UPPSALA UNIVERSITET

Experience from the RF testing at FREIA

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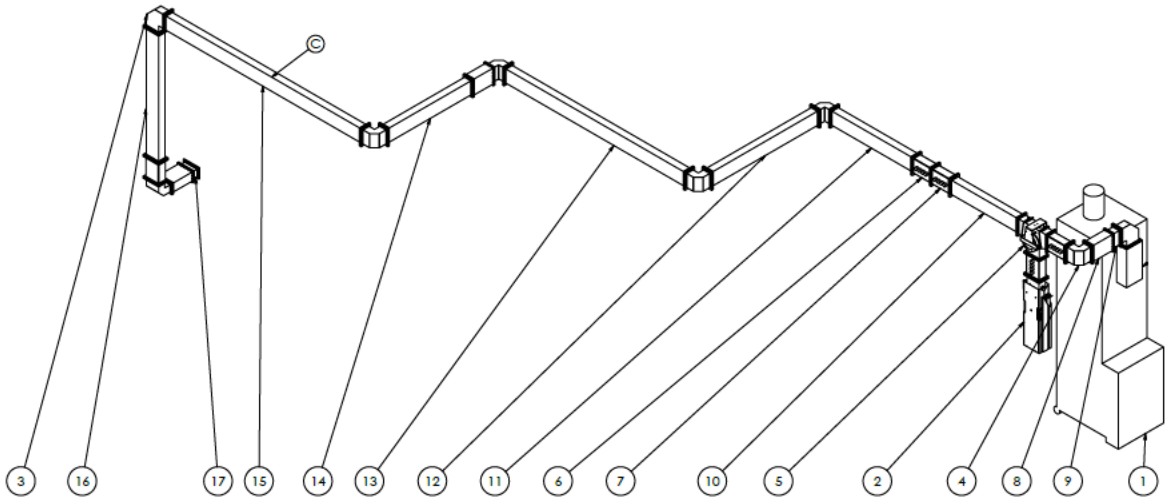
Outline

- 704 MHz RF Overview
- Klystron Overview
- Waveguide Distribution
- Klystron Modulators
- Circulator & Load Behaviour
- Conclusions

RF Distribution Overview



Prototype RF Line

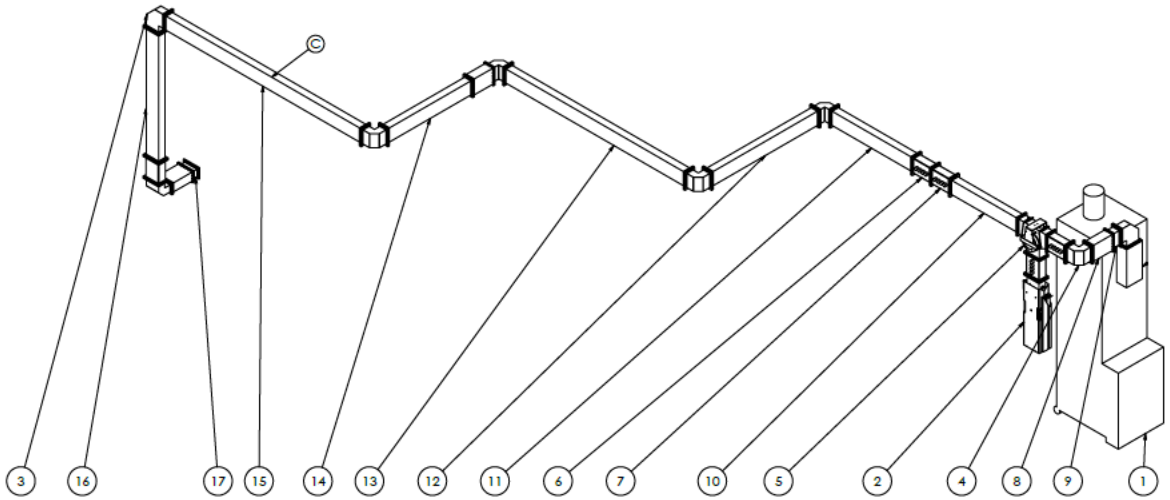
1) Prototype Modulator - Tested
2) Prototype Klystron – Semi-Tested
3) Prototype Control – Semi-Tested
4) Prototype Circulator - Untested
5) Prototype Load - Untested

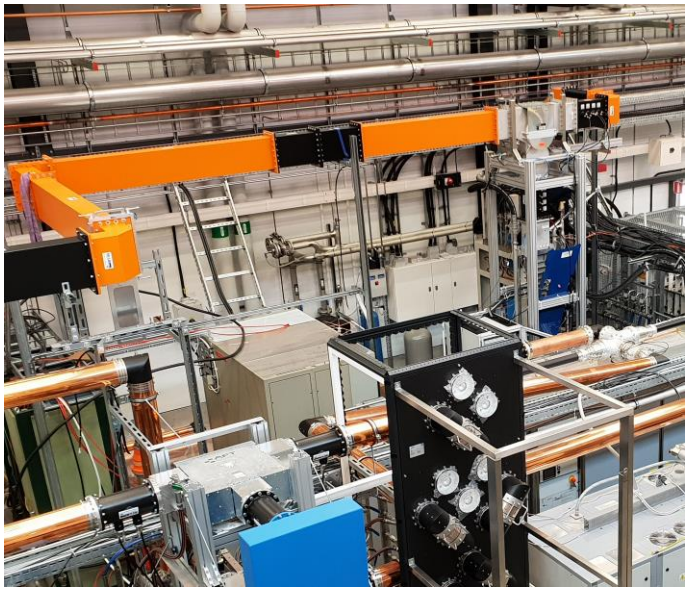
Klystron Overview

Toshiba 704 MHz Prototype Klystron

1) First Commissioned + Tested In Lund
2) Suffered Arcing in Lund, repaired and sent here
3) 1.5 MW at 3.5 ms 14 Hz
4) Delays in getting operational due to facilitating 2 modulators & 2 control systems
5) Commissioned on-site up to 1 MW due to limitations set by RF load
6) All operational parameters correspond well with the Toshiba FAT

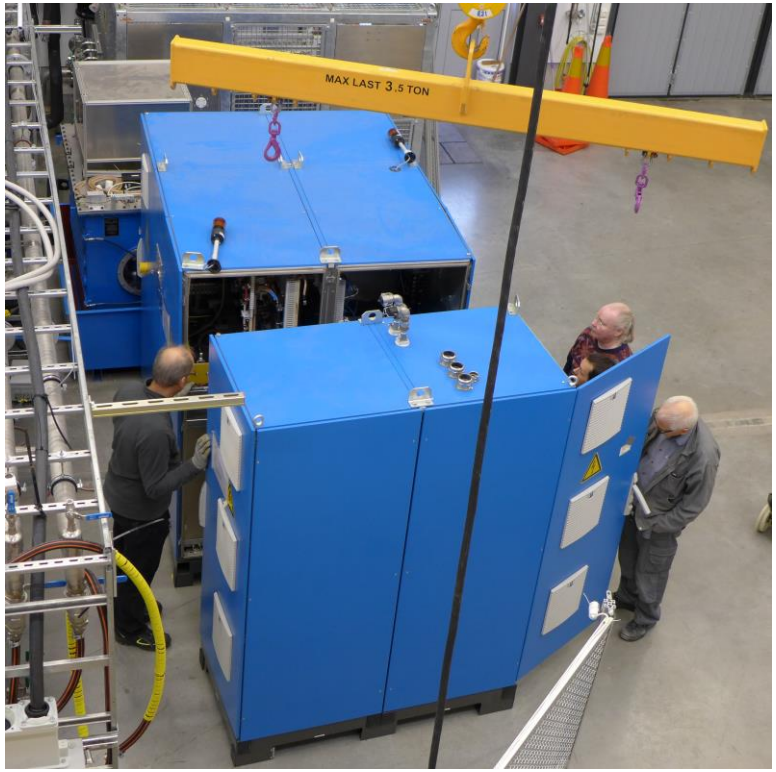
Waveguide Distribution





1) Standard Mega-Ind waveguides
2) H-bend straight after the output of the klystron
3) Very limited changes on guide electrical length
4) Support provided to easy removal of individual parts

Modulators



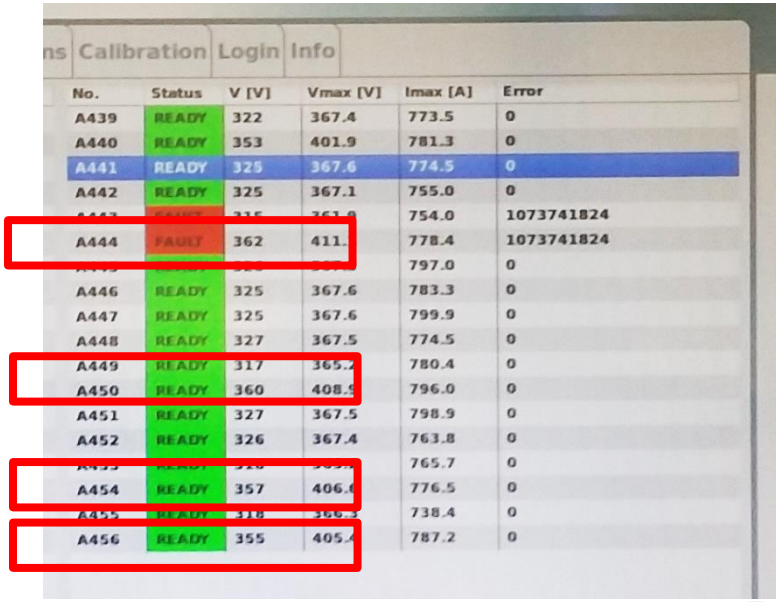
PPT Ampegon Modulator

2.8 ms at 14 Hz
Single Klystron

Ampegon Modulator

3.5 ms at 14 Hz
Dual Klystrons

Modulators



Ampegon Incident

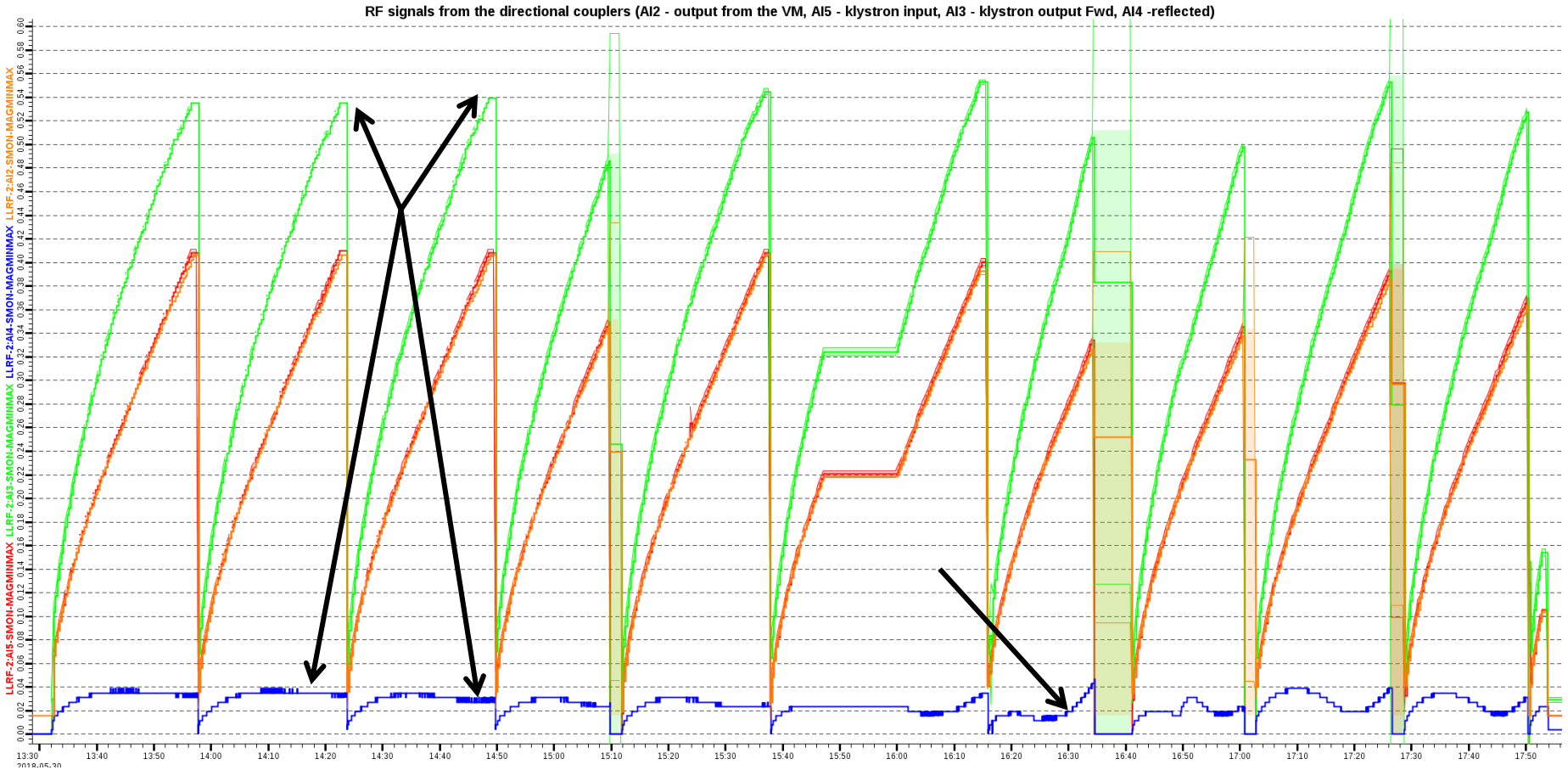
1) Lost one high-voltage module
2) Several modules were showing unusually high ripple
3) Destroyed at 90 kV

704 MHz Ferrite Circulator

Ferrite brand circulator designed for 14 Hz, 3.5 ms, 1.5 MW

1) Running unregulated-tuning due to short RF pulses
2) Required dedicated cooling system due to very high sensitivity of temperature
3) Variations in both cooling temperatures as well as internal temperatures directly affects the klystron gain
4) Example: Same input power with change in temperature causes output to drift from 300 to 380 kW, even though reflected power was always below the 5 kW interlock threshold
5) Experiences some thermal runaway

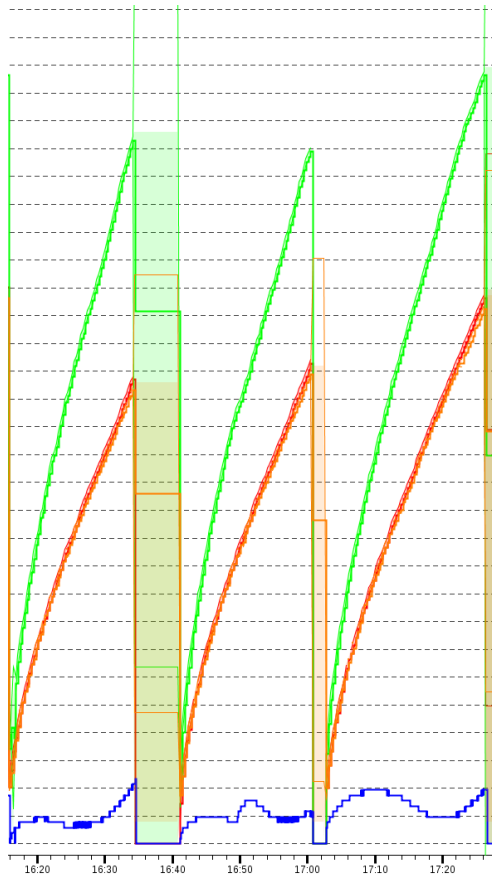
Circulator – Load-pull and thermal drift



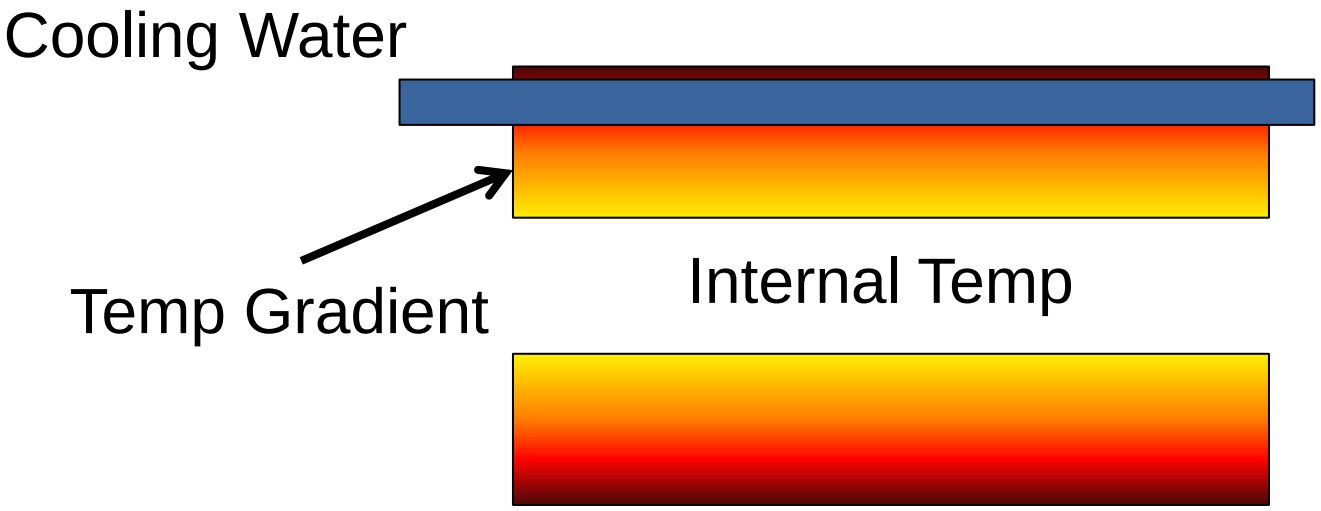
Ramping power to 1 MW with increase pulse length and rep-rate

Green Line: Klystron Output, Blue Line: Circulator Reflected Power

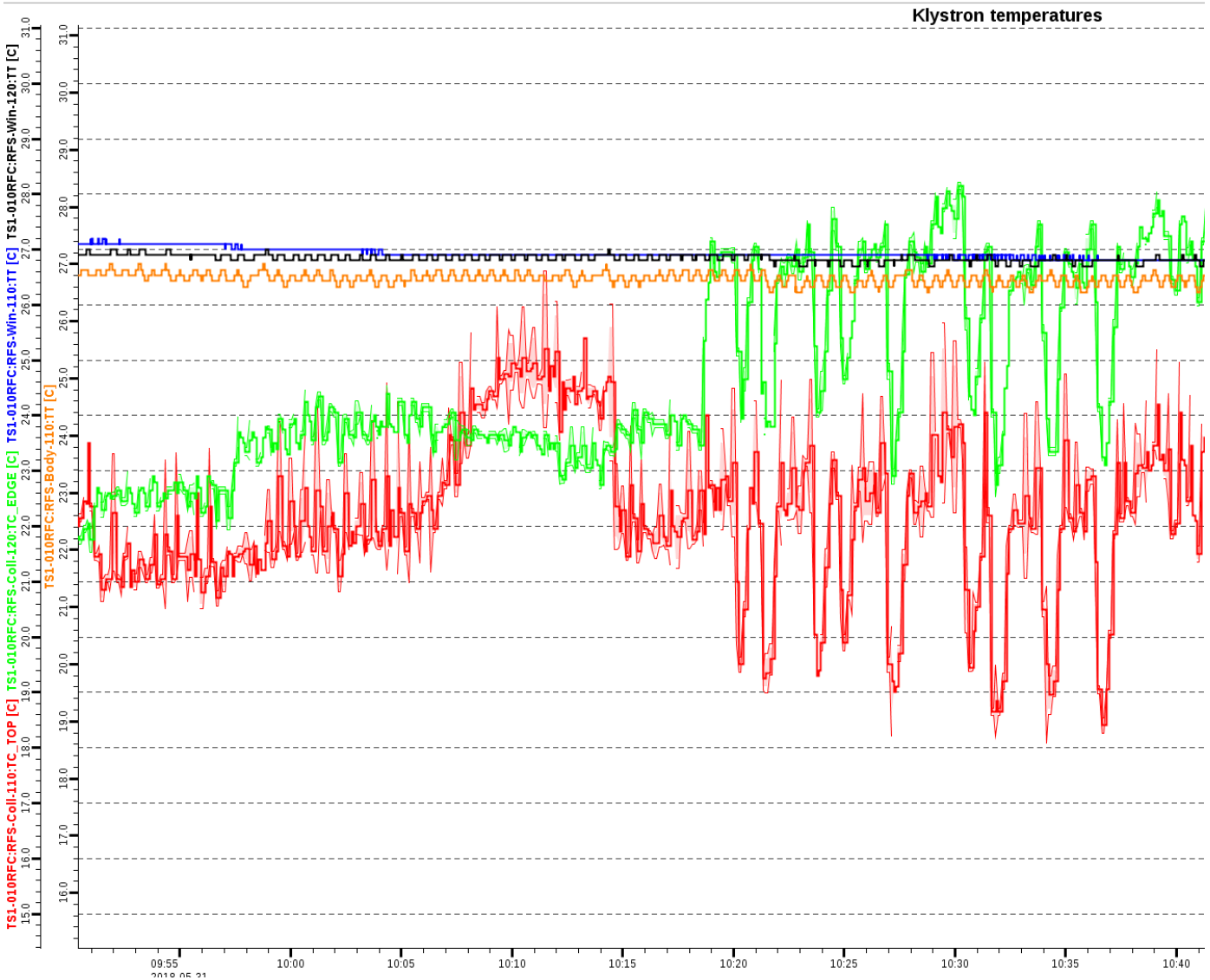
Circulator



1) At room-temperature it was not possible to use the electrical tuning
2) For adequate tuning at 27 degree cooling water the coil-bias current was at maximum
3) Currently regulating by cooling temperature control
4) Reflection can drift from -20 to -30 dB during start of pulse due to internal heating



Cooling

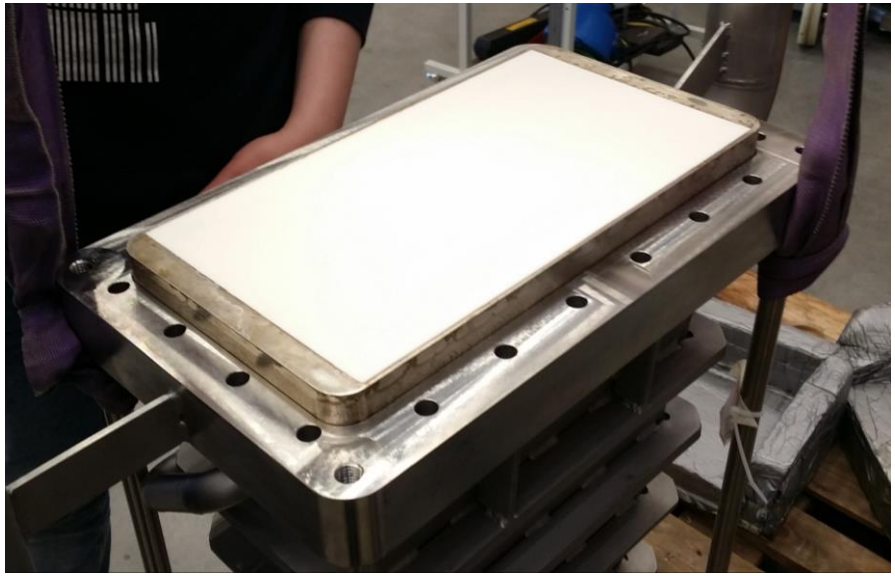

Klystron temperatures
TS1-010RFC:RFS-Coil-110:TC_TOP [C]
TS1-010RFC:RFS-Coil-120:TC_EDGE [C]
TS1-010RFC:RFS-Body-110:TT [C]
TS1-010RFC:RFS-Win-110:TT [C]
TS1-010RFC:RFS-Win-120:TT [C]
09:55
2018-05-31
10:00
10:05
10:10
10:15
10:20
10:25
10:30
10:35
10:40

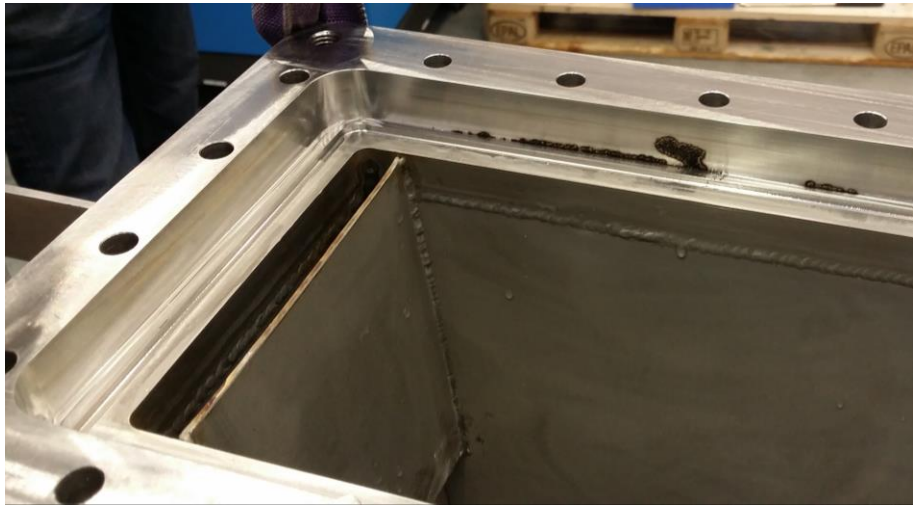
Thales 704 MHz Load

Thales 704 MHz Load for 3.5 ms 1.5 MW

1) Water-based load
2) Designed for both “hot” and cold cooling water
3) Damage due to internal arcing
4) Repaired and tested to 1 MW
5) Still exhibits occasional arcing at high average power

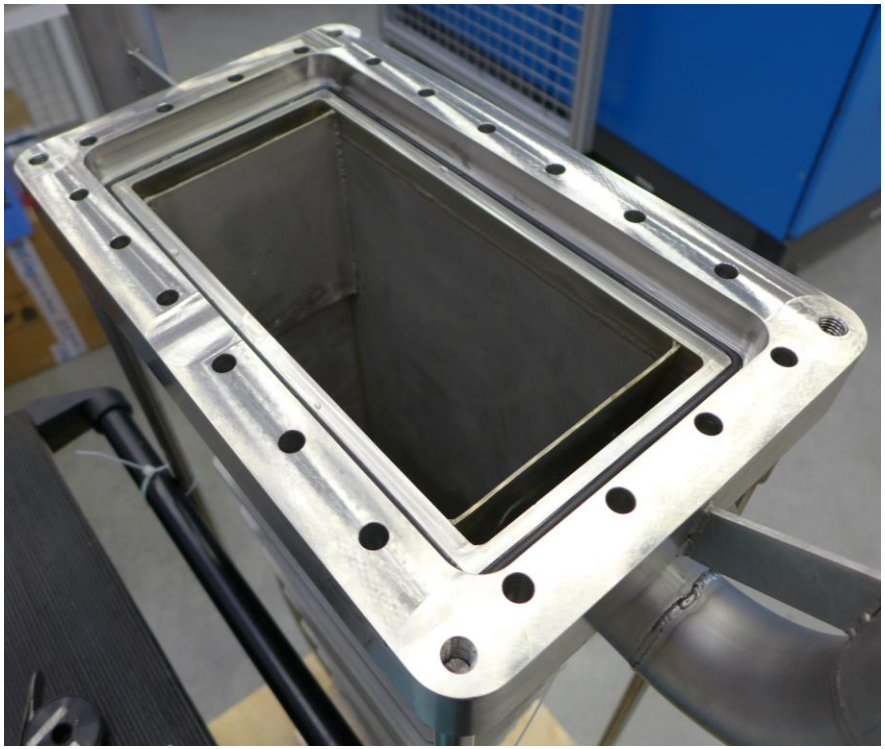
704 MHz Load - Arcing

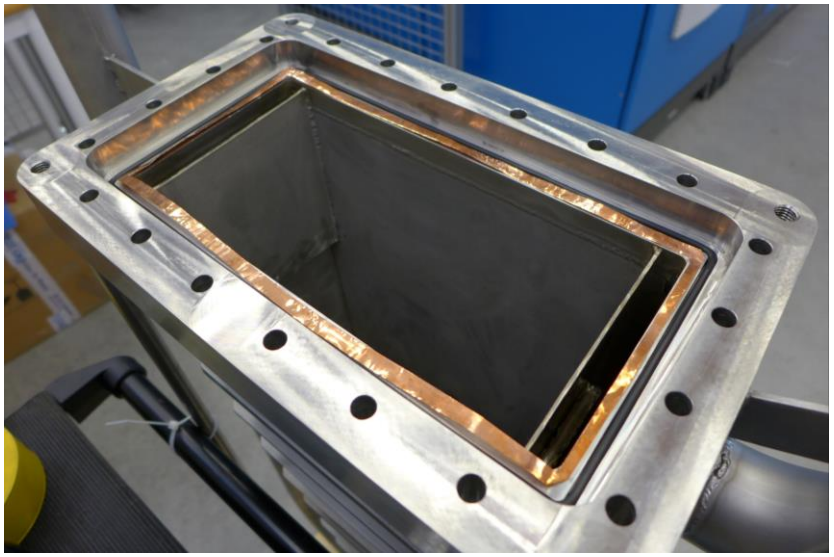




1) Sustational arcing around ceramic window due to uneven quality of window
2) Was not intended ceramic window, shipping was pressed due to time

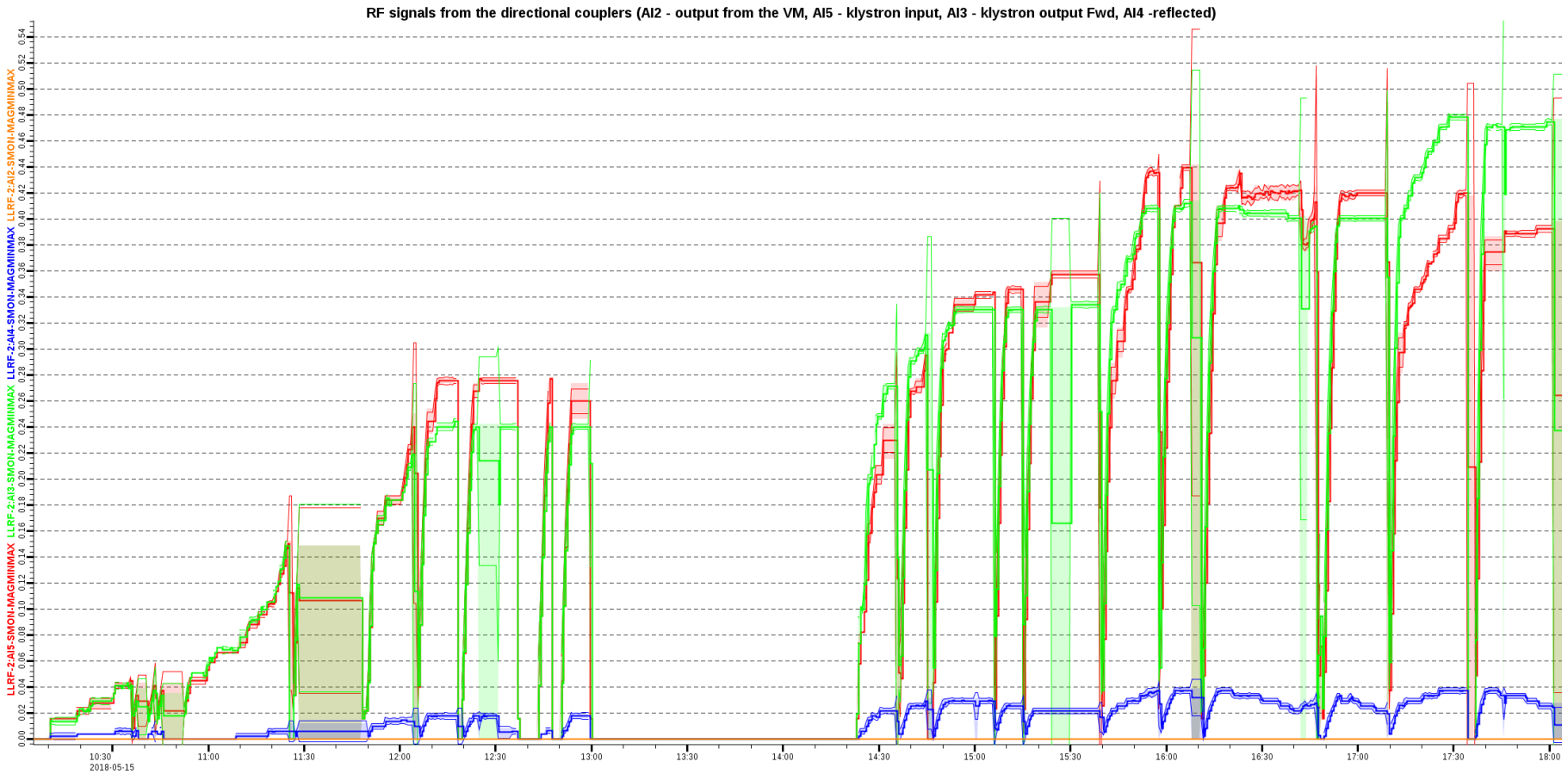
704 MHz Load





Temporary repair while waiting for final solution. Copper lower gasket and upper wire gasket.

704 MHz Load

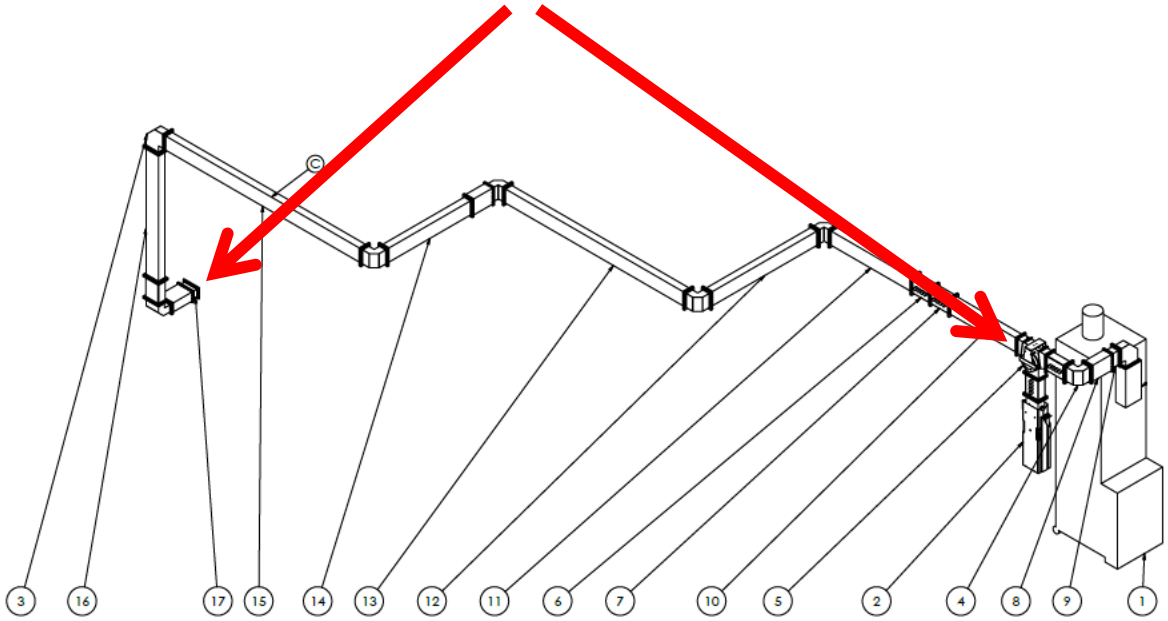


Load was gradually pushed up to 1 MW while also retightening the flange. Some initial smaller arcs but then stable. Still considered a temporary fix.

Standing waves issues

Mismatch of circulator creates standing waves
No variable phase-shifters on this line

Also experiences about 0.5-0.7 dB of error in reading of directional couplers due to limited directivity



Input power to the cavity no longer needs to match
Output power of klystron (Can be higher!)

Summary

1) Full 704 MHz system commisioned up to 1 MW, 14 Hz, 2.6 ms
2) Installing 2 Modulators and 2 Control Systems creates delays
3) ESS Provided very good support, especially for the installation of the second control system.
4) Ferrite circulator is working but needs manual tuning and does affect gain of RF chain
5) Thales load is repaired and working but will be upgraded with new ceram9ic window at a suitable timeslot
6) Standing waves & limited directivity of directional couplers does make calibration extra tricky