Basics of Superconducting Levitation and its Use in the Transport System SupraTrans II

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New means of urban transportation and logistics will become realistic with superconducting magnetic bearings using nanostructured bulk high temperature superconductors [1,2]. Superconducting magnetic levitation works passively stable without any electronic control but with attracting and repelling forces to suspend a vehicle pendant or standing upright from zero to high speed - perfect conditions for the idea of rail-bound individual transport with cabins for 4 - 5 passengers called on demand only. They will levitate noiseless over the track made of RE permanent magnets to the chosen destination saving energy and travel time [3]. A big step forward to this vision can be tested at Dresden. The world largest research and test facility for transport systems using HTS bulk material in the levitation and guidance system in combination with a permanent magnet track was put into operation. A vehicle for 2 passengers, equipped with linear drive propulsion, non-contact energy supply, second braking system and various test and measurement systems is running on an 80 m long oval driveway.

In the presentation the superconducting materials as well as the principle of superconducting levitation by flux pinning in high temperature superconductors will be described. An overview of the SupraTrans II research facility and future directions of superconductivity-based magnetic levitation and bearing for automation technology and transportation will be given.

References:

1. G. Fuchs, P. Schaetzle, G. Krabbes, S. Gruss, P. Verges, K.-H. Mueller, J. Fink, L. Schultz, *Trapped magnetic fields larger than 14 T in bulk YBa2Cu3O7-x*, Appl. Phys. Letters 76 (2000) 2107-2109.
2. S. Gruss, G. Fuchs, G. Krabbes, P. Verges, G. Stoever, K.-H. Mueller, J. Fink, L. Schultz, *Superconducting bulk magnets: Very high trapped fields and cracking*, Appl. Phys. Lett. 79 (2001) 3131-3133.
3. L. Schultz, O. de Haas, P. Verges, C. Beyer, S. Roehlig, H. Olsen, L. Kuehn, D. Berger, U. Noteboom, U. Funk, *Superconductively levitated transport system - The SupraTrans project*, IEEE Trans. Applied Superconductivity 15 (2005) 2301-2305.

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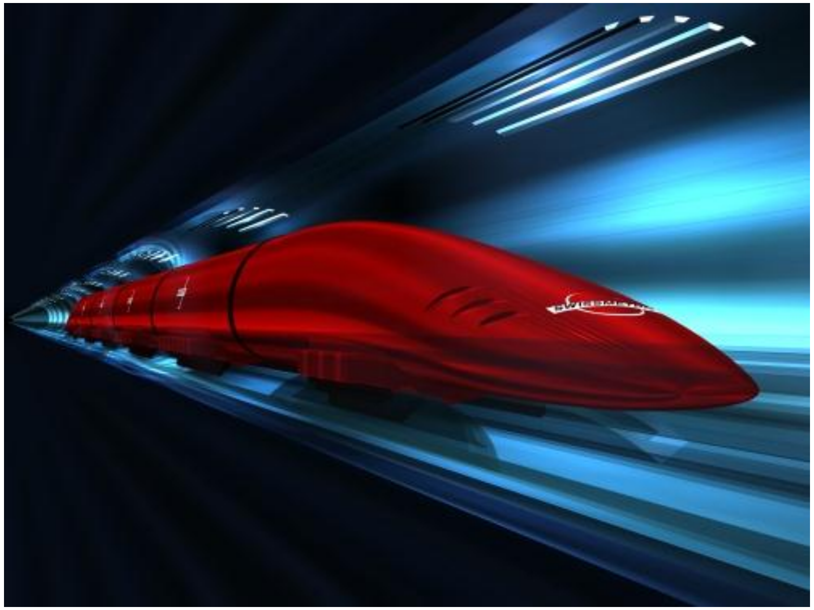
- **Suspension by magnetic fields**
- **High temperature superconductors**
- **The SupraTrans project**
- **Energy-efficient applications**

Levitation why?

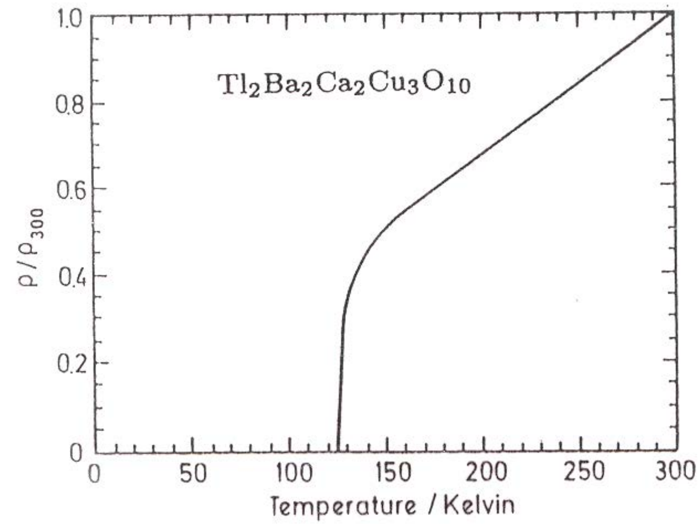
- Fascinating
- No friction, energy efficient
- Soft bearing
  - Incredibly comfortable
  - High velocity
  - Endless durability
  - New traffic concepts



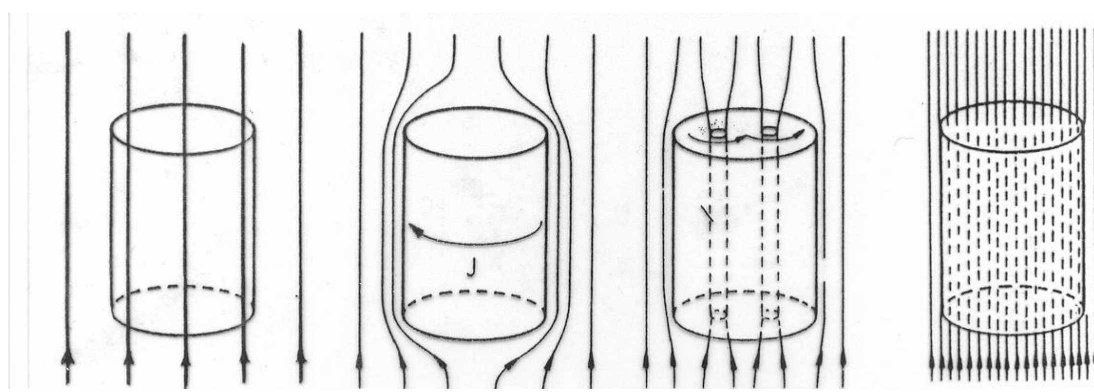
Superconductivity

Two properties:

1) Zero resistance R = 0
for $T < T_c$

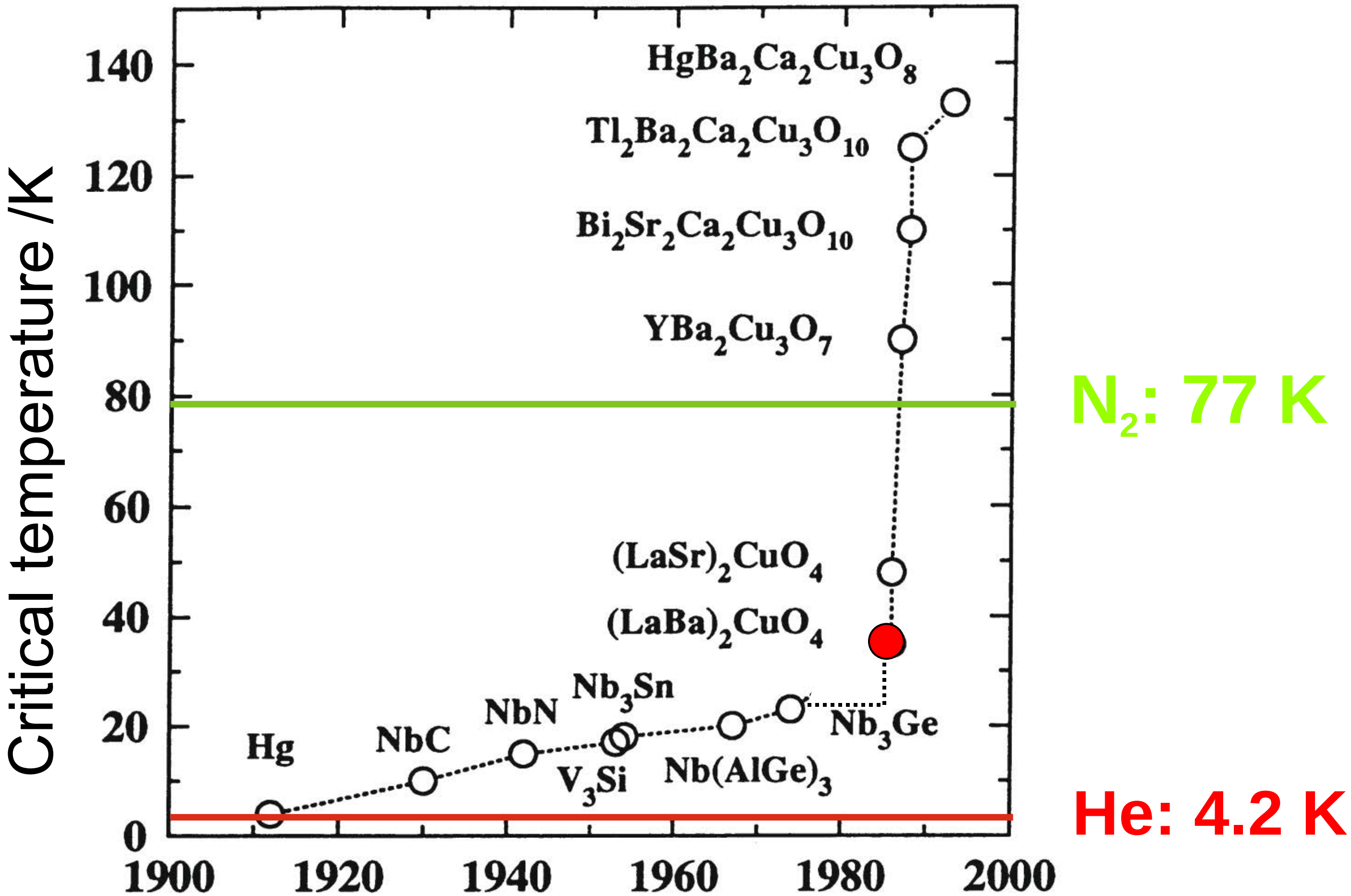


2) Magnetic field is pushed out of the superconductor

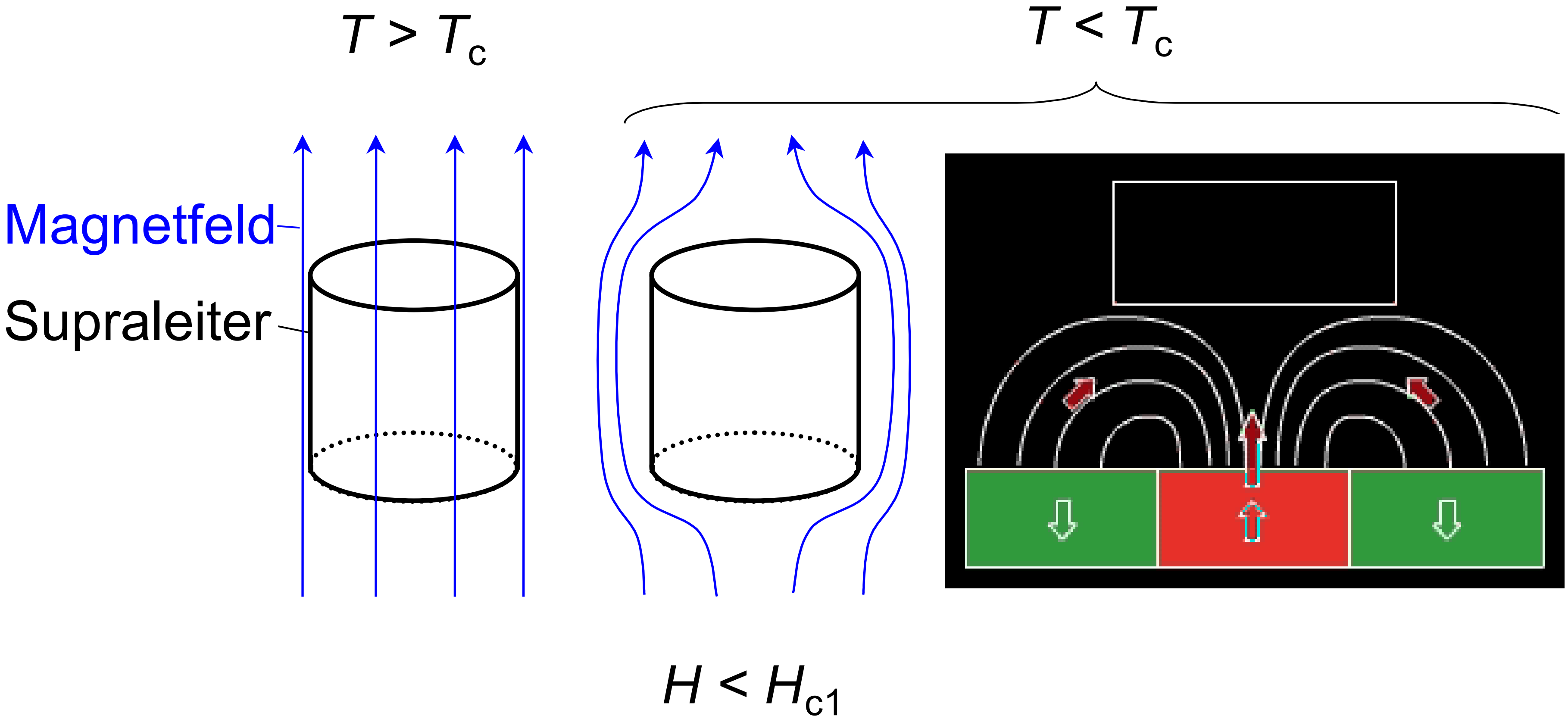


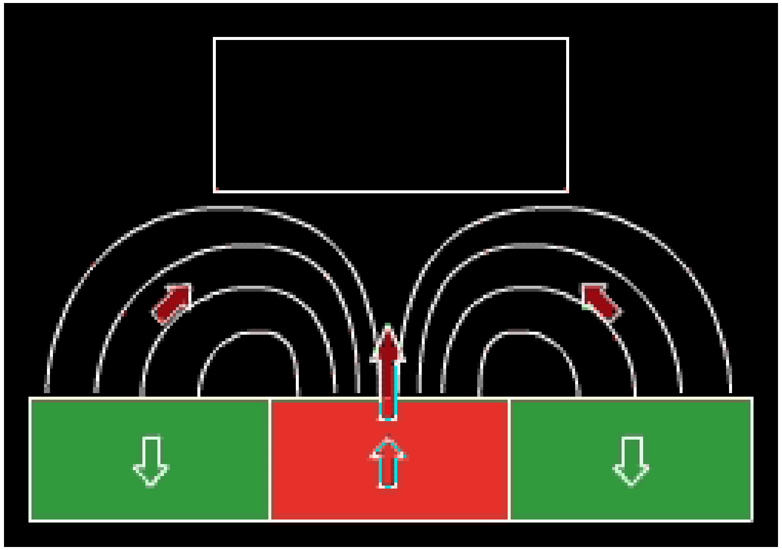
normal state | $B < B_{c1}$ Meissner state | $B_{c1} < B < B_{c2}$ mixed state | $B > B_{c2}$ normal state

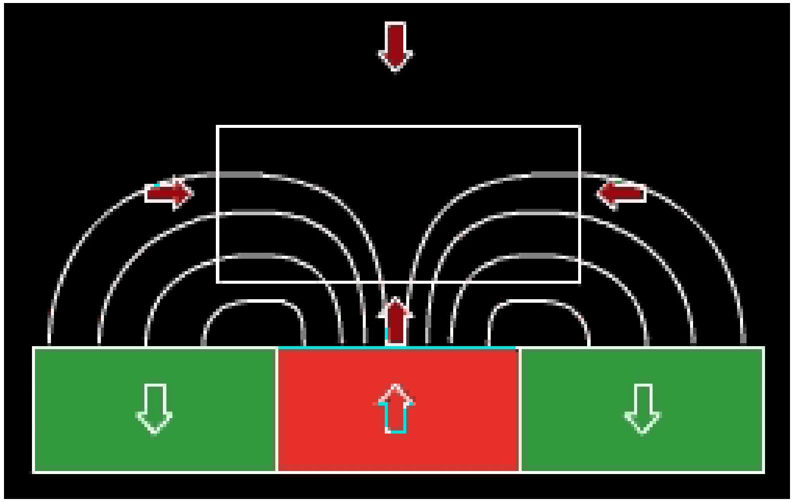
Development of the critical temperature T_c

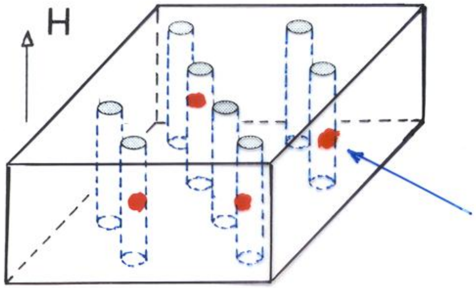


Superconductor in a magnetic field





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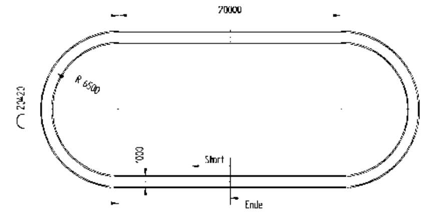
Project SUPRATRANS

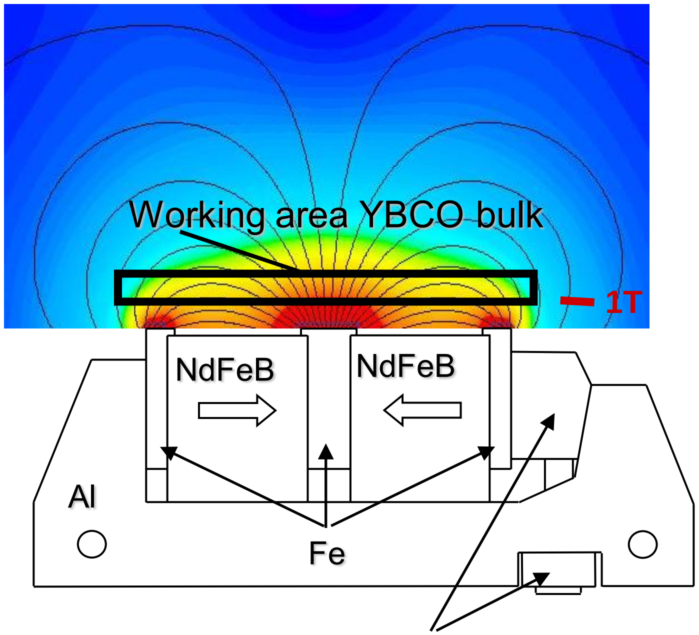
Goals:

- qualification of the superconducting suspension technology for application in transport systems
- increasing size, increasing levitation forces
- construction of a demonstrator
- system integration for propulsion, safety, logistics, power transfer, etc.

SupraTrans II



Permanent magnetic rail



Magnetic design		
Architecture	3 pole - flux collector	
Pole distance	48 mm (centre-centre)	
Perm. magnets	NdFeB N40	
B_r	*1276,8 mT*	
Dimensions (mm)	*50 x 50 x 40*	
Weight	*750 g*	30 kg/rail
Magnets / rail	*40*	
Flux collector	Steel - softmagnetic	
B_{surf}	*1.1 T*	

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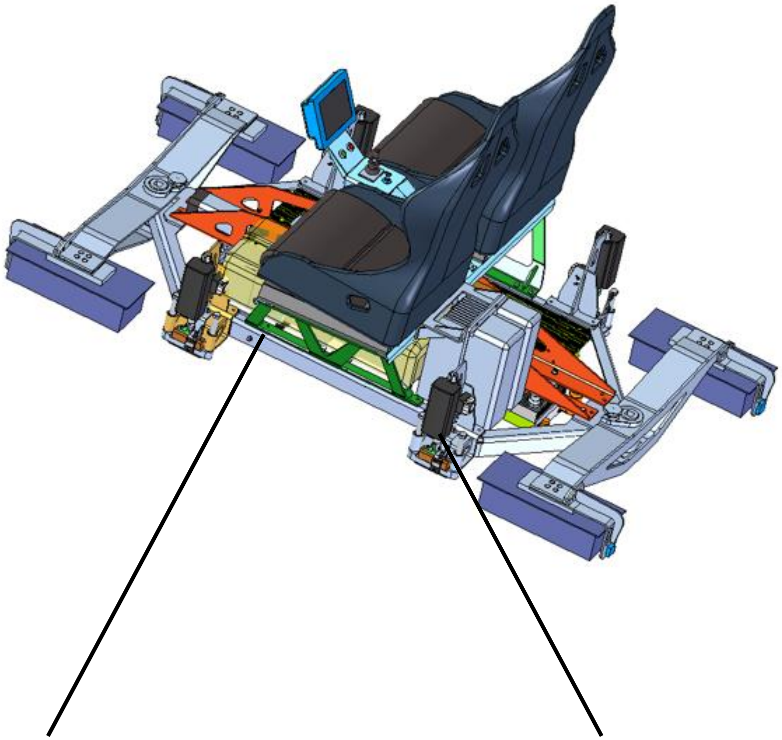
vehicle



Spezification

- Total weight = 400 kg
- Air gap = 10 mm
- 2 braking system
- a = 1m/s²
- v = 20 km/h

4 cryostats

- 24 YBCO bulks/cryostat
- YBCO area = 500 cm²/cryostat
- Force density = 4 – 4.5 N/cm² @ 8 – 10 mm
- Levitation force = 8 – 9 kN @ 8 – 10 mm

4 x lift-/ brake system

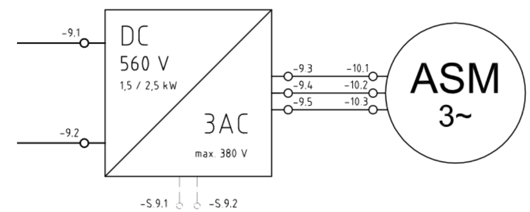
- liftsystem brings vehicle into cooling position
- auxiliary brake

Propulsion system

Features

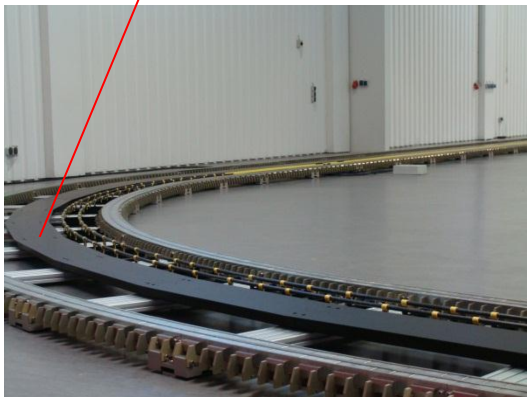
U_n = 380 V
I_n = 45 A
f = 0 – 80 Hz
F_{lin} = 1000 N
η = 30 %
m_{Stator} = 43 kg

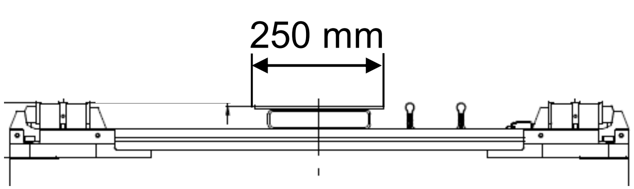
Asynchronous short stator linear motor



Track

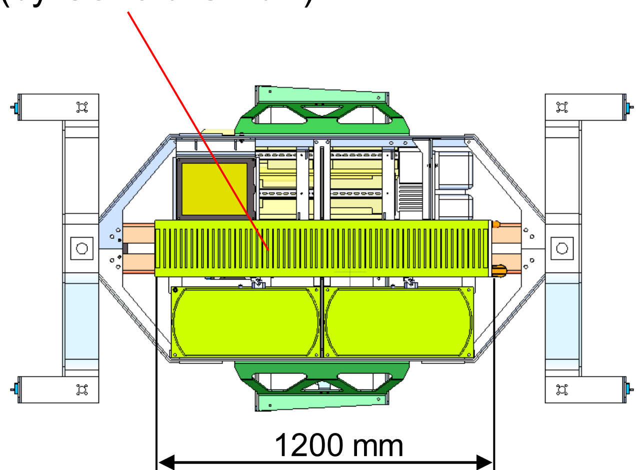
Short circuit "rotor" (5 mm Cu + iron yoke)





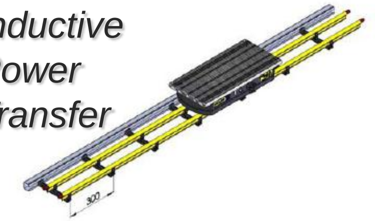
Vehicle

Short stator (ASM 3-phase winding)
(by Oswald GmbH)



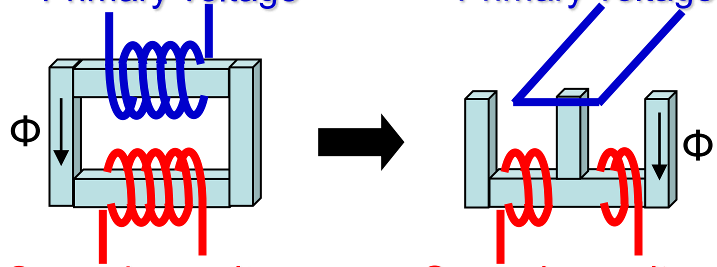
Energy supply

Inductive Power Transfer



Inductive power transmission (non-contact)

→ transformer principle

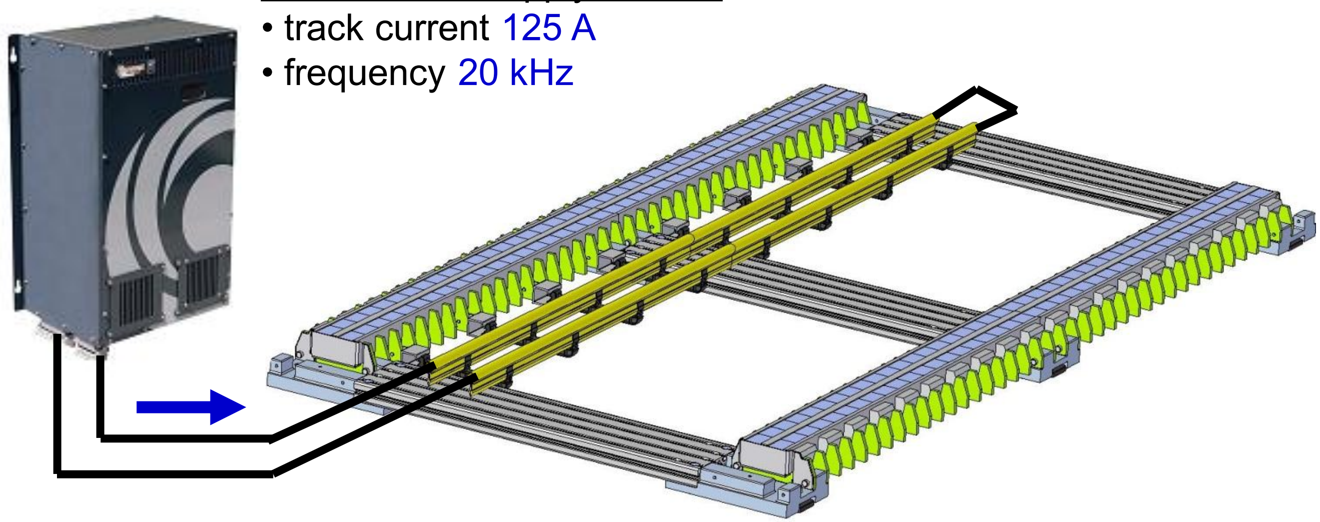


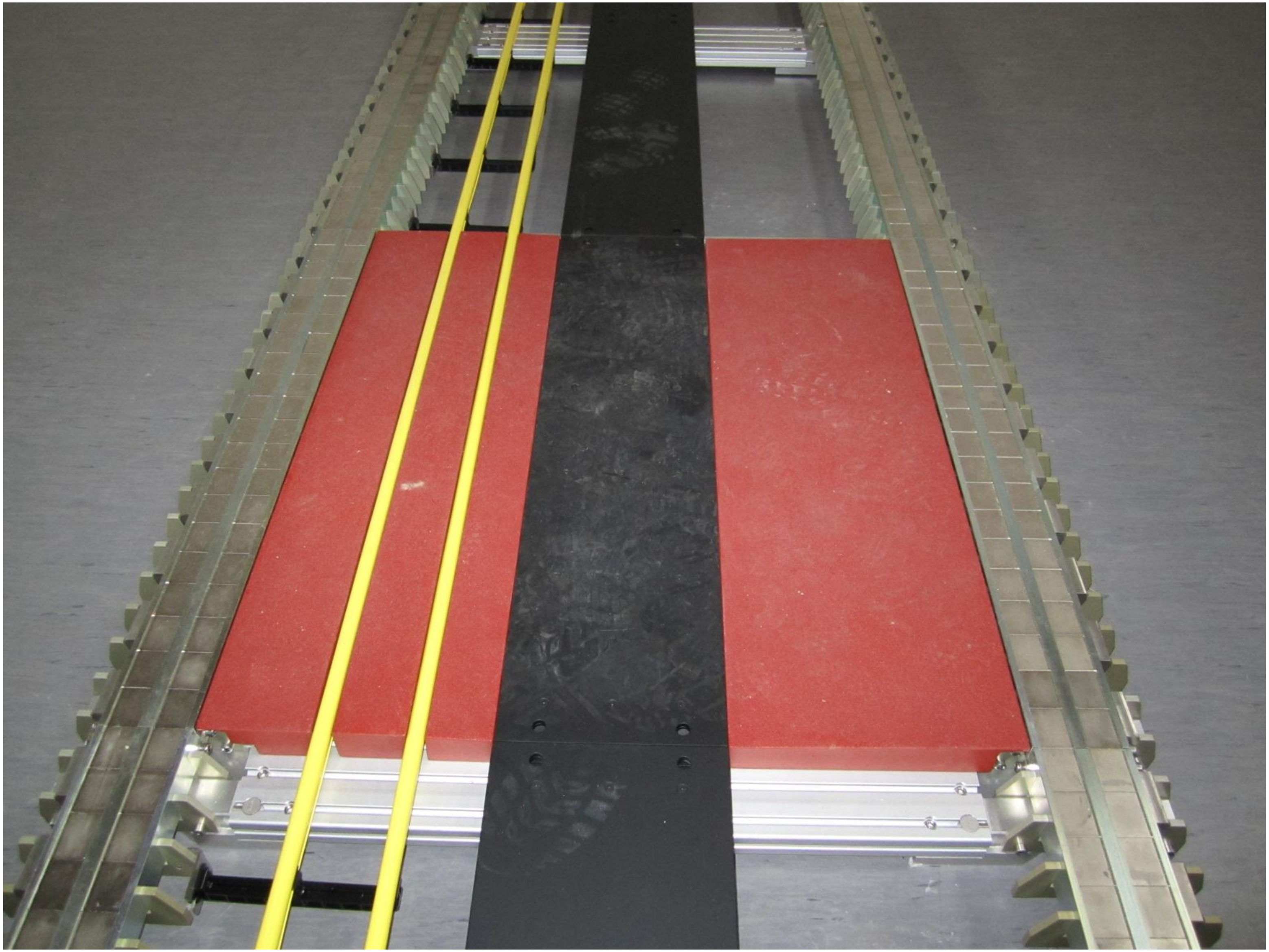
$U_P \sim f * N_P * \Phi$

$U_S \sim - f * N_S * \Phi$

<u>16 kW Track Supply Module</u>

- track current 125 A
- frequency 20 kHz





Preliminary conclusions

- Stable superconductive suspension on a magnetic track is possible
- High energy efficiency due to zero friction
- Noiseless and extremely soft motion

- Remaining issues:
    - Optimization of the permanent magnet track in relation to the shape of the superconductor:
      - reduction of size, weight, costs
      - cheaper magnets
    - Electromagnetic track, crossings, turnout switches
    - Non-liquid cryocooler

- Next demonstration projects:
    - people transportation
    - automation technology (cooperation with Festo)
    - hyper gravity – human centrifuge

Track-bound individual urban transportation

- **Requirements:**
  - magnetic railway
  - cabins for 4 or 5 persons
  - central control
  - central power supply (for the drive)
  - low energy consumption
  - fast turnout switches

- **Advantages:**
  - individual mobility
  - no parking space problem
  - effective use of vehicles
  - fast (compared to mass transportation)
  - service on demand, no fixed schedule
  - continuous night service
  - personal security

SupraTrans II

Superconducting magnetic levitation

Advantages for the construction of transport systems:

- ✓ Passively stable levitation
- ✓ Environmentally friendly, no CO_2 emission
- ✓ Absolutely noiseless
- ✓ 24 h use with just one cryostate filling
- ✓ Ice on the track: no problem

Large Human Centrifuge: System Considerations

- Gravity: 1 g vertically
- Rotation: 1 g horizontally (centrifugal force)
  rim speed must be proportional to SQR (radius)
  (i.e.: about 90 km/h at 150 m diameter)
- Resulting gravity: 1.4 g under 45 degrees
- Main problem for human beings: Coriolis force, proportional to SQR (1/radius) at constant centrifugal force
- Our proposal: mobile home on a circular magnetic track (diameter: 150 m)
  with superconducting suspension
  (soft bearing, comfortable, noiseless)

Thank you for your attention

Acknowledgements

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G. Fuchs, K. Nenkov, B. Holzapfel, G. Krabbes