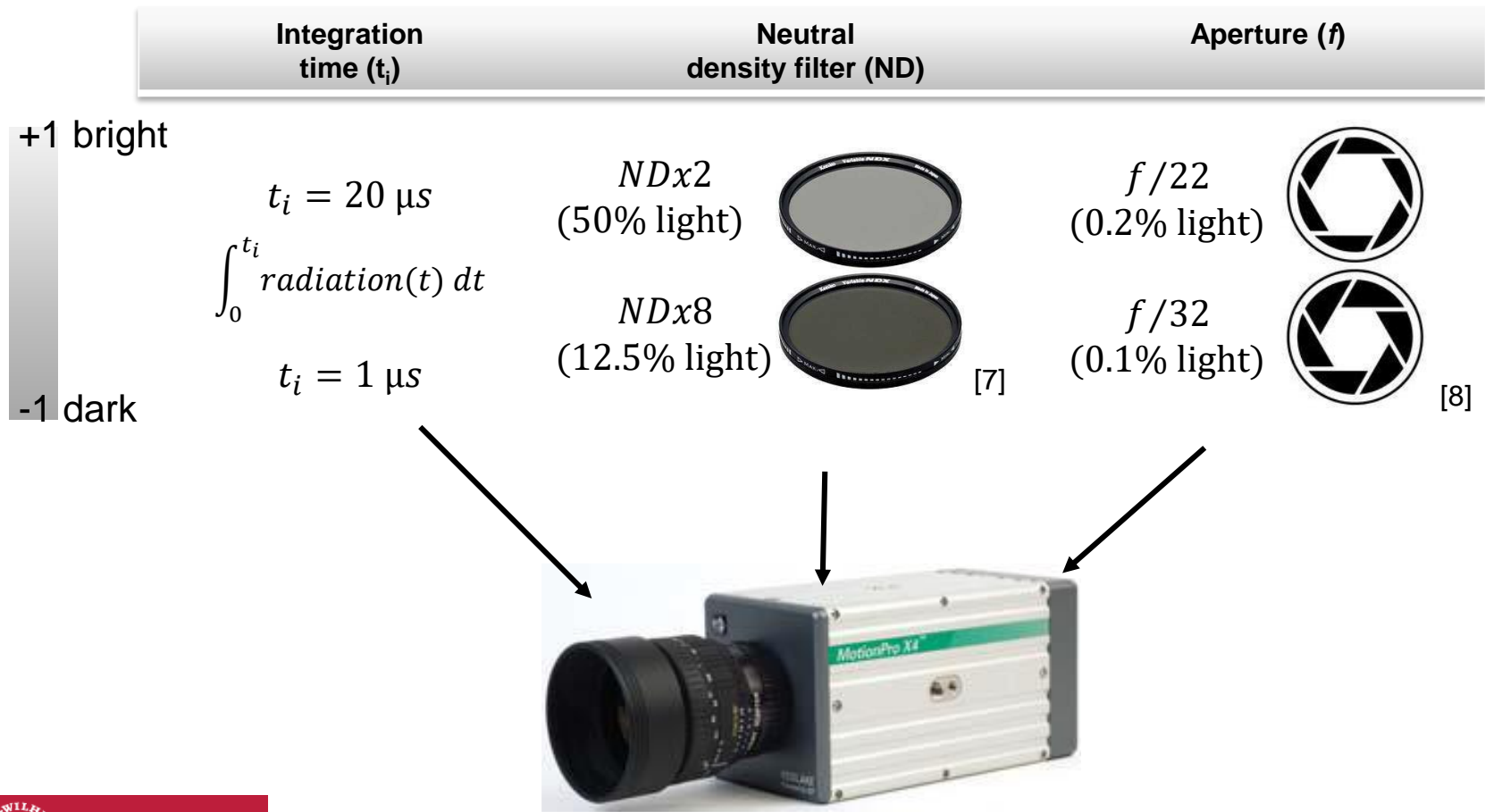
Main problem: **overexposure**



Adjustable **parameters**: integration time (t_i), aperture (f), neutral density filter (ND)

Data preparation

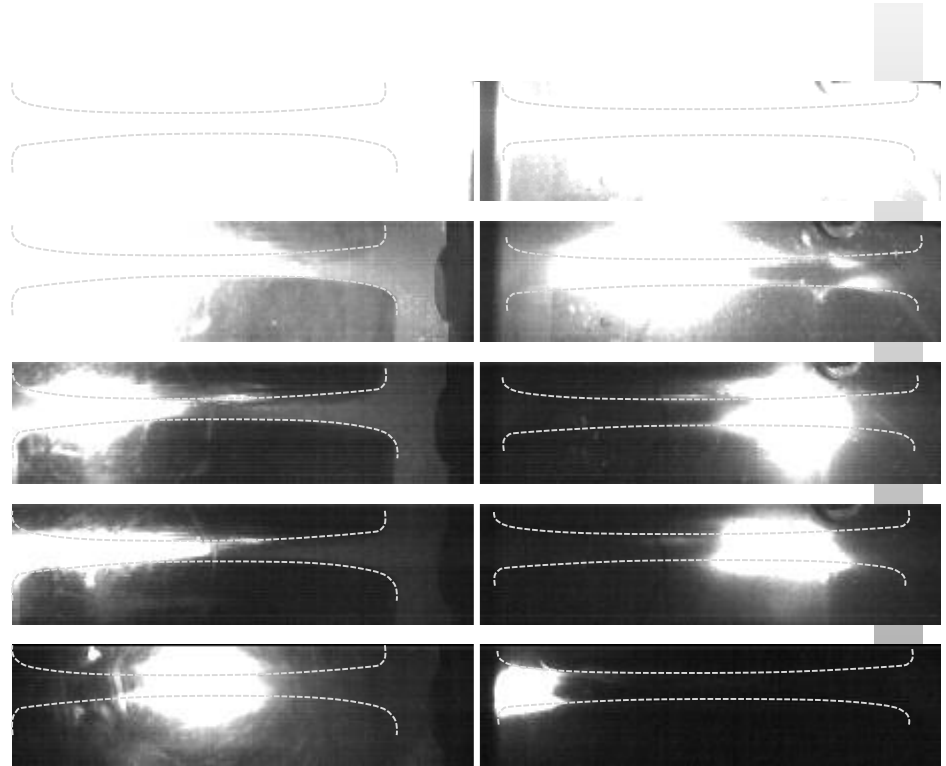
Investigation of **optimized camera settings** for an automatic evaluation through variation and analysis of normalized camera parameters



Data preparation

Measure of overexposure → highest brightness level of a breaking operation

Integration time (t_i)	Aperture (f)	Neutral density (ND)
+1	+1	+1
-1	+1	+1
-1	+1	-1
+1	-1	-1
-1	-1	-1

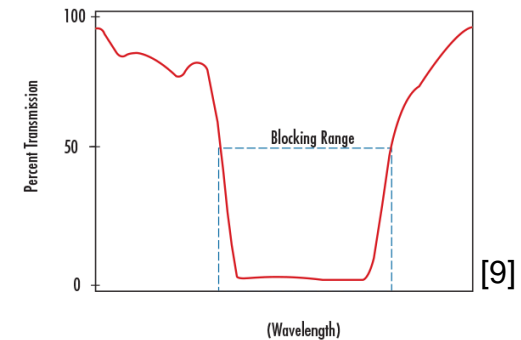


Data preparation

Further influences of the parameters:

Aperture (f) \rightarrow depth of field \rightarrow irrelevant at high aperture

Neutral density (ND) \rightarrow wavelength depended filtering

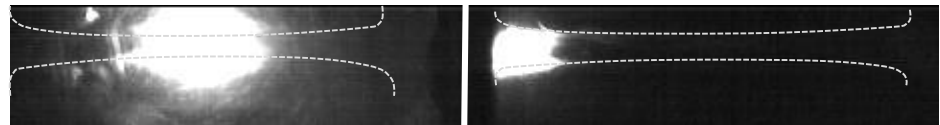


Integration time (t_i) \rightarrow widening of the arc:

The arc moves at speeds of 50 m/s - 500 m/s [10]

\rightarrow arc recorded with $t_{i,1} = 20 \mu\text{s}$ is 0.1 mm to **9.5 mm wider** then with $t_{i,2} = 1 \mu\text{s}$

\rightarrow Decision in favor of darkest settings:

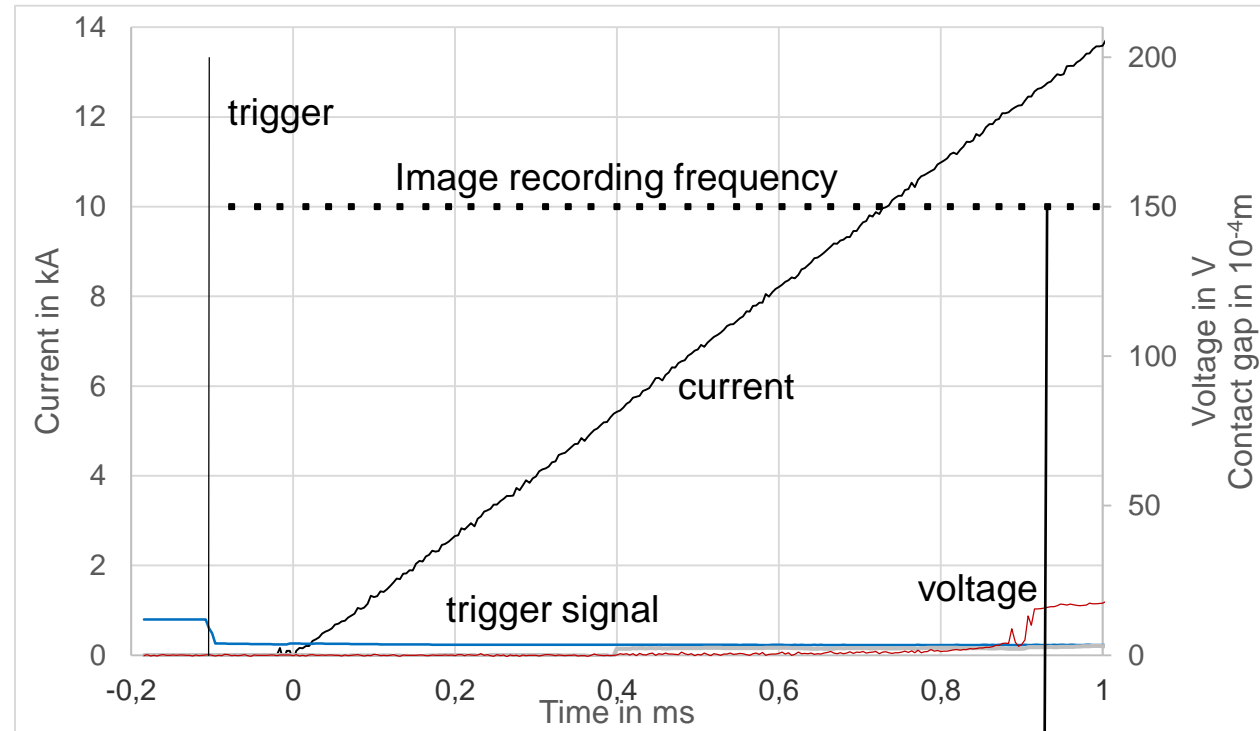


Data preparation

Temporal allocation of images based on the **trigger signal** and **camera frequency**

Every data point has information about:

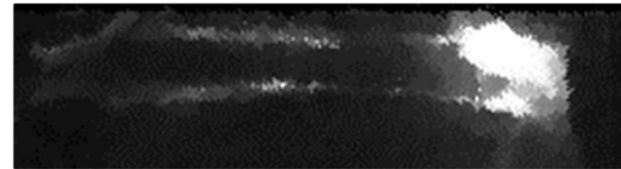
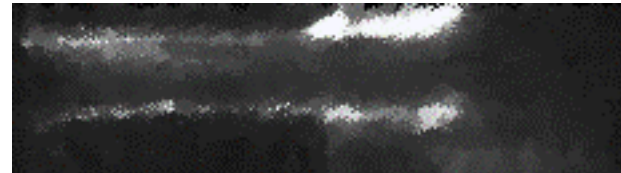
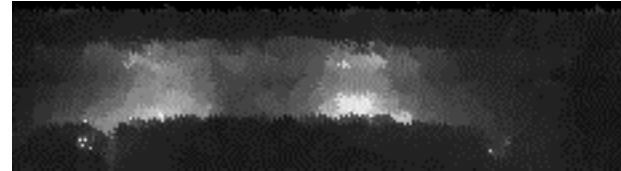
- Current
- Voltage
- Contact gap
- Recorded image



@ 38500 Hz → 1 image every 25,9 μ s

Agenda

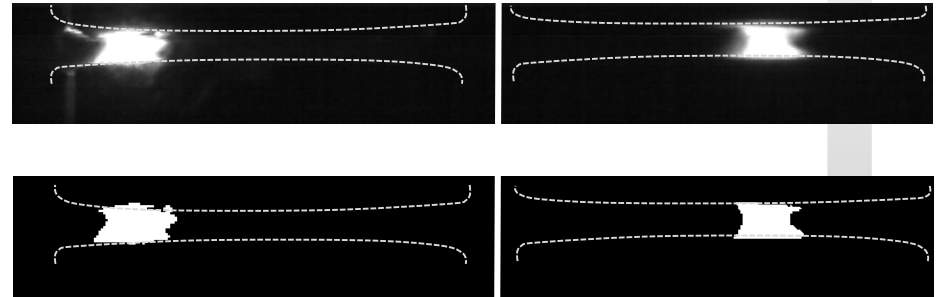
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Data processing

Binarization with dynamic threshold (Otsu's method)

- Separation of vacuum arc from background
- Every pixel has a binary value
- Simplification for further processing



Morphological filtering

- Closing of small holes in complex forms
- Clearing of small particles

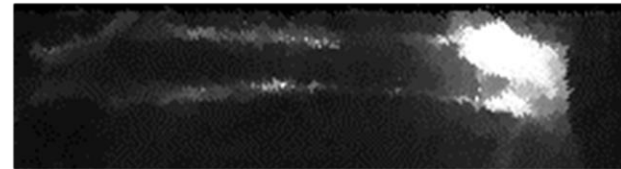
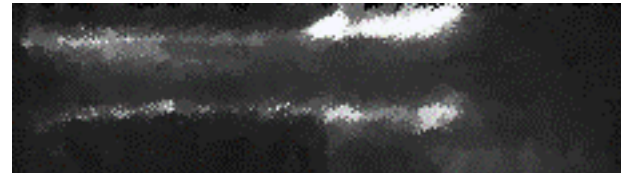
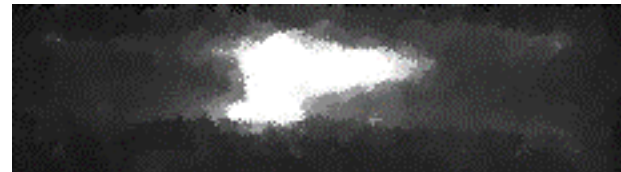
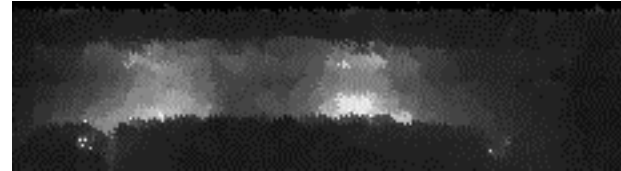


[11]

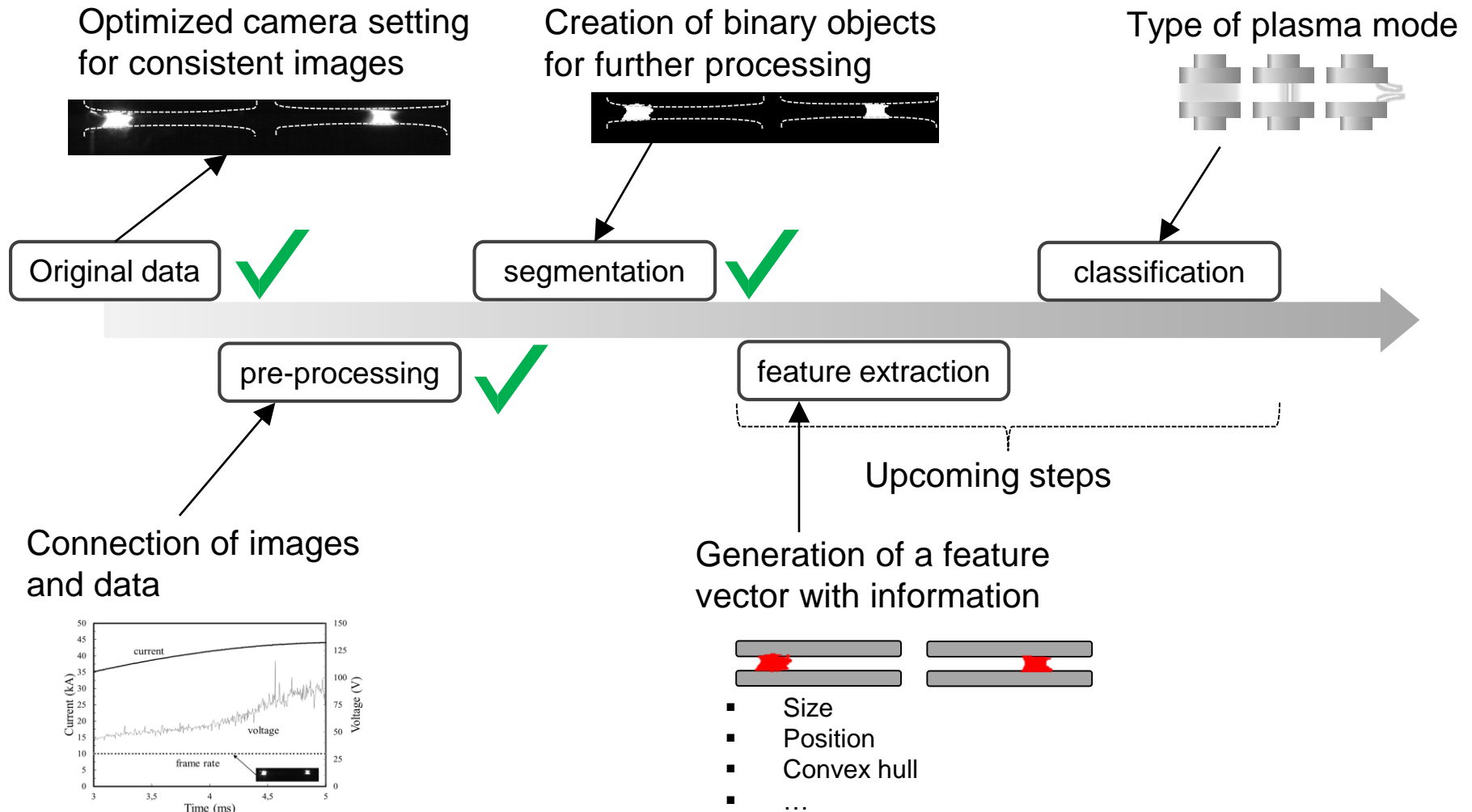
→ Creation of Binary Large Objects (Blob)

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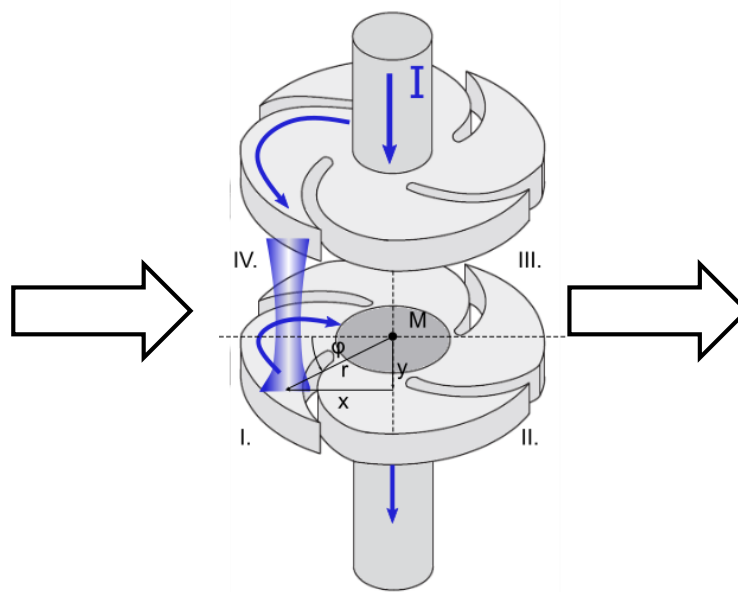
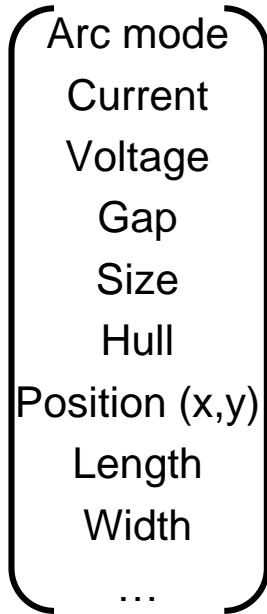
Conclusion



Outlook

➔ We aim for automatic evaluation of influencing variables to optimize switching capabilities

Extended Feature vector:



Future Possibilities:

- Movement over time
- Energy input on contact surface
- Spread of energy during breaking operations
- Current / gap depended arc phenomena
- ...



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Thank you for your attention

Literature

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