Optimisation of SLED Cavities and Waveguide Network to Drive the Linac at the Australian Synchrotron

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Outline

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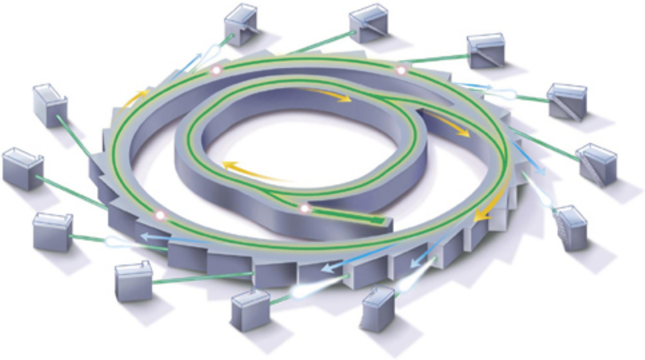


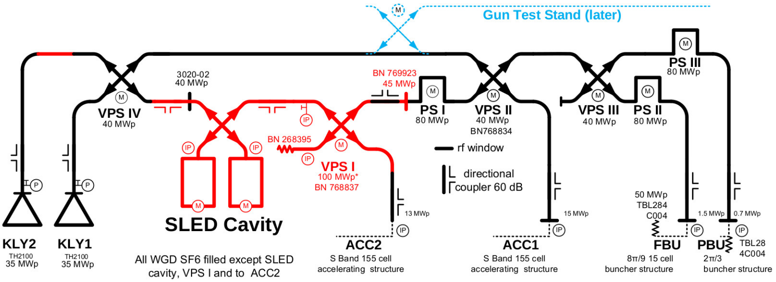
Australian Synchrotron

- 3 GeV Synchrotron Light Source.
- 100 MeV linac to 3 GeV Booster Synchrotron.
- Deliver $> 99\%$ of scheduled beam.
- Storage Ring contains 200 mA for user beam.

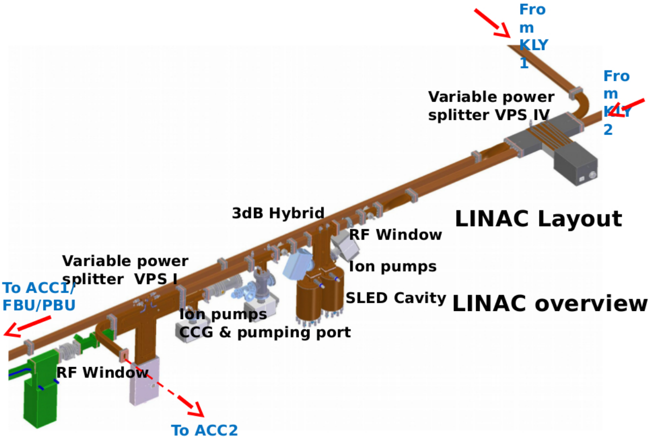
Motivation

Operations: Ageing equipment is prone to faults. A SLED system will allow the linac to run with a single klystron.
Research: Generation of electrons over a range of energies. Aims for an extraction line.

SLED Upgrade to Linac



SLED Upgrade to Linac

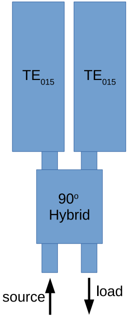


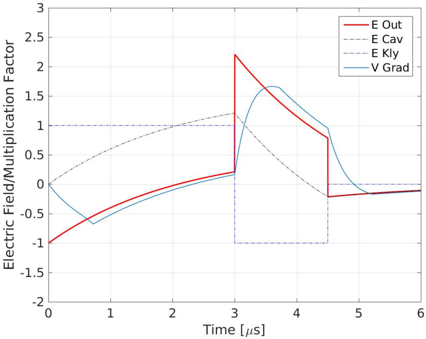
SLED Upgrade to Linac

- An extra variable power splitter VPS I, suitable for vacuum compared to SF6 and a higher peak power level, was added while reusing existing VPS IV as a switch to select either klystron I, II or both.
- The LINAC vacuum section was extended into the waveguide and an extra RF window placed downstream VPS I to reduce the power level and risk of failure.
- The new design will allow to select remotely two operation modes:
  1. with the SLED and klystron I or II; or
  2. operation with two klystrons and a detuned SLED.

SLED Cavities

$$E_O = E_C - E_K \tag{1}$$





SLED Equations

The electric fields in the cavities are governed by the following formula:

$$T_c \frac{dE_c}{dt} + E_c = \alpha E_K \qquad (2)$$

$$\text{where } \alpha = \frac{2\beta}{\beta + 1}$$

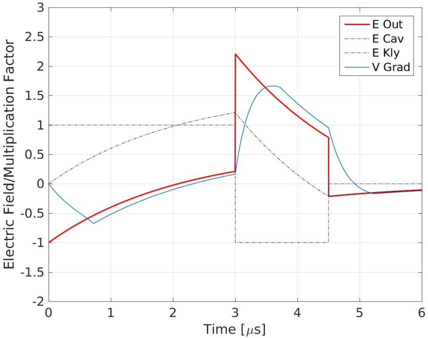
$$\text{and } T_c = \frac{2Q_0}{\omega(1 + \beta)}.$$

Calculations of the accelerating gradient from the electric fields is done by integrating over the structure length L.

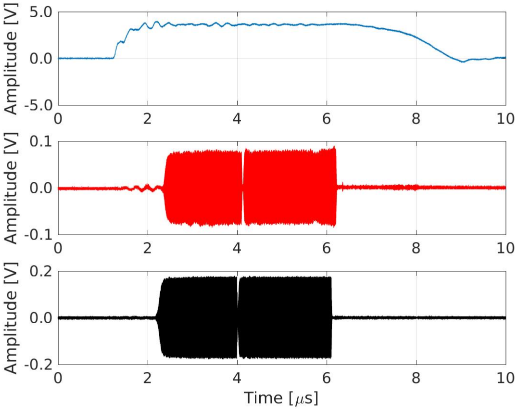
$$\Delta W = q \cos\phi \int_0^L E_a(z, t) dz \qquad (3)$$

Ideal SLED model (Farkas et al. 1974)

$$E_K = \begin{cases} 1 & t \leq t_{flip} \\ -1 & t_{flip} < t \leq t_{pulse} \\ 0 & t_{pulse} < t \end{cases}$$

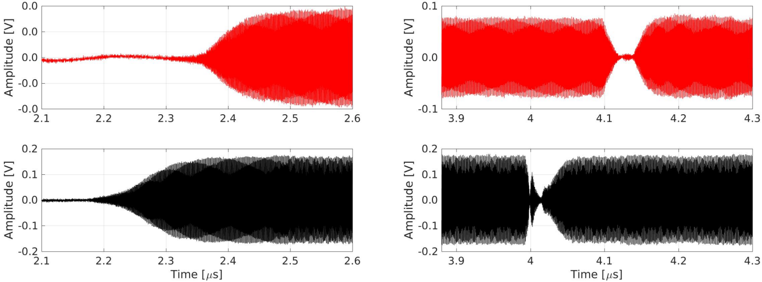


LLRF Testing



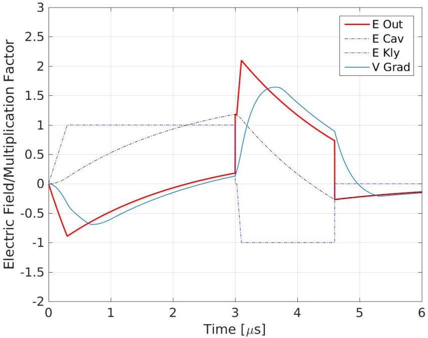
LLRF Testing

- Klystron Rise time $\approx$ 300 ns
- Flip time $\approx 50 - 100$ ns

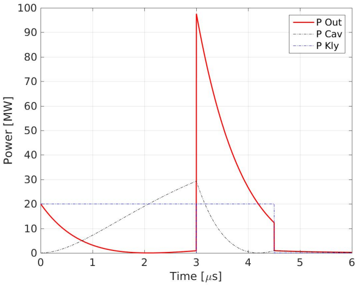


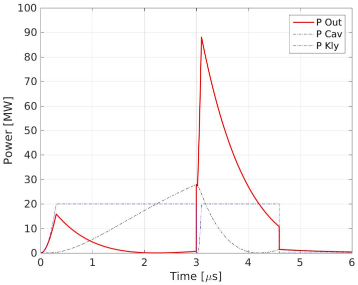
Realistic SLED model

$$E_K = \begin{cases} \frac{t}{t_{rise}} & t \leq t_{rise} \\ 1 & t_{rise} < t \leq t_{stop} \\ 0 & t_{stop} < t \leq t_{f1} \\ \frac{1}{t_f}(t_{f1} - t) & t_{f1} < t \leq t_{f2} \\ -1 & t_{f2} < t \leq t_{pulse} \\ 0 & t_{pulse} < t \end{cases}$$



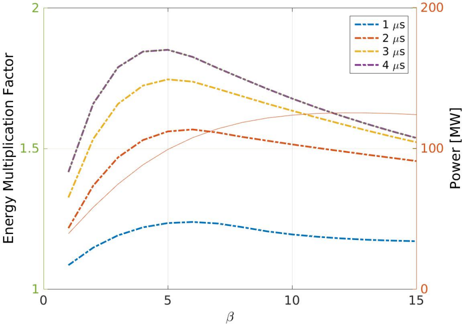
Power Output





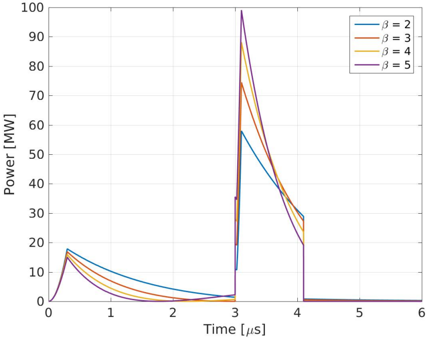
Beta Coupling Optimisation

- 100 MW limit on RF window for VPS I
- Charge time of $3\mu s$ would be used for general user beam.



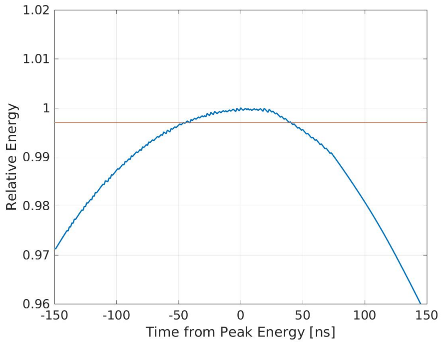
Beta Coupling Optimisation

- Lower beta reduces energy spread



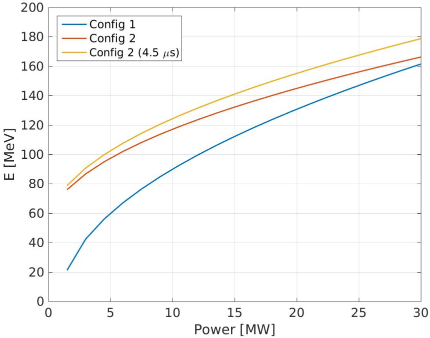
Energy Spread

- Low energy spread vital for booster ring.
- Trade off between high gradient and energy spread.



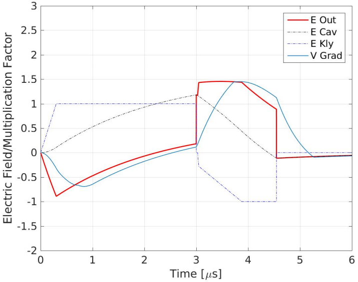
Beam Energy

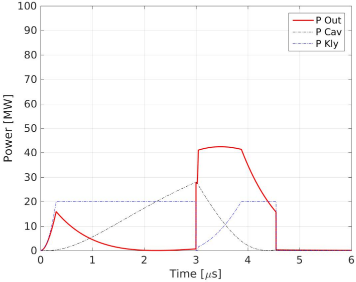
- Two Configurations:
  1. Single klystron + SLED → All Structures.
  2. Klystron 1 at 17 MW → PBU, FBU and ACC1 Klystron 2 + SLED → ACC2



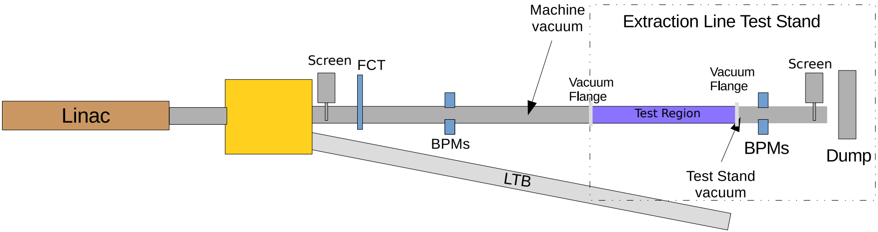
Phase Ramp

- Phase ramp allows for pulse flattening
- Phase slip over long structures.





Extraction Lines



Next Steps

- Installation in September
- Need to compare beam properties with and without the SLED. Optimising the energy spread and maximising the bunch train length.
- μTCA upgrade to the LLRF $\rightarrow$ RF monitoring and phase modulation.

Summary

- Using a realistic input the modelling has shown an optimal beta coupling of 5.
- Manufacturing the ports with smaller beta allows for less energy spread but can be increased later.
- A beam energy of 50-165 MeV electrons possible without changes to hardware.
- Bunch train length of 75 ns possible for MBM to be used for injection. Injection frequency doubles.

Thanks to...

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Questions?