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KFUPM FAST NEUTRON FACILITY

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Abstract: A 350 KeV light ion accelerator system has been installed and tested at King Fahd University of Petroleum and Minerals (KFUPM). The accelerator system is capable of producing high intensities of 14 MeV neutrons via the $^{3}H(d,n)^{4}He$ reaction. Pulsed polarized and unpolarized beams of deuterons are available with timing properties better than 0.5 nSec and 65mA of peak current per pulse. The polarized ion source is of the atomic beam type and is under test for about six months. The features of the facility including the data acquisition and analysis system will be described and test results will be reported.

Introduction

Four years ago, King Fahd University of Petroleum and Minerals decided to establish an Energy Research Laboratory (ERL) to conduct research in the areas of nuclear physics, laser physics and solar energy. The basic concept behind this specialized laboratory is to support the academic departments in the university, and to act as a user facility for people from outside. For the nuclear physics research a 14 MeV neutron generator and a 3 MV tandetron were chosen both of which were designed and manufactured by General Ionex Corporation in the United States. The design features of the neutron generator were described elsewhere[1]. Basically, it is a low energy light ion accelerator which is tested to operate between 20 KeV to about 320 KeV without any difficulty. The high end limit of the acceleration voltage is about 400 KV. The accelerator is equipped with three selectable ion sources and four beam ports (three are in use) selectable by a switching magnet. The beams are transported and focussed at the target location by a series of quadrupole triplets and x and y magnetic steerers. The transport system is able to produce beam spots at the end of the beam line whose diameter is less than 10 mm and whose positional drift measured on the 80 beam line is less than 1 mm during the course of one hour. The two unpolarized ion sources are duoplasmatrons. In addition, a polarized proton and deuteron source is provided and will be described in the next section. The high current unpolarized source is capable of producing 12 mA of current and operates in conjunction with the 0 beam line. This beam line employs a rotating tritium target similar to the one at JAERI in Japan and designed to provide 3×10^{12} neutrons/sec into a 4 pi solid angle. The low current unpolarized source is capable of producing 1.5 mA of deuterium of which approximately 1 mA could be transported to the target.

The system can be operated in a pulsed mode. The pulsing system has two main components: a sweeper-diverter system in the high voltage terminal, and a Klystron buncher on the 45° beam line. The pulsing system was tested with both protons and deuterons and found to have a very good timing characteristics. At 300 KeV, the pulse width at the target location was 0.5 nS as measured by a fast Faraday cup. The pulse width increased to 0.8 nS at 100 KeV. In both cases, the pulse shape was very clean[1]. The peak current of the pulse was determined to be 65 mA. The floor plan of the neutron generator and experimental areas is shown in Fig.1.

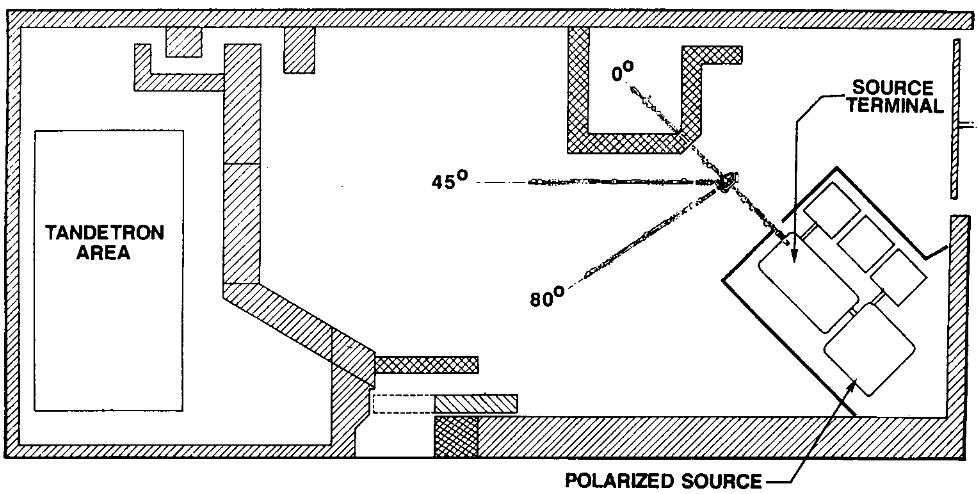

Fig. 1 The floor plan of the neutron generator and experimental areas

The Polarized Ion Source

The ERL atomic beam polarized positive ion source was originally built by SENTEC and later modified by General Ionex to include a dissociator and a cold head similar to those installed at SIN in Switzerland. The principle of operation of this type of sources has been reviewed by several authors[2,3]. Basically, it utilizes the Stern and Gerlach technique to select a specific spin state of the atomic beam. Fig. 2 shows a

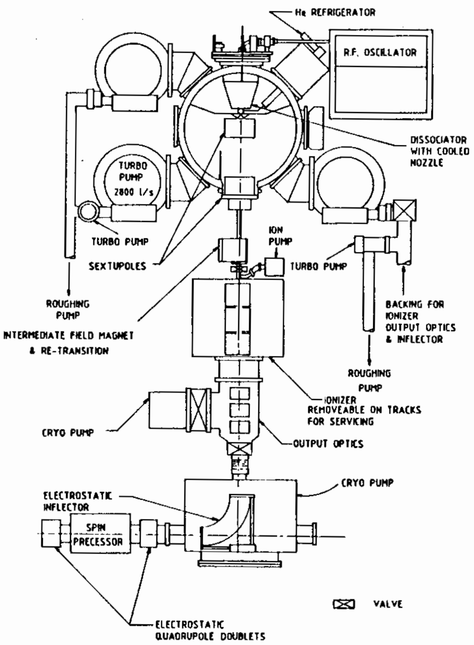

Fig. 2 Vertical Polarized Ion Source

schematic of the ERL polarized source. Molecular hydrogen or deuterium is fed at the top to the dissociator in the atomic beam section. The gas is dissociated into atoms in a gas discharge excited by a 13.56 MHz RF oscillator which can deliver over 300 watts of RF power. Helium refrigeration is used to cool a copper nozzel at the other end of the discharge tube. A typical value for the dissociation ratio is about 33% for Hydrogen. It is found that the minimum recombination on the surface of the nozzel occurs at around 30 K^o. The emerging atomic beam, then, enters the 10 cm long sextupole magnet which selects the spin state of the beam. This first sextupole magnet has a tappered apperture whose entrance and exit diameters are 9 mm and 25 mm respectively. The field at the pole tip is between 0.7 and 0.9 Telsa. The atomic beam component with $m_j = +1/2$ is focussed along the sextupole axis while the component with $m_j = -1/2$ is deflected away from the axis and pumped out by a 2200 l/s turbomolecular pump. The selected beam component is then focussed by the second sextupole magnet which operates at a lower field of about 0.35 Telsa. On its way to the ionizer, the atomic beam passes through the RF transition units. These transitions disturb the initially equally populated nuclear spin states resulting in the non-zero net nuclear polarization of the beam. For deuterons, a weak field and two intermediate field transitions are used. They operate at 10 MHz, 331 MHz and 458 MHz respectively. A combination of these transitions results in a vector polarization of the deuteron beam with a maximum theoretical value ranging from -2/3 to +2/3, while the tensor polarization obtained ranges from +1 to -1. The nuclear-polarized atomic beam enters the ionizer which is an electron bombardment type, and has a strong axial magnetic field of 1000 Gauss. This field confines the electron beam in 30.8 cm long ionization column and provides a quantization axis for the polarized beam. The positively ionized beam is then extracted from the ionizer at 10 - 12 KeV. The beam is then focussed by three electrostatic lenses into a spherical electrostatic inflector which changes the vertical motion of the beam into a horizontal one, to be transported by the beam transport system of the 350 KV accelerator. The electrostatic quadrupole focusses the beam into the spin precessor which controls the spatial orientation of the polarization vector of the beam. Due to the finite-size aperture of the electrostatic quadrupole and the spin processor, the beam transmission through the spin processor has been measured to be 60% for Hydrogen.

At the output of the spin precessor, 5.2μA H^+ with 90% polarization have been measured. However, the current on target is only 1.22μA. Similarly for deuterium, 2.59μA with 84% polarization was measured at the output of spin processor of which only 0.9μA reached the target.

The vector polarization of the deuteron beam was measured at the target using the $d(\vec{d},p)$ reaction. The measured value of P_z was 0.48 ± 0.08 which is 75% of the maximum theoretical value.

The above tests have been performed during a continuous running of the source since December 1987.

The Data Acquisition System

The ERL data acquisition and analysis system was installed in June 1987 and has been in operation since then. The system uses a VAX 11/785 super-mini computer for both data acquisition and analysis. The cluster configuration employed allows increased reliability and facilitates future growth while protecting current investment in both hardware and software. The system has been optimized for speeding up data acquisition and storage and for the efficient utilization of CPU time and memory resources. Standard CAMAC hardware is used for data acquisition and the system allows for experiments running on both the neutron generator and the tandetron system to be monitored simultaneously. The system uses the TUNL XSYS modular software package which supports a wide range of user experiments and can be readily extended to cater for future requirements.

The computer system is a 2-node VAX cluster consisting of a VAX 11/785 CPU and an HSC50 intelligent I/O controller supporting all mass-storage devices; Fig.3. Disk storage is provided by two RA81 fixed disks with a capacity of 456MB and tape storage by two tape units type TA78 and TU78. Both tape units employ high speed (125 ips) drives and are capable of recording data at a dual density of 1600/6250 cpi. With the HSC50 supporting all disk and tape traffic, the UNIBUS is now dedicated to on-line data acquisition (in addition to the relatively light task of terminal communications) and dead time performance is improved. Moreover, data dumping between tape and disk is now performed internally within the

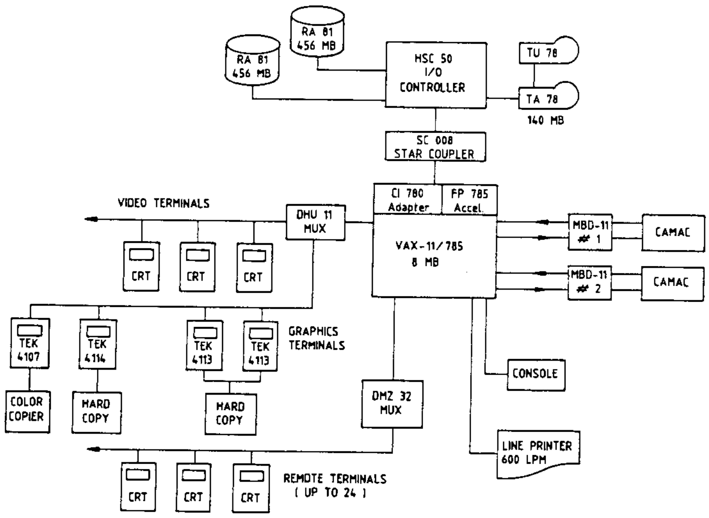

Fig. 3 The ERL Data Acquisition and Analysis System

HSC50, thus reducing the demand on CPU time and physical memory. The data acquisition hardware consists of two CAMAC branches, each connected to the UNIBUS via an MBD-11 branch driver. The use of Lecroy 3511 fast CAMAC ADC modules with a constant conversion time has increased system throughput and simplified the CAMAC interface hardware.

Research Programs

Presently, a neutron time-of-flight setup is under construction. This temporary setup consists of two movable detectors covering the angular range upto 165^{o} and a fixed flight path of 4 meters. This setup allows the positioning of the sample at either 0^{o} or 90^{o} with respect to the beam. Various sizes of liquid scintillator neutron detectors - NE213 are available and a design for a future multidetector system is under study.

The above mentioned setup will be used in the measurement of analyzing power as well as neutron scattering cross sections. Studies on fission dynamics using polarized and unpolarized neutrons and on proton induced reactions pertinent to nuclear astrophysics will also be conducted. The latter will utilize the unique feature of having a high current of protons at energies as low as 10 KeV.

A program on polarization physics of light nuclei at energies in the range between 10 KeV to 400 KeV will soon be initiated.

Experiments are being designed to measure the polarization variables of the deuteron and neutron beams.

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