V. BSRF and Free Electron Laser

5.1 BSRF

5.1.1 Dedicated Operation for Synchrotron Radiation

Three periods of dedicated operation for synchrotron radiation were carried out in 2002. The first period of operation lasted 30 days from March 15 to April 15, 2002 with 744 beam hours provided and 96 proposals arranged. The second period of operation lasted from May 23 to June 15, 2002 with 552 beam hours provided and 67 proposals arranged. The third period of operation lasted from November 22 to December 12, 2002 with 20 days’ beam time provided. The first 10 days were used for recovery and adjustment of the storage ring. In the remaining 10 days, 218 beam hours were provided and 36 proposals arranged.

During the 3 periods of operations, 1514 beam hours were provided and 199 proposals arranged altogether. The users came from 44 institutions of 11 provinces, cities and autonomous regions, including 12 institutes of CAS, 27 universities, and 5 institutes of different departments, and also some users from France, Italy, Australia and Romania. 127 proposals in all were arranged for the 11 experimental stations. The proposals covered the fields of condensed matter physics, materials science, chemistry, biology, environmental science, archeology, medicine, micro-electronics, micro-mechanics, etc.

Most instruments at the experimental stations ran effectively during the operation. By cooperating with the users, we provided necessary conditions for the research subjects. However, due to the upgrading of BSRF, the proposals arranged this year were reduced a little bit and the beam time of some users was also affected.

5.1.2 Upgrading of BSRF

The upgrading of BSRF has been further carried out in 2002 in order to improve the overall property of BSRF. Altogether 13 projects were arranged in 2002. They are all doing very well. In the front-end regions, 4W2, 1W1, 3B3 have been installed and adjusted. It is the same case with the device protecting system and the interlock system. The vacuum reached the design value. During the dedicated operation from November 25 to December 14, 2002, the synchrotron radiation light was extracted from these three front-end regions. The output windows were increased from 4 to 7, thus laying a solid foundation for the improvement of the overall experimental properties of BSRF.

The construction of the bio-macromolecular crystal structure beamline and the experimental station is the main part of the project "the Foundation of Synchrotron Radiation Biological Platform and Application of the Methodological Research on Bio-macromolecular Crystal Structure" and also a basic condition for the project. The total beamline reached the design vacuum in November 2002 and started collecting diffraction data of the bio-macromolecular crystals on Dec. 4, 2002. The station used Mar345 IP as the detector, and sample cooling was used during data collection. During 6 days’ operation from December 4 to 11, 20 kinds of crystals were tested, including neurotoxin, enzyme, etc. About 18 sets of data, more than 2000 frames were collected. Combined with the other stations of BSRF such as XAFS, circular dichromatic spectra, small angle X-ray scattering, a platform that can study the structure from solution to crystal will be established.

Another project “the Research of Experimental Techniques Under High Pressure and Temperature
by Synchrotron Radiation and the Properties of Some Important Mineral of the Earth Mantle and Core also did well. The in-vacuum wiggler 4W2 and the front-end region used for high pressure and temperature were installed in summer. The beamline and HUTC were also installed in November. The adjustment was finished in December, and some beam time was provided for the users. The design of EDXD system has been finished and some parts produced including the hardware and some software of the control system. The design of the laser heating and temperature measurement system has been finished. The total system will be adjusted next year. This station will provide the method for studying the structure of matter in the earth and materials under high pressure and temperature.

Other beamlines such as the 4B9A X-ray diffraction beamline, the 3B1A lithography beamline, have been upgraded and re-opened to the users. The new 3B1B VUV beamline has been installed and operated. The 3B1C LIGA beamline has also been installed and adjusted. The 1W1 EXAFS and 3B3 medium energy beamlines are ready for installation next year.

5.1.3 Scientific Research

1. Enlargement of Research Fields

The research fields of synchrotron radiation have been enlarged this year, especially in the field of environmental science. Lots of projects have achieved good results. With the construction of the bio-macromolecular crystal structure beamline and station, the biological users, especially the users of protein structure have shown great interest. It is expected that a great number of users will join the research on biology.

2. Development of Experimental Techniques

The research of in-line holographic phase contrast imaging was carried out at the X-ray topography experimental station of BSRF by the monochromatic synchrotron radiation with a coherence length of several micrometers provided by the beamline of 4W1A. This technique is available to users. In 2002, we have got the phase contrast images of big (>20 mm) and small (<2 micrometers) samples. The research of atmosphere gel (dimension smaller than 2 micrometers) shows that the resolution is better than 2 micrometers. The research on the cancers of mouse was also carried out using Si(111) single crystal as monochromator. The spot size is 18(H) X 8 (V) mm². Using Si(220) single crystal as monochromator, the spot size can reach 14 X 28mm².

The techniques such as the grazing angle diffraction, the low angle reflection, the mapping and pole figure measurements play important roles in the research on superconductor, semiconductor and ferro-electric material surface. The research on the reflection and scattering of liquid surface was also carried out and the measurement method of surface reflection of organic solution was established. The measurement of the grazing small angle X-ray scattering for studying quantum dots was also developed.

The development of detectors and detecting techniques has been carried out. We studied some metalloprotein by fluorescence XAFS. This is the basis for the future study of the metalloprotein local fine structure.

3. Application Research

Some creative researches on nano carbon tube were carried out. The study of the total electron yield XAFS of C 1s shows the structure of sp2 hybridization (π*) at 286eV and the binding of the nano C tube and residual raw materials at 289eV (C-H, δ*). The hydrogen-restored nano C tube and its electronic structure were also studied and the differences compared. This research has opened a new field of characterization and study of nano C tube structure. The L3 edge of Ce inside nano porphyrin molecule (rare earth sandwich type porphyrin ligand) was studied and compared with the ab initio calculation. The nanometer-sized molecular structure was obtained quantitatively for the first time.

The semiconductor ZnO with nanometer size was synthesized and studied by XAFS to obtain the surface reconstruction and distortion. A series of studies were carried out for nanometer size ZnO, NiO, Fe3O4, CeO2 and TiO2 in order to understand the relationship between the structures and properties. The study of the full electron yield (TEY) of O 1s displayed the difference in the electronic structure and orbital hybridization between the bulk and nano phase. The quadruple transition of nano rutile titanium oxide was confirmed for the first time.

The status of components and strain in different
sizes and shapes of Ge/Si quantum dots were studied. The effect of Si layers in the microstructure of Ge/Si was discussed and a new mechanism of strain suggested.

4. The advancement of Applied Technology

Breakthroughs have been made in the applications of LIGA technology. With the resist and metal structures of high aspect ratio, the heat exchange, the gears for security lock and the slowing nets for positive electrons were provided to users. Many devices were developed for other institutes, for example, the capillary biochip finished by the micro fabrication and high temperature bonding process and the copper microstructure with a thickness of 0.5mm by electrical discharge machining (EDS). The alignment for the second lithography and the tilt exposure are also under way.

5.1.4 High Pressure Research Station

1. Operation

528 beam hours in all were provided to users in 2 periods of operations. 9 projects were carried out and 57 samples measured for the high pressure transition. The fields of research include materials (nanometer sized materials), condensed matter physics (superconductor, colossal magnetoresistance materials), chemistry and geology. The users came from the State Key Laboratory of Super Hard Materials of Jilin University, the Institute of Physics, the institute of Chemistry, the Department of Geology of Peking University, the Institute of geo-chemistry, etc.

2. Construction of New Beamline and Experimental Station

The new beamline 4W2 and HUTCH of the experimental station have been constructed. And they started to operate.

3. The New Experimental System

The new EXDX system under high pressure and high temperature is being developed. It will provide better conditions for the research on geo-science and new materials.

5.1.5 Fluorescence Analysis

1. Experimental Activities and Setup Improvement

A total of 25 user projects were carried out during the three periods of dedicated synchrotron radiation runs in 2002. Some rather difficult problems in our user research programs were solved using SRXRF technique. One of them is the great progress in the trace element analysis of single cell from the two users of Department of Medicine of Peking University, and University of Agriculture of China. The second one concerns about 70 samples of Chinese offshore crude oil, which were quantitatively analyzed by non-destructive SRXRF. The trace element content data can provide scientific information for the exploration of offshore crude oil. The last one is the trace element Ni (about one ppm) which was detected and identified in the metal protein samples from Tsinghua University.

Some experimental instruments were updated. One new Si(Li) solid state detector with the Be window thickness of 7.5 μm and related electronic system were used, the element of Na – U can be detected with higher detection efficiency and energy resolution (134 eV & 5.9 KeV). The converting spectrum program for the new detector was compiled and the normalization of the synchrotron radiation intensity and correction of the air absorption were included in the spectrum data process. The second important upgrade of the setup is the oncoming use of the KOHOZ high precise slit with 1 μm/step. The slit was imported from Japan, but we developed the electronic control system. The other experimental facilities were also improved, such as the laser collimation system, the holder of the microscope, the lamp illumination system, the holders of the new detector and the control system of the total reflection XRF. All the above efforts made it possible for the users to obtain better experimental data. Some research results were published in important international or domestic journals.

The maintenance and improvement of the step motor control devices at BSRF were completed, such as the control devices of the VUV and 4B9 beamlines. Many new step motor control devices were further designed and developed for building several new beamlines and experimental stations at BSRF, such as 1W1, 4W2, 3B3, and the macromolecular beamline and the experimental station. These work played an important role in the dedicated synchrotron radiation experimental activities and the smooth commission of several new beamlines and stations.
2. Progress of Research Projects

For the 4W1B beamline upgrading project, a new photo shutter was designed and made for the white light. The physics design of the construction of FOE and HUTCH was completed. The Be window was plated with aluminum for preventing oxidation. The preliminary design for the monochromator upgrading for the use of white and monochromatic light was finished.

For a high resolution spectrometer and its application project, the physics design and computing of high resolution spectrometer were finished. Investigation concerning the design and product information of spherical crystal was carried out. Two sets of spherical crystals were successfully designed and made by cooperating with BNL. A 16-channel control device for the whole instrument was imported from Japan. The mechanical system design of the whole spectrometer was basically completed.

Concerning the XRF automatic scanning project, the high precise electronic control slit was imported from Japan. We made the control device and related software. The automatic scanning and spectra acquiring software is being developed.

As to the application of high resolution X-ray spectroscopy for chemical state analysis, an international collaboration project (supported by Ministry of Science and Technology) was carried out. The chemical state effect of transition of metal chromium and its compound (three kinds of valence, four kinds of compound) was carefully analyzed. The high resolution spectra of Kb1, 3 and its satellite peak were measured and investigated using high resolution spectrometers based on synchrotron radiation and proton beam. The two research results will be published in the international journals of PIXE and Nuclear Instrument and Method.

3. Research Projects in Progress

The 4W1B beamline upgrading project; the high resolution spectrometer and its application project; the XRF automatic scanning project and the ion acoustic effect simulation. Projects in application contain non-destructive analysis of single fluid inclusion; ancient porcelain nondestructive analysis and application of high resolution X-ray spectroscopy for chemical state analysis.

5.1.6 Photoemission Spectroscopy Station

1. Operation

25 projects were arranged during the 3 periods of operations with 16 finished. The other 9 projects are unfinished because of the problem of samples and instrumentation, such as the replacement of grating, etc.

2. Upgrading

Two gratings were replaced to improve the intensity of the incident beam of the experimental station.

5.1.7 XAFS

1. XAFS Beam Time Running

There were altogether 3 periods of dedicated runs for SR. The actual machine time for experiments is 63 days, and the efficiency is about 98%. A total of 61 proposals have been implemented.

2. Progress of the Engineering Project

The project has been carried out according to our plan. The current status is as follows: The design of the 1W1-XAFS beamline has been finished. The purchase from foreign companies and non-standard manufacture of collimating mirror, monochromator and focusing mirror for the 1W1-XAFS beamline have also been completed.

Two patents about the innovative components were filed for registration. A special BPM amplifier was developed. And what's more, we promoted the homemaking of Be window and resolved the problem in the initial design.

The test of 1W1 WIGGLER has been completed in terms of the size, the vertical distribution and the spectra of X-ray. We also checked the effect of the closed orbit on the X-ray of the 1W1-XAFS beamline, tested the actual orbit of X-ray and made preparations for the installation of the 1W1-XAFS beamline.

The installation and test of the 1W1-XAFS beamline are going on according to plan.

3. The Joint Research Project

Important progress has been made in the joint research with the Institute of Physics, the Chinese Academy of Sciences. We studied the Kr structure in low temperature and obtained liquid and solid Kr XAFS spectroscopy.
The XAFS group cooperated with the National Institute of Material Research, Romania and investigated the structure of nano materials and catalysts. 50 series of XAFS spectra were collected and 3 proposals finished.

The research on environmental science was jointly conducted with the Zoology Center and the Institute of Geography, the Chinese Academy of Sciences. Good results were obtained.

XAFS for low concentration of biology samples (50ppm) was collected. High pressure XAFS was also tested at the XAFS station. The XAFS for sample in 30Gpa was first obtained. It has been confirmed that it is feasible for high pressure XAFS experiment to be done at the BSRF XAFS station.

Study of aerosol was carried out. The effect of atmospheric aerosol on ecological environment, human health and global climate change is a popular research field in the world. During the beam time, the XAFS technique was employed to characterize the local structure and chemical state of Fe, Pb, Cu, Zn aerosols in Beijing and Qingdao.

4. Progress in the Development of Instrumentation and Experimental Methods

The grazing-incidence XAFS method was developed. Using this method, the concentration lower limit was improved by 10 to 20 times.

The chemical valence state was determined by the XAFS technique. The new device consists of two parts: the Lytle-type ion chamber and a PIN photodiode detector. The Lytle-type ion chamber detects the fluorescence signal from the real sample while the PIN photodiode records the transmitted signal from the standard sample separately and simultaneously. Comparing the two spectra, the energy shift of the X-ray absorption edge can be calibrated and the valence state determined precisely.

The PIN photodiodes for XAFS detector were developed. And good results were obtained.

5. New Research Projects

The new projects undertaken include “Study on New XAFS Fluorescence Detector and Filter”, “Development of High Resolution X Ray Fluorescent Detector and Its Application in biological Systems”, etc.

5.1.8 Soft X-ray Optics Station

About 950 hours of beam time were provided to 14 users during the three periods’ dedicated operation. And experiments on the measurement of absorption cross-section of rare gas, the standard of soft x-ray detector and the study of the characteristics of the 3W1B beamline were done in parasitic mode.

Good progress has been made in the construction of the 3B3 soft x-ray double crystal monochromator beamline. The component fabricated in China has been installed in the designed position. The double crystal monochromator made by Kohzu Company, Japan will be delivered in March of next year.

The two projects have been successfully completed. The first one is “Development of the XUV Standard Detector” supported by the USTC National Synchrotron Radiation Lab and the second one is “Study of the Calibration and Characteristic of the Soft X-ray Detector” supported by the National High Technology Project. And progress has also been made in the project “Study of the Synchrotron Radiation Soft X-ray Polarization” supported with our own fund.

5.1.9 The Topography Station

Three dedicated operations of SR were carried out in 2002, totaling 1118 hours. About 660 hours were provided to users. 15 projects were arranged. The beam orbit was adjusted during the third dedicated operation for synchrotron radiation.

The main research work is as follows:

1. Study of X ray diffraction topography of defects present in the crystal material and the growth dynamics for crystal material;
2. Study of the technique and application of hard X ray phase contrast and
3. Study of the microstructure, mechanics of action for composite material.

The research on X ray phase contrast imaging was further developed. The two-dimensional X ray phase contrast imaging system was constructed. This system consists of a single crystal monochromator with an asymmetrictically reflecting silicon (220) crystal or a double-crystal monochromator with a reflecting silicon (111) crystal, an optics table, a sample stage, an exposure stage and a camera. All work on the phase
contrast imaging technique and application was carried out, such as the choice of various X-ray optics, earlier detection of liver tumors from SD rat and the observation of tissue slices from human lung and stomach cancer and the lung from a live rat, etc. Satisfactory results were obtained in the cases mentioned above.

5.1.10 The Diffraction and Small Angle X-ray Scattering Station

The X-ray diffraction and small angle scattering stations share the beamline of 4B9A. In 2002, the main task in this regard is to improve the X-ray diffraction station, the small angle X-ray scattering station and the beamline of 4B9A. A new Si(111) monochromator with a fixed exit and an indirect water-cooling was constructed to replace the old one. The thermal stability of the monochromator was obviously improved. The control software of the beamline and the stations is being rewritten. At the same time, users urgently required beam time for their experiments. In this case, the monochromator was fixed at the energy of 8015 eV and the image plate was used to record the small angle X-ray scattering signal, thus making it possible for us to provide beam time to users when the beamline was being improved. 200 hours in all were provided to users.

A new project “In-situ Heating Study on the Surface or Interface of Materials” was performed to exploit the research field of the beamline of 4B9A. A heating unit used at the X-ray diffraction station is being designed. In addition, a Debye-like camera is being manufactured to record the X-ray diffraction pattern using image plate.

5.1.11 The Diffuse Scattering Station

1. Operation for Research Projects

28 research projects were carried out altogether in the 3 periods’ dedicated operation for synchrotron radiation in 2002. These projects are composed of the sub-project of the National Plan for the Development of Key Basic Research, the sub-project under the Program 863, the project under the Hundred Talents Program of the Chinese Academy of Sciences and the project of the National Natural Science Foundation of China, etc. The users were from 11 institutes and universities, which belong to the Chinese Academy of Sciences and the Ministry of Education, namely, the Institute of Chemistry, the Institute of Semiconductor, the Institute of High Energy Physics, the Shanghai Institute of Optics and Mechanics, Changchun Institute of Optics, Fine Mechanics and Physics, Tsinghua University, Peking University, Beijing Institute of Technology, Fudan University and Nanjing University, etc.

2. Development of the Station

The automatic adjustment of the slits forward and backward was completed by a two-dimensional platform translator. It greatly simplified the procedures of the beamline adjustment and improved the efficiency in using the beam time. The fixed bracket of the detector was designed and fabricated. The whole system of the one-dimensional PSD was debugged and applied in the synchrotron radiation experiment. The method of PSD was systematically mastered, and it was used successfully in detecting the signal of the small-angle scattering of the GeSi strained alloy. The CCD monitor and video system were added to make the beamline adjustment easier and the experimental status in real time was monitored during the experiment. The NaI detector was purchased overseas. The vacuum problem of the beamline tubes was solved in time. And the driver power supply of the adjusting setup of the mirror tank was changed.

3. Engineering Upgrade Project

The design and machining of the monochromator tank was discussed with the experts from Shenyang. The contract on the machining of monochromator tank was signed in September. The tank will be installed at the beginning of January 2003. The beamline connection parts were fabricated by KYKY Technology Development LTD. The gluing method of the bent crystal monochromator was tested at the beginning of 2002. The bending and cooling system of the bent triangular monochromator was redesigned. The parameters of the bending structure were calculated using the analysis of ANSYS, and the way of transmission was determined.

4. Development of New Experimental Method

It is considered in the world that the research of the microstructures of the quantum-dot materials is a great challenge. However, a new experiment method of grazing incident X-ray small angle scattering sensitive to the correlation of the shape and space of the quantum dots buried in the surface layer is being developed.
5. Atomic Resolution X-ray Holography Measurement

The atomic resolution X-ray holography includes the X-ray fluorescence holography, the photoelectron holography and the X-ray absorption holography. The information of the internal atomic structures of the samples will be known by measuring the interference pattern caused by the fluorescence and scattered fluorescence, photoelectron and scattered photoelectron, and the scattering among different atoms. With the cooperation of users, two experiments were carried out to probe the experimental condition and data processing method.

6. Development of Research Projects

a). Experiments were carried out for the first time to measure the average composition and strain of the Ge/Si quantum dots of the shape and size in bi-modal distribution. The results showed that the average composition and strain relaxation of Ge atoms in the dome-like quantum dots in large size were 50% and 46%, respectively, and that in the pyramid-like quantum dots in small size they were 80% and 75%, respectively. In unit volume, the strain energy of the dome-like quantum dots was larger than that of the pyramid-like quantum dots in one time according to the calculation of the strain relaxation. The experimental phenomenon of the coexistence of the two kinds of quantum dots has been explained effectively.

b). The primary study was carried out of the influence of the Si capping-layer on the microstructure of the Ge/Si quantum dots and the influence of the thickness of the Si capping-layer on the distribution of the quantum dots grown on it. The results showed that the Si capping-layer changed the composition and strain distribution of the Ge atoms the buried quantum dots heavily. The strain was increased as the concentration of Ge atoms was reduced from 50% to 40%. The residual strain of the buried Ge dots would make the size distribution of the quantum dots grown on the caplayer more uniform. But the caplayer had no influence on the quantum dots in the surface when the critical thickness of the caplayer was more than 70nm because the strain in the lower layer could not be transferred to the surface.

c). Work on the Ge/Si quantum dots grown on the oblique-cut Si(400) substrate was done to explore the characteristics of the strain distribution of the quantum dots. Three articles have been submitted for publication according to the above results. And two of them have been accepted and will be published in the future.

d). Research of the high energy resolution fluorescence spectroscopy was carried out. The calculation, argumentation and confirmation of many schemes of the project have been done in 2002. The motor driver controller has been ordered. The fixed holder of the crystal monochromator has been designed and machined. The experimental condition has been tested using the back-analysis crystal monochromator provided by Brookhaven National Laboratory. As the crystal is very expensive, we will try to have it made at home.

5.1.12 VUV

1. Operation

In the first half of 2002, the station was closed due to new beamline construction. The new station was open to four users in the winter’s dedicated time and provided 40 hours’ machine time. For the first time the station was open to users under parasitic mode. Applications were received from six new users.

2. Engineering Project

One new beamline was constructed, tuned and debugged. The baffle and zero order traps were installed. Also the new grating and VAT valve with an optical window were ordered and will be installed.

3. The new sample chamber is fully operational and the time needed for vacuum is decreased from the previous average 6h to 0.5h at present.

4. New optical table was installed and the vibration problem figured out.

5. The Oxford CF-V continuous flow helium cryostat was ordered and received. The interface between the sample chamber and the cryostat, mainly a Z-axis transition stage and a bellow, was completed for cryostat’s up and down movement in vacuum.

6. The new amplifier for CD was finished.

The new approved projects include:

1. Hard X-ray Magnetic Circular Dichroism, an innovation program supported by our Institute. It is in progress.
2. Development of Part of VUV CD Instrumentation of the CAS bioplatform program.

5.1.13 The X-ray Lithography and LIGA Station

1. Running Status

The machine time of the LIGA Station and service were provided for Tsinghua University and the Division of Nuclear Analytical Techniques in 2002. The machine time of the X-ray Lithography Station and service were also provided for the Microelectronics Research and Development Center.

2. Project Improvement

Most of the time was spent on the improvement of the 3B1 beamline this year. Now the improvement has been basically finished. A microstructure of PMMA resist with the respect ratio 70 was obtained at the new LIGA station.

3. Scientific Research

New progress has been made in the application of the LIGA technique. Micro heat exchangers, gears of safety combination lock and positron modulator have been fabricated using the LIGA technique. Well-bonding glass micro capillary electrophoresis chips have been obtained. Pores with a depth of 0.5mm have been obtained using micro EDM technique.

4. Fund Application

Joint application with Shanghai Jiaotong University for funding a project under the Program 863 has been approved.

5.1.14 Biological Macromolecular Crystallography

The construction of the beamline and experimental station has been finished. The operation started in cooperation with the users.

The beamline provided monochromatic focusing X-ray with the energy range from 6-16 keV. The intensity measured was 4x10^10 photos/s. The beamline and the station were designed for the MAD experiments.

The detector used now is a Mar345 IP with a desktop beamline diffractometer. An OXFORD Cryosystem 700 provided the sample cooling.

The users from the Institute of Biophysics and University of Science and Technology of China carried on their experiments in December 2002. Altogether 11 kinds of protein crystals were measured.

5.1.15 Summary of Engineering and Technology

In 2002, the Technical Support Group (TSG) completed the construction, installation and commissioning of the three new equipment protection systems for the three new front-ends (1W1, 4W2 and 3B3) and their beamlines on schedule. The three new front-ends and four beamlines were installed around the BEPC storage ring (see Fig.5.1.15) and operated in October of 2002. In these systems, two of the three new equipment protection systems are for the high power wiggler (1W1 and 4W2) beamlines, which are used to protect the front-end and beamline components from being damaged by high power synchrotron radiation, as well as to protect the BEPC storage ring vacuum against vacuum failures in a beamline. After commissioning, the three new equipment protection systems were in operation at the end of 2002. The system operation shows that the systems work well and that the interlock functions of the system are correct. The systems have met the users' requirements.
5.2 BFEL and Its Application

5.2.1 BFEL Operation and Its Application Research

Thanks to the efforts made by the BFEL laboratory, BFEL was operated stably and its performance greatly improved in 2002. Up to December 7, the running time of the accelerator went up to 489 hours and the lasing time up to about 400 hours. The output energy of the optical macro-pulse was 2-6mJ. The laser wavelength could be adjusted continuously between 8µm and 14µm, and the adjustment finished in several minutes as required by users. The fluctuation of the wavelength was reduced to ±1% from the original 5%.

To develop the picosecond electron micro-bunch technique and its application, the operation plan in the second half of 2002 was changed. Instead of providing light to users all the time as originally planned, users were provided with both light and electron beam during different given periods of time. After the summer shutdown, nearly two months were spent on providing electron beam for the user from the BSRF lab to do the preliminary experiments of the application of parameter X-ray radiation (PXRF). And the facility reverted to provide laser for users at the beginning of November.

The users of application research were from either CAS (the Chinese Academy of Sciences) or some
universities, and they carried out about 20 items on the BFEL facility, achieving many significant results. These are described in details as follows.

The irradiation research of some kinds of chemical samples, organic macromolecule material and biologic samples by the Institute of Chemistry, CAS; Infrared broadband detector using pyroconductive membrane YBCO by the Institute of Electronics, CAS; The FEL revulsive nonlinear radiation absorption research on semiconductor material C-InSb, 9691MCT and the FEL revulsive two-photon absorption research on the quantum well material GaAs/AlGaAs by Shanghai Institute of Technical Physics, CAS; The irradiation research of some kinds of chemical samples, organic macromolecule material and biologic samples by Peking University; The preparatory experiment for the research on the incision of cornea-organization using FEL Peking Union Medical College; The measurement experiment using light-energy meter’s probe by Beijing Institute of Technology; The low temperature Hall effect on quantum well material irradiated by FEL and the effect and theory research on quantum well material irradiated by FEL by Sichuan University, and the measurement of the new type of semiconductor's (GaN) micro-spectrum by scanning near-field microscope using BFEL as the light source as well as the scan and analysis of the local district of polymer membrane by scanning near-field microscope using BFEL as the light source by the BFEL laboratory.

The application research of parameter X ray radiation (PXR), which we began to develop in the second half of this year, has just made its first step abroad. PXR is a new kind of radiation mechanism, and it has so many merits such as high electron-photon conversion ratio, single X ray radiation, continuously adjustable energy, excellent direction, relatively simple structure, etc. With all of these, it is very promising that PXR will act as an important part in the domain of medical diagnosis and scientific research in the near future. The work on PXR is very significant.

During the preliminary experiment for this project, a new beam transport line was designed and fabricated, the background noise coming from the environment was studied and some ways were found to restrain the noise

5.2.2 R&D of BFEL User Facility

1. Design Study of the User Facility

The BFEL facility will be moved from Zhongguancun to the campus of IHEP located in Yuquan road and upgraded to be a user facility during the Tenth Five-Year Plan. In 2002, the conceptual design of the BFEL user facility was accomplished, and a review meeting organized by the Science & Technology Council of IHEP was held on November 27. After the meeting, the beam parameters and laser characteristics of the facility were formally determined. What’s more, the facility was fixed to locate in Hall No.1 at last.

The user facility mainly consists of the following parts: the injector, the main linac, the wiggler and the experimental stations. Now, we are involved in the preliminary design study of these parts. The design will be finished next month.

2. Upgrade & Maintenance of the Existing Facility

Most components of the existing BFEL facility will be used in the user facility. The upgrade and maintenance are very important not only for the operation of the existing facility but also for the construction of the user facility.

3. Upgrade of the Injector

To decrease the beam emittance and overcome the electron back-bombing, a new thermionic cathode RF gun was designed. The RF cavity of the gun will be fabricated out of stainless steel in part, having a low Q value. In addition, a new mixed Q magnet was designed, fabricated and measured.

4. Maintenance of the Main Linac

The main transformer of the modulator was repaired for several times. In the summer shutdown, the imported RF amplifier was examined and repaired. To improve the efficiency of beam transport, the polarity of all the magnets was checked carefully, and some steering magnets were installed and tested.

5. Improvement of the Optical Steady State Station

The optical system was rebuilt and the on-line diagnostics of laser characteristics realized, such as the wavelength, the power and the spectral width. This provides a reliable guarantee for the accelerator and
the applied experiments. Various apparatuses including the oscilloscope, the optical energy-meter, the three-dimensional scanning platform and so on were linked with the computer to control and survey the digitals. Under these conditions, safe, accurate and shortcut digitals could be provided for the applied experiments. Based on the applied experiments, we assumed that we could use carbon dioxide laser to simulate the on-line applied system in FEL. This project is being implemented step by step. We think that this measure not only has greatly improved the optical modulation but also played an important role in building the experimental station.

6. Preparation for the Spectral Analysis Experimental Station

To build the spectral analysis experimental station and purchase the Fourier transformation infrared spectrograph as an important facility of the Chinese Academy of Sciences, some famous experts were invited to review the feasibility of installing the FTIR spectrograph to BFEL facility in September of this year. After this, according to the related rules of IHEP and CAS, we investigated the manufacturers of spectrograph, studied the functions of the instruments, discussed the service condition of spectrograph used on the BFEL at present and in the future and confirmed the main functional equipment of spectrograph. Now, we have signed the contract with NICOLET company, and the instrument will arrive next year. Purchasing the FTIR spectrograph is a great step in building the spectral analysis experimental station.

7. Development of the Short Period Wiggler

The material of the wiggler is NdFeB. When the gap is 10mm, the peak value of the magnetic field strength is 4200 Gauss, the length of period is 25mm and the good field region is: ±0.25mm in X direction and ±0.5mm in Y direction.

5.2.3 Other Research Work

1. Application of BFEL as a Light Source of Scanning Near-field Microscope

This project was supported by the National Natural Science Foundation of China. The original shape of the scanning near-field microscope was developed and improved. Some primary researches of application were carried out in terms of the measurement of the new type semiconductor's (GaN) micro-spectrum, and the scan and analysis of the local district of polymer membrane by the scanning near-field microscope using BFEL as the light source.

2. BFEL Wavelength Auto Stabilization System

This project was supported by the Laser Technology Foundation for Junior Scientists under the Program 863. Now it has been finished. With the system running in a closed loop mode, the fluctuation of wavelength decreased to ±1% from the initial 5%.

3. Timing System of the Photo Cathode RF Gun

Thanks to a year's hard work and cooperation with Tianjin University, we succeeded in developing a Ti sapphire ultrafast pulse self mode-locking laser oscillator. The average power is 180mW, the wavelength is 780 ns, the width of pulse is 70fs and the pulse repetition rate is 102MHz.

We also developed a set of synchronization pulse phase-locking circuit and did the simulation test. In the future we will do online test.

4. RF Cavity of the Photo Cathode RF Gun

This project was supported by the National Natural Science Foundation of China. The cavity was designed and machined at our machine shop. And now the low power test is being done. In addition, the design of the coils used for emittance compensation was also accomplished, and they will be fabricated soon.

5. Research of Compact Accelerator

This is a project funded by the National Natural Science Foundation of China. The modulator was examined and repaired for several times and the 5MW klystron improved. After the three-month long experiment, many exciting results were achieved as theoretically anticipated.