International Superconductivity Industry Summit
ISIS -13
Jacksonville, Florida, U.S.A
8 October, 2004
Communique

Executive Summary

The International Superconductivity Industry Summit convened for its 13th annual meeting in Jacksonville, Florida on October 8, 2004. This annual gathering of about 50 global leaders of the superconductor community addressed the major accomplishments and continuing challenges facing the industry; examined the issue of the need for governments to support emerging technology and the level of government spending on superconductivity over the past decade; and reviewed the status of superconductivity based national infrastructures projects in Japan, Europe and the United States.

Major advances in superconductivity were reported for 2004, particularly in the translation of advances in materials and processing technology to demonstration and field testing of large scale prototype equipment, and the integration of other technologies, such as cryogenics, into the superconducting systems. Of particular note are the projects around the world to demonstrate the viability of superconducting cable insertion into national power grids. Superconducting cable can carry 5 – 10 times the power of conventional cables in the same size cable tray and represents a means of addressing the continuing growth in demand for power within the constraints of existing infrastructure. Likewise, several demonstrations of smaller footprint, higher efficiency motors and generators for both industrial and ship propulsion applications demonstrated successful performance, and large superconducting magnets were also shown to be highly effective energy storage devices. In the medical and research fields, advances in superconductor technology enabled the manufacture of even more powerful MRI and NMR machines. This also is encouraging in regard to the proposed $5 Billion international program to demonstrate and develop fusion energy concepts through the construction of the International Thermonuclear Experimental Reactor (ITER).

There were also major advances reported in new superconducting materials and processing and fabrication technologies. Single Flux Quantum (SFQ) electronic circuitry is a superconductor based technology with the potential to be orders of magnitude faster than semiconductor technology, yet it operates at much lower voltages and consumes and dissipates very little power. The major challenge has always been fabrication. Major progress last year demonstrated the capability of fabricating six layer structures integrating >10,000 Josephson Junctions, the basic building block for SFQ circuits, and circuit speeds >10 GHz. While much challenging work remains to be done before this technology is ready for insertion in high speed computing and digital communications, the advances

reported are dramatic and highly encouraging. Another area showing substantial advances in fabrication technology was second generation or ：2G； wire for electric power cables. Reports described demonstrations of much longer and more uniform lengths of wire in the drive for higher performance and lower cost product manufacturing.

Government funding of new technologies is important, given the traditional long development period before products, especially those making use of new materials, reach the marketplace. This is particularly true when those technologies are applicable to major infrastructures, many of them government regulated, such as electric power generation and distribution, communications, transportation, and large pieces of equipment for the medical field and scientific research. All of these industries are necessarily conservative in implementing any new technology. Consequently superconductivity is heavily dependent on government support at the academic and the R&D stages through successful commercial prototype demonstration. In a detailed review of funding for superconductivity by Governments in Japan, Europe and the United States over the past ten years, delegates to ISIS were disturbed to see significant declines in support by all Governments in several areas of superconductivity R&D, despite continuing demonstrated major advances in the technology. The overall impact of these funding reductions has been massive program cuts; layoffs and loss to the emerging superconductivity industry of highly qualified personnel; closure of small entrepreneurial companies, and a delay in the timeframe to reap the benefits of this technology.

Key conclusions from the conference were: (1) considerable progress has been made within the past year in demonstrations of prototype equipment and advances in new materials and fabrication processing; and (2) the recent decline in government funding support has caused substantial disruption and difficulties within the superconductivity industry. The key challenge facing the superconductivity industry is to maintain the rapid pace of advancing the technology towards commercialization and to exhort governments to maintain funding support at a level commensurate with this goal.

A more detailed review of ISIS-13 can be obtained from the attached sections covering ：Conductors；, ：Electric Power；, ：Electronics；, ：High Energy Physics；, ：Medical and Industrial；, ：Transportation； and ：Government Funding of Superconductivity (1995 – 2004)；.

The next meeting, ISIS-14, is tentatively scheduled to be held October 27-28, 2005, in Tokyo, Japan.

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Introduction

The International Superconductivity Industry Summit convened for its 13th annual meeting in Jacksonville, Florida on October 8, 2004. This annual gathering of global leaders of the superconductor community addressed the major accomplishments and continuing challenges facing the industry, examined the issue of the need for governments to support emerging technology and the level of government spending on superconductivity over the past decade, and reviewed the status of superconductivity based national infrastructures projects in Japan, Europe and the United States.

In the course of the day-long summit, delegates reviewed the significant advances in several areas of technology that have occurred over the past year within their regions. The substantial progress towards commercialization, the demonstrated viability and benefits of installed prototype products based on superconductor technology, and the future additional promise from research were all examined. Examples of fields of progress included the development and demonstration of superconductor applications in electronics, electric power, transportation, and high-energy physics. The past year also saw continuing progress in the development and industrialization of core technologies, including both low temperature and high temperature superconductor chips and wire that enable these applications. Much of this year・s discussion also focused on the many challenges that face the industry, including the difficulty of sustaining government support for long-term research and development in an era of constrained budgets and competing priorities. More detailed summaries of the key presentations are shown by field and application below.

Background of ISIS and Participants

The International Superconductivity Industry Summit (ISIS) was formed in 1992 as a joint initiative between the International Superconductivity Technology Center (ISTEC) in Japan and the Council on Superconductivity for American Competitiveness (CSAC) in the United States. ISTEC and CSAC were joined in 1993 by the CONsortium of European Companies determined To Use Superconductivity (CONECTUS), representing superconductivity development in Europe. Since 1992, the global superconductor industry has held an annual conference to promote international cooperation and information exchange between industry, government, and academia worldwide to stimulate rapid product development using superconductivity technology. This year, the conference in Jacksonville was sponsored by the Coalition for the Commercial Application of Superconductors (CCAS).

CCAS, formerly CSAC, is the U.S. based non-profit corporation dedicated to the commercialization of products based on superconductor technology with the goal of providing broad and far reaching societal benefits that are both cost effective and environmentally friendly.

ISTEC was established as a non-profit foundation in January 1988, with the approval of the Minister of Economy, Trade and Industry of Japan, pursuant to the Civil Code of Japan. Its designated objective is to contribute to the advancement of superconductivity studies and the sound development of superconductivity-related industries.

CONECTUS, the CONsortium of European Companies determined To Use Superconductivity, is a non-profit organization founded in 1994 as a private company in the UK. The central objective of CONECTUS is to strengthen the basis for commercial applications of superconductivity in Europe.

Next Summit

ISIS-14 will be hosted by ISTEC and is tentatively scheduled to be held October 27-28, 2005, in Tokyo, Japan.

Conductors

Opportunities

The use of Low Temperature Superconductor (LTS) is the standard solution for economically generating magnetic fields in high energy physics and in the medical industry. Most prominently, LTS conductors are applied to magnetic resonance imaging (MRI) systems used to image soft tissues in the body, for laboratory magnets and in thermonuclear fusion projects such as ITER. Increased capability, such as 3-T MRI magnets and 900-MHz NMR is of value and users will pay more for these benefits. For over a decade High Temperature Superconductor (HTS) wires have seen a continuous performance increase from 10 amperes critical current in 1993 to >130 amperes critical current in 2004. First-generation HTS wire is now available in commercial quantities and in >500-m lengths. Second generation HTS wires (:coated conductors;) are already matching first generation BSCCO wire performance and are expected to be available at lower cost and in commercial quantities by the end of the decade. HTS wire has the potential for broad industrial application throughout the power infrastructure from generation, transmission, distribution, and in the use of electricity. Apparatus that uses HTS wire will be more powerful and compact, more environmentally friendly, and will offer electricity providers operational benefits that will enable expansion and modernization of the grid. Delegates noted that commercially available HTS wires have a critical current density >1 x 106 A/cm2 at 20K and 25-T, making these wires interesting for many high-field applications as well.

Progress, Milestones and Challenges

The performance of the low temperature superconductor, Nb3Sn, continues to improve while there is continued downward pressure on the price for NbTi. The MRI and NMR markets are steadily growing at about 5% annual growth rate, providing a dependable market for LTS conductors. On the physics side, ITER is expected to be the next big project for LTS conductors. LTS capacities therefore are being enlarged further. New projects and applications should be an objective for the industry.

High temperature superconductor Bi-2223 wires are now commercial and are being installed in end-user equipment in laboratory facilities and in the field. Delegates reported on significant progress that has taken place over the past year in the commercial availability of Bi-2223 HTS wires – in length up 1.4 km and with increasing performance. In Japan, a new process has been developed, enabling the production of balloon-free, high-density BSCCO wire with a high mechanical strength. Comparable performance is already reported for the Bi-2223 wires produced in the USA. The installed wire manufacturing capacities in the USA, Japan, China, and Germany are serving the world market and will be further expanded within the next years and applications prove their worth in the field trials underway. Bi-2212 bulk is commercially used in current leads and was successfully tested as a component in resistive fault current limiter applications. An ongoing demonstration of this technology has also demonstrated feasibility for the grid integration of a superconducting component as well as the availability of cryogenic refrigeration.

Delegates also exchanged information on advances in the performance (lengths and current densities) of second generation (:2G;) YBCO coated conductor wire. Process scalability is now being addressed, resulting in reports of a number of hundred meter pieces of coated conductor being produced in a continuous manner with >100-A critical current. In Japan, a new five-year national program for coated conductor development was started in FY2003. The target of this program is to develop a 500-m YBCO wire with a critical current of more than 300A/cm-w by FY2007. The target production cost is $70-100/kAm. So far, Japan has successfully produced wires with a length-Ic product of more than 13,000 A-m. The USA has conducted several impressive demonstrations of prototype :2G; wires with over 10,000 A-m reported in 100-m wires and critical currents at 77K, which equals the best BSCCO tapes reported for 10-m lengths. The US goal is 100-m of 300-A 2G wires by 2006. Coated conductors are a promising solution for a further cost reduction in superconductivity. The outlook for the next several years suggests that within 5 years, the industry could approach a commercial :crossover; point where coated conductor wire will broaden the HTS addressable market and will gradually displace Bi-2223 wire in these new markets.

MgB2 wires are the newest superconducting material under development.

Progress towards long length wires was reported. New companies in Europe are founded for the commercialization. Kilometer lengths were reported in the USA with promising economics.

Recommendations

The next big target for LTS is ITER. The sustained growth in the medical market will not fill the gap after completing the LHC, which is driving the LTS market in Europe. Presently, the world production capacity is greater than the effective market demand for LTS. ITER is expected to compensate for this. The present standard for HTS in power applications is Bi-2223 wire. More demonstrations are needed to develop systems related aspects of the technology in the electric grid and to demonstrate reliability even in harsh environments, such as on board ships. Continued strong Government support for domestic and international projects is essential to maximize the societal benefits expected to result from infrastructure improvements effected by superconductivity. The ISIS framework will continue to offer a useful exchange of views regarding the future LTS and HTS wire markets.

Electric Power

Opportunities

Electric power has long been viewed as one of the most important fields of opportunity for HTS technology, for several reasons. Total power demand continues to grow steadily throughout the world. Electricity consumption is closely related to gross domestic product. Available land for power delivery corridors, however, is becoming a scarce resource. This is especially true in densely urbanized areas where power demand is concentrated. In some nations and metropolitan regions, there is a risk that electricity demand growth will overwhelm the capacity of aging grid infrastructures.

In view of these factors, experts agree there is an acute need for new technologies to improve the capacity, reliability, efficiency and controllability of the power delivery network. If these new solutions are to enjoy community acceptance and commercial success, they must be configured within a smaller physical footprint than conventional solutions, because of heightened sensitivity to land use and environmental issues throughout the developed world. In recent years some countries have experienced several major blackouts; these events have highlighted the importance of implementing new grid technology solutions, from both an economic and security standpoint.

Progress, Milestones and Challenges

Delegates to ISIS-13 exchanged information on a range of power-related projects and activities now underway. These efforts are aimed at translating recent advances in HTS wire and technology into commercially viable solutions for the problems described above.

Detailed presentations were offered on several HTS power delivery cable demonstrations that are now underway or planned on a worldwide basis. In addition to short demonstration projects being pursued in Europe, three major HTS cable demonstrations were formally launched in the USA within the past year. These projects are supported by global teams. These three-phase demonstrations range from a 13.2kV, 200m 3kA :triaxial; distribution cable in Columbus, OH, and a 34.5kV, 350m 800A :triplex; cable in Albany, NY, to a 138kV, 660m 2.4kA transmission cable in East Garden City, NY. The latter is the largest HTS cable demonstration yet undertaken worldwide. Japan is now in the latter stages of a major 77kV, 500m 1kA single phase HTS cable demonstration in the Yokosuka site of CRIEPI, Kanagawa Prefecture. Important technical aspects of these projects include cable bending, the cable expansion and contraction offset required for heating and cooling cycles, and cooling system operation. These projects, and additional demonstrations of HTS cable, will play an essential role in the commercialization process. Such demonstrations help to establish a reliability record for HTS cable, and drive the resolution of grid integration issues. Thus, they will play a critical role in accelerating the widespread acceptance of HTS cable as a commercial solution.

Motors and generators also received extensive reporting. Japan has established the basic high power density technology necessary for a 200,000-kW class generator and the technology base required for a larger scale 600,000-kW class generator. The development program ended after achieving its stated goals.
In the United States, the past year saw the successful test of a superconducting dynamic synchronous condenser or :SuperVAR.; Derived from recent developments in superconducting rotating machinery for transportation purposes, this device represents a new type of solution for grid reliability and power quality problems. This prototype will continue to undergo tests on the grid of the Tennessee Valley Authority (southeastern USA) over the coming year.

In Europe, Siemens started development of synchronous motor / generators with a winding made of BSCCO 2223 tapes. Suitable applications for the compact, superconducting motor are mainly those that call for space-saving and energysaving machines, such as on ships or oil platforms. The technology is also suitable for gas turbines, making it possible to build extremely high-speed generators that can be coupled directly to a turbine without the need for a gearbox. The 400 kW demonstration was very successfully operated over more than three years, thereby proving the concept of a cooling system invisible to a future customer. At present a 4 MVA motor / generator prototype is under manufacture. HTS generators enable highly compact and lightweight gas turbine driven units which allow flexible energy supply on demand on ships or oil platforms.

Superconductors have found application in two forms of energy storage: kinetic energy storage in low-friction flywheels; and true electricity storage in

Superconducting Magnetic Energy Storage or :SMES; systems. Japan is also carrying out a flywheel development program, focusing on the development of a superconducting bearing for a 100-kWh flywheel system. A test to confirm the functionality of a complete small-scale system is currently underway.

Japan also continues to focus on SMES technology development, in particular the development of lower-cost, higher-performance versions of SMES technology that can operate at higher temperatures. Such systems would be used for stabilizing large power systems and compensating for continuous load fluctuations. After cost reduction efforts of SMES system and model coil operational tests, in FY 2004, Japan started a new four-year program aimed at next-generation (HTS) SMES system technologies and the demonstration of a complete LTS-SMES system to be installed in an actual grid. These efforts create the potential to expand the use of SMES, which has been applied in smallscale, low-temperature systems for several years to address instantaneous voltage drop problems affecting industrial users and utilities.

Current controlling devices remain a focus of keen commercial interest. As demand rises and power flows across existing networks increase, and as more generation is connected to existing networks, some grid operators face fault current levels that approach or exceed the ratings of conventional breaker equipment. Superconducting Fault Current Limiters (:FCLs;) could play a critical role in enabling existing grids to meet these rising demands without the need for wholesale replacement or upgrading of breaker equipment. Such devices could also play an enabling role in the design of more compact, cost-competitive HTS cables to solve a broader range of power flow problems.

Japan is developing an FCL technology that includes a 10-cm*30-cm superconductor film manufacturing technology for use in FCL systems featuring a critical current density of more than 1 million A/cm2, a technology for a high voltage of 6.6-kV with a series connection of FCL elements, and a technology for a large current of 1 kA.

Recent progress in Europe includes the demonstration of a 12 kV 10 MVA FCL operated in a substation of RWE in Northern Germany. This is the first successful pilot application of such a device in a public grid so far. Whereas this type of FCL is based on bulk material, the thin film approach could enable technically feasible FCL devices for both AC and even DC applications. A very impressive result was the reproducible test of a 1 kV 1MVA DC current limiter that limited a prospective fault current of 100 kA to about 1 kA (near to nominal current) within less than one millisecond. Generally, switching elements based on ceramic substrates cannot match utility system needs economically. As 2nd generation conductor becomes available, it will greatly improve the chances for very fast limiting thin film FCLs.

Transformers are also under evaluation. In FY2003, Japan manufactured and satisfactorily demonstrated a 1 ␣p, 66-kV / 6.6-kV, 2-MA superconductor transformer in a factory as an element model of transformer. The specification of this device corresponds to that of conventional transformers commonly used in actual power distribution grids in Japan.

All of these applications face challenges in today•s environment of fiscal austerity for public-interest R&D. Furthermore, the ongoing transition of regulatory regimes for the transmission sector has created an environment of investment uncertainty. This is especially the case in the USA where roles for power producers, transmission entities and distribution utilities have been in a state of flux. Until recently, there have been no clear, enforceable rules fixing responsibility for grid reliability functions. As a result, both transmission and gridrelated R&D investment have seen a prolonged depression. This has also resulted in a pent-up demand for new solutions and extended the :window of opportunity; for new technologies that meet cost and performance targets consistent with today•s land use and environmental values.

Recommendations

The development of superconductor power technologies has coincided with a period of significant structural reform in the power sector throughout the world, as well as a general downward trend in public funding for electric power R&D. Despite the structural changes taking place in the industry, electric power remains an essential underpinning of life in modern economies. The electric power industry, and especially the delivery sector, is expected to remain heavily regulated. While regulated utilities have traditionally taken a conservative approach toward new technology solutions, the industry faces urgent needs. Government regulatory and fiscal policies can influence and accelerate the rate of adoption of these new technologies.

In the face of major energy and power delivery challenges facing nations around the world and the promise inherent in superconducting grid technologies, governments can take several steps to remove obstacles to their development, deployment and commercial acceptance. Participants in the ISIS-13 summit join in urging governmental bodies with responsibility for regulatory policy and R&D budgets to examine the effects of their policies on an integrated basis. Governments could provide more robust and predictable multi-year funding of technology demonstration efforts. Regulatory reforms should aim at revealing more clearly the true value of technology solutions that address grid congestion and reliability problems. Incentives, including rate reforms, changes to asset depreciation schedules, and other tax code changes, may also be helpful in speeding the adoption of innovative solutions.

Electronics

Opportunities

Superconducting opportunities in electronics include both passive components and active devices. Passive components, e.g. filters, were among the first HTS devices fabricated, targeting primarily wireless communication base stations with the intent to enhance coverage area, increase capacity, and improve call quality. Extension to satellite and military applications is also envisioned due to the smaller size and weight of the HTS based receiver front end at high performance levels versus conventional filter systems. Market applications for HTS passive devices to date have largely focused on the rapidly growing commercial wireless opportunity.

Active superconducting devices are based on Single Flux Quantum (SFQ) circuitry. SFQ is a superconductor based family of logic circuits that makes use of the quantum nature of superconductivity to define the :0; and :1; states of binary logic. Superconducting Josephson Junctions (JJs) are joined to form Superconducting Quantum Interference Devices (SQUIDs) which are the building blocks for the logic circuits. JJ devices have extremely fast switching time, operate at millivolt levels, versus volts for semiconductors, and consume and dissipate very little power. LTS SFQ devices could potentially achieve speeds of 100 GHz compared to 3GHz for silicon, while HTS SFQ technology could, in theory, achieve THz speeds. Logic circuits are fundamental to the very high value-in-use microprocessors and Digital Signal Processor (DSP) chips. High speed microprocessors are critical to servers, workstations, and high end business PCs, while high speed DSPs are essential to digital communications. Superconducting SFQ devices could therefore provide performance far beyond the theoretical limit of current semiconductor systems.

Progress, Milestones and Challenges

HTS receiver front end systems for wireless communication base stations are under development or being produced commercially by a small number of companies in the U.S., Japan, Europe, China and Korea. Targeted performance has been demonstrated and >4,000 units have been placed in service in commercial wireless networks, mainly in the U.S. Meeting the demands for a lower cost product with demonstrated reliability and performance are continuing challenges.

In the U.S. most work related to JJ devices has historically been conducted in small and large companies funded by the U.S. Department of Defense. In Europe this activity is mainly carried out by academic institutions and outsourced enterprises strongly linked to these research institutes and in a very small number of private companies. Conversely in Japan, superconducting digital technology is driven technically by ISTEC working in close co-ordination with academia and industry. Due to the fundamental nature of the research and development and the long time to potential commercialization, funding in all cases is from the respective governments. The major challenge in both LTS and HTS SFQ technology is device fabrication. Even after decades of research on niobium based systems the challenges of producing large areas of multi-layered materials, incorporating millions of tiny integrated SQUID devices, meeting tight uniformity specifications, all at exceptionally high yield, is daunting. The challenges posed in implementing HTS technology are even greater. Nevertheless, the ultimate benefits necessitate continued substantial effort. The world・s leading program is in Japan. The ：Superconductors Network Device Project； was started in FY2002 as part of the Ministry of Economy, Trade and Industry・s ：Advanced Program on IT Infrastructure；. Under the project a five year LTS device development program was initiated in FY2002. In FY2003, a four year HTS device development program for A/D converter and sampler technology was begun. These programs include the research and development of design and fabrication technologies for superconducting devices. The basic technologies required for superconducting network devices will be established by FY2006. The current program status has demonstrated 6 layer niobium structures, integration of >10,000 JJs, and circuits operating at >10GHz. Circuits incorporating >100 HTS JJs have also been demonstrated. Considerable effort in LTS digital electronics for joint tactical radio, switching and computing was also expended in the U.S. beginning in 1988, with total funding in excess of $100 M. After a decline in the late 90・s funding support has again increased in the past two years.

Recommendations

The amount of communication traffic is increasing more rapidly than previously expected. In order to meet the demands of such growth, the early commercialization of superconducting network devices is urgently desired. In this context, fabrication technology must be developed and prototype systems must be realized and their high speed system performance demonstrated to persuade potential users to adopt superconducting network device technology for practical applications. Continued strong Government support is essential to achieve these goals.

High Energy Physics

Opportunities

The study of high energy physics (HEP) and the attendant equipment is enabled by Low Temperature Superconductor (LTS) magnets. No other technology is capable of achieving the necessary high field strength and precise control of magnetic field. Consequently all particle accelerators and colliders use NbTi and/or Nb3Sn magnets. Continued demand for new installations and upgraded facilities worldwide in HEP augur well for continued growth. The largest single opportunity, currently well along in the approval phase, is the International Thermonuclear Experimental Reactor (ITER) for proof of concept and development of fusion energy. ITER is projected to cost $5 billion and would require by last report 517 tons of Nb3Sn and 244 tons of NbTi for a total Nbbased materials value of $650M.

Progress, Milestones and Challenges

Substantial progress has been made in HEP, both internationally and nationally, since the ISIS-12 meeting in September, 2003. Driven by extremely stringent ITER specifications, the quality of LTS materials has shown continued substantial improvement and commercial production capabilities are being expanded. Several nations have committed to funding of the ITER project at a level of approximately $500M each. The major and ongoing challenge for ITER is its physical location. Potential sites have been narrowed to two. The Japanese location at Rokkasho is supported by Japan, U.S.A. and Korea, while the Cadarache location in France is supported by the EU, China and Russia. Resolution of the location impasse is expected in 2005.

An announcement was recently made relative to the International Linear Collider (ILC) program 。V the announcement being that the ILC would go cold; meaning that approximately 20,000 high-purity Niobium superconducting RF cavities will be required. The timeline for this venture is considered mid-term by the US Department of Energy, Office of Science 20-year plan

In the USA, construction is well underway on the Spallation Neutron Source (SNS) using high-purity niobium superconducting RF cavities. The SNS project is the last large scale facility to be built by the DOE・s Office of Science. However, in November, 2003, the DOE announced its 20-Year Science Facility Plan which is essentially a roadmap for HEP and fusion energy projects. This plan sets the priorities for 28 new, major science research facilities. Primary amongst these projects are the Rare Isotope Accelerator (RIA) and the much anticipated 12GeV upgrade to CEBAF at Thomas Jefferson Laboratory.

Another challenge could be a future fusion reactor utilizing HTS technology. As the upper critical magnetic field strength of YBCO has been shown to be much higher than that of niobium-based LTS materials, this feature might open the door to promising new applications, including very strong magnets for future nuclear fusion. In parallel with the international effort required for construction of ITER, development of superconductor materials with higher performances could facilitate the realization of a future commercial fusion reactor.

Recommendations

Governments need to recognize the criticality and international nature of major science projects and move speedily towards setting priorities, approving funding and implementing international agreements. While site selection is of major importance, science ministers need also to recognize and emphasize the ：international； aspect of HEP when awarding projects.

Medical and Industrial

Opportunities

The market for MRI is projected to grow 8-10% annually as a result of both expanded clinical application (e.g. functional MRI and MRI guidance imaging) and continued technology advances leading to higher performance as well as smaller, more efficient and more affordable systems. Both superconductor and cryogenic advances are enabling more powerful NMR spectroscopy systems. Higher performance Nb3Sn and BSCCO-2212 superconductors are also paving the way for High Energy Physics to achieve higher field and higher energy particle accelerators that advance fundamental understanding of the universe.

Progress, Milestones and Challenges

The installed MRI base has now surpassed 20,000 systems, and the challenges going forward are continued reductions in helium use, size and cost while simultaneously increasing performance (magnetic field). Japan achieved NMR spectroscopy at 930 MHz using improved Nb3Sn, and the challenge of 1 GHz and higher will be aggressively pursued using even higher performance conductors now in development. As an example of these, BSCCO-2212 tapes were used in a high field insert magnet that reached a record setting 25 T in a superconducting magnet. Newly developed Nb3Sn strands for HEP achieved 3000 A/mm2 at 12 T, and enabled a world record 16 T dipole magnet. ITER waits on the threshold of construction while facing the challenge of new levels of international cooperation in site selection. Once underway another major challenge will be scaling up worldwide Nb3Sn production rates by a factor of ten while meeting the cost and performance targets. Efforts will continue to improve high field performance in conductors and to lower costs, especially in HTS materials. A potentially very low cost superconductor, MgB2, has rapidly improved to long lengths and useful current densities.

Recommendations

The present LTS market using NbTi and Nb3Sn and continues to show a solid balance of commercial value and future prospects. It is evident that LTS will continue to contribute substantially to the superconductor market and to the public welfare, particularly through the growing importance of MRI and NMR spectroscopy. These LTS materials need continued support to enable future advances in high energy physics and fusion science and technology. Continued government funding is particularly important for newer HTS materials which hold tremendous promise for advancing higher field superconducting magnet performance for NMR, high energy physics, and laboratory applications. Government support is also needed to enable and nurture partnerships for new applications of these materials. New levels of international cooperation are needed to enable large scale projects such as ITER.

Transportation

Opportunities

Transportation infrastructures throughout the world are facing major challenges in the air, by sea, and on land to move more people and commerce than ever before, and to do so in a cost effective and environmentally acceptable manner. Superconductor technologies have the potential to improve the efficiency and reduce the physical footprint of transportation systems. For land-based transportation, electrification offers a pathway to ensure the continued availability of high-speed transport services. At sea, HTS ship propulsion motors will offer the benefits of smaller size and weight, improved efficiency, less noise, and more useful cargo space.

Progress, Milestones and Challenges

Delegates exchanged information on a number of important milestones achieved and remaining challenges, in the transportation sector. Japan continues its effort to develop LTS-MAGLEV technology. A new HTS racetrack-type superconducting magnet was also developed for use in the MAGLEV system and the superior performance of this magnet was demonstrated in FY2003. In Germany a 1 MVA HTS railway transformer has been tested which showed a major reduction of up to 45% in both mass and volume, while at the same time, clearly increasing efficiency from 93% to more than 99% for a transformer that could be used for instance in a regional train. The past year also marked significant progress in the United States in the area of HTS technology for ship propulsion. Recently, the US Navy・s Office of Naval Research completed successful testing, under full load conditions, of a 5 MW HTS ship propulsion motor at Florida State University・s Center for Advanced Power Systems. This test marks an important milestone in a development program that is aimed at demonstrating an HTS ship propulsion system suitable for the next generation of U.S. navy warships. This program is also expected to yield technologies suitable for a wide range of commercial ship applications.

Recommendations

Large-scale transportation projects offer dramatic public benefits but, by their nature, entail high development costs and long development timeframes. In these initial viability demonstration years, sustained, multi-year governmental commitment and support is therefore necessary to ensure that these projects reach their goals in an orderly and cost-effective fashion.

Government Funding of Superconductivity (1995 – 2004)

Summary

In examining the past ten years of funding by Government in Japan, Europe and the United States, several trends are clear:

- substantial progress has been made in demonstrating technological success both at the research level and in prototype demonstrations

- Government funding has steadily declined, despite the demonstrated high benefits that will accrue to the implementation of superconductor based systems, and the fact that the technology is progressing to the most expensive prototyping demonstration phase of development
- funding focus has moved from more general R&D exploration to highly focused applications demonstration projects.
- the overall impact of funding reduction has been massive program cuts;

layoff and loss to the emerging superconductivity industry of highly qualified personnel; closure of small, entrepreneurial companies, and a delay in the timeframe to reap the benefits from this technology
While not included in this discussion it would be interesting to see the relative commitments of China and Korea to superconductivity as large and rapidly expanding efforts in these two nations appears to have been underway for the last five years.

Japan

Superconductivity R&D budgets from FY1988 through FY2004 controlled by the New Energy Technology Development Department of the New Energy and Industrial Technology Development Organization (NEDO) were presented. While this represents a large percentage of the total spending on superconductivity by the Japanese Government, it focuses primarily on those budgets allocated to R&D of electric power and electronics applications but does not include budgets of the other departments. The expenditures within NEDO however give a good historical picture of the relative importance of program segments, funding trends and future directions.

Over the past 10 years the NEDO budget for superconductivity totaled about 「D62.6B. Materials and devices development accounted for approximately half of the total at 「D31.4B. The remainder was directed primarily at the following major projects: generators, 「D12.4B; SMES, 「D8.7B; Flywheel, 「D3.9B; and alternating current equipment, 「D6.2B. Even though R&D in the past has covered a wide variety of equipment, work on some applications has been discontinued. Approximately 「D31.2B was spent between FY1988 and FY2003 to successfully complete model units of 70MW LTS generators which demonstrated 1500 hours of continuous operation and was terminated after R&D cost reduction studies for 200MW and 600MW generators were completed. The flywheel project is closed in FY2004 as are development programs on cable conductors, FCL and HTS magnets. Conversely the interest in wire and devices is strong and entered into a second phase (FY2003 – FY2007) funded at a level of 「D7.1B in FY2003 and FY2004. The program focus is to develop more efficient, longer and less costly YBCO wire and the development of larger scale single flux quantum (SFQ) devices in both LTS and HTS materials. Likewise, superconducting magnetic energy storage (SMES) project entered into a new phase (FY2004–FY2007) and was funded at a level of 「D0.7B in FY2004. The new SMES program aims to demonstrate a full SMES system performance and develop HTS SMES technologies

Europe

The European Union in Brussels provides some limited funding for superconductivity within their different program areas although there is no specific and dedicated program for superconductivity. Major projects in superconductivity have always been funded within national programs, mainly in Germany, Italy, Spain, The Netherlands and the UK and to a smaller extent within other EU countries. However in most of the countries mentioned, the governments are substantially reducing their support with the one exception being Italy. For example in Germany, annual government funding for industrial development projects over the last five to ten years has been between .5M and .10M. This is being phased out by 2006. This is occurring at the critical time when increased levels of funding are required to meet the larger costs of prototype development and demonstration. Some funding for national laboratories remains stable at present. At Karlsruhe Research Centre .1M per year for high current conductor and demonstrator developments and .1.5M per year for nuclear fusion (via EURATOM) is budgeted, although this is dependant on the future of ITER.

Funding of 6 HTS projects by the EU Commission has occurred under the ：Framework Programme； between 1998 and 2002. This was at a level of .6.2M and required 50% cost share by participants. Within the Framework Programme for 2003 to 2006, .9.3M has been awarded for four projects to date with other proposals in preparation. The projects funded are a short length YBCO transmission cable (Nexans) for .2.5M; a magnesium boride conductor development program (Twente University) for .2.5M; 2G conductor development (Trithor) for .2.0M and a similar amount, also with Trithor as the leading company, to develop a 25T magnet.

The European Commission also funds a Network of Excellence for Superconductivity (SCENET) at a budget level of .2M per duration period. The duration periods to date ran 1996 – 2001 and currently 2002 – 2006. SCENET includes about 65 universities and research centers and 25 industrial companies and is active in summer schools, young scientist exchanges, workshops and working groups aimed at promoting excellence in superconductivity and guidance for new projects.

Due to the highly fragmented nature of the funding throughout Europe it is difficult to assess quantitatively total government expenditures but estimates suggest approximately .150M funding was provided between 1998 and 2003. Of this amount approximately .43M or 29% was spent in support of materials development.

United States

Prior to 1994 most of the historical US Government funding information on superconductivity was collected and published in a report entitled :Federal Research Programs in Superconductivity;. However, since that time, budget information has not been collected under a superconductivity heading other than at the US Department of Energy (DOE). Information on HTS research over the past 10 years is therefore based on published information from multiple sources and while the numbers are believed to be good estimates their accuracy cannot be verified. If programs have been missed from the assemblage, the overall numbers will be low. Conversely, the DOE numbers are approved budget numbers that do not reflect actual expenditures on superconductivity programs due to a process known as :earmarking; in which individual Members of Congress have redirected up to about 35% of the superconductivity budget to fund programs in their home districts that are unrelated to superconductivity.

Over the past 10 years (1995 – 2004) U.S. Government funding for superconductivity, primarily from the Department of Defense (DoD), Department of Energy (DOE), National Science Foundation (NSF), Department of Commerce (DoC), and NASA, has totaled approximately $1.1B. The major funding support over this time period have come from DoD (ca. $350M), DOE (ca. $300M) and NSF (ca. $170M). In the early 1990▪s U.S. Federal funding was about $140M annually. This level steadily decreased across all Agencies in the late 1990▪s and early 2000▪s to about $90M per year, with the single exception of the DoD funding increases in both 2003 and 2004, coming from the U.S. Navy program in ship propulsion, which raised annual total funding levels in 2003 and 2004 to about $110M. One clear trend is the switch in funding from the more basic R&D to product development and demonstration projects. In 2004 about one half of the total U.S. Government funding went to only two programs – the U.S. DOE superconducting cable projects and the U.S. Navy electric ship propulsion program, which is due to be completed in 2006.
