Cryogenics in high-current busbars and multistage cooled current leads

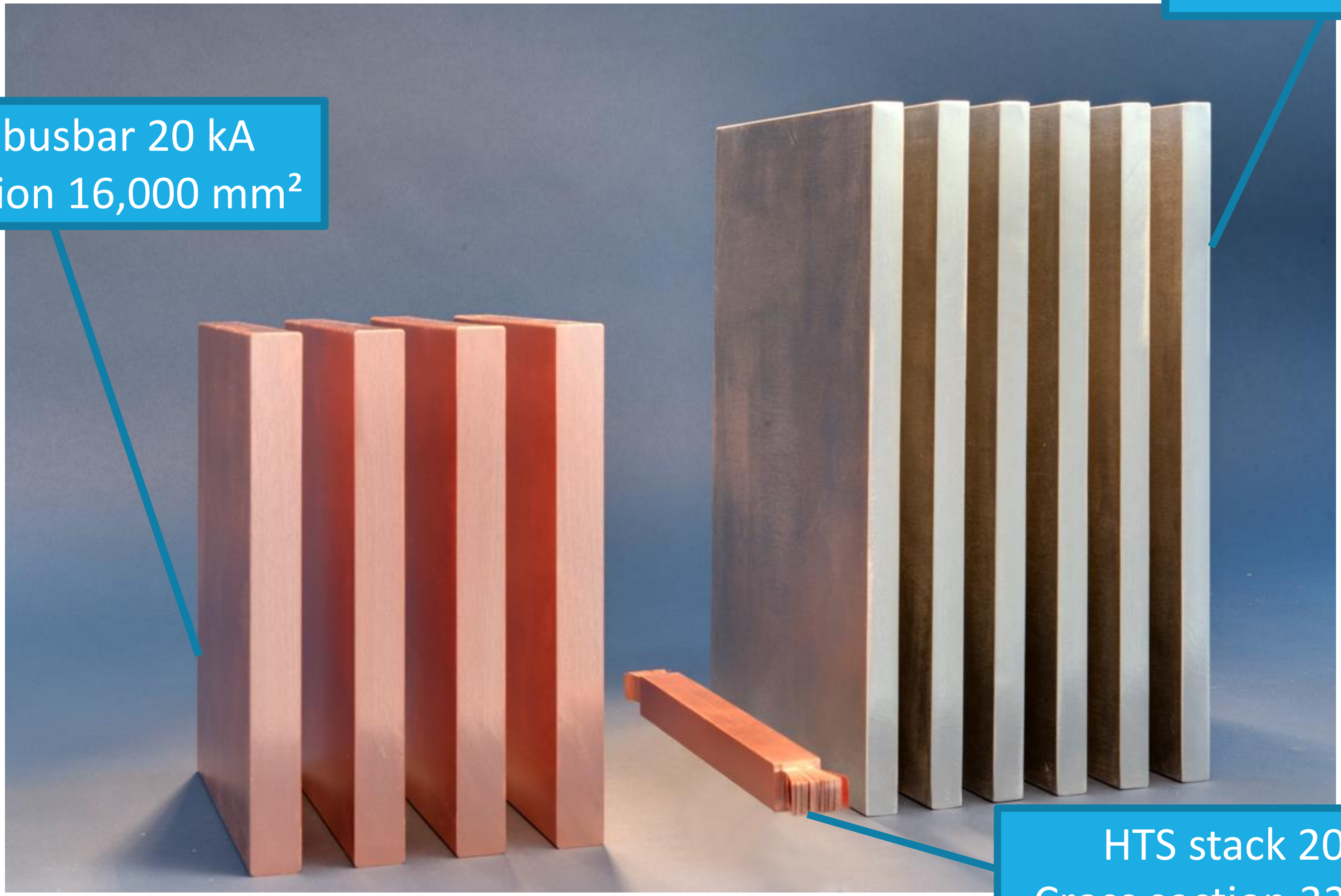
2ND INTERNATIONAL WORKSHOP ON COOLING SYSTEMS FOR HTS APPLICATIONS, KARLSRUHE, GERMANY

Outline

1. Motivation
2. 20 kA/1 kV/20 m demonstrator
3. Multistage cooled current lead
4. Busbar
5. Conclusion

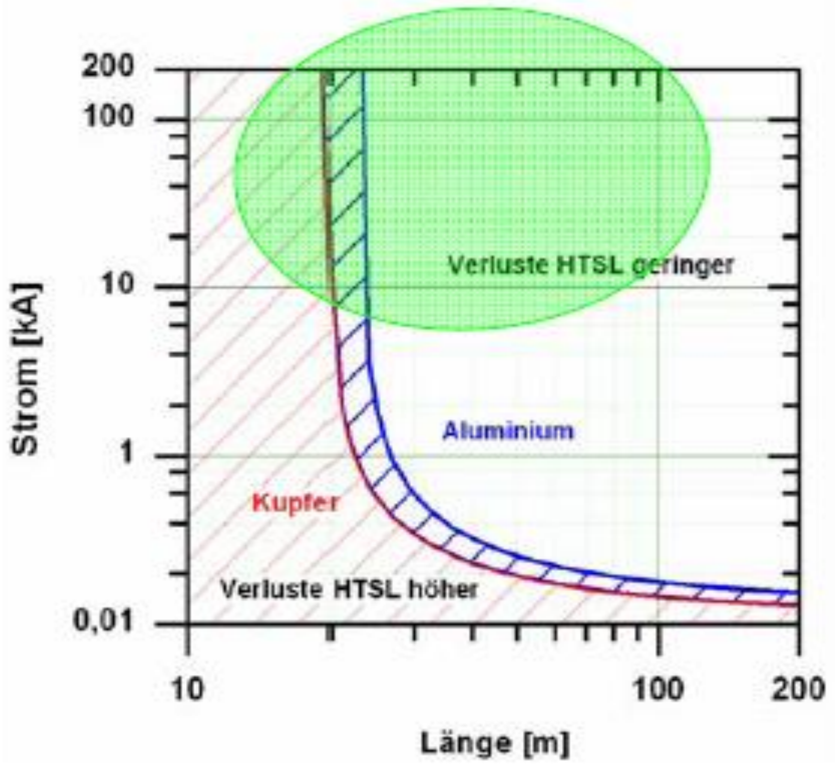
Busbars for 20 kA

Comparison of Copper, Aluminium and Superconductor



Busbar systems in high-current applications

Application	**Typical Current**	**Length**
Chlorine Plants	approx. 20 kA	30 - 300 m
Data Centers	15 - 40 kA	40 - 500 m
Copper Electrolysis	40 - 80 kA	200 - 400 m
Zinc Electrolysis	120 - 200 kA	100 - 300 m
Aluminium Plants	200 - 350 (500) kA	100 - 1200 m



Power losses and operation costs of superconducting busbars are lower above 10 kA / 25 m than those of normal-conducting Cu- or Al-busbars.

Applications for busbars

Chlorine elektrolysis, 20 kA

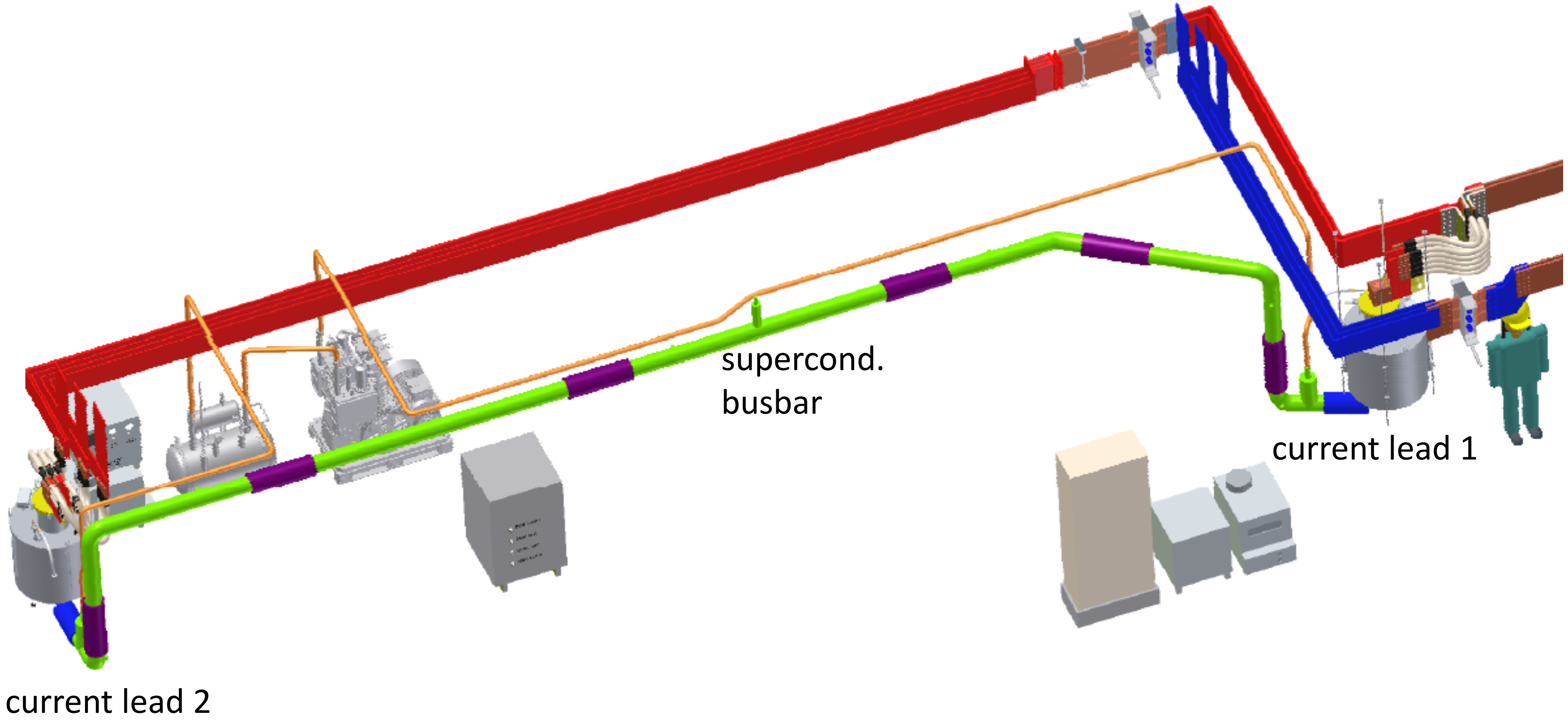
Aluminium plant, 200 kA

Conventional busbars

space limitation

cellar situation →

20 kA/1 kV/20 m demonstrator in chlorine electrolysis



- Closed-loop operation
- Busbar operated between 65 and 70 K to increase current density
- Superconductor: YBCO
- Conventional positive busbar bypassed
- Demonstrator in real industry
- Installation in chlorine plant at BASF, Ludwigshafen in 2017

Project partner:

Karlsruher Institut für Technologie

ILK Dresden
Institut für Luft- und Kältetechnik gemeinnützige Gesellschaft mbH

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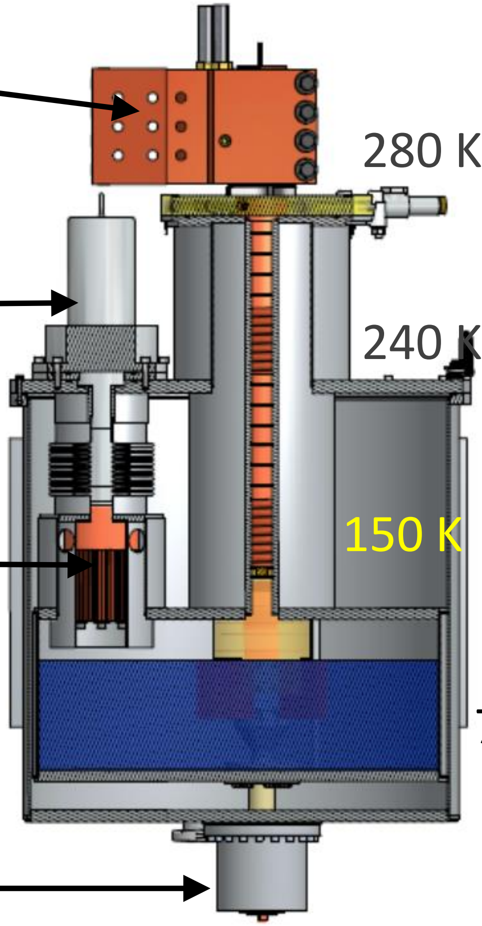
Current lead “ICE®Link”, 20 kA



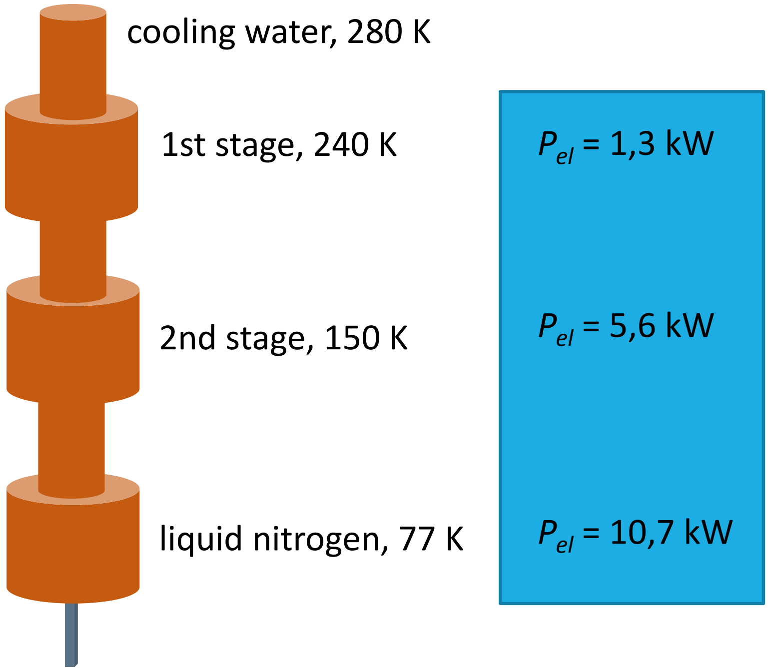
- Efficient due to cooling on different stages
- Closed-loop operation “zero boil-off”
- Reduced losses in comparison to conduction cooled and gas cooled current leads
- Standardized components for reasonable production costs

In cooperation with

TECHNISCHE UNIVERSITÄT KAISERSLAUTERN

Test of current lead

- Copper lamellas in open bath cryostat for return line
- Cool down with mixed-refrigerant machine to save liquid nitrogen
- Test at 0, 10 and 20 kA
- Zero boil-off operation at all tested currents



Power consumption of cooling machines at 20 kA

$P_{el,\ ges}$ = 17,6 kW

≈ 0,88 kW/kA

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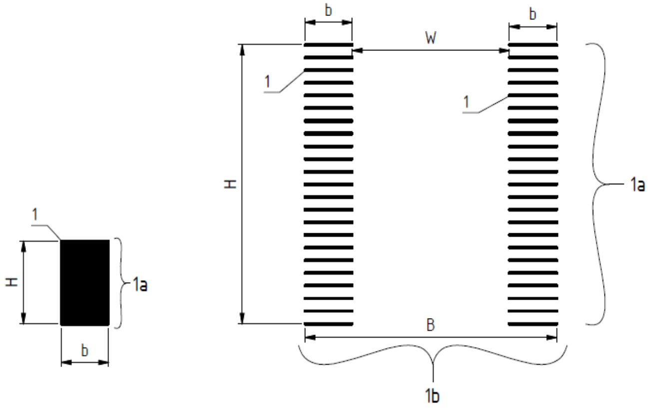
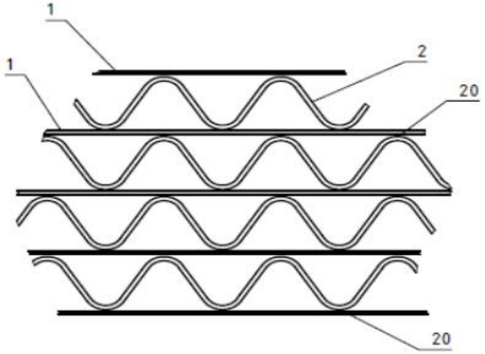
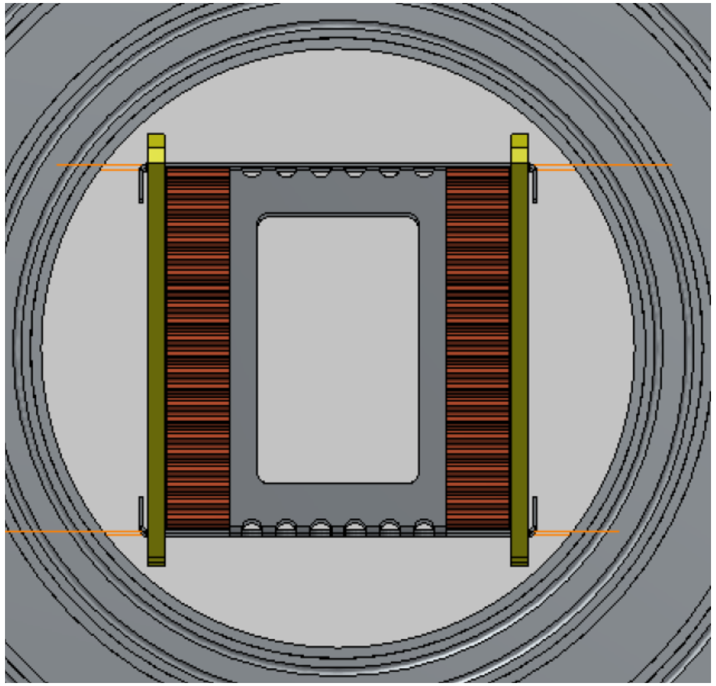
Busbar: cross section



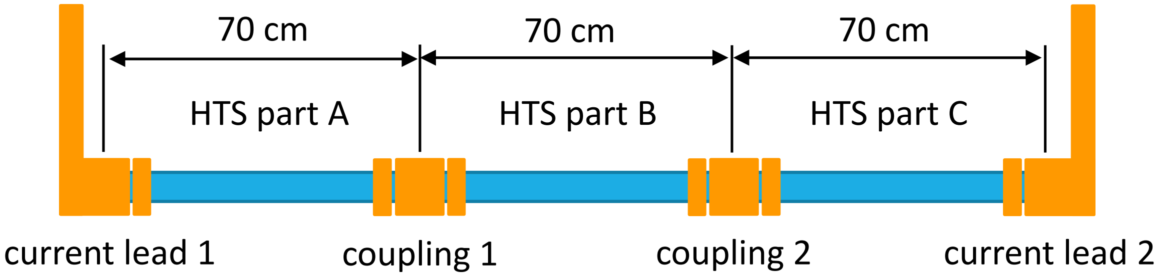




- Two spreaded HTS stacks instead of one compact stack
- Lower impact by magnetic field
- 50 % less HTS tapes
- Higher cryostat costs more than compensated by lower HTS costs
- Small pressure drop for liquid nitrogen transport
- Good cooling and wetting for each single HTS tape
- Smooth support of the tapes

Test of busbar subscale

Test set-up at KIT Campus North



- Busbar in open bath cryostat at 77 K
- Subscale consists of three HTS parts with two low-resistance couplings and two inputs
- 46 HTS tapes in parallel
- Test up to 20 kA
- No relevant voltage above I_c-criteria at 20 kA

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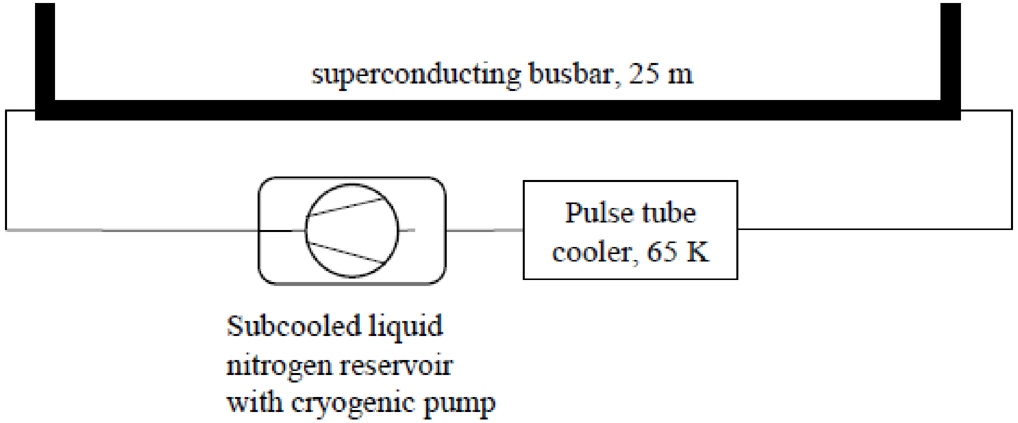
Busbar "ICE®Bar" cooling



- Busbar cooling independent of current lead cooling
- Pulse-tube cryocooler provides about 400 W cooling power at 65 K
- Cryogenic pump circulates sub-cooled liquid nitrogen (65 – 70 K) in busbar

Pump for liquid cryogens (courtesy of ILK Dresden)

For details see poster P-19 this afternoon:
Moritz Kuhn et al. (ILK Dresden, Germany)
Cooling system for a superconducting DC-rail

Conclusion

- Novel multistage current lead successfully tested at 20 kA
- Current lead achieves zero-boil-off
- Busbar cooling also designed as closed loop
- Lack of evaporating nitrogen advantageous in industrial applications
- Busbar subscale successfully tested at 20 kA
- Installation and test of 20 m demonstrator at BASF starts in October 2017

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AiF

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ptJ Projektträger Jülich Forschungszentrum Jülich

Thank you very much for your attention

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