A Short History of Facility Development and User Scientific Programs

In commemoration of the tenth anniversary of user operation, the Activity Report 2002/2003 includes this retrospective article to record important events in the development of the institution during the past twenty years. The history began in July 1983 when the Executive Yuan of Taiwan's government approved establishment of the Synchrotron Radiation Research Center (SRRC). At that time Taiwan had little expertise about accelerator-based technology. For the past twenty years, the country has been transforming from a labor-intensive economy toward an economy based on high technology; SRRC has been steadily gaining advanced accelerator technology as well as evolving in scientific research. In May 2003, the Center formally became a national laboratory and has taken a new name, the National Synchrotron Radiation Research Center (NSRRC). In this article, we give a short account of the Center's development. For convenience of discussion, we divide the history into four phases: the preparatory phase (1982-1986), the construction phase (1987-1993), the operation phase (1994-2000), and the upgrade phase (2000 and beyond). Table I lists major events in these phases. A memorial CD entitled "Tenth Anniversary of Operation" is distributed with this Activity Report, which includes historical pictures of the events. [1] Through this article and the CD, we seek to share with readers a sense of our past and a perspective of our future.

The Preparatory Phase (1982 — 1986)

In early 1980s, the Physics Research Center of National Science Council (NSC) made a recommendation to identify thrust research areas and to build large-scale facilities to enhance the scientific capability of this country. Concurrently, the possibility of constructing a synchrotron radiation facility in Taiwan was enthusiastically discussed and supported by a group of overseas Academicians of Academia Sinica. [2 - 4] A feasibility study was initiated in December 1981 and completed after a "Synchrotron Radiation Feasibility Report" [5] was submitted to NSC in November 1982. The Report was reviewed by a panel of six distinguished scholars from abroad [6], and received strong support from the panel on the construction of a synchrotron. In July 1983, the SRRC project was approved by the Executive Yuan which also appointed the six review panel members and another six distinguished domestic members to form the first Board of Directors [6] to look after the project. Dr. Luke C. L. Yuan (袁家騮) of Brookhaven National Laboratory (retiree) was appointed Chairman of BOD, a position Dr. Yuan had served until 2002.

The first organization of SRRC consisted of Construction Division (策劃興建小組) and User Training Division (用戶培育小組). Dr. Lee C. Teng (鄧昌黎) of Fermilab was appointed Director of Construction Division with Dr. K. C. Liu (劉光霽) of Institute of Nuclear Energy Research (核能研究所) as Deputy. The User Training Division was under Director Prof. Robert T. Poe (浦大邦) of University of California at Riverside and Prof. Edward Yen (閻愛德) of Tsing Hua University (清華大學) served as Deputy. By the end of 1983, an interim office of SRRC was set up in Taipei and the planning activities took place soon after; the construction site was chosen to be at Hsinchu Science-based Industrial Park.

As a matter of fact, the story of SRRC should be traced a few years back to year 1979 when the Symposium on Atomic and Molecular Sciences was held in Taipei, in which a possible synchrotron initiative in Taiwan was first raised [3, 4]. Since then, Prof. R. Poe had been actively promoting the Taiwan synchrotron project. He and Prof. E. Yen organized the first two synchrotron symposia, in July 1982 and August 1984, which had inspired great enthusiasm in synchrotron radiation research in Taiwan. Unfortunately, Prof. Poe died unexpectedly of heart attack during a staff meeting in December 1984, just before the 6th BOD meeting.

Table I. Major milestones of TLS development.

Preparatory Phase (1982 - 1986)	
1982/11	Feasibility Study Report
1983/07	SRRC approved by the Executive Yuan
/10	1st Board of Directors appointed, Chaired by Luck C. Yuan
	Planning and Construction Division formed, headed by Lee C. Teng
1984/03	Users Training Division formed, headed by R. T. Poe
1986/03	Preparatory and Construction Office of SRRC established
	Director L. A. Chen appointed
/08	Ground breaking of Hsinchu site
Construction Phase (1987 - 1993)	
1987	Civil construction started
1989/04	SRRC Design Handbook issued
1990/06	Taipei office relocated to Hsinchu
/07	Director E. Yen appointed
1991	Booster installation began
1992	ooster commissioning, Storage Ring installation began
1993/03	Storage Ring commissioning
/04	Beam stored
/07	Director Y. C. Liu appointed
/10	TLS open to users
Operation Phase (1994 - 2000)	
1994/07	SRRC Five-Year Plan draft issued
/12	W20 installed
1995/03	SRRC reorganized
/06	1st Annual Users Meeting
/10	U10 installed
1996/05	Transverse Feedback System installed
/09	Ring Energy raised to 1.5 GeV
/10	1st SRRC Annual Report published
1997/03	U5 installed
/04	Director C.T. Chen appointed
/12	21st Technical Review Committee Meeting
1998/01	Utility Improvement started
/12	1st Science & Technology Advisory Committee Meeting
1999/04	U9 installed
/09	EPU5.6 installed
2000/02	Booster/BTS Upgraded to 1.5 GeV
Upgrade Phase (2000 and beyond)	
2000/03	Superconducting RF Modules contracted out
/04	Construction of Cryogenics System & Utility Building #2 started
/05	1st Machine Advisory Committee Meeting
2002/01	Protein Crystallography Core Facility funded
/02	Top-up Injection Mode pre-study initiated
/04	Superconducting Wave Length Shifter installed
/07	44th Board of Directors Meeting
2003/02	Cryogenics Plant commissioned
/05	SRRC became NSRRC
	1st Board of Trustees appointed, Chaired by Yuan-Tseh Lee
/10	9th Users Meeting & Celebration of 10th Anniversary of Operation

Due to lack of local accelerator expertise, Dr. L. Teng formed the first technical team consisting of professors, engineers, and some INER staff. Dr. Teng personally taught the team on accelerator physics and technology. The Technical Review Committee (TRC) was also formed by a group of international accelerator physicists [7] to provide required technical expertise during the accelerator design stage. The project started to proceed with help of foreign consultants.

After putting the accelerator design team in working, Dr. L. Teng resigned his Division Directorship after the 6th BOD meeting. As the planning work continued, the Construction Division and User Training Division joined to become the Preparatory and Construction Office (籌建處) of SRRC in March 1986. Dr. Li-An Chen (陳履安), then Chairman of NSC, acted for the first Director of SRRC. Shortly thereafter, ground breaking of the Hsinchu site took place in August 1986, followed by Phase-I civil construction of administrative and research buildings. Thereafter, Deputy Director E. Yen assumed major responsibilities in coordinating accelerator design and user training program.

Accelerator Design

The task of accelerator design had been going intensively. In February 1988, SRRC organized the International Workshop on Constructing 1-2 GeV Synchrotron Radiation Facilities [8]. The workshop invited many international experts to Taipei at a time that the design of third generation synchrotron was a very active subject of studies. A year later, a third-generation synchrotron light source, the Taiwan Light Source (TLS), with nominal energy 1.3 GeV, extendable to 1.5 GeV, a full energy injector, a triple-bend-achromatic lattice with six long straight sections, aluminum vacuum chambers, and other equipment, was finally specified in a Design Handbook [9].

User Training Program

At the time of construction, there were few experienced synchrotron users except a handful of x-ray crystallographers in Taiwan [2 - 4]. In early 1980s, the high-technology sector of industrial technology in Taiwan was just emerging with IC and IT industries leading the change. Research with synchrotron radiation was a young field even in industrialized countries at that time. To establish a national facility like SRRC in Taiwan in early 1980s was based more on a vision of future need in science and technology developments of the country. Because of lack of synchrotron users, a user-training program was necessary concurrently with accelerator construction. The program progressed vigorously with the help of Prof. M. C. Wang (王明建).

For SRRC, we note that the preparatory phase was a time of learning how to plan a large complex scientific facility and a time of excitement about the emerging scientific opportunities in synchrotron radiation research. Many distinguished scholars and top ranking government officers [4, 6] had played very critical roles in many different aspects to make the synchrotron project a reality in Taiwan. Two scholars, Prof. C. S. Wu (吳健雄)and Prof. R. Poe (浦大邦) should be especially acknowledged for their contributions behind numerous critical events occurred during this period. [4] Afterward, the hard work of construction began.

The Construction Phase (1987 — 1993)

The civil construction of the storage ring building was completed and the Taipei office was relocated to Hsinchu in June 1990. Deputy Director Dr. Edward Yen (閻愛德) was promoted to Director of SRRC and the construction of TLS core facilities began. Technical personnel were reorganized into ten groups in the Technology Division headed by Deputy Director Yuen-Chung Liu (劉遠中). The ten technical groups (each with Group Leader) were: Beam Dynamics Group (C. S. Hsue 許貞雄), the Magnet Construction Group (G. J. Hwang 黃光治), the Magnet Field Mapping Group (P. K. Tseng 鄭伯昆), the Magnet Power Supply Group (Y. C. Wu 吳永春), the Vacuum Group (Y. C. Liu 劉遠中), the Radio Frequency Group (K. R. Chu 朱國瑞), the Instrumentation and Control Group (G. J. Jan 詹國禎), the Injector Group (K. C. Cheng 鄭國川), the Photon Beam Line Group (C. N. Chang 張秋男), and the Radiation Safety Group (S. H. Jiang 江祥輝).

Most of these Group Leaders undertook this work on loan assignment from nearby universities, including five from Tsing Hua University, two from Taiwan University, and one each from Chiao

Tung University and Normal University. Detailed designs and fabrication of subsystems of TLS began with training of newly recruited group members by the leaders themselves, with help from consultants from abroad whenever needed. In the construction phase, the integration of separate groups and effective coordination among these task forces was indeed a big challenge.

Accelerator Construction and Installation

The construction of the booster injector was contracted out to Scanditronix AB and the RF system was built by SRRC staff. [10] Most components were constructed and tested in 1989-1990. The booster installation was completed in late 1991 and commissioning took place in 1991-1992. The first electron beam of 50 MeV from the Linac was injected into the booster in February 1992. Two months later, the beam energy was successfully increased to 1.3 GeV. The early experience gained during commissioning of the booster was helpful in commissioning the storage ring in the following year.

Installation of the storage ring began in May 1992 after components of each subsystem had been successfully fabricated. [10] An intensive effort was made to learn the technology of survey and alignment. Tedious alignment procedures for networking the storage ring were of a much larger scale than had been experienced previously in the laboratory. After reduction of uncertainties in the survey and alignment, the injection components were installed piece by piece. The installation of the storage ring, which required the integration of the 120-m vacuum chambers, hundreds of aligned magnets, two RF cavities, one injection septum and four kickers, diagnostics and power supplies and controllers of several types, was completed in February 1993. Immediately after this installation, the first electron beam was successfully circulated in the ring on February 23, 1993. Shortly after the final connection of a RF transmitter and the kicker power supplies, the electron beam was successfully stored at 3 a.m., April 23, 1993. Within two weeks of operation the beam current reached the design value 200 mA and in eight weeks a beam lifetime of 4 hours was attained.

After the successful beam injection into the storage ring, Prof. E. Yen resigned his directorship in July 1993 and returned to his teaching post at Tsing Hua University. Deputy Director Yuen-Chung Liu (劉遠中) was promoted to Director of SRRC. Accelerator studies continued intensively on measuring machine parameters including the betatron function, synchrotron tune, energy dispersion, bunch length, beam size, closed-orbit distortion and others. A maximum beam current 450 mA was successfully obtained. After the performance of the machine was verified, the TLS was opened to users on October 16, 1993.

Beamline Development and Scientific Program

In early 1993 when TLS was commissioned, three bending magnet beamlines built by the Photon Beamline Group were in operation: 1 m-SNM (04B), low-energy SGM (08A), and high-energy SGM (20A). These three beamlines provide photons with energies from 4 to 1500 eV to serve the initial scientific needs in VUV and soft x-ray research for Taiwan users.

The user training program, started by Prof. E. Yen in 1984, was followed by Prof. M. C. Wang (王明建), then continued by Prof. S. L. Chang (張石麟) and Prof. Y. Wang (王瑜). The User Division was formed in 1990 with Prof. Chang as Division Head. In ten years, twenty-five junior researchers had been recruited as trainees and sent to institutes abroad for two to three years of training to learn about synchrotron radiation experiments in photoemission, photoabsorption, EXAFS, x-ray diffraction, lithography, and protein crystallography. In late 1980s and early 1990s, numerous Taiwanese students in the United States and other countries with Ph.D. training in synchrotron research were also recruited to SRRC. These young researchers took charge of establishing experimental stations in the first group when the TLS was still in the construction phase.

The Operation Phase (1994 — 2000)

After commissioning of TLS, the immediate challenges of SRRC were to make the machine meet specifications of a third-generation synchrotron source and to implement world-class research programs. A study was initiated in late 1993 to do a Five-Year Plan [11]. The study was conducted by SRRC staff under an *ad hoc* Science Advisory Committee [12] appointed by Director Liu. Through this planning exercise, targets for TLS facility development in succeeding years had been clearly identified. As we look today, most of these targets have been achieved (see Table II).

Following the Five-Year Plan, a divisional reorganization of SRRC occurred in March 1995 to regroup technical and research personnel into five divisions: Light Source, Instrumentation Development, Beamline, Research and Radiation Safety Divisions. About the same time, most professors on loan requested to return to their teaching posts at universities. Dr. Chien-Te Chen (陳建德) of Bell Laboratories was recruited and appointed to be Deputy Director in charge of scientific programs in July 1995. Dr. Richard Sah (薩支平) returned to be Assistant Director in charge of machine operation in July 1996. In April 1997, Prof. Liu returned to Tsing Hua University for retirement after his ten-year service at SRRC. Dr. C. T. Chen became the next Director of SRRC and Dr. Keng Liang (梁耕三) of Exxon returned to become Deputy Director of scientific programs shortly thereafter. In the following year the Technical Review Committee (TRC), which operated under BOD since 1983 and had held 21 review meetings, was transformed to the Science and Technology Review Committee (STAC). As a result of these reorganizations, the institute has realigned its focus more on scientific research. We note that through these years BOD, TRC, and STAC have played very significant roles in the Center's development. Appendix I lists members of BOD, TRC, and STAC from 1983 to 2002.

Accelerator Development

The performance of the TLS machine was set to improve in four major areas. (1) The energy of the storage ring was increased to its limit 1.5 GeV, which was done in September 1996. Later, the booster energy was also raised from 1.3 to 1.5 GeV for full energy injection in February 2000. (2) A longitudinal kicker was installed in 1998 to correct bunch phase errors and a Landau cavity was also installed to test its effect on bunch lengthening. The kicker system was successfully tested at a beam current 80 mA, but advanced systems had to be redesigned because of insufficient capacity for beam operation at 200 mA. (3) The stability of the beam orbit, a serious problem for users at that time, was studied. Several actions were initiated: improving the resolution of the existing electron beam position monitor, implementing a transverse feedback system (mainly vertically in this phase), implementing photon-beam position monitors in the front ends, implementing mechanical positioning monitors with submicrometer resolution, and upgrading the stability of utility systems. (4) Several undulators were constructed. Among them, U10 and EPU, were built at this center.

By the end of the operation phase, all proposed insertion devices in the Five-Year Plan had been constructed, installed and successfully operated. The installation of insertion devices and improvements of the machine have made the performance of TLS close to a third-generation synchrotron light source. Figures 1- 4 present improvements of important machine parameters during this phase. [13]

It is worth mentioning that a major earthquake, measuring 7.6 on the Richter scale, struck central Taiwan at 1:47 a.m., September 21, 1999. (A mag-

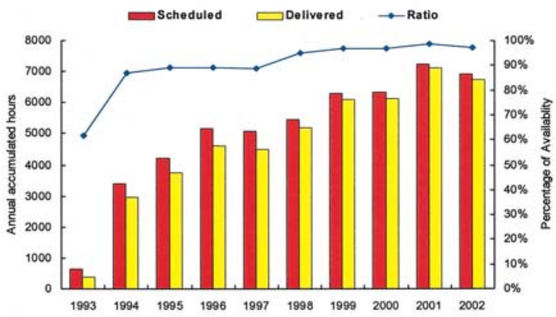

Fig. 1: Machine statistics of user shift from 1994 to 2002.

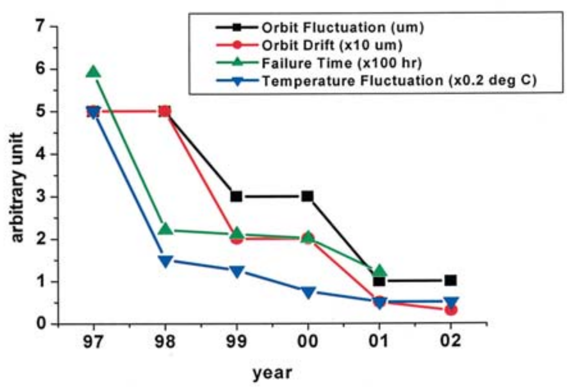

Fig. 2: Performance improvements of TLS from 1997 to 2002.

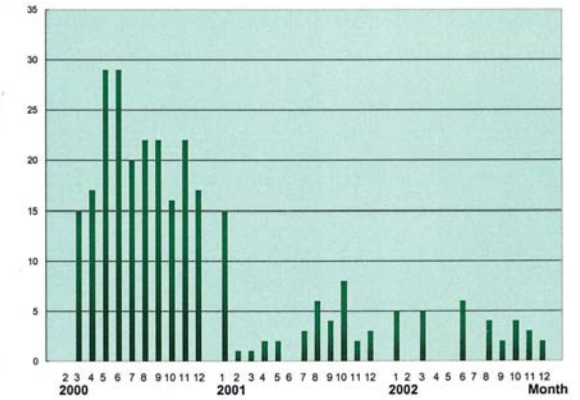

Fig. 3: Number of beam loss per month from 2000 to 2002. The performance in year 2000 was abnormal due to some coincidental problems.

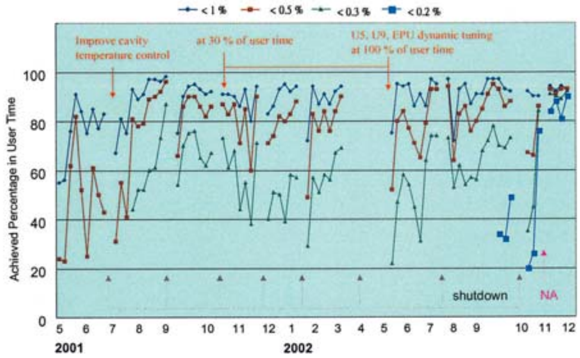

Fig. 4: Instability index (△I/I) from May 2001 to December 2002.

Table II. Main targets of the TLS for Operation and Upgrade Phases.

TLS Targets in Upgrad Phase	GOAL	Y2K	2003	Achieved date
Storage Ring Energy (GeV)	1.5	1.5	1.5	1996/09
Booster Energy (GeV)	1.5	1.5	1.5	2000/02
SR Beam Current (mA)	400	200	200	(2004)
Beam Life Time (at 200 mA)	> 10	8	12	2001
Beam Size (μm) (σy)	80	130	85	
(μm) (σx)	250	300	360	
Orbit Stability (μm in rms)	1	6	< 1	2001
Orbit Drift (μm/8 hr)	5	30	~ 5	2001
Orbit Reproducibility (μm/wk)	10	~ 100	~ 50	(Top-up: 1 μm)
Photon Beam Stability (ΔI/I)	0.1%	0.5%	0.06%	2002/11
Bunch Phase Stability (degree)	1	8	--	(LFB)
Refill Time (min, 0-400 mA)	5	20 (0-200 mA)	5 (0-200 mA)	
Filling Pattern Uniformity (%)	10	~30	(~10)	
System Failure Rate	< 1/ month	~ 3/wk	< 1/month	2001/03
Injection Efficiency	> 80%		(~30%)	(Top-up)

nitude 5.2 was measured in Hsinchu city.) The machine was fortunately shut down at the time of this earthquake. No major damage was found on machine components or subsystems. The maximum displacement of the lattice was found to be ~ 1 mm. When electric power to Hsinchu Science-based Industrial Park was recovered a week later, the machine was restarted smoothly without realignment. The reliability of the TLS construction was highly recognized, thanks to the solid work of the construction team of TLS.

Beamline Development

In the operation phase of TLS, beamline construction had been a major task at SRRC as outlined in the Five-Year Plan [11]. The Beamline Group became the Beamline Division in 1995. Since then, on average two beamlines per year have been added into operation at TLS as shown in Fig. 5 (grouped in VUV/soft x-ray and hard x-ray) and in Table IV (grouped in scientific areas). At present only four bending-magnet ports remain open for future addition of beamlines.

As more beamlines were installed, the Research Division has expanded concurrently to take charge of beamline operation and scientific programs of the two user communities of VUV/soft x-ray and hard x-ray (see Table III).

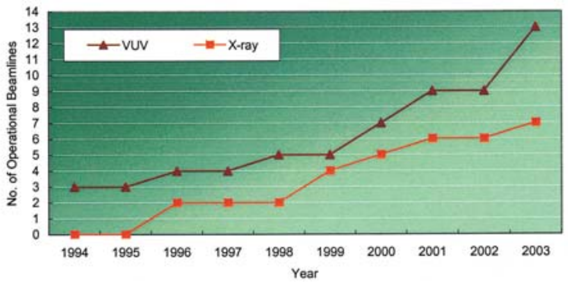

Fig. 5: Increase of number of operational beamlines with year.

VUV and Soft X-ray Research

At the beginning of the user program in early 1990, the VUV and soft x-ray research had only two groups, one in photoemission and the other in photoabsorption. As more researchers joined SRRC, the User Division expanded and became the Research Division, within which new Groups were formed. In VUV and soft x-ray areas, these Groups in early 1995 included Atomic and Molecular Spectroscopy, Condensed-matter Spectroscopy, and Industrial Application. These groups have remained since except some altered names of groups and minor group-level reorganizations. At present, they are Atomic and Molecular Science, Surface and Nano Science, Magnetism, and Micro/Nano Technology.

The Surface and Nano Science Group originated from the first research group at SRRC. The Group used the first three bending magnet beamlines, 1-m SNM (04B), low-energy SGM (08A) and high-energy SGM (20A) to perform valence and core-level photoemission and absorption spectroscopy. The HSGM line has been oversubscribed since the beginning because of great demand for soft x-ray core-level measurements. Later, a new line wide-range SGM (24A) was constructed to cover 10 - 1500 eV that also allows valence and core-level experiments on the same line. Diverse investigations, including high-Tc materials, semiconductor surfaces, electrochemical interfaces, surface photochemistry, MOCVD process, are now conducted on these beamlines. Readers are referred to past SRRC Annual Activity Reports [13] for these research activities.

The research on nano science at NSRRC was initiated with construction of two photoelectron microscopy stations on undulator ports: scanning photoelectron microscopy (SPEM) on U5 (09A1) and photoelectron emission microscopy (PEEM) on EPU (05B2). SPEM is a Participating-Research-Team station developed jointly with the Institute of Atomic and Molecular Sciences, Academia Sinica. These two stations, both delivering 90 nm special resolution, have been open to users since 2001 and 2003, respectively, and they become the first work horses for nanoscience research at NSRRC (see Research Highlights: Nanostructure and Fabrication).

In Atomic and Molecular Science, the Group had only one beamline 04B (Seya) for experiments until three more lines were added in late 2002: 03A1 (high flux on bending magnet), 21A1 (white light on U9) and 21B2 (monochromatic light on U9). The high-flux line houses a gas-phase absorption station. For two branches on U9, that for white light is a molecular-beam station for research in chemical dynamics and the monochromatic-light branch for coincidence and two-color gas spectroscopy. Users in this group are studying photochemistry, thermochemistry, chemical dynamics and kinetics of molecules related to subjects in atmospheric chemistry such as acid rain and ozone depletion. This research has recently been extended to astrochemistry in the atmosphere of extraterrestrial bodies and photochemistry of cometary materials [14]. The Group also leads the development of a two-color pump-probe technique (see Research Highlights: Experimental Methodology). This Group has recently added a mid-IR line 14A1 equipped with an IR microscopy station that will serve for IR imaging

Table III. Scientific Programs and Beamline Developments

Research Groups		Beamlines & End Stations				
Group	**Open Date**	**Source**		**Mono**	**Energy (eV)**	**End Station**
Surface & Nano Science	1994/04	BM	08A1	SGM	15 — 200	PES
		BM	20A1	SGM	110 — 1500	PES
	2000/05	BM	24A1	SGM	10 — 1500	PES
	2001/01	U5	09A2	SGM	60 — 1500	Spectroscopy
	2001/09	U5	09A1	SGM	60 — 1500	Microscopy (SPEM)
	2003/01	EPU	05B2	SGM	60 — 1500	Microscopy (PEEM)
	2003/09	BM	14A1	FTIR	mid-IR	IR Microscopy
Atomic & Molecular Science	1994/04	BM	04B1	SNM	4 — 40	Gas Phase Spectroscopy
	2002/01	U9	21A1	none	5 — 500	Chemical Dynamics
	2003/01	BM	03A1	CGM	4 — 40	Gas Phase Spectroscopy
	2003/01	U9	21B2	CGM	5 — 100	High-resol. G.P. Spectroscopy
Magnetic Spectroscopy	2000/05	BM	11A1	SGM	8 — 1500	XAS, MCD
	2001/09	EPU	05B1	SGM	60 — 1500	PES-spin resolved
	2003/01	U9	21B1	CGM	4 — 100	UPS-ultra high resolution
Micro-Nano Technology	1996/01	BM	18B1	none	> 500	Micromachining
	1998/05	BM	19A1	none	800 — 1800	Lithography
X-Ray Materials Research	1996/01	BM	15B1	DCM	2k — 7k	XAS, Scattering
	1996/01	WG	17B1	DCM	5k — 14k	XAS, Diffraction
	1999/01	WG	17B1	DCM	5k — 14k	Diffraction, Scattering
	1999/01	WG	17C1	DCM	5k — 14k	XAS, EXAFS
	2000/05	WG	17A1	BCM	9.3k	Powder X-ray Diffraction
	2001/01	SP12B1		DCM	6k — 70k	XAS, Scattering
	2003/09	SP12XU		DCM	6k — 30k	Inelastic X-ray Scattering
X-Ray Protein Crystallography	2001/09	WG	17B2	DCM	6k — 14k	MAD
	2002/09	SP12B2		DCM	6k — 22k	MAD
X-Ray Experimental Technology	2004	SWLS	01B1	DCM	6k — 20k	SAXS, X-ray Microscopy

of polymers, biological and environmental samples (see Beamline Development).

The Magnetism Group was formed when Dr. C. T. Chen joined SRRC. In 1996, his renowned Dragon beamline was transported from NSLS at Brookhaven National Laboratory to SRRC. The Dragon beamline was upgraded and re-installed on port 11A, and became fully operational in 1999. Using circularly polarized soft x-ray photons of the Dragon beamline, Magnetic Circular Dichroism measurements have become possible at TLS. A more brilliant polarized light source was designed with construction of EPU5.6 undulator. After installation and operation of this internally built device, the EPU line became operational in mid 2001 and currently houses a spin-polarized photoemission station (05B1) and PEEM station (05B2). A third branch line dedicated for an inelastic soft x-ray scattering spectrometer is currently under construction (see article in Beamline Development). These beamlines and end stations together have already advanced the magnetic research facilities at NSRRC to the world class. The current research of the group is focused on highly correlated systems and advanced materials for spintronics [15].

The Micro/Nano Technology Group has focused on development of soft x-ray lithography for micro/nano fabrication. The Group operates two beamlines; the LIGA beamline 18A1 has been operational since 1996 and the soft x-ray lithography beamline 19A1 since 1998. Besides photo-exposure capabilities at these beamlines, a class-1000 clean room was installed in 2002 to house equipment associated with LIGA fabrication.

The community of VUV and soft x-ray users is relatively established in Taiwan. The total number of active beamline proposals has reached one hundred and sixty as shown in Fig. 6. For a cross-sectional view of research activities, readers may refer to those sections of Research Highlights, Activity Reports, and List of Publications in two Activity Reports of 2001/2002 and 2002/2003.

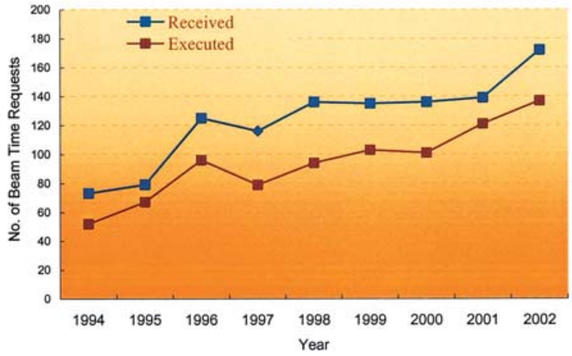

Fig. 6: Number of active vs. executed proposals in VUV and soft x-ray research.

Hard X-ray Research

The importance of x-rays from a synchrotron for research in materials and biology was well recognized at the beginning of the SRRC project. The choice of a 1.3-GeV storage ring, even though not ideal for producing hard x-rays, was due to technical and budgetary limitations at the time. An *ad hoc* Committee on Synchrotron X-ray Research and Instrumentation [16] was called in 1989 by Deputy Director E. Yen to help plan future x-ray research at SRRC. To include synchrotron x-ray research in SRRC's development plan, the Committee strongly endorsed installation of a wiggler source as early as possible even though TLS would be a low energy machine. The Committee also made recommendation of a layout of wiggler x-ray beamlines for initial operation. The installation of a 25-pole wiggler [17] was approved at the BOD meeting in July 1990 and the wiggler became the first insertion device of TLS. Three hard x-ray beamlines at the wiggler port were then actively planned [18]. Under the user training program several junior researchers had been recruited and sent to institutions abroad to learn new areas of x-ray research in late 1980s. The wiggler beamlines have become an important home base for development of contract beamlines at SPring-8 later.

The wiggler was installed in December 1994. Two x-ray beamlines, one "tender" x-ray line 15B1 on bending magnet and one wiggler line 17B1 (without mirrors), were available to users in January 1996. This marked the beginning of synchrotron x-ray research at SRRC. The installation of x-ray mirrors of three wiggler beamlines was delayed due to technical difficulty in mirror fabrication. The mirrors were finally fabricated and installed into the lines in November 1998. Soon after, these three wiggler beamlines equipped with end stations, 17A for powder x-ray diffraction, 17B for x-ray scattering and 17C for EXAFS, have become available to x-ray users (see Table IV). Since that time, the synchrotron x-ray community has been growing steadily. The specially configured 8-circle diffractometer at 17B for multiple beam x-ray diffraction [19] has also been extensively used for surface x-ray scattering of thin films and quantum dots. The stations at 17A and 17C have been widely used in structural studies of new materials of Li batteries, fuel cells, mesoporous zeolites, etc. [13]

Besides wiggler development, possible access to foreign high-energy synchrotron facilities began to be actively explored in late 1990s. With strong support of National Science Council, SRRC submitted a Letter of Intent to the Japan Synchrotron Research Institute (JASRI) in April 1998, proposing the construction of two Taiwan contract beamlines at SPring-8. This event marked an important beginning of advanced synchrotron x-ray research for NSRRC users (see Research Highlights: Taiwan Beamline Office at SPring-8). A multimode x-ray beamline 12B2, which complements the wiggler beamlines at home for materials research with x-ray energy extended to 70 keV, was open to users in January 2001. The undulator beamline 12XU for inelastic x-ray scattering, which offers new capabilities to probe electronic structure with hard x-rays, was open to users in September 2003 (see Research Highlights: Experimental Methology).

As is occurring in other synchrotron facilities worldwide, protein x-ray crystallography has been accorded our highest priority of x-ray activity in recent years. To develop a state-of-the-art facility for protein x-ray crystallography, an *ad hoc* Advisory Committee on the Construction of Protein Beamline and End Station [20] was called in early 2001. Through collaboration with JAERI, our first modern protein crystallography station with an ADSC Quantum 4R CCD detector was installed at SPring-8 beamline 12B2 and became available to biological users in September 2002. The existing station at wiggle 17B was also upgraded. Within a brief interval since, numerous protein structures have already been solved (see Research Highlights: Biology). More importantly, both protein stations are operated concurrently with the new initiative of the National Science and Technology Program for Genomic Medicine. Under the support of this program, NSRRC was funded to construct a new protein crystallography facility with a superconducting multi-pole wiggler source and two dedicated and highly automated beamlines to be the X-ray Core Facility for the Program. This new facility is expected to be commissioning by the end of 2004. The design of new protein crystallography beamlines is discussed in the section on Beamline Development.

The growth of x-ray research at NSRRC is reflected in the increased number of x-ray beamlines (see Fig. 5), the number of x-ray proposals (see Fig. 7), and the organization expansion. SRRC had only one x-ray group in the Research Division before 1999. At present, there are four groups, for X-ray Materials, Taiwan Beamline Group at SPring-8, X-ray Biostructure, and X-ray Experimental Technology. The last group was formed only recently and charged with development of x-ray imaging and small-angle x-ray scattering for research in soft matter and bio-materials.

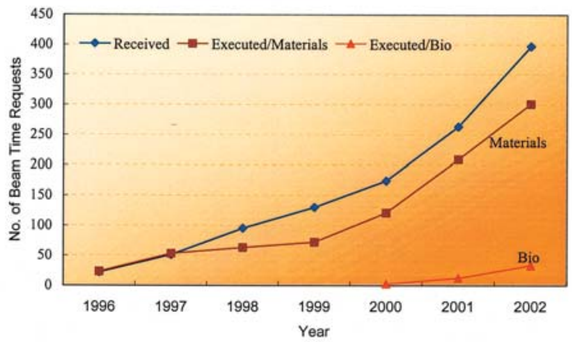

Fig. 7: Number of active vs. executed proposals in hard x-ray research

User Operation

As SRRC gradually transformed from the facility construction phase to a user-based research institution, the User Service Group become the User Administration Office (UAO) in 1997 and the User Executive Committee (UEC) was established. The UEC Chairs are Dr. Y. K. Hwu (胡宇光 1997-1998), Prof. W. F. Pong (彭維鋒1999), Prof. K. J. Chao (趙桂蓉 2000), Prof. R. S. Liu (劉如熹 2001), Prof. S. Cheng (鄭淑芬 2002), and Prof. C. H. Lee (李志浩 2003). The UAO serves as NSRRC's contact window for users and manages user business such as user registration, beamline proposal submission and review, beamtime schedule, student financial aid, and annual user meeting. There are at present three Proposal Evaluation Committees (VVU/soft x-ray spectroscopy, x-ray materials research, and x-ray biostructure) with members formed from the external user community. An Annual User Meeting has been held regularly since 1995. In addition, many workshops and short courses have been organized to promote synchrotron radiation research in Taiwan (see Appendix II). Many synchrotron scientists from around the world have been invited to lecture at these workshops.

The UAO has set up web-site operation and manages the user data base. Figures 8 and 9 show two aspects of user data: a profile of distribution of research proposals in various scientific disciplines and statistics on publications. Scientific activities shown in Fig. 8 cover a broad spectrum of our academic community. Published papers, as shown in data of Fig. 9, are collected in the memorial CD, "Tenth Anniversary of Operation". [1] Today's scope seen in both figures reflects the growth of the synchrotron community in Taiwan.

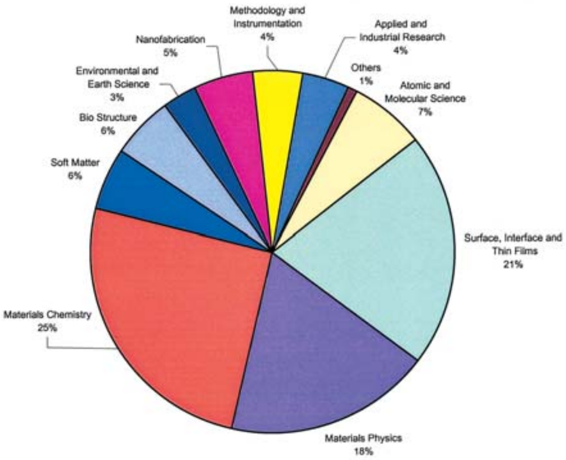

Fig. 8: Distribution of research proposals in various scientific disciplines.

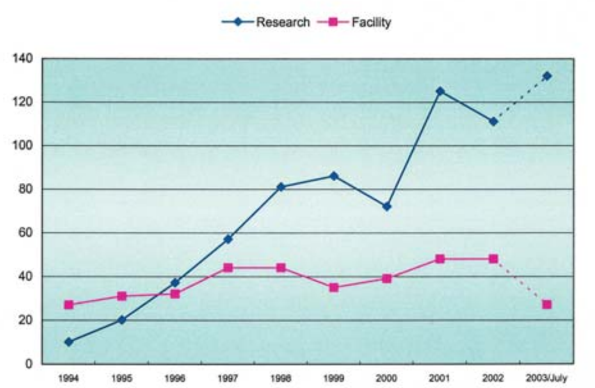

Fig. 9: Numbers of publications based on work done at NSRRC facilities.

It is of great interest for NSRRC to promote further the user program to the international community. The Taiwan Beamline Office at SPring-8 was established in 1999. At home, our list of users from abroad has recently been extended to cover users of the Australian Synchrotron Project.

The Upgrade Phase (2000 and beyond)

Year 2000 was a year near the completion of the Five-Year Plan. New emerging scientific programs such as photoelectron microscopy and protein crystallography demand improved performance of the storage ring. It was a time to examine critically the machine status and to identify areas of future upgrade. In May 2000, the Machine Advisory Committee [21] was called by Director Chen to address machine studies, in particular issues related to future machine upgrade.

In response to increased demand for hard x-rays, one upgrade is to enhance the TLS spectrum in the high energy region. Making TLS produce hard x-rays involves taking the step to use superconducting devices. SRRC started to develop superconducting insertion devices for a hard x-ray source (see article in Accelerator Development). The first device, a superconducting wavelength shifter, was constructed and installed at TLS in February 2002. A second device, a multi-pole superconducting wiggler for protein crystallography beamlines, is currently under final test for installation. Two further such wiggler devices can ultimately be installed at TLS to serve x-ray community.

At the same time, the replacement of two old cavities (from DORIS storage ring in Germany) with a single superconducting RF cavity has been initiated [22]. This replacement is expected to increase the beam current from 200 mA to 400 mA and can improve the stability. The project involves construction of a new cryogenics plant that is near completion. A schematic of an upgraded TLS machine is shown in Fig. 10. Most recently, a study of top-up mode injection has been initiated (see articles in Accelerator Development). These tasks have already moved far beyond the goals envisioned in the early plan of TLS twenty years ago.

Final Remarks

Finally, the Synchrotron Radiation Research Center (SRRC), a Preparatory and Construction Office (籌建處) has been changed to the National Synchrotron Radiation Research Center (NSRRC) in May 2003. The NSRRC is now a national laboratory formally approved by the Legislative Yuan. The Board of Directors, having held 44 meetings since 1983, was dissolved and a new Board of Trustees has been formed. Dr. Luke Yuan (袁家騮) had served Chairman of BOD from 1983 until the end of 2002. Prof. Yuan-Tseh Lee (李遠哲), President of Academia Sinica and member of BOD since beginning of SRRC, is appointed the first Chair of BOT by the Executive Yuan. In the tedious legislative process of reorganization, a special committee headed by Dr. Shih-Cheang Cheng (鄭士昶), Deputy Director of administration, was formed to take charge of planning the by-laws and new regulations of NSRRC. Under the new organization, the NSRRC is better empowered to pursue the challenge of making the institution a world-class center in synchrotron radiation research.

To conclude, we quote Professor Poh-Kun Tseng's (鄭伯昆) statement [3] in the first SRRC Annual Report, 1995: "We made mistakes, we learned from them, we proceeded, and we succeeded. Repeating this process, we have trained a talented pool of scientists and engineers..... Now we are preparing ourselves to take a place as a world class institution." The story will continue with new scientific thrusts and, hopefully, a second storage ring of 3 GeV or a free electron laser.

Acknowledgements

The birth of a complex facility from nothing to the realization of its full potential has been due mainly to solid hard work and full commitment of the entire SRRC-NSRRC staff. Our heartfelt gratitude goes to all members [Appendix I] of the Board of Directors, Technical Review Committee, Science and Technology Review Committee, and Machine Advisory Committee. Our special gratitude is due to Dr. Herman Winick (TRC Chair 1984-1994), Dr. Yves Petroff (TRC/STAC Chair 1994-2001), and our former Directors Prof. Edward Yen (閻愛德) and Prof. Yuen-Chung Liu (劉遠中). Special tribute is due to Prof. Robert Poe (浦大邦), Dr. Luke Yuan (袁家騮BOD Chair 1983-2002), and Prof. Sung-Mao Wang (王松茂 Executive Secretary of BOD 1984-2002). We thank consultants and friends at home and abroad who have not only been a constant source of support to us throughout the years but also contributed to our success with their invaluable advice.

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3. P. K. Tseng, "Brief History of Constructing SRRC Synchrotron", SRRC Annual Report 1995; P. K. Tseng, private communications.
4. Science Monthly, vol. 26, no. 4, (1995). (in Chinese科學月刊二十六卷四期, 浦大邦先生逝世十週年紀念文集)
5. Y. C. Liu, P. K. Tseng, Edward Yen, C. N. Chang and K. C. Cheng, "Synchrotron Radiation Feasibility Study Report", National Science Council, R.O.C., November 1982. (in Chinese: "同步輻射可行性研究報告", 劉遠中(召集人), 鄭伯昆, 閻愛德, 張秋男, 鄭國川)
6. Members of the 1st Board of Directors included six distinguished scholars from abroad, Luke Yuan (袁家騮, Chair), Chien-Shiung Wu (吳健雄), Lee C. Teng (鄧昌黎), Samuel C. C. Ting (丁肇中), Robert T. Poe (浦大邦), and Yuan-Tseh Lee (李遠哲), and six distinguished domestic members, Szu-Liang Chien (錢思亮), Ta-Yo Wu (吳大猷), Kwoh-Ting Li (李國鼎), Yen-Shih Tsiang (蔣彥士), Chen-Hsang Yen (閻振興), and Ming-Che Chang (張明哲 NSC Chairman).

7. Members of the 1st Technical Review Committee were H. Winick (SSRL), J. Blewett (BNL), A. van Steenbergen (BNL), A. Hofmann (SSRL), G. Mulhaupt (BESSY), R. A. Jameson (LANL), M. Allen (SLAC), and C. S. Wu (Columbia Univ.).
8. Proceedings of the International Workshop on Constructing 1-2 GeV Synchrotron Radiation Facilities, Feb. 22-27, 1988, Taipei, Taiwan, R.O.C.
9. "SRRC Design Handbook", April 1989.
10. Y. C. Liu, "A Preliminary Proposal for Installation and Commissioning Tasks of the SRRC 1.3 GeV Electron Storage Ring," November 1989.
11. "SRRC Five-Year Plan", 1st draft issued in July 1994. The Plan was reviewed at the 15th TRC Meeting on Nov. 4-5, 1994; a final version was issued in April 1995.
12. The *ad hoc* Science Advisory Committee consisted of 17 domestic and 3 overseas senior scientists (see list in Ref. 11). The three oversea members, W. T. Weng (翁武忠) of BNL took a sabbatical leave to SRRC in 1994 - 1995 to help the Plan, and C. T. Chen and K. S. Liang joined SRRC in the following years.
13. See progress reports in SRRC Annual Reports of years 1996 - 2000.
14. B.-M. Cheng, et al., SRRC Activity Report 2001/2002, p. 6-9.
15. D. J. Huang, SRRC Activity Report 2001/2002, p. 10-13.
16. Members of ad hoc Committee on Synchrotron X-ray Research and Instrumentation were Hayden Chen (程海東Chair), Keng Liang(梁耕三), Andrew Wang(王惠鈞) and Joe Wong(黃念祖).
17. S. L. Chang, "Report on SRRC Wiggler Planning", April 1990.
18. C. H. Lee, "Description of Wiggler X-ray Beam Lines at SRRC", March 1992.
19. S. L. Chang, SRRC Activity Report 2001/2002, p. 18-21.
20. Members of *ad hoc* Committee on Protein X-ray Crystallography included Peter Kuhn (Chair, SSRL), Howard Padmore (ALS), Tetsyua Ishikawa (SPring-8) and Edward Westbrook (APS).
21. Members of the Machine Advisory Committee are Shyh-Yuan Lee (李世元Chair), Alex Wu Chao (趙午), Hank Hsieh (謝啓淮), Alex Pei (裴小敏) and Yiton Yan (顏貽通).
22. Ch. Wang et al., SRRC Activity Report 2001/2002, p. 46-50.

Appendix I. List of Members of BOD, TRC and STAC

Board of Directors (BOD), 1983 － 2002

(in Chinese)

袁家騮 (主任委員, 1983 — 2002)

丁肇中(1983 — 2002)	李遠哲(1983 — 2002)	李國鼎(1983 — 2001)	吳大猷(1983 — 2000)
吳健雄(1983 — 1997)	浦大邦(1983 —1984)	*張明哲(1983 — 1984)	閻振興(1983 — 2002)
鄧昌黎(1983 — 2002)	蔣彥士(1983 — 1998)	錢思亮(1983)	*陳履安(1984 — 1993)
*夏漢民(1988 — 1994)	*郭南宏(1993 — 1996)	*劉兆玄(1996 — 2002)	*黃鎮台(1998 — 2000)
+楊世緘(1999 — 2000)	陳定信(1999 — 2002)	+蔡清彥(2000 — 2002)	*翁政義(2000 — 2001)
*魏哲和(2001 — 2002)	史欽泰(2001 — 2002)	沈元壤(2001 — 2002)	陳長謙(2001 — 2002)

*: 國科會主委 +: 行政院政務委員

Luke C. L. Yuan (Chairman, 1983 — 2002)

Samuel C. C. Ting (1983 — 2002)	Yuan-Tseh Lee (1983 — 2002)	Kwoh-Ting Li (1983 — 2001)
Ta-Yo Wu (1983 — 2000)	Chien-Shiung Wu (1983 — 1997)	Robert T. Poe (1983 —1984)
*Ming-Che Chang (1983 — 1984)	Chen-Hsang Yen (1983 — 2002)	Lee C. Teng (1983 — 2002)
Yen-Shih Tsiang 1983 — 1998)	Szu-Liang Chien (1983)	*Li-An Chen (1984 — 1993)
*Han-Min Hsia (1988 — 1994)	*Nan-Hung Kuo (1993 — 1996)	*Chao-Shiuan Liu (1996 — 2002)
*Jenn-Tai Hwang (1998 — 2000)	+Shih-Chien Yang (1999 — 2000)	Ding-Shinn Chen (1999 — 2002)
+Ching-Yen Tsay (2000 — 2002)	*Cheng-I Weng (2000 — 2001)	*Che-Ho Wei (2001 — 2002)
Chintay Shih (2001 — 2002)	Yuen-Ron Shen (2001 — 2002)	Sunney I. Chan (2001 — 2002)

*: Chairman of NSC +: Minister without Portfolio of the Executive Yuan

Technical Review Committee (TRC), 1984 － 1997

Herman Winick (1984 — 1997, Chairman 1984 — 1994)

Yves Petroff (1992 — 1997, Chairman 1994 — 1997)

Matthew Allen (1984 — 1997)	John Blewett (1984 — 1993)	Albert Hofmann (1984 — 1997)
Robert Jameson (1984 — 1997)	Gottfried Mulhaupt (1984 — 1993)	Arie van Steenbergen (1984 — 1997)
Chien-Shiung Wu (1984 — 1997)	Massimo Cornacchia (1987 — 1997)	Kazuo Huke (1989 — 1993)
Boris W. Batterman (1992 — 1997)	Brian M. Kincaid (1992 — 1997)	
Franz Himpsel (1994 — 1997)	William B. Peatman (1994 — 1997)	

Science and Technology Advisory Committee (STAC), 1998 － 2001

Yves Petroff (Chairman, 1998 — 2001)

Boris W. Batterman (1998 — 1999)	Massimo Cornacchia (1998 — 2000)	Franz Himpsel (1998 — 2000)
Keith Hodgson (1998 — 2001)	Robert Jameson (1998)	Brian M. Kincaid (1998 — 1999)
William B. Peatman (1998 — 1999)	George A. Sawatzky (1998 — 2001)	Ward Plummer (1999 — 2001)
Sunil K. Sinha (1999 — 2001)	Howard A. Padmore (2000 — 2001)	Volker Saile (2000 — 2001)
Seshi Kikuta (2001)	Ingolf Lindau (2001)	

Appendix II. List of Workshops and Short Courses

1979	August	Symposium on Atomic and Molecular Sciences (Co-Chairs: R. T. Poe浦大邦, E. Yen閻愛德)
1982	Apr. 8-9	Workshop on Synchrotron Radiation (Chair: L. C. Teng鄧昌黎)
1982	July 16 - 17	Symposium on Research Opportunities in Synchrotron Radiation (Chair: R. T. Poe浦大邦)
1984	March - May	A Serial Lectures on Synchrotron Radiation Research (Organizer: M. C. Wang王明建)
1984	Aug. 20 - 24	Symposium on Synchrotron Radiation (Co-Chairs: C. S. Wu吳健雄, R. T. Poe浦大邦)
1985	Mar. 21 - 23	Symposium on Application of Synchrotron Radiation in Atomic and Molecular Science(Co-Chairs: C. D. Chang張昭鼎, E. Yen閻愛德)
1988	Sept. 5 - 7	Symposium on Synchrotron Radiation - Photon Beamlines and Their Applications (Chair: E. Yen閻愛德)
1989	June 26 - July 7	Lectures on X-ray Absorption Spectroscopy (Speakers: H. Chen程海東, S. K. Chen陳世傑, J. Wong黃念祖; Organizers: Y. Wang王瑜, J. F. Lee李志甫; Sponsor: Chem. Dept., NTU)
1991	Jul. 2 - 4	Symposium on Synchrotron Radiation Applications (Chair: E. Yen閻愛德)
1992	Jul. 27	Workshop on Applications of Synchrotron VUV Radiation (Chair: S. L. Chang張石麟)
1993	June 30 - July 6	Short Course on VUV Spectroscopies and Applications (Speaker: L. C. Lee 李隆吉; Organizer: J. M. Chen陳錦明)
1993	Oct. 16	Workshop on Third Generation Synchrotron Radiation Sources (Chair: Luke Yuan袁家騮)
1994	Sep. 22 ~ Oct. 7	Microsystem Technology Intensive Course (Y. Cheng程曜)
1995	Jan. 31 - Feb. 3	First Workshop on Micro-Electro-Mechanical Systems (Chair: Y. Cheng程曜)
1995	Sep. 1-8	Workshop on Absorption Spectroscopy and Related Phenomena (Co-Chairs: Y. Wang王瑜, J. F. Lee李志甫; Sponsor: Chem. Dept., NTU)
1995	Sept. 4 - 5	Seminar Series on VUV and Soft X-ray Applications of Synchrotron Radiation (Chair: Y. W. Yang楊耀文)
1996	Jan. 8 - 10	Second Workshop on Micro-Electro-Mechanical Systems (Chair: Y. Cheng程曜)
1997	Aug. 9 - 10	International Symposium on X-ray Absorption Spectroscopy (Co-Chairs: W. F. Pong 彭維鋒, J. F. Lee李志甫; Sponsor: Tamkang U.)
1998	Nov. 17 - 21	X-ray and Neutron Scattering Workshop (Co-Chairs: S. H. Chen陳守信, Y. C. Chou周源卿, K. Liang梁耕三; Sponsors: INER & SRRC)
1999	July 26 - 31	Summer School of X-ray Absorption Spectroscopy (Organizer: J. F. Lee李志甫)
1999	Oct. 20 - 21	Workshops at Fifth Users Meeting: Real-Time Film Growth Research (S. Y. Lee李信義, C. H. Hsu徐嘉鴻) New Materials for Future IC Industry (T. W. Pi皮敦文) Catalyst Research and Environmental Science (J. F. Lee李志甫) Synchrotron Radiation Application in Materials Science (W. F. Pong 彭維鋒)
2000	May 31	Workshop on Synchrotron Radiation Research in Atomic and Molecular Science (Chair: K. Liang梁耕三)
2000	Jul. 3 - 7	Summer School on XAS and X-ray Powder Diffraction (Organizers: J. F. Lee李志甫, H. S. Sheu許火順)
2000	Oct. 25 - 26	Workshops at Sixth Users Meeting: New Scientific Opportunities in Life Science (Co-Chairs: A. Wang王惠鈞, K. Liang梁耕三) Synchrotron-based Microscopies and Studies of Nanostructure (W. F. Pong 彭維鋒, K. L. Tsang曾金榮)
2000	Dec. 6	Workshop on Scientific Opportunities in Inelastic X-ray Scattering (Co-Chairs: C. C. Kao高季昌, C. T. Chen陳建德)
2001	Oct. 31	Workshop at Seventh Users Meeting: Strongly Correlated Electrons Systems (D. J. Huang黃迪靖)
2002	Oct. 31	Workshop at Eighth Users Meeting: Application of Synchrotron Radiation in Biology (C. J. Chen陳俊榮)