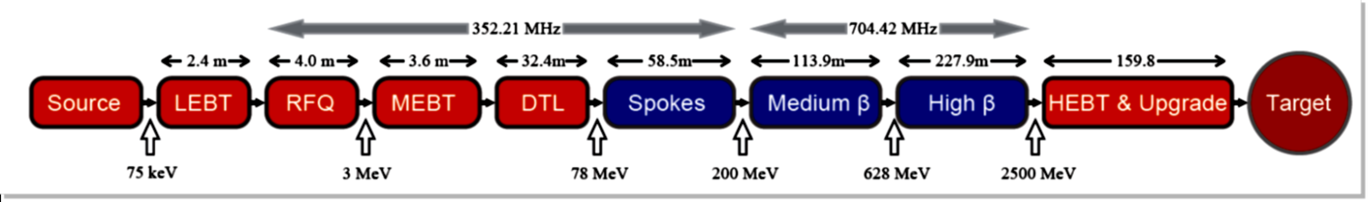
RF Power Station and High Power Test Program at FREIA

Rutambhara Yogi and FREIA Group

RF Source Requirements

Schematic of ESS Linac

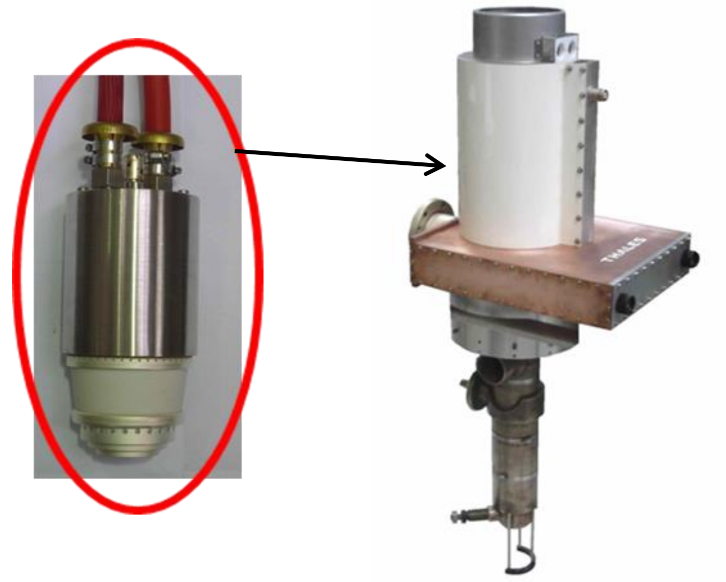


- Maximum RF power coupled to beam = 320 kW
- Considering LLRF overhead = 15% (12.5% power overhead: Simulink model)
  (planning to use excursions of gain curve to reduce this overhead)
- RF loss in distribution system = 5%,
  Power of RF source = 390 kW ≈ 400 kW
- Beam pulse width = 2.86 ms, repetition rate = 14 Hz,
  Natural fill time = $t_f = 2Q_L / \omega$ = 135 µs, ($Q_L = 1.5 \times 10^6$)
  RF pulse width = 3.1 ms
  Duty factor of the amplifier ≈ 4.28 %
- Spoke cavity band-width = 2.34 kHz
  system band-width ≈ 100 times larger than spoke resonator band-width for tuning and regulation delay.
  3 dB bandwidth > 250 kHz.

FREIA:
- Development of ESS Spoke Linac amplifier
- High power test of Spoke cavities.

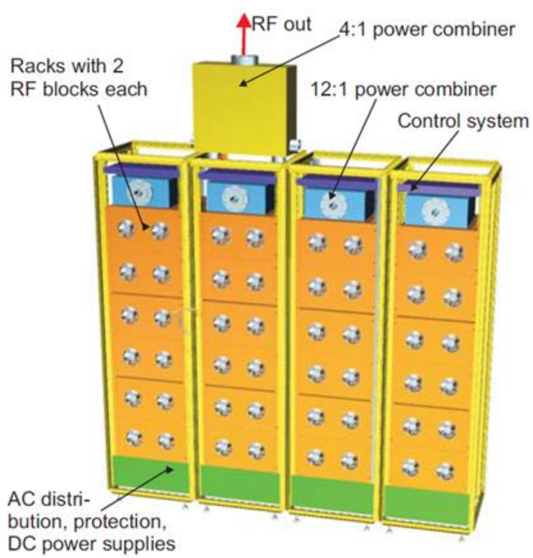
Targets:
- Beam reliability 95 %
- Reliable operation - Beam will be lost if more than one Spoke Amplifier fails
- RF system reliability 99 %

Challenges:
- RF Amplifier doesn't exist at ESS specifications
- FREIA: Developing amplifier at ESS specifications
- Testing to confirm specifications and reliability



Compared all the possible RF Transmitters like Tetrode, Klystron, IOT, Solid state amplifier and selected Tetrode for the first RF power station (availability, price, footprint). [Reported in SLHiPP2012, Katania]

Expeted delivery: Dec 2013

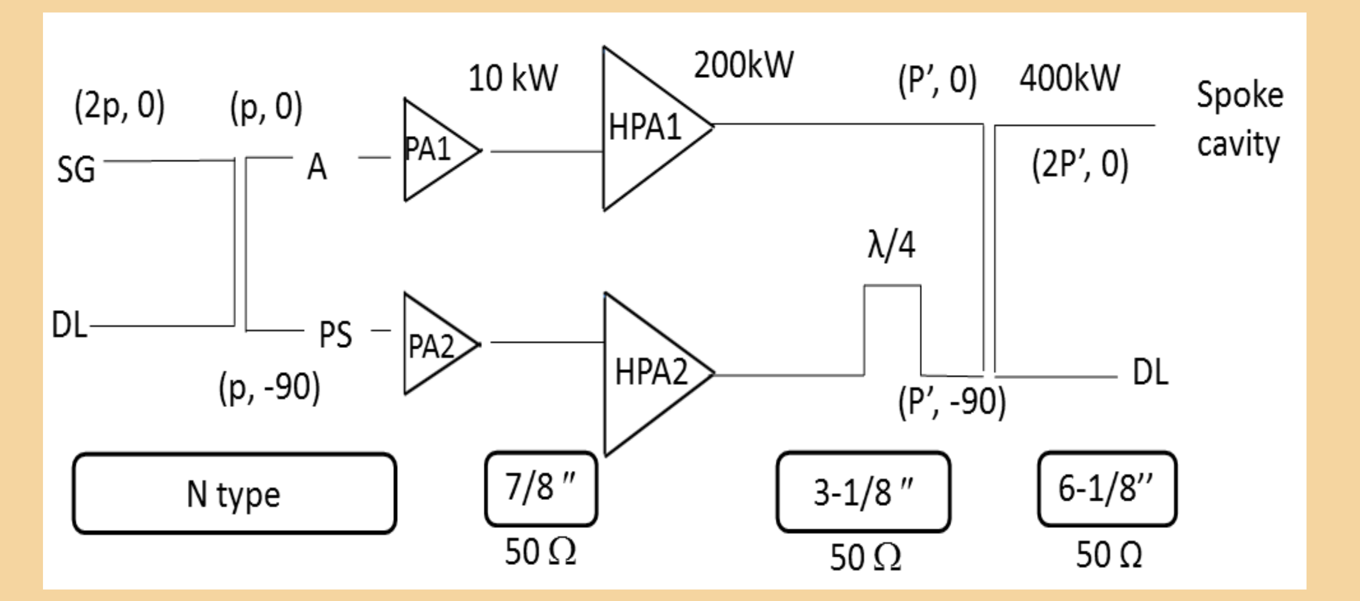


High power RF Power Station using solid state technology under development by Siemens Research centre.

Expected delivery Jan / Feb 2014

ESS Amplifier technology will be proposed after testing tetrode and solid state RF power stations.

Tetrode RF Power Station



TH595 (tested at Thales) for 200 kW output power.
(for double pulse width, with half pulse repetition rate)

Specifications:

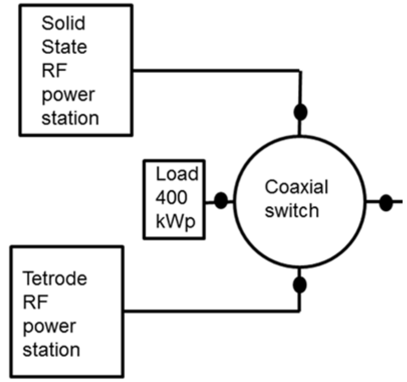
Frequency = 352 MHz
Peak power = 400 kW
Average power = 20 kW
Pulse width = 3.5 ms
Pulse repetition frequency = 14 Hz

- Tetrode TH595 is selected as HPA
  [Reported in SLHiPP2013, Belgium]
- Conservative gain for TH595 = 13 dB
- Preamplifier (Solid state amplifier):
  Peak power = 10 kW
  Average power = 0.5 kW

High power tests at FREIA

RF power station test on load

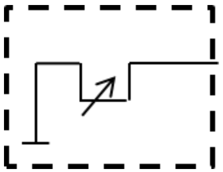
- Test of preamplifier (10 kW peak / 0.5 kW avg)
- Test of amplifier (200 kW peak / 10 kW avg)
- Test of Tetrode RF power station (400 kW peak / 20 kW avg)
- Test of Solid state RF power station (400 kW peak / 20 kW avg)



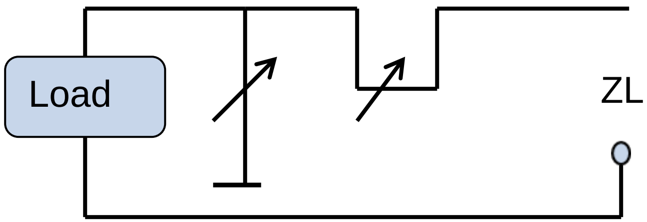
Schematic of test layout on dummy load

Solid state RF power station test on Mismatch load

- Test with variable short with all phases



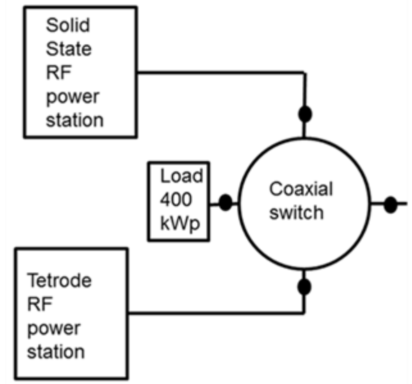
- Test with mismatched load



Lstub (mm)	Reflection coefficient
20	0.95
40	0.85
80	0.59
120	0.37
160	0.20
200	0.04

- Test with arc: Eric Montesinos(CERN) will provide the device.
  (Transmission line section in which arc will be created by a RF short circuit device)

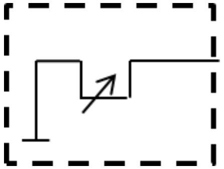
Tetrode RF power station test on Mismatch load



Schematic of test layout on dummy load

- Circulatorless operation of tetrode: Under study.
  collaboration with Eric Montesions (CERN)
  Test it at FREIA and then propose for ESS.

- Test with variable short with all phases
  for total peak power 200 kW.

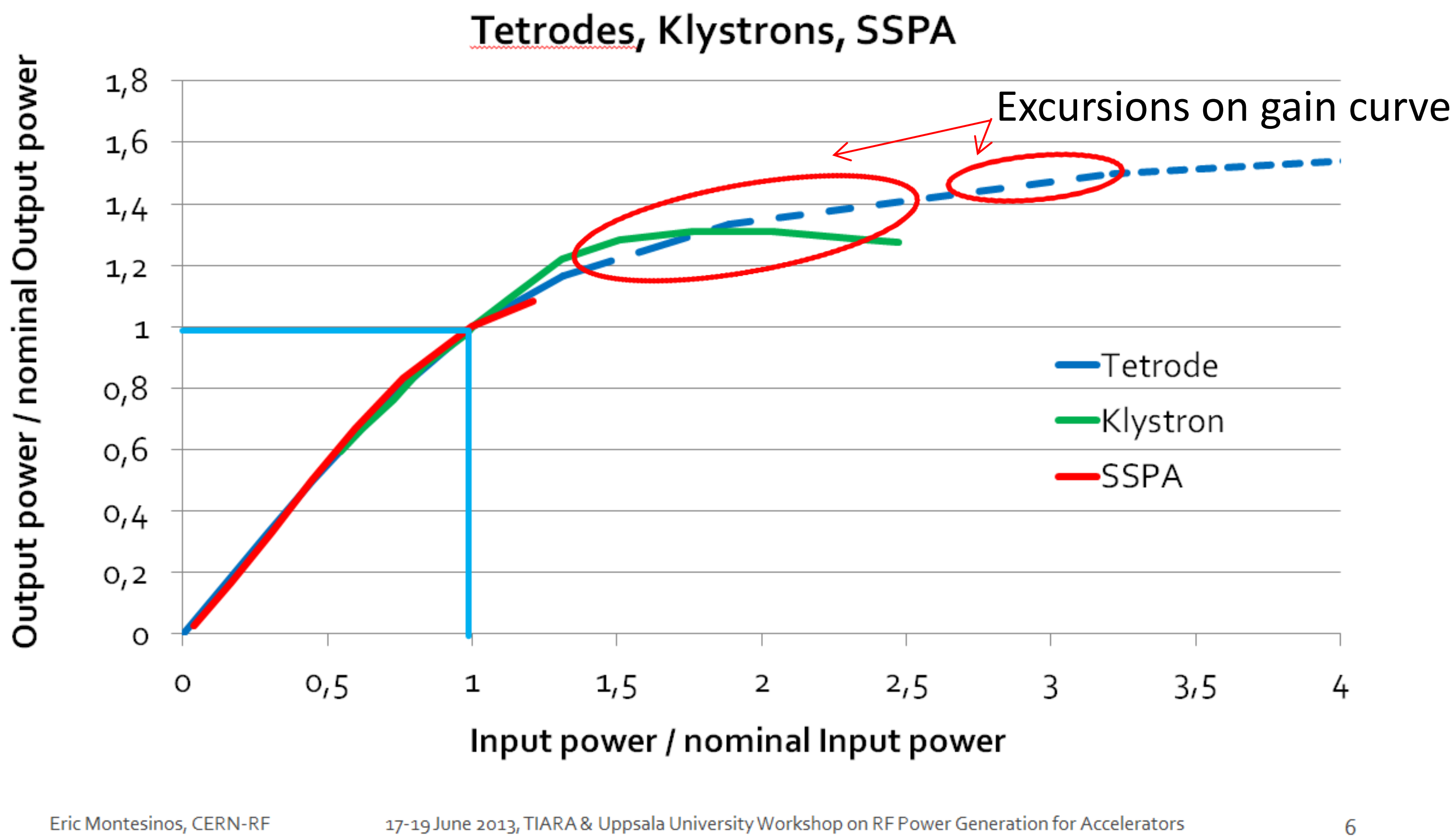


Coupler Conditioning (400 kW)

- Detune the cavity (by few kHz)
- Start from low power and small pulse width and then slowly reach full power (352 MHz, 400 kW, 3.5 ms)

RF test of cavity

- Apply RF power needed to build maximum Eacc = 9 MV/m
- Start from low power and small pulse width and then slowly reach full power (352 MHz, 400 kW, 3.5 ms)
- Maximum Power = 100-200 kW, pulse width = 3.5 ms

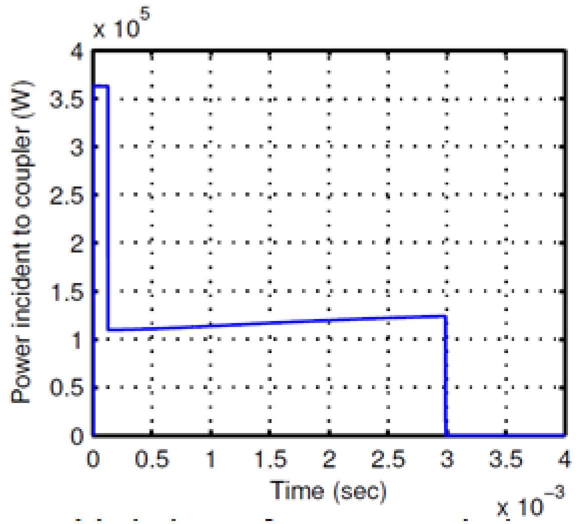


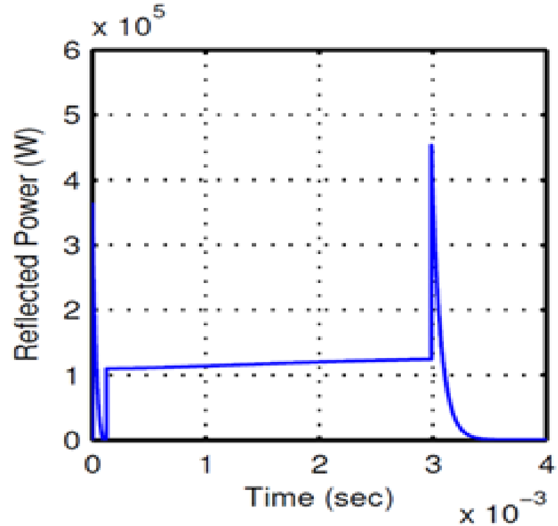
Courtesy: Eric Montesinos (CERN)

Tetrodes can provide more than 1.5 times the nominal power for short time.

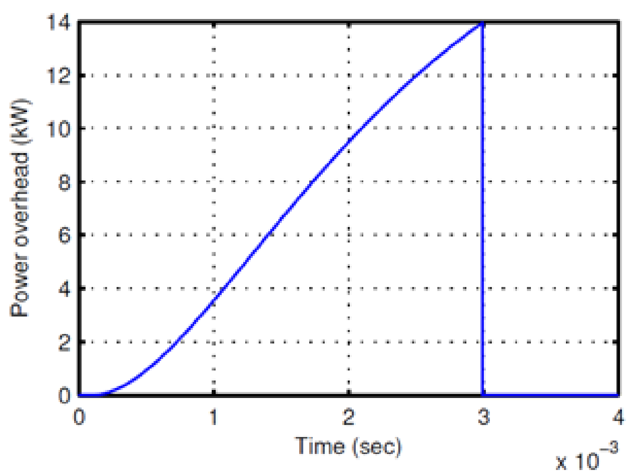
Can be used to decrease LLRF overhead for Amplifier power calculation.

Lorentz detuning compensation of cavity





Special pulse shape needed Due to absence of beam.



Courtesy: Report from Vitaliy Goryashko, FREIA, UU

- Instead of power sweep, pulses of power can be given ie. excursion of gain curve can be used.
- Feed-forward can be used to decrease the reflected power at the start of the pulse.
- To confirm experimentally in FREIA and then propose to ESS

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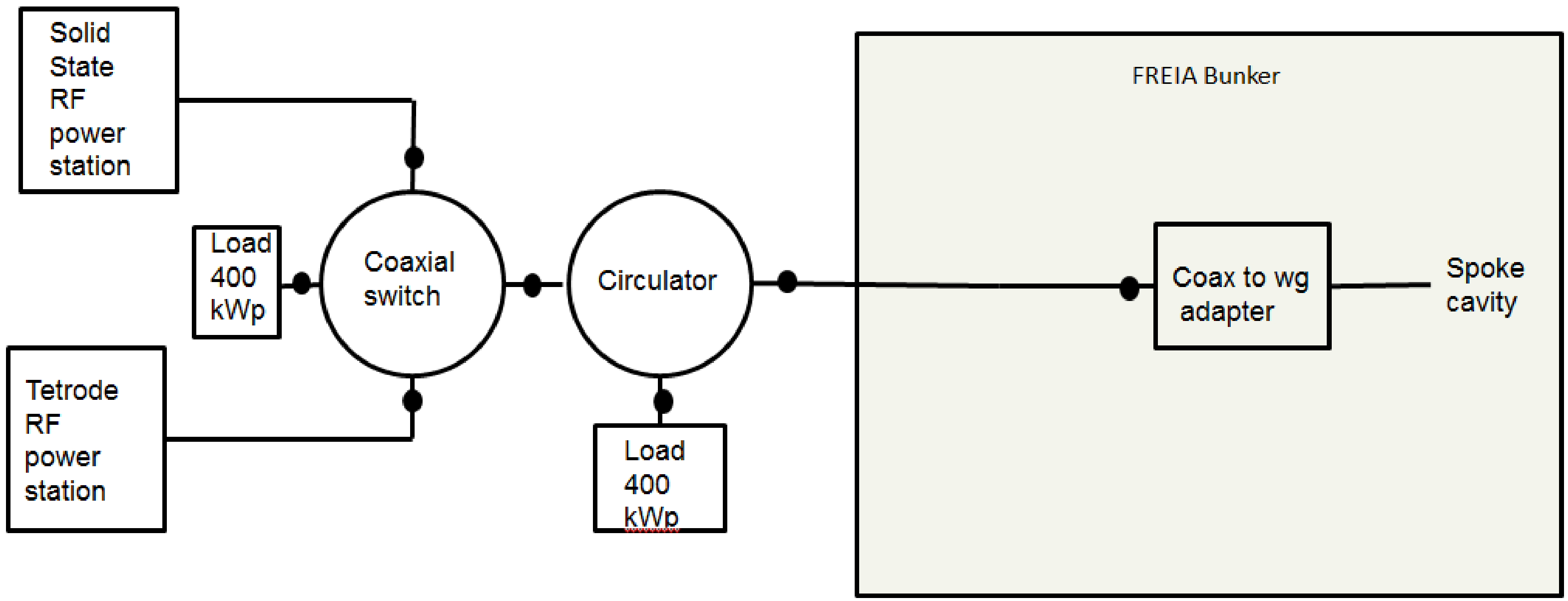
Schematic of RF Distribution layout at FREIA laboratory.

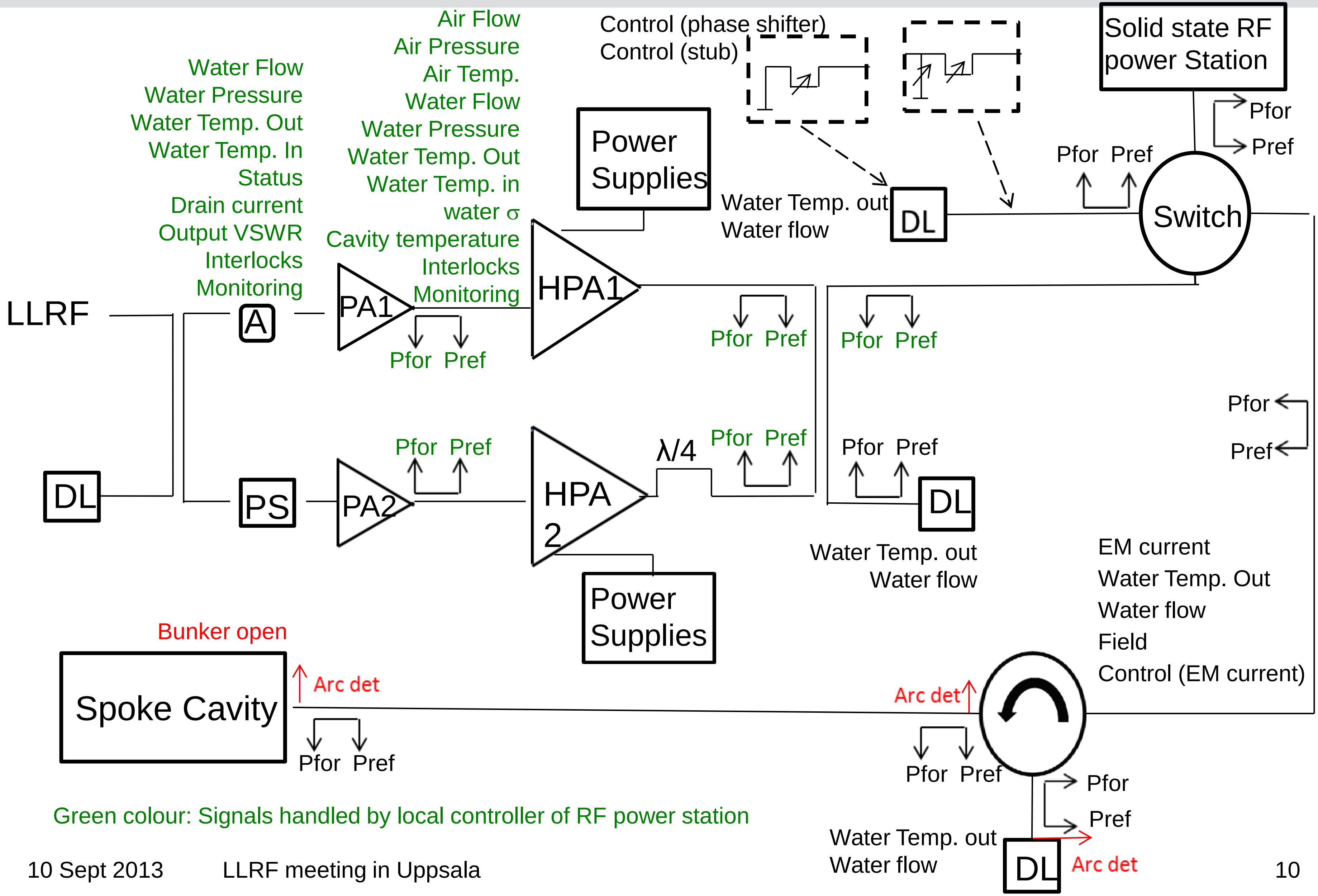


—— : 6-1/8 inch 50 Ohm coaxial line, ●: Dual directional coupler (DDC)

For first chain:
Inside FREIA bunker: 6-1/8 inch coaxial line with ceramic supports is used
Outside FREIA bunker: 6-1/8 inch coaxial line with teflon supports is used

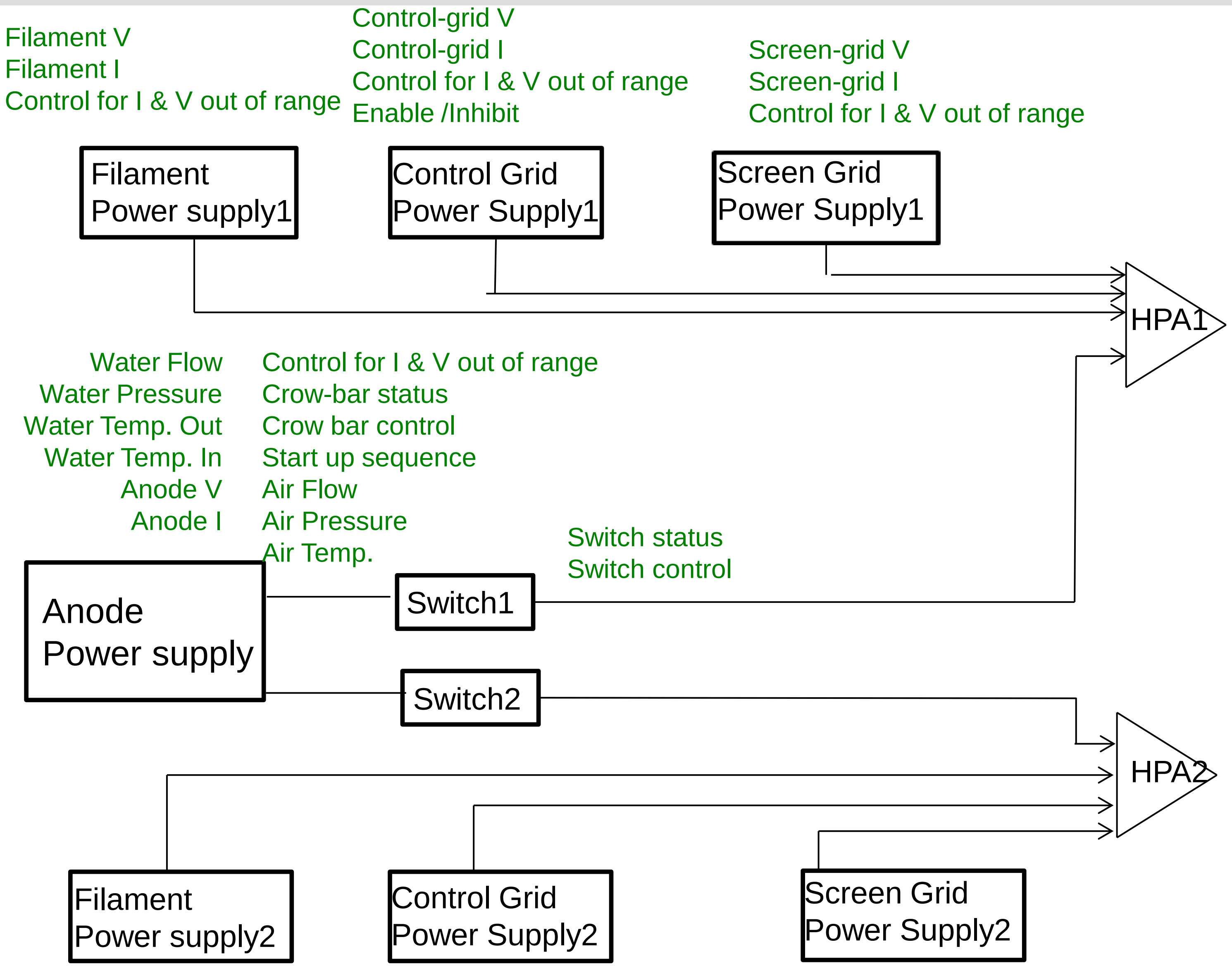
For second chain:
WR2300 (half-height) waveguide to be used.

Signals for RF Amplifier and RF Distribution



Green colour: Signals handled by local controller of RF power station

Power Supplies



Thank you !