

■ National Synchrotron Light Source II

Operation and Upgrade Experience of K2 Klystron Modulators in National Synchrotron Light Source -II at Brookhaven National Laboratory

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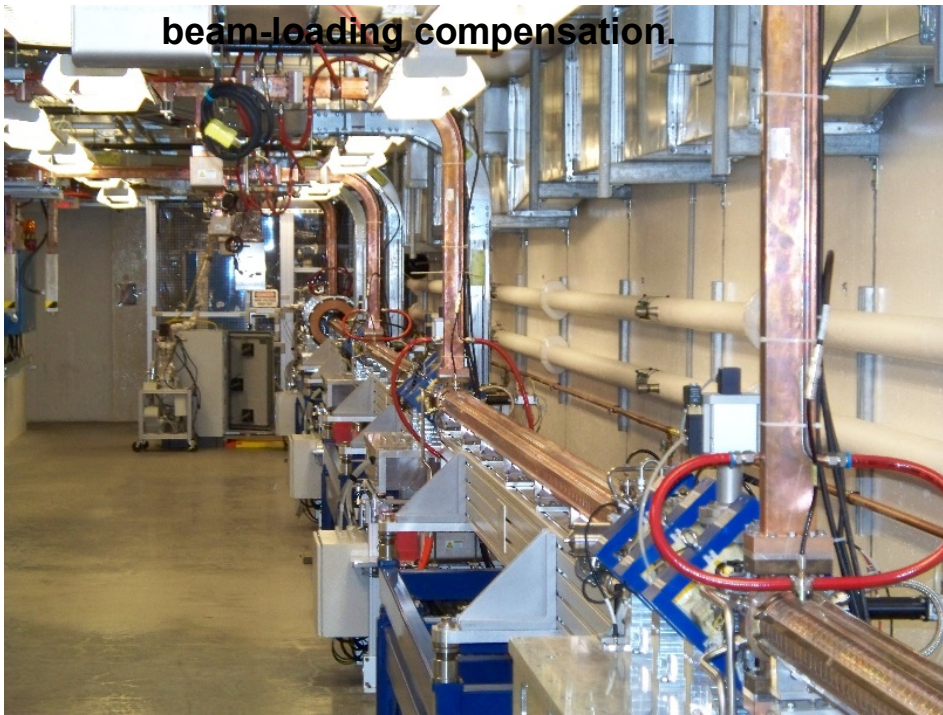
Outline

- NSLS-II LINAC RF System and Motivation for Upgrade
 - Klystron Upgrade – from Thales TH2100A to Toshiba/Canon E37302A
- Required Klystron Modulator Upgrade: K2 -> K300 Model
 - Modulator components upgrade: SU, Controls, Cooling
- Operation Performance of Upgraded K2 Modulator
- A Remaining Issue

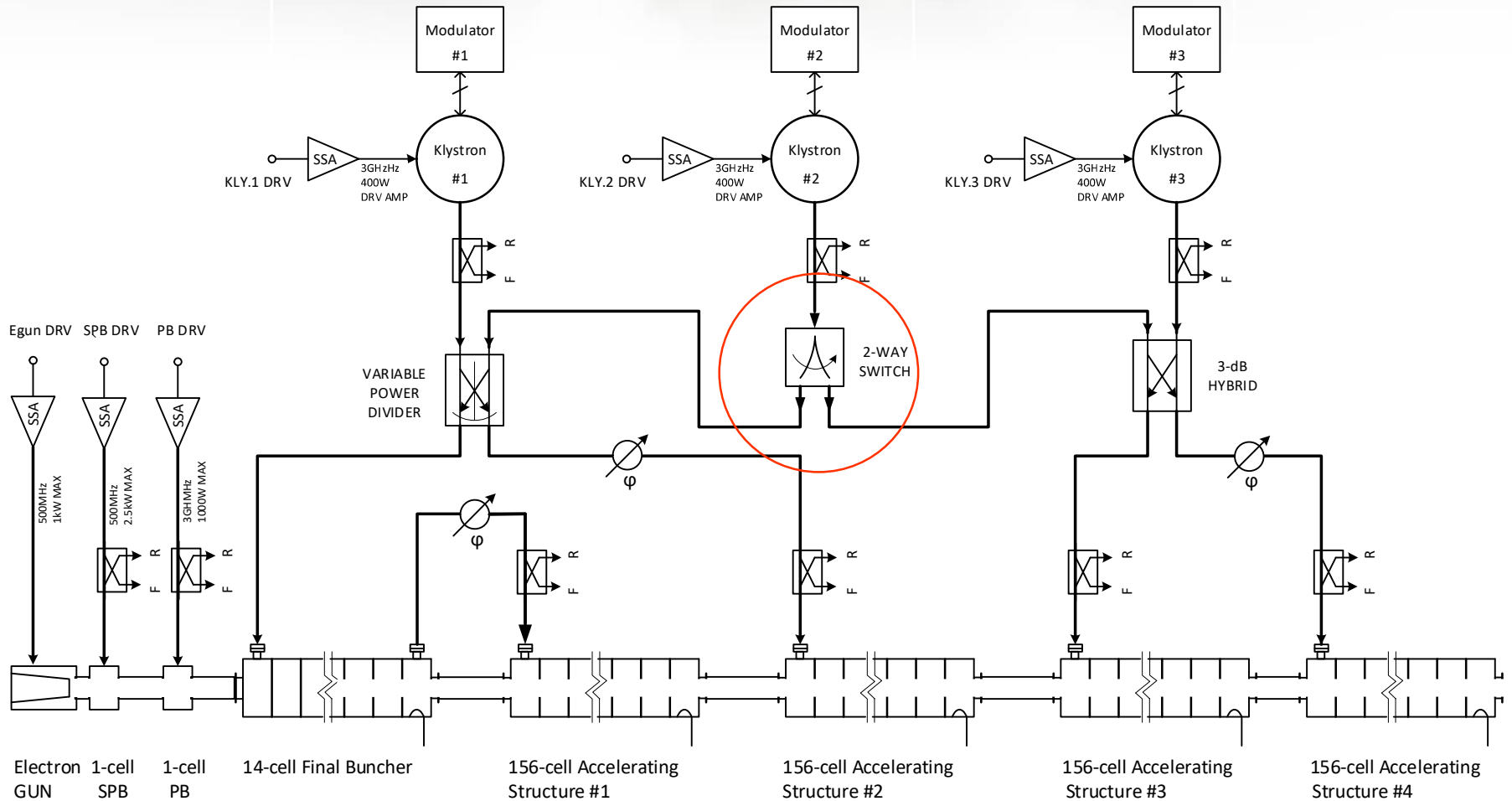
NSLS-II Pre-Injector LINAC is Turn-Key Solution by RI

LINAC Tunnel and Klystron Gallery

- NSLS-II LINAC is a pre-injector to Booster ring, 3GHz, 200MeV, 1~10Hz rep rate,
- Two Beam Bunchers, followed by 4 Traveling wave Accelerating Structure Sections,
- Four 45MW Klystron Transmitter Stations; two for LINAC operation, **one online as standing-by backup station, and one off-line spare as the test station**
- Powered by 3 Model K2-2 ScandiNova Modulators (upgraded from original K2 model)
- LINAC runs both Single Bunch Mode (SBM) and Multi-Bunch-Mode (MBM) Beam
- MBM beam length varies from 20 to 150 bunches Max. (40~300nS), resulting in a need for **AFF beam-loading compensation.**



NSLS-II LINAC RF Power Chain



MOTIVATION for Klystron/Modulator UPGRDE

Severe problems with Thales TH2100A klystrons (arcing, short life) and resultant the premature failures of all stocked Thales klystrons prompted an urgent need for Klystron upgrade;

1. Upgrade to better/bigger Toshiba klystron E37302A, AND
2. Necessarily upgrade existing K2 modulators to the new K300 model standard to meeting the increased power rating of the new klystrons.

MODULATOR UPGRDE

K2 Modulator Upgrade to K300 Model standard was done by OEM – ScandiNova, the work involves the following areas ;

1. Modulator controls upgrade to Beckhoff PLC system
2. Tank Upgrade
 - 1) New mounting plate and socket for Toshiba klystron
 - 2) Add calibrated commercial toroid for HV current measurement
3. Add the 8th SU to meet the 350 A beam current rating of the new klystron
4. Upgrade of the cooling system to meet the increased cooling flow
Requirement: 90L/min. (vs. 52L/min.)
5. Replace the double E-bend klystron output waveguide to single E-bend waveguide, duo to change in the klystron output waveguide port orientation.

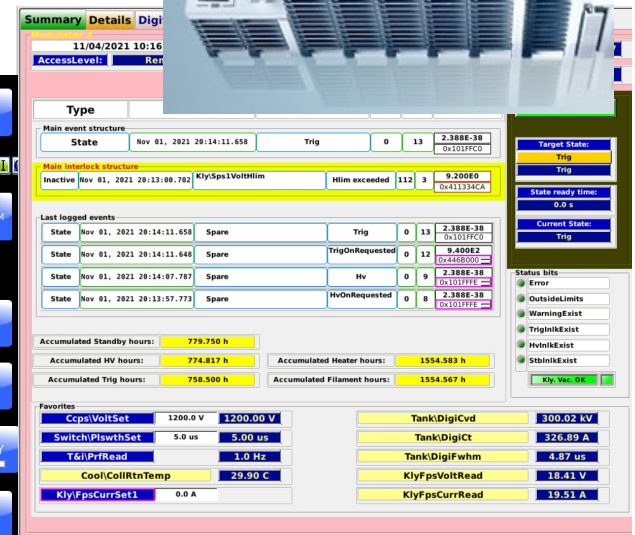
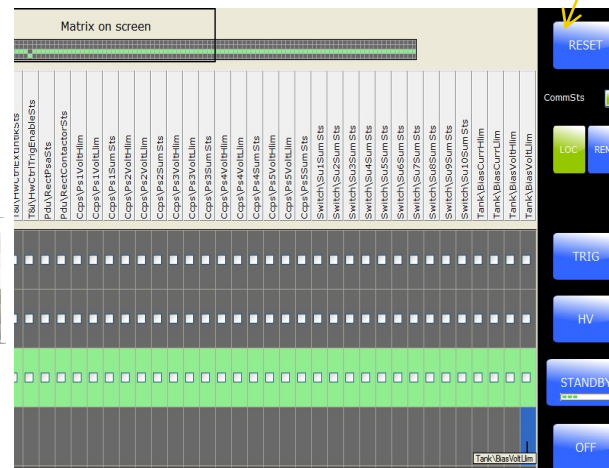
MODULATOR K2 -> K300 UPGRADE: Controls/Platform

New Components

- Upgrade the controls to ScandiCat System of K300
 - Industrial PC-based Virtual PLC, more user friendly
 - More I/O's for control/monitoring
 - Stronger interlock, and better reliability
 - Remote support possibility * (Win 7, remote access)
- New control supported auxiliary PS's and Interlocks
 - Power Distribution Unit (PDU),
 - Solenoid, filament, and HV PS
- Upgrade SU's to be compatible w/ new control,
- Add 8th SU (in addition to the existing 7) to meet the increased klystron current demand of 389A for E37302A

Reused K2 Components

- Chassis/cabinet - smaller than that of K300, means the in-cabinet components have to be rearranged to fit in the crowded space.
- Oil pump
- Cooling



MODULATOR K2 -> K300 UPGRADE: Tank Components

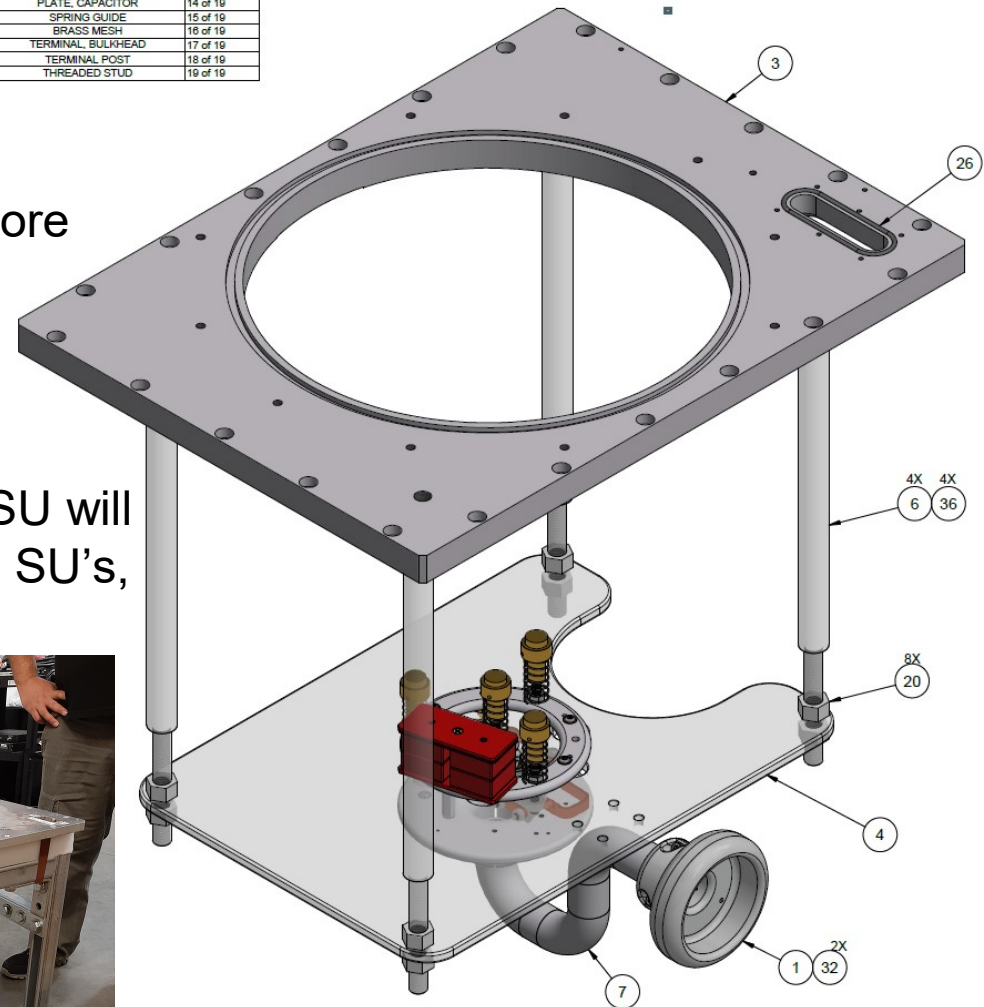
New Components

- E37302A klystron mounting plate
- E37302A klystron socket assembly
- E37302A specific tuning-circuits
- Calibrated commercial CVD/CT for more accurate HV V/I measurement

Reused K2 Components

- Klystron Oil Tank
- HV pulse transformer – its 7-group secondary winding means the added SU will have to be paralleled with one of the 7 SU's, not so good for the balance.

| | | |
|------|--------------------------|----------|
| 0-7 | PIPE WELDMENT | 10 of 10 |
| 0-8 | COPPER BUSBAR #1 | 11 of 10 |
| 0-9 | COPPER BUSBAR #2 | 12 of 10 |
| 1-10 | GASKET, PLATE, CAPACITOR | 14 of 10 |
| 1-11 | PLATE, CAPACITOR | 14 of 10 |
| 1-12 | SPRING GUIDE | 15 of 10 |
| 1-14 | BRASS MESH | 16 of 10 |
| 1-15 | TERMINAL, BULKHEAD | 17 of 10 |
| 1-16 | TERMINAL POST | 18 of 10 |
| 1-17 | THREADED STUD | 19 of 10 |



K300 Kly. Mounting plate and socket assembly for E37302A

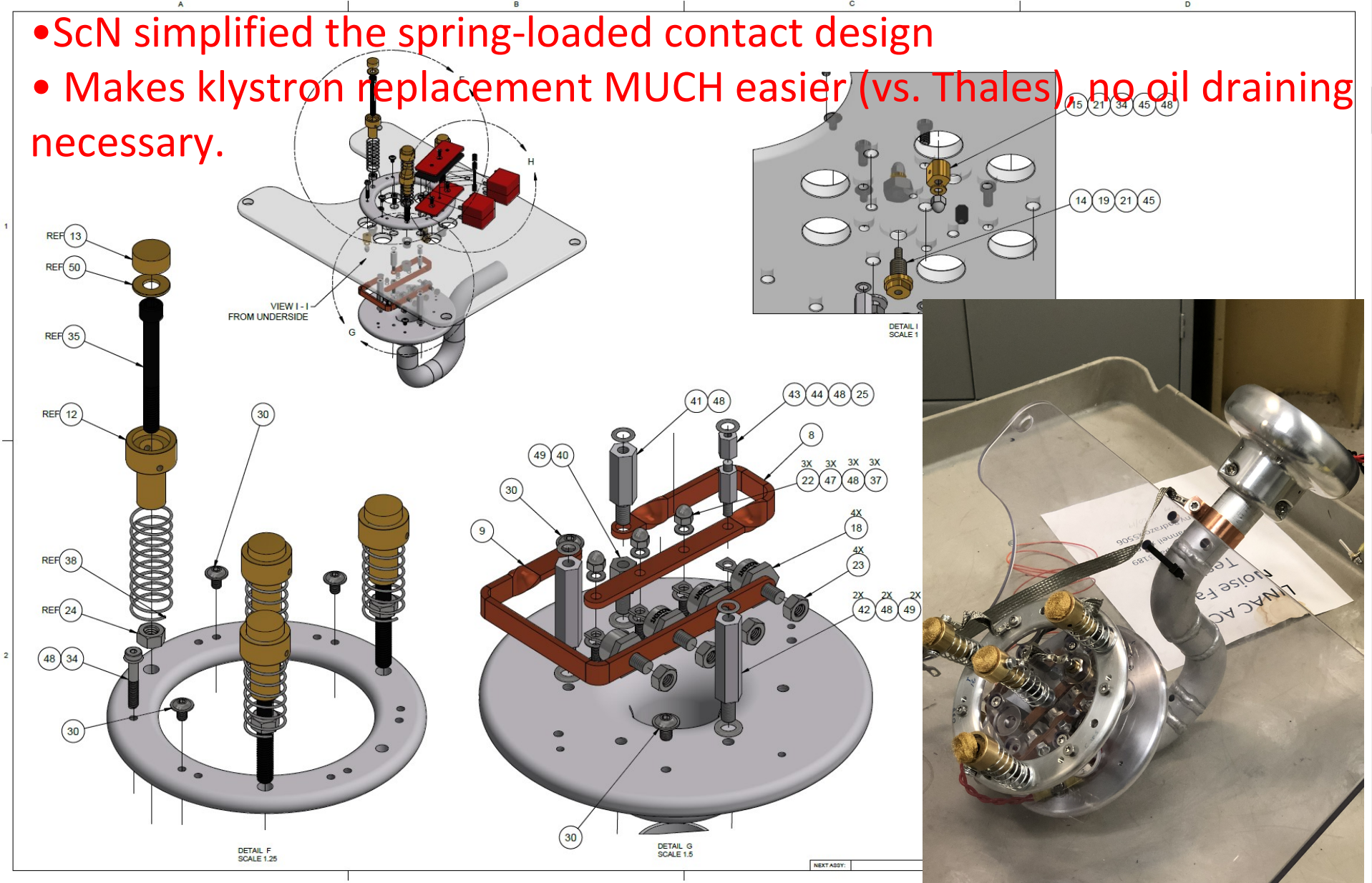
K2 kly. mounting plate and socket assembly for TH2100A



MODULATOR K2 -> K300 UPGRADE: Tank Components (2)

- Toshiba klystron socket for E37302A

- ScN simplified the spring-loaded contact design
- Makes klystron replacement MUCH easier (vs. Thales), no oil draining necessary.

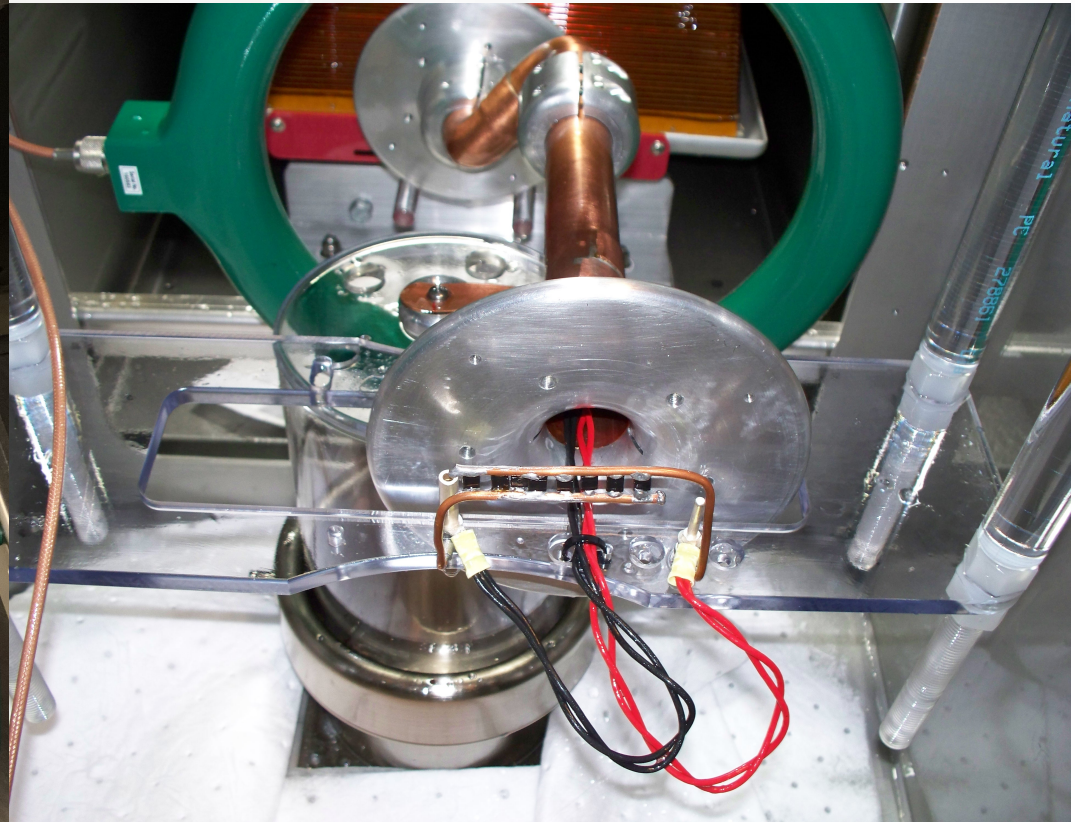


MODULATOR K2 -> K300 UPGRADE: Tank Components (3)

Upgrade ScandiNova HV Meas. devices to Commercial CVD/CT



CVT/CT arrangement in K2/K300 Upgrade Tank



CVD/CT arrangement in original K300 Tank

MODULATOR K2 -> K300 UPGRADE: Cooling System.

- Much of the K2 cooling system hardware is reused, BUT we had a problem: K2 cooling system could only supply a total flow of ~52L/min. , good enough for Thales, but CANNOT supply ~90 L/min. flow required by the Toshiba tube with 8 SU's. Thus, we need to upgrade K2 cooling system to achieve the required 90L/min. flow.
- Upgrade the main valve from old flow-restricting needle valve to a large-bore plunger valve (the most important upgrade !)
- Increase hose sizes
- Replace the other flowmeters and needle valves to a new and model with an integrated flow control valve



New plunger-type, larger-bore MAIN valve and flow meters



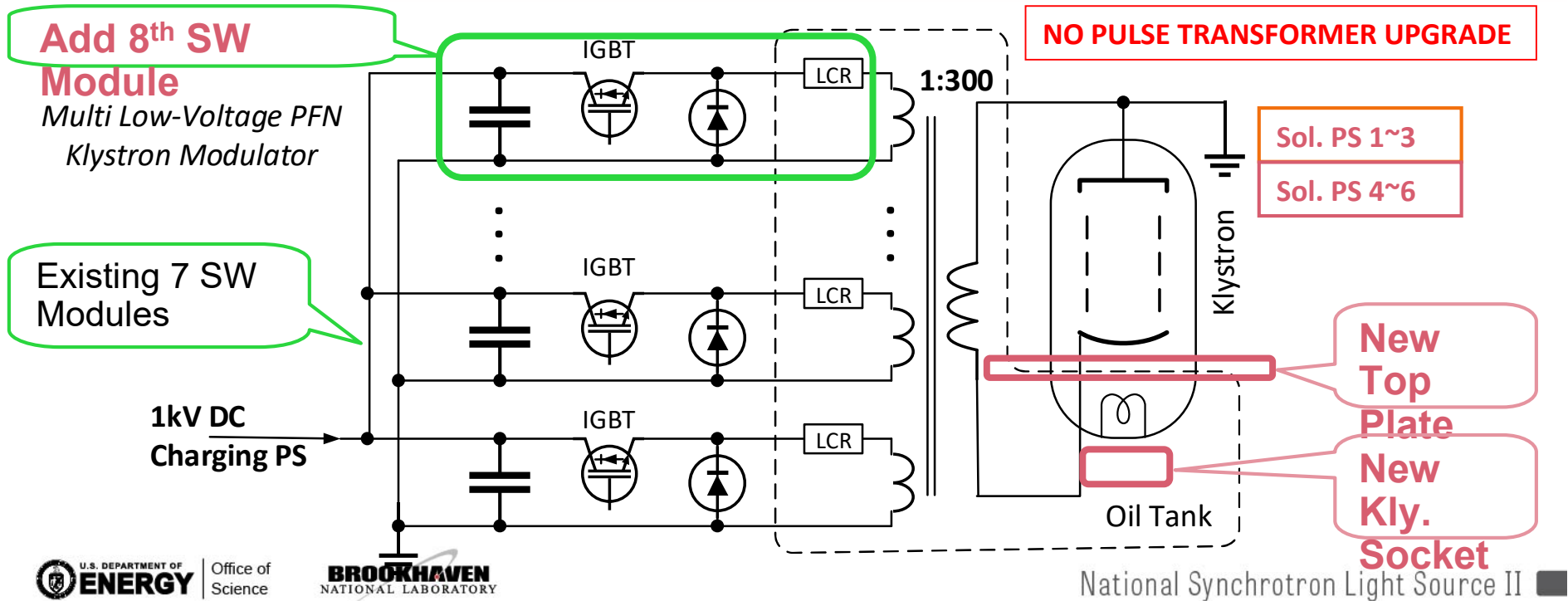
Old flow-restricting needle valves and flow meters

Na

MODULATOR K2 -> K300 UPGRADE: Add 8th SU

NSLS-II LINAC had three existing ScN K2 modulators for Thales TH2100A klystrons that need to be upgrade to K300 Model specifications to support the the bigger Toshiba Klystron E37302A. The upgrade was done by ScN, and the **SOW** includes;

| UPGRADE AREA | INVOLVED COMPONENTS |
|----------------------|---|
| Control and Platform | Upgrade to new K300 control system, PDU, and interlocks |
| Auxiliary PS's | Add 1 SU to increase total # to 8, new SOL., FIL., and HV |
| In-Tank Components | New Kly. mounting plate and socket; CVD/CT; tuning circuits |
| Cooling System | Upgrade valves, flowmeters, and hose sizes to for high flows. |

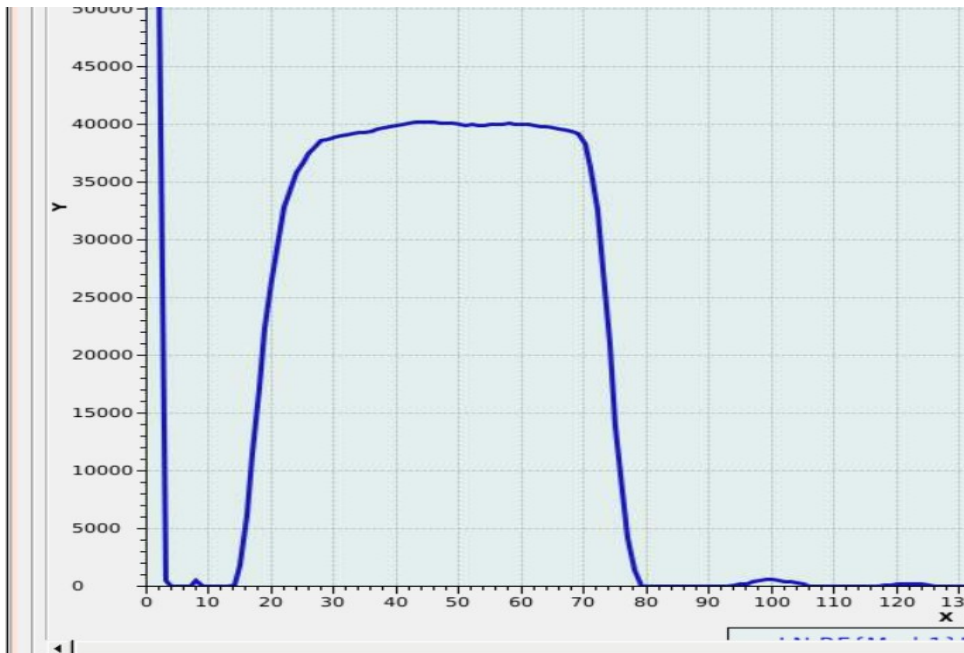


MODULATOR K2 -> K300 UPGRADE: Performance with 8 SU's

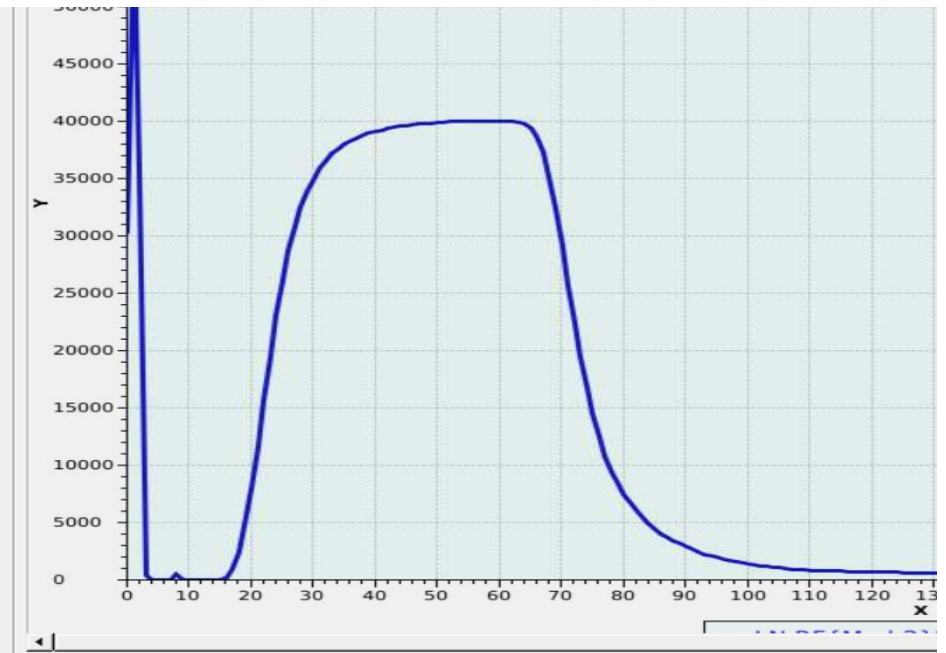
BNL K2 Upgraded K300 Modulator vs. Original K300 Model

- The two are very similar in major specs and performance
- In some areas, the K2/300 is actually better than K300, such as AC power load distributions.
- Small difference in pulse waveform quality
 - Cleaner rising and falling edge with the TRUE K300 Model
 - Flatter flattop with the TRUE K300 Model
 - This difference is resulted from the fact that K300 has a 8-group secondary winding HV pulse transformer to perfectly match with 8 SU's, versus the K2/K300 modulator with a 7-group winding transformer connected to 8 SU's in 6+2 form. (we did not upgrade the pulse transformer for cost reason)
 - Not a real issue for BNL as we use only a small portion (up to 300nS) of the 4-us flattop, thus we only need it be "piece-wise" flat for 300nS. Plus, we have the AFF rf compensation to make the final result FLAT.

K300 modulator. CVD waveform



K2/K300 modulator CVD waveform



K2 Modulator Upgrade to K300: Replace double-Ebend Waveguide with Single-Ebend Waveguide



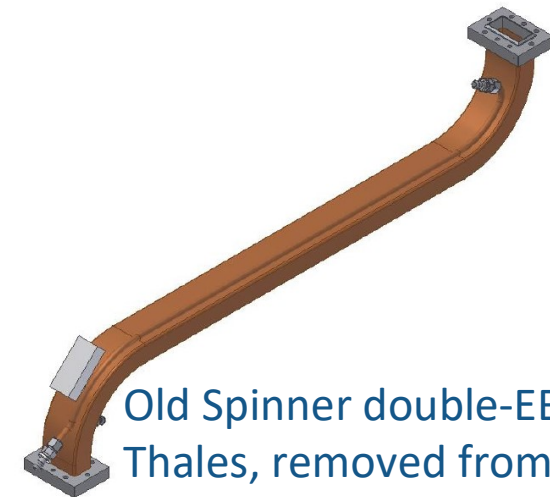
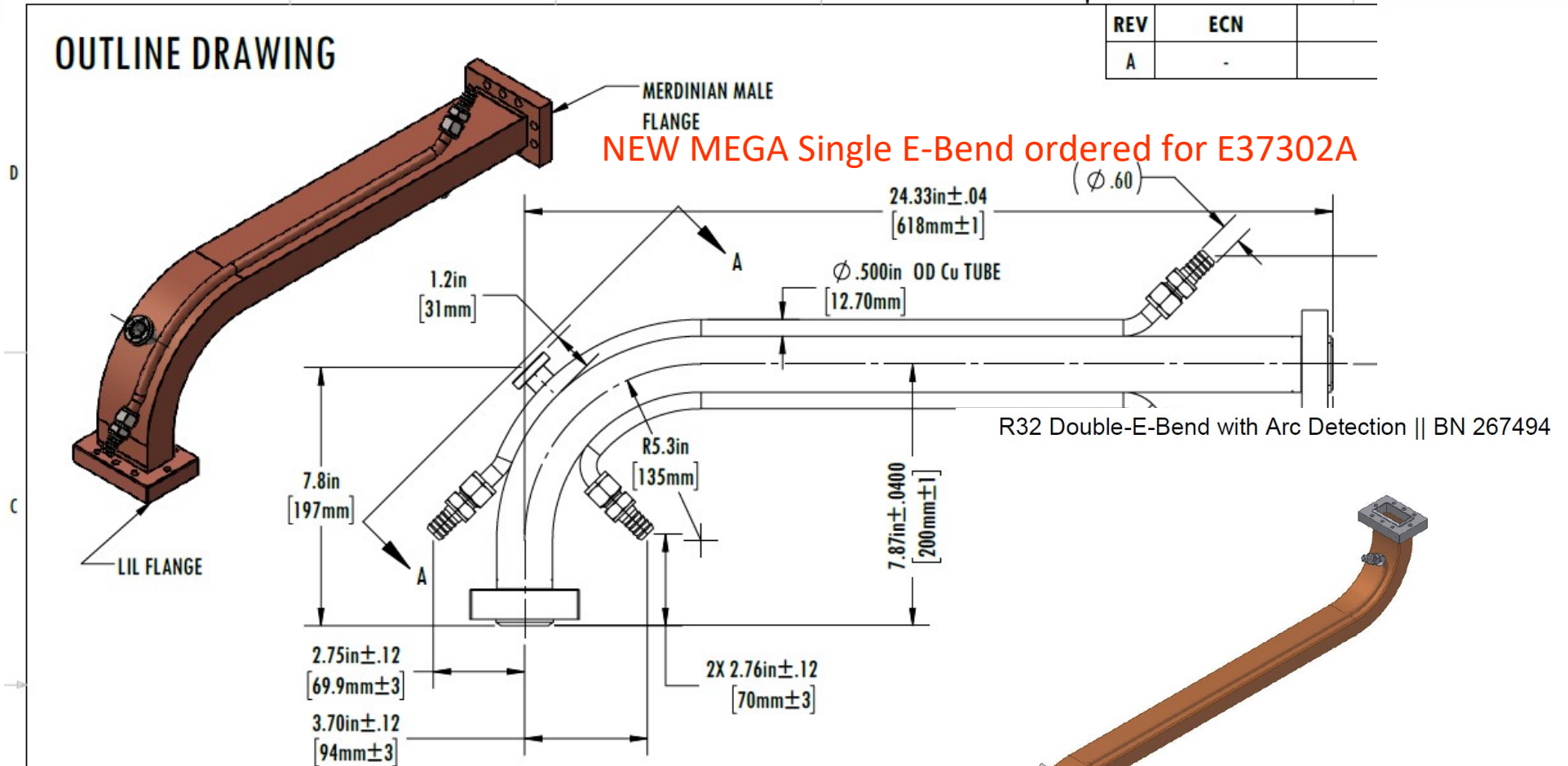
- Toshiba has a vertical output WG vs. horizontal on Thales;
- Lead shielding is also skinnier on Toshiba

MODULATOR K2 -> K300 UPGRADE: Klystron Waveguide

Toshiba E37302A klystron has an upright output waveguide port, vs. a horizontal one on Thales, therefore the original double-EBend waveguide has to be replaced with a single-EBend waveguide. The new waveguide can be obtained by either modifying the old waveguide, or ordering from WG manufacturer. We did both ways.

OUTLINE DRAWING

| REV | ECN |
|-----|-----|
| A | - |



Old Spinner double-EBend for Thales, removed from K2

- **Conclusion:** BNL K2 to K300 modulator upgrade project is a great success. It has significantly improved our LINAC in both performance and reliability.
- **Remaining issue:** Obsolete Windows-7 OS of the modulator control PLC -> no possibility of installing approved remote desk apps for ScN remote technical support.

Thanks for your attention !

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