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ASD / Linac L6 SLED Testing to Repair L5 Operational System

February 2009

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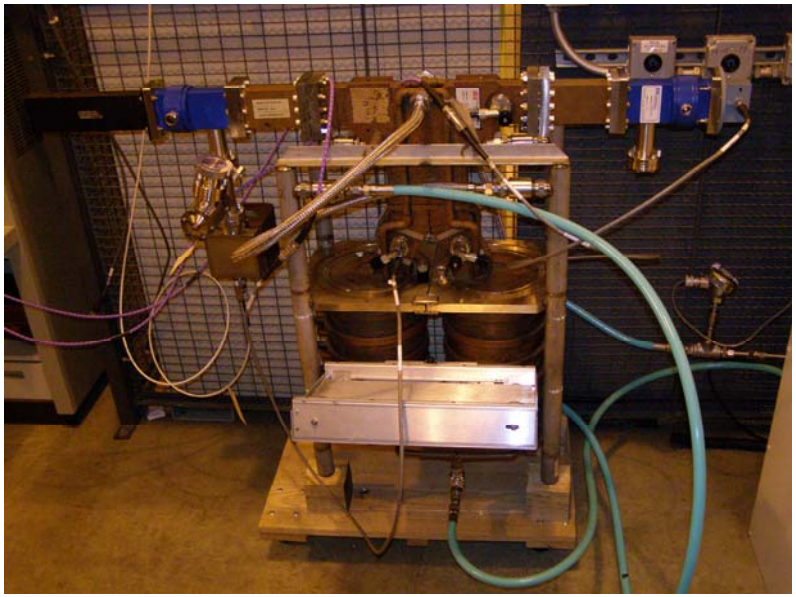
ASD / RF Group

Overview

Linac SLED

SLED = Slac Energy Doubler

- A method of achieving RF pulse-compression through the use of high-Q resonant cavities.
- The cavities store klystron energy during a large fraction of each pulse and then discharge this energy rapidly into the accelerator during the remainder of the pulse.



AS&E SLED

IHEP SLED
(Chinese Academy of Sciences)

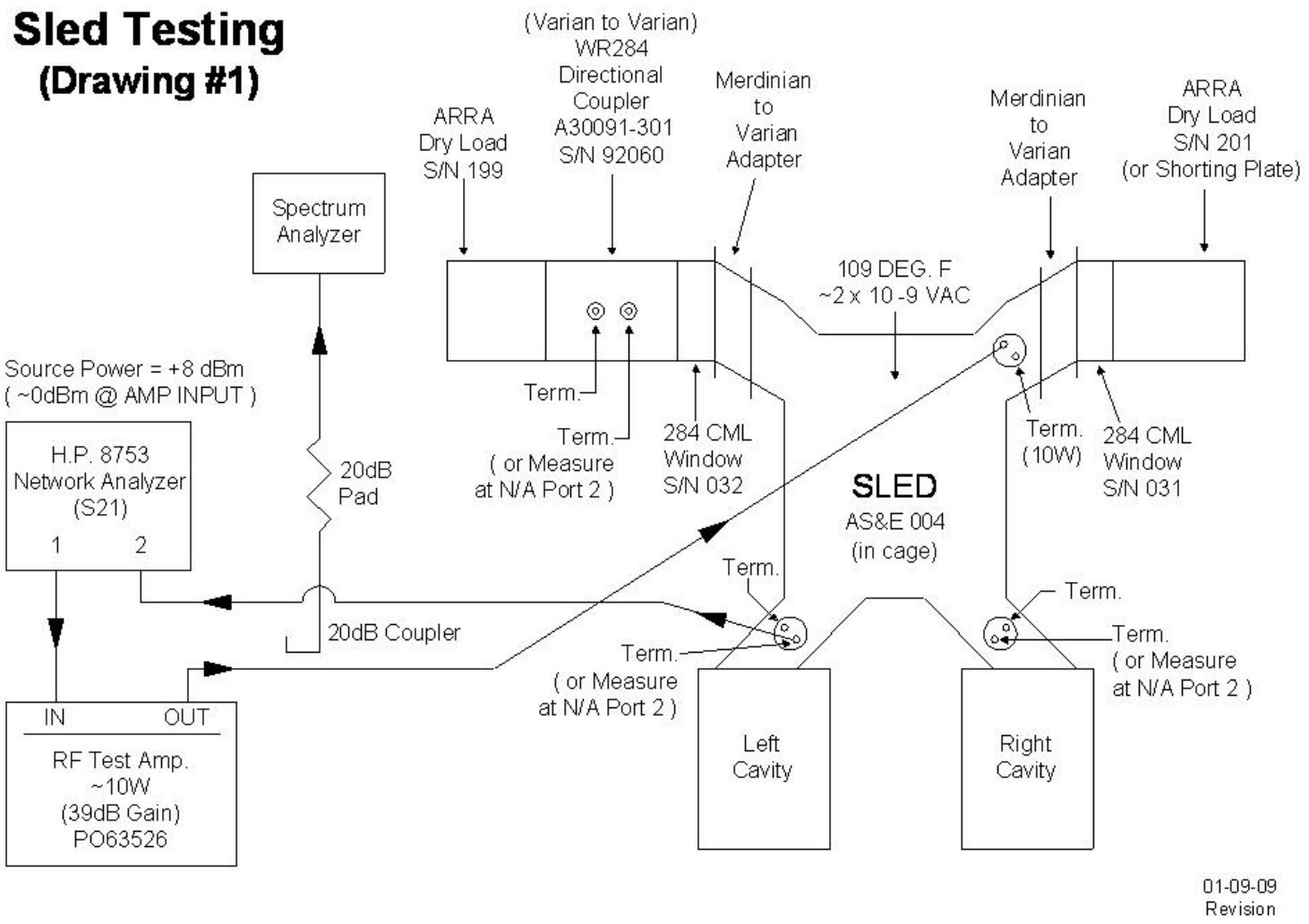
Technical Specifications

2856.00 ±0.1 MHz	Operating Frequency
100,000	Cavity Q
45 MW	Peak input power in a 4.5μs pulse, 60 Hz maximum repetition rate
TE 015	Cavity resonant mode

Linac SLED

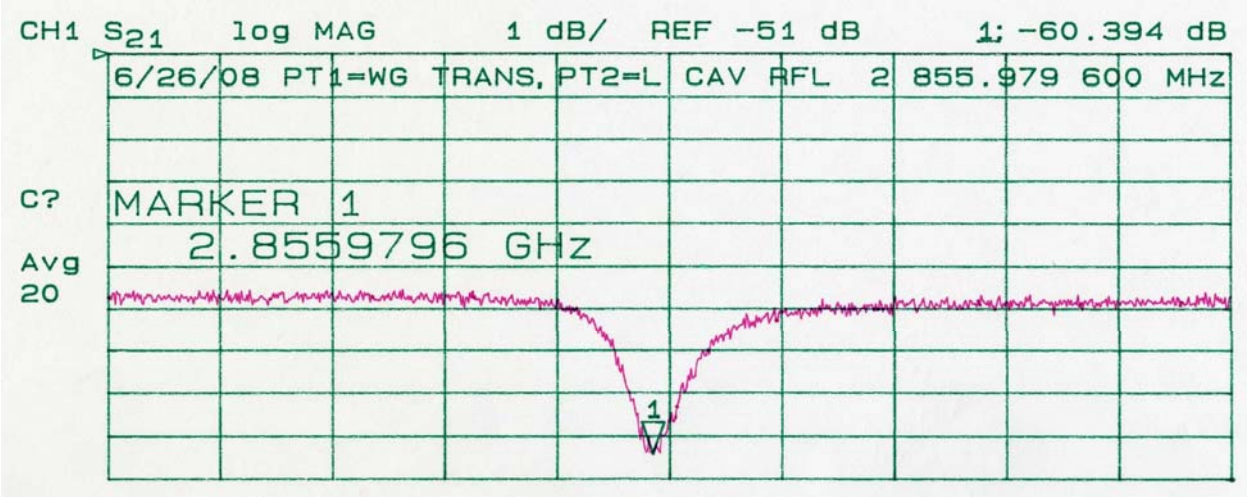
- Will not increase average power consumed by the accelerator.
- Peak RF power will be enhanced at the expense of the RF pulse length.
- A fast-acting triggered PIN diode phase shifter is inserted into the klystron drive-line.
- Energy stored in the cavities re-radiates an RF wave which travels to the accelerator exactly out of phase with the transmitted klystron wave.
- The field at the input to the accelerator is due to the sum of these two waves.
- Detuning is achieved by inserting tungsten needles into the cavities (about 100 bandwidths).

SLED Testing in Par Cage



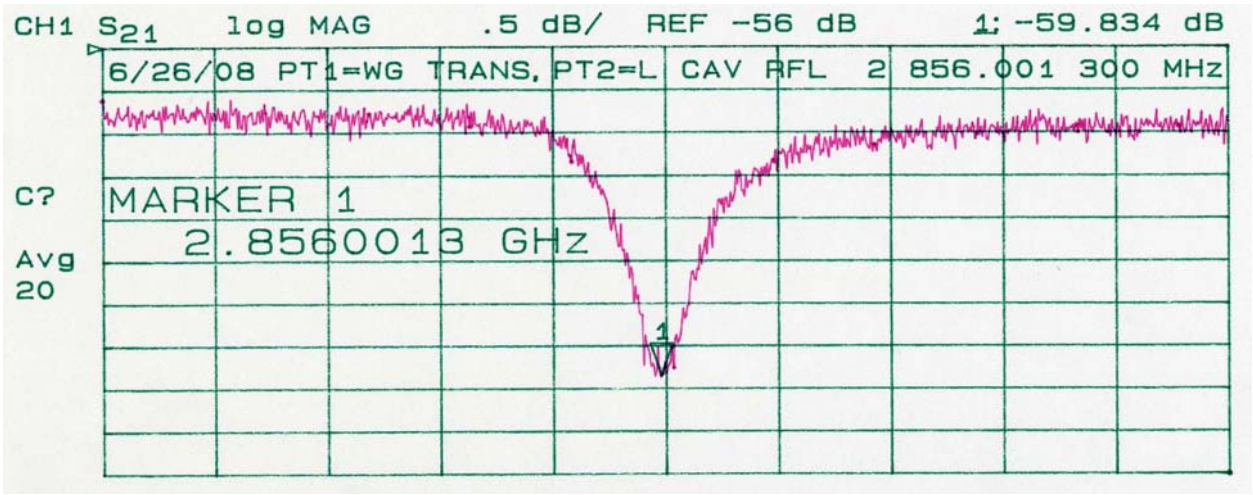
AS&E SLED sn.004 Cavity Tuning – In Par Cage (109°F, Vac)

- Fine adjustments will be made in-situ.



Left cavity
before tuning

~20.4 kHz low



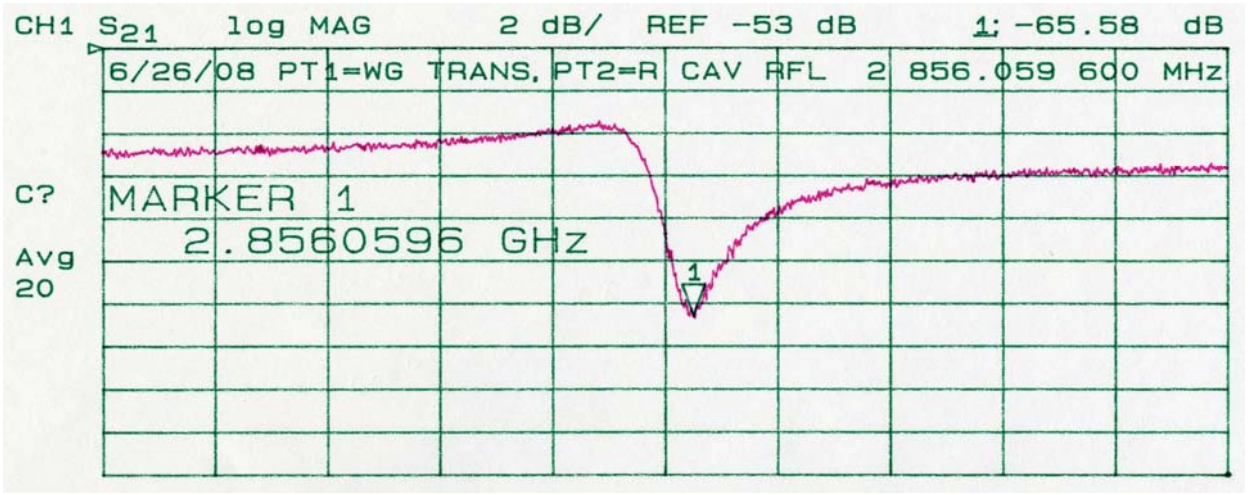
Left cavity
after tuning

~1.3 KHz high

(Adjusted left cavity
~ 1/8 turn CW.)

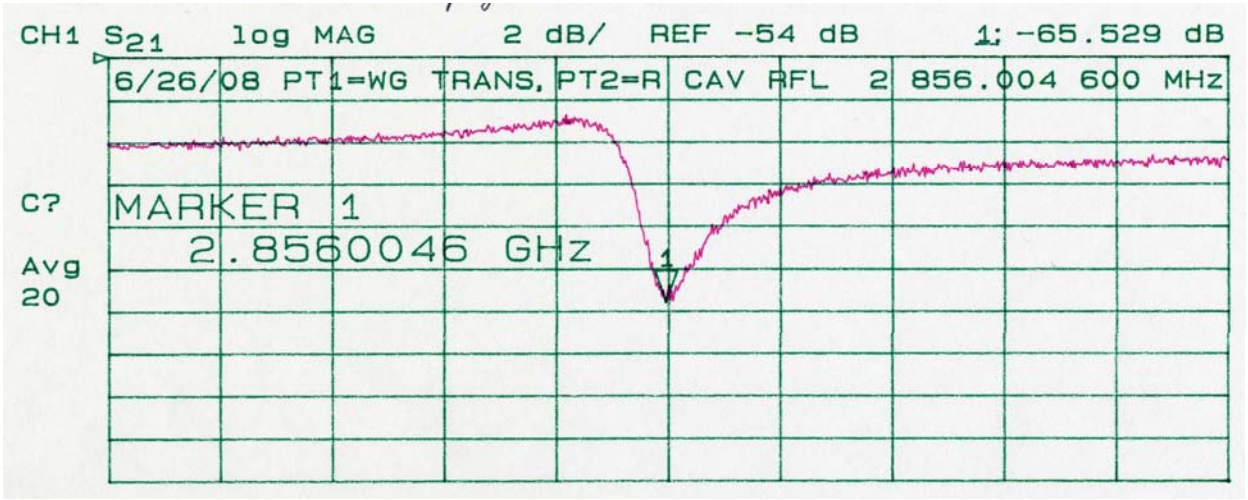
AS&E SLED sn.004 Cavity Tuning – In Par Cage (109°F, Vac)

- Fine adjustments will be made in-situ.



Right cavity
before tuning

~59.6 kHz high

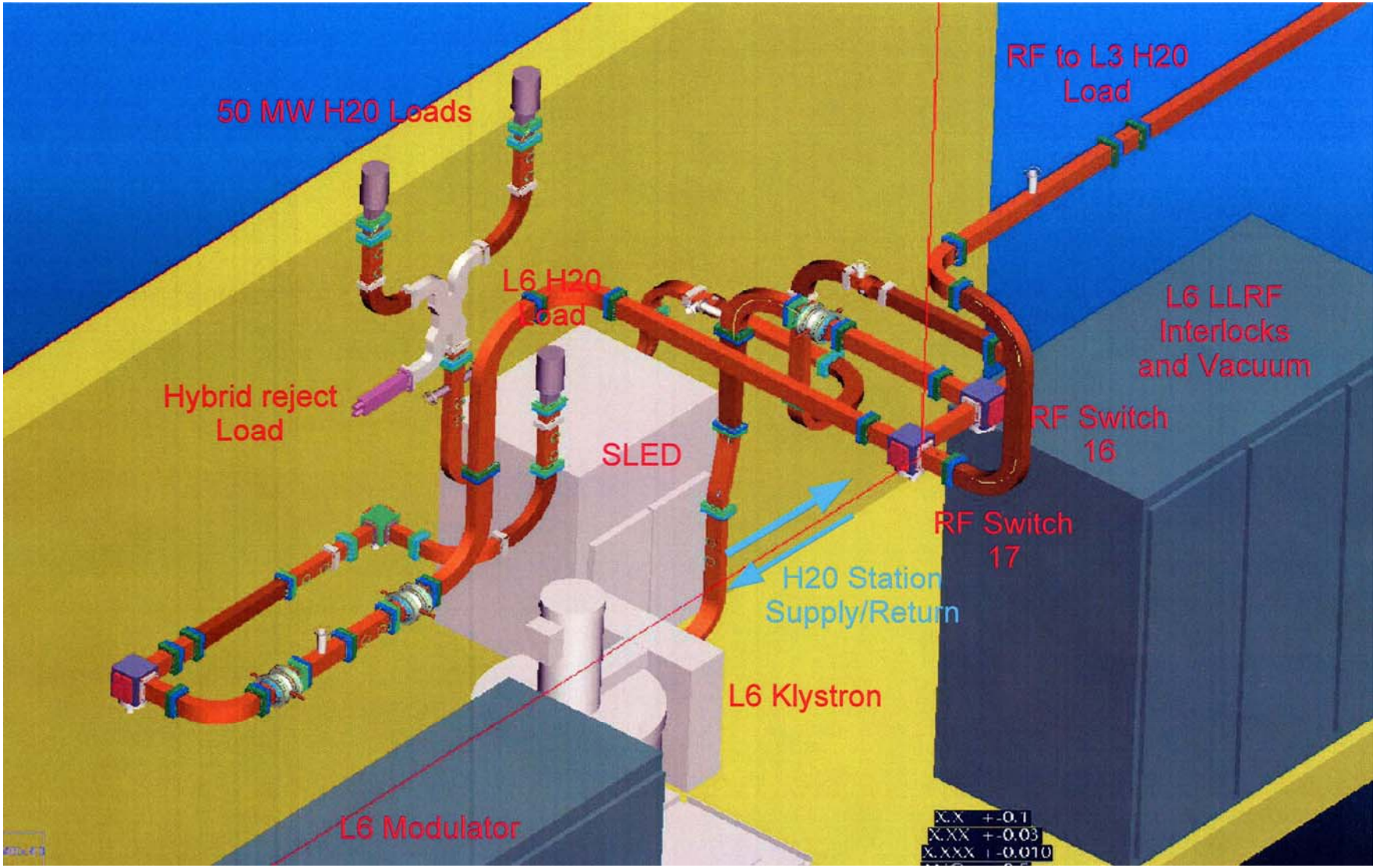


Right cavity
after tuning

~4.6 kHz high

(Adjusted right cavity
~ ½ turn CCW.)

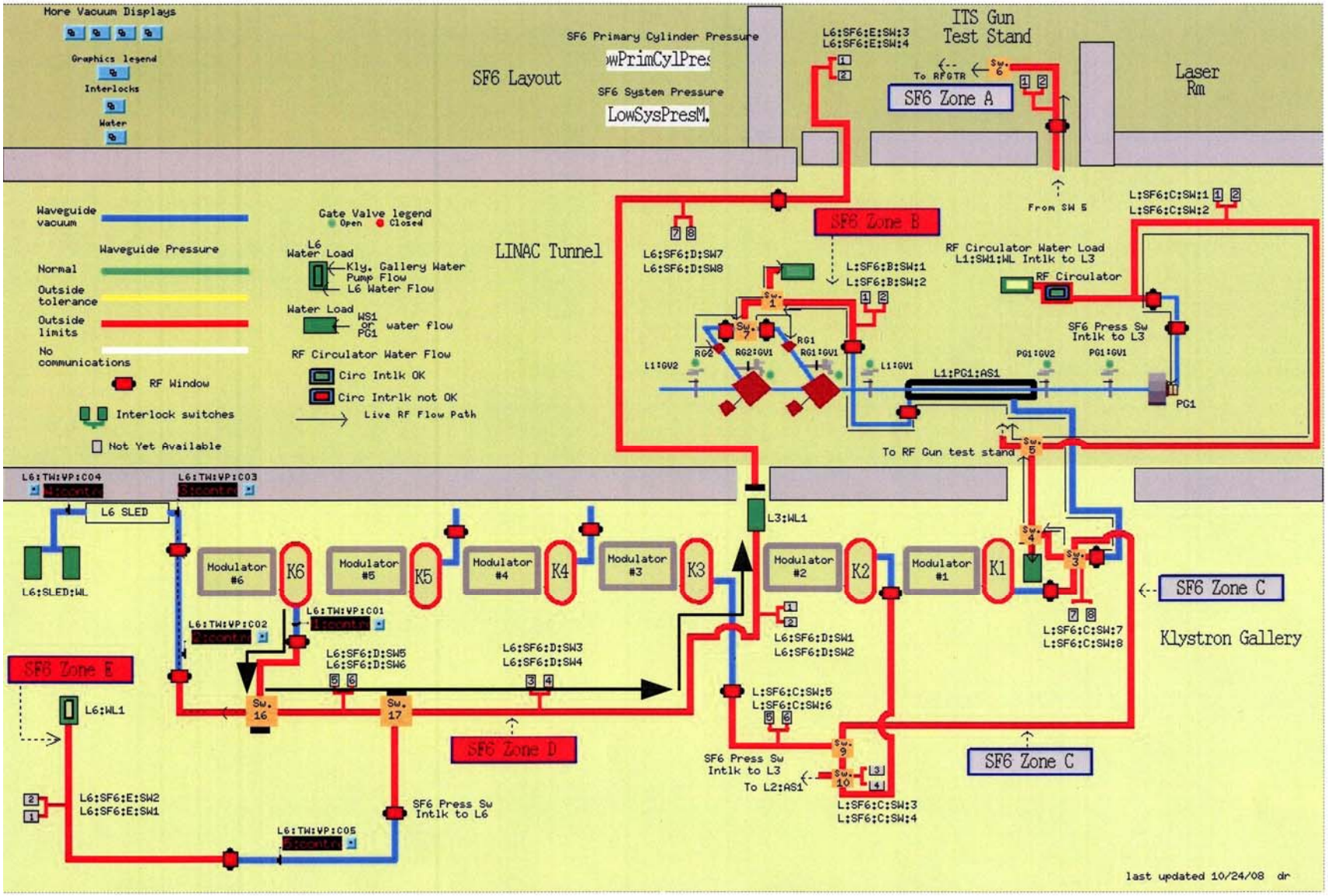
L6 SLED Test Stand Assembly



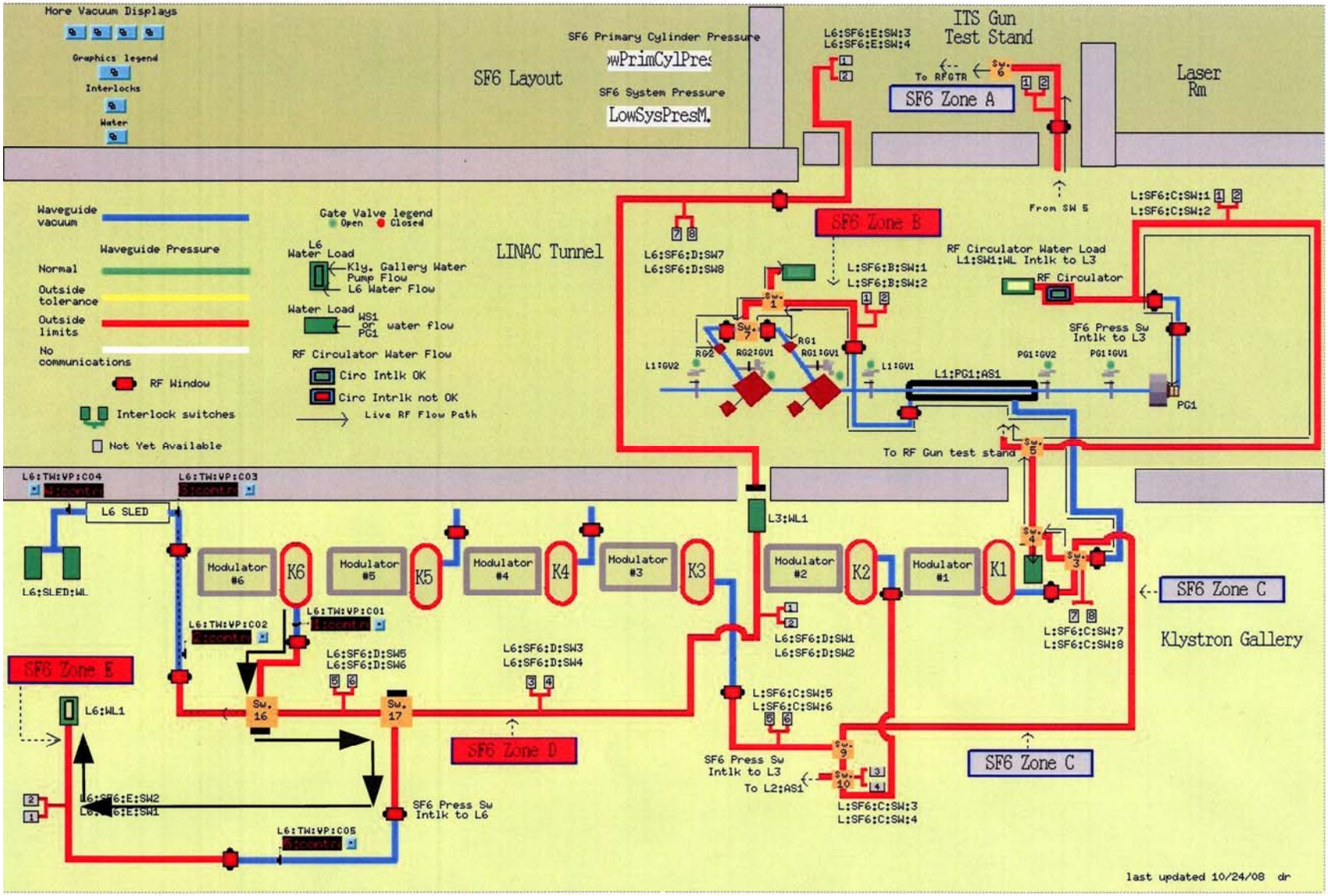
L6 SLED Test Stand Operating Modes

- Three operating modes depending on where the rf power goes:
  - RF power goes to L3 water load (Mode 1).
  - RF power goes to the L6 water load (Mode 2) for conditioning waveguide components; wg couplers, switches, windows, etc.
  - RF power goes to the L6 SLED (Mode 3).
- First two modes have been in use for many years now.
- Mode 3 is the new mode to be added.
- All three modes will have their own machine protection and interlocks implemented.

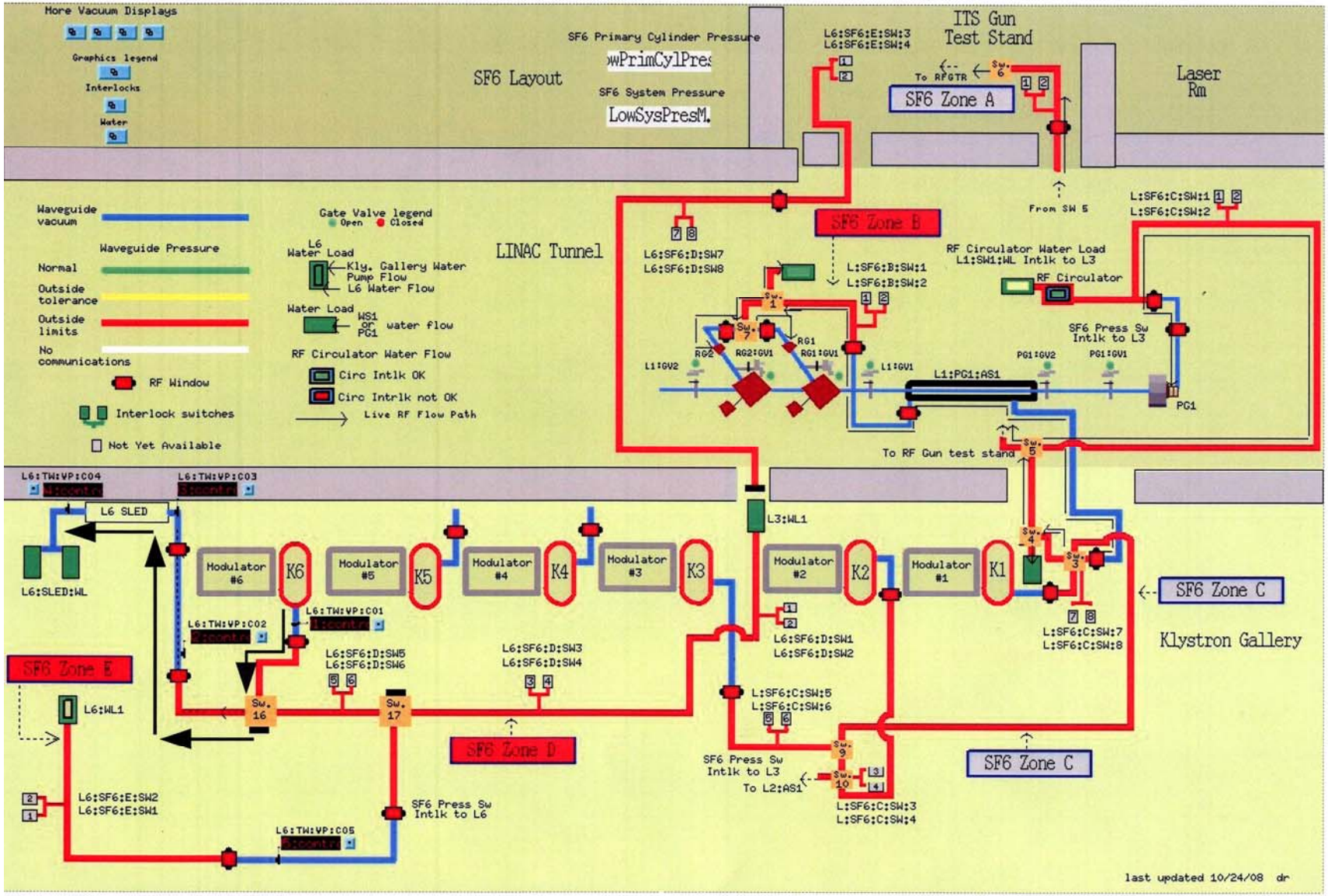
L6 SLED Test Stand Operating Modes - Mode 1 (L3 Water Load)



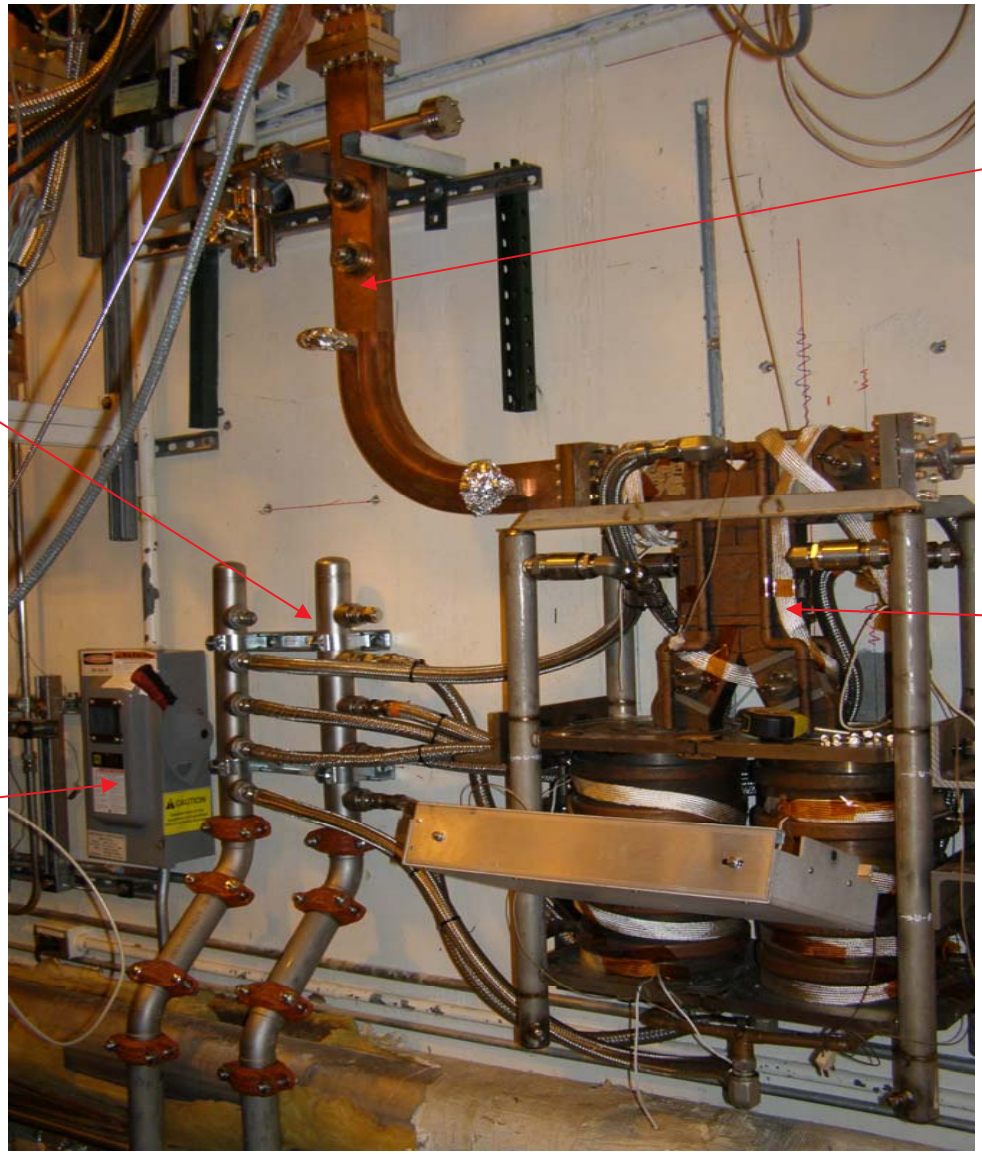
L6 SLED Test Stand Operating Modes - Mode 2 (L6 Water Load)



L6 SLED Test Stand Operating Modes - Mode 3 (L6 SLED)



L6 Test Stand SLED Installation



SLED Waveguide Output Coupling Piece (water temp. stabilized)

SLED Water Header (newly installed)

AS&E SLED (ser no.004)

480V Disconnect to be relocated (previously existing)

Adding High Power RF SLED Testing Capability in L6

Benefits:

– Condition the spare AS&E SLED sn.004 as soon as possible so it can be installed in the L5 linac (replaces broken SLED sn.003 in L5).

– Ability to test SLED sn.003 from L5 and repair, if possible.

– Fully conditioned spare SLEDS will condition faster when they are installed in linac sectors L2, L4 or L5 (hours vs weeks).

– Provide a test bed to test / condition IHEP SLEDS purchased from China.

– Provide a realistic test bed for the new water station developed by the MOM group.

Deliverables Prior to Commissioning: (Completed)

- Final commissioning plans including HP stop points.
- Complete commissioning interlock validation checklist.
- Inspections of new electrical systems by a DEEI.
- NFPA 70E Hazard posting must be in place.
- Any new or modified safety or maintenance procedures relevant to commissioning or operation of the test stand should be entered in ICMS unless the document is being created from information gained during the commissioning process.

L6 SLED Conditioning Work Controls & Hazards: (Completed)

- Commission new water station with / without SLED.
- Commission waveguide components WITHOUT SLED first.
  - Raise power in steps up to 30 MW from L6 klystron.
  - Have HP perform surveys after each 1 MW power increase.
  - Post radiation signs as needed and/or stop conditioning/assess and correct problem with excessive emission of radiation if necessary.
- Commission and test machine protection interlocks for L6 Klystron / SLED system.
- Commission AS&E (spare) SLED sn.004 first.
  - Raise power in steps up to 30 MW from L6 klystron.
  - HP performs surveys after each 1 MW klystron power increase as with waveguide commissioning.
  - Post radiation signs as needed and/or stop conditioning/assess and correct problem with excessive emission of radiation if necessary.
  - Mechanical supports around the SLED can be used for lead curtains if required.

Additional Review Committee Comments and Concerns: (Completed)

- LOTO procedures where required shall be referenced for final approval to proceed.
- Following commissioning, evaluate dBa levels for water system.
- Complete review / testing of machine protection interlocks.
- Analyze data from HP TLD sets to prepare for initial shielding requirements.
- A review of electrical distribution and disconnects located on the Linac / Klystron gallery wall should be performed in the future.
- TLDs should be required in L6 test area and rad-level monitoring is required by EQO during rf ramp-up.
- Is an RWP required during initial commissioning?

  If HP measures ≥ 5mr / hour @ 30cm, all testing will stop until corrective measures are taken.

L6 Test Stand Conditioning / Troubleshooting

Waveguide Component Troubleshooting:

- Many new waveguide pieces were added (hybrid, couplers, switches, loads, windows, straights, bends, etc.) in mode 3 to allow for high power SLED testing. At the start of "L6 test stand conditioning" (No SLED - spool piece inserted), it was noticed that there was an unsatisfactorily low return loss of ~ 13dB. With this condition, the klystron reflected trip level of 1.4MW would be reached before the test stand is at full power. Therefore one or more pieces of new waveguide components installed is sub-standard and does not provide the proper match.

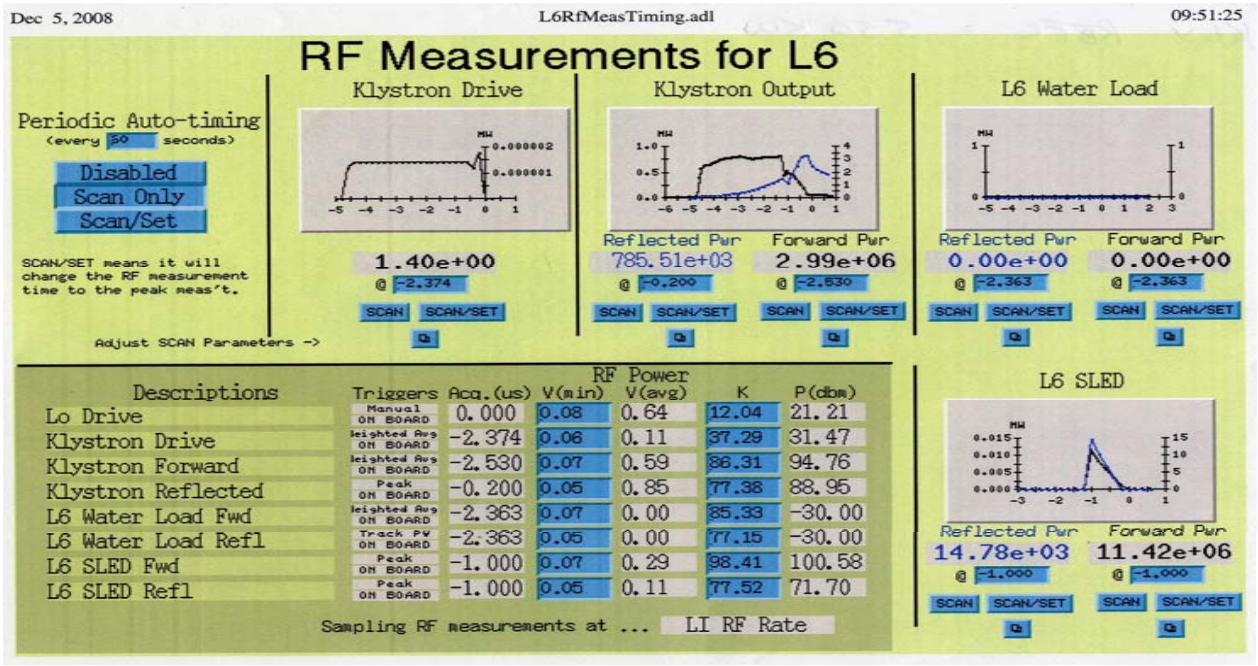
- To find and repair any sub-standard waveguide components, break vacuum & SF6 in mode 3 and perform an S11 network analysis on all new waveguide component pieces in-situ. Do in separate sections and narrow down to an individual waveguide piece.

- Removed the 1st WR284 wg window in mode 3 section and replaced it with a new Titan-Beta sn.023 window, which improved the system reflected power by ~ 2dB. The L6 test stand now has the ability to go to full RF power without tripping on klystron reflected power.

L6 Test Stand Conditioning

- Conditioned L6 test stand, mode 3 (without SLED, spool piece inserted), required thirteen 12 hour days to achieve a klystron output of 30MW at 4.5μs.
- After the SLED sn.004 was tuned in Par cage, the SLED was "baked", which may slightly change cavity resonance.
- Removed wg spool piece and installed SLED sn.004 in L6, conditioned with RF. Klystron output (~ SLED input), set at 3MW.

Measurement taken before In-Situ SLED tuning:



SLED Gain = 11.42 / 2.99 = 3.8
Klystron Reflected Power = 785 kW

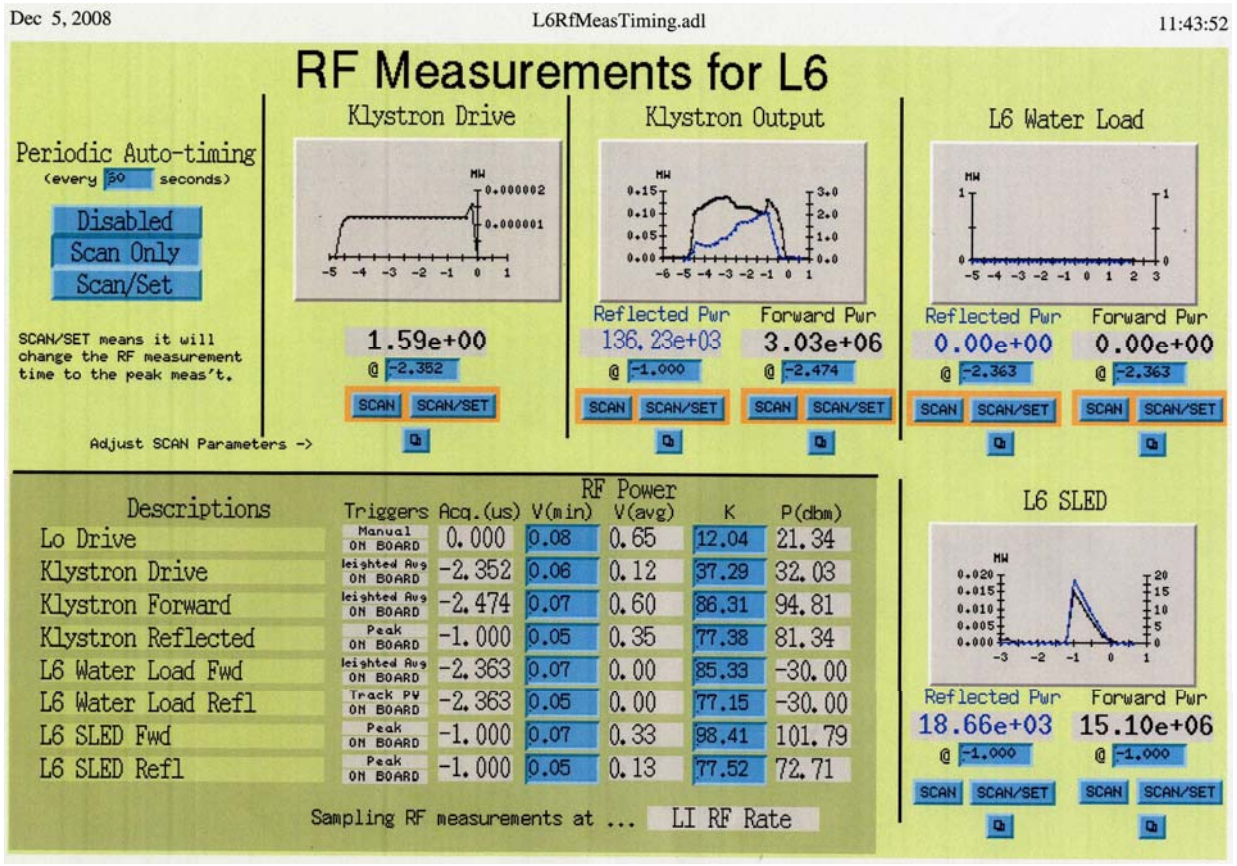
Perform In-Situ SLED Tuning in L6, sn.004

- Do this to improve SLED gain and to reduce klystron reflected power by providing a better match.
- Connect Agilent 8648D signal gen to L6:LLRA:1, top of rack, N-Type feedthru, “LO RF IN.” Adjust gen level (at 2856 MHz) up to ~ +5 dBm.
- Determine which SLED cavity is highest Q (shows highest amplitude and sharper freq response). Adjust highest Q cavity (dominate cavity) first. SLED sn.004, left cavity is highest Q.

1) Set up peak power meter to SLED left cavity, terminate all other ports, left cavity peaks at 2856.06 MHz, 60 kHz high, adjust left cavity ~ ½ turn CCW to peak left cavity at 2856 MHz. Klystron refl pwr on EPICS drops from 370 kW to 63 kW.
2) Peak power meter to SLED right cavity, right cavity peaks at 2855.96 MHz, 40 kHz low, adjust right cavity to ~ ¼ turn CW to peak at 2856 MHz.
3) Cavities have some interaction. Re-adjust left cavity ~1/8 turn CW to peak at 2856 MHz (was ~25 kHz low).

L6 Test Stand Conditioning

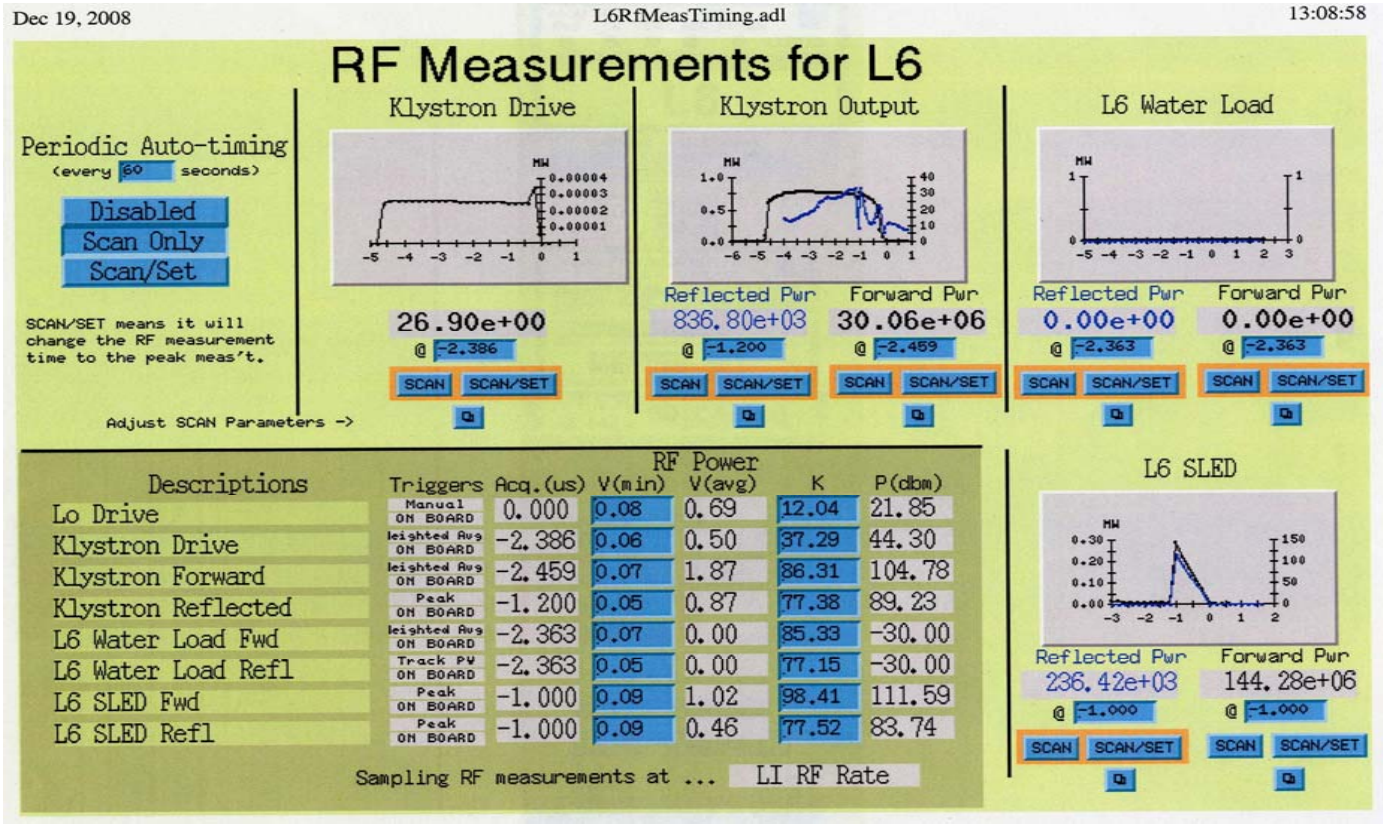
Measurement taken after In-Situ SLED tuning.



SLED Gain = 15.10 / 3.03 = 5.0 (was 3.8 before in-situ tuning)
Klystron Reflected power = 136 kW (was 785 kW before in-situ tuning)

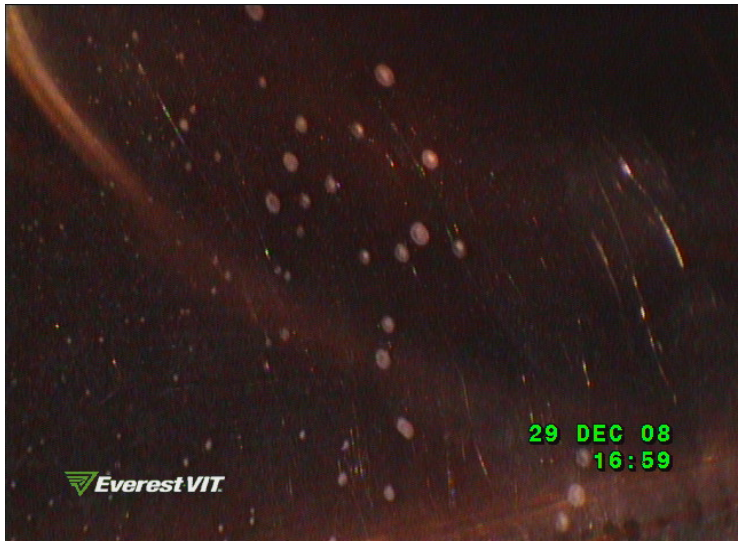
L6 Test Stand Conditioning

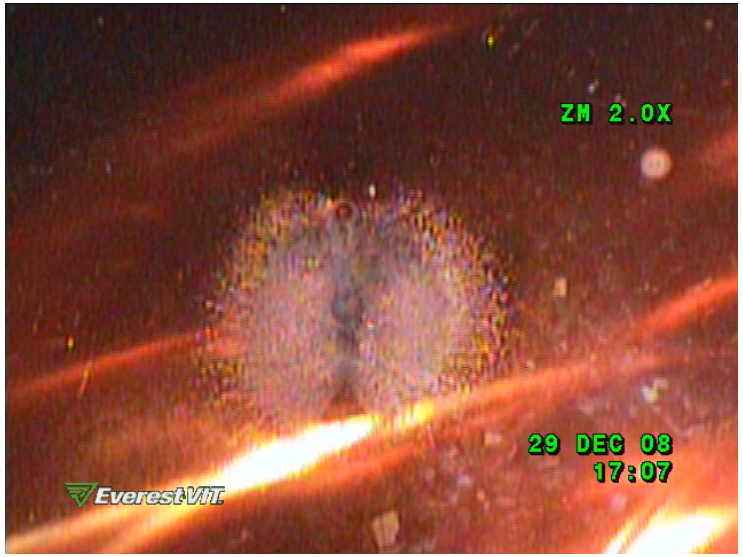
- SLED sn.004 conditioned to L6 klystron maximum output power of 30 MW
- SLED output = 144 MW

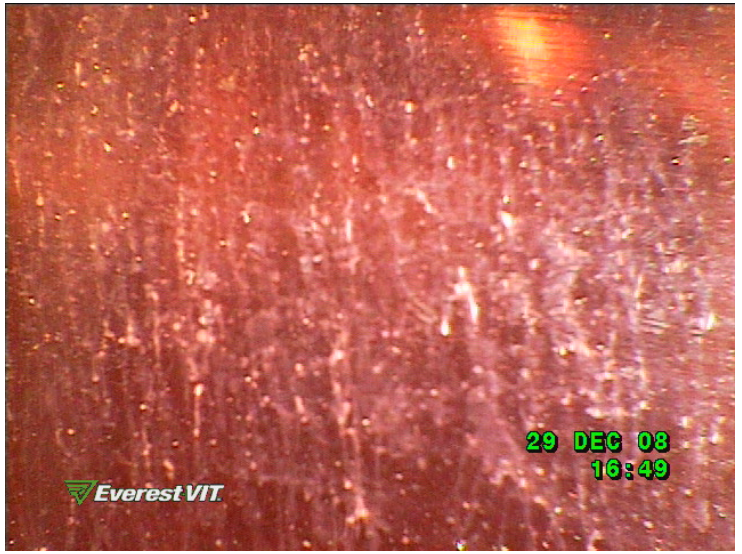


- Required an additional fourteen 8 hour days of SLED conditioning to achieve a SLED output of 144 MW.

Contaminated SLED sn.003 removed from L5
Surface Damage

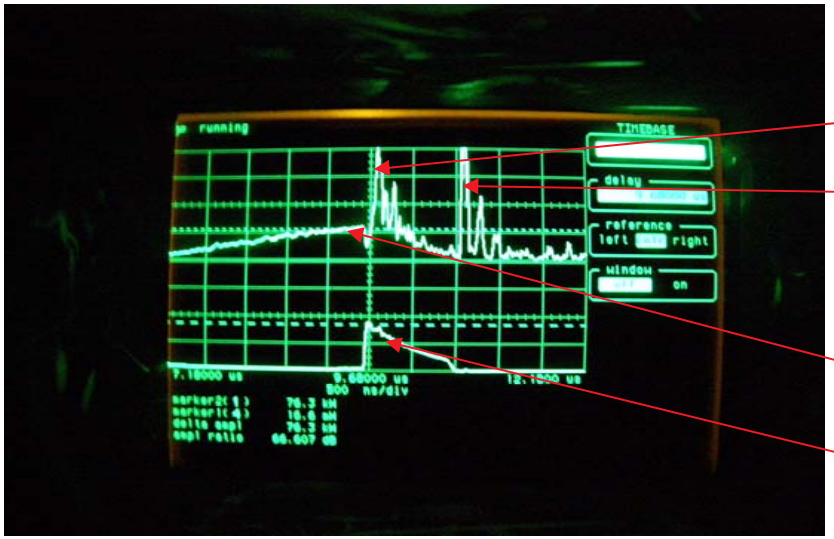






Results of SLED sn.004 installation in L5

- **SLED Tuning:** Adjust SLED left cavity (lower Q cavity) slightly to lower klystron reflected power in the L5 system.



Before Tuning:

180º Phase Reversal

RF Off

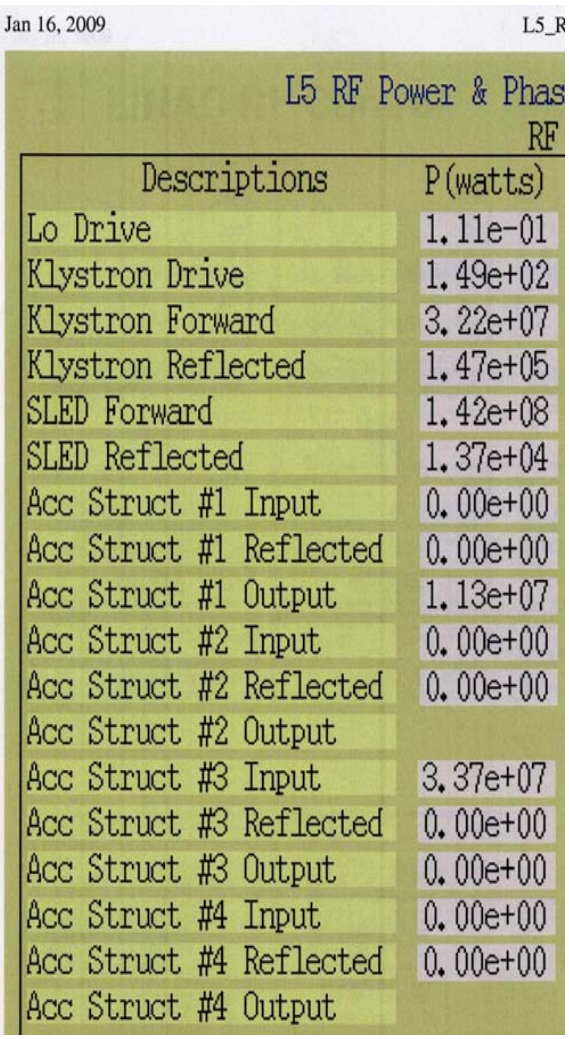
Klystron Reflected Power
(EPICS reads 85 kW)

SLED Forward Power

After Tuning:
Left cavity adjusted ~ 1/8 turn CCW

Improved Klystron Reflected Power
(EPICS reads 24 kW)

Results of SLED sn.004 installation in L5



- L5 is now operational at full RF power.
- A SLED RF output of ~ 140 MW is required from L4 or L5 to individually support Storage Ring injection.
- With L5 klystron output set at 32.2 MW:

  SLED output = 142.5 MW
  SLED gain = 4.42
  Klystron refl. = 147 kW