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Drift Tube Linac Conditioning of Tank1

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Summary

Tank1 of the Drift Tube Linac (DTL) of the Linac4 has been conditioned at the Linac4 tunnel. The tank was tuned for resonance at 352.2 MHz, and stable operation has been achieved with 725 µs long RF pulses at a repetition rate of 1 Hz. The maximum RF level that has been reached is 810 kW with a pulse width of 600 µs. Since this was the first RF structure exclusively conditioned in the Linac4 tunnel with the operation and control software of Linac4, some related issues and limitations had to be taken into account.

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1 Introduction

Three Drift Tube Linac (DTL) tanks are being constructed to accelerate the Linac4 RF beam from 3 to 50 MeV. The first RF structure, DTL Tank1, has exclusively been conditioned at the Linac4 tunnel during the months of July and August 2014 and the results are presented in this report. The goal of conditioning was to achieve 700 kW peak power with 1000 μs pulse flat-top and final vacuum pressure of the order of 10^{-8} mbar.

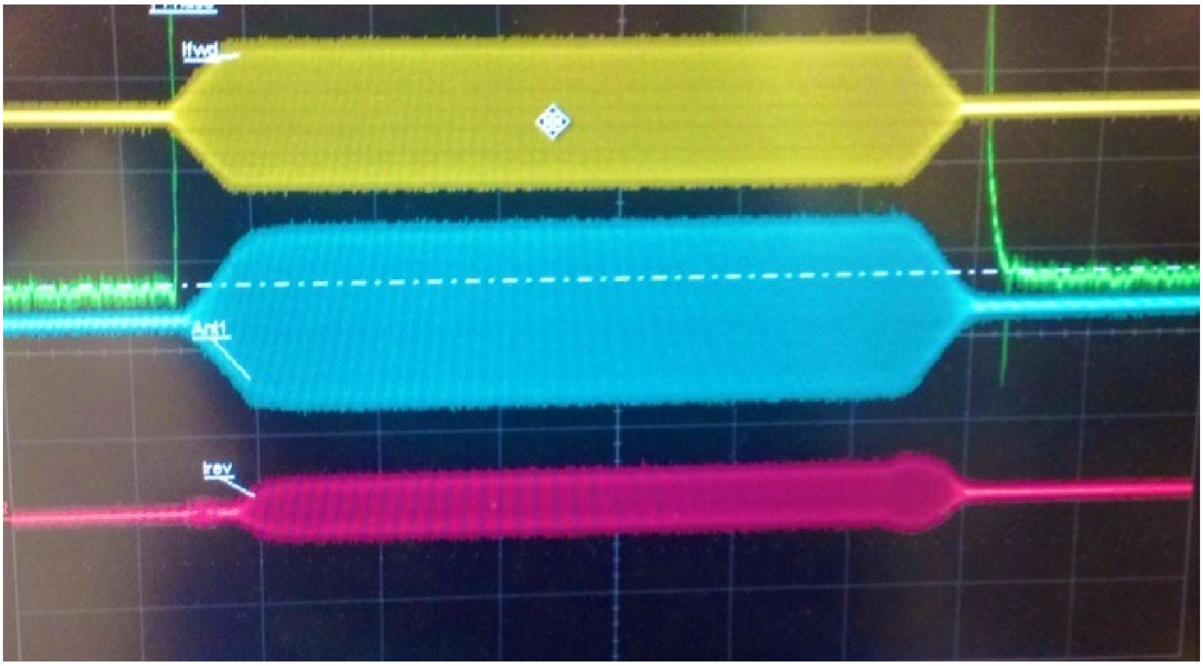

Figure 1 Captured image of RF pulses; blue is the signal from the pickup antenna, yellow is forward and red is reflected power.

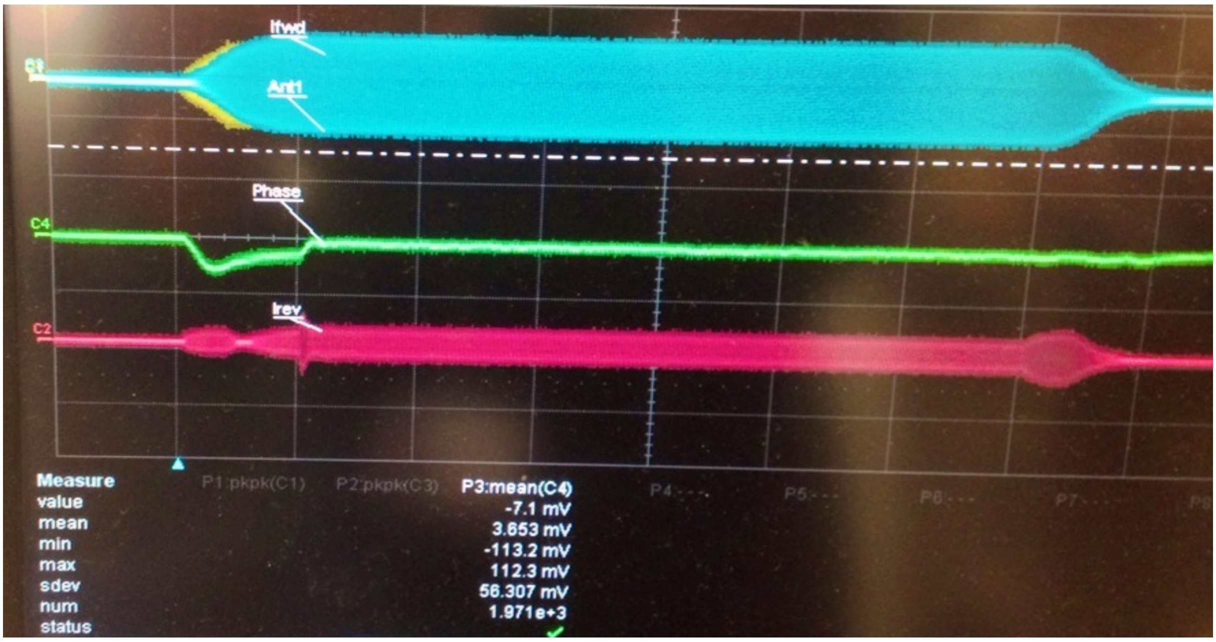

Figure 2 Captured image of RF pulses during close loop operation blue is the signal from the pickup antenna, yellow is forward, green is phase and red is reflected power

2 Conditioning History

The conditioning process of DTL Tank1 was monitored using an oscilloscope and the RF control system provides a special setup for conditioning in Linac4. The parameters such as RF forward power, reflected power, pick-up signals from two antennas, and the RF pulse width are monitored and logged manually while vacuum and other interlocks are taken care of by Linac4 control software.

Conditioning of DTL Tank1 started on 9th July 2014. Effective conditioning time was 286 hours. The total conditioning process can be divided into three phases. The first phase from 9th July 2014 to 18th July 2014 conditioning was done with RF pulses with a rise-time of 150 µs. In the second phase of conditioning rise-time for RF pulses was reduced to 50 µs which is the nominal rise-time during normal operation. In the third phase of conditioning from 29th July 2014, the tuner of the power coupler was exchanged in order to adjust the coupling factor.

Note that the reference level in dB corresponds to approximately 1 MW (±~10%) in the cavity (see Table 1).

Table 1 Klystron output power measured between klystron and circulator

−1 dB	810 kW
−2 dB	682 kW
−3 dB	565 kW
−6 dB	290 kW

2.1 Phase 1 (RF pulse rise-time 150 µs)

The first conditioning phase of 102 hours was done with an RF pulse rise-time of 150 µs. The maximum stable RF level of 682 kW (−2 dB) with pulse widths of 500 µs was attained.

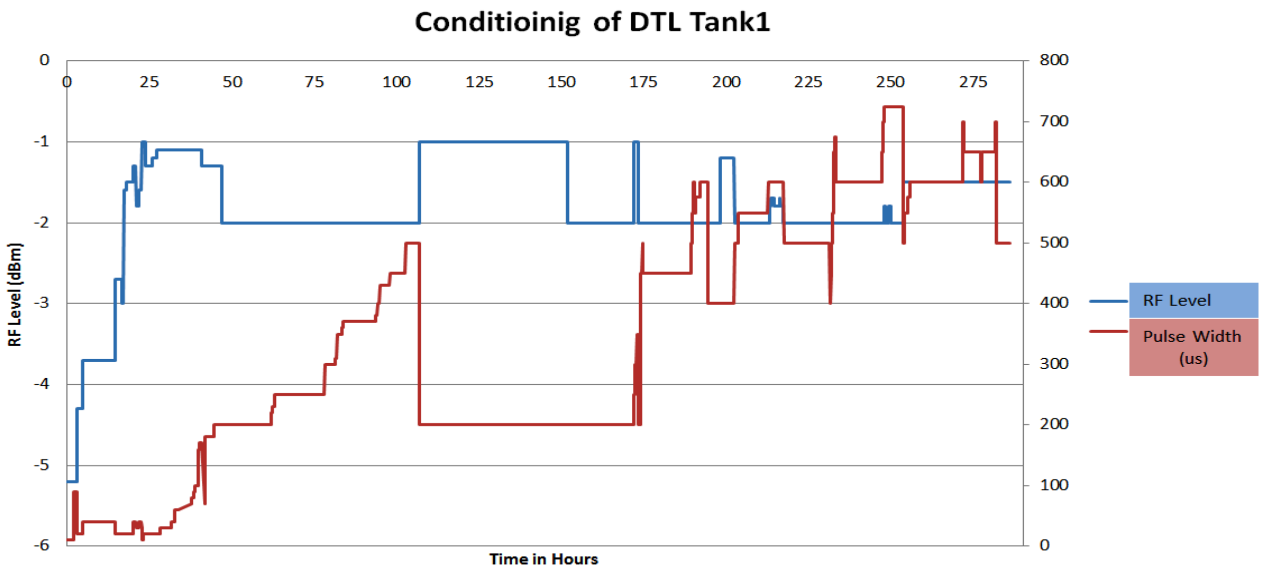

Figure 3 Conditioning history of DTL Tank1

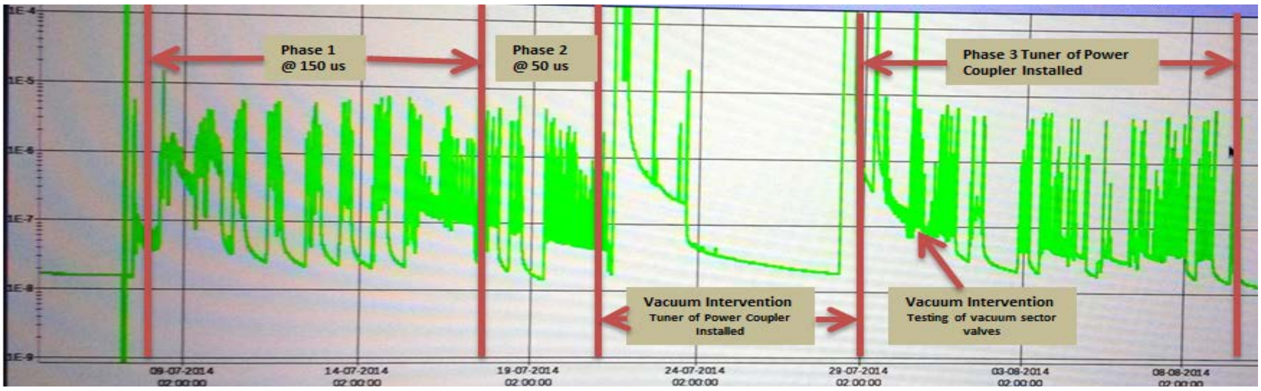

Figure 4 Captured image of vacuum history during conditioning process including off times

As shown in Figure 1, at the start Tank1 was pushed to high power levels with very short pulse widths of 10 to 20 µs while the vacuum was monitored manually. The vacuum interlock is set at $5 \cdot 10^{-8}$ mbar. It was noted that with higher power levels it was not possible to push the pulse width beyond 200 µs due to frequent vacuum interlocks. So after 46 hours of effective conditioning the power level was reduced to -2 dB and pulse width was increased and stable operation with vacuum level $\sim 7.8 \cdot 10^{-8}$ mbar was attained with 500 µs pulse width after 102 hours of conditioning. Listed below are the significant events, which occurred during this phase in chronological order.

- Around 35-40 h: The tunnel was set to special access to modify water interlocks and to move the radiation probe close to the high energy end cover. Disconnection of temporary test interlocks solved the problem of tripping from the temperature interlock.
- At the same time it was noted that the pulse width could not be increased beyond 280 µs flat top due to some limitation in the operation software.
- Around 60 h: The issue of pulse width limitation was resolved and the klystron was switched to low power levels -10 dB with a pulse width of 400 µs and then switched off for RF output power calibration and measurement.
- Around 100 h: RF pulse rise-time was reduced to 50 µs.

2.2 Phase 2 (RF pulse rise-time reduced to 50 µs)

Total conditioning time during this phase with reduced rise-time was around 52 hours. During this phase Tank1 was powered up at a -1 dB power level and 200 µs pulse width which was a requirement for beam operation. With the reduction in rise-time of the RF pulse, it was noted that the conditioning process became easier. Stable operation of around 45 hours with vacuum $\sim 5.8 \cdot 10^{-8}$ mbar was attained with -1 dB RF level and 200 µs pulse width.

- Around 152 hr: Klystron was switched off for intervention, so no conditioning for 8 days. During this intervention the tuner of the power coupler was installed.

2.3 Phase 3 (Tuner of power coupler was installed)

Total conditioning time during this phase was 132 hours. During this phase stable operation was attained with -1.5 dB and 600 µs pulse width with a vacuum level $\sim 3.3 \cdot 10^{-8}$mbar. Since the tuner of the power coupler was installed during the intervention the coupling factor changed from ~2.2 to 1.8 changing the RF power level in the DTL tank at constant forward power. Maximum pulse width attained was 725 µs close to a firmware limitation of the control cirucuits. Listed below are the significant events, which occurred during this phase in chronological order.

- Around 155-160 hr: Frequency was changed to 352.235 MHz manually. The power setting in the DTL Tank1 was -10 dB and 200 µs while the vacuum was improving.

Breakdowns appeared to be at the power coupler. The situation improved after around five hours of conditioning and at higher RF levels.

- Around 170-175 h: There was a vacuum intervention to test the vacuum sector valves and the adjustment of movable tuners to shift the frequency back to 352.2 MHz.
- Around 190 h: It was found that the pulse width could not be increased beyond 600 μs again due to some limitation in the control software. Stable operation was attained with −2 dB and 600 μs with vacuum $\sim 8.2 \cdot 10^{-8}$ mbar.
- Around 231 h: The conditioning was stopped for beam operation of Linac4 for three days. Stable operation was attained at a −2 dB power level and 600 μs pulse width with vacuum $\sim 4.3 \cdot 10^{-8}$ mbar.
- Around 247 h: It was found that the pulse width could not be increased beyond 725 μs due to a firmware limitation that will be solved at the next firmware upgrade foreseen in a few months time.
- Around 275 h: The klystron tripped on the vacuum interlock and there was no RF power in Tank1 for around seventeen hours. This helped to improve the vacuum to $1.1 \cdot 10^{-8}$ mbar.
- Around 280-285 h: There were concentrated breakdowns. The system was again switched to closed loop for beam operation.

3 Summary

DTL Tank1 has been successfully conditioned at the Linac4 tunnel in the conditioning setup of the operation and control software of Linac4. Effective conditioning time for DTL Tank1 was 286 hours. This was the first module exclusively conditioned at the Linac4 tunnel, and several issues like the pulse width, the rise-time, the calibration of the RF output power of the klystron were resolved during the conditioning period.