REVIEW
OF
THE NEUTRON SCIENCE LABORATORY KENS
IN
THE HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION KEK, JAPAN

Summary and Recommendations
of
the KENS Review Committee

June 2004

<u>KENS Review Committee Members</u>

Doctor Suzuki, Kenji (Chair)
Professor Emeritus, Tohoku University
Advanced Institute of Materials Science
Japan

Doctor Carpenter, John M. (Vice-Chair)
Argonne National Laboratory
Technical Director of IPNS
USA

Doctor Carlile, Colin J.
Institut Laue-Langevin
General Director
France

Doctor Taylor, Andrew D.
Rutherford-Appleton Laboratory
Director of ISIS
UK

Professor Yasuoka, Hiroshi
Japan Atomic Energy Research Institute
Director of Advanced Science Research Center
Japan

Professor Hashimoto, Takeji
Kyoto University
Professor
Japan

Professor Yoshizawa, Hideki
Institute for Solid State Physics, The University of Tokyo
Head of Neutron Science Laboratory
Japan

Secretary — Professor Ikeda, Susumu
High Energy Accelerator Research Organization
Head of KENS Neutron Science Laboratory
Japan

Contents

Executive Summary

The history of KENS is one of tremendous achievement and innovation. KENS continues to deliver pioneering contributions to science and technology by improving the neutron performance of the source itself through innovative upgrades and by expanding and developing an imaginative suite of neutron scattering instruments. In addition, staff at KENS has initiated many R&D activities, which are essential to the development of J-PARC. That this programme has been achieved is worthy of praise; that it has been achieved within the current budget and staffing constraints at KEK is nothing short of a miracle. The plans outlined for R&D for J-PARC and the initial thoughts on the instrument suite continue this tradition of innovation and achievement.

The pulsed spallation neutron source KENS started its operation in 1980 as a user facility dedicated for condensed matter science and neutron physics. The first KENS Review Committee was held in 1997 and concluded that the KENS facility had successfully contributed to worldwide production of high quality scientific and technological research using pulsed neutrons, meeting the highest standards in the world.

Since 1997 the situation surrounding the KENS has much changed, because a new tantalum-clad tungsten target was installed to provide a 20% increase of source intensity in 2000 and several instruments were newly constructed or improved. The most striking impact on KENS will result from construction of a MW-class pulsed spallation neutron source, JSNS (Japan Spallation Neutron Source), based on the 3-GeV proton accelerator of the J-PARC (Japan-Proton Accelerator Research Complex) project, begun in 2000. Consequently, it is now necessary for KEK to survey the status of the KENS facility between 1998 and 2004 and the future program of the JSNS, which will start its operation in 2007.

The second KENS Review Committee was held in Friday and Saturday, 18 and 19 June, 2004, by the request of the Director General of KEK, Professor Yoji Totsuka. The Committee extensively evaluated the scientific and technical achievements accumulated from 1998 to the present by using the KENS facility, the status of the JSNS program, and the scenario of how to transfer and totally maintain the high activity of the present KENS in the future JSNS.

The conclusions and recommendations presented by the Committee are summarized as follows:

<u>Scientific achievements in KENS:</u>
The scientific research activities performed since 1997 have significantly contributed to the progress of materials research and neutron physics in the world; the quality of the research is at a very high international standard. The scientific fields covered by the KENS ranges from (a) Crystallography to (b) Liquid and Amorphous materials to (c) Polymer and Bio-materials and (d) Spin Dynamics in magnetic materials. Some highlights are structural evaluation of ferroelectric random access memory materials, mesoscale structure of aqueous solutions, nano-structure of polyacid brush in

amphiphilic block copolymer monolayer at the air/water interface, and observation of the spin excitation continuum in low-dimensional quantum spin systems. It should be also emphasized that the UK-Japan collaboration largely extended the KENS user programme and extremely enhanced scientific activities of KENS users.

JSNS activities in the J-PARC project:

Construction of four epoch-making day-one instruments is starting in the first stage of the JSNS program: (a) High-resolution chopper spectrometer, (b) High-resolution powder diffractometer, (c) Total scattering instrument, and (d) Horizontal reflectometer. Provisional scientific programs proposed for the experiments to be done using these instruments aim at the observation of extremely high resolution in space and energy. Some highlights are liquid/liquid interface, extremely high reflectivity measurement(~10^{-10}), measurement of milligram-order specimens, structure of nano-scale hybrid materials, and high-energy resolution spectroscopy over a wide energy and space range of strongly correlated electron systems.

It must be emphasized that KENS staff has been playing an indispensable role in the development and construction of the target, moderator, T_0-chopper, polarization filters, detectors, data acquisition system, engineering matters such as ^{7}Be transport and the measurement of the neutron yield at high proton energies, and so on, necessary in the JSNS program. In particular, the spectrometers to be installed at JSNS cannot be built without the long-accumulated experience of the KENS staff.

However, the Committee was very surprised to find that the budget for the instrumentation has not been approved so far in KEK. It is strongly recommended that construction of the four day-one instruments for which KEK is responsible be delayed until 2007, while raising the necessary money during the shut-down term of the facilities related to the KENS. In addition, the number of staff must be increased by more than 30.

Scenario regarding JSNS:

KENS staff and users are facing the serious problem of how to keep and develop their activities after decommissioning the KENS facility in 2005 until the start of operations at JSNS in 2007. The Committee suggests a special arrangement for the neutron partners, ISIS, IPNS, JRR3-M, and ILL, to support scientific activities of KENS staff and users during the period of no pulsed neutron source in Japan. This is an effective way to insure having the manpower of young persons that will be necessary after the commissioning of JSNS in 2007. KEK should arrange financial support for these collaborations.

Because KEK is in a very profitable situation with three different radiation sources, neutron, light, and muon, in the same campus and many research institutes located near KEK in Tsukuba city, a unique forum for materials structure science should be organized by KEK.

Introduction

The KENS Review of 2004, convened by the KEK Director General, took place on Friday and Saturday, 18 and 19 June, at KEK in the Seminar Hall of Building 4. The Committee members were C. J. Carlile, J. M. Carpenter, T. Hashimoto, K. Suzuki, A. D. Taylor, H. Yasuoka, and H. Yoshizawa. After welcome and introductions by Professor A. Koma, Director of the KEK Institute of Materials Structure Science, and designation of Committee Chairman K. Suzuki and Vice Chair J. Carpenter, and after reaching agreements as to procedures, an all-day program of presentations and discussions followed. On Saturday the Committee toured the KENS facility and met to discuss and formulate this report. Dr. Taylor was unable to attend but provided comments available beforehand to the committee.

The charge of the Committee is first to evaluate the operation, performance, and scientific achievements of the KENS in a period from the last external review in 1997 to the present. Secondly, the Committee was asked to review the state-in-art of the J-PARC (Japan Proton Accelerator Research Complex) project, which is a huge national project including the construction of a new MW-class pulsed spallation neutron source facility, JSNS (Japan Spallation Neutron Source). The third charge is to recommend how to keep and promote the activities of the KENS facility during the period of about three years between the shut-down of KENS and the start-up of JSNS. At the time of this meeting, sweeping changes are underway which affect KENS and its community of users.

KEK will complete building the new MW-class pulsed spallation neutron source facility JSNS at the end of 2007 collaborating with the Japan Atomic Energy Research Institute. Therefore, KEK has proposed a scenario for the shutdown and decommissioning of the KENS in 2005, as well as the move of scientific activities from the KENS to the JSNS. Reviewing the J-PARC activities and the scenario toward J-PARC is also charged to the Committee.

The first international Review Committee for evaluating the KENS activities was held in 1997. The committee concluded that there was a significant contribution by KENS to the progress of materials research and neutron physics in the world, but they recommended the increase in the number of KENS staff and the approval of the JHF (Japan Hadron Facility) project. This second Review Committee verifies the fulfillment of this recommendation.

Each reviewer presented to the chairman his report of the subject charged to him. This booklet is a summary and recommendation of the Review Committee completed by collecting the reviewers' reports and arranging them under the responsibility of the chairman. The result of the evaluation is reported to the Director General of KEK, Professor Yoji Totsuka.

General Survey of KENS

(1)KENS Operation

Conceived in 1978 and brought into operation in 1980, the KENS Facility has operated as an inter-university research center as a division of the Booster Synchrotron Utilization Facility (BSF) within the National Laboratory for High-Energy Physics (KEK). KENS was the first pulsed spallation neutron source dedicated to neutron scattering applications, following prototype installations ZING-P and ZING-P' at Argonne. The rapid initial realization of the KENS source and its continuous record of source and instrumentation improvements, accompanied by ever-increasing proton current, are a result of and a tribute to the high competence and great dedication of all involved. Highlights of recent developments include a 500-MeV proton beam current (10 μA at 20 Hz), evolution of target and moderator systems (through many stages) to the present highly efficient Ta-clad W disk target, optimization of decouplers and poisoned moderators, and cost/performance optimization of the Be reflector. These outstandingly commendable accomplishments result from applications of the experience gained over the years and of close and fruitful collaborations with Hokkaido University testing facilities and of Los Alamos National Laboratory neutronics simulation power. A theme carried out from the beginning of KENS into the present is the tight coupling of the primary neutron source (target) to the moderators, which provides a ratio of slow neutron current to proton beam power twice or more than that of other installations. KENS receives protons 2400 hours each year, operating with nearly perfect reliability. The companion muon research facility receives proton beam 2400 hours each year.

The KENS facility has seen continued development with the linear increase in beam intensity and delivery parameters being particularly impressive. This is a real achievement given the advent of J-PARC. Reliability has been satisfyingly high, reflecting well on component quality and maintenance routines. With the source still being relatively low power, the KENS team has taken advantage of the opportunity to reduce dimensions wherever possible in order to benefit from "brightness and coupling", the tight coupling of the source to the moderators. This means that the path from the incident proton beam to the output of the moderated neutron beam has been kept to a minimum, and thus losses have been kept to a minimum also. The ratio of thermal neutrons out to high-energy protons in is therefore much higher than has been achieved in higher power sources, meaning that good quality science can still be done. It is essential that elements of this philosophy be retained in the design of the target and moderator assembly for J-PARC, although it is more difficult.

The second experimental halls added in the 1997 provided for addition of six new instruments. Meanwhile, several instruments in the original hall have been upgraded or replaced. What is immediately impressive about the experimental halls at KENS is the dense concentration of instruments and instrumentation. Pulsed-source instruments are very different in concept to reactor-based sources, and new initiatives have therefore had to be explored. There simply has not been the time available or the quantity of pulsed sources around the world to reach the levels of development which have been achieved at reactor sources. Ingenuity has had to be employed in order to catch up here. One sees much evidence for this process at KENS. The combination of instrument quantity and quality, as well as variety, impresses the observer. Small-angle scattering machines, high-resolution spectrometers, and diffractometers have helped to define the standards for instruments world-wide and will feed directly into the instrument suite at

J-PARC. We congratulate the management for the continuing evolution of the instrument suite since 1997 despite instrument numbers remaining constant. Equally well done, there is a wide variety of groundbreaking, and ambitious, ancillary equipment which has been developed. One need look no further than the polarisation filters which are in use.

One point, which cannot be stressed too much, is the small number of high-quality young staff who have carried out these achievements. Scientists are young and necessarily self-sufficient. There are no armies of engineers and technicians here to whom jobs can be delegated. This culture is clearly a great resource, which will pay dividends in the operational culture at J-PARC.

(2) Personnel

The activities of KENS are supported by in-house staff, cooperating researchers from universities, local industry, and the "company people". Since 1998, the total number of KENS in-house staff has been almost constant (15 to 17) including professors, associate professors, research associates, and technicians. Many efforts to increase the staff as well as the budget (external and internal) have been made. The number of post-doc fellows and research assistants (part-time) has been increased up to 12 in FY2003, mainly by using the external budget. The total number of cooperative researchers (including B1-group researchers and students) became 80 in FY2003. It is noticed that the activities of KENS are actually supported by about 110 researchers.

KENS has now two major missions: KENS operation and J-PARC construction. Taking into account both KENS and J-PARC activities, the current number of permanent KENS in-house staff is absolutely too small.

(3) Budget

The special budget for upgrading the neutron source was approved in 2000. However, the annual budget for operating KENS, maintaining the neutron source, and improving the new spectrometers, around 250 million yens, has shown essentially no fluctuation,.

Since 1997, KENS staff has received many continuously-increasing Grants-in-Aid for Scientific Research, while the original budget of the KENS is almost constant. During the period of JFY1998-2003, KENS received funding from the Japan-UK contract. Further, in the period of JFY2004-2008, KENS staff will receive Grants-in-Aid for proceeding with KENS International Collaborative Research (including the Japan-UK collaboration) as well as for developing new neutron science fields for the J-PARC project.

(4) Inter-University Research Program

External scientists and the KENS staff have formed a Cooperative Research Group (B1-group) for each spectrometer. This is a unique feature of the KENS facility. Each B1-group has a strong obligation to develop, maintain, and improve its spectrometer as well as to act as a local contact for "pure" outside users. In return for such an obligation, the KENS gives each Bi-group about 50% of the total experimental period as well as financial support for research. Many research achievements in KENS have been produced by the B1-groups.

The Inter-University Research Program accepts proposals from academic researchers. Each proposal is received, refereed by three referees, and reviewed by the Neutron Science Committee (PAC). Since 2002, the program has accepted proposals twice a year. This has been working well. The increase of proposals in 2003 is due to doubling the yearly proposal opportunities.

There are three characteristic trends in the recent Inter-University Research Program. One is oversubscription, which results in an increase in the number of rejected proposals. The second trend is a concentration on some specific scientific subject, mainly materials science. Third, in order to help advance these subjects, new instruments, SIRIUS, SWAN, ARISA, PORE, and EXCED, have been installed and some of the other instruments, SWAN, VEGA, INC, LAM-D, LAM-40, INC, and RAC, have been upgraded.

In 2002 KENS had about 700 registered users , the sum of all members in proposals. Almost all users of KENS come from outside the facility as visiting scientists and research students from universities and institutes in Japan. Although users from overseas are still relatively small in numbers, eight oversea proposals were received in FY2003.

(5) Educational Activities

KEK takes part in the Graduate University for Advanced Studies (Sokendai) under MEXT. Sokendai is a university for doctoral studies. Some KENS staff are members of Sokendai, and they give lectures as at ordinary universities. Seven students have been supervised by KENS staff members during 1997 to 2003, and five of them obtained a PhD. In addition to their Sokendai affiliation, KENS staff members are frequently invited to be lecturers at external universities. It is also noted that KENS staff members are often asked to give introductory lectures for public people, that is, other than researchers or university students. In recent years, people in industry are gradually becoming interested in using neutrons, and KENS staff are asked to give talks for them. KENS is an appropriate place to host training schools, and financial support for these and all such purposes is highly recommended.

(6) International Collaboration

The second period of the UK-Japan Collaboration Program on Neutron Scattering began in 1997, with an innovative chopper spectrometer MAPS constructed at ISIS. About 20 scientific proposals and 110 experimental days from Japanese universities and institutes have been approved each year. The KENS-LANSCE and KENS-IPNS collaborations were also established in 1998 and 2000, respectively. Further, the KENS has collaborated with Asian countries. The KENS-BATAN (Indonesia) Collaboration was established in 2003. Also in 2003, KENS promoted the Neutron Science Collaboration between Japan and Korea, and workshops have already been held in both countries. A collaboration with Taiwan for new spectrometers in J-PARC is now in the planning stage.

This KENS-ISIS link has been particularly fruitful, resulting in powerful inelastic spectrometers being built at ISIS and the technology transferred back to KENS instruments. These instruments rapidly became flagships in the world of neutron scattering. This technology will doubtless benefit the new instruments being built at J-PARC, thanks to the far-sightedness of KENS leaders. One tangible inheritance of these collaborations is the twice-yearly UK-Japan meetings, which operate on the scientific as well as the technological level.

For three decades now there has been a valuable and co-operative collaboration with international efforts in the technology of pulsed neutron sources. This is exemplified by the setting up of ICANS in the early 70s in which KEK scientists were leading figures. Profs. Ishikawa and Watanabe from the university and the KENS side, respectively, played instrumental roles. This collaboration has proved to be extremely effective, and it is to the credit of all concerned that world-wide efforts have been co-ordinate in this way. KENS personnel are to be congratulated for their initiative and openness here.

As a result, many scientific collaborations have been developed which have used the best qualities of the Japanese team and the overseas teams, for example, one side providing high-quality samples and the other side, characterizing methods. As J-PARC becomes operational, there will be a concentration on getting the programme on the road, but these collaborations will still retain a mutual benefit and without doubt must be nurtured.

Research Activities in KENS

(1) Renewal of Pulsed Neutron Source

In 2000, KENS was renewed by replacing the whole target-moderator-reflector assembly (TMRA) with a new tantalum-clad tungsten target, which was fabricated by the HIP method. The gadolinium poison, giving a sharper pulse, was installed in the ambient moderator. The new target increased source intensity by about 20% compared to the former tantalum target. Cold neutron intensity of the former TMRA, which had decreased about 70% from its initial state, was recovered. Neutron performance was measured at several spectrometers. Cold neutron intensity is fully recovered and epithermal neutron flux was increased as the neutronic design calculations had indicated. The scattered-neutron profile shows low background and becomes more symmetrical by the shortened tail. At the total scattering spectrometer, the radical distribution function shows better resolution in position. As a whole, it can be said that the new KENS has a quite good ability to investigate materials.

(2) New and upgraded spectrometers

A new high-resolution powder diffractometer, SIRIUS, was completed in 1998, a new reflectometer, ARISA, was constructed under the collaboration of KENS and a Japanese polymer group in 2000, and an eV-diffractometer, EXCED, was constructed in 2000. Further, the detector system of the single-crystal diffractometer FOX was improved in 1997. The high-intensity powder diffractometer VEGA and small-to-medium angle scattering spectrometer SWAN were improved using a Grant-in-Aid in 2002. The chopper spectrometer INC was improved with the PSD in 2003.

(3) Scientific Research Achievements

(3-a) Crystallography

A number of experiments have been performed on the single-crystal diffractometer (FOX), Epithermal diffractometer (EXCED) and on two powder diffractometers (a versatile powder diffractometer, VEGA, and a state-of-the-art high-resolution instrument, SIRIUS). For structural analysis studies, strong efforts were concentrated to elucidate the relationship between material functions for practical applications and the structure of the materials themselves.

(3-a-i) Single-crystal diffraction (FOX and EXCED)

Two-step ordering in an fcc crystal was first observed on the Pt-rich Pt-Mn alloy. With a rising temperature, successive transformations, from the ABC_6-type to Cu_3Au-type transformation and then to a disordered fcc structure, were established. In addition, a variety of experiments have been carried out on the FOX spectrometer, for example, “SDW formation in the ordered Pt-12.5% at.% Mn alloy”, “Two-dimensional magnetic superstructure in a ternary alloy $TbRu_2Ge_2$”, “Multi-step metamagnetic phase transition under external magnetic field in $TbRu_2Si_2$”, and “Characteristic diffuse scattering in beta-Sn”.

The excellent diffraction experiments on natural abundant Gd compounds were achieved with an epithermal neutron diffractometer, EXCED. One of the highlights is confirmation of a peak at (1/2 1/4 1/4) from GdB6. It has been believed that this peak must disappear in Gd compounds because of lack of orbital moment of Gadolinium atom. This result completely renewed the concept of magnetic interaction of this class of compounds.

(3-a-ii) Powder diffraction studies (VEGA and SIRIUS)

It should be emphasized that continuous efforts have been made to improve these two powder instruments , and their performance is literally at a state-of-the-art level. From work with these spectrometers, 99 publications resulted from 1997 to 2004 (Instrumentation research group (B1), 62; general users, 31; and Industry groups 6). Work conducted on these two instruments is categorized as “Structural studies on new material and science”. Two of the important topics covered are “Ferroelectric random access memory materials” and “Origin of structural transition in the first pyroclore superconductor $Cd_2Re_2O_7$ and its orbital ordering”.

Development of the analysis method is crucial to powder diffraction studies. Along this direction, the development of the TOF/MEM method and its beautiful application to the study of a Li-ion conductor is one of the highlights in the powder diffraction studies conducted at KENS. An in-situ measurement of hydrogen alloys under hydrogen pressure offers another typical example of the strong instrumental support to new experimental techniques at KENS. The structural evaluation of a new electrode material, the lithium manganese spinel, contributed to the improvement of battery performance, and a study of the solid oxide fuel cell is expected to open a new energy life for industrial society.

(3-b) Liquid and Amorphous

Studying the nano-scaled structure of liquids and amorphous solids is one of the ongoing activities of the KENS and ISIS facilities. Between 1998 and 2003, the main subject in this field shifted from metallic system to a non-metallic one, including aqueous solutions and hydrogeneous materials. Based on experimental results obtained by using the spectrometers HIT, SWAN, LAM-40, LAM-D, LAM-80ET, INC in KENS, and MARI in ISIS, the excellent work completed so far has been published in 85 original papers.

These excellent activities are summarized:

- Static structure of energy materials; Observation of hydrogen atoms in hydrogen absorbing materials,
- In-situ measurement of molecular glass by using a novel cryostat,
- Mesoscale structure of aqueous solution,
- Collective motions in glasses,
- Dynamic structure of methane hydrate for a future neutron moderator,
- Hydrogen dynamics on the surface of nano porous silicon, and
- Structure of two-dimensional solids.

Two highlights are among the subjects previously mentioned: the study on the mesoscopic phase separation in a l-propanol aqueous solution, which is well characterized by a mass-fractal model, and the detailed dynamical structure of the Boson peak in SiO_2 glass, in which the buckling motion of a six-fold ring is first observed.

The nano-scaled structure of liquids and amorphous solids is expected to be a major field for the coming J-PARC. Significant step-up of instrumentation and the supporting system for this field is needed to keep the activity going in J-PARC.

(3-c) Polymer and Bio-materials

High-quality research output in the fields of polymers and bio-materials has resulted from the use of the neutron reflectometer (ARISA), the small-angle neutron scattering (SANS) spectrometers (SWAN and WINK), and the inelastic neutron spectrometer (LAM-40).

ARISA has been installed quite recently (2000) and opened for public users since 2002. Nevertheless, the reflectometer has already been producing quite good outputs and will certainly make further important contributions to surface science and technology. From SWAN and WINK came important contributions to examination of the static structures of polymers and bio-materials. We should note an outstanding research output obtained on keratin protein: results clearly proved that these spectrometers can help elucidate hierarchical structures extending over a wide length scale (from ~0.1 nm to ~100 nm). Exploration of such hierarchical structures and their cooperative dynamics will have an important impact on life science. LAM-40 has produced excellent research results on the dynamical aspects of glass-forming polymers.

In conclusion, the high-level research activities attained so far in this field should be further extended to various research topics by attracting a greater number of external users.

(3-d) Dynamics in Spin Systems

The dynamics of solids and liquids, particularly of magnetic materials, is one of the strongest research areas in KENS. In this review, we heard research achievements for (1) 1D antiferromagnets utilizing INC, MARI, and PRISM spectrometers, (2) High-T_c Superconductors by MAPS, (3)Magnetic Quasicrystals by LAM-40, and (4) Percolating system by IRIS, LAM-80ET, PRISMA, OSIRIS, and PONTA-NSE. Here, MARI, PRISM, MAPS, and IRIS are the spectrometers installed at ISIS. In what follows, we summarize briefly their achievements and evaluations.

(3-d-i) 1D Antiferromagnets

The inelastic neutron scattering experiment on 1D HAF systems, $CsNiCl_3$ (S = 1), $CsVCl_3$ (S = 3/2), and $CsCrCl_3$ (S = 2) with deferent spin quantum numbers, has been performed, and the dispersion relation for the magnetic excitations at low T as well as the T dependence of the inverse correlation length have been measured extensively. The good agreements between experiments and theoretical prediction confirm the validity of the spin-dependent quantum renormalization scheme. We are quite impressed by the systematic studies of the spin-dependent quantum effects in 1D HAF that should be classified as reaching a high level of achievement.

(3-d-ii) High-Tc Superconductor

Among the High-T_c(HTSC) Cu-oxides, both $(La,Sr)_2CuO_4$ (LSCO) and $YBa_2Cu_3O_{6+d}$ (YBCO) are the only systems in which the static and dynamical incommensurate properties in some carrier contents are reported. The time-of-flight technique with a pulsed neutron source is particularly well-suited for such wide and high-energy transfer measurements. Spin correlations of the optimally doped superconductor $YBa_2Cu_3O_{6.9}$ (T_c = 92.5 K) were extensively measured for wide energy and wavelength range on the MAPS spectrometer. The conclusion that incommensurability and intensity cannot be described by the so-called the stripe model is quite important and opens further discussions regarding the mechanism of High-T_c.

(3-d-iii) Magnetic Quasicrystals

Quasicrystals have distinct spatial symmetry characterized by highly ordered but non-periodic (quasiperiodic) atomic structure, which differs from both the periodic and random structures. To understand the dynamics of quasiperiodically-arranged spins, Zn-Mg-RE (RE: rare-earth) icosahedral quasicrystals have been studied by inelastic scattering experiments using LAM-40. They have shown the existence of the localized collective spin dynamics in the icosahedral Zn-Mg-Tb quasicrystal, appearing as a broad inelastic peak at 2.5 meV. This piece of work contributes to the understanding of the dynamical aspects of the quasicrystals and should be highly appreciated.

(3-d-iv) Percolating system

It is accepted that the atomic connectivity of a percolating network takes the form of a fractal. A diluted antiferromagnet is the simplest and ideal percolating network. When magnetic ions are randomly replaced by nonmagnetic ions, the Néel temperature (T_N) decreases, and $T_N = 0$ at the percolation concentration (c_P), where a percolating network spans in the crystal and the network may be of a fractal structure. The magnetic properties of a percolating network have been investigated by using single crystals of the two-dimensional Ising system, $Rb_2Co_cMg_{1-c}F_4$, and the two- and three-dimensional Heisenberg systems, $Rb_2Mn_cMg_{1-c}F_4$ and $RbMn_cMg_{1-c}F_3$. It is impressive that with measurements of the critical scattering on IRIS and LAM-80ET,researchers clearly correlate the percolation regime to the fractal structure in the square lattice. Although detailed studies should be continued, this work is unique and one of KENS's highlights in the area of pulsed neutron studies of Spin Dynamics.

JSNS facility in the J-PARC project

(1)JSNS Construction

KENS personnel have been central to the development of plans for the JSNS, including definition of goals, layout of the experimental arrangements, definition of the moderator complement, conceptualization and design of neutron scattering instruments (shared with JAERI and others), and development of instrument components, measurement techniques, and software. All of these activities continue.

JSNS started construction in JFY2001 and is planned to be finished in JFY2007. The JSNS will have 1 MW beam power with 25 Hz repetition rate and 1 μs pulse width. JSNS is a short-pulsed spallation neutron source, whose technology is based in important measure on experience in the KENS facility in KEK.

The 25-Hz accelerator repetition rate of the JSNS facility will allow unique performances among pulsed neutron facilities. Not only will intensity itself largely exceed that of present facilities ISIS (UK), IPNS (USA), and KENS (Japan), but also the slower repetition rate can give another important advantage for instruments, a wider time band with the time-of-flight method. It enables using slower neutrons and realizing high resolution with a long flight path without reducing available time frame. It is also unique in that all moderators are cryogenic liquid-H_2 moderators, which will give usable intensity for instruments in a very wide energy band with naturally narrow pulse-width down to low energy (~20 meV). JSNS will have 23 beam ports, a number determined after consideration of practical engineering constraints and users' demands. Those are 11 ports for high-intensity coupled moderators, 6 ports for good-resolution decoupled ones and 6 ports for high-resolution poisoned decoupled ones.

Established in 1980, KENS was the first pulsed neutron source user facility in the world constructed for neutron scattering applications. Since then KENS staff has been accumulating experience which has become indispensable to the promotion of the J-PARC project. Especially important are the following:

Target and moderator design, Determination of the required performance of a moderator for instruments and science, R&D work on a background suppression chopper, Helium polarizing filter, Nuclear polarization technique, detector development, data acquisition electronics, data acquisition and analysis software, and Promotion of its inter-university program. Based on those experiences, KENS staff will have a leading role in the JSNS, especially in the instrumentation group of JSNS.

(2)KEK instruments and sciences in JSNS

KEK and JAERI will construct 10 day-one instruments by the completion of the first phase of J-PARC in 2007. Among the 10 instruments, KEK is responsible for building four epoch-making instruments aiming at the observation of extremely high resolution in space and energy range:

(2-a) High-performance neutron reflectometer with horizontal sample geometry

This instrument has a declined beam line to make possible study of free liquid surfaces as well as liquid/liquid surfaces with the world's highest reflectivity of 10^{-10} up to $0.5Å^{-1}$.

(2-b) Super-High-Resolution Powder Diffractometer at J-PARC

This is the world's highest resolution powder diffractometer for study of the structure of hybrid nano-scale novel materials. The resolution (0.03%) is comparable to the highest resolution of SR powder diffractometers. The combination of these high-quality data from SR-XRD and JSNS will definitely open a new scientific window on materials structure study.

(2-c) High-Intensity Total Scattering Diffractometer

This is a high-intensity total scattering instrument to study liquid and disordered materials such as glass and amorphous solids in very high spatial resolution and at very high intensity, clarifying the structural hierarchy in materials for creating functions.

(2-d) High-Resolution Chopper Spectrometer

This is a high-resolution inelastic scattering instrument to study dynamics related to function and properties of a wide range of materials including a highly correlated electron system, magnetism, superconductor, amorphous materials, liquids, etc. The spectrometer covers very wide energy and special ranges.

(2-e) R&D of neutron devices

Neutron scattering instrumentation requires continuous development. This depends greatly upon what can be termed "peripheral" devices, which in fact are intrinsic to the performance of any given instrument. An impressive program of such developments has taken place at KENS, within a relatively restricted set of resources. The vast majority of these developments will directly benefit the instrument suite at J-PARC. Examples which can be quoted include the following:

- The building of t_0 choppers–fruit of the collaboration with Mechanical Engineering Center at KEK and very necessary for J-PARC. This work is well along and a prototype is in operation. Collaborations with ISIS, IPNS, and SNS facilitate the work of all parties.

- The program of neutron detector development, particularly high count-rate position-sensitive detectors which will be essential for J-PARC. For neutron detectors, specific attention is going to micro strip gas counters (MSGC), which have the prospect for sub-millimeter resolution and high data rates. Tests show interesting results. These efforts connect to the gathering world collaboration on neutron detector development.

- Neutron helium-3 spin filters, where an impressive storage time has been achieved. A prototypical system, based on Rb spin exchange, is under test. Pumping and ^{3}He-polarization lifetime questions are objects of study. The prototype system already gives results comparable with those in other laboratories, with whom the developers maintain communications.

- Particularly worthy of mention is the development of pulsed magnetic fields up to 32 Tesla (in collaboration with Tohoku University), which represents the highest available fields in the world for neutron scattering measurements. This will be especially valuable on J-PARC, where intensities in a single pulse will be particularly high and able to match the performance of this magnet.

- KENS played host to the International Neutron Optics conference in January 2004. Developments of neutron optical devices, a helium-free high-power refrigerator, and a device for polarizing protons in scattering samples are underway.

There are many developments both in Japan and worldwide in these areas, which complement the programs at KENS. The panel observes that many of these activities will benefit from close collaborations with other centers. It may even be possible to pool resources in order to achieve the optimum use of resources.

Scenario looking toward J-PARC

(1) Role of KENS in J-PARC project

KENS will become the main body to support an inter-university program, and JAERI will mainly support industrial use and other activities in JSNS. J-PARC will be operated under cooperation by KEK and JAERI. It is natural and important that KENS staff participate in the JSNS facility, work with JAERI staffs, and share the supporting of users from universities and industries. The arrangements under which KENS scientists have carried out their 25-year program of source and instrument development, collaborating with university participants and “company people” are especially noteworthy. These collaborations will be extremely useful in relation to J-PARC.

(2) Budgetary scheme for constructing instruments

JSNS will have 23 neutron beam ports, a number decided on by taking engineering constraints into account. By the time of full operation of J-PARC (expected to be FY2012), KEK will have constructed 10 instruments, including university-funded instruments, and JAERI will also have constructed 10 instruments. Because of budgetary constraints, JAERI and KEK will collaborate and complete only 10 day-one instruments by the time of the first neutron production in December 2007. Hence, KENS has the main responsibility for four of the 10 day-one instruments:

High-resolution powder diffractometer,

Total scattering instrument,
Horizontal reflectometer, and
High-resolution chopper instrument.

KEK originally proposed a budget for the neutron instruments in JSNS. However, this proposal was postponed to the second phase of the J-PARC project. Therefore, no budget for neutron-related matters has been allocated to KEK, while a budget for the neutron target station and facility construction were allocated to JAERI. This is a serious deficiency of the project budget scheme.

Therefore, we recommend as follows;
(2-a) The PS complex (Proton Synchrotron accelerator complex including KENS, the nuclear physics facility, and the K2K neutrino line) will probably be shut down in 2005. Along with this shut-down, KEK should request a new budget to move the present PS activities to J-PARC. By spending a part of this new budget and by utilizing the existing KENS instruments, KENS should construct the main parts of the afore-mentioned four instruments by the end of 2007.

(2-b) KEK is the main body of the inter-university program. Under collaboration with the universities, KEK should have another six instruments when full-power operation starts in J-PARC.

(3) Manpower

According to international standard, a reasonable and practical number of staff members to operate a world-class instrument is five. Currently having only 17 staff members, KENS will eventually need a staff of at least 50. Therefore, it is obvious that KENS will definitely need a drastic increase in staff.

Hence, the committee recommends increasing the number of KENS staff along with and according to the increase of JSNS instruments for which KENS is responsible. Such an increase is also a good way to keep Collaborative Researchers from universities similar to the present circumstance at KENS, collaborating with several universities. However, the committee feels that whilst a source the size of KENS can survive at this level of staffing, it will not be able to be transferred to J-PARC as a model system. The huge science factory which J-PARC will become, with its thousands of users, will necessitate a change of scale, a different paradigm, and a widening of the variety of staff and support facilities.

(4) Collaboration

In a period of 2005-2008, there will be no pulsed neutrons in Japan. Therefore, it is very important to have support and/or special arrangements from international partners, ISIS, IPNS, JRR3-M, and ILL, to maintain activities by Japanese scientists, including KENS staff, KENS collaborative researchers, and the B1-group members, during the dead time. For such an arrangement, KEK must prepare ample financial support.

Conclusions and Recommendations

In 1997, the first Review Committee was held for evaluating the scientific and technical achievements accomplished during the 17 years since the KENS operation began in 1980, and concluding that the KENS facility was remarkably successful in promoting materials science and neutron physics research by means of a pulsed spallation neutron source and functioned at the world's highest standard.

Since 1997 the KENS has much changed. A new tantalum-clad tungsten target was installed to provide a 20% increase of source intensity in 2000, and several instruments were newly constructed or improved. The most striking impact to the KENS is the year 2000 commencement of construction of a MW-class pulsed spallation neutron source, JSNS, based on the 3-GeV proton accelerator of the J-PARC project. Therefore, the second Review Committee was called up in June 2004 to survey the status of the KENS facility between 1998 and 2004. The charge given the Committee by the Director General of KEK, Professor Yoji Totsuka, is to evaluate the scientific and technical activities in KENS, to review the JSNS program in the J-PARC project, and to recommend a way to maintain its activities during the period between shut-down of PS and start-up of J-PARC.

The Committee extensively studied the achievements and activities carried out by KENS staff and users by hearing their presentations, reading the written documents, and visiting the facility site. The conclusions and recommendations of the Committee are as follows:

1. The scientific and technical achievements carried out so far in the KENS have significantly contributed to the progress of condensed matter research and neutron physics in the world. This research is of the highest quality according to the world-wide standard. The productivity continuously maintains a high level. Achievements accumulated in KENS are certainly helpful to realize the J-PARC project and cannot be replaced with any other ones.

2. KEK and JAERI will construct 10 day-one instruments by the completion of the first phase of J-PARC in 2007. Among 10 instruments, KEK is responsible for building four epoch-making instruments aiming at the observation of extremely high resolution in space and energy range:

- High-performance neutron reflectometer with horizontal sample geometry,
- Super-High-Resolution Powder Diffractometer,
- High-Intensity Total Scattering Diffractometer, and
- High-Resolution Chopper Spectrometer.

The Committee expects that these spectrometers installed at JSNS could open challenging doors to the frontier of materials structure such as mg-order small specimens, liquid/liquid interface, nano-scale hybrid material and electron-correlated materials under extreme environmental conditions.

3. It must be emphasized that KENS staff has been playing an indispensable role in the research and development of peripheral devices such as target, moderator, T_0-chopper, polarization filters, detectors, data acquisition system, and so on, which are necessary to the JSNS program. In particular, the instruments to be installed at the JSNS cannot be built without the long-accumulated experience of the KENS staff.

4. The Committee was very surprised to find that the budget for the instrumentation has not been approved so far in KEK. Therefore, the Committee strongly recommends that the four day-one instruments for which KENS is responsible be constructed with monies raised during the shut-down term of the facilities related to the KENS. In addition, the Committee expects that substantial arrangements for preparing the budget for the construction of the remaining six instruments in the second phase begins earlier than previously planned.

5. KENS staff and users are facing the serious problem of how to keep and develop their activities after the shut-down of the KENS facility in 2005 until the start of the operation of JSNS in 2007. Therefore, the Committee suggests a special arrangement with the neutron partners, ISIS, IPNS, JRR3-M, and ILL, to support scientific activities of KENS staff and users during the period of no pulsed neutron source in Japan. This is an effective way to insure the manpower of young persons necessary when starting the operation of JSNS in 2007.

6. Despite their excellent activities, the low number of in-house researchers is serious. The Committee agrees with the proposal of KENS that the number of in-house staff must be increased by more than 30. Meeting the following needs is important to assure the future activities of KENS, especially with regard to the J-PARC project:

(1) Drastic increase in the number of in-house researchers,
(2) System of employing "senior post-docs", which allows some excellent post-docs to stay more than two years but less than five years in total, and
(3) An increased number of Ph.D. students who are associated with such national facilities as KENS. KENS staff should attract more young Ph.D. students to neutron scattering research by way of inter-university programs

7. KENS has intensively expanded the international collaboration outside Japan with pulsed neutron partners ISIS, IPNS, and LANSCE. These collaborations are certain to continue and expand to Asian partners in Indonesia, Korea, and Taiwan. The Committee well recognizes that the J-PARC project must be a flagship in the world societies of neutron scattering and recommends that KEK promote more valuable co-operative collaboration particularly in the development of pulsed neutron technology.

8. KEK has a splendid situation for the total research of materials structure, because the three different kinds of radiation source, neutron, light, and muon, are operated within direct-contact distance. KEK is located in Tsukuba city, where more than 80 government and private research organizations exist. Therefore the Committee suggests that KEK should take the initiative to organize a forum for promoting mutual collaboration in the field of materials structure research.

9. Finally, the Committee asks the Japanese government and KEK not to delay the construction of J-PARC behind its present time schedule. This is a very crucial point to be compatible with the collaboration and competition among ISIS, SNS, and JSNS.