Report of the Review Committee on the Institute for Solid State Physics, the University of Tokyo (ISSP)

Executive Summary

After the Institute for Solid State Physics, the University of Tokyo (ISSP) has been operating for 5 years on the new Kashiwa campus, the activities of the Institute during that time should be reviewed and recommendations for its future should be made.

The review process and planning for the future has become more urgent due to the recent changes in the university system in Japan, which will also have lasting consequences for the ISSP.

The review was done by an International Review Committee which visited Kashiwa campus from November 14 – 16, 2005. During the two and a half days the Institute presented itself through a number of talks, laboratory tours and a poster session. Detailed discussions with the Director of the Institute and a number of research leaders took place so that the Review Committee could obtain a rather complete overall view of the past and the present character of the scientific work, working conditions and the budget situation.

Restructuring the University system in Japan has had an immediate consequence for the financing of the ISSP which is affiliated now more than before with the University of Tokyo. In the past the Institute had negotiated directly with the Ministry of Education, Culture, Science, Sports and Technology (MEXT) for the part of the budget which concerns facilities serving the science community of Japan as whole while the budget for educational purposes was determined by the President of the University. In the future this distinction may no longer be made. Instead the total budget of the ISSP, including the one for large facilities (neutron scattering, synchrotron radiation etc.), will be carried by the University of Tokyo. One early consequence of these changes has been that the plans for the construction of a High-Brilliance Light Source Facility (Super SOR) at Kashiwa campus had to be given up for the time being, on the reason that they would overstrain the financial resources of the University of Tokyo. The Review Committee understands and accepts this decision by the University. It should be kept in mind though, that the possible construction of a High-Brilliance Light Source was a prime argument for moving the ISSP from its location in Roppongi to Kashiwa campus. A possible compensation for the cancellation of the ring construction would be very desirable, as mentioned later.

When the budget requests from the ISSP are negotiated with the office of the President of the University of Tokyo in the future, a clear distinction should be made between those for educational duties and the ones required to ensure the leadership of the ISSP in the condensed matter community of Japan through its own research activities and the service to the whole community.

Basic research pursued on the highest international level as should be true for the ISSP requires stable financial support over long periods of time. Nothing is more damaging to high quality work than large fluctuations in the budget. The Review Committee trusts that the University of Tokyo and MEXT will be well aware of this fact in the future as they have been in the past. It also trusts that it is understood that for an institution like the ISSP to provide facilities that will adequately serve the scientific community of Japan, extra support for major investments of the order of ¥ one (or even several) billion will be required from time to time.

Present standing of the ISSP

The 3rd generation period of the ISSP started after a review of the Institute in 1995 and included the move to Kashiwa campus which was completed in the year 2000. The goal of the Institute has been to become an internationally recognized research institution of the highest level. This has been achieved by now. The

Institute belongs presently to a small group of worldwide leading research institutes in condensed matter physics. This statement is substantiated by a detailed description of the accomplishments of the five Research Divisions and the three Research Facilities in the main part of this report. This description is supplemented by a number of recommendations for the different groups. In the following we list the most important of them.

Future of the ISSP as a leading research institution

The landscape of Solid State and Condensed Matter Physics is constantly changing. In order to retain its leadership role in Japan and internationally the ISSP must not only maintain and revitalize its outstanding research groups and facilities but also seek out and establish a leadership role in emerging areas of condensed matter physics. To meet those challenges the Review Committee is making the following recommendations:

Concerning the research program as an Institute within the University Tokyo and as an Institution serving the needs and demands of the scientific community of Japan:

- The staff which was involved with the planning of the Super-SOR in the Accelerator Physics Group should be transferred to other institutions where its expertise and its experiences are required and can be used. The positions which then become available for the ISSP should be used to install a new group in one of the emerging new fields in condensed matter physics. We advise to consult in the decision making process also colleagues from outside and to consider possible interfaces with other activities at the Kashiwa campus.

- The division of Nanoscale Science should be asked to work out a plan for its future development.

- The Materials Design and Characterization Laboratory are very inhomogeneous in its (widely recognized) research activities and therefore should be restructured. The excellent activities in physical chemistry deserve special recognition with the possible consequence of creating a chemistry division. The supercomputing facility is first-rate, and should continue to provide an extremely valuable service to the condensed matter community in Japan.

- New beamlines in the soft X-ray regime should be built up at existing low-energy synchotron radiation facilities either in Japan or abroad.

- A beamline within the pulse neutron source project (JPARC) should be implemented.

- The investment for a 100 Tesla and 100 milliseconds long pulse magnet is endorsed.

Concerning the interaction of the ISSP with the international science community:

- The Institute should compete for good foreign Ph.D. students. In order to be competitive, tuition fees for Ph.D. students should be waived and student support should be made competitive with other institutions internationally. Otherwise it will be very difficult to link the ISSP to other centers of science and research outside Japan more strongly than in the past. For the moment this may be achieved on a practical basis, e.g., by employment as a Research Assistant, but on a long term a more solid basis is required with the involvement of MEXT.

- The program for foreign guests at the ISSP should be increased.
- The program of international workshops could be extended.
- Exchange of Ph.D. students with foreign Universities may be a step to improve international contacts.

Concerning the embedding of the ISSP in the Japanese science community:

- The ISSP should make greater efforts to ensure that the opportunities it offers Japanese science students become more widely recognized.
- By creating the new beam lines of synchrotron radiation and neutron recommended above and the pulsed high magnetic field laboratory that the ISSP is going to build, the services to other research institutions will increase. It is recommended that this trend will be continued.
- Offering undergraduates the opportunity to work at the ISSP during summers early in their undergraduate carriers would increase their interest in the Institute. They might be more likely to consider condensed matter physics as their future field, and for their graduate study.

Concerning the role of the ISSP within the University of Tokyo:

- The cooperation with the "Graduate School of Frontier Sciences" on the same campus should be enhanced as much as possible. In conjunction with the graduate school, the ISSP can substantially extend its possibilities, including work in emerging fields. The Review Committee encourages the ISSP to use these opportunities.
- Better opportunities should be made available for ISSP members who are willing to lecture at the Hongo campus. ISSP members are encouraged to make efforts on an individual basis for good Ph.D. students.
- Other outstanding groups at the University of Tokyo should be encouraged to use more than in the past the unique facilities of the ISSP.

Concerning general aspects:

It is recommended that the ISSP continue to look actively for especially qualified women researchers in physics and related fields. At the same time, the Review Committee realizes also that this is difficult due to the limited number of female physics students. Quality standards should not be lowered in this search as this would be counter productive.

In conclusion, the high international standing of the ISSP is reconfirmed. The Review Committee considers it a pearl in the crown of the University of Tokyo, and expects it to remain a central figure in research within the University, throughout Japan, and within the world scientific community for years to come.

Detailed Report

I. Preface

The Review Committee was invited by the director of the ISSP Prof. K. Ueda and by the chairman of the Preparation Committee Prof. Y. Iye to evaluate the Institute by visiting it on Kashiwa campus. The members of the Review Committee were:

Prof. Paul M. Chaikin, New York University/Princeton University, USA
Prof. Jacques Flouquet, CEA Grenoble, France
Prof. Peter Fulde (chairman), Max-Planck-Gesellschaft, Dresden, Germany
Prof. Steven G. Louie, University of California, Berkeley, USA
Prof. Kazumasa Miyake, Osaka University, Japan
Prof. Douglas D. Osheroff, Stanford University, USA
Prof. Kazuhiko Seki, Nagoya University, Japan
Prof. Charles V. Shank, Berkeley National Laboratory, USA

The visit took place from November 14 – 16, 2005. The schedule of the visit is found in the Appendix of this report. It consisted of nine oral sessions in which the Director of the ISSP the five Research Divisions and the three Research Facilities of the Institute reported on their scientific programs and plans for the future. In addition two tours of the Laboratories and a poster session took place. The Activity Report 2005 was sent before the meeting to the Review Committee members. So an adequate preparation of the meeting was ensured.

II. Purpose of the Review

The purpose of the review was stated in the invitation letter: to asses the activities of the ISSP, to make recommendations and to evaluate the plans for the future development of the Institute after moving to Kashiwa campus with particular emphasis on points of success and points to be improved.

The Institute consists at present of five Divisions:

Division of New Material Science
Division of Condensed Matter Theory
Division of Nanoscale Science
Division of Physics in Extreme Conditions
Division of Advanced Spectroscopy

and three Research Facilities

Synchotron Radiation Laboratory
Neutron Science Laboratory
Materials Design and Characterization Laboratory.

III. Historical context

The ISSP was founded in 1957 as part of the University of Tokyo. During the first twenty years of existence (“First Generation”) it served as a well equipped laboratory of materials which helped to bring in Japan science in this field to a respected international level. A restructuring of the Institute, starting its “Second Generation” aimed at establishing most advanced experimental techniques in order to enter new territories. That included creation of a Division of Physics in Extreme Conditions, construction of a Neutron Scattering Laboratory and building a Synchotron Radiation Laboratory. Also a Division of Materials Development was started.

The review of the ISSP in 1995 by an external Review Committee served as a start into the “Third Generation” of the Institute. The goal was to become an international center of materials sciences and to open new frontiers in that field. This has been achieved by searching for new physical phenomena through combinations of different extreme external conditions and by artificially designed materials. In the year of 2000 the ISSP moved from Roppongi to the Kashiwa campus and reorganized itself. At present it consists of the five Research Divisions and three Research Facilities listed above. There are also by now three Visiting Staff Divisions existing. The originally set goals have been successfully reached to a large extent.

With the transformation of the University of Tokyo into a national university corporation the ISSP has to respond to the new situation. It also has to consider its future role as one of the world leading institutes in condensed matter physics.

IV. The ISSP as part of the University of Tokyo

The restructuring of the University system in Japan has a number of direct consequences for the ISSP. Although it has always been part of the University of Tokyo, the Institute has in the past negotiated directly with the Ministry of Education, Culture, Science, Sports and Technology (MEXT) the part of its budget which concerned facilities serving the science community of Japan as a whole. These facilities deal with neutron scattering, synchrotron radiation, running a supercomputer etc. and are a basis of the strong international standing of the ISSP. On the other hand, the budget of the Institute for educational purposes has been determined by the President of the University. This has changed now. In the future the total budget of the ISSP will be carried by the University of Tokyo and the distinction made in the past has become obsolete. One immediate consequence of that change has been that the construction of a High Brilliance Light Source Facility (Super SOR) at Kashiwa campus, a prime reason for the ISSP to move from Roppongi to Kashiwa campus has been cancelled. It would have overstrained the financial resources of the University of Tokyo. The Review Committee understands and accepts this decision.

Basic research pursued on the highest international level requires stable financial support over long time periods. Large fluctuations in the budget are deadly for high-quality work. An institution like the ISSP providing facilities which serve the scientific community of Japan needs extra support from time to time for major investments of the order of ¥ one (or even several) billion. Otherwise it will loose its position in international competitions. The Review Committee trusts that the University of Tokyo and MEXT will be aware of this fact in the future as they have been in the past. It suggests that in the future when budget requests are negotiated with the office of the President of the University of Tokyo a clear distinction should be made between requests for educational duties and those to ensure the leadership role of the ISSP in condensed matter physics in Japan through its own research activities and services for the whole community.

Distinct from economical questions is the embedding of the ISSP as an academic institution within the University of Tokyo. The Review Committee feels that better opportunities should be made available for members of the ISSP who are willing to teach at the Hongo campus. It encourages ISSP members to make efforts on an individual basis for good PhD students. There is a great opportunity to strengthen cooperations with the Graduate School of Frontier Sciences on Kashiwa campus. They should result in joint research efforts in new emerging fields.

V. The ISSP within the science community

The goal of the "Third Generation" of the ISSP was to become an internationally known center of materials sciences. This goal has been reached. The Institute belongs by now to a small number of world leading institutes in solid-state physics. The Review Committee recommends doing undertaking now the next step towards larger internationalization. It implies educating and exchanging foreign students, hiring foreign post-docs and sending the best young researchers of the ISSP for some time abroad. It also implies extending the guest program for foreign visitors. The importance of an institution like the ISSP as a center of the community has increased after the conversion of national universities into national university corporation. Since the "select and focus" policy will make research at small or local universities more difficult, it is important for the active people in these universities to have a place where they can pursue high quality research and interact with other active researchers.

As regards competition for good foreign students the tuition fees for PhD students should be waived. Otherwise it will be very difficult to link the ISSP more strongly than in the past to other high-quality centers of science outside Japan. For the moment this may be achieved, for example, by employment as Research Assistants within the different projects. On a long term though this matter should be dealt with in a more systematic way with the involvement of MEXT. Furthermore, the program of international workshops should be extended. It would increase the visibility of the ISSP and more important it would bring the results of the Institute earlier to the attention of the international community than it is presently the case.

VI. The Research Division and Research Facilities

In the following an assessment of the five Research Divisions and the three Research Facilities is given. Recommendations have been added at appropriate places.

Division of New Materials Science

The work on advanced materials of ISSP has lead to important discoveries with an excellent interplay between new materials, macroscopic and microscopic measurements and theoretical development.

Magnetism and superconductivity

The data published by the Takigawa group (NMR) and Sakakibara group (thermodynamic measurements) are known to be very sound and thus are an important basis for theoreticians. A recent example is the study of the frustrated quasi-two-dimensional dimer system $SrCu_2(BO_3)_2$ with the highlight of the study of the high magnetic field 1/8 plateau phase. There is clear evidence for a symmetry breaking spin superstructure. In the same spirit, i.e., to discover new order parameters, experiments on $PrPb_3$ by neutron scattering with the proof of modulated quadrupole ordering are considered a major break through.

The observation of exotic superconductivity at the borderline of charge ordering or magnetic instabilities is still a rich domain of research with quite different interplays. Different studies were realized on the new 1,1,5 cerium family and notably on $CeCoIn_5$ suspected to be at zero pressure near an antiferromagnetic instability. An important discovery is the clear evidence of a first-order transition seen in the upper critical field line for $H/H_{C2} > 0.8$ and the occurrence of strong anisotropies in the angular dependence of the magnetic-field response relative to the crystal axes measured either by thermal conductivity or specific heat. For this last measurement, a d_{xy} order parameter has been favored in agreement with the proposal of superconductivity induced by valence fluctuations. Extensions of the experiments to lower temperatures will be worthwhile notably to clarify the discrepancy
between the two probes used until now.

Organic conductors

ISSP is fortunate to have Prof. Mori on its faculty. She has been involved in some of the most important discoveries in the field of organic superconductors and continues to innovate and discover remarkable materials.

The Mori group has recently worked on two major problems in organic conductors, control of the band filling of a series of organic charge transfer salts, and structural control using designed steric hindrance. The materials produced in this group fit perfectly with the expertise of several other groups at ISSP and together result in first-rate science. The organic conductors are strongly correlated systems, with high compressibility, high crystalline perfection and long mean free paths. As such they are ideal systems for high pressure and high magnetic field studies. In fact, the phase diagrams produced by these variations are a virtual textbook for modern solid state physics. A typical example is the newly discovered beta-(meso-DMBEDT-TTF)$_2$PF$_6$ system which shows a competition between checkerboard charge ordering and superconductivity. The determination of the (P, T) phase diagram is an excellent example of a successful merger between the realization of a new material and its subsequent study under pressure and magnetic field. Higher applied magnetic fields are expected to lead to new superconducting phases and also to a strong variation of superconducting and charge ordered states. Transport measurements on charge-transfer complexes composed of inorganic anions (with localized moment) and molecular donors are particularly interesting and so are studies on electroluminescence spectra of bimolecular light emitting diodes.

Some of the new capabilities of the ISSP should make studies of these materials even more profound and exciting. For example, the new ability of the photoemission group to probe the bulk (rather than the surface) electronic structure will make detailed electronic studies of organic conductors possible for the first time. This should provide insight into the nature of the correlated states and challenges for the theory group.

Observations:

This is a core research activity at ISSP and in Japan. The presence of a first rate chemical synthesis group with close contact to the experimental and theoretical physicists is ideal.

Recommendations:

This group operates excellently in the ISSP context and should continue at least at the present level. The departures of M. Ishikawa (retirement) and Y. Matsuda (for Kyoto University) demand to open at least a new position for an experimentalist (transport and/or optic).

New materials under high pressure

The exploration of new materials under pressure oriented to earth science is obviously a large field of research. With the combined use of diamond anvil and laser heating different materials under various conditions can be obtained. Furthermore the group succeeded in the determination of many crystallographic structures as well as precise phase equilibrium studies. Its interaction with other ISSP researchers appears to be very successful.

Recommendations:

- Reinforce the interaction with the high pressure user facility.

Division of Condensed Matter Theory

From the beginning, members of the Division of Condensed Matter Theory of the ISSP have made original, lasting contributions to condensed matter physics. For examples, essential advances to the Kondo effect, itinerant magnetism, and transport properties in two-dimensional electron systems were made at the ISSP. After the discovery of high-T_c superconductivity in the mid '80, much high quality work in strongly correlated electron systems have been produced. Theoretical studies at the highest international level have also been carried out on the electronic, structural, transport, optical, and magnetic properties of a variety of materials and nanostructures. The works of the Ueda group and the Imada group, for examples, have attained international distinction; also the work of some of the young people such as Sugino are first-rate.

A tradition of the theory group of the ISSP has been a good balance between many-body theory on model systems, including exact solution in one dimension, and theories of realistic systems based on first-principles calculations or cluster analysis taking into account characteristic properties of individual materials.

During the third generation that started in the '95, the quality and quantity of the research continued to maintain at a high level. However, two senior faculty members, Fukuyama and Kotani, retired two years ago, and another two senior theorists, Takayama and Takahashi, are expected to retire in a couple of years. Moreover, Imada is now moving to another institution. This transition provides a major challenge and also a tremendous opportunity for ISSP to recruit several exceptional theorists in the near future, either senior faculty members with international distinction or promising young faculty at the junior level.

Recommendations:

The Review Committee feels that a number of important considerations need to carefully enter into the hiring process. The personnel transition in the theory division provides a unique opportunity for the division and ISSP to move into new research directions. A new frontier in theory is the exciting recent development of combining ab initio electronic structure methods with many-body theory to attack real materials systems with strong electron correlations. Links to experiment and experimentalists in the Institute should also be stressed from the viewpoint of synergetic effect in the ISSP. Thus, first-principle calculations in strongly correlated systems including f- or d-electrons are an area to be strengthened in view of the high-level experimental activities in this field at the ISSP. Another need is to find someone with broad background and interests in a range of phenomena, someone like Fukuyama, who will able to interact with many groups and provide leadership and vision for the division. Moreover, with the strong future growth of soft matter and nanoscience here in Japan and worldwide, it would also be wise to consider the possibility of adding to the division of a first-rate researcher in the area of the theoretical study of the structure, properties and dynamics of soft matter systems.

Division of Nanoscale Science

Nanoscience consists of many subfields interrelated by an attempt to understand the crossovers from single atom/molecule to more complex structures and from quantum to classical behavior. Aside from the fundamental questions of electronic coherence and dynamics of few spin systems a large driving force for this field lies in its potential applications to fast, high density and novel information storage and processing and for biological and chemical sensing and activity. More traditional areas of nanoscience deal with electron coherence, charging and interference effects for one and two dimensional structures on the 0.1 - 10 micron scale. Forefront areas include spin interactions, dynamics, and coherence on similar and smaller scales (spintronics), electronic, optical and transport properties of structures on the 1 - 100 nm scale (nanoparticles) and organic nanoscale particles from biology (e.g., proteins) and novel chemistry (e.g., dendrimers). Forefront areas also include novel lithography to produce patterns on a sub 100 nm scale by writing, imprinting or self-assembly.

The Division of Nanoscale Science is a rather new organization in the history of ISSP, which was formed at the reform of the University of Tokyo in 2004 into the university corporation by unifying the research area of Surface Science and the mesoscopic physics part of Condensed Matter Experiment. The activity of the group can be also classified according to the former organization,

(1) the construction and characterization of nanoscale systems based on semiconductors and oxides, and

(2) the surface science on well-characterized surfaces.

Mesoscale systems

At ISSP there is first-rate research in mesoscale physics in the groups of Iye and Katsumoto. Using the in house molecular beam epitaxy and electron beam lithography on semiconductor heterostructures they have structured two dimensional electron systems to form periodic arrays of dots and wires. Novel interference effects have been seen involving commensurability of cyclotron orbits and periodic arrays and separately interference from coupling to spin-degrees of freedom. Spintronics is being ably pursued by both Katsumoto's group and the newer Otani group.

Surface science

As for the surface scientific studies 3 associate professors are working. The subjects span the exploitation of experimental methods such as atomic-resolution AFM at low temperatures, nano-structure fabrication, and manipulation of the surface by various means such as career injection, adsorption and surface reaction with molecules. Hasegawa's Group is working on the exploitation of the use of STM techniques at atomic resolution for examining interesting systems realized on clean and well-defined surfaces, with control of conditions such as low temperature, high magnetic field, and irradiation by synchrotron radiation. For example, they were able to observe Friedel oscillations near a step at the surface by a periodic variation of the surface potential by scanning tunneling spectroscopy (STS). Komori's group is working on nanostructures formed on surfaces, e.g., by adsorption of nitrogen atoms on Cu(100) surfaces. Such surfaces could be further used for getting nanostructures by subsequent deposition. Also they succeeded to manipulate the Ge(100) reconstructed surface by injecting charge careers into the π and π* surface bands. Yoshinobu's group is working on molecule-related aspects, e.g., the migration of adsorbed molecules on metal surfaces examined by the space distribution of adsorbed molecules by STM and the unique covalent bond formation reaction discovered by him between unsaturated molecules on reconstructed Si(100) surfaces. The latter are examined by various tools.

Observations:

The current subjects are interesting, with active publications and appreciable amount of joint research. At the same time the committee feels that work on inorganic and organic nanoparticles is missing. Electronic, magnetic, optical and transport properties of inorganic nanoparticles would fit well with the expertise and interests of the present groups.

Recommendations:

Efforts should be made to further reduce the length scale of the structures and the range of materials studied by adding a group headed by a chemist or physicist specializing in nanoparticles (e.g., along the lines of the Lieber Group at Harvard, or the one of Alivisatos at Berkeley).

This possible extension should distinguish the ISSP activities from those of competing centers. For accomplishing this, it is recommended

(1) to promote the interaction among the groups in the Division and with other groups in the ISSP,

(2) to consider the incorporation of an increased variety of methods to form various types of unique nanostructures utilizing various methods including chemical and biological aspects, possibly through the appropriate involvement of the expert researchers in these related fields,

(3) to increase the contact with people working on practical applications.

Division of Physics in Extreme Conditions

The work in this Division includes research at ultra-low temperatures, in high magnetic fields and under high pressure.

Ultra-low temperature group

Japan has long been a world leader in studies at ultra-low temperatures (ULT). This effort is carried out by Hidehiko Ishimoto and Minoru Kubota of the ULT group. The facilities supporting this work include four copper nuclear demagnetization cryostats and two rotating cryostats, both of which are recent additions to this effort. This is a large number of cryostats for just two people to operate, but this number makes it possible for the ISSP to undertake long-term collaborations both with Japanese and foreign scientists without having to repeatedly change the sample chambers on these complex cryostats.

The ULT group has long been active in studies of nuclear magnetism in solid ^{3}He and ^{3}He films localized on graphite surfaces. These studies have involved other researchers in Japan and beyond. Recent studies of the 4/7 registered second layer of ^{3}He atoms on graphite down to 10 μK have strongly suggested that this is a spin liquid at very low temperatures, owing to both geometrical frustration and a combination of ferromagnetic and antiferromagnetic spin interactions. This is a very impressive piece of work and one that has had broad impact. David Ceperley at the University of Illinois has shown repeatedly that he can calculate the frequencies for various ring exchanges in such systems with ~10% precision. In addition, the dipole-dipole, exchange and lattice energies in these systems are well separated. These factors all make solid ^{3}He an excellent model magnetic system. Recent studies of superfluid ^{3}He A under rotation have shown a surprising difference of the critical velocity for vortex generation in narrow cylinders when the magnetic field is applied parallel vs. antiparallel to the sense of rotation. This work has provided the first experimental evidence of how much the angular momentum of ^{3}He Cooper pairs contribute to the angular momentum of the rotating fluid. This is another example of very impressive work by the ISSP group, which has created some of the most powerful and unique cryostats in the world, and is using them very productively.

Copper demagnetization cryostats are, in principle, general purpose devices that can be used to study almost any system at temperatures well below 10^{-3} Kelvin. The rotating cryostats, however, are specifically designed to study fluids under rotation. While this generally means superfluid ^{3}He and superfluid ^{4}He physics, plans are underway to better characterize the apparent 'supersolid' state of ^{4}He recently discovered by Moses Chan. This is an excellent idea, and has the potential to make an important contribution to this very intriguing discovery. Quite generally the ULT effort at ISSP has made many important contributions to the field of ULT physics, and as the ordered phases of solid and liquid helium serve as important model systems for understanding similar order in systems which are more complex and difficult to control and understand (such as the unconventional superconductors), these studies benefit condensed matter physics quite generally.

Professor Ishimoto will be retiring in a few years, and the ISSP needs to begin considering the future of this facility. While Kubota is far from retirement, it is hard for a single individual to support such a large and rather complex set of facilities. Over the past three decades Japan has been a world leader in studies of solid ^{3}He and the many types of magnetic phenomena exhibited by its solid films and crystals. Japan has not played such an active role in studies of superfluidity in ^{3}He, but could easily do so using one of their rotating cryostats. However, ISSP's human resources are limited, and one must consider supporting other areas of research as well. It is our opinion, given the value of the present research program and the facilities available, that it would be advantageous for ISSP to hire a ULT person to replace Ishimoto, provided his or her research interests extend beyond quantum fluids and solids to include other topics in low temperature physics, such as studies of 2D electron gases (fractional quantum Hall states), low temperature glassy behavior, or specific aspects of nano-science. While such studies will not benefit from the very lowest temperatures attainable by the ULT group, they all present refrigeration challenges of comparable magnitude.

High magnetic field studies

This group has traditionally been a world leader in the area of non destructive and destructive pulsed magnetic fields and remains as such today. The group was built under the directorship of Prof. Miura and later Prof. Goto who developed the materials, magnet designs, magnets and instrumentation to produce some of the highest magnetic fields ever attained on the planet. These included nondestructive solenoids powered by large capacitor banks in the 40 - 50 Tesla 10 millisecond range; similarly powered explosive single turn loops in the 100+ Tesla several microsecond duration ranges which preserved the sample and 200+ Tesla microsecond range implosive magnets which destroyed both magnet and sample. The facilities were heavily used by both internal research groups and in collaboration with groups from within Japan and internationally. The most heavily used facilities were the robust 40 Tesla nondestructive fields conveniently set up in multiple banks. The highest field-record setting magnets were used primarily for optical studies.

With the retirements of Miura and Goto and the transfer from Roppongi to Kashiwa the lab has passed into the able hands of Profs. Takeyama and Osada. A new more powerful, better controlled capacitive power supply was commissioned. The pulse magnets are operational in the new facility and already improvements have been made to the destructive coils by innovative design changes resulting from collaboration with international visitors. Field capabilities now range to 300 Tesla for explosive and 600 Tesla for implosive. Importantly an effort was made to extend the number of different physical measurements which could be performed. Instrumentation and microfabrication improvements now allow a host of transport and magnetization measurements to be done in the microseconds that a sample spends in megagauss fields. Scientific accomplishments of this lab include: advanced studies of the II-VI and III-V semiconductors with their interacting optically excited excitons, high field properties of carbon nanotubes, magnetic nanocomposites, and two dimensional electron systems coupled coherently or incoherently.

The addition of Prof. Kindo to the lab has presented new capabilities and new opportunities. Kindo's group has innovated a new type of reinforced nondestructive solenoid reaching a world record 80+ Tesla repeatably. Using the technology developed in these magnets the group has proposed and received University and MEXT support for the creation at Kashiwa of a 100 Tesla, 10 millisecond, long pulse magnet. This magnet will put ISSP on an even footing with groups in Germany and the United States in this forefront area. Such a magnet will greatly simplify a host of experiments conventionally performed in DC fields or with great effort in destructive short pulse fields and will enable sets of experiments with thermal and optical measurements that could not previously have been done. The guess in the magnet community is that these long pulse magnets will be widely used collaboratively with outside groups.

Observations:

This group has traditionally been a world leader and a resource for Japanese science. They are now challenged by the increased capabilities of DC magnets in individual labs and by the large magnet facilities internationally. As a result some of the service role has declined for the under 50 Tesla magnets. On the other hand they have kept a role as world leaders in the highest pulsed fields.

Recommendations:

The main future project for this group is a long pulse magnet with an aim of 100T and 10 milli seconds. We endorse the investment in this world class facility which will enable a new dimension to high field research in Japan.

High-pressure group

The high pressure group has two goals: being open to high pressure users and the development of high pressure technology and its application to various scientific fields. The realization of high-pressure experiments is often a difficult task even though the principles are well known. The group has improved considerably the reproducibility of high-pressure experiments as well as the range of techniques (NMR, specific heat). It has also extended the limits of other parameters (temperatures down to 30 mK, magnetic field up to 15 T) which enter high-pressure experiments. The main targets of research concern

a) the appearance of superconductivity under pressure:

- $ZrTe_3$ with the interplay of the formation of a charge-density wave,
- organic conductors with the interplay of charge ordering,
- low dimensional systems

b) valence- or spin instabilities in different materials notably in $YbInCu_4$ and other heavy fermion materials.

Due to the high demand of users, the development of new instrumentations towards new high pressure limits has been difficult since it requires time and freedom. Despite the constraints, the Review Committee appreciated the attempt towards small sample experiments including diamond anvil and detection techniques.

Recommendations:

- Try to reduce the services regarding high-pressure experiments.
- Find some freedom to develop really new high-pressure instrumentation.
- Select few materials where extensive studies will be especially worthwhile.

Division of Advanced Spectroscopy

This Division has a rich history of accomplishment that has contributed enabling technologies for the measurement of processes important to the work of the ISSP. We find today, the Division is firmly positioned to continue this work into the future. The new laboratory is well equipped and the technologies pursued are at the cutting edge. The ISSP has a state of the art laboratory that is developing new sources for spectroscopy that extend measurement capability to higher phonon energies and enhanced temporal resolution.

The Committee was impressed with the work presented on ultrahigh-resolution photoemission spectroscopy. This group achieved energy resolution well under a millivolt by using a newly developed laser source and an advanced electron spectrometer. The novel laser source generated a quasi-CW photon beam with 7 eV energy. The CW nature the source was key to minimizing the effects of space charge. Combined with a new spectrometer a world record resolution of 360 μeV was achieved. In addition this approach permits bulk sensitively at low temperature and small spot size. The work is a clear example of the benefit of having a world class laser group supporting the mission of the ISSP.

There was also work on the development of a T-shaped GaAs quantum wire laser presented to the Committee. The goal of the work was to study the quantum wire laser to develop a very low threshold laser and to study the 1D confined system in a well defined geometry. A new annealing technique dramatically improved the interface quality. Laser action was achieved and gain was measured. The gain spectrum could not be defined by the 1D density of states alone but also required the inclusion of Coulomb effects. Future work will include current injection and the study of quantum wire laser theory. It remains to be seen whether this work leads to a useful low threshold laser or creates new physics understanding.

Prof. Watanabe, the senior member of the group, is approaching retirement age. Within the next few years it will be important to develop new leadership.

The following observations and recommendations are made:

- The work of this division clearly demonstrates the value of these efforts today and the importance of maintaining support for the future. Optical techniques are expected to be quite relevant for future ISSP efforts.

- The lab is well equipped today but will require continued investment in the future to keep it at the cutting edge.

- The ISSP is planning to build new synchrotron beamlines in the near future. The laser expertise in this division should be encouraged to contribute to beam lines in which lasers are synchronized to the synchrotron.

- The new 7.0 eV photon source should be explored for possible applications in imaging.

- Priority should be given to identifying, recruiting and training leadership to assure continuity into the future.

The Research Facilities

Three large research facilities of the ISSP with their own Steering Committees serve the physics community of Japan as a whole.

Synchrotron Radiation Laboratory

The synchrotron radiation group has had a long and proud history of contribution to synchrotron science. After the closure of the SOR-RING, construction of beam lines at the Photon Factory and the movement of the ISSP to Kashiwa, the reorganization of the Japanese university system has created a set of barriers to building a new synchrotron at ISSP that appear to be insurmountable at present.

The Photon Factory and Spring 8 are both optimized for high energy photons. Japan does not have a high-brilliance low energy facility. The committee proposes to build VUV and Soft X-ray beamlines at facilities either domestic or abroad. The plan is to build beam lines for scientific fields such as microscopy and electronic structure. The decision not to build a new synchrotron will leave the Accelerator Physics Group without a clear path to contribute to the ISSP mission.

The following observations and recommendations are made:

- We understand that the cost of construction of a new synchrotron is at present outside the range of possibility for the ISSP as part of the University of Tokyo.

- We support the plan to build beam lines at low energy facilities either in Japan or abroad. In addition, broader plan of the future of synchrotron-related activities at the ISSP should be designed by interaction with the community.

- When it becomes clear that the services of the Accelerator Physics Group are no longer required, its members should be transferred to other institutions where their work would be relevant. The resultant open positions can possibly be used for starting new groups at the ISSP for emerging fields of condensed matter physics.

Neutron Science Laboratory

The neutron scattering group of ISSP continues to play a leading role in the successful application of neutron scattering to different fields of condensed matter. This achievement is quite unique as the user community in Japan is very eager to use the neutron facility but also likes to combine that use with experiments on other neutron spectrometers in the world. This requires maintenance and further development of the spectrometers. A continuous training of newcomers to neutron facilities should be guaranteed. Moreover, it is important that the ISSP implements a beamline within the pulse neutron source project (J-PARC).

In parallel to this key role ISSP researchers are very successful in their own research which is often including material preparation. As shown in the Activity Report, quite different areas are studied: crystallographic and magnetic or exotic multipolar structures, spin dynamics (high-T_c superconductors, quantum magnets, quasicrystals) phonons (nanoscale spectral structure in relaxors), complex condensed matter (glasses, various liquids) and vortex matter in superconductors. The work on soft matter is discussed separately below.

The strength of the ISSP is a strong interplay between the achievement of excellent materials (grown within the ISSP or obtained via different collaborations) clever and deep neutron scattering studies plus direct contact with theory. It is a successful example for many laboratories in the world. Despite the heavy service demands, the group maintains its high research level. It perpetuates the spirit of a group which is open minded for a large diversity of problems in physics and solid state chemistry.

Recommendations:

- Continue to be the leading group in Japan for the use of neutron scattering.
- Concentrate on one or two major interdivision ISSP studies.
- Choose your project for J-PARC (see below).

Soft condensed matter

Soft Matter at ISSP at largely being conducted by the Shibayama lab, which at the same time is responsible for the operation of the Small Angle Neutron Scattering (SANS) facility at Tokai. This facility serves the condensed matter community with about 2/3 of the use in solid state physics and 1/3 in biology/ soft matter research.

Prof. Shibayama's research is centered on the properties of polymer gels and especially on the roles played by inhomogeneities in the swelling and elastic properties. Using static and dynamic light scattering and the SANS facility they have demonstrated the effects of conventional cross links and novel slide-ring cross links in the deformability and local structure of gels. This is an old and continuing fundamental problem in polymer science and the contrast between the sliding and fixed crosslink's provides needed insights. There are as well both proven and potential applications.
Research in this general area is to be encouraged. It is by its nature interdisciplinary, fundamental, yet connects with and supports industry. For example Prof. Shibayama's teaches and has collaborations with soft matter and biology groups in the Institute for Fundamental Education in the

building neighboring ISSP at Kashiwa, has students from that institute and has external industrial support for his research. In times of decreasing budgets and students this represents a means to expand both support and the number of students involved in research.

Observations:

Innovative fundamental work on gels. Good service to community in SANS facility. Good collaborations with nearby neighboring institute but the work is isolated in ISSP

Recommendations:

- Install a beamline within the pulsed neutron source project (J-PARC).
- Define the specific preference for the new generation of spectrometers.
- By direct interaction with other groups focus on particularly interesting problems.
- The area of soft condensed matter should be enhanced with additional faculty in experiment, and in theory. Connections to neighboring Institutes and to industry should be encouraged. The new faculty should serve as a seed for further expansion.

Materials Design and Characterization Laboratory

This facility consists of groups with quite different goals and backgrounds. There is one group on Material Design and another on Materials Synthesis and Characterization and there is a Supercomputer Center.

Materials groups

The incorporation of solid state chemistry at the ISSP is certainly one of the greatest accomplishments of the ISSP which needs to be reinforced.

$SrCu_2(BO_3)_2$ has been a remarkable success which has led to important research inside the ISSP, notably microscopic studies by neutron scattering and NMR (including the field study of the so-called plateau phase in the magnetization) but also outside the ISSP especially by different neutron scattering groups. By themselves NaV_2O_5 systems are also very interesting research objects with their Devil's-Flower phase diagram. But also the discovery of superconductivity in $\beta - A_{0.33}V_2O_5$ (A = Li, Na, Ag) at the fraction of a charge ordered phase.

In the same spirit, the discovery of β-pyrochlore oxide superconductors opens new roads and new phenomena like a structural transition below T_c in KOs_2O_6 are nice puzzles for experimentalists. A large variety of frustrated systems can be realized. The challenge is, of course, to combine frustration with doping. Photo-carrier injection into transition metal oxides is an interesting path.

It is apparent that the solid-state chemistry groups are strongly interacting with the Division of New Material Science.

Supercomputer Center

The Supercomputer Center of the ISSP (SCC-ISSP) is world class among computer facilities of its kind, with 13.5 TFlop capability and 4.1TB memory dedicated to condensed matter physics calculations. It is well set-upped and efficiently run by two technical staff members and 3 research associates on a part time basis. The recent decision of acquiring two systems of different characteristics was excellent and appropriate for the mission of the Center. The Hitachi SR1100/48 vector machine is powerful and best suited for projects that required high speed single node operations and fast communications. The SGI Altix3700/1280 machine is most suitable for scalable calculations that can take advantage of massive parallelism and multiple nodes. However, in view of the general rapidly development of computer hardware technologies, a five-year lease of the two systems seems too long of a commitment for any supercomputer facility.

The SCC-ISSP's mission since 1995 has been to supply timely and steady computer cycles to the condensed matter physics community in Japan for the purposes of large-scale simulations/computations and development of codes and algorithms. The projects are first refereed by the Supercomputer Project Advisory Committee, and the final approval and resources allocations are made by the Steering Committee composed of researchers inside and outside of ISSP. SCC-ISSP has filled its mission admirably well. Of the over 150 projects currently at the SCC-ISSP, only about 10 % are in-house ISSP research projects and the projects are divided among the three categories: first-principles calculation of materials properties (36 %), strongly correlated quantum systems (39 %) and cooperative phenomena in complex macroscopic systems (25 %).

The SCC-ISSP is aspired to be an international center of computational materials physics. It is making plans to further enhance their service to the condensed matter physics community. Among these are: development of optimal allocation scheme to support meritorious large-scale computations, creation of data base of calculations results, formation of a depository of state-of-art computer codes, and start of international cooperative research activities. These are all valuable services and admirable goals. In particular, our committee feels that a scientific merit and computational need based allocation policy would be of great value. The concern is that sufficient technical staff support must be provided for carrying out such a program.

Advances in theoretical methods and simulations techniques have now made computer facilities such as SCC-ISSP an indispensable tool for research in condensed matter science. Computations now not only provide quantitative understanding and prediction of properties; they are means for discovery of new phenomena and concepts. Thus the continued existence and success of computational facilities such as the SCC-ISSP dedicated to condensed matter physics research with its resources under peer management is vital to the health of the field.

Recommendations:

The Materials Design and Characterization Laboratory does excellent work but is very inhomogeneous. Therefore it should be restructured.

VII. General aspects and summary

There are efforts worldwide to improve the situation for women in sciences. Traditionally their number has been especially low in natural sciences and particular in physics. The ISSP should keep its eyes open and try to identify highly-qualified young women. Quality standards should not be lowered in this search but one should search with an open mind. The majority of the staff of the ISSP graduated from the physics and applied physics departments of the University of Tokyo. Most of the members have experienced the work at other institutions. An enhancement of the diversity and heterogeneity of staff members will in long terms be the benefit to the Institute.

The Review Committee reconfirms the high international standing of the ISSP. It has made recommendations how to solidify its position in the future. In accordance with its standing the Institute should strengthen its efforts towards internationalization. Practical steps have been suggested by the Committee. The University of Tokyo can be proud to count the ISSP among its Institutes. The Review Committee expects that the ISSP will remain one of the great research Institutes within the world scientific community for the years to come.

Appendix: Time schedule of the visit

The following time schedule was followed during the visit of the Review Committee on Kashiwa campus.

ISSP International Review On-Site Meeting Schedule

	Monday (14th)	Tuesday (15th)	Wednesday (16th)
9:00	Meeting (Reception Room)	Session 5 [Yoshizawa] M.Shibayama	Session 8 [Y.Ueda] Z. Hiroi
10:00	Session 1 [Iye] K. Ueda; coffee break	K. Hirota, A. Kakizaki; coffee break	H. Mori; coffee break; Session 9 [Takigawa]
11:00	Session 2 [Watanabe] Y. Iye; Session 3 [Suemoto] S. Shin	Session 6 [Takeyama] H. Ishimoto, K. Kindo; lunch	T. Sakakibara, T. Yagi; free discussion
12:00	H. Akiyama; lunch		lunch
13:00	Lab Tour	Lab Tour	Committee Meeting
14:00		coffee break	break; Committee Meeting
15:00	coffee break; Session 4 [Komori] S. Katsumoto	Session 7 [Imada] Y. Takada, N. Kawashima; break	
16:00	J. Yoshinobu; break; * free discussion	# free discussion, Committee Meeting	
17:00	Committee Meeting	leave for the hotel	
18:00	Poster Session 6F Lobby	Party Crest Hotel	
19:00			

short presentations
\# Neutron Sci. Lab
\# High Mag. Field Lab

short presentations
* MDCL
* Synch. Rad. Lab