Accelerators for Atomic Energy Research

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The research and educational activities accomplished using accelerators for atomic energy research were studied. The studied items are research subjects, facility operation, the number of master theses and doctor theses on atomic energy research using accelerators and the future role of accelerators in atomic energy research. The strategy for promotion of the accelerator facility for atomic energy research is discussed.

1. Introduction

Many research groups for atomic energy research in universities and institutes have used various accelerators. The research and educational activities accomplished using accelerators in the atomic energy research field were studied. The studied items are research subjects, facility operation, the number of master theses and doctor theses on atomic energy research using accelerators, and the future role of accelerators in atomic energy research.

The studies were carried out in cooperation with following facilities:
(1) Faculty of Engineering, Hokkaido University: 45 MeV electron LINAC,
(2) School of Engineering, Tohoku University: 4.5 MeV Dynamitron,
(3) JNC, O-arai Engineering Center: high power electron LINAC
(4) JAERI, Takasaki: 90 MeV Cyclotron
(5) Nuclear Engineering Research Laboratory, Univ. of Tokyo: 35 MeV LINAC,
(6) Research Lab. for Nuclear Reactors, Tokyo Institute of Technology: Pelletron,
(7) Research Reactor Institute, Kyoto University: 46 MeV electron LINAC and CW
(8) Faculty of Engineering, Osaka University: OCTAVIAN.

2. Subjects studied using accelerators

The main subjects at each facility are given in the following.

(1) Faculty of Engineering, Hokkaido University: 45 MeV electron LINAC:
Development of cold neutron sources, Pulse radiolysis, Generation and application of radiation, and Accelerator engineering.

(2) School of Engineering, Tohoku University, 4.5 MeV Dynamitron:
Nuclear data related to fast reactor, fusion reactor and new type reactor, Hydrogen behavior in material, Impact by ion beam, PIXE, Application of ion beam for medical, biological and environment research, and Educational activity for citizen and young students.

(3) JNC, O-arai Engineering Center, high power electron LINAC:
Feasibility study of a high-current electron LINAC for transmutation of nuclear waste.

(4) JAERI, Takasaki, 90 MeV Cyclotron:
Study of radiation resistance of material and apparatuses, Nuclear data for accelerator shielding, Production of radioisotope, Radiation effects, and Basic technology of accelerator and beam handling.

(5) Nuclear Engineering Research Laboratory, Univ. of Tokyo, 35 MeV LINAC:
Generation and measurements of ultra short electron beam pulse, Pulse radiolysis, Generation and application of positron beam, Free electron laser, and Acceleration using wake field generated by laser.

(6) Research Lab. for Nuclear Reactors, Tokyo Institute of Technology, Pelletron:
Data of neutron induced reactions, Nuclear reaction model and observable for evaluation of neutron data, and Study of collision between ion beam and atoms or molecules.

(7) Research Reactor Institute, Kyoto University, 46 MeV electron LINAC and C.W.:
Reactor physics through neutron production and transportation, Compilation of neutron cross section, Application of electron beam for irradiation, Production of positron, Generation of synchrotron radiation, Production of radioisotope, Parametric X-ray, Criticality of the sub-critical reactor, and Neutron transportation in a thorium system.

(8) Faculty of Engineering, Osaka University, OCTAVIAN:
Double differential cross section of neutron reactions, Integral experiment of neutron engineering for a D-T reactor, Radiation damage of material, Radiation transportation, Neutron effects in space, and Application of ion beam.

3. Operation of accelerator

The operation status, the number of subjects, and the number of collaborative subjects with outside groups at each facility are shown in table 1. The operation of accelerators is mostly more than 100 days per year.

Table 1 Operation status of accelerator

Facility	Operation	No. of subjects	No. of subjects in collaboration with outside group
Hokkaido Univ.	240 d	13	3
FNL Tohoku Univ.	150 d	11	7
Univ. of Tokyo	191 d	8	2
Tokyo Tech. Insti.	115 d	10	1~2
LINAC of KUR	1800 h	12	All
C.W. of KUR	30 d	1~2	All
OCTAVIAN	240 d	23	4

4. Research by graduate students

The number of graduate students who got Master thesis and Doctor thesis are shown in table 2.

Table 2 Number of Master and Doctor thesis

Facility	Master degree	Doctor degree
Hokkaido Univ.	143	7
FNL Tohoku Univ.	89	11
Univ. of Tokyo	33	13
Tokyo Tech. Insti.	80	6
LINAC of KUR	67	18
C.W. of KUR	3	0
OCTAVIAN	150	9

5. Future plan at each facility

The future plan for each facility is as follows:

(1) JAERI, Takasaki, 90 MeV Cyclotron:

High intensity positron beam facility, a few GeV super-conducting cyclotron, and a X-ray irradiation facility using electron accelerator are now discussed.

(2) Nuclear Engineering Research Laboratory, Univ. of Tokyo:
Femto second electron beam facility using radio-frequency acceleration and wake field acceleration generated by a high-power laser is planned.
(3) Research Reactor Institute, Kyoto University:
Replacement of a Cockcroft-Walton accelerator with a medium size accelerator for development of an accelerator driven sub-critical reactor is discussing.
(4) Faculty of Engineering, Osaka University, OCTAVIAN:
Ten times more intense neutron flux facility or multi-function quantum-beam center is now under discussion.

6. The expected role of the accelerator facility for atomic energy research

Various accelerators have been used by many scientists for atomic energy research. Accelerators are expected to play an important role in atomic energy research. Each facility is expecting that accelerators will be used in the following subjects.

(1) Faculty of Engineering, Hokkaido University:
Electron accelerators below 100 MeV will be useful for atomic energy research in universities for usage of neutron beam, application of variable energy X-ray field, and material research in extreme conditions.
(2) School of Engineering, Tohoku University:
Accelerators will be used as an analyzing device for research in environmental, material, medical, and biological fields. Fine beam control in space and time will be important in future use. The advanced measuring method of radiation and research facility for graduate students is also important.
(3) Nuclear Engineering Research Laboratory, Univ. of Tokyo:
Small or medium size accelerators are important for advanced research in atomic energy field at university while the large size accelerators will be used for atomic energy research at national laboratories for transmutation of long-lived nuclear waste and nuclear fuel.
(4) Research Lab. for Nuclear Reactors, Tokyo Institute of Technology:
Nuclear data will be crucial for development of transmutation of nuclear waste using accelerators. Neutron reaction cross sections for neutron rich nuclides are also interesting.
(5) Research Reactor Institute, Kyoto University:
Development of a new neutron source and energy production using accelerator driven sub-critical reactor will be critical issue for atomic energy research.
(6) Faculty of Engineering, Osaka University:

Accelerators will be important as a standard neutron source. Study of interaction of intense pulsed ion beam with various substances is interesting. Low-energy nuclear physics and nuclear data using neutron beam will be important.

7. Future accelerators for atomic energy research

Although large size accelerators will play an important role in national laboratories, various small seize accelerators are useful for atomic energy research in universities. Large size accelerators will be used for transmutation of nuclear waste, energy production by combining accelerators with sub-critical reactors, transmutation of thorium, and neutron sources. The development of high stability and high efficiency accelerators are crucial for these applications.

Various small size accelerators could be used as a specific device for nuclear research and application by various research groups of university. The machine in university should have unique feature such as high resolution of time and space, ultra-short pulse generation and so on.

The most accelerator facilities in universities were built when research groups for atomic energy were founded in universities. Since then these facilities have not had modification for improvement or replacement to an advanced facility. Thus systematic effort to improve the present situation is argent, The future plan of research activity using accelerators should be discussed at organizations related to atomic energy research, such as Liaison Committee for Atomic Engineering, Science Council of Japan, and Atomic Energy Society of Japan. The plan to promote research activity using accelerators for atomic energy obtained through deliberative discussions should be presented at the Atomic Energy Commission.