FINAL REPORT

DEPARTMENT OF ENERGY GRANT

To

KANSAS STATE UNIVERSITY - J. R. MACDONALD LABORATORY

TITLE: "ATOMIC PHYSICS WITH HIGHLY CHARGED IONS"
Supplementary Request for Accelerator Improvement Project

GRANT NO; DE-FG02-94ER14444

GRANT PERIOD: 09/01/94 - 12/31/01

GRANT AMOUNT: \$1,678,000

Principal Investigator:

Patrick Richard

Patrick Richard

Director, J. R. Macdonald Laboratory

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ARIM FINAL REPORT

SUBJECT GRANT: DE-FG02-94ER14444

Funding History

FY94	\$ 621,000	(Original)	09/01/94 – 08/31/96
FY96	\$ 395,000	(MOD001)	08/31/96 – 08/31/97
FY97	\$ 412,000	(MOD002)	02/15/97 – 08/31/99
FY00	\$ 250,000	(MOD003)	09/01/99 – 08/31/01
FY01	-0-	(MOD004)	08/31/01 – 12/31/01

Summary of Projects for DE-FG02-94ER14444

FY94	LHe compressor relocation	Completed
	LINAC RF electronics upgrade	Completed
	Tandem Van de Graaff foil changer	Completed
	Tandem Van de Graaff terminal pump installation	Completed
	Replace power transistors in magnet power supplies	Completed
	New EBIS beam line vacuum system	Completed
	EBIS beam optics upgrade	Completed
FY96	Tandem Van de Graaff cryopumps	Completed
	Tandem upcharge system	Purchased
	PIG source for Ion-Ion system	Completed
	LINAC beam line	Completed
	EBIS beam optics and safety upgrade	Completed
	EBIS beam power upgrade	Completed
	Ion-Ion facility upgrade	Completed
FY97	Ion-Ion upgrade	Completed
	New LINAC beamline	Completed
	LINAC cryostat upgrade	Completed
	LHe plant equipment	Completed
	EBIS beamline upgrade	Completed
FY00	High voltage platform and ion-beam handling peripherals	Components Purchased

FY94 1. LHe Compressor Relocation:

The large Sullaire compressor for the LHe refrigerator system was moved from its original location on the roof of the laboratory to a location adjacent to the laboratory. A new building to house the compressor and allow for additional compressor capacity was provided by State funding. The laboratory technical staff performed the relocation and installation. This move reduced noise and vibration levels in the laboratory and allowed an improvement in the safety and working conditions around the coldbox of the LHe refrigerator system.

2. LINAC RF Electronics Upgrade:

The rf control modules for the LINAC Nb split ring resonators were replaced with the newer design from the ATLAS system at Argonne National Laboratory. This upgrade allowed the individual rf control modules to be utilized in conditioning procedures for the individual rf resonators of the LINAC. The new rf control modules have lower control input signal sensitivity, which is necessary when conditioning to remove low-lying multipacting barriers resident in the resonators.

3. Tandem Van de Graaff Foil Changer:

An additional multiposition stripping foil assembly was added to the terminal stripping box in the tandem Van de Graaff accelerator. This upgrade added an additional 256 stripping foils to the 60 stripping foils available with the foil stripper that was provided with the tandem accelerator when it was originally installed in 1969. Note: When the tandem was upgraded from a belt charging system to the Pelletron charging system in March 2000, this foil stripping assembly was removed and modified to fit the new charging system installation. We are in the process of designing a terminal computer drive system to control the modified stripper.

4. Tandem Van de Graaff Terminal Pump Installation:

A recirculating gas stripping system was installed in the tandem terminal. We added a 200//s turbo pump to the terminal stripper box and connected the turbo pump output to the stripper canal gas input line. The recirculating stripper improved the beam intensity a factor of 2.5 on average for the higher charge states of heavy ions accelerated by the tandem accelerator. This has improved the abilities of users to perform experiments where the maximum available beam intensity was required.

5. Replace Power Transistors in Magnet Power Supplies:

We replaced the 70 power transistors in the HVEC 12KW DC magnet current supplies that provide currents for the large 90° analyzing magnets and switching magnets of the tandem or LINAC accelerator systems. This upgrade extended the useable lifetimes of the HVEC power supplies. Note: Since this upgrade was done, the HVEC magnet current supply for the 90° analyzing magnets failed six years after the transistor replacement upgrade. We temporarily replaced that supply with an ALPHA unit, which was surplus equipment from the shutdown of the accelerator laboratory at the University of Pittsburgh. We have ordered a Dan Fysik power supply to permanently replace the HVEC supply, and will return the ALPHA supply to standby status.

6. New EBIS Beam Line Vacuum System:

We purchased vacuum components, pumps and controls to support seven user beam lines on the CRYEBIS source. The purchased equipment includes turbo pumps, roughing pumps, ConFlat vacuum nipples, ion gauge systems, and thermocouple vacuum controller systems. With these components, we were able to keep all experimental lines

under high vacuum at all times, providing better charge state purity at the user's target as well as better vacuum in the target chambers for lower backgrounds.

7. EBIS Beam Optics Upgrade:

We built and installed new electrostatic ion-beam optical elements to aid in the transport of low energy beams from the ion source. The optical elements were built in-house. The control electronics were also put together in-house based on commercially available modular units. These upgrades allow us to reliably deliver ion beams to user experiments with energies below 1 keV/q. These low energy beams (1-3 keV/q) currently make up over half of our beam requests.

FY96 1. Tandem Van de Graaff Cryopumps:

We purchased two eight-inch cryopumping units with He compressors as replacement units for the cryopumps that we had installed on the tandem accelerator during the initial tandem upgrade. These additional units have proven to be extremely valuable in limiting accelerator downtime associated with cryopump maintenance and failures.

2. Tandem Upcharge System:

We purchased a new fast energy system for the tandem as a replacement for the Varian fast energy control system that was part of the original installation in 1969. The age of the original Varian control system and advancing technology have contributed to a situation where the lack of spare parts and the lack of service support by the original vendor would place the laboratory in a potentially critical position in the event of a major system failure with the original Varian system. The Varian system remains operational and will be replaced with the new HVEC system once it fails.

3. PIG Source for Ion-Ion System:

Two commercial PIG sources were purchased. One of them is intended for use with gas samples; the other is designed to produce beams of metal ions from sputtering of the cathode in the source. The gas-sample PIG source has been put into use on a user's experiment, and the sputter source has been tested on an independent test bench as an exploratory step for a future experiment.

4. LINAC Beam Line:

Beamline RB15, which is the 15° right deflection beam line of the second LINAC switching magnet was converted to a KSU second generation COLTRIMS beam line. A two-stage supersonic jet was designed and built in-house; a new electron-positive ion recoil spectrometer with first order time and position focusing was designed and built in-house; and two double-channel plates plus backgammon detector systems were designed and built in-house and mounted on the spectrometer. A vacuum chamber housing for beam transport, jet housing and spectrometer was designed and installed, which completed the system. This system is in operation and has been used to perform several experiments.

5. EBIS Beam Optics and Safety Upgrade:

A general upgrade was made to the control systems and interlocks on the ion source to make it more reliable and to provide more stable beams. A new high-voltage divider was added to the platform so that the platform voltage could be accurately monitored and set by users. A backup power supply was put on the platform so that the protection systems on the superconducting solenoid would function during power

outages. Optical data links were provided to and from the HV platform, and remote controls were added to slits and beam monitoring detectors on the platform.

6. EBIS Beam Power Upgrade:

New high-voltage amplifiers were purchased to allow us to run the electron beam through the EBIS ion trap with greater ionizing power. The new HV drivers will allow the beam to be run at 20 keV in the trap. However, we cannot achieve this without having the source down for an extended period of time for redesign of the drift tubes. Currently, we can run the beam at up to 12 keV. Additionally, enhancements were made to the timing electronics for the trap batch processing to produce a better duty cycle, or shorter pulses, or synchronization with user events (pulsed lasers) as needed by the experimenters.

7: Ion-Ion Facility Upgrade:

A new interaction region for the ion-ion collision apparatus was built and installed to yield improved vacuum conditions and to decrease background event rates.

FY97 1. Ion-Ion Upgrade:

A new turbo pump was added to the ion-ion interaction region to improve vacuum and decrease background events. A new extraction supply was installed to increase the source potential up to 20 kV.

2. New LINAC Beamline:

Beam line LA45, which is the 45° left deflection beam line of the first LINAC switching magnet, was converted to a third generation general purpose COLTRIMS beam line. A three-stage supersonic jet and a large area electron-recoil spectrometer equipped with 80 mm² delay-line detectors were installed in a new stainless steel high vacuum chamber vessel. The chamber was designed in-house and fabricated by a commercial vendor. The chamber is 22" in diameter and 55" long. Five turbo-pump systems were purchased and installed on the system, which is in complete operation. It is presently being adapted to use with our new high power laser system.

3. LINAC Cryostat Upgrade:

The LINAC large cryostats were upgraded by redesigning the power and signal cable systems for the resonators within the cryostats. New LN₂ cooling pots were designed, fabricated, and installed to eliminate problems with LN₂ leaks into the cryostat vacuum space. The number of metal-to-insulator signal feedthroughs from the LN₂ space to the cryostat vacuum space was minimized to lower the incidence of seal failures from stress due to thermal cycling.

4. LHe Plant Equipment:

We purchased a spare expansion engine for the LHe coldbox. This action has greatly decreased the LHe refrigerator downtime that was associated with maintenance and repair of an expansion engine. Our experience with the LHe refrigerator shows that an expansion engine runs for nominally 8,000 to 9,000 hours before normal maintenance is required. We have experienced several catastrophic engine failures in the 14 years of refrigerator operating experience. Given the hostile environment in which the expansion engines operate, we have vastly improved our ability to keep this critical system continuously operational by having the spare engine available as a replacement when needed.

5. EBIS Beam Line Upgrade:

Components were purchased to build a computer control system for the trap switchyard on the ion source. The system is controlled at a ground station with optical links to the source platform. This system has been installed and demonstrated. It allows the ion source to be optimized with the beam tuned to the experimental target (due to the optical links) and also allows for extended control of the ion expulsion to greatly increase the duty cycle of the beam for those experiments that have a limited peak beam current bandwidth. Additionally, beam-viewing systems were installed on the experimental beam lines to facilitate beam tuning by the users.

FY00 1. High Voltage Ion-Source Platform:

The request for funding for a new high-voltage platform was intended to allow us to build a capability to extend the range of ion beams that can be delivered to users of the Low Energy Ion Collisions Facility. The new platform is intended specifically for the production of low-charge-state high-duty-cycle ion beams at flux rates that the EBIS cannot produce, as well as to serve as a pedestal for new permanent magnet ECR sources that produce high-charge ion beams with flux rates that exceed that of the EBIS.

To meet this goal, we have designed a system that will have multiple ion sources mounted on a single high-voltage platform. The ion source which best meets the needs of the user's experiment can be easily started and the beam tuned down a common acceleration column. The way the source switching is accomplished is to use a charge-analyzing magnet on the HV platform with multiple entry ports, each producing a different deflection angle through the magnet. All of the sources can be kept under vacuum with this system so that switching between sources involves only starting the source and setting the magnet field appropriately.

We specified a magnet design with three ports, at 20, 50, and 90 degrees, respectively. This design was sent out for bids, and the contract awarded to the lowest bidder. The magnet has been delivered to the Macdonald Lab. We have also contracted for a power supply for this analyzing magnet after separate competing bids were received. This supply is scheduled for delivery in December of 2001.

We have purchased isolation transformers to bring ac power up to equipment on the platform. The transformer system we have acquired has enough capacity to power the analyzing magnet to its full specification with 4 kW in reserve for driving the ion sources and vacuum generators. Our platform design allows an additional transformer to be installed if more power is needed.

The design specification for the platform is that it will operate at up to 250 kV. We have purchased insulating supports for the platform to meet this specification. We have also purchased an accelerating column for the ion beam that is rated for operation at this voltage.

The HV bias supply for the platform has been purchased. This is an ultra-stable low-ripple supply capable of sourcing 1 mA of current at 250 kV. We have also purchased a monitoring system for the voltage on the platform that has both a voltage divider to measure the dc potential on the platform and a capacitive-coupled ripple monitor so that we can measure the ac ripple with high sensitivity.

Other commercial components that have been purchased for use with the platform include four turbo pumps, gate valves for the common beam line from the platform to the switching station, a Gauss meter for the analyzing magnet, vacuum gauges, and standard vacuum crosses to be used in assembling ion transport lines.

The remaining parts of the system we expect to build in house. These will include the structural parts of the platform and its corona shields, and the electrostatic ion optical systems needed for beam transport and control.

The platform will be installed during the next year, and existing sources will be placed on the platform. The platform will be configured to take into account the new high intensity laser facility, which will be used to study ion-laser interactions. The KSU 5GHz source will be used in initial ion-laser experiments, but will however not be mounted on the new platform due to power requirements. It is our plan to seek funds to purchase a 14.5 GHz permanent magnet supermanogan ECR. This source could be mounted on the new platform. It would replace the KSU 5GHz ECR. The supermanogan produces one or more orders of magnitude more ion current for some highly charged ions than does the KSU 5GHz ECR.

FINANCIAL STATEMENT

Our records indicate that all allocated funds under Grant No: DE-FG02-94ER14444 have been committed.