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The LLNL Multi-user Tandem Laboratory

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THE LLNL MULTI-USER TANDEM LABORATORY*

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Abstract

An FN tandem laboratory, cofounded by several Lawrence Livermore National Laboratory Divisions, Sandia Livermore, and the University of California Regents, is now operational at Livermore. The accelerator, formerly the University of Washington injector, has been upgraded with SF_6, Dowlish tubes, and a NEC pelletron charging system. A conventional duoplasmatron, a tritium source, and two Cs sputtering sources will be fielded on the accelerator. Pulsed beams will be available from two source positions. The laboratory has been designed to accommodate up to 19 experimental positions with excellent optics and working vacuum. The facility is unshielded with both accelerator and radiological systems under the control of a distributed microprocessor system. Research activities at the tandem include nuclear physics and astrophysics, materials science and characterization programs, and accelerator mass spectrometry for archaeology, biomedical, environmental and geoscience investigators.

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1. INTRODUCTION

The Physics Department of the Lawrence Livermore National Laboratory has recently constructed a new FN tandem accelerator laboratory to execute a wide variety of basic and applied measurement programs. The laboratory and its research equipment were constructed with support from a consortium of LLNL Divisions, Sandia Laboratories Livermore and the UC Regents. Primary design goals for the facility were inexpensive construction and operation, high beam quality at a large number of experimental stations, and versatility in adapting to new experimental needs. To accomplish these goals, the main design decisions were to place the accelerator in an unshielded structure, to make use of reconfigured cyclotrons as effective switching magnets, and to rely on computer control systems for both radiological protection and highly reproducible and well-characterized acceleration operation.

2. PROJECT SCHEDULE

The project began in August 1985 with relocation to LLNL of the injector FN tandem from the University of Washington. Construction of the laboratory building on the Livermore site began in June 1986. Development of computer control hardware was done in parallel on the EN tandem of the LLNL cyclograaff until it was shut down in October of 1986. Beneficial occupancy of the new laboratory for installation and activation activities was possible for LLNL staff in Feburary 1987. First beam was achieved in the accelerator in July 1987 with research operation beginning in September 1987. Since then, the accelerator has operated routinely at voltages of 5 MV and below, allowing simultaneous research operation and continuing construction of research beamlines.

3. ACCELERATOR SYSTEMS

Floorplan of the laboratory and major accelerator components are shown in Figure 1. The arrangements of components selected provides a total of 19 experimental beamlines in a single large experimental area.

3.1 Ion Sources

Five ion source positions are provided at the low energy end of the tandem. Injection voltages for sources at the three rear positions can be as high as 120 kV. Beam pulsing is possible for these positions as well. At present, a duoplasmatron (Genus Model 358) and a Cs sputtering source (Genus Model 860) can be interchanged at one 45-degree position, with the other 45-degree position reserved for a dedicated Cs sputtering source (Genus Model 845) for tritium beams. The central position is reserved for a dedicated sputtering source to be developed for tritium accelerator mass spectrometry (AMS), using a Wien filter for species selection in zero degree injection.

The two 90-degree positions are reserved for AMS sources, one a developmental sputtering source, the other a Genus Model 846 sputtering source with a 60-sample cassette. The vacuum tank of the double-focusing inflection magnet is floated and can be pulsed by a bouncer for species selection in injection.

3.2 High Voltage

The FN tandem has been upgraded with Dowlish tubes and a National Electrostatics pelletron charging system. Initial operation of the accelerator has been with a conventional nitrogen-carbon dioxide gas mixture, limiting operation to 5 MV. The sulfur-hexafluoride gas handling system is now complete, allowing operation at higher voltages to begin soon. The accelerator is expected to operate at above 10 MV as achieved at MacMaster. At present, conventional foil and gas stripping are used. The machine is stabilized to 500 eV with corona points through a GVM/CPU feedback system. A pumped stripper canal and fast active control of the stripper voltage will be added in the future.

3.3 Beam Transport Components

The majority of beam transport components have been recycled from other accelerators. The beam pulsing hardware, Faraday cups, scanners and other diagnostics, the 10-cm aperture quadrupoles, and three of the ion sources come from the LLNL cyclograaff. The two 5-cm aperture switching magnets were built from 22 MeV and 15 MeV cyclotrons. Thw two 90-degree, 5-cm aperture magnets that form the accelerator mass spectrometer beamline are reworked switching magnets. The large apertures available in the magnets have produced virtually aberration-free transport of the beams. Of particular note is that the AMS spectrometer was designed to be uncompromised by other uses of the laboratory.

3.4 Vacuum Systems

Vacuum components are primarily stainless steel with viton o-rings. Pumping is provided by a combination of cryopumps and turbomolecular pumps. Twenty-centimeter cyropumps are installed in pairs at the tandem baseplates and on the vacuum boxes of the two switching magnets. Small turbopumps (330 I/s) are installed near the ion sources to handle localized gas loads and near scattering chambers that represent similar loads or require quick pumpdown capabilities. Forepumps are located in a service basement running the length of the accelerator. Operating vacuum in the system is typically 10^{-6} torr or better, except near the ion sources.

3.4 Computer Control

Control of all accelerator and beam transport systems is accomplished through a distributed system of Hewlett-Packard 9000 computers organized in a geographic heirarchy [1]. Discreet geographic portions (e.g., ion sources, low energy transport, high voltage generator and high energy transport experimental beamlines, etc.) of the accelerator are connected through CAMAC hardware to individual HP 9000/319 machines that maintain the local state vector and communicate over an IEEE-802.3 LAN to the HP 9000/350 machine that is the operator interface. A separate HP 9000/310 monitors the radiation protection hardware. The software for this computer is not accessible to the accelerator operator and/or experimentalists.

4. FACILITY SYSTEMS

The building housing the accelerator is a simple metal shell over a flat slab floor. Good lighting and environmental control are provided to create a pleasant working environment in the facility. Approximately 2,000 square feet are provided for the ion sources and high voltage generator. Another 5,000 square feet are available for the experimental area.

4.1 Radiological Protection and Interlocks

Many proposed experiments for this facility are performed either with heavy ions or at low currents (e.g., ion microbeams) under conditions that produce little radiation. These operating modes made possible construction of an unshielded facility monitored by a relatively elaborate radiation and interlock system. Such a facility is a cost-effective and extremely safe replacement for conventional heavily shielded concrete structures. Equipment assembly and debug has proven to be rapid in the uncluttered and open structure that resulted from this design philosophy, an unexpected but not surprising dividend. The radiological system continuously monitors the accelerator work environment, and automatically suspends accelerator operation if preset radiation levels are exceeded. The monitoring system consists of both hard-wired radiation detectors and computer-controlled detectors. The computer-controlled system monitors both the hourly integrated radiation dose and the instantaneous dose rate. The computer monitors ten photon detectors and five neutron detectors, providing trips both on instantaneous rate (100 mrem/hr) and on integrated dose for the current hour (1 mrem). The system is expandable up to 30 detectors. Three hard-wired detectors (at the control console, the data taking position being used, and one other picked at random) are configured to trip the machine off if the dose rate at the detector exceeds 0.25 mrem/hr. Safety of operation with each new beam tune is demonstrated by initial operation at reduced currents. Proximity shielding around slits and beam dumps is then added as required. The hard disk on the radiological computer can maintain a ten-year record of hourly doses.

The original facility concept envisioned retreating to the electron linac building 50 meters away, locking the perimeter fence around the facility, and operating the accelerator over a fiber optic link for those experiments that must be performed at unavoidably high radiation levels (e.g., neutron scattering, some tritium or deuterium operation, conditioning or other conditions producing high bremsstrahlung flux from the machine itself). The ease and attractiveness of operating close to the machine and experimental area have led us to revise this concept. A small shielded control and data-taking area will be added to the facility when conditions require operation at higher radiation levels. At present, the control console is placed at the low energy end of the tandem; data-taking electronics are sited as radiation levels permit.

4.2 Utility Distribution

Utilities and equipment that support the ion sources, accelerator and experimental beam lines are placed in a 10-foot-wide and 10-foot-deep basement that runs the length of the building under the central axis of the machine. The basement can be entered from both inside and outside the building and has a weather tight hatch at one end to allow removal of heavy equipment. To field an ion source or experimental beamline, a utility bundle of the necessary utility, control, and metering lines is assembled in the basement and then fed through an opening below the equipment. Clean power for data-taking electronics and the cableways for experimental signals are placed on the peripheral walls of the building to isolate them from equipment power and controls. Buried conduits lead from the walls to each experimental station, leaving the floor clear for forklift access for assembly and maintenance.

The gas storage tank for SF_6 and the associated pumps, compressors, and dryers are located outside the building to minimize any hazard resulting from small leaks. The basement is equipped with oxygen deficiency monitors that sound an alarm both locally and at the laboratory fire department.

5. EXPERIMENTAL STATIONS

Eight of the nineteen possible experimental stations are in operation or various stages of installation and activation. A charged particle scattering chamber, neutron physics beamline, nuclear chemistry irradiation line, ion microprobe [2] and radioactive ion spectrometer are installed on the first switching magnet and have been used in epxeriments to date. The accelerator mass spectrometry beamline [3] (magnetic rigidity $ME/Z^2 = 150$) has been given its initial checkout with beams of ^{12}C, ^{13}C and ^{14}C and will be completed by spring with the installation of the abundant isotope detection systems, Wien filters, and several sets of detector systems. A superconducting beta spectrometer for in-beam measurements has been installed behind the second magnet of the AMS beamline and will be activated by January 1989. A beamline for near-surface measurement of hydrogen with fluorine beams and a gamma spectrometer-polarimeter will be added to the first magnet in the next six months, completing the set of experimental stations planned there.

The cyclotron for the second switching magnet (originally the injector for the TUNL cyclograaff) is in the laboratory and is in the process of being reconfigured. Installation of this second magnet will be done as resources allow and pressure for more beamlines dictates. Some of the simpler beamlines may be relocated to this magnet, and the lines for tritium targets and/or tritium implantation will be fielded on it. Possible major experimental stations on this magnet include a beam swinger for elastic and inelastic neutron scattering and a spectrometer for (n,gamma) experiments.

6. EXPERIMENTAL PROGRAM AND NEW CAPABILITIES

The near-term program for the accelerator will concentrate on the capabilities fielded to date in materials science, nuclear astrophysics, nuclear spectrometry, neutron physics, and accelerator mass spectrometry. Participants in the research program will be from LLNL, Sandia Livermore, the campuses of the University of California, and other academic institutions. Of particular emphasis will be development of capabilities for automated operation for neutron physics and accelerator mass spectrometry. Operation for multidisciplinary applications of AMS, particularly in the biomedical and environmental sciences, is expected to increase to half of the machine time. As there is an upper limit on the availability of this accelerator for mass spectrometry, we have acquired the EN tandem from the University of

Texas and retain sufficient magnets to field a dedicated laboratory fortthis application by cloning the systems of the present machine. The feasibility of this project will be determined in the next year.

References

[1] T. H. Moore, proceedings of this conference.

[2] A. E. Pontau, proceedings of this conference.

[3] I. D. Proctor, proceedings of this conference.

Figure Captions

Figure 1: Plan view of the tandem laboratory showing the location of major components.

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