The Institute for Solid State Physics at The University of Tokyo

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THE UNIVERSITY OF TOKYO (UTOKYO)

The University of Tokyo (UTokyo) was founded in 1877 and is the oldest national university in Japan. UTokyo has three main campuses, namely, Komaba campus with interdisciplinary links between established academic fields, Hongo campus with traditional academic activities, and Kashiwa campus, which has the motto, "Adventures in Knowledge". The Institute for Solid State Physics (ISSP) moved to the then newly established Kashiwa campus in 2000 and has explored a wide variety of phenomena exhibited by various materials from the viewpoint of the fundamental sciences, using the state-of-art experimental facilities and techniques. Materials under study include those that are critical for today's high-tech society and those that will be integral for our society's future development [1].

Fig. 1: Yasuda Auditorium and the three main campuses (Kashiwa, Hongo, and Komaba) at The University of Tokyo.

THE INSTITUTE FOR SOLID STATE PHYSICS (ISSP)

ISSP, which became 62 years old in 2019, was established in 1957 as a joint-use research institute attached to UTokyo. During that time, with the support of the science community, we have aimed to lead in the frontiers of condensed matter and materials science and to contribute to science and technology from the view of basic research. We have promoted activities focused on the areas of cutting-edge research, education for the next generation, and joint-use/joint-research.

HISTORY

ISSP was established as a National Joint-Use Research Institute attached to UTokyo in 1957.

1st generation (1957 – 1979);

ISSP at UTokyo was established on April 1, 1957, as a joint-use/joint-research laboratory based upon the recommendation of the Science Council of Japan and a concurrence between the Ministry of Education, Science and Culture and the Science and Technology Agency in order to lead fundamental research in condensed matter physics. Within approximately the first 20 years, ISSP had achieved its original mission to serve as the central laboratory for materials science in Japan, equipped with the state-of-art facilities that were open for all domestic research with the objective of bringing research in Japan up to par with international levels.

2nd generation (1980 – 1995);

The next goal was to develop advanced experimental techniques that were difficult to achieve in most university laboratories. The "second generation" reorganization of ISSP took place in 1980. The Division of Physics in Extreme Conditions included groups in the areas of ultra-high magnetic fields, laser physics, surface science, ultra-low temperatures and very high pressure. The Division of Physics in Extreme Conditions sought to create extreme conditions and to explore new phenomena. The Neutron Scattering Laboratory was constructed in Tokai in collaboration with the Japan Atomic Energy Agency. Its capabilities were significantly improved from 1990 – 1992, due to renovation of the research reactor. The Synchrotron Radiation Laboratory operated the SOR-RING in the Tanashi Campus of UTokyo and maintained beam lines in the Photon Factory at the High Energy Accelerator Research Organization (KEK) in Tsukuba. The Condensed Matter Division and the Theory Division maintained small groups motivated by individual interests and ideas. From the fomer group, the Materials Development Division was formed in 1989, with the objective of exploring new materials and their novel properties.

3rd generation (1996 – present);

In March 2000, ISSP relocated to a new campus of UTokyo in Kashiwa, after 43 years of activities at the Roppongi campus in downtown Tokyo. ISSP seeks to create new areas of science, in collaboration with other institutions in Kashiwa. In addition, a visiting staff division as well as two foreign visiting professor positions have been created. In 2003, the Neutron Scattering Laboratory was reorganized to become the Neutron Science Laboratory. UTokyo was transformed into a "national university corporation" in 2004 and thus ISSP adopted a new role as a joint research laboratory in the university corporation. In the same year, the Division of Frontier Areas Research changed its name to the Division of Nanoscale Science. In 2006, ISSP established the International MegaGauss Science Laboratory and started serving as an international center of physics in high magnetic fields. In 2011, the Center of Computational Materials Science was established at ISSP, with the objective of promoting materials science with advanced supercomputers. Regarding the Synchrotron Radiation Laboratory, after the closing of SOR-RING in 1997, the Harima branch of the Synchrotron Radiation Laboratory was established at SPring-8 in 2009. Furthermore, in 2012, the Division of Advanced Spectroscopy and the Synchrotron Radiation Laboratory (LASOR) were reorganized into the newly established Laser and Synchrotron Research Center. In 2016, the Divisions of New Materials Science and Physics in Extreme Conditions were reorganized into the Division of Condensed Matter Science, and the Functional Materials Group and the Quantum Materials Group were launched in order to widen the scope of condensed matter sciences at ISSP, marking a new step forward in these interdisciplinary research fields. The Division of Data-Integrated Materials Science was established in 2019 as the first Social Cooperation Program at ISSP, working in collaboration with industrial groups. (Fig. 2)

FUNDAMENTALS

The organization of ISSP is depicted in Fig. 2. ISSP consists of four research divisions (Divisions of Condensed Matter Science, Condensed Matter Theory, Nanoscale Science, and Social Cooperation Programs), two interdisciplinary groups (Quantum Materials and Functional Materials Groups), five research facilities (Materials De-

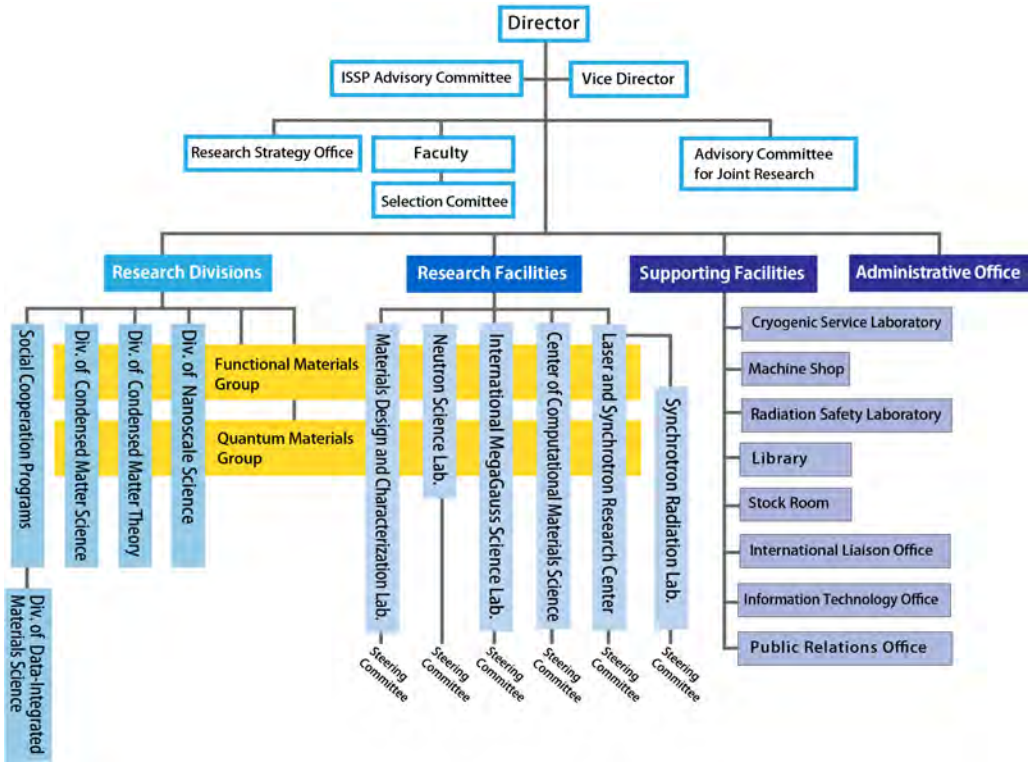

Fig. 2: Organization of the Institute for Solid State Physics.

sign and Characterization Laboratory, Neutron Science Laboratory, International MegaGauss Science Laboratory, Center of Computational Materials Science, and Laser and Synchrotron Research Center), supporting facilities, and an administrative office. Since ISSP is a joint research/joint use institute, the management of ISSP reflects the perspectives of the research community; 1/4 of the members of ISSP's advisory committee are recommended by the Science Council of Japan. Approximately half of ISSP's selection committee and half of the advisory committee for joint research are also recommended by members of the physics and chemistry communities.

There were 86 faculty members at ISSP in 2018: 27 professors, 16 associate professors, and 43 research associates. In addition, 70 postdoctoral researchers, 30 technicians, and 12 administration staff members were affiliated with ISSP. Furthermore, in 2018, ISSP had 138 graduate students.

RESEARCH

The studies in condensed matter physics and materials science have three axes: (1) a conceptual axis (design), (2) a materials axis (synthesis), and (3) an investigation method axis (characterization) as shown in Fig. 3. These three axes interact in what we call a DSC cycle, promoting innovative research. This institute is organized around 40 laboratories with the small-scale, and the medium-to-large-scale equipment and facilities. All labs work together to maintain the DSC cycle.

As for some of the most prominent findings from the DSC cycle at ISSP, the first Weyl antiferromagnet (Mn_3Sn)

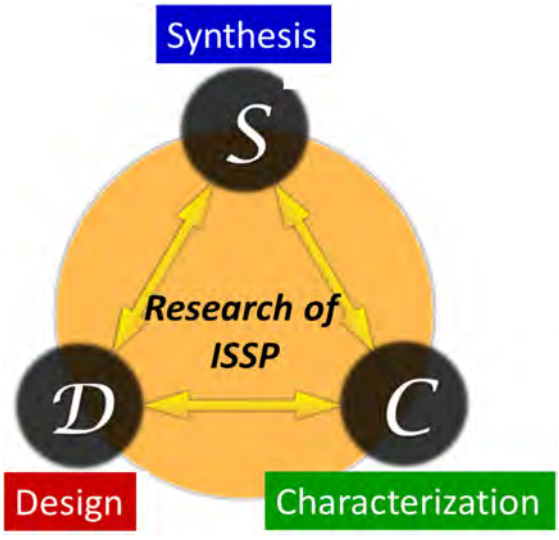

Fig. 3: Design – Synthesis – Characterization (DSC) cycle in Research at ISSP.

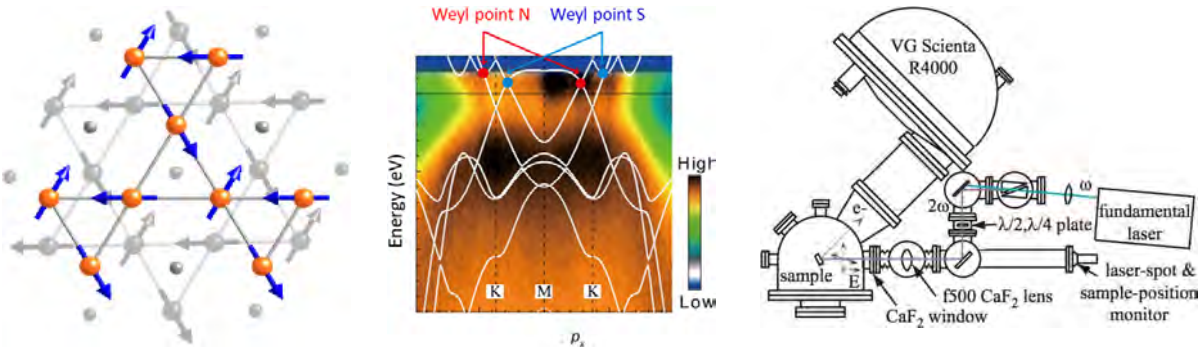

Fig. 4: The first Weyl antiferromagnet (Mn_3Sn) was discovered and the magnetic Weyl fermions were proved by angle-resolved photoemission spectroscopy (ARPES) measurements and density functional theory (DFT) calculations. [2]

was discovered, and the magnetic Weyl fermions were proved by laser angle-resolved photoemission spectroscopy (ARPES) measurements and density functional theory (DFT) calculations, as shown in Fig. 4. [2] The Weyl antiferromagnets reveal an anomalous Hall effect and a Nernst effect, leading to more efficient coverage of the heat source.

Another significant achievement was reported from one of our large-scale facility, the International MegaGauss Science Laboratory. The world record for an indoor magnetic field of 1,200 T was generated by electromagnetic flux compression at ISSP in 2018 (Fig. 5) [3]. The achievement has opened up some interesting possibilities, such as the development of new kinds of electronic devices and the elucidation of biological chirality related to the origins of life.

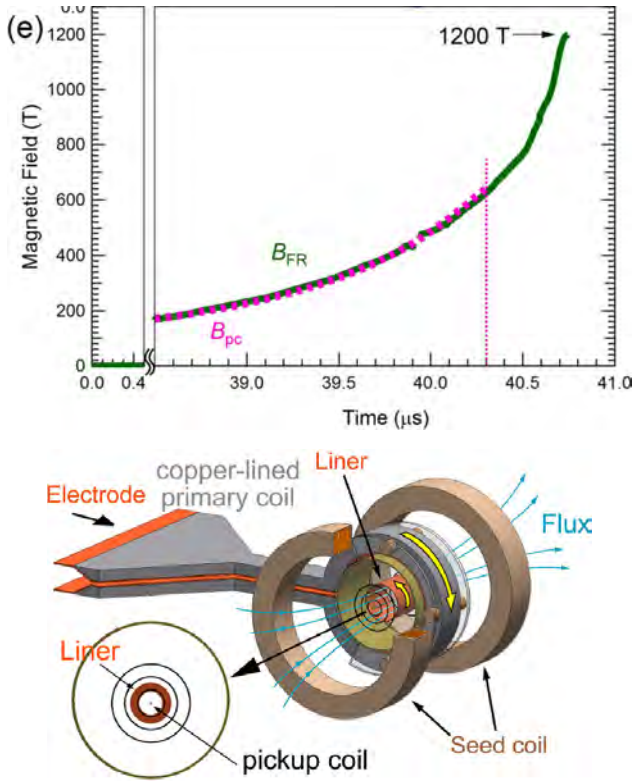

Fig. 5: The world record for an indoor magnetic field of 1,200T was generated by electromagnetic flux compression at ISSP in 2018. [3]

JOINT USE and JOINT RESEARCH

ISSP has been established for joint research with condensed matter scientists in Japan. After UTokyo transformed from a national university to a "national university corporation", ISSP was authorized as a joint-use/research center in 2009, and its joint-use programs with the newly authorized status started in 2010. ISSP has a variety of systems supporting such joint-research activities; continuously, numerous outside researchers visit ISSP and utilize our facilities. The ISSP joint-research program is operated by two committees consisting of ISSP faculty members, and of board members external to our laboratory operations recommended by the physics and chemistry communities.

The facilities of ISSP are open to researchers in Japan, who are encouraged to submit joint research proposals. The submission of research proposals is received twice a year, and the proposals are selected by the Advisory Committee for Joint Research. In addition, ISSP provides opportunities for young scientists, including graduate students from across the country, to do research for extended periods of time. For those visitors, ISSP assists with their travel and research expenses.

Figure 6 shows that around 1,400 domestic and foreign researchers visited ISSP and approximately 8,000 (researchers • days) visitors took part in joint use and joint research in 2017. Moreover, ISSP holds domestic and in-

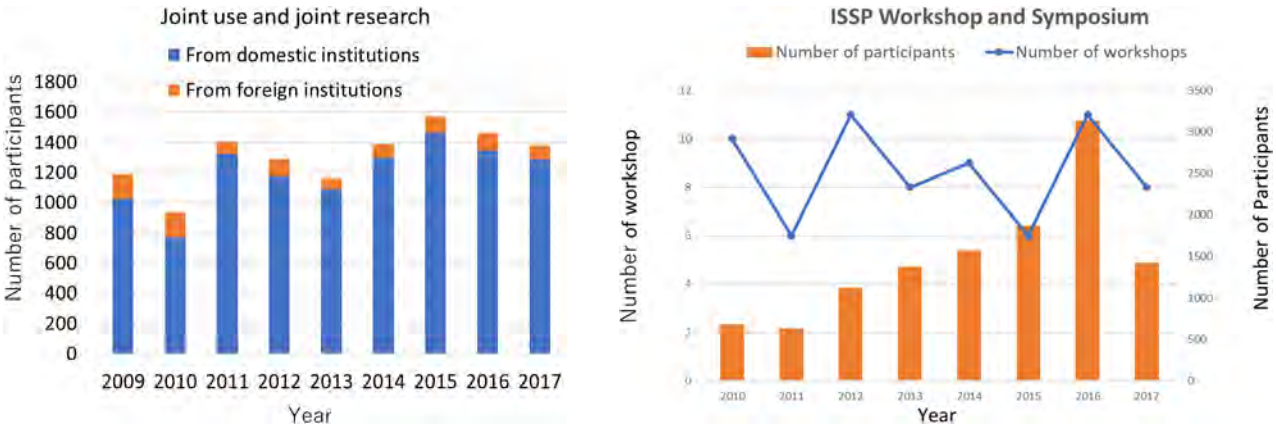

Fig. 6: Statistics for joint use and joint research in regard to ISSP workshops and symposia held at ISSP. Around 1,400 domestic and foreign researchers visited ISSP in 2017. Several ISSP events, consisting of workshops and symposia, have been held yearly; there were approximately 1,400 participants in 2017.

ternational workshops and symposia on specific subjects of condensed matter science. A typical workshop is two to three days long and approximately 1,400 people participated in 2017. Proposals for workshops are submitted by researchers across Japan and are selected by the Advisory Committee for Joint Research.

DEVELOPMENT OF HUMAN RESOURCES

ISSP contributes to graduate education in condensed matter science through its unique facilities. Currently, the faculty members participate in the following departments of the graduate school of UTokyo: physics, chemistry (Graduate School of Science), applied physics (Graduate School of Engineering), advanced materials, and complexity science and engineering (Graduate School of Frontier Sciences).

In 2018, there were 89 graduate students in the master's program and 49 graduate students in the doctor's program. In recent years, female students have accounted for fewer than 10 percent of the student body ; however, through outreach programs, we hope to increase the number of women studying at ISSP.

Every year, in May, ISSP hosts its graduate program information session for future students to explain the system of graduate school programs, to introduce research groups/laboratories at ISSP, to provide guided tours to the laboratories and related facilities for the participants, and to provide other necessary information.

ISSP's various initiatives to foster and develop young researchers include lectures and training sessions organized by the Center of Computational Materials Science (CCMS). The center hosts and provides lecturers for lectures and training sessions in the Kashiwa campus and the Kobe branch. Its monthly training program, Kashiwa/Kobe Hands-On, provides an opportunity for young researchers to get accustomed to various application programs.

ISSP also contributes to the development of young researchers in related fields. For instance, ISSP members participate in educational programs for domestic and international researchers held at large synchrotron and neutron facilities. In addition to sending lecturers, ISSP is engaged in organizing and operating such programs as a co-host organization.

INTERNATIONAL ACTIVITIES

ISSP plays an important role as an international center of materials science. There are various international collaboration programs at ISSP such as (1) two positions per year for foreign visiting professorships for 3-12 months, (2) visiting researcher/scientist positions for 1-3 months, (3) international collaboration research of a duration within two weeks, and (4) international research opportunities for ISSP students lasting for more than four weeks. The unique facilities of ISSP have been used in many international and collaborative activities. Many foreign researchers have spent their early careers at ISSP, supported by various fellowship programs sponsored by ISSP, the Japan Society for the Promotion of Science (JSPS), and other agencies.

Moreover, in order to promote international activities, a global collaboration system was initiated at ISSP in 2018. The ISSP task force team, composed of members in the fields of high magnetic fields, pressure, neutron science,

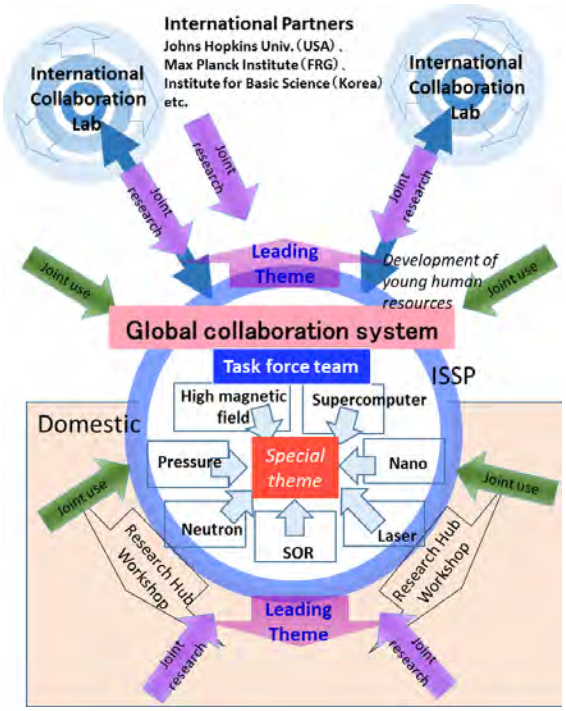

Fig. 7: The global collaboration system at ISSP. A task force team, composed of members in the fields of high magnetic fields, pressure, neutron science, SOR (synchrotron radiation), lasers, nanoscience, supercomputers, materials, etc., collects special scientific themes and announces a leading scientific theme in order to promote collaboration between ISSP and domestic and international teams; ISSP acts as a hub of global collaboration.

SOR (synchrotron radiation), lasers, nanoscience, supercomputers, materials, etc., collects special scientific themes and announces a leading scientific theme in order to promote collaboration between ISSP and domestic and international teams; in this way, ISSP operates as a hub of global collaboration.

ISSP has also been coordinating international research programs, e.g., the US-Japan cooperative program on neutron scattering since 1981; an international contract with Johns Hopkins University, USA; a memorandum of understanding (MOU) with the Center for Correlated Electrons Systems (CCES) of the Institute for Basic Science (IBS) in Korea since 2018; and an agreement with the Max Planck Institute for the Physics of Complex Systems (Germany) for academic exchange, as shown in Fig. 7.

SUMMARY

The Institute for Solid State Physics (ISSP) was established in 1957 as a joint-use research institute attached to The University of Tokyo (UTokyo) and celebrated its 62th anniversary in 2019.

Our goal is to lead in cutting-edge research in the studies of the physical properties and functionalities of materials.

In every era, our missions have been (i) to develop the medium- and large-scale state-of-the-art research equipment for opening or advancing new research fields, (ii) to promote prominent young scholars and to facilitate personnel exchange, and (iii) as a joint research hub, to develop new fields of academic research based on ideas collected from a broad research community. Moreover, (iv) as an international research hub, we have developed global networks in condensed matter physics and materials science and (v) we have contributed to society, both nationally and internationally, by cooperating with industry and giving feedback on basic science issues.

In this spirit, we are proud to be a leader in groundbreaking research in condensed matter physics and materials science and are committed to further developing as a global center of excellence for the scientific community and for society at large.

References

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Hatsumi MORI has been the director of the Institute for Solid State Physics (ISSP) at the University of Tokyo (UTokyo) since April, 2018 and a council member in AAPPS since 2017. After receiving her B. Sc. (1984) and M. Sc. (1986) degrees from Ochanomizu University, and a D. Sc. (1992) degree from UTokyo, she worked as a technical associate at ISSP, as a researcher at the International Superconductivity Technology Center (1989-2001), and as an associate professor (2001-2010) and professor (2010-) of ISSP at UTokyo. Her research areas are in the interdisciplinary fields of chemistry and physics for molecular functional materials.