VISION ELECTRIC Super Conductors

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

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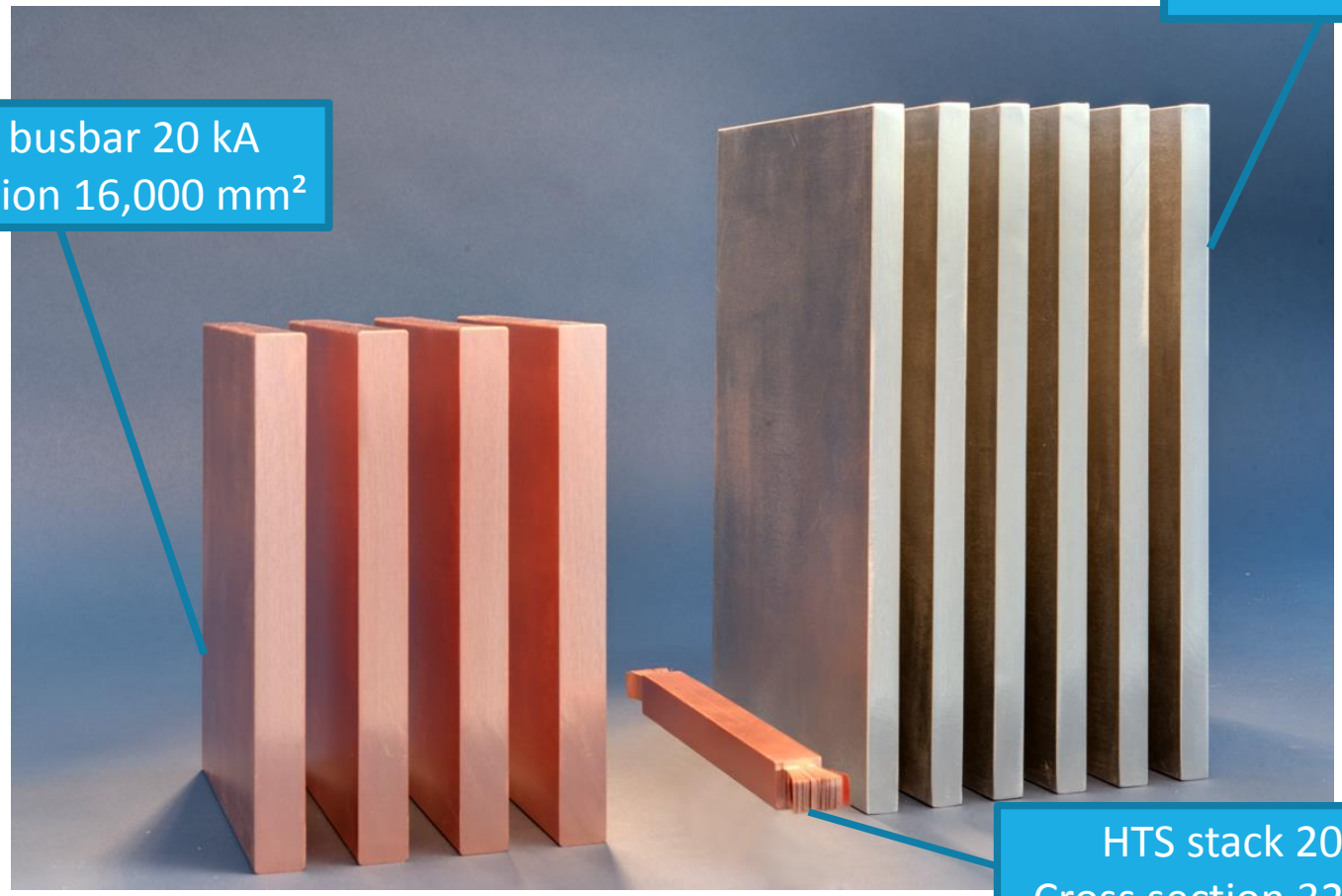
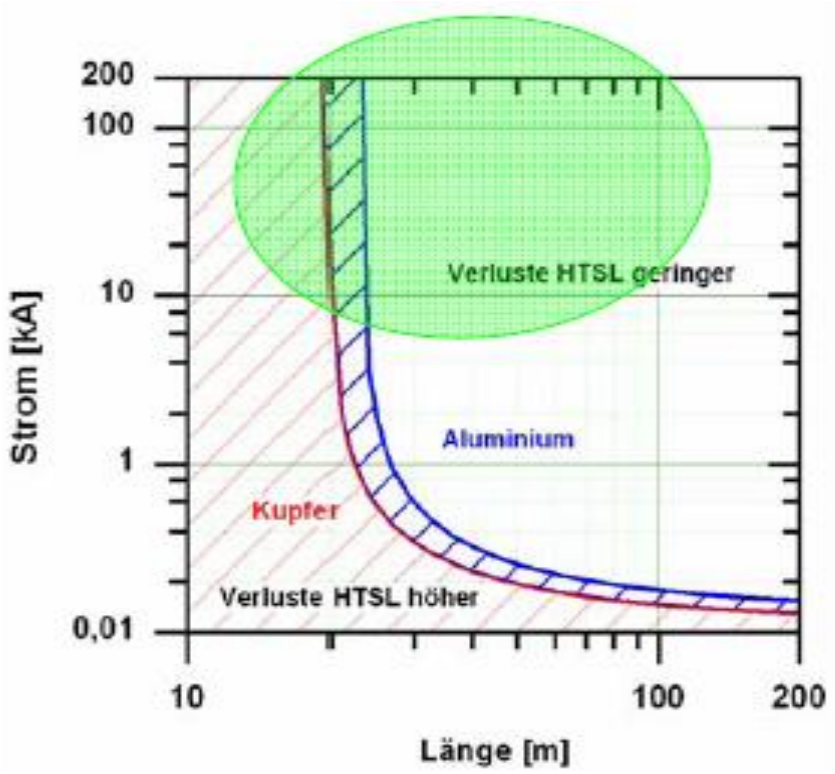
Busbars for 20 kA

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

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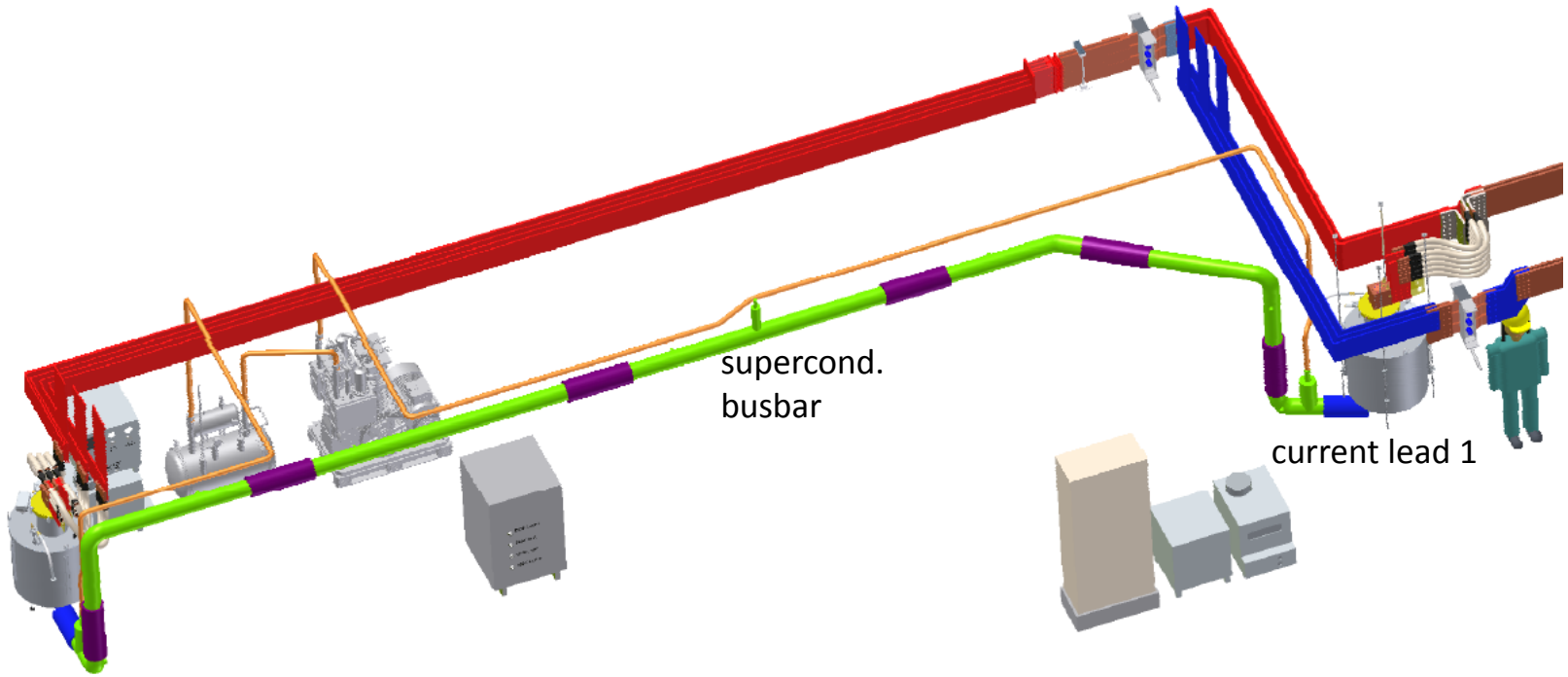
Conventional busbars

space limitation

cellar situation →

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



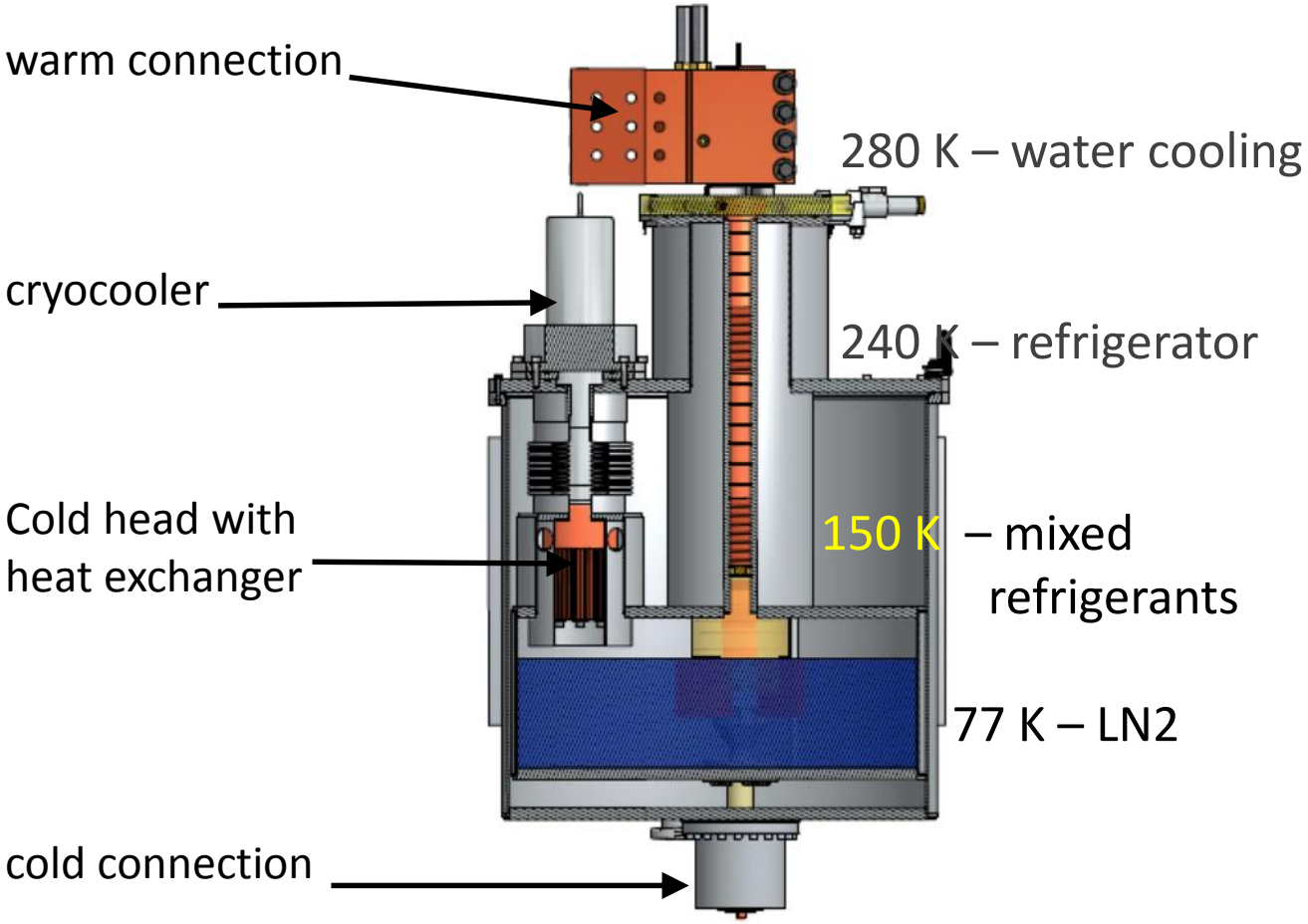
- Closed-loop operation
- Busbar operated between 65 and 70 K to increase current density
- Superconductor: YBCO
- Conventional positive busbar bypassed
- Demonstrator in real industry
- Installation in chlorine plant at BASF, Ludwigshafen in 2017

Project partner:

Karlsruher Institut für Technologie

ILK Dresden
Institut für Luft- und Kältetechnik gemeinnützige Gesellschaft mbH

Current lead “ICE®Link”, 20 kA



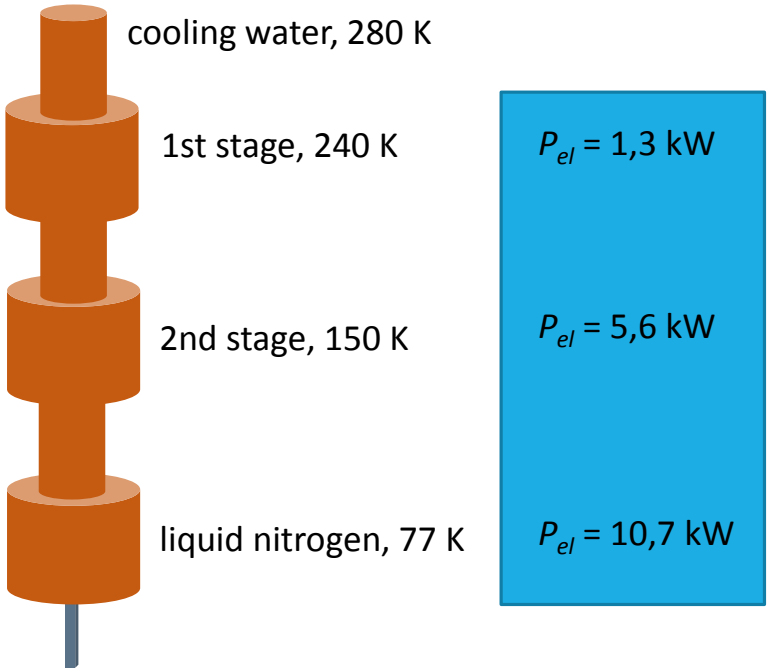
- Efficient due to cooling on different stages
- Closed-loop operation “zero boil-off”
- Reduced losses in comparison to conduction cooled and gas cooled current leads
- Standardized components for reasonable production costs

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

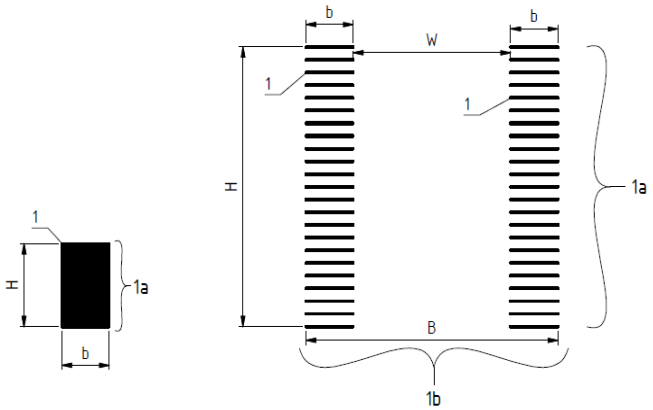


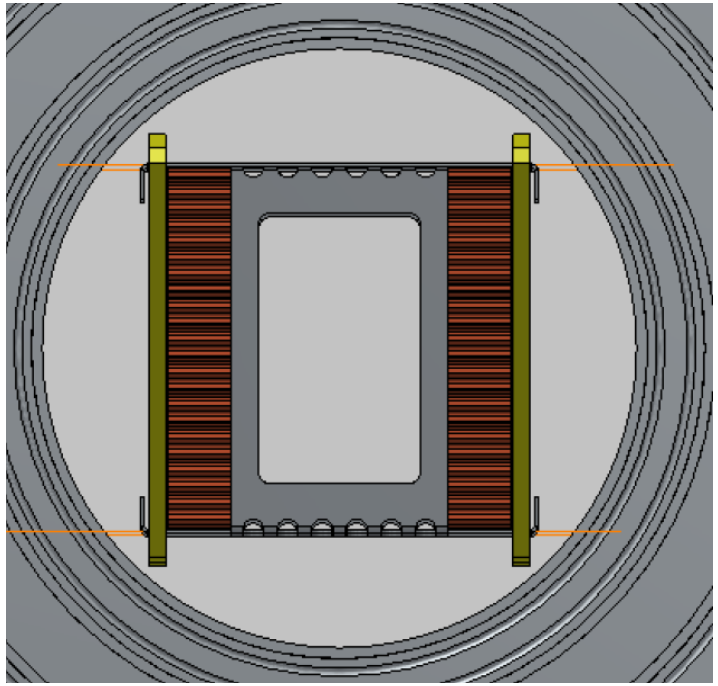
Power consumption of cooling machines at 20 kA

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

≈ 0,88 kW/kA

Busbar: cross section

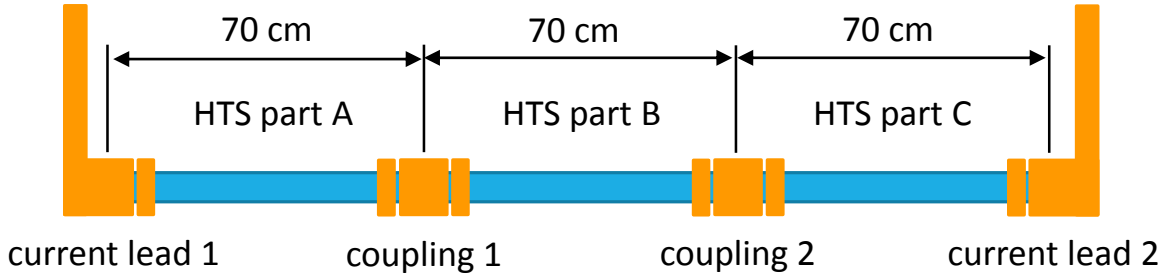




- Two spreaded HTS stacks instead of one compact stack
- Lower impact by magnetic field
- 50 % less HTS tapes
- Higher cryostat costs more than compensated by lower HTS costs
- Small pressure drop for liquid nitrogen transport
- Good cooling and wetting for each single HTS tape
- Smooth support of the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

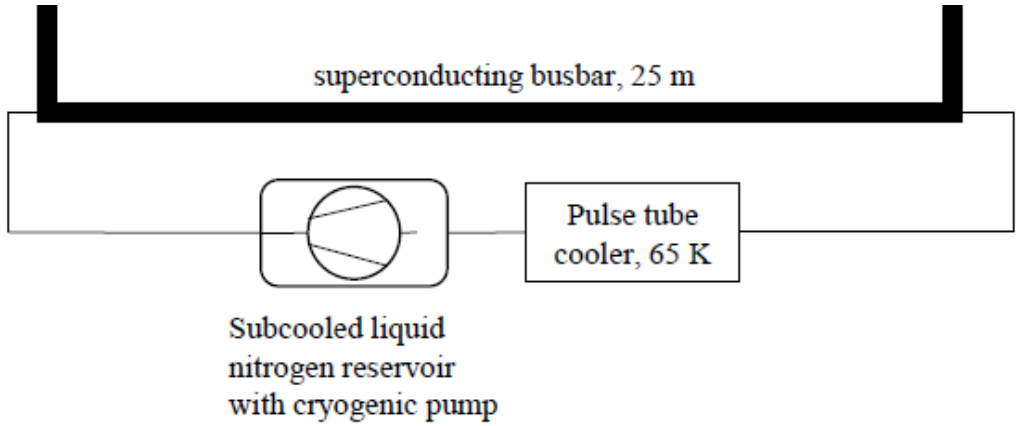
Test of busbar subscale

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

Busbar “ICE®Bar” cooling



Pump for liquid cryogens (courtesy of ILK Dresden)

- 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

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

Gefördert durch:

Bundesministerium für Wirtschaft und Energie

aufgrund eines Beschlusses des Deutschen Bundestages

ZIM Zentrales Innovationsprogramm Mittelstand

Projektträger Jülich Forschungszentrum Jülich

Thank you very much for your attention

Vision Electric Super Conductors GmbH

Trippstadter Str. 122 (DFKI-Gebäude)

67663 Kaiserslautern

www.vesc-superbar.de

info@vesc-superbar.de

+49 (0)631 20575-1070