American Nuclear Society
Fusion Energy Division
June 2016 Newsletter

Letter from the FED Chair, Susana Reyes, Lawrence Livermore National Laboratory, Livermore, CA.

In my final message as a Chair, I would like to provide a summary of plans for the upcoming 22nd ANS Topical meeting on the Technology of Fusion Energy (TOFE), ongoing activities at the ANS, and some important developments within our Division. As a preamble to the various updates that follow, I want to first thank our incoming Chair, Dr. Arnie Lumsdaine, for his excellent job as acting-Chair during my 5-month maternity leave, and welcome him in his new role as he assumes the Chairmanship at the conclusion of the June annual meeting in New Orleans. As usual, I would also like to welcome all the newly elected members of the Executive Committee (see election results below), for their willingness to serve on behalf of the Division members, and I sincerely thank the Executive Committee outgoing members whose term was just completed, for their valued contributions.

It is a pleasure to begin my bi-annual update by providing you with a few highlights of the plans for the upcoming TOFE meeting that will take place in Philadelphia, August 22-25 of the present year, under the theme of "Advancing the Globalization of Fusion Energy Technology." We are particularly excited to announce that we have received over 200 abstracts to date and are expecting a good attendance based on our initial projections. We plan to have project updates from the leadership of the ITER Project, so as participation from leaders of the main Fusion Programs in the US and around the world. One important feature in this TOFE program, in addition to the world-class line-up of plenary and invited speakers, is a special panel on the "Industry perspective of Fusion Energy" where we expect industry representatives (related to ITER and others) to share their views in key areas of interest/impact of fusion technology development, the pros and cons of industry early engagement in fusion, and other related matters that should be considered in the strategy towards fusion power. I take this opportunity to thank all the TOFE Organizers, in particular the Local Organizing Committee, for the outstanding work in the preparation for this meeting. More details can be found in the conference website, which will continue to be updated as we approach the meeting dates: http://tofe2016.ans.org/

Secondly, I will provide a summary of the annual ANS meeting that just took place in New Orleans, LA, June 12-16, 2016. It was a successful meeting under the general title of "Nuclear Power: Leading the Supply of Clean, Carbon Free Energy". Donna Jacobs, from Entergy Corporation, was the General Chair for this meeting that was as usual very well attended by professionals of the domestic and international nuclear industry and research institutions. As it has been the tradition during the last few ANS meetings, FED held its own session on "Fusion Energy – Technology and Applications" on Thursday morning (June 16th), organized by Arnie Lumsdaine and co-chaired by Arnie and myself. A total of three papers were presented in this session, including some contributions relevant to the ITER project and beyond. During this meeting there were also some important developments related to the governance of our Division.

I am proud to report that our Division continues to improve, and the ANS standardized vitality metrics serve as an encouraging proof of this development. In addition to positive membership and financial trends, I am very excited to confirm that the ANS Scholarship committee voted in favor of approving our first ever FED scholarship, which I previously had announced as one of my main goals for the current year. I would like to thank all who have contributed driving the FED towards this milestone, in particular our FED Scholarship Chair, Prof. Leigh Winfrey, and the honorable Dr. Ken Schultz of General Atomics, for offering his name for this undergraduate scholarship. Dr. Schultz retired in 2011 after an impressive 40 year career as a nuclear engineer at General Atomics in San Diego, working on a wide variety of roles, including Director of GA Inertial Fusion Technology Division and Manager of GA Magnetic Fusion Technology Development Department. He is well known member of the ANS who had served twice on its Board of Directors. Details about scholarship eligibility and application guidelines will be posted on the FED website as they become available. Another important development for the FED Division is the approval by the ANS Board of Directors of our updated Position Statement on Fusion Energy, which you will be able to download soon from the FED website. Regarding other FED activities, as some of you may know, we recently co-sponsored the 11th International Conference on Tritium Science and Technology (TRITIUM 2016, http://tritium2016.org/), which took place in Charleston, SC, from April 17-22, 2016, gathering tritium experts, scientists, engineers and students from all around the world working in the area safe tritium handling for fusion and other peaceful applications. Later this year our Division will co-sponsor the 5th International Conference on Nuclear and Renewable Energy Resources (NURER2016, http://nurer2016.org.cn/dct/page/1) hosted by Institute of Nuclear Energy Safety Technology, Chinese Academy of Sciences, in Hefei, Anhui, China, from September 18 to 21, 2016, in addition to another FED session within the next ANS Winter meeting.

As a wrap up to my last Letter from the Chair, I would like to thank all of you for your continued support of the Division and congratulate each of you for the key milestones summarized above. I am now ready to step down of my current position to start my new term as FED Past-Chair, and look forward to seeing you all at TOFE 2016.

List of Officers and Executive Committee Members, Minami Yoda, Georgia Institute of Technology, Atlanta, GA.

The FED election was held in the spring of 2016. Keith Rule (PPPL) was elected to the position of Vice-Chair/Chair-Elect, Kelsey Tresemer (PPPL) was elected to the position of Secretary/Treasurer, and Nicole Allen (PPPL), Lauren Garrison (ORNL), and Leigh Winfrey (U. Florida) were elected to the Executive Committee. Congratulations to all!

Our FED Chair, Susana Reyes (LLNL), completed her two-year term of office at the end of the ANS summer meeting in June 2016, and will be succeeded by Arnold Lumsdaine (ORNL). Paul Humrickhouse (INL) will also complete his two-year term as Secretary/Treasurer. We thank Susana Reyes and Paul Humrickhouse, as well as outgoing Executive Committee members Jean Paul Allain (UIUC), Kevin Kramer (LLNL), and Kelsey Tresemer (PPPL) for their service to the Division.

Since Keith Rule will give up his role on the Executive Committee to become Vice Chair, the Executive Committee will discuss at their June meeting identifying a candidate to serve out the remaining two years of his three-year term.

FED Officers:

Arnold Lumsdaine (ORNL) Chair (16-18)
Keith Rule (PPPL) Vice Chair/Chair-elect (16-18)
Kelsey Tresemer (PPPL) Secretary/Treasurer (16-18)

Executive Committee:

Nicole Allen (PPPL) (16-19)
Blair Bromley (AECL) (14-17)
Lauren Garrison (ORNL) (16-19)
Ahmad Ibrahim (ORNL) (15-18)
Takeo Muroga (NIFS) (15-18)
Craig Taylor (LANL) (14-17)
Neill Taylor (CCFE) (14-17)
Leigh Winfrey (U. Florida) (16-19)

Past Chair:

Susana Reyes (LLNL) (16-18)

FED Standing Committee Chairs:

Nominating: Susana Reyes (LLNL) – Chair
Honors and Awards: Nermin Uckan (ORNL) – Chair
Program Committee: Keith Rule (PPPL) – Chair

FED Representatives on National Committees:

ANS Publications: Nermin Uckan (ORNL)
ANS Public Policy: Susana Reyes (LLNL)
ANS Program Committee: Keith Rule (PPPL) – Chair

Editors:

Newsletter: Laila El-Guebaly (UW)
Fusion Science and Technology Journal: Nermin Uckan (ORNL).

Treasurer's Report, Paul Humrickhouse, Idaho National Laboratory, Idaho Falls, ID.

As of the end of calendary year 2015, our division had a balance of $60,802.62. First quarter financials are not yet available, but we anticipate ~$1700 in income from membership dues in 2016, on par with previous years. Our only expense thus far in 2016 has been a $1,000 contribution to support the ANS student conference at the University of Wisconsin. Other budgeted expenses for 2016 include $1700 for awards (the Technical Accomplishment award, Outstanding Achievement award, and Best Student Paper award) and plaques for the 2016 TOFE; $600 for national meeting costs (i.e. conference call telephones); $3800 in student support including $3000 for student travel to the TOFE and $300 for travel to national meetings; and $500 to support the ANS NEED program. While we have two Class I sponsored meetings in 2016 (the recently convened Tritium conference in Charleston, and TOFE in Philadelphia in August), the books are not expected to close on either meeting within the year, so any income from these meetings will not be realized until 2017. Because the expenses related to TOFE are still incurred in 2016, our projected year-end balance will be lower, at $55,023.

Fusion Award Recipients, Laila El-Guebaly, Fusion Technology Institute, University of Wisconsin-Madison, Madison, WI.

Fusion awards have been established to formally recognize outstanding contributions to fusion development made by members of the fusion community. The following awards (listed in alphabetical order) were available to the newsletter editor at the time of publishing this newsletter. We encourage all members of the fusion community to submit information on future honorees to the editor (laila.elguebaly@wisc.edu) to be included in future issues. The ANS-FED officers and executive committee members congratulate the honored recipients of the 2015 fusion awards on this well-deserved recognition and our kudos to all of them.

MA-FNT Award

The Miya-Abdou Award for Outstanding Technical Contributions to the Field of Nuclear Technology has been presented to Dr. **Masashi Shimada** (Idaho National Laboratory) at the ISFNT symposium held September 14-18, 2015 in Jeju Island, South Korea. The award aims at acknowledging outstanding technical contributions to the field of Fusion Nuclear Technology for scientists and engineers of age 40 or younger.

News from Fusion Science and Technology (FS&T) Journal, Nermin A. Uckan, FS&T Editor, Oak Ridge National Laboratory, Oak Ridge, TN.

During the past 12 months (from May 1, 2015 to April 30, 2016), FS&T received a total of 220 manuscripts. Of the 220 manuscripts, 89 were from North America, 63 from Europe (including Russia), 57 from Asia, and 11 from other regions. [*Papers rejected/withdrawn from pre-selection of the conferences and special issues are not included in paper counts and regional breakdowns in the ANS/FS&T database.*]
The following dedicated/special issues were published during the period 05/01/2015 to 04/30/2016:

- Selected papers from OS2014 – FS&T Jul. 2015
- Selected papers from TOFE2014 – FS&T Sep. & Oct. 2015
- NIF-NIC Special Issue – FS&T Jan./Feb. 2016
- 1st IAEA-TM on Fusion Data Processing, Validation & Analysis – FS&T Apr. & May 2016.

The following dedicated/special issues are scheduled for the remainder of 2016 & 2017:

- Target Fabrication 2015 special issue – FS&T Aug./Sept. 2016
- Selected papers from Tritium2016 – FS&T (2017)
- Selected papers from TOFE2016 – FS&T (2017)

- Selected papers from APS-DPP Mini Conf. on Measuring and Modeling of Plasma Material Interactions - FS&T (2007).

First-Look articles are available at: http://www.ans.org/pubs/journals/fst/firstlook/. These pre-publication articles (posted on-line months ahead of print publication) are peer reviewed, copyedited, and proofread. They can be cited using DOI.
Electronic access to FS&T is available from 1981-to-current. Tables of contents and abstracts of papers can be accessed at http://www.ans.org/pubs/journals/fst/. Individual and library subscribers can access the full text articles at http://epubs.ans.org/.
Please send your comments on FS&T contents and coverage as well as suggestions for potential future topical areas that are timely and of interest to fst@ans.org.

ONGOING FUSION RESEARCH

W7-X First He/H Plasmas and Implications for the Worldwide Stellarator Program, Samuel Lazerson, Princeton Plasma Physics Laboratory, Princeton, NJ.

On December 10, 2015, the Wendelstein 7-X (W7-X) experiment opened up a new avenue of stellarator research with its first helium plasma. This event was the culmination of close to 20 years of design and manufacture of the world's first high-performance, steady-state, optimized stellarator [1,2,3]. Two months later on Feb 3, 2016, German Chancellor Dr. Angela Merkel christened the experiment by igniting the first hydrogen discharge in the experiment.

The stellarator concept of magnetically confined nuclear fusion was one of the first methods pursued by scientists in the multi-generational quest to harness fusion energy [4]. In a stellarator, the magnetic fields which confine the charged particles of a plasma are generated predominately by a set of external coils. Such a configuration is inherently steady-state and stable to perturbations which plague other confinement concepts. However, these features initially came at a price. Classical stellarators were plagued by poor neoclassical confinement which appeared to become worse as plasma temperatures and densities became larger. Thus access to the plasma parameters necessary for nuclear fusion appeared out of reach for stellarator designs. What's more, calculating coils shapes which produced the zeroth order confining magnetic surfaces were laborious at best. Thus, tokamaks with their simple set of coils and good neoclassical confinement became the shortest path to a reactor in the early days of fusion research. So, why build the W7-X stellarator?

The W7-X experiment is built on an optimized design, leveraging data from the W7-AS stellarator, computational advancements, and significant expansion in the scientific community's theoretical knowledge of plasma physics. At the core is theoretical work showing that while classical stellarators had poor confinement, this was not inherent to stellarators. It was shown that, with sophisticated computer models, the three dimensional magnetic fields could be designed which approached the confinement levels of tokamaks. Additionally, these magnetic fields could be tailored in such a way as to avoid a degradation in performance as plasma parameters relevant to nulcear fusion were approached. The result is a stellarator experiment whose end goals are 1800 second long dischages, at 5% plasma beta, with reactor levels of divertor heat loads.

The implications of a successful W7-X experiment for a nuclear fusion reactor are clear. While the magnetic coil complexity of an optimized stellarator is greater than that of a tokamak, the stellarator eliminates the need for many auxiliary systems including that of an Ohmic transformer. This reduces recycled power allowing a larger margin on energy production in a reactor. The steady-state nature of the stellarator also solves a long-standing problem in tokamak operation, namely the disruption. While stellarators do experience beta-limiting phenomena, they are nothing like the catastrophic termination of plasma operation a tokamak reactor must be designed to survive. Additionally, stellarators may exceed the tokamak density limit, greatly expanding their operating space. Add to this the absence (or relatively small amplitude) of edge localized modes in stellarator high performance discharges, the utility of the W7-X experiment as a demonstration of what can be done is clear.

The goals of the first experimental campaign were modest [5], focusing mostly on device commissioning, systems checkout, and operational readiness after a two decade construction period. However, scientific and engineering accomplishments exceeded expectations, with contributions from the United States playing significant roles. The trim coil system [6] manufactured and supplied by the U.S., will allow scientists to address the presence of error fields. This should help to confirm the accuracy of the superconducting coils. An X-ray Imaging Crystal Spectrometer (XICS) will provide the sole measurement of ion temperatures during the first campaign and confirm measurements of electron temperatures made by the ECE and Thomson scattering systems [8]. This diagnostic may also provide the first measurements of radial electric field. Camera systems will provide detailed measurements of limiter heat patterns and interactions of the plasma with the limiter. Such measurements will help validate sophisticated numerical simulations and provide guidance in the analysis of the full divertor which will be installed for the next experimental campaign.

The scientific gains which can be made in W7-X are also numerous, including stellarator divertor operation, beta limiting phenomena, turbulence, and energetic particle confinement. The island divertor system is a first of it's kind which will allow scientists to study power exhaust under reactor-like conditions. The predicted low levels of neoclassical transport and over 30 MW of heating will allow the explorations of phenomena which limit the achievable plasma beta. The temperatures and gradients achieved in W7-X will also allow tests of the gyrokinetic theory of turbulence, allowing scientists to confirm predictions of optimization of such quantities. Finally, the ion heating systems (ICRH and neutral beam) will confirm predictions of energetic particle loss. These results combined will allow the design of stellarators which improve upon W7-X, building confidence in future reactor designs.

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Neutron Irradiation Effects on Superconductors for Fusion Magnets,

Harald W. Weber, Atominstitut, TU Wien, Vienna, Austria.

One of the presently most demanding applications of superconductivity is the design of superconducting magnets for particle accelerators and nuclear fusion, both requiring a high tolerance of radiation and stresses produced by Lorentz forces and thermal cycling. In the following, I'll focus on research carried out in the framework of the nuclear fusion programme and aimed at establishing the suitability of currently available commercial superconductors, i.e. coated conductors and Nb_3Sn wires, for the fabrication of the toroidal field coils for the next generation of nuclear fusion devices (DEMO), where magnetic fields of around 15 T are needed and the fast neutron exposure will reach around 5 x 10^{22} m^{-2} ($E > 0.1$ MeV), i.e. five times the level expected at ITER, currently under construction in Cadarache, France.

RE-123 Coated Conductors for High Temperature Superconducting Magnets

This material form certainly has the greatest application potential among all high temperature superconductors (HTS), much in the same way as Nb_3Sn (and NbTi) among the classical low temperature superconductors (LTS), because of the prospect of producing extremely high magnetic fields in superconducting magnets potentially operating at temperatures well above 4.2 K. Although we are presently dealing with tapes instead of multifilamentary structures, which are highly desirable for fabricating stable magnets, progress is steady and suitable high-current high-field configurations will very likely emerge in the near future.

The interaction of fast neutrons with RE-123 primarily leads to two distinct effects, firstly the production of collision cascades, which are suitable as flux pinning centres, and secondly, the displacement of atoms in the crystal structure, preferably of the lightest atoms, i.e. oxygen. The latter will lead to changes in the transition temperature T_c as confirmed in Figure 1 below (note that all data refer to commercially available conductors provided by American Superconductor (AMSC, ASC), Bruker (EHTS), SuperPower (SCS) and SuNam). The decrease in T_c is initially linear and amounts to about 2.5 K per 10^{22} m^{-2} fast neutrons (-2.7 %) which is not too dramatic, the percentage change being comparable to the results on Nb_3Sn. However, T_c gets close to liquid nitrogen temperature at the highest fluence available at present [1].

In view of this data set, we expect that not only the "reversible" thermodynamic properties of the material, such as T_c, H_{c2}, etc., but also the "irreversible" flux pinning-related properties will be affected, especially in the most desirable temperature range for applications, i.e. between 77 K and the solidification temperature of nitrogen at ~ 64 K. This is confirmed by the results shown in Figure 2 (left panel), where the irreversibility lines (IL's) are plotted versus temperature for (H||c). We note that the IL's initially become "steeper" indicating the presence of additional pinning-effective defects, but start to fall below the initial behaviour above a fluence of ~ 1 x 10^{22} m^{-2}. The radiation response is very different if we look at the situation where the field is applied parallel (right panel) to the tape surface (H||a,b). Since the radiation-induced disorder immediately starts to "disturb" the intrinsic pinning mechanism, the IL's already shift to lower temperatures at very low fluences, in agreement with many previous results on single crystals.

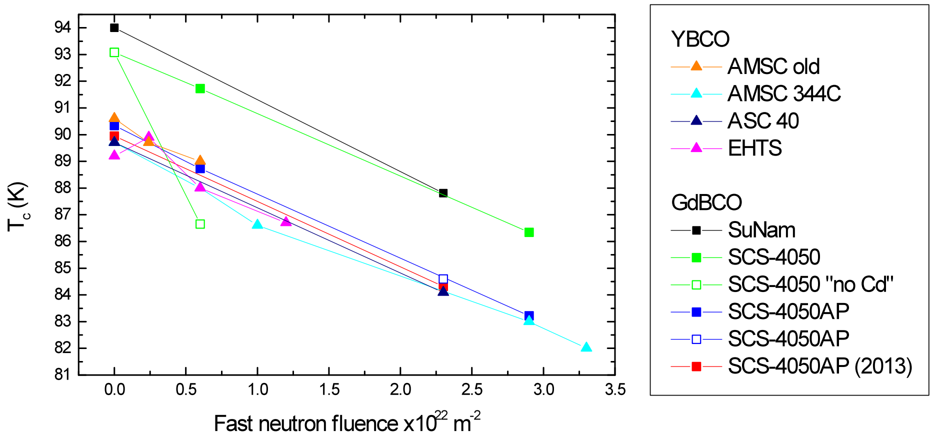

Figure 1. Transition temperatures of Y- and Gd-123 coated conductors as a function of fast neutron fluence up to ~ 3.3 x 10^{22} m^{-2}. Note that the data point "SCS-4050 – no Cd" is not relevant for our purpose and reflects the *thermal* neutron capture cross-section of Gd and the resulting additional disorder. (Thermal neutrons are present in the fission reactor used for the irradiation experiments, but not in the fusion spectrum at the magnet location of a fusion device. They can be eliminated by suitably shielding the samples, e.g. by Cd foils).

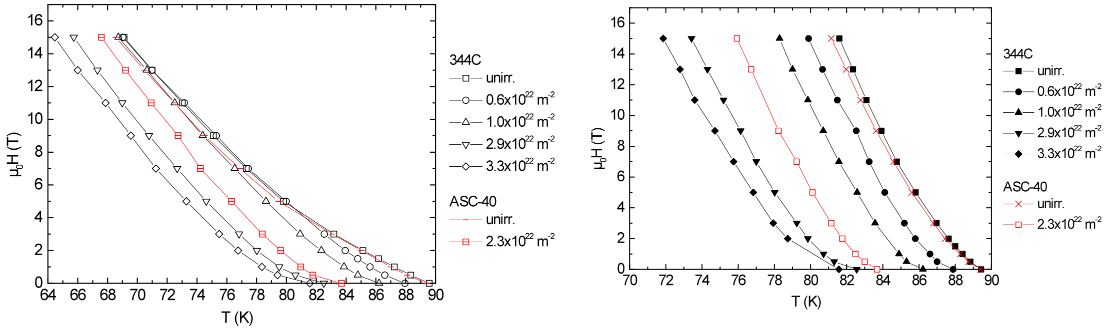

Figure 2. IL's of Y-123 coated conductors provided by American Superconductor Corporation at fast neutron fluences of up to ~ 3.3 x 10^{22} m^{-2}. The magnetic field is applied perpendicular (left panel) and parallel to the tape surface (right panel), respectively.

Transport measurements on the conductors in fields of up to 15 T confirm these trends. Whereas the critical currents degrade for both conductor orientations at 77 and 64 K, enhancements of J_c are still found for H||c at 50 K and below, a temperature range where the critical currents for H||a,b are very high and almost field independent and where the changes in J_c are also moderate (Figure 3). This interplay between disorder-induced changes (mainly for H||a,b) and pinning-induced changes (mainly for H||c) is best appreciated by comparing the complete angular dependence of J_c prior to and following irradiation to a certain fluence (Figure 4). Note the drastic reduction in critical current within a narrow angular range around a,b (α=90° in this graph) and the rather uniform angular distribution of J_c as a consequence of the irradiation.

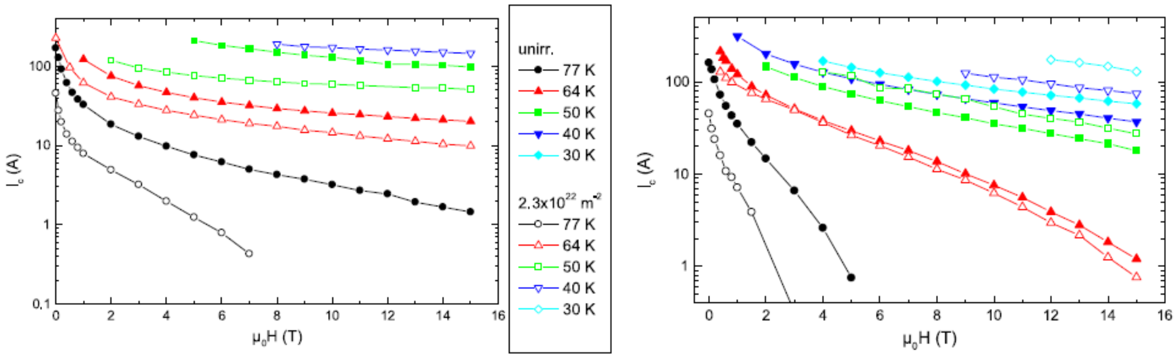

Figure 3. Critical currents of Y-123 coated conductors provided by American Superconductor Corporation prior to and following fast neutron irradiation to 2.3 x 10^{22} m^{-2}. Left panel: H||a,b; right panel: H||c.

To conclude this Section, comments on the stress tolerance of these conductors seem to be appropriate. Depending to a certain extent on details of the conductor architecture, coated conductors are in general rather stress-tolerant, e.g. compared to Nb_3Sn. Recent studies [2] confirmed that this stress tolerance was hardly affected by neutron irradiation to a fluence of 1 x 10^{22} m^{-2}. Further work along these lines is certainly necessary, since the above experiments only refer to tensile stresses measured in fields of up to 1.4 T and at a temperature of 77 K.

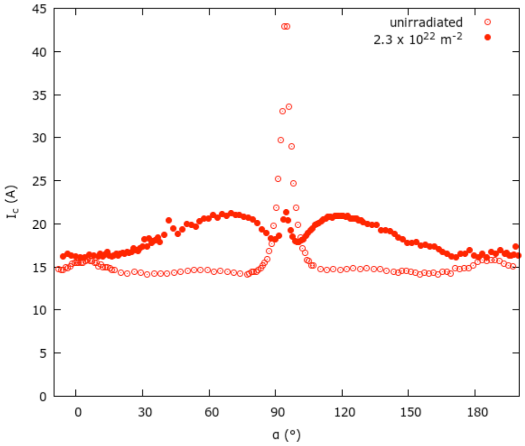

Figure 4. Angular dependence of the critical currents in a Gd-123 coated conductor provided by SuNam prior to and following fast neutron irradiation to 2.3 x 10^{22} m^{-2} (64 K, 5 T).

Nb_3Sn Superconductors

Readers of the review article "Radiation effects on superconducting fusion magnet materials", written in 2010 [3], might come to the conclusion that the physics of radiation effects on today's most important technical superconductor is completely understood. However, driven by challenging developments in accelerator design (High Luminosity Upgrade of the Large Hadron Collider at CERN, Geneva) new irradiation campaigns on present day state-of-the-art superconductors involving fast neutrons, very high energy protons and other charged particles have been initiated and have led to quite surprising results and new concepts for the interaction of radiation with the existing defect landscape of these materials. All previous data were well described by the concept of (radiation-induced) disorder affecting the intrinsic properties of the "ordered" compound Nb_3Sn, i.e. the transition temperature T_c, the normal state resistivity ρ_n and thus the upper critical field H_{c2}, their interplay defining the functional dependence of the critical current densities on magnetic field, temperature and radiation fluence. Doping the compound with, e.g. Ti or Ta, enhances ρ_n and the upper critical field, slightly reduces T_c, but enhances J_c quite significantly, at least at low temperatures. Introducing additional disorder by radiation consequently leads to J_c degradations at lower fluence levels than in the pure (undoped) compound.

Neutron irradiation experiments on recently developed high-J_c multifilamentary Nb_3Sn superconductors proved to be in striking disagreement with the above picture [4,5,6]. As shown in Figure 5, all conductors, completely independent of the substitution elements (Ta, Ti) and the doping level (IT-246 is undoped), respond to the neutron fluence in exactly the same way, the J_c enhancements persisting to fluence levels far beyond anything observed in previous generations of these conductors. At the same time, only very small changes of the upper critical fields could be detected, thus indicating that another mechanism must be responsible for the dramatic increase in flux pinning capability (nearly a factor of 2!). The J_c-fluence dependence must, however, reach a maximum at some fluence level, because the accompanying disorder will always result in a reduction of the transition temperature, as shown in Figure 6, which will finally manifest itself in a reduction of J_c even at liquid helium temperatures.

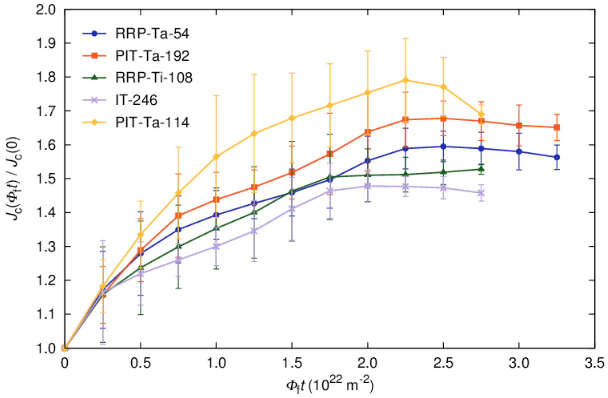

Figure 5. Changes of the critical current densities at 4.2 K and 6 T relative to the unirradiated state $J_c(0)$ with neutron fluence up to 3.3 x 10^{22} m^{-2} (E > 0.1 MeV). The expected peak seems to occur for all conductors at approximately this fluence level.

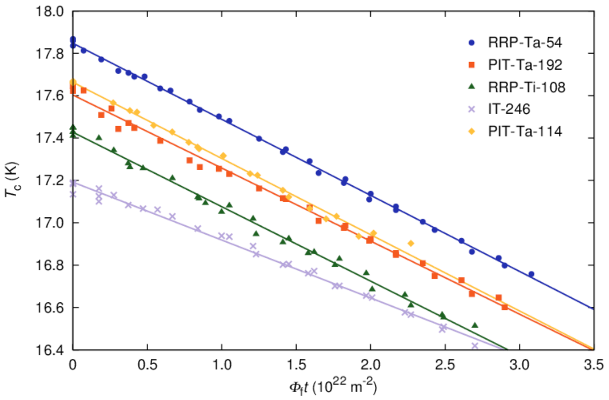

Figure 6. Transition temperatures as a function of fast neutron fluence.

Understanding this data and modelling the results is still ongoing. Starting from the neutron data, it was noted from a scaling analysis of the volume flux pinning force that the peak position of the pinning curves shifted upon irradiation to higher fields, i.e. scaling did not work any longer, thus indicating the emergence of different pinning mechanisms in addition to the dominating grain boundary pinning mechanism in Nb_3Sn. Therefore, assuming that the radiation-induced defects contribute a fraction β via core pinning ($0 \leq \beta \leq 1$) to the total pinning force, the fraction α being provided by grain boundary pinning ($\alpha + \beta = 1$), nice agreement between all data on the conductors of Figures 5 and 6 was obtained, as demonstrated in Figure 7. Accordingly, the contribution β of the new pinning centres initially increases quite rapidly, but then tends to saturate towards the expected peak near 2-3 x 10^{22} m^{-2}. The actual results on the volume pinning forces in the unirradiated and irradiated state are shown in the right panel of Figure 7. We note that pinning by a high density of point-like defects is clearly more effective at higher fields and, therefore, leads to the observed shift of the pinning curves to higher fields. In fact, transport current measurements on the samples directly show that non-Cu J_c values of 4.09 x 10^9 Am^{-2} at 12 T and 2.27 x 10^9 Am^{-2} at 15 T are achievable in Nb_3Sn wires. For industrially produced multifilamentary conductors, this performance is unprecedented in literature.

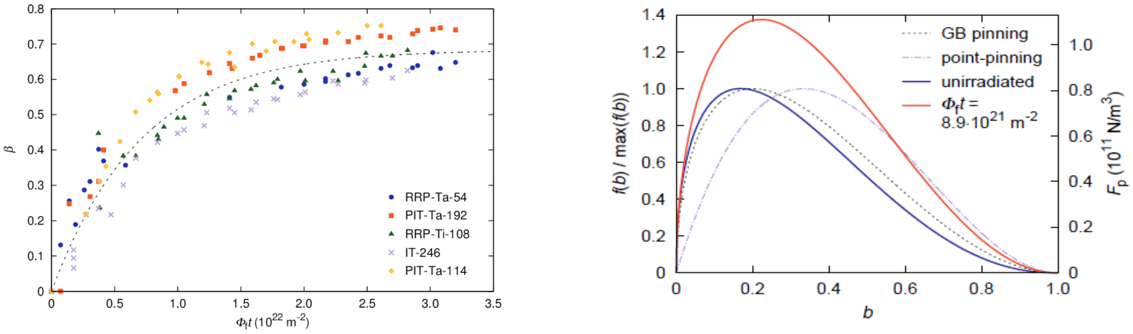

Figure 7. Left panel: Pinning contribution β of various superconducting wires as a function of fast neutron fluence. Right panel: Illustration of radiation-induced changes in the volume pinning force. The dashed curves represent the normalized functional dependence for grain boundary and for point pinning (left scale); the solid lines show the actual volume pinning forces in the pristine and the irradiated states ($b = B/B_{c2}$).

In summary, irradiation experiments on the latest generation of Nb_3Sn multifilamentary conductors have not only led to a wealth of unexpected and new results, but also to records in the field and current performance of this material. Micro-structural investigations have revealed unique grain structures as a consequence of new processing techniques, and are now being extended to attempt assessing the radiation-induced defect microstructure.

Conclusions

In view of the application concerned, special emphasis has been placed on fast neutron irradiation. It turned out that "disorder" is always introduced into superconductors, either as the main feature of the irradiation process or as a secondary effect accompanying the creation of extended defects. Disorder will generally affect the intrinsic properties of the superconductors, e.g. by displacing oxygen atoms in the cuprates or by disturbing the long range order in Nb_3Sn or by reducing the intrinsic anisotropy of the material, thus generally leading to a degradation of the primary superconductive parameters. On the other hand, the creation of extended defects, preferably of those with a size matching the superconducting coherence length, can lead to rather spectacular improvements in the critical current density J_c, the most important parameter for applications. The final result of such experiments will therefore depend on a balance between the beneficial effects, such as the enhancement of J_c or possibly the irreversibility lines and an increase of the upper critical fields H_{c2} through the enhancement of the normal state resistivity ρ_n by disorder on the one hand, and the detrimental effects introduced by disorder, e.g. on the transition temperature T_c, on the other hand. Some details of this general behaviour have been discussed for the most important classes of superconducting materials for the application in fusion magnets.

With regard to DEMO, the requirements currently envisioned by the designers could be (just) met by Nb_3Sn conductors operating at liquid helium temperatures. According to our present knowledge the cuprates will presumably not be suitable in the liquid nitrogen temperature range, but could operate at temperatures substantially above the liquid helium temperature range. Also, in view of the rapid progress in conductor processing, other disadvantages of the cuprates, such as the present tape geometry, could very well be eliminated in time for their application in the DEMO magnets.

Acknowledgements

The dedicated research efforts by M. Eisterer, T. Baumgartner, R. Prokopec and D.X. Fischer are gratefully acknowledged. I wish to thank L. Bottura and the CERN staff for the fruitful collaboration on the Nb_3Sn superconductors.

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INTERNATIONAL ACTIVITIES

US ITER Report, Ned Sauthoff, US ITER Project Office, Oak Ridge National Laboratory, Oak Ridge, TN.

Integrated planning by the ITER Organization’s Central Team and seven Domestic Agencies matured the preliminary schedule that had been presented to the November 2015 Council meeting; the schedule was subsequently reviewed by an independent group that presented its findings and recommendations at an Extraordinary Council meeting in April 27, 2016. At the June 2016 Council meeting, The Director General presented a further-evolved version; the Council endorsed the updated schedule with December 2025 as the fastest technically-achievable date of First Plasma. This endorsement provides the basis for ITER Members to seek funding for the completion of the construction through First Plasma.

The ITER team proposed an approach for the subsequent evolution of the ITER hardware configuration and the related research plan that includes research periods following each of several periods of fabrications and installations, leading to the full configuration before the beginning of the nuclear operations phase. The Council directed the ITER team to extend its schedule planning through completion of the installation of the full configuration for DT operation and to present it at the November 2016 Council meeting, with a Ministerial decision meeting envisioned in 2017.

At the November 2015 Council, a set of 2016-2017 milestones to measure project performance was established. At the June 2016 Council meeting, the Director General showed successful completion of all project milestones to date, on or ahead of schedule; the Council considered this to be a positive indicator of the collective capacity of the ITER Organization and the Domestic Agencies to continue to deliver on the updated Schedule.

The fiscal year 2016 Appropriations Bill that funds the U.S. fusion program included language calling for the Energy Secretary to present to the Appropriations Committee chairs his recommendation on whether the U.S. should stay in ITER. In May 2016, Secretary Moniz presented his report; in his opening message, the Secretary wrote, “ITER remains the best candidate today to demonstrate sustained burning plasma, which is a necessary precursor to demonstrating fusion energy power. Having fully assessed the facts regarding the U.S. contributions to the ITER project, I recommend that the U.S. remain a partner in the ITER project through FY 2018 and focus on efforts related to First Plasma. The U.S. along with all ITER Members across the world have witnessed and acknowledged the significant progress made at ITER by the new leadership, but there is still much that remains to be done. Prior to the FY 2019 budget submittal (late in calendar year 2017 to early 2018), I recommend that the U.S. re-evaluate its participation in the ITER project to assess if it remains in our best interests to continue our participation. My recommendation to support First Plasma cash and in-kind contributions is predicated on continued and sustained progress on the project, increased transparency of the ITER project risk management process, as well as a suite of management reforms proposed in this report that we expect will be agreed upon by the ITER Council. At this time, our continued participation in the fashion recommended is consistent with DOE's science mission and is in the best interest of the nation. The report discusses the critical issues that factored in this recommendation." The Congress is considering the recommendation and the FY 2017 budget.

At the ITER site in France, concrete is being poured for the next (B1-level) floor of the Tokamak Building and the Biological Shield that will surround the cryostat. The 730-ton roof of the Assembly Hall was put in place in September 2015 and the girders for the Assembly Hall cranes arrived at the site in March/April 2016 and were put in place in June. Tanks for the detritiation system were installed in the Tokamak Complex. More steady-state electrical equipment from the U.S. is being delivered, as well as large transformers for the pulsed power system from China and first cryostat components from India.

Around the world, major components are in fabrication: AC/DC power converters in Korea; cryostat components in India; vacuum vessel components in Europe, Korea, India, Russia and the U.S.; thermal shield in Korea; secondary-loop cooling water system in India; poloidal field coils in Europe and Russia; Central Solenoid (CS) conductor in Japan; CS winding, support, and assembly tools in the U.S.; TF conductor around the world; toroidal field coils in Europe and Japan; magnet supports, correction coils and feeders in China; cryoplant in the EU; cryolines and cryodistribution in India; neutral beam test facility in Europe; DC generators and transmission lines in Japan; ion cyclotron sources in India; electron cyclotron gyrotrons in Russia; diagnostics around the world; and more.

RECENTLY PUBLISHED FUSION BOOKS

Mitsuru Kikuchi and Masafumi Azumi, **Frontier in Fusion Research II: Introduction to Modern Tokamak Physics**
http://www.springer.com/us/book/9783319189048

Francis Chen, Introduction to Plasma Physics and Controlled Fusion
http://www.springer.com/us/book/9783319223087

CALENDAR OF UPCOMING CONFERENCES ON FUSION TECHNOLOGY in 2016

ANS 22^{2d} Topical Meeting on the Technology of Fusion Energy – TOFE-2016
August 22-25, 2016, Philadelphia, PA, USA
http://www.ans.org/

29th Symposium on Fusion Technology – SOFT-2016
September 5-9, 2016, Prague, Czech Republic
http://www.SOFT2016.EU

5th International Conference on Nuclear and Renewable Energy Resources (NURER2016)
September 18 - 21, 2016, Hefei, Anhui, China
http://nurer2016.org.cn/dct/page/1

26th IAEA Fusion Energy Conference
October 17-22, 2016, Kyoto, Japan
http://www-pub.iaea.org/iaeameetings/48315/26th-iaea-fusion-energy-conference

ANS Winter Meeting
November 6-10, 2016, Las Vegas, NV, USA
http://www.ans.org/