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Simulation of Gas Metal Arc Welding with CFX-5

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Introduction
ChopArc project

Research project funded by bmb+f:
Welding or soldering of thin metal sheets

Duration: 1.4.2001-30.9.2004

- Technical University Berlin
- Zeuna Stärker, Augsburg (Arvin Meritor)
- REHM Schweißtechnik, Uhingen
- CFX Berlin
- GFaI, Berlin
- Inst. for Low-Temperature Plasmas, Greifswald

Introduction
The Reality

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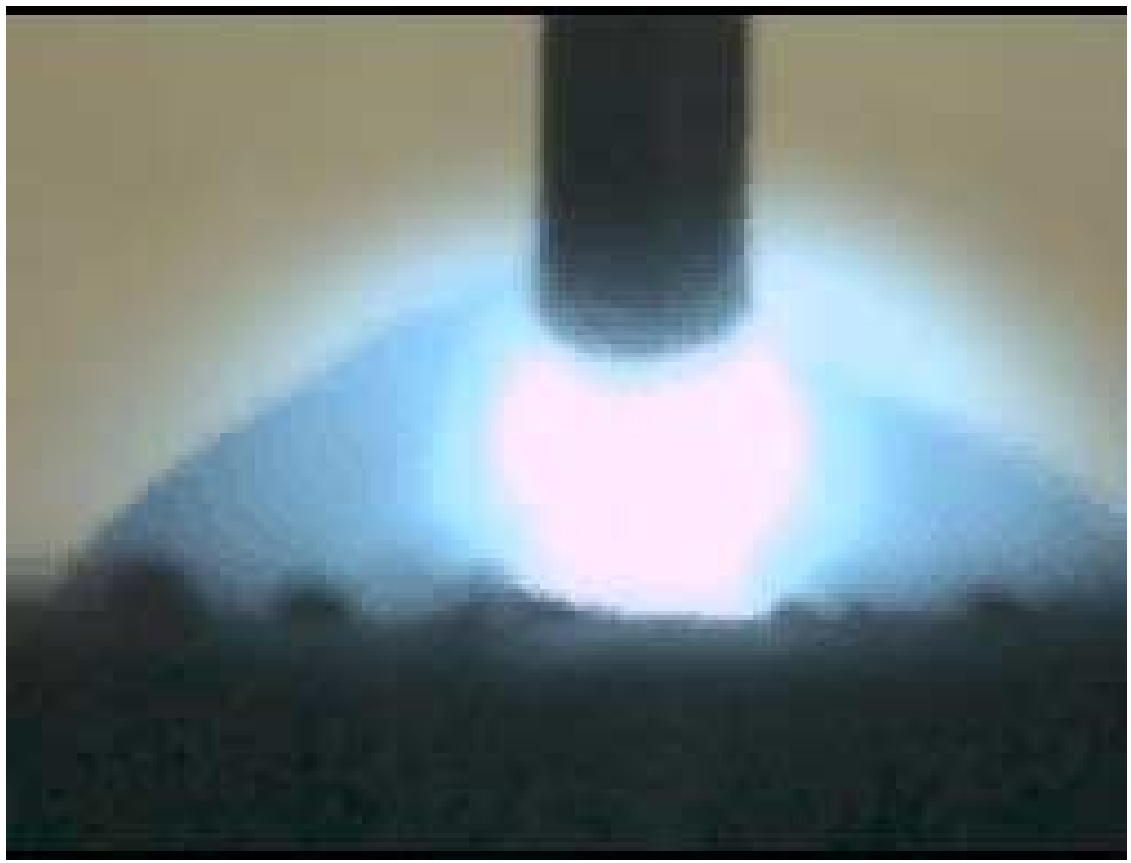
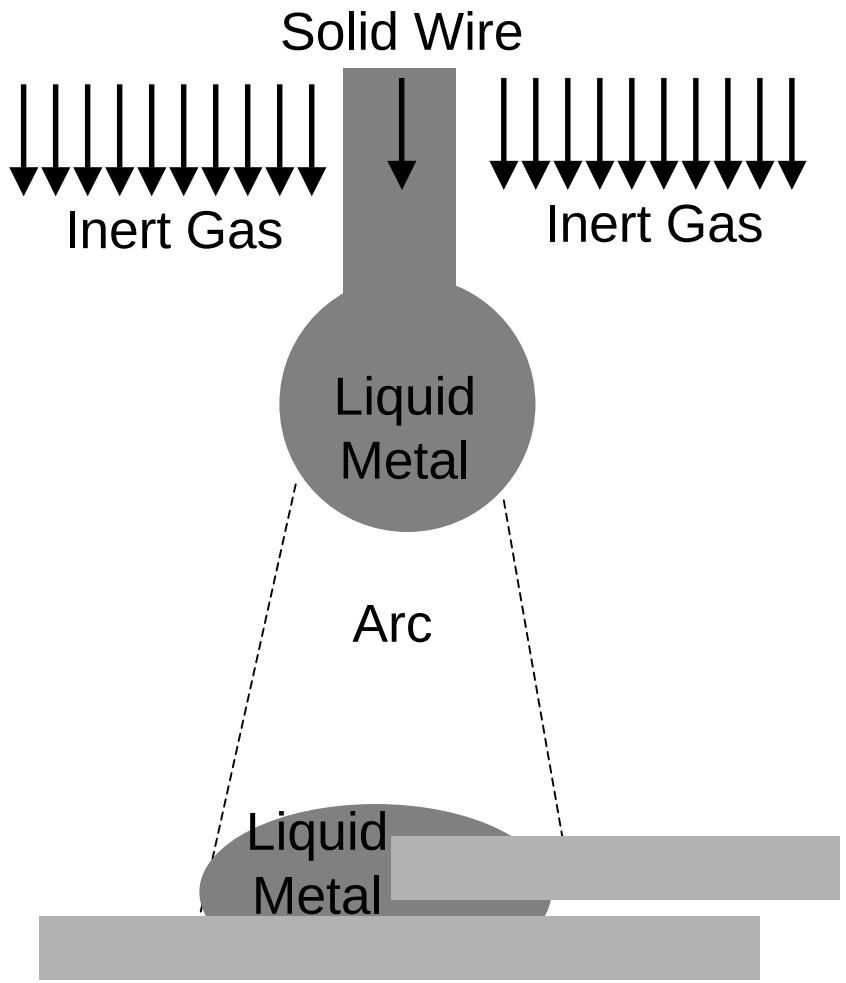


4.000 Pictures/s

1,2 mm Steel, Ar + 2% CO_2

Introduction
Physical issues

- ✓ Free surface two phase flow
- ✓ Multi-component gas phase
  - – Argon + CO_2 + Metal steam
- ✓ Heat conduction and transport
- ✓ Surface effects
- ✓ Melting / Solidification
- ✓ Radiation
- ✓ Electro-Magnetics
- ✓ Plasma Physics:
  - ✓ Arc Column in LTE
  - ✓ Cathode/Anode sheath layer
- • Evaporation / Condensation



Short-circuit phase
Surface tension and melting/solidification

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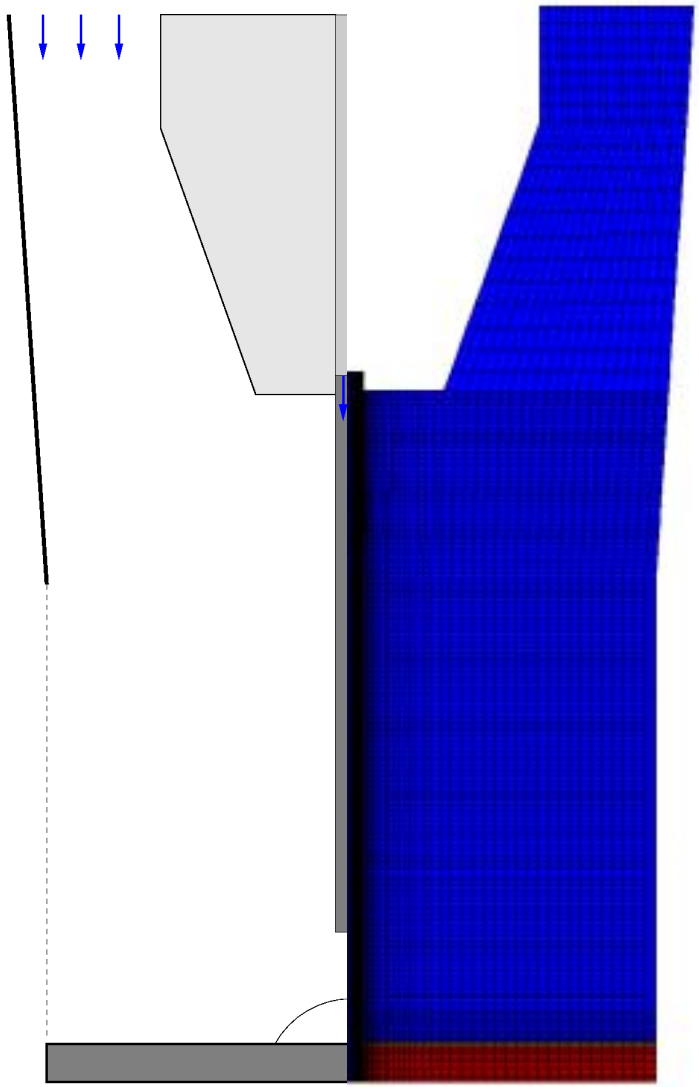

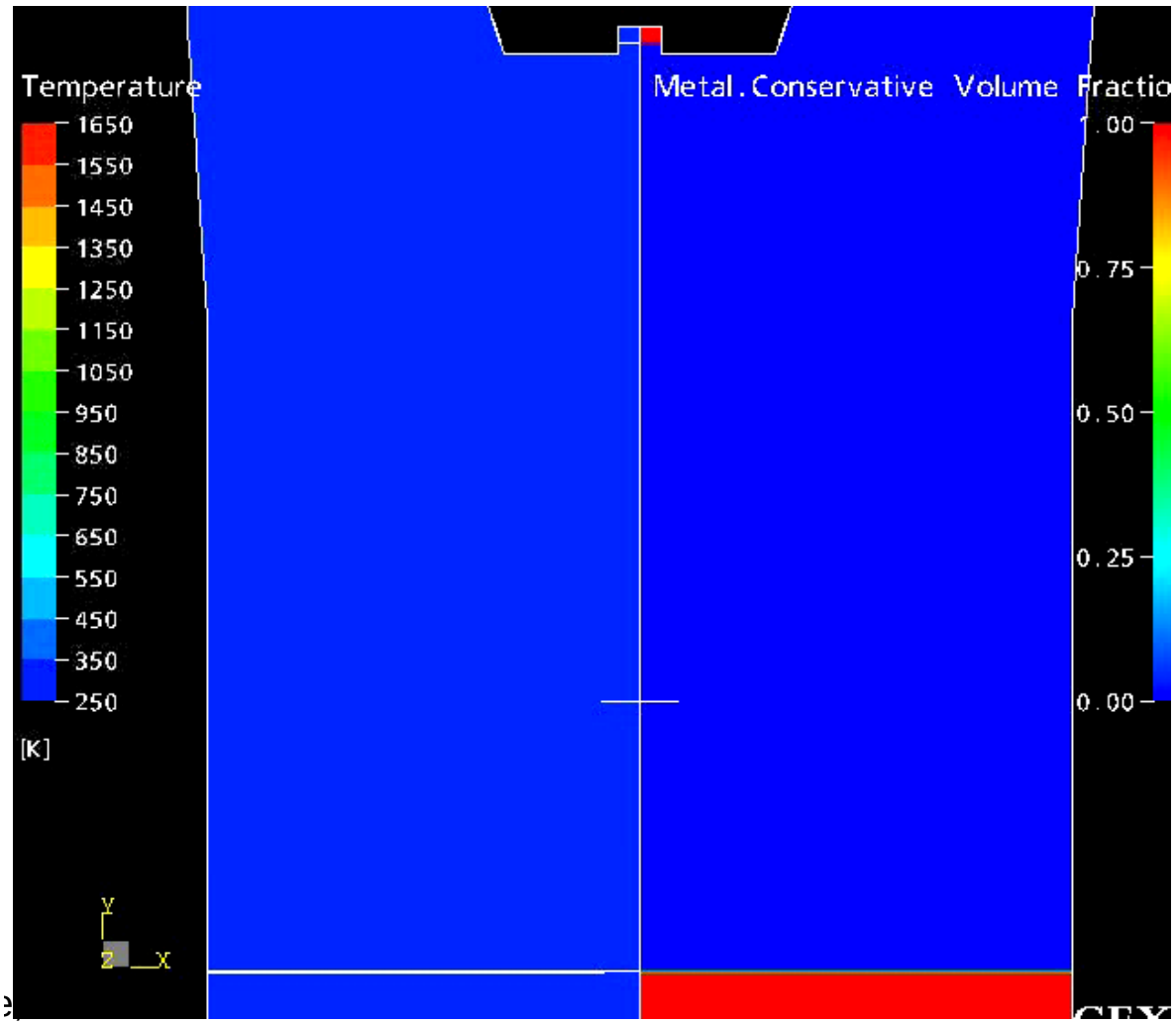

Short-circuit phase
Electro-magnetic effects

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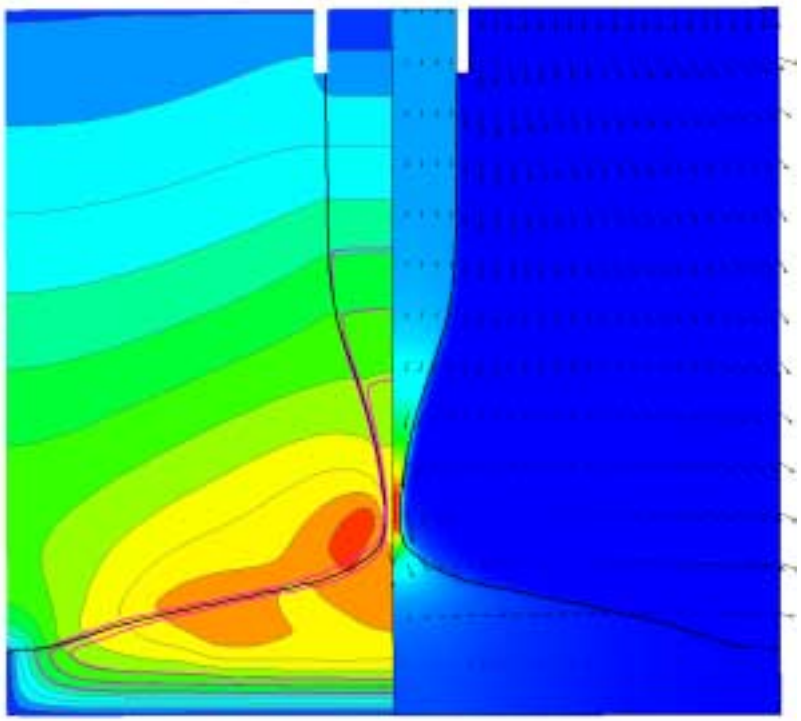
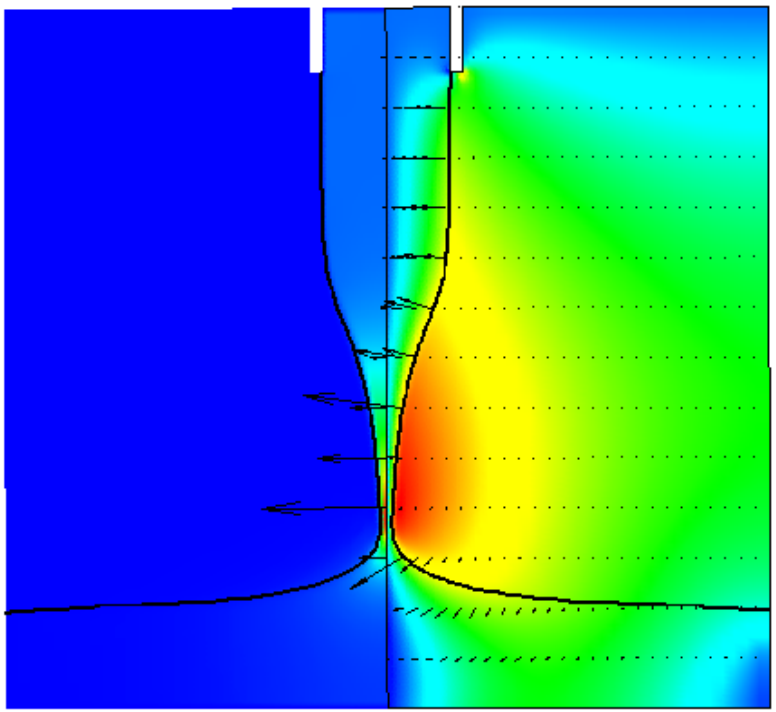
Colours: temperature current density current density magnetic field





Vectors: velocities Lorentz force

Arc simulation without sheath regions

Overview

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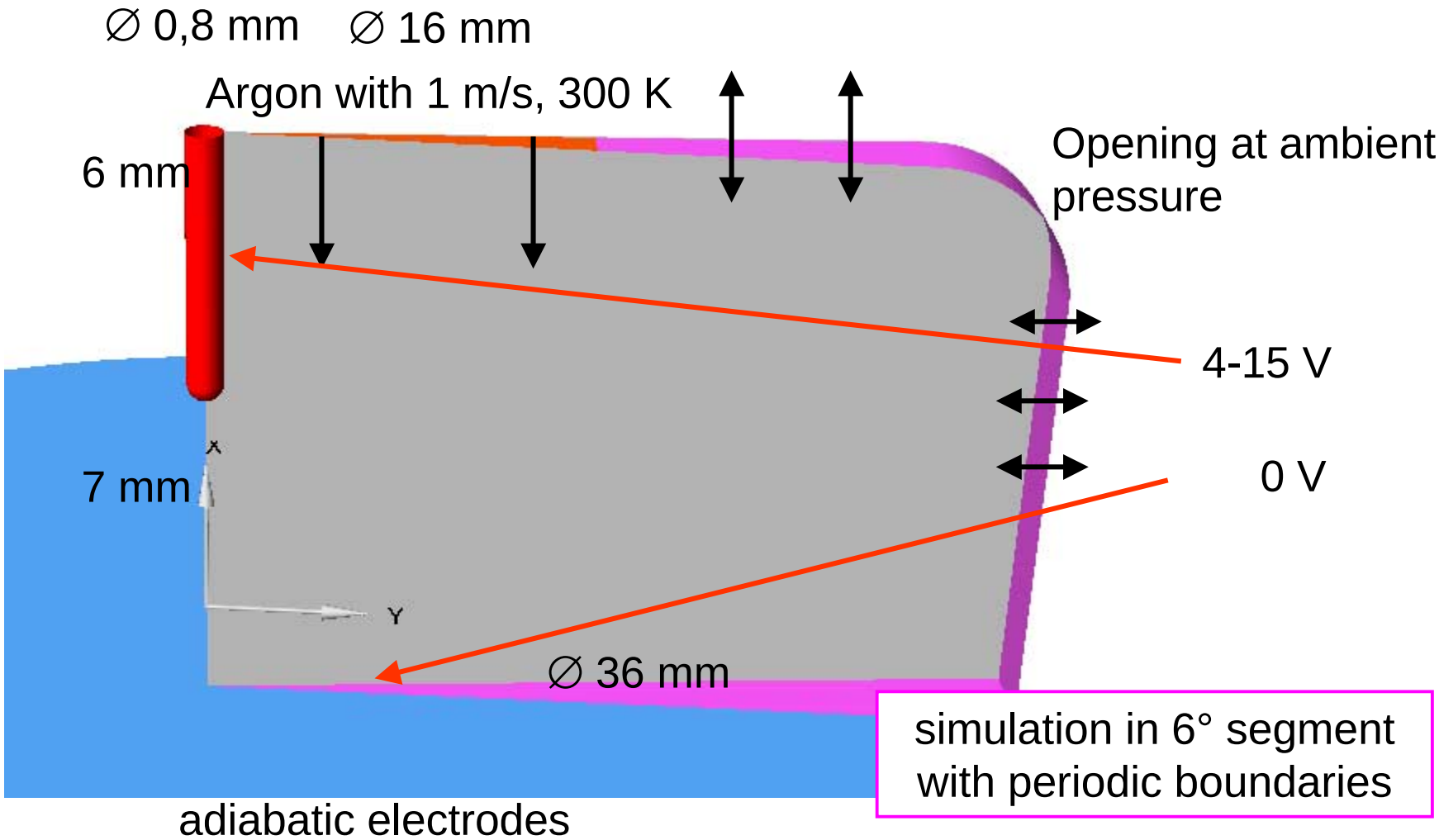
- temperature-dependent functions for Argon properties in LTE (Murphy, CSIRO)
- radiation by temperature-dependent net emission (Bauder)
- steady-state and transient simulations with equations for momentum, mass, temperature, electric and magnetic fields

Arc simulation without sheath regions

Geometry



Arc simulation without sheath regions
Description of figures

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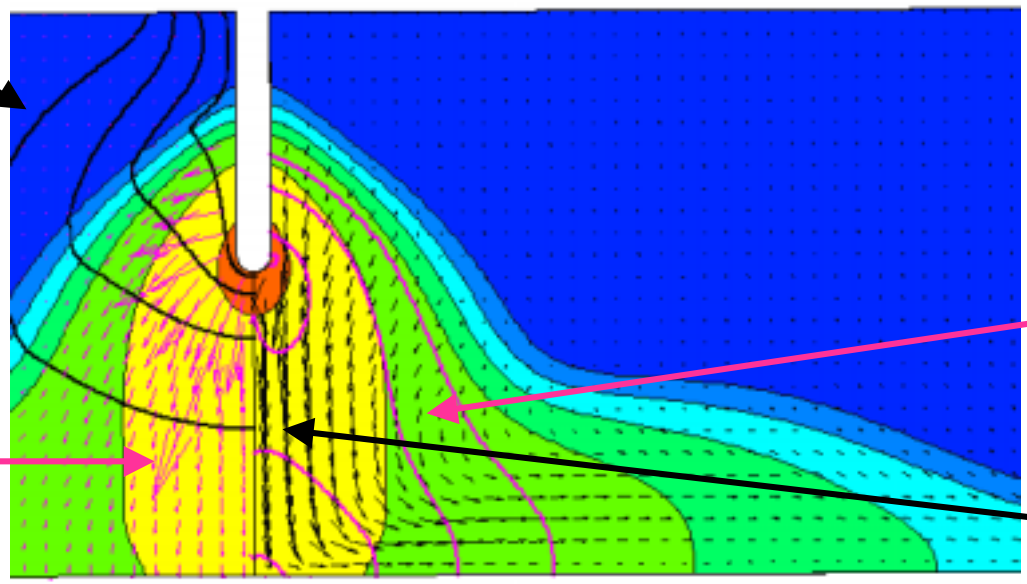
Lines of constant electric potential

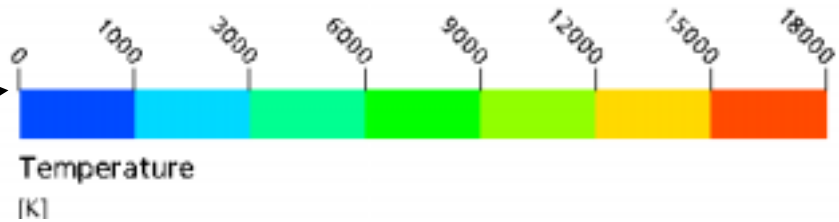


Isobars

current density vectors

velocity vectors

temperature as coloured contour plot



Arc simulation without sheath regions
Steady-state at 255 A

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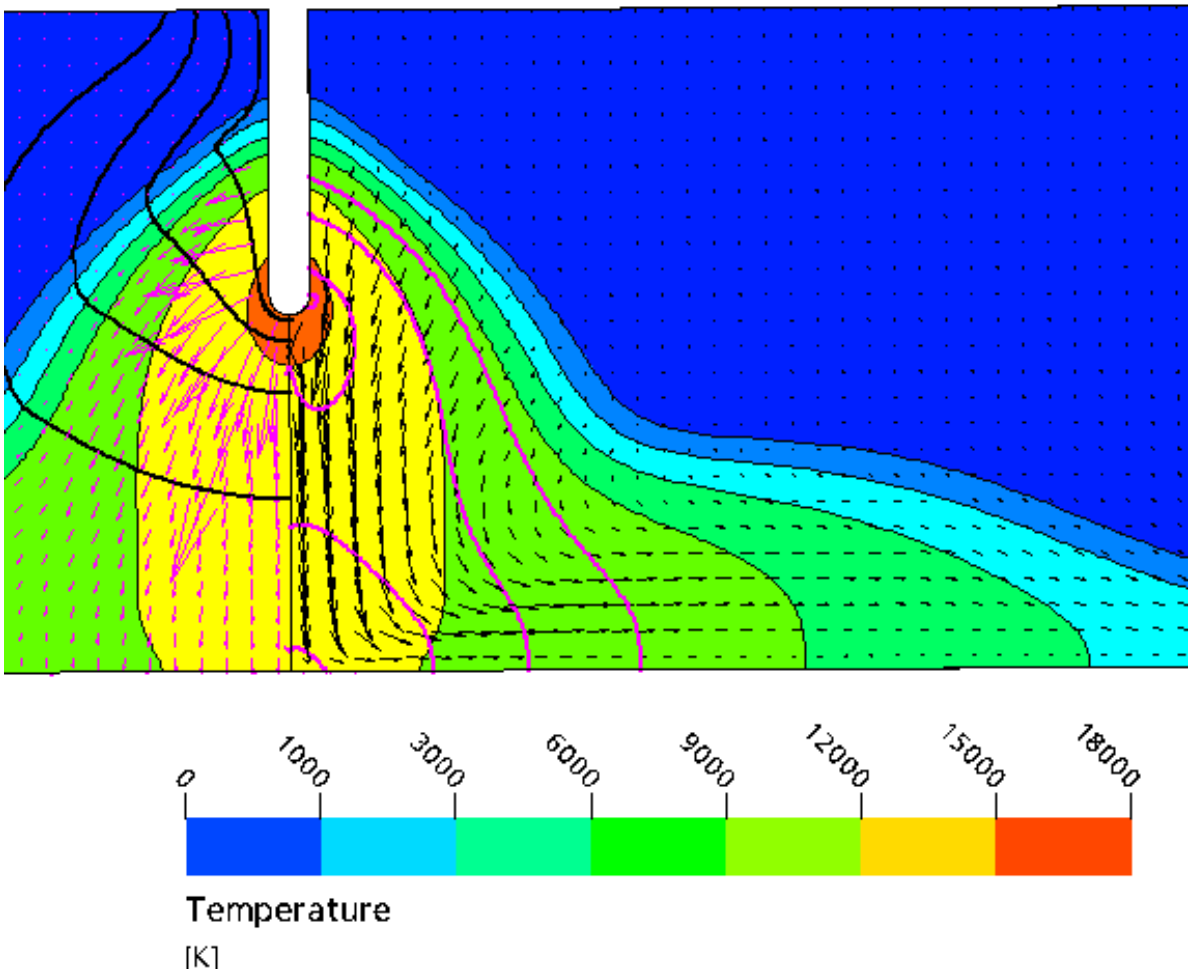
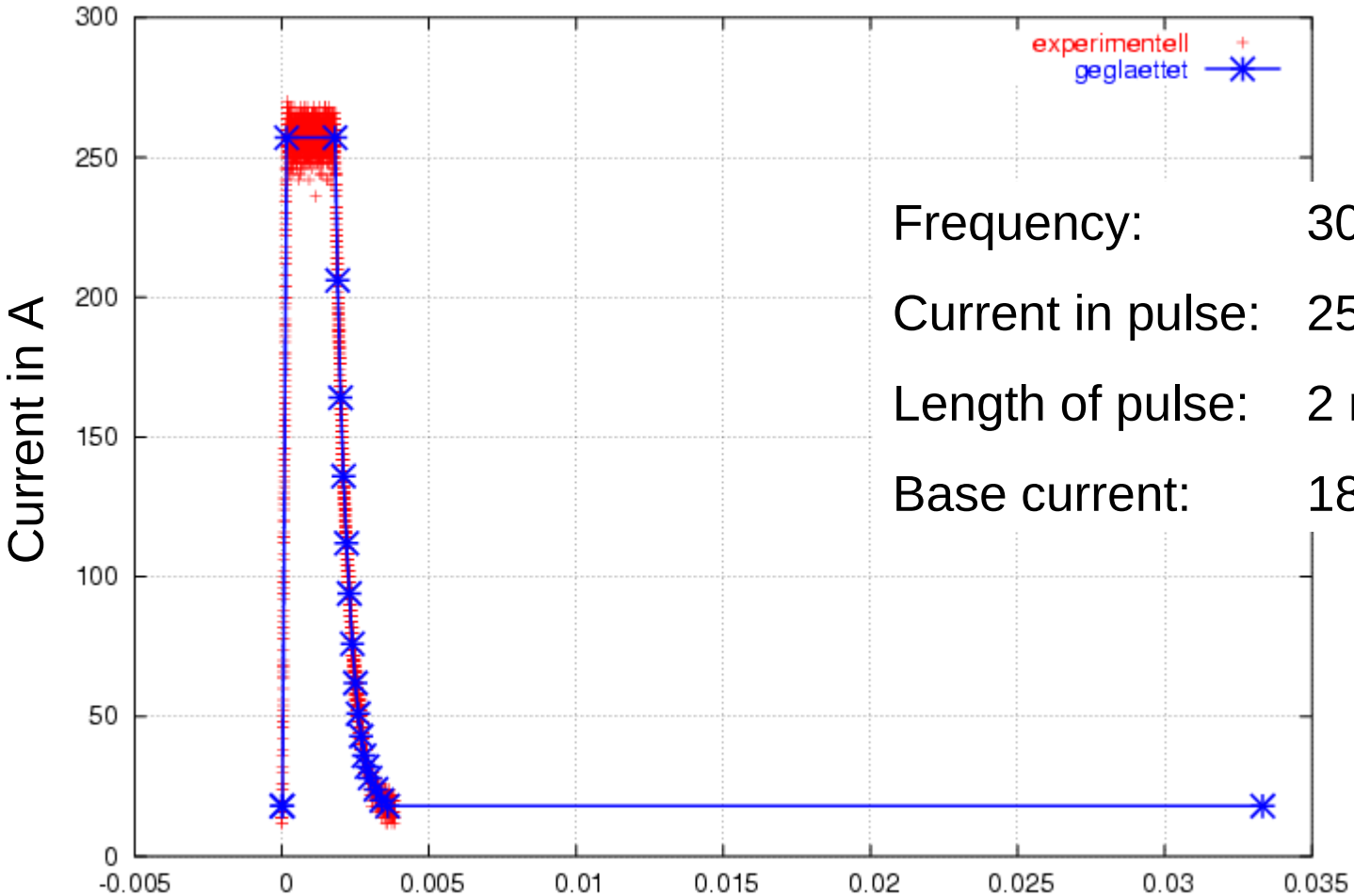


Voltage	U = 9 V
Power	P = 2300 W
Velocity	u ≤ 115 m/s
Pressure	p ≤ 213 Pa
Temperature	T ≤ 17,526 K

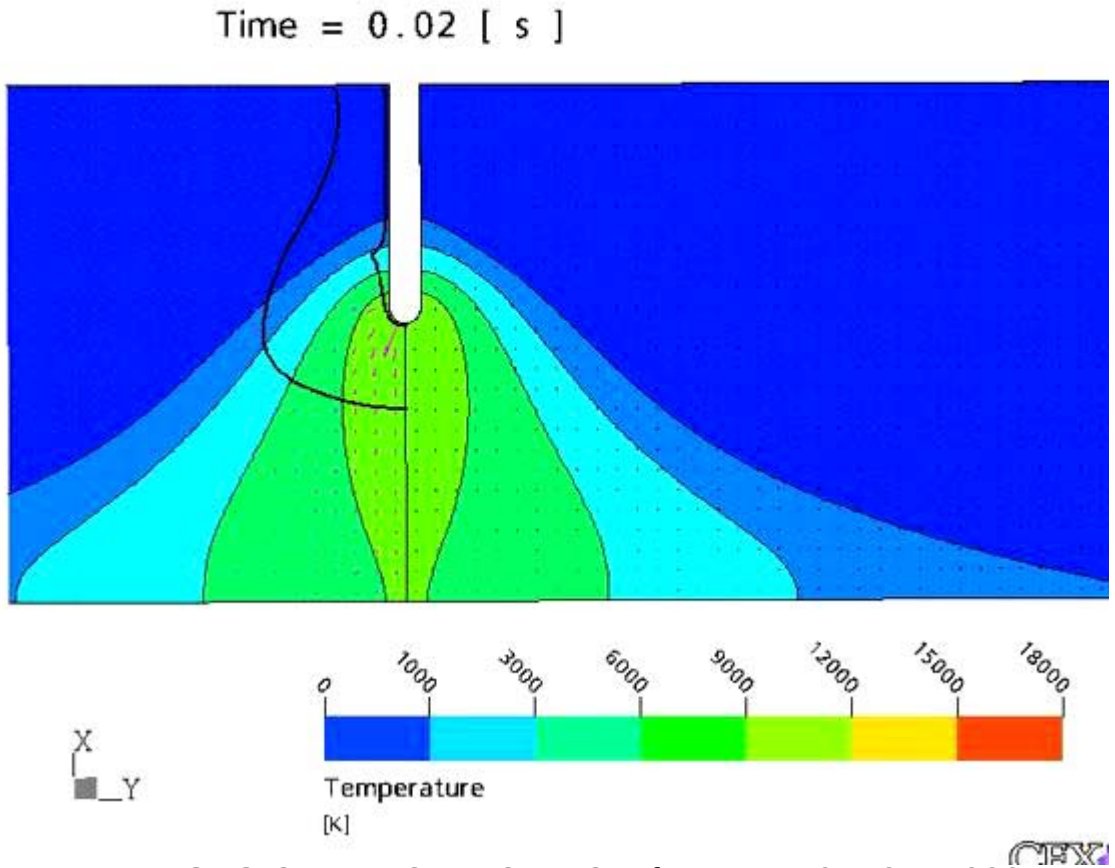
Arc simulation without sheath regions

Pulsed welding: Current over time



Frequency:	30 Hz (33 ms)
Current in pulse:	255 A
Length of pulse:	2 ms
Base current:	18 A

Arc simulation without sheath regions
Pulsed welding: Movie



Frequency: 30 Hz (33 ms)

Current in pulse: 255 A

Length of pulse: 2 ms

Base current: 18 A

Distance between pictures: 0.01 – 0.2 ms

Arc simulation with sheath layers

Sheath model (Sansonnens, Haidar, Lowke 2000)

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- diffusion equation for electron density:
  - ambipolar diffusion
  - ionisation, recombination
- current density includes diffusion current
- electric conductivity:
  - calculation from collision cross sections
- anode/cathode: heating/cooling by electron absorption/emission
- cathode: heating by ion absorption

Arc simulation with sheath layers
Mesh resolution

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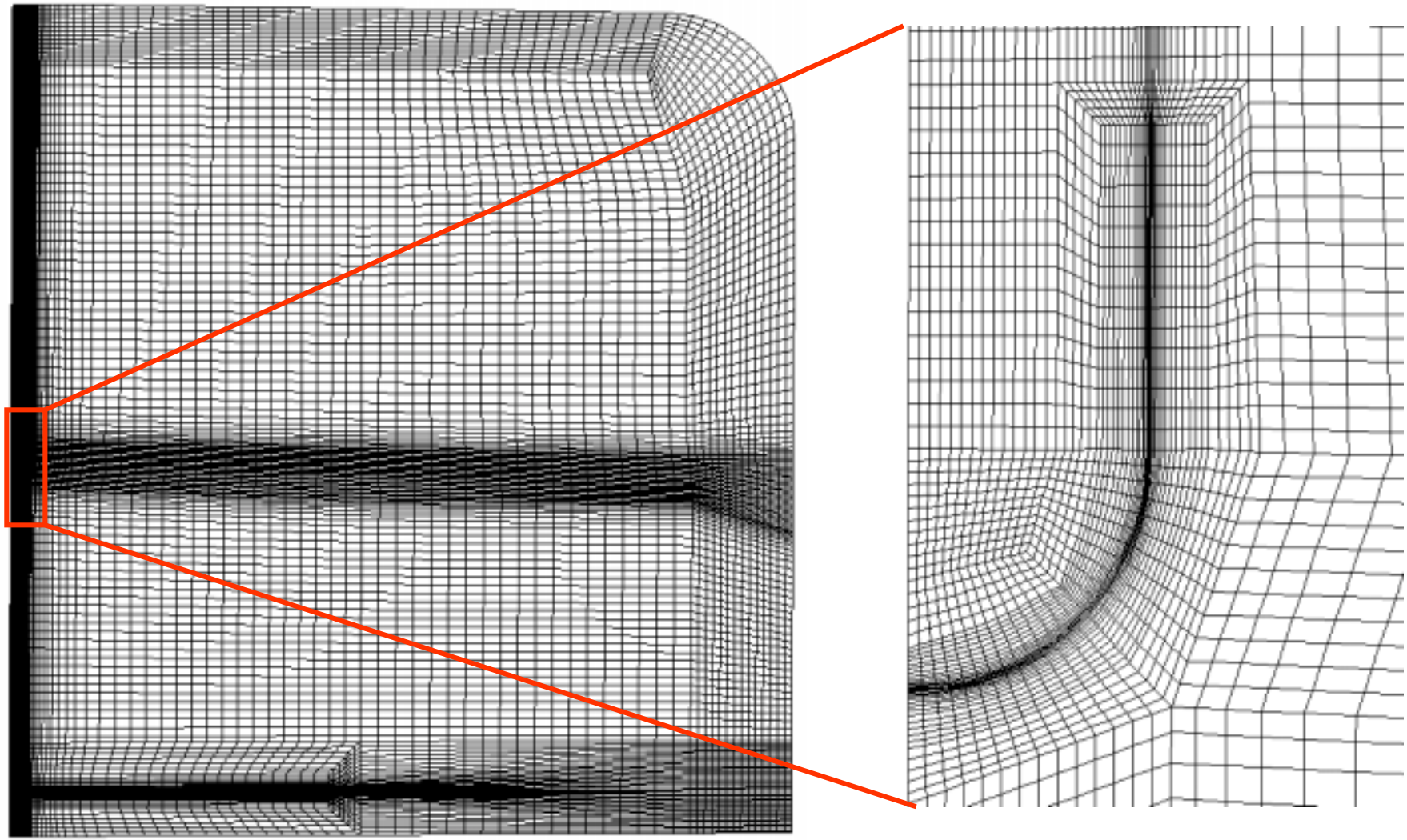
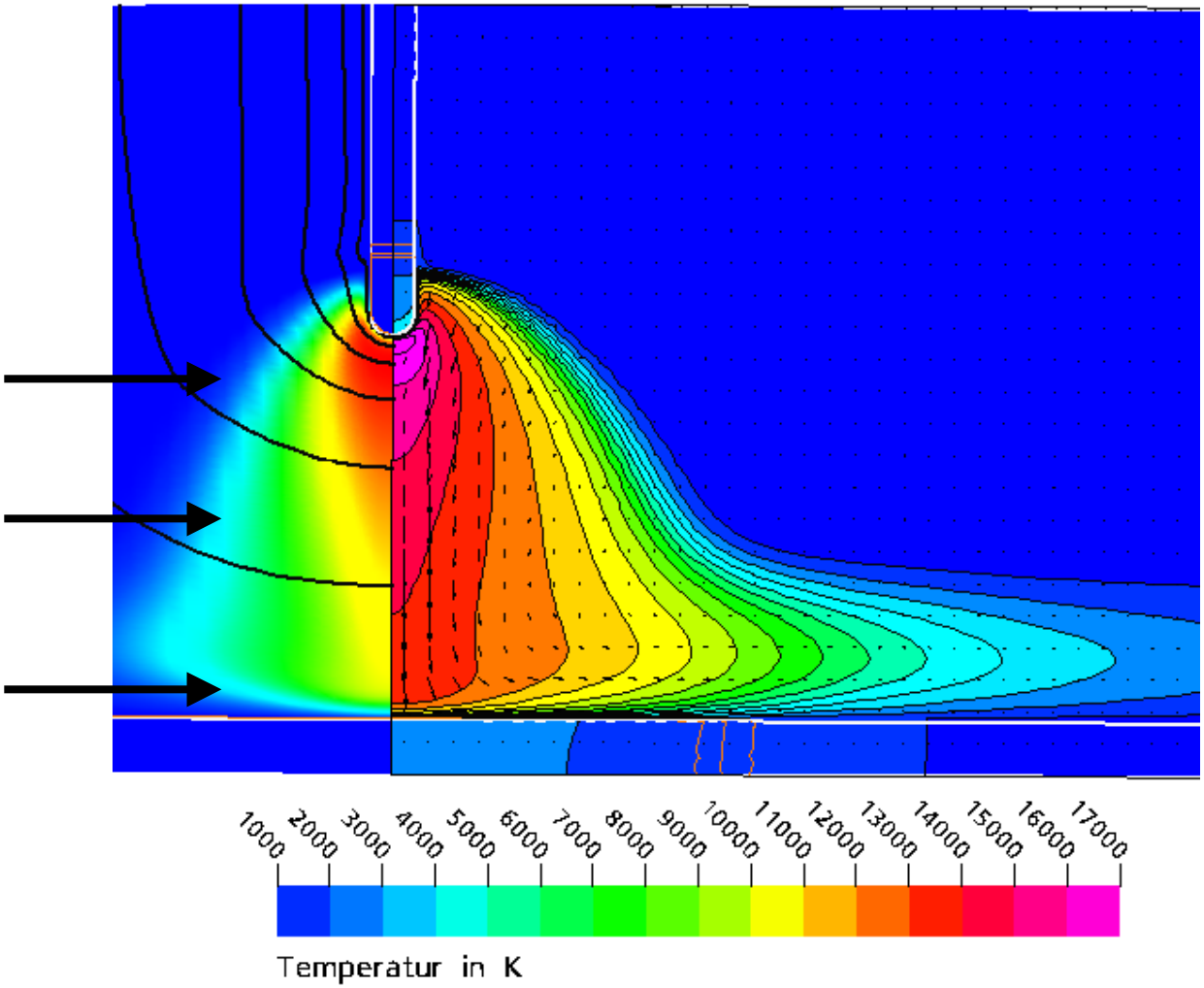


Arc simulation with sheath layers

Steady-state at 255 A



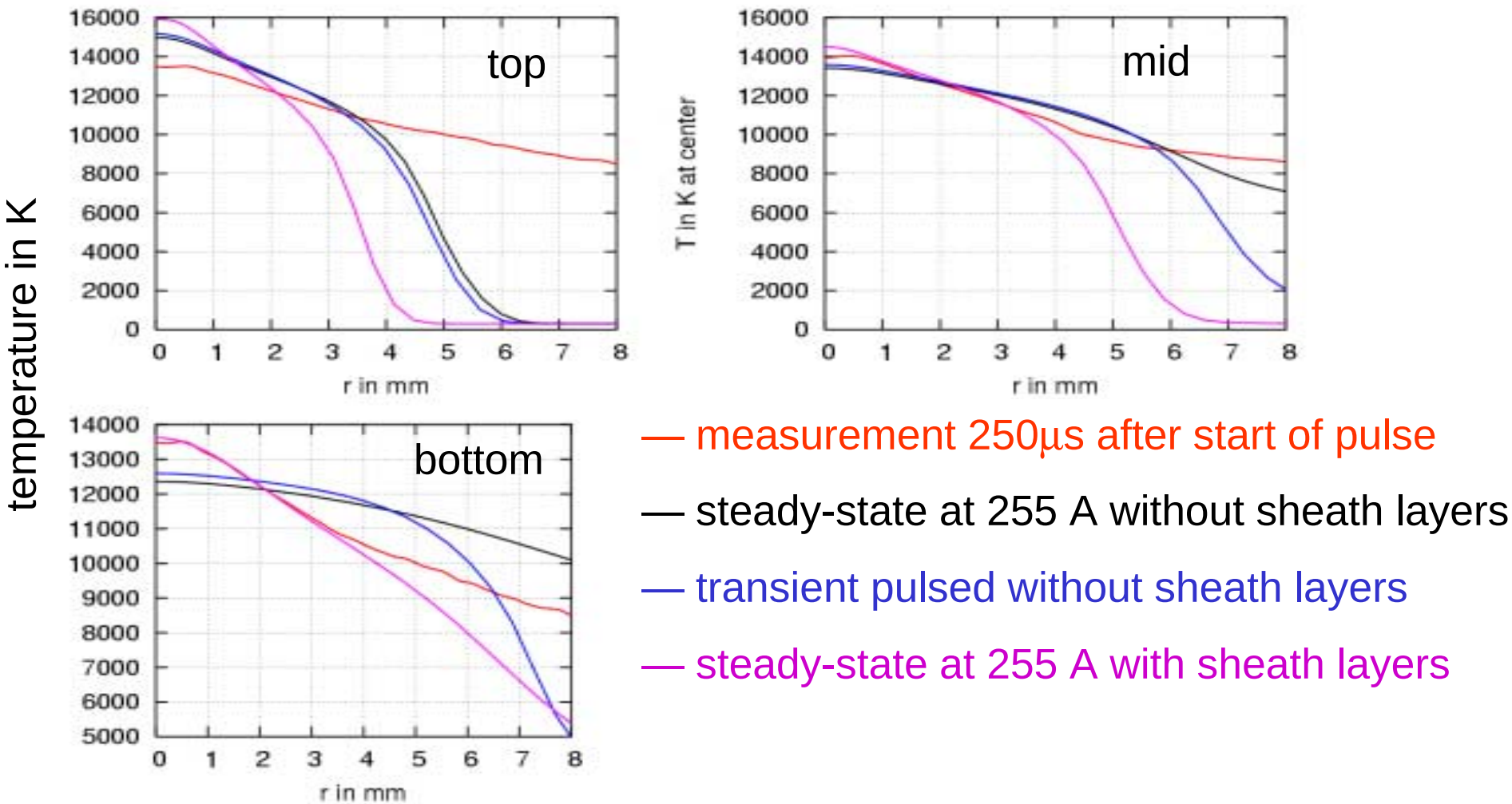
Voltage	U = 12.6 V
Power	P = 3200 W
Velocity	u ≤ 410 m/s
Pressure	p ≤ 2740 Pa
Temperature	T ≤ 17,510 K
Evaporation	70%

Without sheath regions:

Voltage	U = 9 V
Power	P = 2300 W
Velocity	u ≤ 115 m/s
Pressure	p ≤ 213 Pa
Temperature	T ≤ 17,526 K

Arc simulation

Comparison to spectral measurements at INP



— measurement 250µs after start of pulse

— steady-state at 255 A without sheath layers

— transient pulsed without sheath layers

— steady-state at 255 A with sheath layers

Summary

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- Extension to CFX-5: surface effects, melting/ solidification, electro-magnetics, plasma physics
- Simulation of ChopArc process:
  - Short-circuit phase
  - Arc phase without sheath regions
  - Arc phase with sheath regions
- Other applications:
  - Plasma tools (TU Dresden)
  - Circuit-breakers (RWTH Aachen)

Outlook

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- improved radiation model
- inclusion of metal vapour
- inclusion of active gas components
- improved model for sheath layers

- database with material properties
- coupling to FEM simulation of workpiece

Further Information:

- www.cfx-berlin.de → Entwicklung (german)
- www.choparc.de (german)
- **andreas.spille@cfx-berlin.de**

Thanks!