SUPERCONDUCTING RF ACTIVITIES AT ANU

Nikolai R. Lobanov[†], David C. Weisser, T. Kibédi, D. Anderson, A.K. Cooper, D. Gibson,
J. Heighway, A.G. Muirhead, R.B. Turkentine,
Department of Nuclear Physics, Research School of Physical Sciences and Engineering,
The Australian National University, Canberra ACT 0200 AUSTRALIA

Abstract

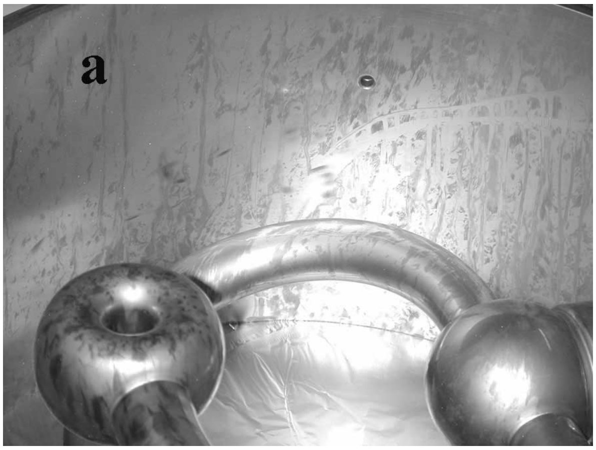
An upgrade of the LINAC at the ANU would rely upon the proven success of PbSn plating split loop resonators to perform at accelerating fields of 3.6 MV/m combined with 21, two and three stub resonators. The design features of the multi-stub resonators include a demountable stub assembly joint with acceptably low currents and adequate frequency splitting between the accelerating and other modes. Superconducting RF activity in the last two years has been targeted on improving performance of the ANU LINAC by re-plating the twelve; split loop resonators, SLRs. A prototype two-stub half wave resonator, HWR2, was manufactured with associated assembly hardware. Development work for HWRs is discussed. The upgrade of the LINAC cryogenic system is described.

1 INTRODUCTION

LINAC development work at ANU is currently aiming to improve performance and further expand the existing superconducting heavy-ion accelerator. ANU used methyl sulfonic acid, MSA, chemistry to re-plate resonators achieving an average accelerating field, E_a of 3.6 MV/m. The resonators had originally been plated before 1989 using lead fluoroborate and achieved average accelerating field of 1.7 MV/m. The LINAC upgrade proposes adding eight β=0.065 three-stub half wave resonators, HWR3s, three ASI SLRs, eight β=0.1 two-stub half wave resonators, HWR2s, and four β=0.15 HWR2s. The design features of the multi-stub resonators include a demountable stub assembly employing an RF gasket with acceptably low currents [1,2] and therefore, losses. The fabrication of resonators is greatly simplified by eliminating electron beam welding or vacuum brazing. All cavities for the ANU LINAC operate at 150 MHz. The new geometries are consistent with lead plating onto copper substrates and, perhaps, with Nb sputtering. The upgraded cryogenic system has sufficient capacity to service future cryostats. With a nominal 6 Watts RF load in each of the 11 resonators installed in 5 cryostats, there is about 180 Watts excess cooling capacity. The cooling power can be further increased with liquid nitrogen pre-cooling to the cold box. This is yet to be exercised.

2 RE-PLATING ANU LINAC

Prior to re-plating, four of nine resonators were found to have cracks in electron beam welds at the base of the stem that supports the split ring. The 60%Sn, 40%Pb solder, with melting temperature of 180°C, was used to repair cracks. Layers of nickel and copper were brush-electroplated over the solder provided a convenient and economical crack repair for large RF currents. A detailed account of crack repair and plating technology is given elsewhere in this proceeding [3] and in [4]. The split loop resonator, R#310, before and after re-plating is shown in Figure 1.



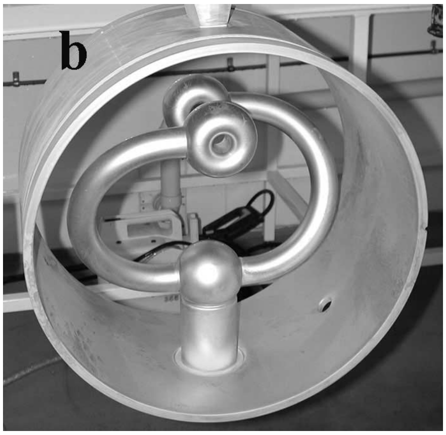


Figure 1: SLR R#310 opened the first time for inspection in March 2001 (a) and re-plated in May 2001 (b).

Recently, six SLRs in two ASI module cryostats were installed in the ANU LINAC. The average accelerating field was 3.6 MV/m at 6 Watts and the best resonator performed at 3.8 MV/m. Improved understanding of lead plated superconducting films, evidenced by the satisfactory performance of the SLRs, encourages the

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[†] Nikolai.Lobanov@anu.edu.au

expectation that this technology can lead to successful fabrication of HWRs for the LINAC.

3 ANU LINAC UPGRADE USING MULTI-STUB RESONATORS

A proposal has been prepared to upgrade LINAC at ANU relying upon the success of PbSn plated SLRs to be combined with 21 two and three stub resonators using demountable stub assembly joints. The demountable joints in the multi-stub resonators, eliminates the need for electron beam welding or brazing. The same RF electronics components will be used since the entire LINAC will continue to operate at 150 MHz. With this approach, all the technologies required to implement the project are available at ANU immediately.

The present LINAC configuration is shown in Figure 2. The LINAC comprises nine β=0.1, SLRs, with average accelerating field of 1.7 MV/m, housed in three ASI module cryostats, labeled "A". Before entering the LINAC, the beam is super-bunched, employing a superconducting quarter wave resonator, QWR, "E". The accelerated beam traverses an 180° achromat and is then directed along an as yet unpopulated. On this line, a similar QWR, "F", is used as the Time-Energy Lens, which either re-bunches or energy-homogenizes the beam. The next stage of development will include re-plating all 12 SLRs and adding another module cryostat adjacent to the existing ones.

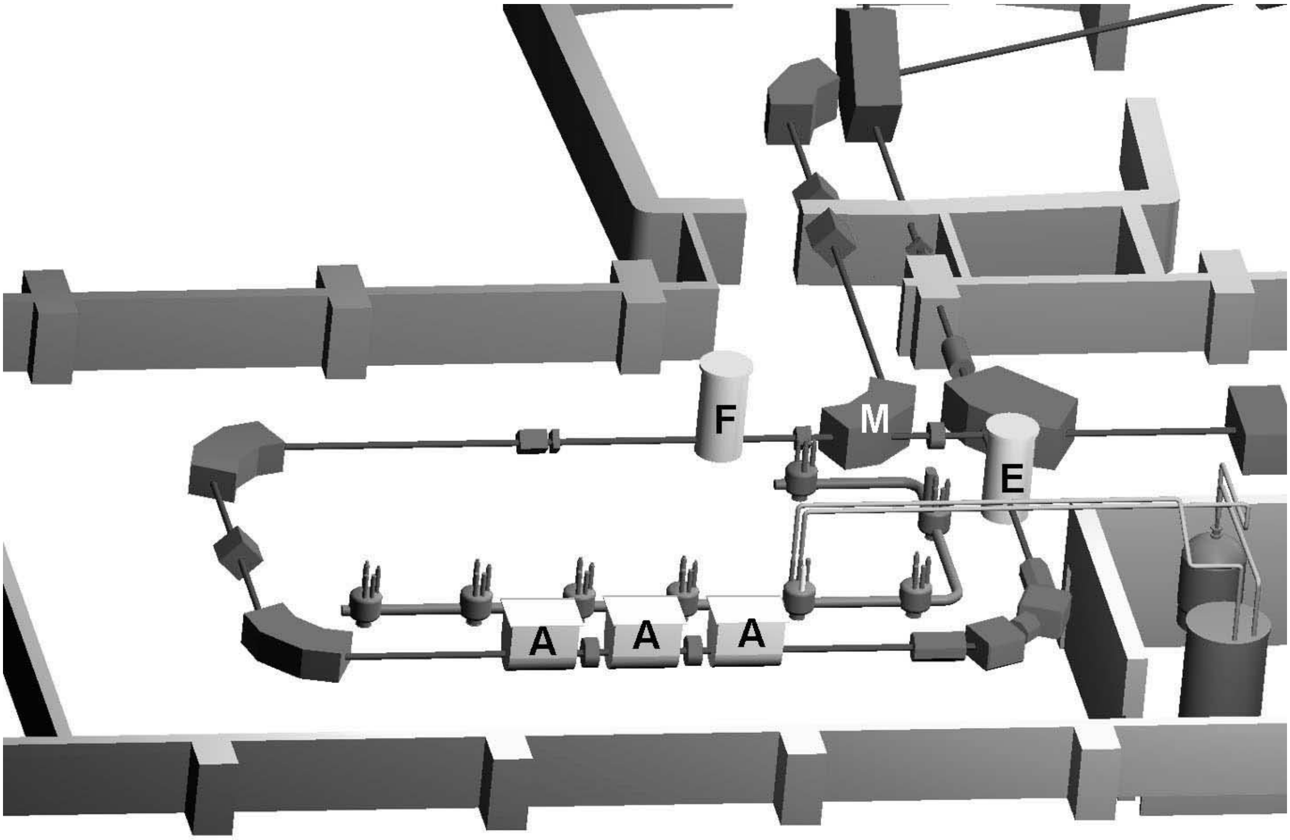

Figure 2: The ANU heavy-ion accelerator facility. A: 3xSLR, β=0.10; E: 1xQWR, β=0.09; F: 1xQWR, β=0.09.

Figure 3 shows the fully developed LINAC. The beam will first traverse the buncher that will be a beta 0.1, HWR2, "E". Then it will proceed to two cylindrical cryostats, each housing four β=0.065, HWR3s, "B". The cryostats are similar to those designed at the Weizmann Institute and manufactured by Janis Co. [5]. The previously unpopulated beam line will accommodate an existing ASI module cryostat containing three β=0.1, lead-plated SLRs, "A". This beam line will also contain three Janis-like cryostats, the first two housing four β=0.1, HWR2s each, "C", and the third one with four β=0.15, HWR2s, "D". The complete system is designed to provide 6 MeV/amu, ^{107}Ag. The beam will be gas stripped in the terminal of the 14UD and then foil stripped at the entrance to the LINAC. Employment of a LINAC foil stripper allows the 180° achromat (ME/Q^2=123) to transmit beams with Mass up to 200 amu. The only new beam optics component required is a large bore rebuncher, “G”, in the middle of the 180^{o} achromat needed to reduce the bunch time spread due to the long drift space. The Time-Energy Lens, TEL, also upgraded to a HWR2, “F”, will be relocated to just before the switching magnet servicing the LINAC hall. While this location of the TEL will provide full energy beams pulsed to the LINAC hall, beams returned to the 14UD target area will be of lower energy. The last resonator in cryostat “D”, before the return 90^{o} magnet, “M”, will serve as the energy homogenizer but require many of the preceding resonators to be turned off to provide adequate drift space.

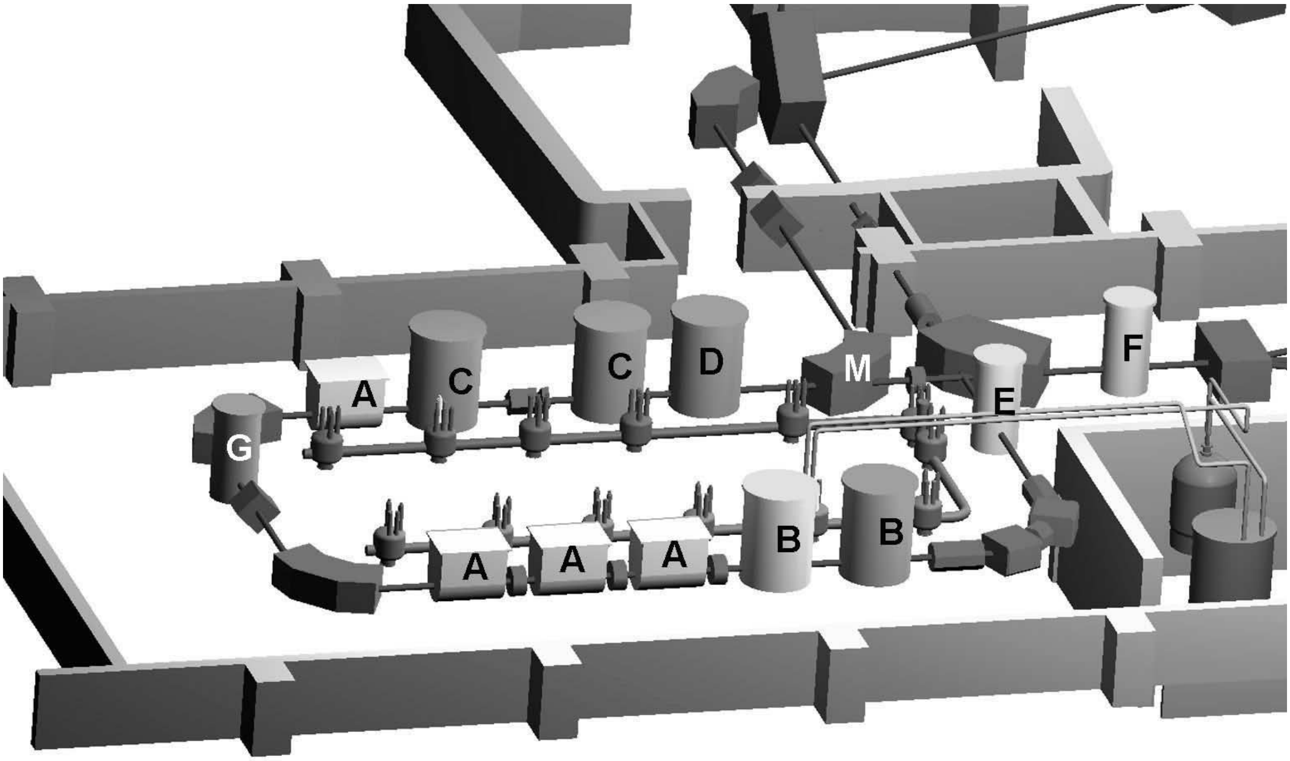

Figure 3: The fully developed LINAC. A: 3xSLR, β=0.10; B: 4xHWR3, β=0.065; C: 4xHWR2, β=0.1; D: 4xHWR2, β=0.15; E: 1xHWR2, β=0.10; F: 1xHWR2, β=0.10; G: 1xQWR.

4 PROGRESS IN MULTI-STUB RESONATORS MODELING

A set of expressions for the electromagnetic properties of low velocity accelerating structures, based on quarter-wavelength resonant lines [6], was used to derive electromagnetic properties of HWRs as described in [2]. The geometry of the electrodes that the beam traverses was developed with a help of Superfish/Poisson software. Aluminium models of the two and three stub designs have been built and optimized for frequency tuning, splitting between accelerating and other modes as well as minimizing the current in the demountable joints. Copper prototypes (Figure 4) have been constructed and are being prepared for plating with PbSn for cold testing. Sputter coating with Nb will be tested in the future.

Temperature and mechanical characteristics of HWRs were simulated using finite element software Pro/Engineer. A detailed account of thermal and structural modeling of HWRs is given elsewhere in this proceeding [7]. Figure 5a illustrates the variation in the temperature profile at 6 Watts absorbed RF power and Figure 5b shows the lowest mode of mechanical vibration of the HWR3.

Figure 4: Copper prototype for β=0.1 150 MHz HWR2 utilizing two RF demountable joints.

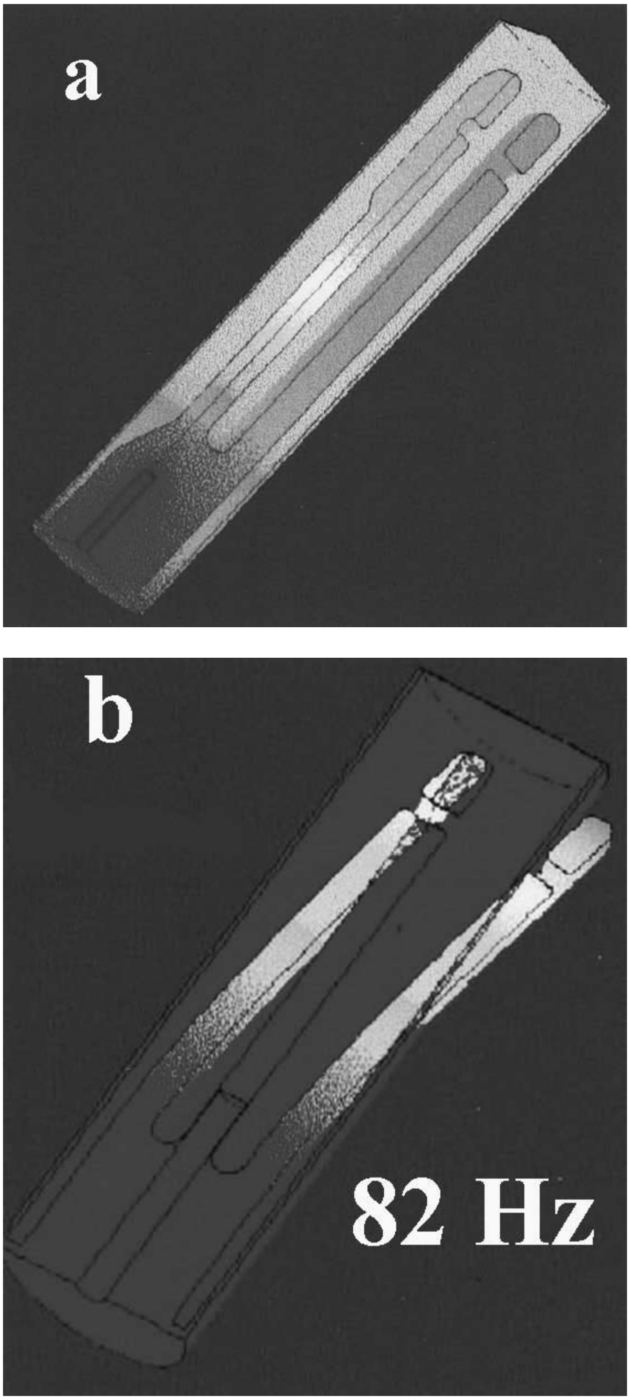

Figure 5: One quarter of the model cut along the symmetry planes is shown; a) the temperature profile and b), the lowest vibrational mode of the HWR3.

The model shows components on one side of each symmetry plane of the three-stub resonator. Thus an outside stub and one half of the center stub are illustrated. This design had a mode one frequency of 82 Hz and a maximum temperature of 4.46 K. Increasing the thickness of the stubs should reduce the vibration response of the resonators beyond this already acceptable level.

5 LINAC CRYOGENIC SYSTEM UPGRADE

A Linde/Sultzer, TCF50 refrigerator/liquifier that incorporates a SattCon 31-10 process controller, provides the liquid helium. After a number of years in service, the process controller [8], had reached it limits. It was originally designed to control only the cold box, which is how it was used in the Daresbury Laboratory from 1987 to 1993. At the ANU, it was recognized that a single processor should supervise the production and distribution of all cryogens. This approach was gradually implemented over the last 6 years, but because of the limited capacity of the SattCon 31-10, some input/output as well as controlling functions were delegated to a VME crate connected to a dedicated VAX computer. The stable operation of the cryogenic plant was dependent on the link between these computers, and each has a rather different operating environment. The load of the SattCon 31-10 PLC was 95-97%, far more than the recommended maximum of 80%.

Based on our positive experience with SattCon and the fact that all existing input/output boards could be re-used, it was decided to upgrade the system rather than replace it. The new SattCon 200 central processor, ABB Automation Products AB (Sweden), is about 20 times faster, has a much larger storage capacity and a more advanced operating system. With the newly installed cards, it features 64 digital input, 64 digital output, 40 analogue input, and 24 analogue output channels. This allows access to all instrumentation on the cold box, distribution line and 5 cryostats and is capable of further LINAC expansion.

The application software for the SattCon 200 has been developed using the DOX10 programming tool, which runs on a PC and communicates with the process logic controller, PLC, either through a serial port or TCP/IP network. Major modifications have been made in the application software, allowing the cooling down of the cryogenic plant without any operator assistance. The operator console is a terminal emulator program, running on a PC, which updates parameters in every 2.5 seconds. This PC, located next to the liquefier, can be accessed either via the TCP/IP network, or via a dedicated modem line, allowing remote monitoring and control. The new layout is shown in Figure 6.

The SattCon 200 was tested during several short runs. The initial cool down was completed in about 60 hours, compared to 72 hours for the previous manual system. The pressure stability of the system, a crucial factor to the frequency stability of the resonators [2], is now better than ±5 mbar, an improvement of a factor of 2-3. The new system has sufficient resources to service future cryostats. With a nominal 6 Watts RF load in each of the 11 resonators installed in 5 cryostats, there is about 180 Watts excess cooling capacity. The cooling power can be further increased by 100 W with liquid nitrogen pre-cooling to the cold box. This is yet to be implemented.

The operator functions will be greatly enhanced with the future development of a human-machine interface application, using the SattGraph 5000 software. This open system architecture employs modern graphical interaction techniques to provide easy to understand operator interactions. It also has a facility to generate various historical records, which is very useful for reviewing the operation of the system, identifying instabilities and problems.

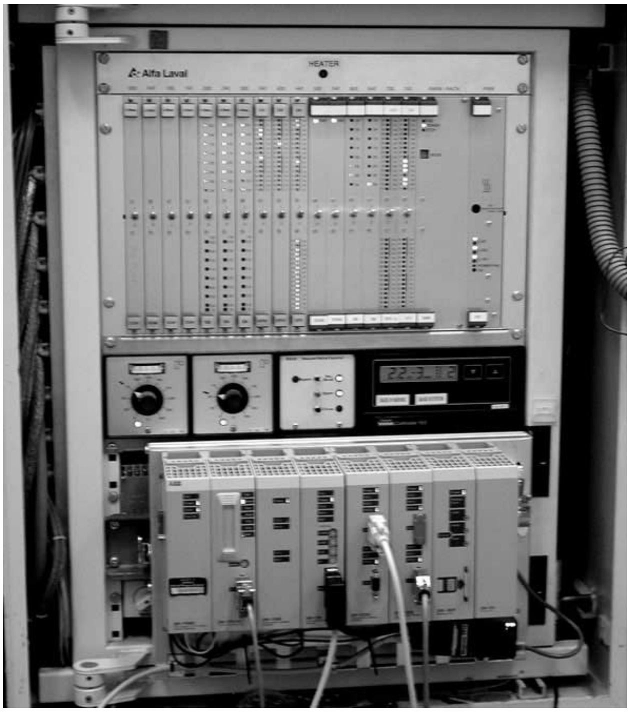

Figure 6: The new SattCon 200.

6 CONCLUSIONS

A road map has been drawn for the continuing upgrade of the ANU LINAC. It will exploit either proven PbSn plating or Nb sputtering and multi-stub resonators. The PbSn plating chemistry, which provides 3.6 MV/m in SLRs, needs to be demonstrated in HWRs and Nb sputtering of these complex shapes explored. Measured characteristics for three-stub and two-stub HWRs encourage their use. To confirm cavity parameters, prototypes will be cold tested in early 2002. Other areas of LINAC infrastructure development include demonstrating that the cryogenic system has the capacity of to serve future cryostats and modernizing the vacuum instrumentation. The LINAC's modularity allows development as resources permit concurrent with the exploitation of its increasing capabilities for nuclear physics research.

7 ACKNOWLEDGEMENT

The authors sincerely thank their colleagues from Electronics and Mechanical Workshop of the Research School of Physical Sciences and Engineering, ANU for their enthusiasm and dedication on all stages of the project.

8 REFERENCES

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