

Final review meeting of the JST-EU joined research program “Superconductivity”

Monday 9th March 2015
JST Tokyo Headquarters(K's Gobancho)

Super Iron

*Exploring the potential of Iron-based
Superconductors*

Jun-ichi Shimoyama



The University of Tokyo

Marina Putti

CNR-SPIN



Super  Iron

J-I Shimoyama - M Putti, Final Review Meeting, 9th March 2015, Tokyo



PI: M Putti



PI: J-I Shimoyama

➔ M Putti, CNR-SPIN (Italy)



➔ J Karpinski, EPFL (Switzerland)



➔ B Holzapfel IFW (Germany)



➔ D Johrendt, LMU (Germany)



➔ M Eisterer, TU (Austria)



➔ J-I Shimoyama  THE UNIVERSITY OF TOKYO

➔ T Kiss, Kyushu University



➔ H Eisaki, AIST



➔ Y Takano, NIMS



1. Introduction
2. New Superconductors
3. Synthesis of High Quality Superconductors
4. Tuning of Superconducting Properties
5. Thin Films
6. Evaluation of Grain Boundary Characteristics
7. Fabrication of High Performance Tapes
8. Modelling
9. Summary on Publications, Patents and Exchanges
10. Conclusions

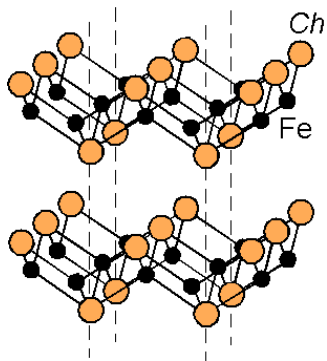


Introduction

by J-i Shimoyama

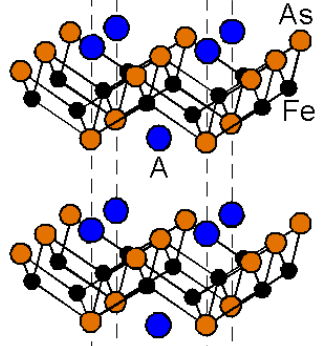
Representative Iron-Based Superconductors in 2010

A large number of iron-based superconductors have been discovered since 2008.

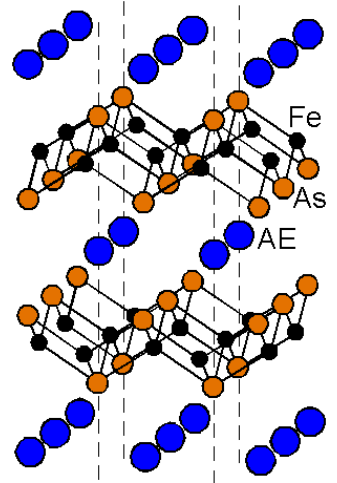


FeCh
[11]
 Ch: Se, Te, S
 $T_c \sim 15$ K

simple
 As-free
 high T_c by pressure

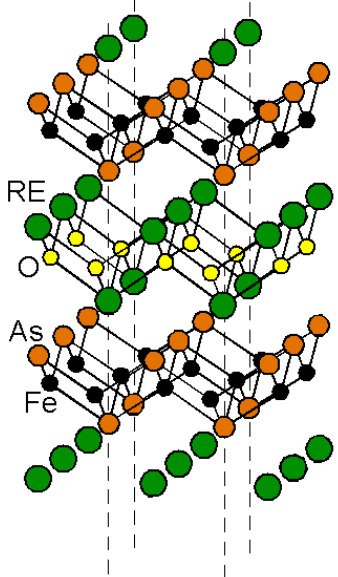


AFeAs
[111]
 A: Li, Na
 $T_c \sim 18$ K



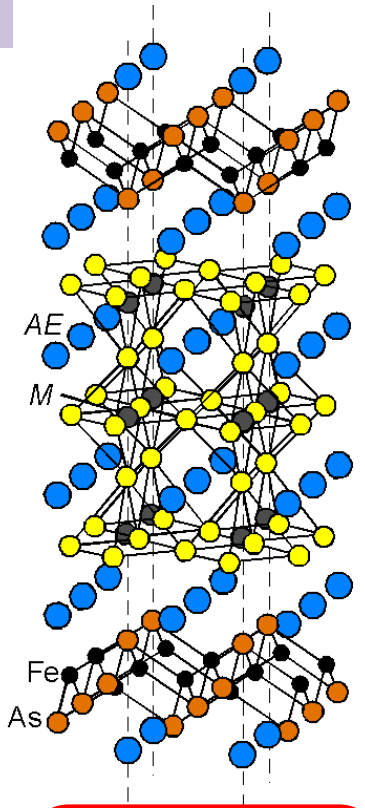
AEFe₂As₂
[122]
 AE: Ba, Sr
 $T_c \sim 38$ K

high H_{c2}
 low anisotropy
 various doping



REFeAsO
[1111]
 RE: rare earth
 $T_c \sim 55$ K

very high H_{c2}
 various doping



(Fe₂As₂)(AE₄M₃O₈)
[PB: 22438]
 M: (Sc,Ti), (Mg,Ti)
 $T_c \sim 47$ K

tunable lattice
 various doping

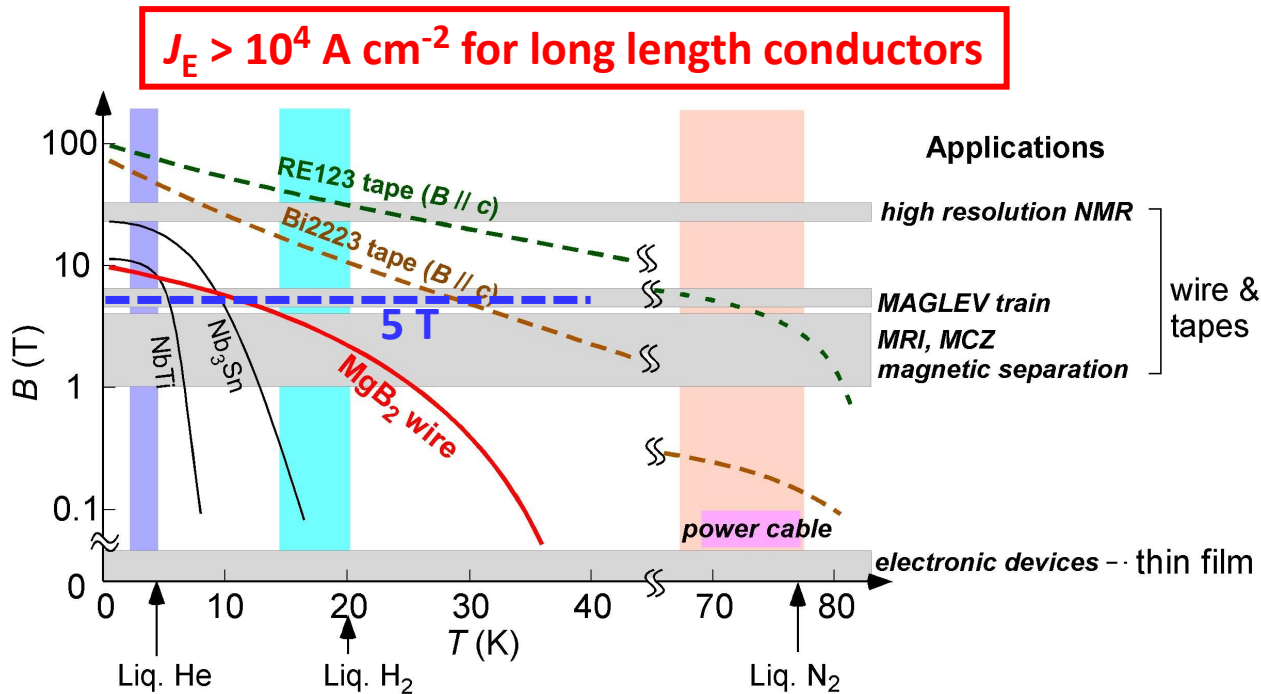
Major Purpose of SUPER-IRON Through 3.5 Years Project

Exploration of derivable potential of iron-based superconductors to judge whether they are promising materials or not

Criterion for judgment

$$J_c > 10^5 \text{ A cm}^{-2} \text{ in 5 T (up to 15 K)} \Rightarrow J_E > 10^4 \text{ A cm}^{-2} \text{ (tapes or wires)}$$

Applicable conditions of superconducting materials



Objectives of SUPER-IRON

1. **Developing preparation methods**
of single crystals, thin films, and polycrystals
2. **Qualifying the ultimate potential of iron-based superconductors for high field applications,**
after optimization of sample quality and grain boundary properties
3. **Comparison the developable potential with that of already existing superconductors** (HTSC, MgB₂, Nb based SC)

Work Packages To Achieve Purpose Through EU-Japan Collaboration

WP1: Iron-based material preparation

WP4: The issue of Grain Boundaries

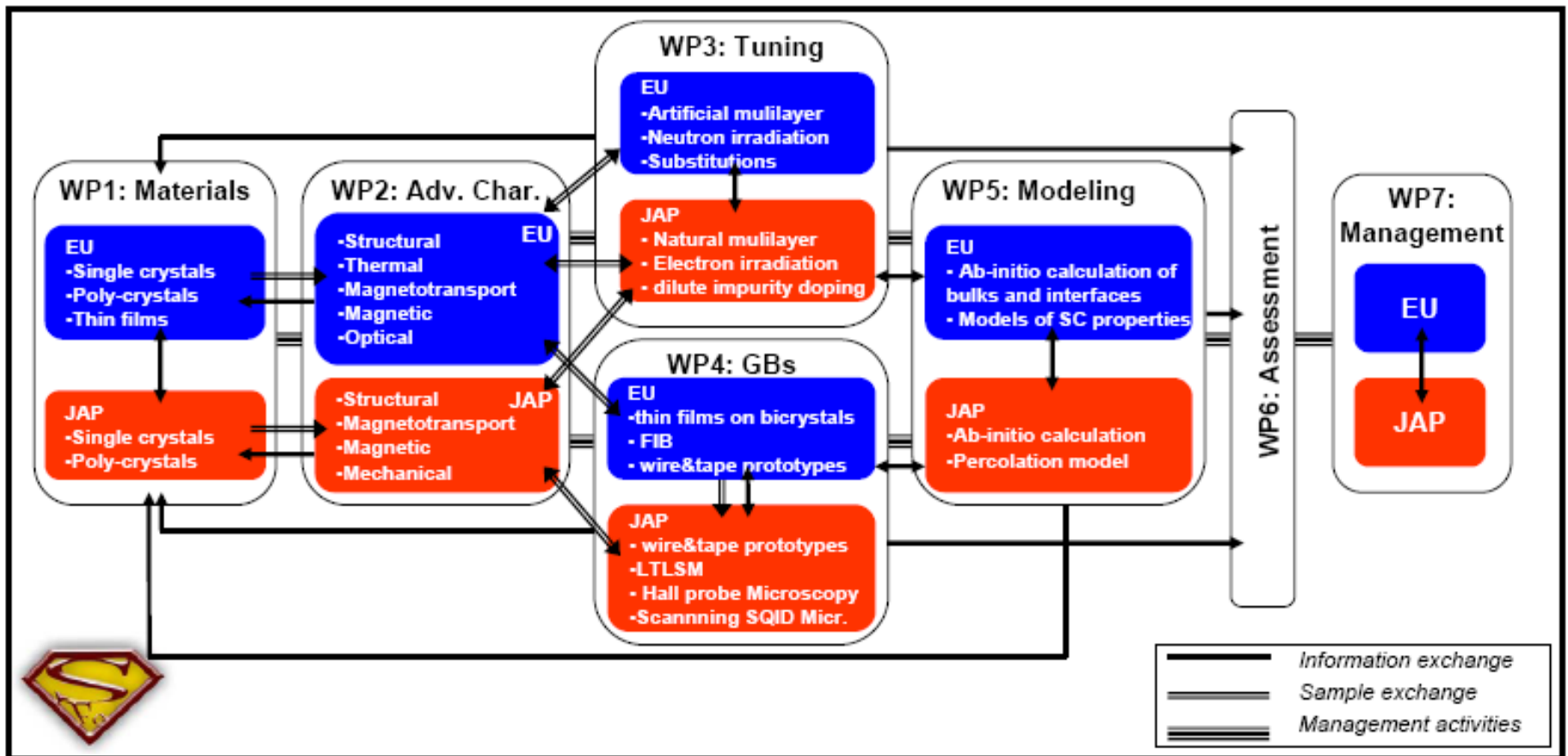
WP2: Advanced characterization

WP5: Modelling

WP3: Tuning of the superconducting properties

WP6: Assessment



WP7: Management





Developing preparation methods

Single crystals

EPFL 
 AIST, NIMS 



Thin films

IFW 
 CNR 

Poly crystals

LMU, CNR 
 UT, AIST 

Wires and tapes

CNR 
 NIMS 

Advanced characterization



Structural

IFW, LMU 
 AIST, NIMS 

Magnetic, thermal, transport

IFW, CNR, TUW, EPFL 
 AIST, NIMS, UT 



Local probe of SC properties

TUW 
 KU 





Tuning of the superconducting properties



Particle irradiation

TUW 
TU 

Impurity doping

LMU 
TU 

Multilayers

IFW, CNR 
TU 

Theoretical modeling of the effect of impurities

CNR 
IFW

The issue of grain boundaries



thin films on bicrystals

IFW 
CNR

Theoretical modeling of interfaces

CNR 
IFW

Realization of wire-tape prototypes

IFW, CNR 
NIMS, AIST 

Concept of SUPER-IRON

Toward Practical Materials in Near Future

WP7

Milestone 7
Highly efficient
Japan-EU cooperation

WP2, WP4, WP6

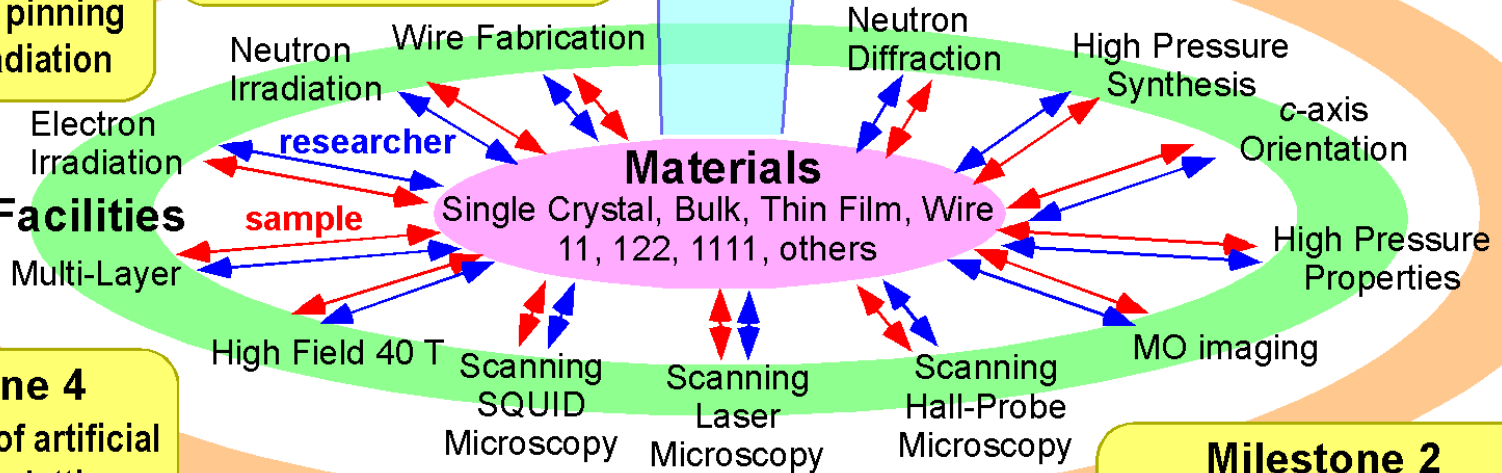
Milestone 6
 $J_c > 10^5 \text{ A/cm}^2$ in low field
and/or $J_c > 10^4 \text{ A/cm}^2$ in 5 T

WP1, WP2, WP3, WP4

Milestone 1
Synthesis of pure polycrystals
with well connected grains

WP2, WP3, WP4, WP5

Milestone 5
Introduction of pinning
centers by irradiation



Open Facilities

Milestone 4
Development of artificial
pnictide superlattices

WP1, WP2, WP3

Milestone 3
understanding
 J_c vs misorientation angle

WP2, WP4

Milestone 2
Microscopic modelling of
critical current across GBs

WP5



New Superconductors by J-i Shimoyama

UT → PB, 112, BiOS

AIST → PB, 112, others

NIMS → BiS

EPFL → 42214

LMU → $[(\text{Li}_{0.8}\text{Fe}_{0.2})\text{OH}]\text{FeSe}$



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Synthesis of High Quality Superconductors by J-i Shimoyama

UT → 1111, PB
AIST → 122, 112, 111
NIMS → 11
EPFL → 1111sc
LMU → 1111



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Tuning of Superconducting Properties by J-i Shimoyama

UT → 1111, PB
AIST → 122sc
NIMS → 1111
EPFL → 1111sc
LMU → 1111
TUW → 1111, 122



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THIN FILMS

by M Putti

IFW → 122 thin films

CNR → 11 thin films

KU → scanning Hall probe microscopy

TUW → Angle-resolved transport measurements



☑ Effect of the strain

☑ Optimization of the superconducting properties



EVALUATION OF GRAIN BOUNDARY CHARACTERISTICS

by M Putti



UT → 1111 and 122 bulks

CNR → 11 bulks

KU → Scanning Hall probe microscopy

TUW → transport measurements and modelling



- ✓ Optimization of synthesis processes
- ✓ Systematic studies of the intergrain J_c



FABRICATION OF TECHNOLOGICAL CONDUCTORS

by M Putti



NIMS → 11 PIT wires/tapes

CNR → 11 & 122 PIT wires/tapes



AIST → 122 PIT tapes

IFW → 122 coated conductors



- ☑ Improvement of the phase purity and density
- ☑ Biaxially texturing on technical substrates



THEORETICAL RESULTS

by M Putti

CNR → ab-initio calculation



IFW → modelling



- ✓ Theoretical **Interpretation** of experimental results
- ✓ Theoretical **Understanding** of New Materials
- ✓ **Predictions** of New Superconductors



QUANTITATIVE ASSESSMENT

by M Putti



- ✓ Dissemination
- ✓ Exploitation
- ✓ Training
- ✓ Recruitment
- ✓ Follow up



History

Based on the Exchange of Letters, JST and EC DG RTD have agreed to establish a new scheme for coordinated funding of Japanese-EU coordinated research projects
(Photo credit Reinhard Schulte)



Search

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European Partners

Japanese Partners

News



- 14/04/2014 SUPER-IRON 30 MONTH MEETING - Antalya (Turkey) April 29th 2014
- 23/11/2012 SUPER-IRON 2nd meeting
- 04/05/2012 Informal 6-month Meeting at ICISM2012 (Istanbul)

About Us

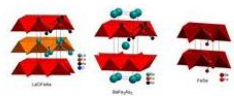


The European Consortium of SUPER-IRON

The European consortium lead by prof. Marina Putti has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013)

[Read More](#)

Concept



New perspectives in Superconductivity

Two years after Hosono's discovery of Fe-based superconductors (FESCs) a crucial question arises: will they turn out to be tame materials for applications?

[Read More](#)

Upcoming events



- 14/04/2014 SUPER-IRON 30 MONTH MEETING - Antalya (Turkey) April 29th 2014
- 20/03/2014 2nd STUDENT WORKSHOP (April 6th-8th, 2014) in Tsukuba (Japan)

Dissemination

11th European Conference on Applied Superconductivity



September 15-19 2013 - Genova, Italy

Wednesday September 18th from 16:15 to 18:30

- [3A-EL] Squid Applications Room Libeccio 176
- [3A-MA1] Fe-based Superconductors - Bulks and Tapes (hosted by SUPER-IRON EU-Japan project) Room Maestrale 177
- [3A-MA2] Pinning and Flux Dynamics 1 - in memory of John Clem Room Levante e Ponente 179
- [3A-SS] HTS Conductor Form - The Device Builders' Point of View Room Scirocco 180



EUROPEAN SUPERCONDUCTIVITY NEWS FORUM



A joint project of the IEEE Council on Superconductivity (CSC) and the European Society for Applied Superconductivity (ESAS)

[CSC Home](#) | [ESAS Home](#) | [Europe Tech. Committee](#) | [Europe Guide](#) | [Transactions](#)

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The New EC-Japan SUPER-IRON Project

July 27, 2012 (HE66). On October 1, 2011, the European consortium lead by Prof. Marina Putti has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013). Its FP/ call identifier is FP7-NMP-2011-EU-Japan, the topic NMP.2011.2.2-6 is "Fundamental properties of novel superconducting materials". The coordinated Japanese project, lead by Prof. Jun-ichi Shimoyama, has received funding from the Japan Science and Technology Agency. The European partners from

CONFERENCES

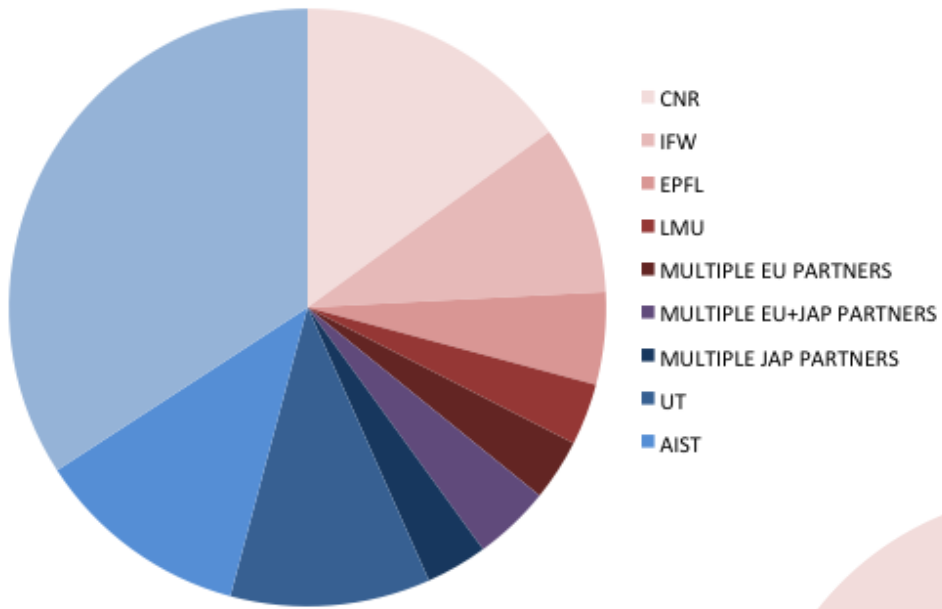
[Regional and National Meetings](#)

[Major Intl. & US Conferences, CSC list](#)

RESOURCES

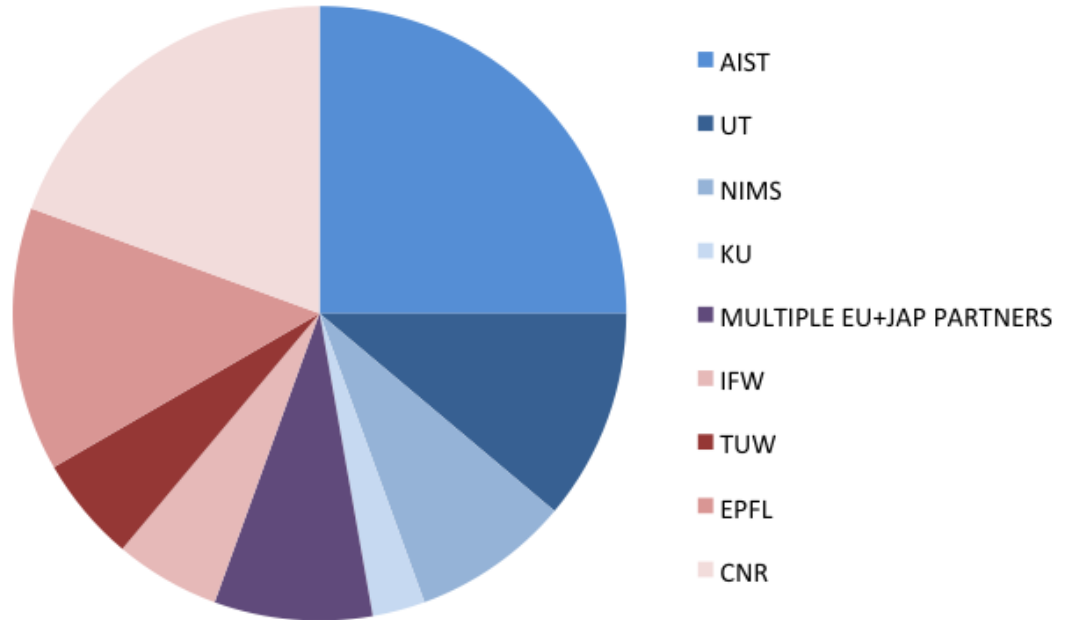
- [Cryogenics](#)
- [The EC Japan](#)

Dissemination



159 communications
17 joint (Eu&Jap partners)
36 invited talks

120 publications
on Intern. Journ.
13 by multiple partners



Two patents by AIST group

- ➡ **new superconductors and synthesis**
- ➡ **Phosphorous superconductors and their application**

Exploitation



Meetings



Kick-off meeting
Genova, December 2011

2nd meeting
Yamanaka Dormitory-naito Seminar House,
November, 30th - December 2nd, 2012



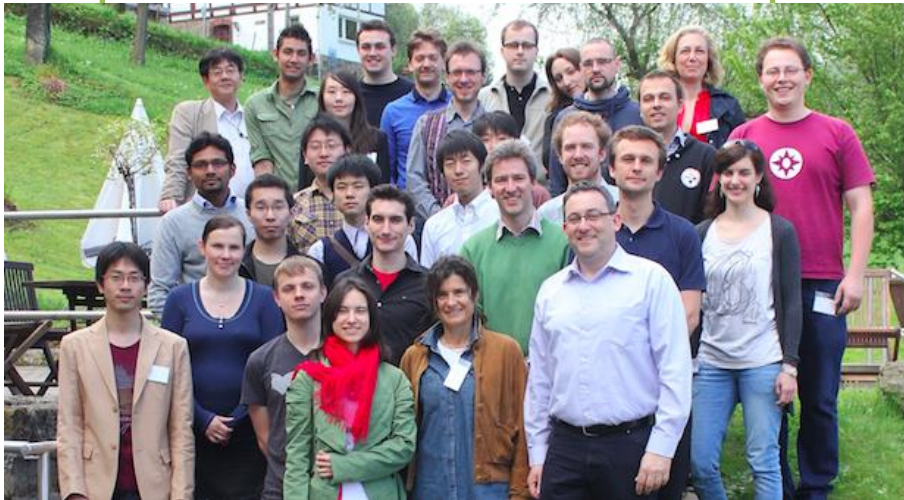
3rd meeting
Genova, September 2013



Final meeting
JST Tokyo Headquarters,
Science Plaza,
10th-11th March, 2015

Training of young researchers

First Student Workshop:
Bad Schandau (Germany), May 2013
(21 participants)

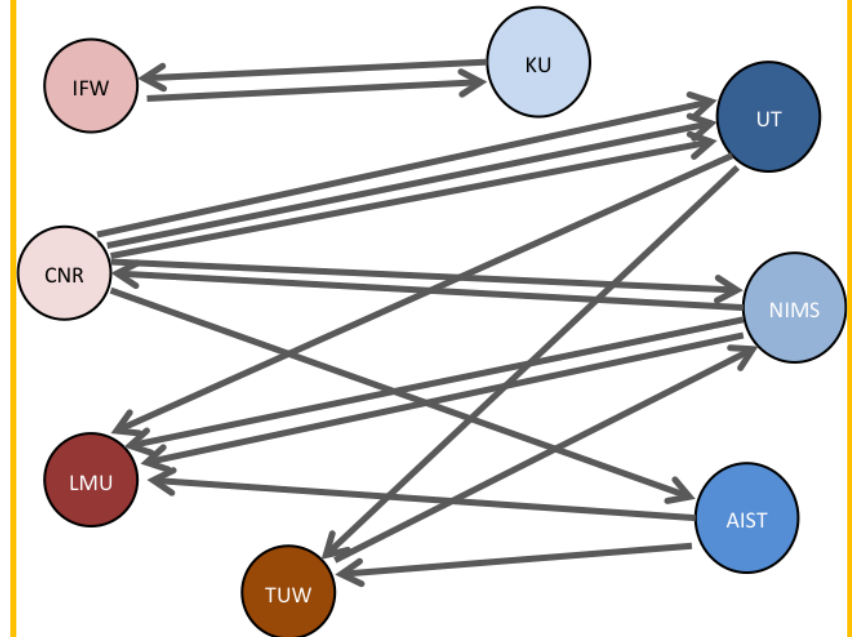


exchanges of young researchers is important for their scientific formation and also for strengthening the connection and inter cultural awareness

Second Student Workshop:
Tsukuba (Japan) April 2014
(24 participants)



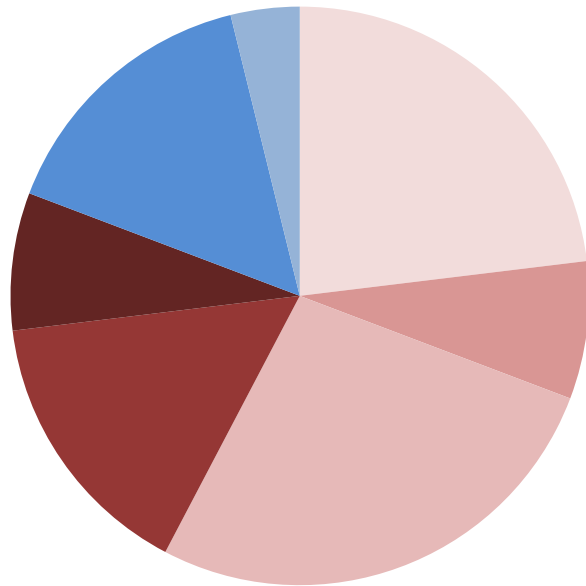
Researcher exchanges



Recruitment

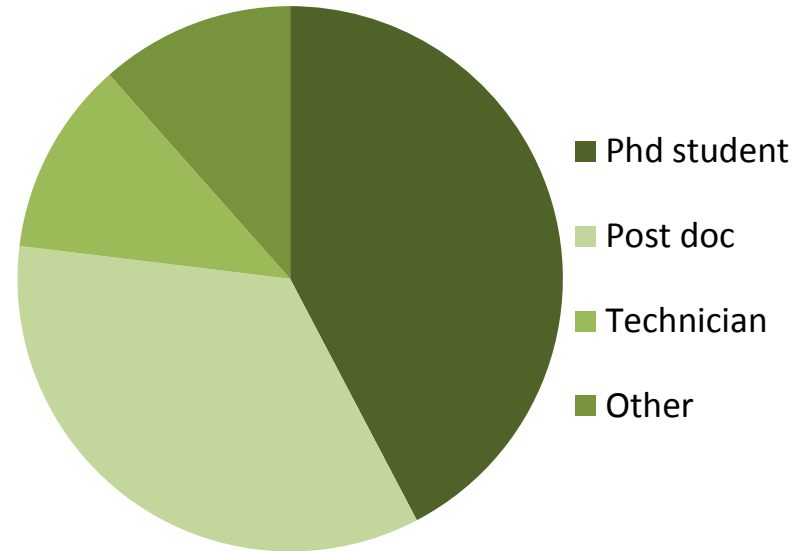
Personnel recruited on fixed term contracts

Partners involved



- CNR
- EPFL
- IFW
- LMU
- TUW
- AIST
- NIMS

Contract type



- Phd student
- Post doc
- Technician
- Other

26 contracts stipulated

Follow-up

New collaborative project, 2015-2020,

Super  Iron II

Will be signed by:

The Department of Applied Chemistry, University of Tokyo **(TU)**

The Kyushu University **(KU)**

The National Institute of Advanced Science and Technology **(AIST)**

The National Institute for Materials Science **(NIMS)**

The Consiglio Nazionale delle Ricerca – Istituto Superconduttori, materiali innovativi e dispositivi **(CNR-SPIN)**

The Ecole Polytechnique Fédérale de Lausanne **(EPFL)**

The Leibniz Institut für Festkörper – und Werkstoffforschung Dresden e.V. **(IFW)**

The Ludwig – Maximilians University LMU

Department of Chemistry The Vienna University of Technology **(TUW)**,

Department of Physics of the University of Genova (UNIGE)

CONCLUSION

by J-i Shimoyama

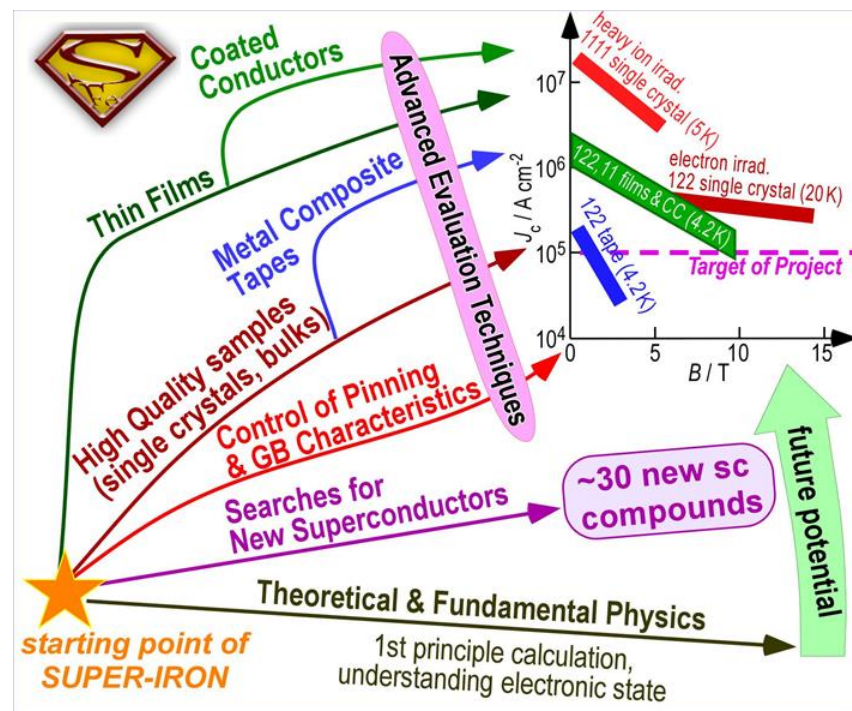
Through the group-to-group collaboration between EU and Japan along SUPER-IRON, we have proved that iron-based superconductors have strong potentials for application, in particular for high field generation.

The ultimate potential of iron-based superconductor has not been well excavated yet. Grain boundary issues have not been optimized thus far.

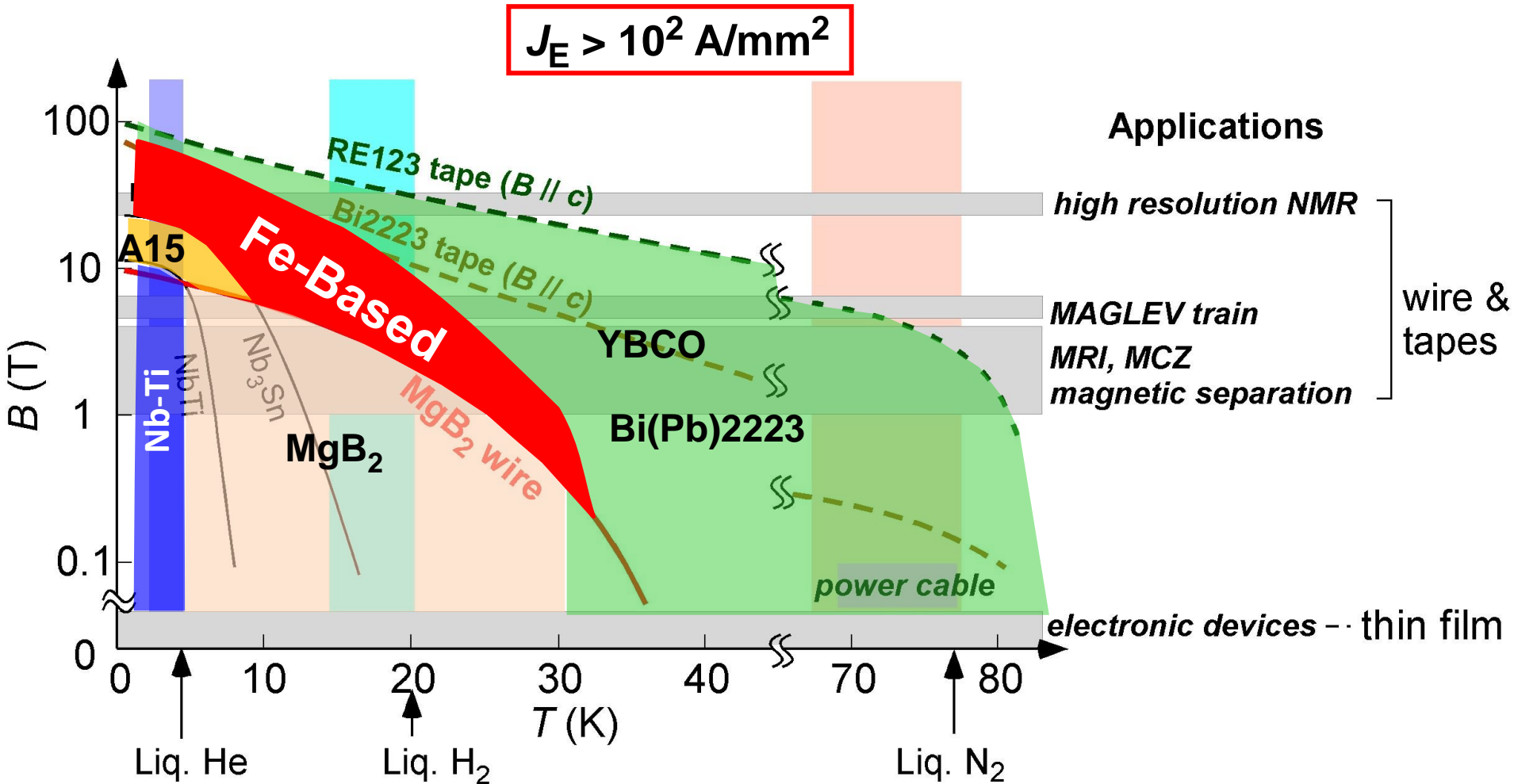
There is a large room remaining for the improvement of material performance of iron-based superconductors, **GROWING MATERIAL**.

Next Steps

1. Selection of the best family/doping/strain which optimize the superconducting phase diagram (T_c , H_{c2} , J_c)
2. Demonstration of the feasibility and reproducibility of optimized properties on large scale
3. Development of a scalable and industrially appealing method for the production of first generation cables as for iron-based superconductors.



Application of Superconducting Materials in Future



Conditions for practical applications of iron-based superconductors;
 high performance, long length, homogeneous, high productivity, low cost, etc.

Thank you.