The China Institute of Atomic Energy

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Abstract. The China Institute of Atomic Energy (CIAE), established in 1950, carries out multidisciplinary research in nuclear science, technology and engineering. It has three research reactors and ten low energy accelerators. The focus of its nuclear energy related R&D is on reactor engineering and technology. In the area of nuclear techniques for applications, R&D is carried out on accelerators, isotope production, nuclear electronics and utilization of radioisotopes and radiation. There is also a strong programme in basic nuclear physics and radiochemistry. New major facilities under construction in CIAE include China Advanced Research Reactor (flux $8x10^{14}n/cm^2/sec$) and China Experimental Fast Reactor. China has been successfully using the products of its R&D for a variety of applications in medicine, industry, materials science etc. A dynamic research programme is tuned to attract young talent to CIEA and there is good collaboration with the Beijing University. CIEA has been an active participant of RCA programmes of the IAEA and has been a resource for many developing countries. The management expects the Institute to be a leading multidisciplinary institute in the field of nuclear science, technology and engineering.

Past and present situation of China Institute of Atomic Energy (CIAE)

R&D programs and the related finances, manpower and infrastructure

China Institute of Atomic Energy is a multi-disciplinary research institute in nuclear science, technology and engineering. It was established in 1950. Since the construction of the heavy water research reactor and the cyclotron constructed in 1958, CIAE has been a Chinese core institute and played a pioneer and leading role in related research fields. The main activities of CIAE are oriented towards the following: R&D and application of nuclear energy and nuclear techniques; fundamental research of some hi-tech and basic science on nucleus, especially low energy nuclear physics and radiochemistry; promotion of non-nuclear application for national economy in combination with the technical advantages of the institute.

CIAE is composed of five departments: nuclear physics, reactor engineering and technology, radiochemistry, nuclear technique and computer applications, isotope. two divisions: health physics and radiation metrology, two shops: machine and electronic instrument and two centres: centre of scientific and technological information, centre of education and training.

CIAE is equipped with three research reactors; four zero power facilities; around ten low energy accelerators: 30 MeV high intensity cyclotron, 13 MV tandem, 14 MeV electron linac and so on.

The major research fields of nuclear fundamental research are experimental and theoretical physics, nuclear data measurement and evaluation, condensed matter physics — application of thermal neutral scattering, intense particle beam, laser physics and fundamental chemistry. R&D of nuclear energy focuses its studies on reactor engineering and technology. Research activities are conducted in the area of experimental and theoretical reactor physics, nuclear material, nuclear fuel element and its post-examination, thermohydraulics, hydrochemistry and sodium technology, The interest is also concentrated to the development of nuclear power reactor technology and its safety, nuclear chemistry and radiochemistry.

The activities on applications of nuclear techniques are R&D of accelerator technique and irradiation technique, nuclear electronics and detector techniques, radioisotope and stable isotope production.

Nuclear techniques for general purposes are: health physics, radiation protection, radiation metrology, computer and computational mathematics. CIAE also has the activities on applications of non-nuclear techniques such as fine chemicals, oxygen-measuring devices for industrial furnaces (ZrO_2) and so no. Graduate school, and nuclear industry school are located in the same area. Training courses on special topic are held now and then.

The publications and journals in Chinese or in English organized by CIAE: Science and Technology of Atomic Energy, Chinese Journal of Nuclear Physics, Nuclear Chemistry and Radiochemistry, Isotopes except annual report of CIAE. Total employees of CIAE are 3500 and half of them are scientists or engineers.

Strengths and limitations

The knowledge and experiences accumulated in 50 years have helped CIAE play an important role in nuclear science of China and make influence in the world. The heave water experimental reactor and the cyclotron put into operation in 1958 in CIAE were the symbol of China entered the Atomic Age. Many outstanding scientists have been training and making their contribution to the courses. There were 23 outstanding scientists who made a historical contribution to the R&D of atomic bomb, missile, satellite praised by Chinese Government. 7 of them have worked in CIAE. China wishes to contribute back to the world by leading the advancement of nuclear science and technology and by promoting the safe and peaceful use of nuclear energy for the betterment of mankind. CIAE becomes a largest consultant organization for such purpose. The operation and utilization experiences on the research reactor have made help for trouble shooting in nuclear power plants. The isotopes produced by reactors and accelerators are widely used for medical or industrial purposes.

CIAE is a research institute on fundamental nuclear sciences. Now the Chinese government pushes all research work to serve the industrial and economy and uses their research results to promote product quality and improve the social living standard. Of course that is complete right. Unfortunately, the results from fundamental research are not so easy to transfer to industry. Therefore it is not easy to get benefit from industry. Meanwhile the financial support from the government reduced year by year in real value estimation. China is one of the most dynamic countries in the world in the course of economic progress. The average income of China increases rapidly also. Many managed well enterprises can attract bright professional people to join. The income of CIAE staff is increasing in recent years, but it is not compatible with managed well enterprises. The brain drain becomes a serious problem. The fundamental research is a kind of job with creativeness. Young talents are really required for CIAE. D & R of CIAE are limited by such difficulty now and in near future if the situation is not changed essentially.

Challenges faced by CIAE

New direction

Currently, with twenty-first century, many challenges lie ahead. CIAE's major strategy is to seek the new type of nuclear energy according to the development stratagem of energy source

of China in long term. Fast breeding reactor is under construction. The purpose of the project is to solve the fuel shortage problem.

Accelerator drive system (ADS) might be a way to explore new type of nuclear energy source. The preliminary research work on ADS has started this year. The future aims might toward spent fuel transmutation, or energy production if it is possible. So far the target is limited to build a strong intensity accelerator injector (2.5 MeV, peak current 60 mA).

Peaceful use of nuclear science and technology to enhance quality of humankind life is our objects. Environment protection, new material served for the people's living condition and isotope production and R&D of applied electronic instruments based on radioisotopes are the main interests of CIAE. In these fields, radiation technology used for coal fired flue gas treatment is proposed. Radiation disinfecting of Chinese herb medicine, radiation has also applied for sterilization of medical supplies, food irradiation and so on.

Innovation in basic science and nuclear technology are expected in 21st century by use of high intensity neutron flux. CIAE has launched 60 MW China Advanced Research Reactor. The neutron flux will be 8×10^{14} /cm^2/sec. The future research is continued on the mechanism of the enhancement of neutron diffraction, structure analysis and dynamical properties of superconducting material, particularly high "T" materials, magnetic materials, hydrogen storage materials as well as various crystals and amorphous materials.

To enhance the fundamentals research a Radioactive Isotope and Nuclear Structure Study Facility (RINSS) is proposed. The project will base on an existing HI-13 tandem accelerator that put into operation in 1987. It will be extended to combine with other two new accelerators: The pre-accelerator will be a 100 MeV high beam intensity proton compact cyclotron, A superconducting linac will used as a booster. The proton cyclotron will be used for R&D of radioactive isotope production, study of nuclear structure and radiation physics if it operate along. And the cyclotron will be used for the production of radioactive nuclei to be isotopically separated by an on-line mass separator and injected into the pre-existing HI-13 tandem accelerator for RIB experiences with lower energy. A superconducting heavy ion linear accelerator (LINAC), booster, high intensity and high energy resolution RNBs of A ~up to 140 can be obtained with energies above the Coulomb barrier (ISOL).

Examples of successful orientation

Part of fundamental research of CIAE transfer to application is a successful orientation. Nuclear techniques are oriented towards the research, development and application of accelerator and irradiation techniques. Co-60 source irradiation, radiation chemistry and irradiation technology are the successful example. NTD mono-crystal silicon and its processing, nuclear well logging, industrial testing and measuring devices (e.g. radiography accelerator, radioisotope instruments etc.) nuclear electronics and detectors (e.g. smoke- and temperature- sensitive detectors as well as their measuring and control system and other relevant fire fighting products: fire alarm systems), nuclear analysis (neutron activation analysis and ion beam analysis), electron magnetic separators and stable isotope production, etc.

R&D of radioisotopes, radioactive source, labeled compounds and radioimmunoassay kits have brought significant benefits to CIAE. More than three thousand hospitals in home and abroad use isotope products produced by CIAE. Social opinion supports such actions since it provides variety of nuclear medicine for therapy or diagnostic. Meanwhile one-fifth budget of

CIAE comes from the isotope products for medicine or industrial use. Many electronic instruments based on radioisotope applications are originated such as radiotherapy simulator, bone densitometer, teletherapy unit, instrument for prostate hyperplasia treatment and so on.

Research reactors made all isotopes only in CIAE five years ago. Thanks to a 30 MeV cyclotron put into operation in 1995, many short live time isotopes have been producing. Some medium life time isotopes have been exported to developed countries except varieties of short lifetime isotope supply for the hospitals in China, like ^{18}F, for PET.

Nuclear safety is one of the largest concerns of public. Safety of nuclear power plant is a sensitive point. CIAE has made every effort to help the nuclear power plants in China get highest reliability and utmost safety. CIAE play an advisor roles when a new nuclear power plant is proposed. Experts from CIAE are sent to the nuclear power plants whenever they have engine trouble or maintenance requirement. CIAE experts are successful to help them solve many operation problems.

Some critical and fuel tests have been taken in the research reactors of CIAE. The spent fuel has been checked in CIAE. Proposal of decommissioning of research and power reactors have been put forward. Successful experiences on reactor physics, nuclear material, nuclear fuel element and its post-examination, thermohydraulics, hydrochemistry and sodium technology plus many test facilities like nuclear material laboratory with nuclear fuel assembly and material testing hot cell, fuel assembly testing loop, sodium dynamic corrosion testing loop, re-submerged heat transfer testing loop have proved CIAE has ability to design new type reactors. Now there are two reactors are under construction in CIAE: China Advanced Research Reactor (CARR) and China Experimental Fast Reactor (CEFR). It should be noted that CARR would use low enrichment uranium (LEU) as fuel. The enrichment will be lower than 20%. And the neutron flux will be $8\times10^{14}n/cm^2/sec$. That is a tough design task!

Works on health physics serve for radiation protection and environmental protection of the institute. The assessment of environmental impact is also conducted in CIAE. Environmental radiation continuous monitoring system with high pressure ionization chamber.

Preservation of expertise

Basic research:

Nuclear physics including experimental and theoretical, nuclear data measurement and evaluation, condensed matter physics with thermal neutron scattering, intense particle beam and laser physics have made excellent progress, such as in-beam spectroscopy, heavy ion fusion reaction, light particle nuclear reaction, polarization phenomena, measurement of cross section of neutron nuclear reactions, secondary neutron energy spectra, nuclear fission, neutrino measurement, theoretical calculation of nuclear data, nuclear microscopic optical potential, few-body and nuclear matter problem, nuclear high spin states, reaction mechanism of intermediate and high energy heavy ions, non-equilibrium process in nuclear reaction as well as the basic problem of nuclear force and elementary particles. Theoretical research of condensed matter and free electron laser are also being conducted. Further research on the mechanism of the enhancement of neutron diffraction, structure analysis and dynamical properties of superconducting materials, high power electric pulse, production of intense particle beam and its transmission and interaction with matter, excimer laser pumped by intense electron beam.

Radiochemistry:

Concerning with chemistry: actinides chemistry, especially transplutonium chemistry, fission chemistry, co-ordination chemistry and separation chemistry. Also methods of waste treatment, liquid or solid

Reactor technology and related research:

Various tests are being conducted at hot-laboratory for nuclear fuels and materials irradiated in reactors. Production of silicon semiconductor is also carried on reactor applications. Neutron scattering experiments: by examining the status of scattered neutron as a material, or materials' atomic/molecular structure and kinetic status can be determined by computer analysis. Neutron activation analysis is also preserved to be developed.

Interaction of CIAE with their environment

Social and economic sector

CIAE has tried to change its part of fundamental orientation towards to applied science in last more than ten years. Thus social and economic environment is important to CIAE. CIAE has been promoting joint venture in home and abroad. CIAE has superiority of know-how over other social or economy enterprises. But the enterprises have advantages in management and financial ability. To transfer the know-how into the production, it is our basic police to collaborate with social and economic sectors to form hi-tech industry. CIAE now set up few joint-stock corporations with other industrial enterprises. CIAE is responsible for R&D of hi-tech. The fire alarm system product is one of examples.

Academia

Talent problem, especially young, becomes a bottleneck for the development of CIAE. To attract more bright young talent to join us a few academics centres are set up with universities. For example, CIAE and Beijing University have set up a nuclear science centre. The students from the university join us to do research work and CIAE becomes their practice base. Once the students are interested in the job though their thesis, they would like to join CIAE. Even the students just do their thesis in CIAE and do not intend to join us, some technical tasks can be complemented since their thesis are connected with our research work. Good relations have been established with some other institutes because the new scientific points with creative power usually happen in the intersect of two or more disciplines.

Public

Public opinion influences the support from the government and other resources. We have tried hard to win the public support. Public is afraid of safety problem happen. Public is afraid of radioactivity near their home. They are against reactors being built once some nuclear accident happens anywhere in the world. We have to do explanatory statements to the public. Of course, it is most important for public understanding to keep safety for our nuclear facilities. Open days of CIAE help public to understand us.

Collaboration and co-operation

North-South and South-South

Collaboration on safeguard with research institutes of US is an example of North-South collaboration. Also collaborations of CIAE and many institutes of the world have been established. There are many exchanges of scientists with Europe, the States, Russian and Japan every year.

Miniature neutron source reactors developed by CIAE as collaboration projects have been installed and operated in Pakistan, Iran, Syria, Ghana, and Nigeria. The 15 MW experimental heavy water reactor operated in Algerian is considered as an example of South-South collaboration. Besides there is a zero power reactor assisted by CIAE works in Iran. All are united to realize the full potential of the 21st century in partnership with CIAE.

IAEA role

CIAE has been cooperating with IAEA well since China affiliated IAEA. CIAE has played an active role in the regional co-operation programs in Asia (RCA). Collaboration of CIAE and IAEA has increased year by year. Fruitful results have been obtained both by assistants from IAEA or contribution to IAEA from CIAE.

CIAE cooperating with IAEA to organize seminar on related specialty topic were 13 times and participates were 261 in last decade. And same time IAEA and CIAE co-sponsoring international training classes on nuclear technology were hold 11 in CIAE, 161 students came from abroad. 253 experts from CIAE attended IAEA activities supported by IAEA, including scientific inspect, meeting, workshop or training. Near 20 experts from CIAE carried out the program abroad supported by IAEA about $100 k in last ten years. CIAE got budget of TC program from IAEA is about $1M during the decade. During 1999–2000 financial year there are three TC projects: Study on nationwide monitoring of size fractionated air particle matter using nuclear analytical technology; Development of radioactive label peptides for tumor diagnosis; Using radiotracers to determine residual oil saturation. Total budget of the projects is around $500 k. The collaboration of CIAE and IAEA help the use of atomic energy for the peaceful purpose in China.

Meanwhile many other actions are assisted by IAEA. Such as miniature neutron source reactors installed in Syria, Ghana, Nigeria is the projects supported by IAEA.

Other issues considered relevant

With the 21st century near at hand, our aim is to make CIAE become world-class multi-disciplinary research institute in nuclear science, technology and engineering. Now China is one of most dynamic countries in the world, but it is still a developing country and financial support to CIAE is limited. With economy progress of the country, CIAE itself renovation, research orientation towards to peaceful use, globalized management concept, armed with top-class technology CIAE would become a initiative pioneer and great support in the nation's economic development.

Meeting on NRC would provide a chance to exchange the idea and opining how to manage the NRC well. 21st is a new century full of hope of human being. NRC should use their advantages in hi-tech to help the world to realize their dream! We, CIAE will do our best!