TANDEM ION-BEAM ACCELERATOR CENTRE AT PANJAB UNIVERSITY

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Abstract

The proposal of establishing a National Accelerator Centre within the Panjab University infrastructure is aimed towards the growing need of low-energy, and high-current accelerators by a wide range of scientific community. The main instrument for the application program is a Tandem Accelerator with terminal potential ranging few hundred kV- 6 MV and capable of providing atomic ions ranging from hydrogen to actinides with ion-beam currents ~ tens of μA's. The ion beam energy range and currents are advantageous for nuclear physics experiments of astrophysical interest, Material modifications (irradiation/Ion implantation) and Neutron generation experiments. One of the major objectives of the laboratory is to provide specialized analytical services for the determination of measurands down to sub-parts per billion levels of concentration over μm dimensions with depth resolution of few nm. Major analytic facilities including the time of flight backscattering system and a heavy ion ERDA spectrometer, and for the material modification experiments, the ion implantation and cluster beam facilities have been proposed. The tandem machine based Accelerator Mass Spectrometer will be optimized for analysis of the ^{10}Be, ^{14}C, ^{26}Al, ^{36}Cl, ^{41}Ca, ^{129}I and ^{235}U isotopes having wide applications in Geosciences, Biosciences and Nuclear physics of astrophysical interest. Accelerator-based Neutron calibration facility will be unique in the country. Beam pulsing system is required for various nuclear physics experiments and material characterization techniques. Various parameters of accelerator for the proposed research activities have been discussed.

Indian Universities in the last thirty years have been engaged in a very spirited manner in the development of experimental science activities. There are more than two hundred scientists from the universities who are pursuing accelerator-based research in Nuclear, Atomic, Material and Biomedical Sciences. The Nuclear Physics community in the Country has always been supportive of an accelerator-based facility on a university campus to serve as an educational tool for training of manpower in several important accelerator-based areas. Following continuous discussions at various symposia and seminars during the past more than one decade, it is decided to establish four low-energy accelerators in Universities to promote accelerator-based research at a meeting on Joint DAE-DST roadmap for Nuclear Physics/Particle and Astro-Particle Physics/Accelerator Physics and Technology held at BARC, Mumbai, April 7-8, 2006. Over a period of over 50 years, the Physics Department at Panjab University has emerged with a coherent scientific standing with most of its faculty members from the Nuclear Physics, Condensed Matter and High Energy groups related to accelerator-based research. A 66 cm variable energy cyclotron, built at University of Rochester, USA, was made operational in 1976 at Physics Department, Panjab University, Chandigarh. The beams available from this facility were 2.0 -5.0 MeV proton, 4 MeV deuterons, and 8 MeV alphas. Several research programs for nuclear structure studies based on Coulomb excitation and (p,nγ) reactions have been completed. Since 1999, the facility is now serving as a Regional Centre for PIXE. The accelerator has played an important role in grooming young scientists with expertise in the accelerator-based Physics and Technology. Interest of Panjab University in setting up such a facility has always been greatly appreciated by DST, DAE and UGC. The proposal of establishing a tandem electrostatic accelerator-based laboratory will be a multi-disciplinary National Research Centre administered by the Panjab University.

The areas of research that are planned to be addressed at the Accelerator centre are identified as: (a) Atomic Physics and cluster beam research, (b) Materials characterisation and modification - Elemental analysis using ion-matter interaction based techniques - RBS, PIXE, ERDA, NRA, etc. and Microbeam applications, (c) Nuclear Astrophysics and low energy Nuclear Physics, (d) Neutron induced reaction cross sections and Accelerator-based Neutron Calibration Source, (e) Accelerator Mass Spectrometry (AMS) - Nuclear astrophysical, Biological, Geological, Archaeological and other research applications, (f) Biosciences – Investigation based on Ion beam irradiation, AMS, production of few radioisotopes of medical interest, and Neutron based reactions for treatment of malignancy; (g) Testing of detectors developed for international collaborative research programmes. A beam brightness of 10-50 A m^{-2} rad^{-2} eV^{-1} is required for microbeam applications. Low energy ions of few hundred keV and high currents of ^{1}H, ^{3}He and ^{4}He, and ^{7}Li ions are required for nuclear astrophysics experiments. The beam energy spread should be low. Cluster beam experiments will be done on a beamline connected to the switching magnet at ~3 degrees. It is planned to generate beams of C, B, Al, and Au clusters and C_{60}.

The accelerator at Panjab University should meet the requirements of a multidisciplinary scientific community. All the proposed research applications require ion beams in the energy range few hundred keV to few tens of MeV, which would be best met by a Tandem Machine up to 5-6 MV terminal potential. The high current beam ~ tens of μA's are advantageous for Nuclear Physics, Atomic Physics, Material modifications (irradiation/Ion implantation) and Neutron generation experiments. Beam sweep system is required for Ion-implantation and beam pulsing system is required for various nuclear physics experiments and material characterization techniques. Atomic and cluster ion beams will be available for material modifications, analytical techniques for material characterization, neutron generation and basic research in atomic physics and nuclear Astrophysics. One of the major objectives of the laboratory will be to provide specialized analytical services for determination of measurands down to sub-parts per billion levels of concentration over μm dimensions, with depth resolution of few nm; validation support to analytical efforts in industry and relevant areas like Environment, Geological, Material and Life Sciences. Analytical techniques based on interactions of MeV ions with matter permit microanalysis and imaging of sample constituents. This include techniques based on the analysis of excited X-rays (PIXE - Proton Induced X-ray Emission), gamma-rays from nuclear reactions (PIGE - Proton Induced Gamma-ray Emission), outgoing nuclear reaction particles (NRA - Nuclear Reaction Analysis), elastically scattered ions (BS - Backscattering), (ERDA - Elastic Recoil Detection Analysis), visible and infrared emissions from the sample (IL - Ionoluminescence). The ion beam can also be channeled through crystal axes and planes. Many of the aforementioned techniques can be combined with channeling to study the lattice location of species (CCM - Channeling Contrast Microscopy). Major analytic facilities including the time of flight backscattering system and a heavy ion ERDA spectrometer, and for the material modification experiments, the ion implantation and cluster beam facilities have been proposed. The accelerator mass spectrometry is one of the important and ultra sensitive measurement technique based on the tandem accelerators. The tandem machine based Accelerator Mass Spectrometer will be optimized for analysis of the ^{10}Be, ^{14}C, ^{26}Al, ^{36}Cl, ^{41}Ca, ^{129}I and ^{235}U isotopes having wide applications in Geosciences, Biosciences and Nuclear physics of astrophysical interest. The system should be able to measure ^{14}C from both solid graphite and from CO_2 gas, using one and the same ion source, and handle 50 or more samples.

It is proposed to set up a neutron calibration facility based on the nuclear reaction using the light ion beams from the Tandem accelerator. The neutron generation beam line will be established in collaboration with Department of Atomic Energy (DAE). Neutron beams from few keV to about 5 MeV will be produced using nuclear reactions such as ^{45}Sc(p,n)^{45}Ti, ^{7}Li(p,n)^{7}Be, ^{3}H(p,n)^{3}He, ^{2}H(d,n)^{3}He and ^{3}H(d,n)^{4}He reactions. A neutron beam hall of size about 12 m x 12 m x 7 m(H) with adequate shielding all around to reduce the radiation level outside the room below the permissible level is also planned. Such an unique facility in our country is required for scientific investigations and routine services such as calibrations, especially, when we are planning to go for nuclear power in a major way.

The main accelerator machine is proposed to be equipped with

(i) Duoplasmatron ion source and sputter ion source along with the provision of fixing cluster ion source at 0^{o}.
(ii) 90^{o} analyzing magnet with 3 degree port for cluster beam.
(iii) 9-port switching magnet.
(iv) AMS for ^{10}Be, ^{14}C, ^{26}Al, ^{36}Cl, ^{41}Ca, ^{129}I, ^{235}U, and other along with two AMS ion sources with provision of loading 50 or more samples and analyzing magnet.
(v) IBA/IBM end station and RBS-channeling set up.
(vi) Ion-implantation end station (wafers up to 50 mm).

The accelerator machine should be rugged, reliable, and well proven machine which is easy to handle and maintain. It must have long life expectancy. The accelerator machine in horizontal configuration should be preferred. In case of vertical configuration, it is required to go for unusually high tower building, beam halls in the basements or multistory building especially for the cluster ion beam and Lift arrangements for approaching ion source. Indeed the machine preferably with solid state power supply with no moving parts. This accelerator must have long life, need little maintenance and provide extremely stable terminal voltage conditions. Keeping the above points in mind, an accelerator machine having a standard and well-tested configuration is suitable for Panjab University. Accelerator machines up to 6 MV, the machine would be less complex, particularly with regard to gas handling and charging systems. Since out of the various beamlines, the most critical one from the accelerator design point of view is the Accelerator Mass Spectrometry, one can think of this facility as AMS one with other beam lines woven on to it.

The project will be carried out in collaboration with Indian Universities and National institutions especially Inter-University Accelerator Center, New Delhi. The accelerator centre will serve the research and postgraduate students of various Physical Sciences, Biosciences and Engineering Streams. An exhaustive MOU will be signed between the Panjab University and DST regarding the constitution of various Committees for management and smooth functioning of the Accelerator Center, and take care of the Construction work of the Accelerator building which has to be done with specific quality control and within the specified time frame. Five Acres of land (~ 20,000 m^2) within the campus has been allocated for this purpose with a possibility of further expansion by Five Acres of land. A project of this magnitude would require substantial investments and sustained recurring support even after installation for timely commissioning, efficient running, timely upgradation, and continued and uninterrupted use. It will take about two years to complete the installations. The infrastructure can be installed only after completion of the building though it can be ordered much earlier. The ion-beam accelerator machine based research centre at Panjab University Campus is going to be the first of its kind in the University system in India, its success is extremely important from the point of view of setting up major facilities in such a system.

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