Recent Activities on Pulsed Magnets

presented by L. Bottura

CARE-05 General Meeting

CERN, November 23rd-25th, 2005

Overview

- Ongoing R&D for FAIR at GSI
  - Design optimization, prototyping and test work on SIS-100 model (2 T, 4 T/s, 2 s, 200 x 10^6 cycles)
  - Test and analysis of a model for SIS-200 (4 T, 1 T/s, 24 s, 1 x 10^6 cycles)
  - Design work on SIS-300 (6 T, 1 T/s, 24 s, 1 x 10^6 cycles)
- Pulsed Magnet Working Group see http://pmwg.web.cern.ch/pmwg/
  - informal working group with 25 participants, 5 institutions collaborating in CARE-HHH-AMT
  - Foster exchange of information and steer R&D on superconducting pulsed magnets for accelerators (LHC & FAIR)
  - 2 meetings on design issues (strand, cable, magnet)
- ECOMAG-05
  - Workshop on pulsed superconducting magnets for accelerators
  - October 26th-28th, 2005 in Frascati (I)

ECOMAG-05

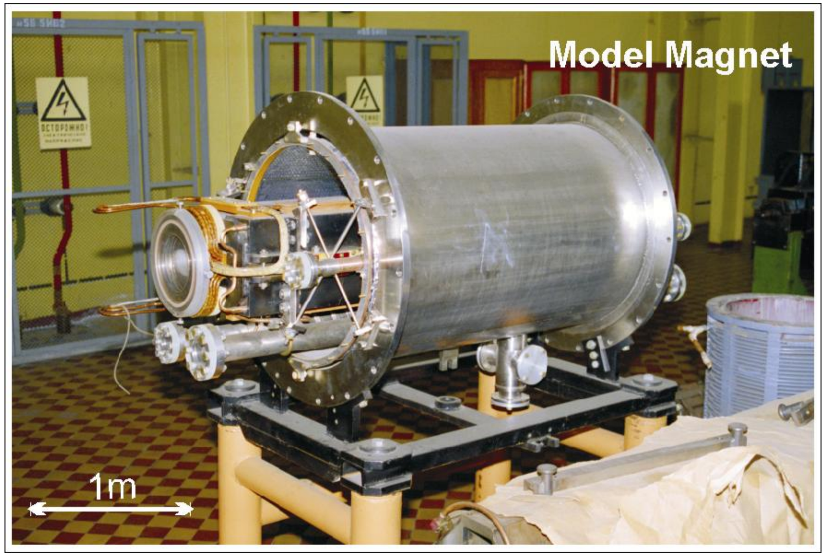
- Aims
  - Define a set of magnet design parameters for the development of pulsed superconducting magnets for accelerators (this is one of the main objectives of HHH-AMT)
  - Review the state-of-the-art of design and manufacturing capability
  - Specify performance requirements and define R&D needs
- Workshop jointly hosted and sponsored by ENEA and INFN Frascati
- Organizing committee:
  - L. Bottura (CERN), A. Della Corte (ENEA), P. Fabbricatore (INFN), U. Gambardella (INFN), G. Moritz (GSI), W. Scandale (CERN), D. Tommasini (CERN)

A Workshop !

- Three working groups
  - Wires and Cables (WG-1) J. Kaugerts (GSI)
  - Low losses pulsed magnets (WG-2), E. Salpietro (EFDA-CSU)
  - Heat transfer, quench protection and magnetic measurements (WG-3), A. Siemko (CERN)
- Invited talks from specialists in the field
  - D. Leroy (CERN) - Low-Loss Wires
  - P. Bruzzone (EPFL-CRPP) - Low-Loss Cables
  - J. Minervini (MIT-PFC) - Pulsed and AC Magnets
  - B. Baudouy (CEA-Saclay) - Cryogenic Heat Transfer
- Contributions from industry
- Summary and round table session

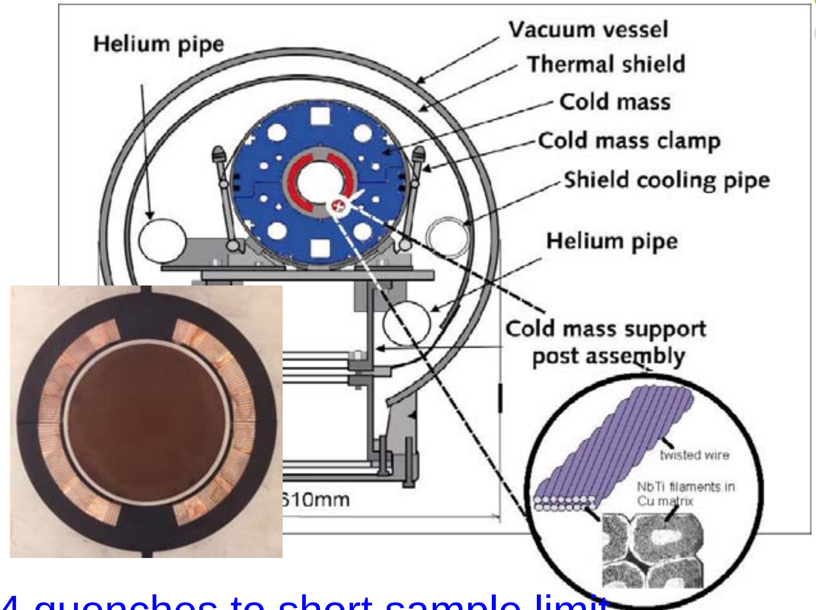
Superconducting Pulsed Accelerator Magnets

2 T, 4T/s SIS-100 prototype



Heat load to helium, 1.4 m dipole
2 T, 4 T/s, 1 Hz
Q_{total} = 38 W
Q_{iron} = 29 W
Q_{coil} = 9 W

4 T, 1 T/s SIS-200 prototype



4 quenches to short sample limit
Continuous operation at 2 T/s
3 cycles at 4 T/s to 4 T
AC loss within a factor 2 of calculation

Heat load optimization
Long-term mechanical stability

Characterization
Industrial production issues

Magnet Design Parameters for FAIR SIS-100 and SIS-300

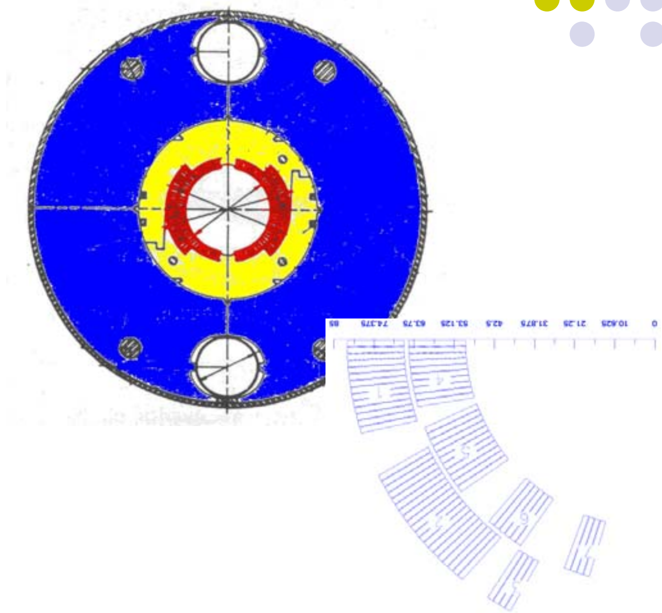
	SIS-100	SIS-300
Peak field [T]	**2**	**6**
Good field region [mm]	HxV = 130x60	Φ = 80
Magnet length [m]	2.9	2.9
Number of dipoles	108	108
Field quality [10^{-4}]	**± 6**	**± 2**
dB/dT [T/s]	**4**	**1**
Duration of a cycle [seconds]	2	24
Number of cycles (20 years) [-]	**200 x 10^6**	**1 x 10^6**
Radiation load [W/m]	1	1
Average refrigeration power [W/m]	**10**	**10**

Magnet Design Parameters for the Upgrade of LHC Injectors

	PS^+	SPS^+
Peak field [T]	**3**	**4.5**
Good field region [mm]	HxV = 130x80	Φ = 80
Magnet length [m]	4	6
Number of dipoles	100	750
Field quality [10^{-4}]	**± 4**	**± 2**
dB/dT [T/s]	**3.5**	**1.5**
Duration of a cycle [seconds]	3.6	12
Number of cycles (20 years) [-]	**60×10^6**	**1×10^6**
Radiation load [W/m]	10	10
Average refrigeration power [W/m]	**20**	**10**

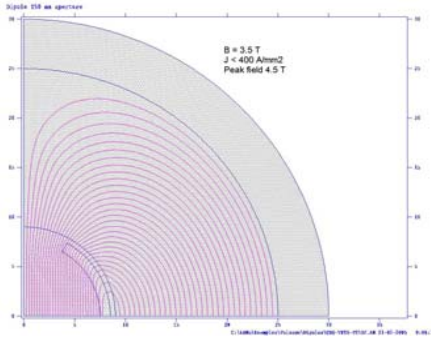
Magnet Design Options: from 2 T to 6 T

6 T for SIS-300

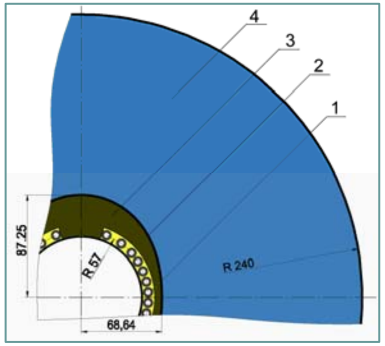


Efficient use of conductor
Good field quality

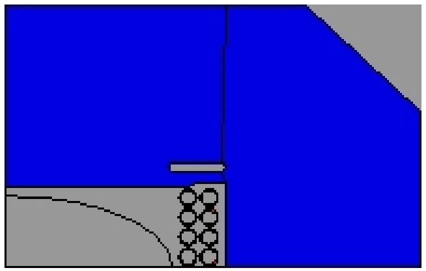
3.5 T for PS$^+$



3 T for PS$^+$



2 T for SIS-100



Optimised cross section
Operating margin

Internally cooled cables
Controlled heat transfer

Comments on the Magnet Design Options

- All magnet families have difficulties and challenges
  - Balance of conductor margins, losses, heat removal
  - Field quality in ramped conditions
  - Large dynamic range (a factor 30 in energy for the PS^{+})
  - Magnet protection during quench
  - Pulsed SC joints
  - Fatigue (several 1…100 MCycles)
  - Radiation (1…10 MGy)
  - Measurement and test issues
- All factors can be addressed and seem to be in reach of present technology, possibly with optimized industrial process (strand, cable)

Can we build and measure these magnets ? YES

Networking Results - 1

- More than 70 participants (initial plan on 30 to 50)
- 17 laboratories and universities
  - Bochvar Institute, CEA, CERN, **CIEMAT(*)**, **EFDA-CSU(*)**, **ENEA(*)**, **EPFL-CRPP(*)**, **FzK(*)**, GSI, IHEP, INFN-Frascati, INFN-Genova, INFN-Milano, JINR, KEK, **MIT(*)**, Ohio State

    (*) fusion/energy laboratories
- 7 major European industries:

ACCEL

Ansaldo Superconduttori

ALSTOM

BABCOCK NOELL NUCLEAR GmbH

BRUKER

EAS

OUTOKUMPU

Networking Results - 2

- Cross-breeding among laboratories (HEP and Fusion research in particular) on the topic of pulsed superconducting magnets
- Industry involved from the start of the brainstorming, bringing focused and relevant experience in this technology
- Very positive response !

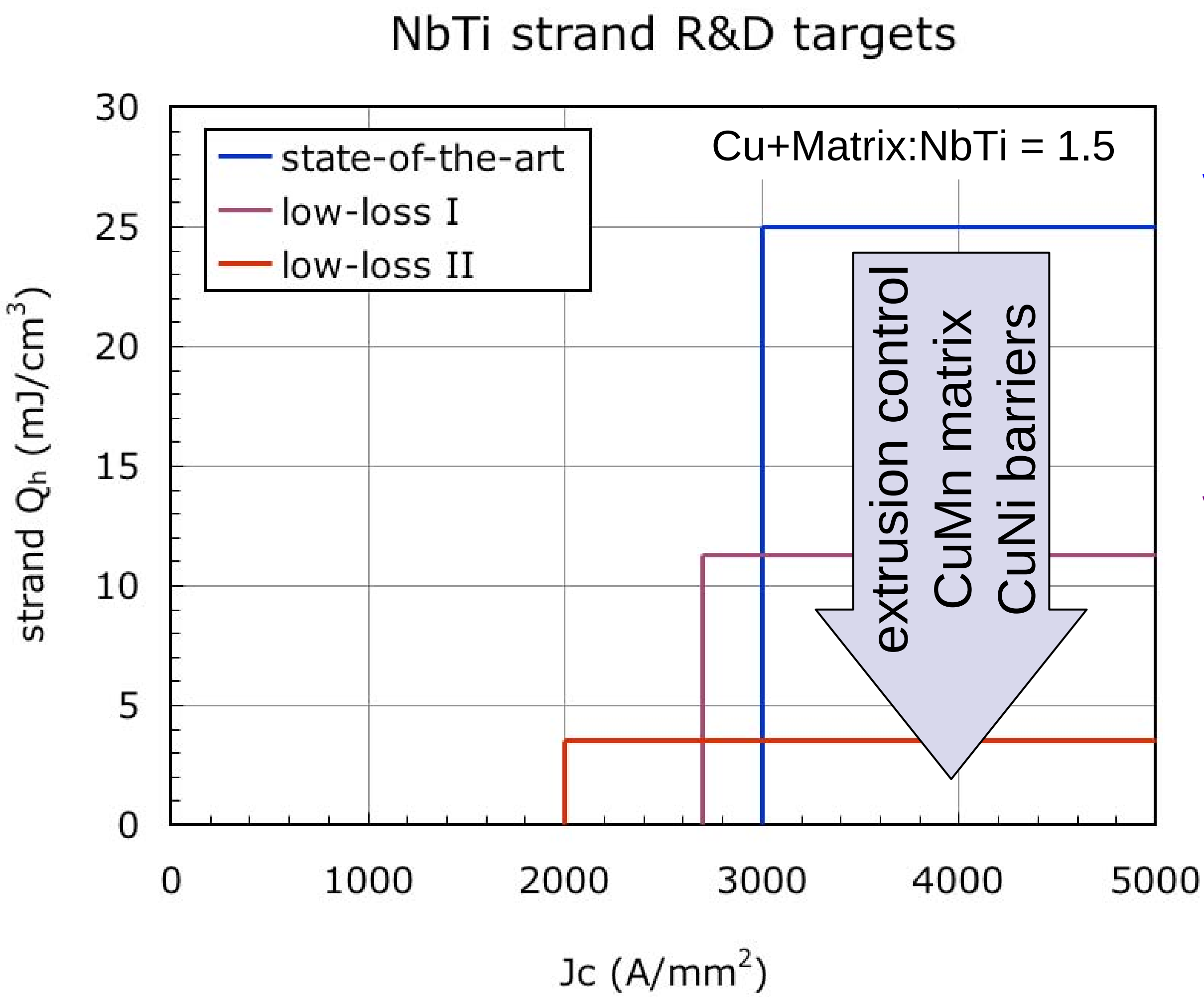
We have identified a general interest in the community of *clients* and *producers*

Follow-up

- The material discussed is collected and will be posted on the www site of the Workshop
- The design coordinators will maintain momentum on the issues identified
- Reconvene in 6 months to verify progress

Special session at **WAMDO**
April 3-7 2006
CERN (Archamps)

Strand R&D Targets



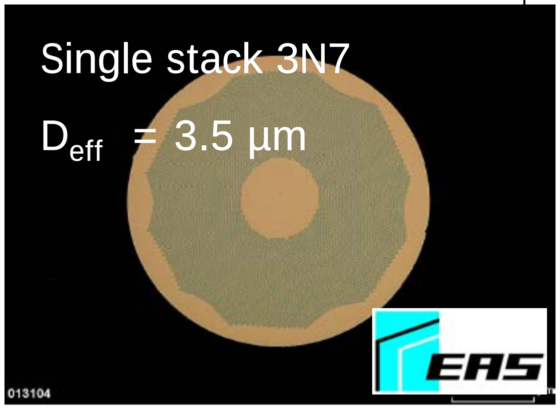
D = 0.5 … 0.8 mm
Jc > 2500 … 3300 A/mm^2
D_{eff} = 3.5 … 5 µm

D = 0.8 mm
Jc > 2700 A/mm^2
D_{eff} = 2.5 µm

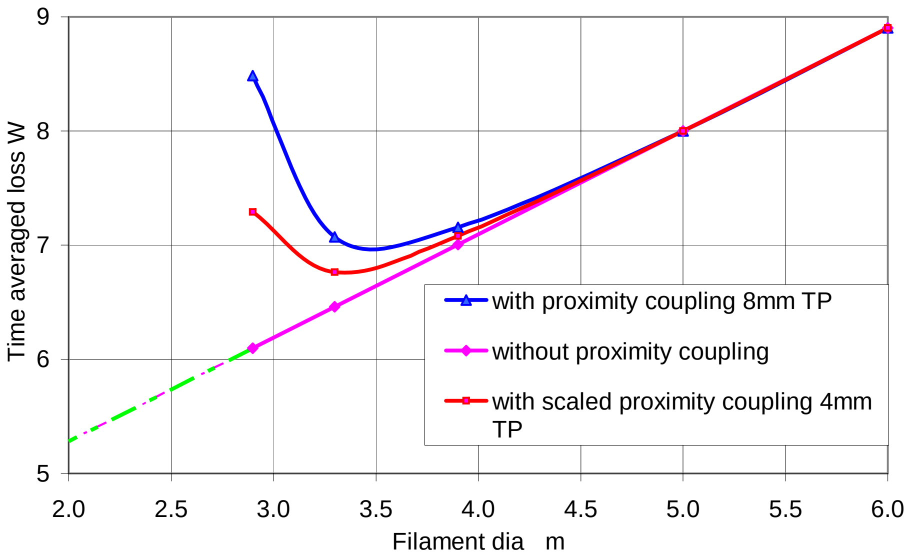
D = 0.5 … 0.8 mm
Jc > 2000 A/mm^2
D_{eff} = 1 µm

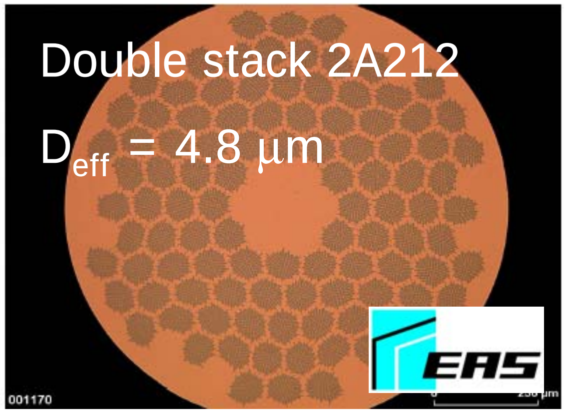
Small Filament R&D - 1

- About 50 % of the loss is generated by hysteresis in the filaments
- Simply reducing the filament size does not work



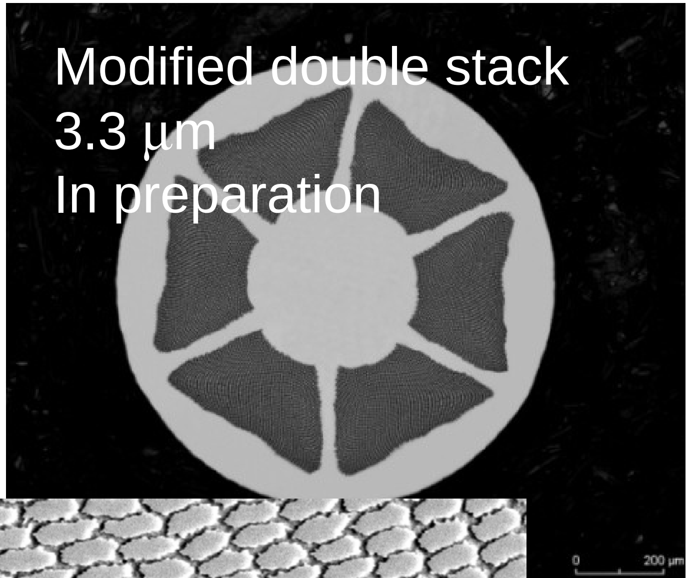
12000 monocores (1.5 mm wide)!

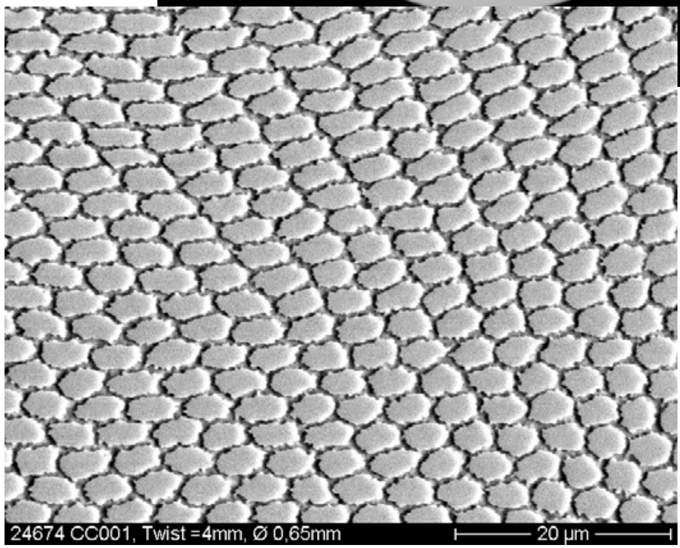


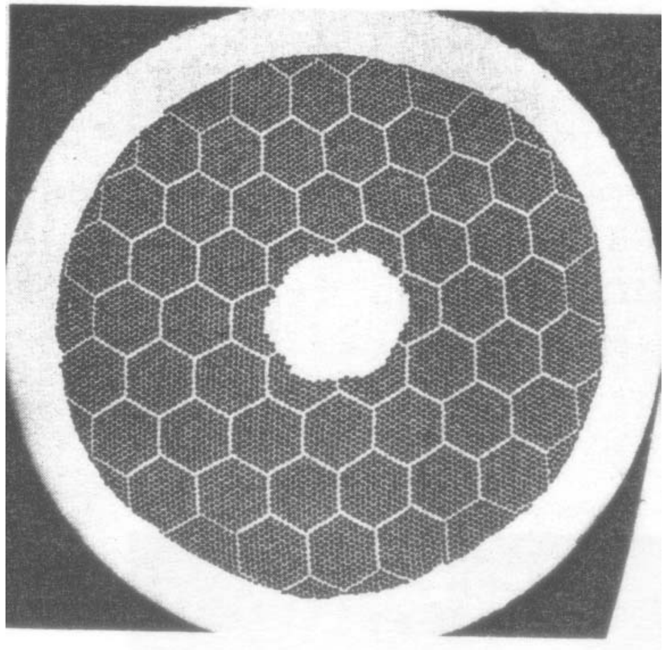


filament distortion near the copper !

Small Filament R&D - 2



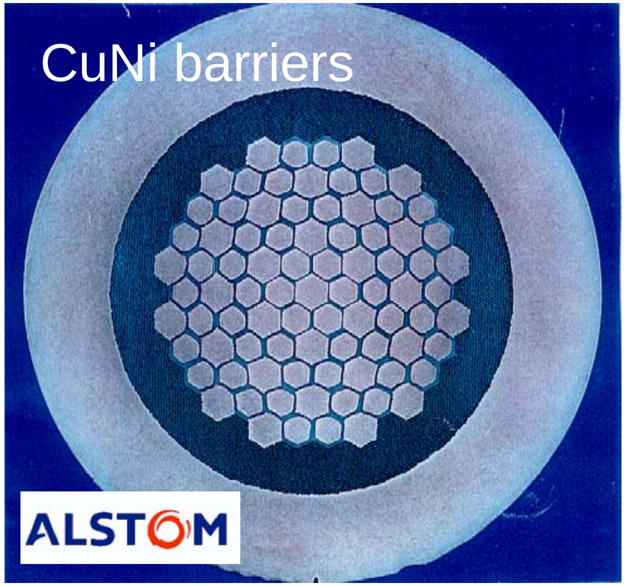


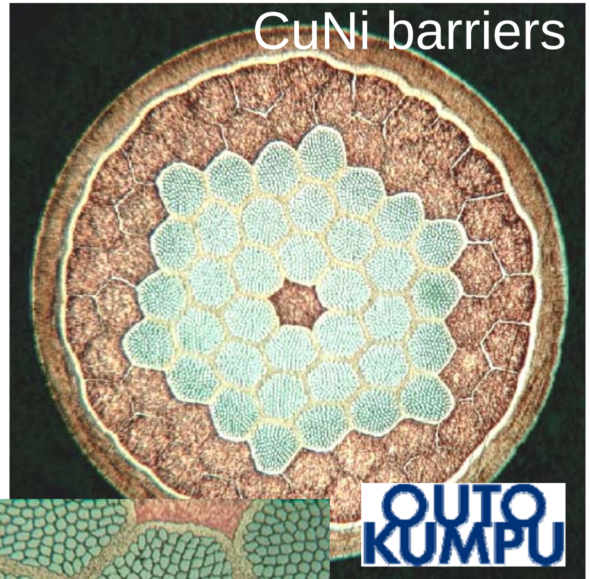


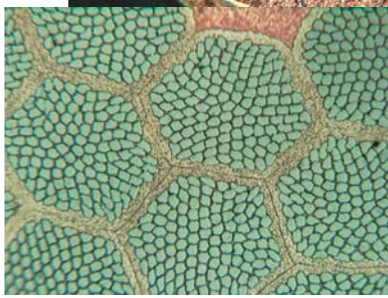
Hex single stack

Better geometry control

Small Filament R&D - 3







CuNi to reduce coupling

CuMn to reduce proximity