Progress report on the accelerators upgrade at ANU

Dr Nikolai Lobanov

on behalf of Accelerator Operation and Development Team
22 tonnes of SF6
Ion beams from 14UD and Linac

<table>
<thead>
<tr>
<th>M</th>
<th>Q1</th>
<th>Q2</th>
<th>E/M\text{STS}</th>
<th>\beta_{\text{STS}}</th>
<th>E/M\text{DTS}</th>
<th>\beta_{\text{DTS}}</th>
<th>E/M_{\text{DTS+Linac}}</th>
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<th>\Delta \tau, ns</th>
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<th>\Delta E_{\text{Post-Linac}}, MeV</th>
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<td>356</td>
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1st stripper 4 mkg/cm²
2nd stripper 10 mkg/cm²

\[ \varepsilon_{z\text{STS}} \sim 0.45\pi \text{ (keV x ns)/M} \]
\[ \varepsilon_{z\text{DTS}} \sim 0.9\pi \text{ (keV x ns)/M} \]

\[ \Delta E_{\text{Post-Linac}}/M \sim 0.03 \text{ MeV} \]

Longitudinal emittance of beam from 14UD (a) and post-Linac beam (b)
14UD and Linac capability
14UD development projects

Goal: increase reliability of operation and the range of heavy beams

- New accelerator computer control and data acquisition systems
  - Replacement vacuum pumps and gauges
  - Replacement major magnet power supplies by modern systems. Integration with new computer control
  - Automated tuning of the beam transport. Compensation off daily ion source displacement
  - New alignment system based on laser trackers (with ACAS collaborators)
  - Fully equipping with BPMs and FCs allowing optimal beam focusing
Current control and data acquisition systems are based on DEC VAX machines and use VMS OS.

Urgent need to migrate to supported computer platform.

VME crate controllers, accelerator control and data acquisition computers need to be replaced.

EPICS control software has been developed.

The hardware and basic software has been acquired.

The transition from present obsolete to new system will be complete by June 2012.

Once fully operational and debugged, the lab-wide transition will be rapidly implemented by 2013.
14UD development projects

- **New accelerator computer control and data acquisition systems**
- **Replacement vacuum pumps and gauges**
  - Replacement major magnet power supplies by modern systems. Integration with new computer control
  - Automated tuning of the beam transport. Compensation off daily ion source displacement
- **New alignment system based on laser trackers (with ACAS collaborators)**
- **Fully equipping with BPMs and FCs allowing optimal beam focusing**
Replacement inadequate vacuum pumps and gauges

In-house manufacture of control units and adapter flanges
14UD development projects

- New accelerator computer control and data acquisition systems
- Replacement vacuum pumps and gauges
- Replacement major magnet power supplies by modern systems. Integration with new computer control
- Automated tuning of the beam transport. Compensation off daily ion source displacement
- New alignment system based on laser trackers (with ACAS collaborators)
- Fully equipping with BPMs and FCs allowing optimal beam focusing
Replacement major magnet power supplies by modern systems

Danfysik power supplies are 2ppm stability version
14UD development projects

- New accelerator computer control and data acquisition systems
- Replacement vacuum pumps and gauges
- Replacement major magnet power supplies by modern systems. Integration with new computer control
- **Automated tuning of the beam transport.**
  Compensation of daily ion source displacement
- New alignment system based on laser trackers (with ACAS collaborators)
- Fully equipping with BPMs and FCs allowing optimal beam focusing
Automated tuning of the beam transport

Ion source (L5) moves up to 1.5 mm in relation to 14UD tank due to accelerator tower temperature gradient
14UD development projects

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14UD development projects

- New accelerator computer control and data acquisition systems
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- Automated tuning of the beam transport. Compensation off daily ion source displacement
- New alignment system based on laser trackers (with ACAS collaborators)
- Fully equipping with FCs and BPMs allowing optimal beam focusing
New FCs and BPMs

There is need for better beam diagnostic particularly reliable Faraday Cups

Issues: bellow failure in FC18 (ORNL)
14UD development projects continued

- New Terminal Potential Stabilisation system TPS 6.0 (NEC) including GVM, Slits and CPO amplifiers and corona probe controller
- New NEC remotely operated 4 x jaw HE slits and two 2 x jaw image HE slits. Slit controllers are made in-house
- Purchasing SF₆ gas to allow optimum tank pressure. Upgrade SF₆ monitoring system. New fast SF₆ containment valves
- Implementation oxygen depletion monitoring system to make safer cryogenic operations and SF₆ handling
- Enhancement AMS capability
- Enhancement RIB capability
- New beam lines
14UD Performance with old system

- Based on GVM, terminal voltage stability is ~ 0.2%, much higher than NEC specs of 0.02%

- Noise in GVM coax is at the same level as GVM $U_T$ (AC)

- Noise in coax should be reduced and pre-amp moved to L3
CPOs calibration

In anticipation of new NEC slit/GVM controller TPS 6.0

- 115 VAC at 50 Hz is applied to the terminal
- Challenge: to deliver CPO signal noise-free to Control Room

- Raw signal on CPO, 16 μV/V
- CPO signal after pre-amp, 70 μV/V
New NEC controller TPS 6.0

Corona Probe Controller and CPO amplifier

New Drusch NMR replacing 40 year old unit
14UD development projects continued

- New Terminal Potential Stabilisation system TPS 6.0 (NEC) including GVM, Slits and CPO amplifiers and corona probe controller
- New NEC remote operated 4 jaw double HE slit and two 2 jaw single HE slit. Slit controllers are made in-house
- Purchasing SF$_6$ gas to allow optimum tank pressure. Upgrade SF$_6$ monitoring system. New fast SF$_6$ containment valves
- Implementation oxygen depletion monitoring system to make safer cryogenic operations and SF$_6$ handling
- Enhancement AMS capability
- Enhancement RIB capability
- New beam lines
New High Energy remotely operated slits

All slits with 24 VDC motor drives, Ta elements

Controllers are built in-house
14UD development projects continued

- New Terminal Potential Stabilisation system TPS 6.0 (NEC) including GVM, Slits and CPO amplifiers and corona probe controller
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- Enhancement RIB capability
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Top up $\text{SF}_6$ and upgrade monitoring/safety

- Purchased 1040 kg of $\text{SF}_6$ in August 2010, tank operational pressure increased to 104.5 PSI
- Annual submission on emissions from HIAF for the National Greenhouse and Energy Report
- Evaluated direct measurement of $\text{SF}_6$ inventory in storage vessel with load cells (accuracy $\pm$ 5 kg) - project cancelled
- High precision system to log pressure and temperature of $\text{SF}_6$ in the 14UD tank
- New custom designed fast $\text{SF}_6$ containment ball valves via A&N Corporation
- Implemented RGA system to monitor moisture and air concentration in $\text{SF}_6$
RGA system to monitor moisture and air concentration in SF₆
14UD development projects continued

- New Terminal Potential Stabilisation system TPS 6.0 (NEC) including GVM, Slits and CPO amplifiers and corona probe controller
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- Enhancement RIB capability
- New beam lines
Oxygen depletion monitoring

6 channel MicroRack Alarm Controller with DGuard oxygen transmitter

- Integration to 14UD Computer Control system
- Simple audible and visible alarm signals
New Terminal Potential Stabilisation system TPS 6.0 (NEC) including GVM, Slits and CPO amplifiers and corona probe controller

New NEC remote operated 4 jaw double HE slit and two 2 jaw single HE slit. Slit controllers are made in-house.

Purchasing SF$_6$ gas to allow optimum tank pressure. Upgrade SF$_6$ monitoring system. New fast SF$_6$ containment valves.

Implementation oxygen depletion monitoring system to make safer cryogenic operations and SF$_6$ handling.

**Enhancement AMS capability**

**Enhancement RIB capability**

**New beam lines**
New Terminal Potential Stabilisation system TPS 6.0 (NEC) including GVM, Slits and CPO amplifiers and corona probe controller

New NEC remote operated 4 x jaw HE slits and two 2 x jaw image HE slits. Slit controllers are made in-house

Purchasing SF₆ gas to allow optimum tank pressure. Upgrade SF₆ monitoring system. New fast SF₆ containment valves

Implementation oxygen depletion monitoring system to make safer cryogenic operations and SF₆ handling

Enhancement AMS capability

Enhancement RIB capability

New beam lines
Enhancement RIB capability

- Feasibility of producing short-lived radioactive isotopes $^6$He using 1 eμA primary $^7$Li beam, superconducting 6.5 T solenoidal reaction product separator and pair of Parallel Plate Avalanche Counters has been demonstrated.
- This device is in great demand for many users.
- RIB project will purchase second solenoid with PS and computer control. A dedicated radioactive isotope beam-line will be developed.
New Terminal Potential Stabilisation system TPS 6.0 (NEC) including GVM, Slits and CPO amplifiers and corona probe controller

New NEC remote operated 4 jaw double HE slit and two 2 jaw single HE slit. Slit controllers are made in-house

Purchasing SF$_6$ gas to allow optimum tank pressure. Upgrade SF$_6$ monitoring system. New fast SF$_6$ containment valves

Implementation oxygen depletion monitoring system to make safer cryogenic operations and SF$_6$ handling

Enhancement AMS capability

Enhancement RIB capability

New beam lines evaluation stage
New beam lines

- Demands on existing beam-lines is increasing
- Space has been identified for three beam-lines in Target Area 1 making use of capability to rotate the analysing magnet
- Similarly, there is need for additional target station in Target Area 2
- This will be addressed through in-house design, manufacture and installation
Gas cathode ion source setup
Gas Cathode Source Negative Ions
Cesium Sputtering (SNICS)

 Implemented GC source Improvements:
- Cathode position actuator
- Improved vacuum conditions
- Combined focusing and steering

SNICS development:
construction the second source for better maintenance and reliability;
New Glassman cathode PS
Beam pulsing development projects

Goal: increase efficiency of operation and the phase stability

- Improve the performance of the RT resonators and phase detector
- Custom re-design of the complete rf electronics capable of phase and amplitude locking for 3-frequency buncher and choppers
- Upgrade slow chopper electronics
- Develop 150 MHz room temperature superbuncher with the aim of improving time resolution from ~1 ns to ~ 0.1 ns
Upgrade Chopper #1 resonator

Chopper #1 Tuner Drive
- stepping motor
- belt drive
- tuner plate

Chopper #1 9.375 MHz Resonator
rf control systems for C1, C2 and B2

\[\Delta f / f = \tan(\Delta \Phi / 2Q)\]
Performance of new rf control system @80 W
Chopping oxygen beam @80 W

\[ ^{16}\text{O}^{16} \text{MeV chopped beam, open loop, chopper #1 cold start at 80 W} \]

- Cold start @80 W
- 12 min @80 W
- Off for 20 min

Counts

Channel

0.19 ns/ channel

\[ ^{16}\text{O}^{16} \text{MeV chopped beam, controlled loop, chopper #1 cold start at 80 W} \]

- Cold start @80 W
- 10 min @80 W
- 20 min @80 W
- 50 min @80 W

Counts

Channels

2.5 ns FWHM

2.1 ns FWHM

0.19 ns/channel
Beam pulsing development projects

- Improve the performance of the RT resonators and phase detector
- Custom re-design of the complete rf electronics capable of phase and amplitude locking for 3-frequency buncher and choppers
- Upgrade slow chopper electronics
- Develop 150 MHz room temperature superbuncher with the aim of improving time resolution from ~1 ns to ~ 0.1 ns
Upgrade slow chopper electronics

- Old system: concern about its life expectancy and duty factor limited to 25%
- Purchase of state-of-the-art fast-switching power supply from FID GmbH
- Pulse amplitude 0 to 400 V; pulse/pause width 100 ns to ∞
- Repetition rate 0 to 5 MHz; rise/fall < 20 ns;
- duty factor 50%

Slow chopper test of 26th Feb 2010
100 ns per div;
Specs have been met

Commissioning is expected in couple of months, still sorting out problems with power supply
Beam pulsing development projects

- Improve the performance of the RT resonators and phase detector
- Custom re-design of the complete rf electronics capable of phase and amplitude locking for 3-frequency buncher and choppers
- Upgrade slow chopper electronics
- Develop 150 MHz room temperature superbuncher with the aim of improving time resolution from ~1 ns to ~0.1 ns
Beam steering

The horizontal steering due to $E_x$ mostly in inner gap. Weak vertical steering due to cancellation $E_y$.

The vertical steering due to $H_x$ mostly in inner gap. Weak horizontal steering due to cancellation $H_y$. 
Electromagnetic steering is a function of rf phase and couples longitudinal and transverse motion. The beam steering and increase of its transverse dimension during bunching is much stronger than during acceleration since it happens over 90 degrees range of phase variation.

The longitudinal phase ellipse will be also affected in complicated way.
Bunching 14UD beam with HEB

Develop 150 MHz room temperature superbuncher with the aim of improving time resolution from ~1 ns achieved with LE pulser to ~ 0.1 ns

$L_{SB\text{-target}} \approx 13.5 \text{ m}$
Assumed $\varepsilon_z \sim 0.9\pi (\text{keV} \times \text{ns})/M$. It takes into account straggling in the strippers, foils thickness variation but NOT terminal voltage stability. $\Delta \tau \sim 0.13 \text{ ns}$ is feasible for heavy ions. Maximum relative energy spread $\Delta E/E = 1\%$ is required for light ions.
Accelerator tubes upgrade

14UD enhancement projects:
Six high precision accelerator tubes (TO#113). Resulted in more consistent transmission. Bias control is being installed in the low energy entrance of 14UD in order to reduce beam losses and the need for installing shorting rods.
Aug 2011 spare resistors for tubes and posts have been ordered from Welwyn

Failed Resistor in Unit 1, Tube 4, Gap 8

 Jul 2010: 7 out of 210 resistors had resistance degraded above specified 2% tolerance

Nylon sleeve

In situ Resistance Test at 30 kV

Accelerator posts and resistors
Refurbishment and replacement 14UD posts

TO#112
November 2009

Deposit across 10th Gap, Post B, Unit 1

- Protrusion of Al foil

April 2011 Eight posts have been ordered from NEC

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<tr>
<th>Unit #</th>
<th>Material</th>
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<td>Stainless Steel</td>
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<tr>
<td>Unit #27</td>
<td>Stainless Steel</td>
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2nd generation posts installed in 80th

Dirty insulator
Charging system

14UD enhancement:
Improvement charging system through installation of the new charging chains and oil-free conductive wheels
Chain #3 oscillations

-20 -10 0 10 20

rms amplitude, mm

DC idlers
15
16
17
18
19
20
21
22
23
24
25
26
27
28

under 14UD tank

- Chain#1 UP
- Chain#1 DWN
- Chain#2 UP
- Chain#2 DWN
- Chain#3 UP
- Chain#3 DWN

suppressor under tank
twist
Unit #21 stiff
VERA has successfully demonstrated damping chain oscillation by controlling the chain speed with variable frequency inverter (Peter Steier, AMS Conference NZ 2010).

Few problems:

1. High frequency switching up to 20 kHz and short rise time can stress the motor insulation system;
2. Transient voltage spikes nearly twice as the DC bus can cause pin holes in the motor's insulation
3. Reflected wave voltage (standing wave) at long distances between motor and inverter
4. Additional heat in the windings because waveform is not sine
5. Switching and transient spikes build up high frequency voltage between rotor and stator. It is dissipated by arcing through the ball bearings.
Oscillations disturb uniform voltage distribution

Chain #3 is special:
A. Mechanically noisy
B. Close proximity to resistors

Therefore it is more likely to initiate sparking

Also in the past petals replaced with 2-1/8” inside diameter rather than 1-7/8” see TOR72
Distribution of spark marks in Chain #3
Spark damage of new Ni-plated chain

- New in TO#113, 6/2010, 1.366khours
- Significant spark damage, lip to lip on chain #3
- NEC moved away from chrome plating due to high rejection rate
- Twisted when new, but better that Ch#2
- Put old chain #3 back into service. New chain retired.
- Another new Ni-plated chain #1 is still in service
- Awaiting resolution RE: chrome-plated chain from NEC
Superconducting Linac-booster
Current Linac configuration

- 90° achromat
- Linac Stage I medium $\beta$
- To New TA
- From 14UD
- To OTA
- SB medium $\beta$
- TEL
Working backward approach

start at the end and work toward beginning
Linac development projects:

Add new tall cryostat with four Nb resonators guiding for future project to replace all Pb resonators with Nb.

Vendors has been identified (TRIUMF and INFN) but project was cancelled due to lack of funds.
Surface treatment

tumbling
degreasing
Electropolishing copper substrate
Thin film coating laboratory

- PbSn plating
- high pressure rinsing
- GN$_2$ drying
Electroplating twin-stub resonator
Characterization of thin films

Energy Dispersive X-ray Spectroscopy PbSn film

EBSD 0.3 μ PbSn

SIMS PbSn film

X-ray Diffraction

ERDA PbSn film

RBS PbSn film

AFM PbSn film
Clean room assembly facilities class $\sim 500$

assembling SLR and module cryostat
Linac enhancement:
Implementation measurement of the time-structure of the beam from the Linac based on LiF2 detector and fast FC. Low beam intensity diagnostics with improved BPM
Beam time structure measurement

- LiF$_2$ scintillation detector SCIONIX, energy resolution at 662 keV < 11% FWHM
- ORTEC: Time to Amplitude Converter Single Channel Analyzer, Constant Fraction Discriminator; Expected time resolution 0.5 ns
Pulse width measurement

Pulse width of $^{58}\text{Ni}^{22}$ 160 MeV as a function of B1 voltage peak to peak

Rates vs Channel
High sensitivity BPM

- Bias improved sensitivity as factor of 2.5;
- further improvement by using thicker (~1 mm diam) scanner wire and fitting additional shield around collector.
Cryogenic system

Linac cryogenic system enhancement:
Addition of LN2 pre-cooling to the liquid He plant to boost its cryogenic capability by 20%
Announcement

ACAS collaboration between ANU, UM, ANSTO and AS has been launched on 13th July 2010

Conclusion

Facility Operation and Development Team is facing challenging tasks over the next 4 years.

Outlook

Education Investment Funding over the next 4 years will enhance computer control and data acquisition system, beam intensities and energies, 14UD accelerator, beam pulsing, AMS capabilities, Linac, beam-lines, RIB capability and Accelerator User Support
Motivated and skillful technical staff

Technical Staff:
A. Cooper, A. Muirhead, J. Bockwinkel,
A. Harding, G. Crook, T. Kitchen,
T. Tunningley, C. Gudu, L. Larioza

IT Staff:
D. Tsifacis, A. Grafton

EU Staff:
D. Gibson, D. Tempra,
D. Anderson, D. Kelly
T. Steele

Accelerator Director: Keith Fifield

Accelerator Guru: David Weisser