Maintenance and Optimization of Aviza HSE Sputter Etch Chamber

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plasma metrology experience

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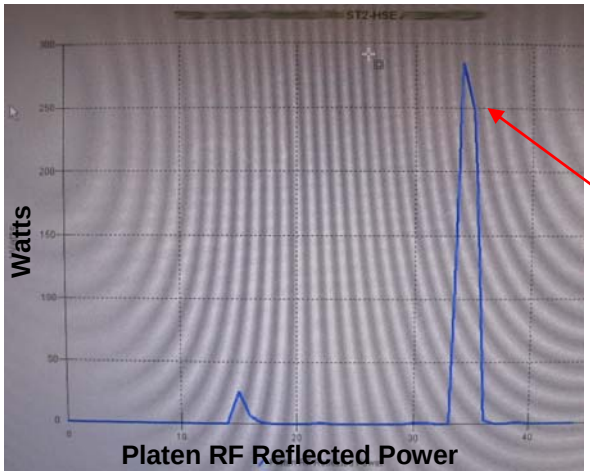
Outline:

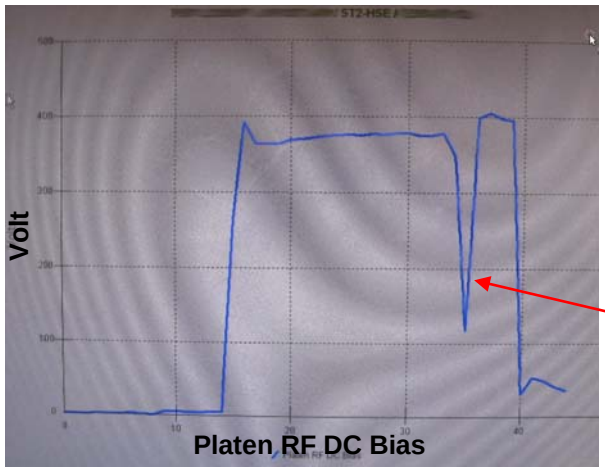
- Process issue and understanding
- RF characterization of chamber parts
- Failure Analyses
- Solution by RF system refurbishment
- Results - Failure statistic
- Summary

Process Issues: Reflected Power Warnings / Aborts …



- Our Aviza **H**ot **S**putter **E**tch chamber (HSE) frequently suffered from:

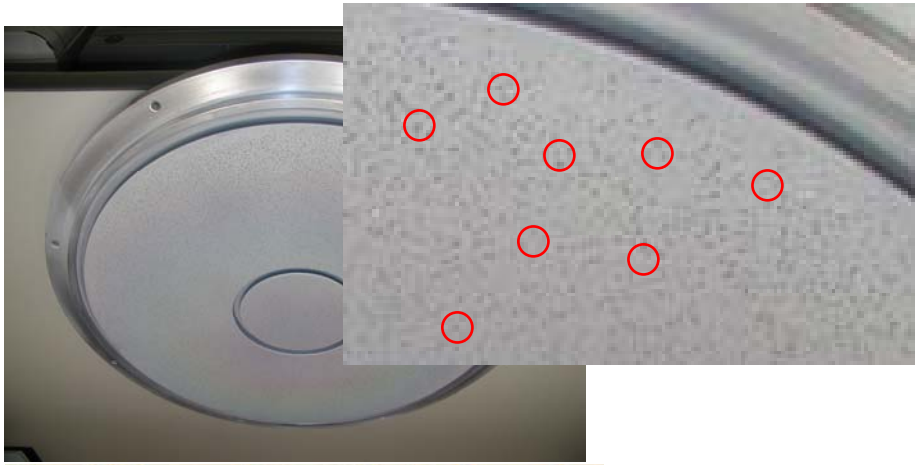
  Platen RF Reflected Power Warnings/ or Aborts



- Accompanied by instable etch plasmas and therefore

  Platen RF DC Bias Warnings/ or Aborts

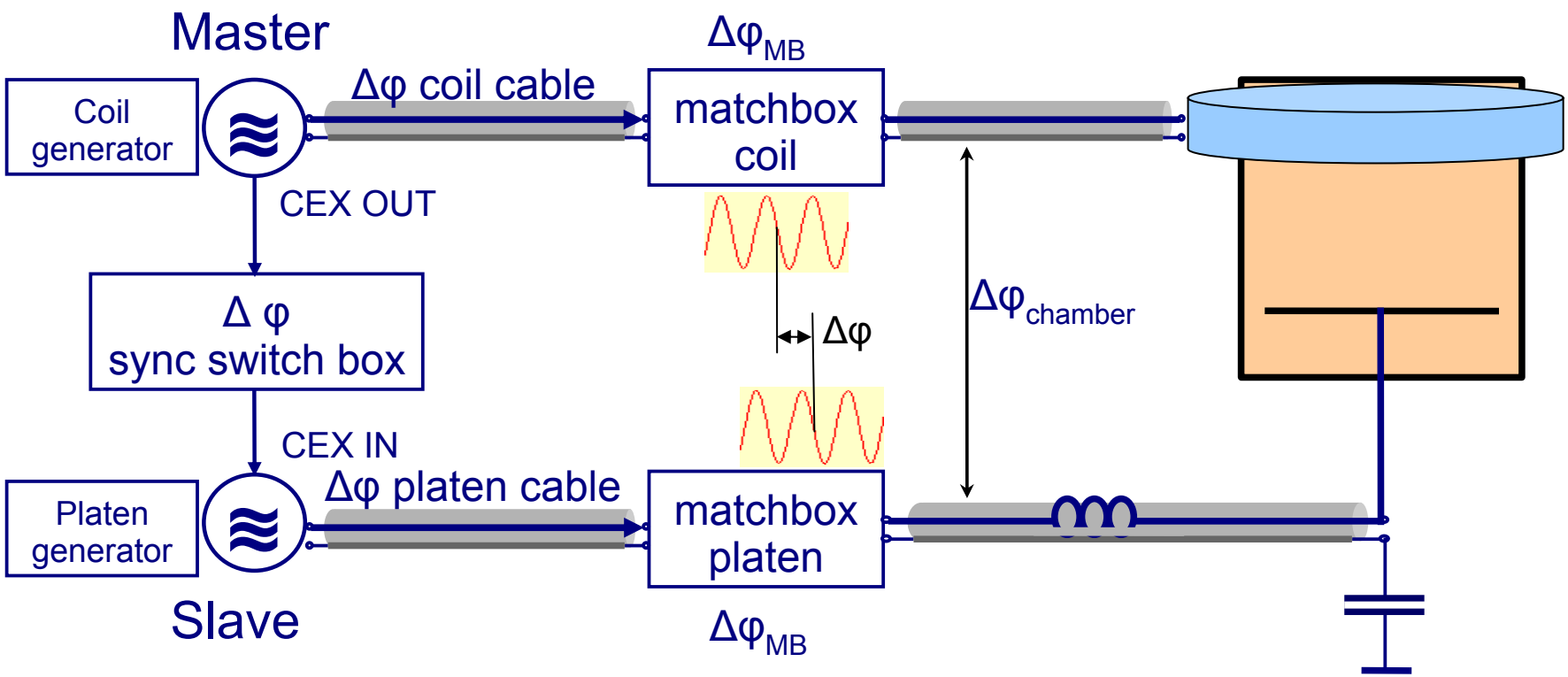
Arcing…



- Opened Chambers showed signs of Arcing
  - On the chamber lid
  - Or in strong cases even black residuals on the chamber walls
  - Resulting in increased DD and single wafer Scrap

Chamber Setup - Phase Angle – How it works

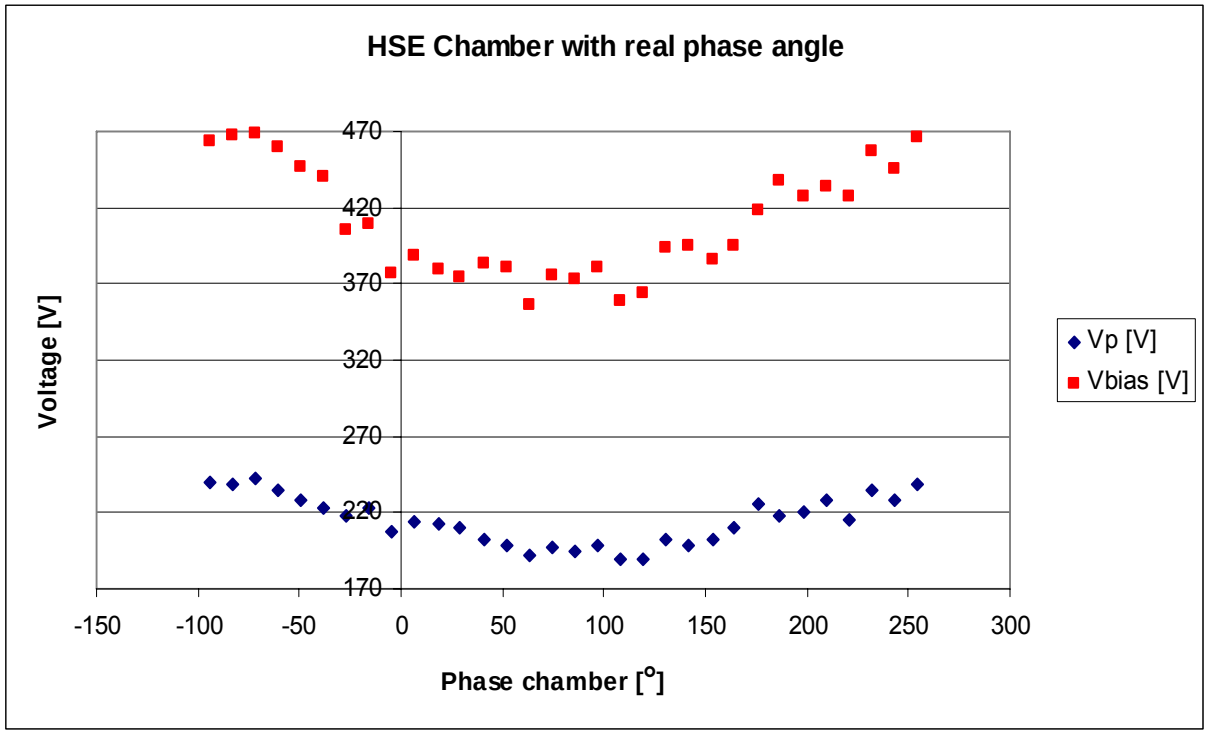
- Synchronization of coil and platen generator:



Why is the Phase Angle important for the Etch Rate & Damage?

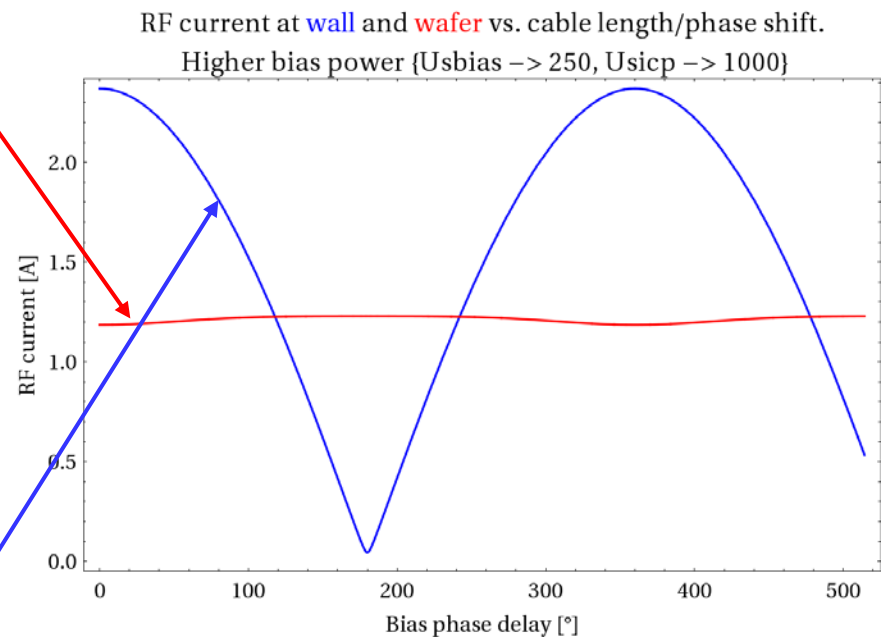
- Phase Angle between Coil and Platen impacts
  - Bias voltage → Ion energy → Etch rate & Damage

measured by TI – recalculated with corrected values



Why is the Phase Angle Important for Process Stability?

- RF Hardware stability → RF current in chamber → Process stability
- Stable Wafer RF current → ion energy → etch rate → no big influence



Nonlinear plasma model for Aviza HSE by Plasmetrex

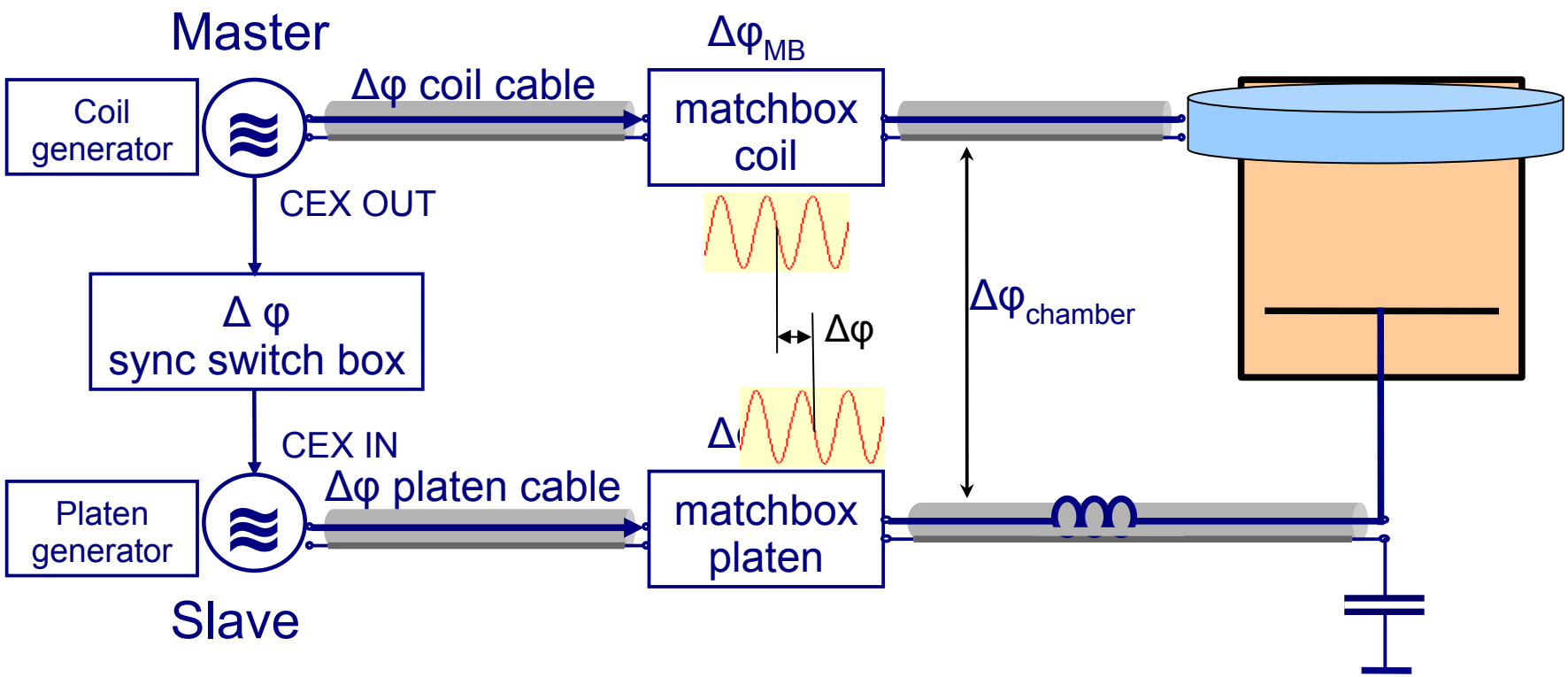
- High RF current variations at chamber lid → Process instability, ignition problems, aborts, arcing …

RF Characterization of Chamber Parts

- The main Principle
- Generators
- Phase shifter (SSB = Synchron Switch Box)
- Entire system

Phase Angle – How it works

- Synchronization of coil and platen generator:

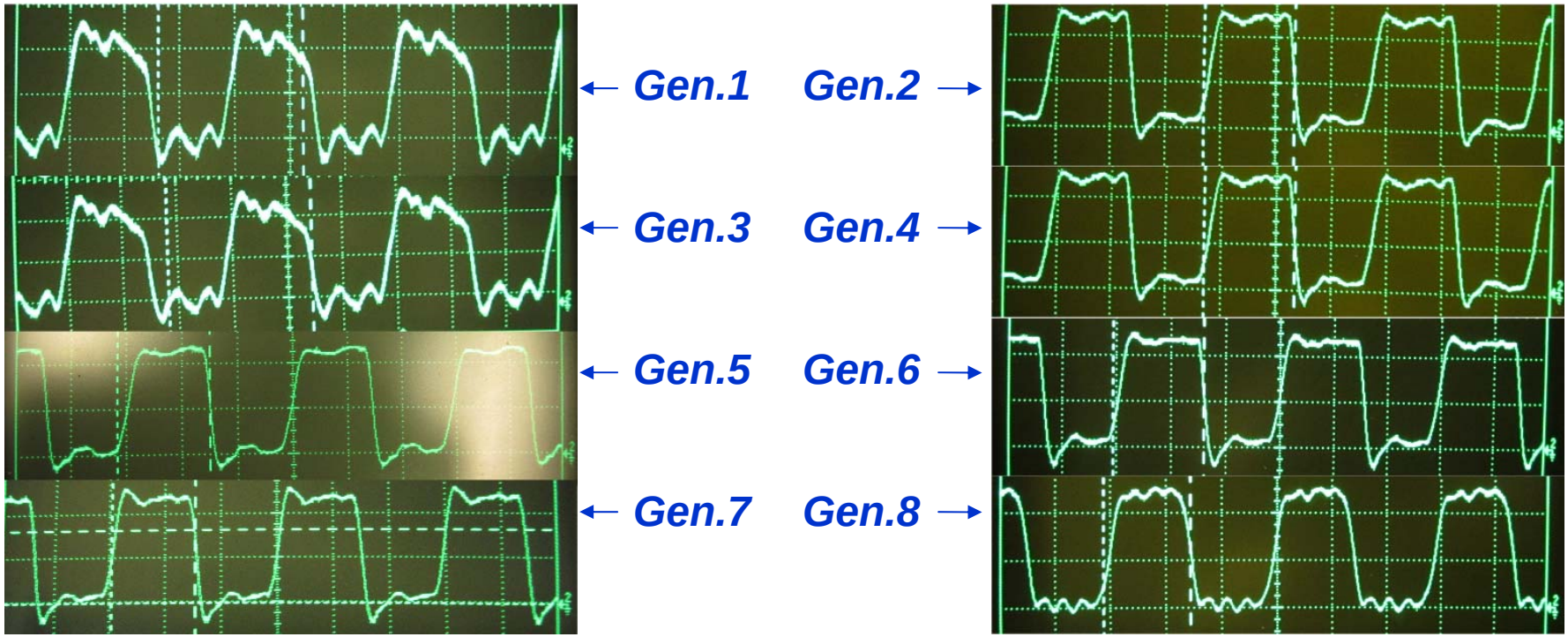


What is needed for stable RF Hardware and Process?

- The control signal from the Master Generator (CEX OUT) must be well defined in shape and phase angle: ideally a rectangular signal.
- Transmission of the control signal must not influence neither shape nor phase significantly.
- The Slave Generator must use the input signal (CEX IN) correctly.

Generator: Shape of Control Signal at Output

Variations across different Generators:



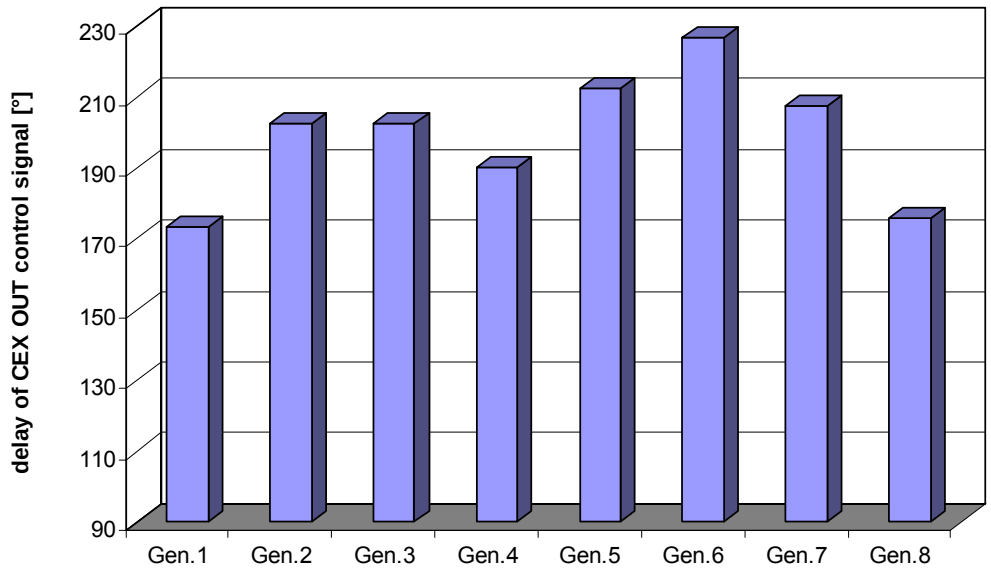
The ideal shape of the control signal should be a rectangular signal.
This signals are recorded with dummy loads - real loads are even worse
Possible reason: Generator aging.

Measurement Equipment used: Digital 500 MHz Scope HP 54615A with various hf probes.

Generator: Phase Variance of Control Signals

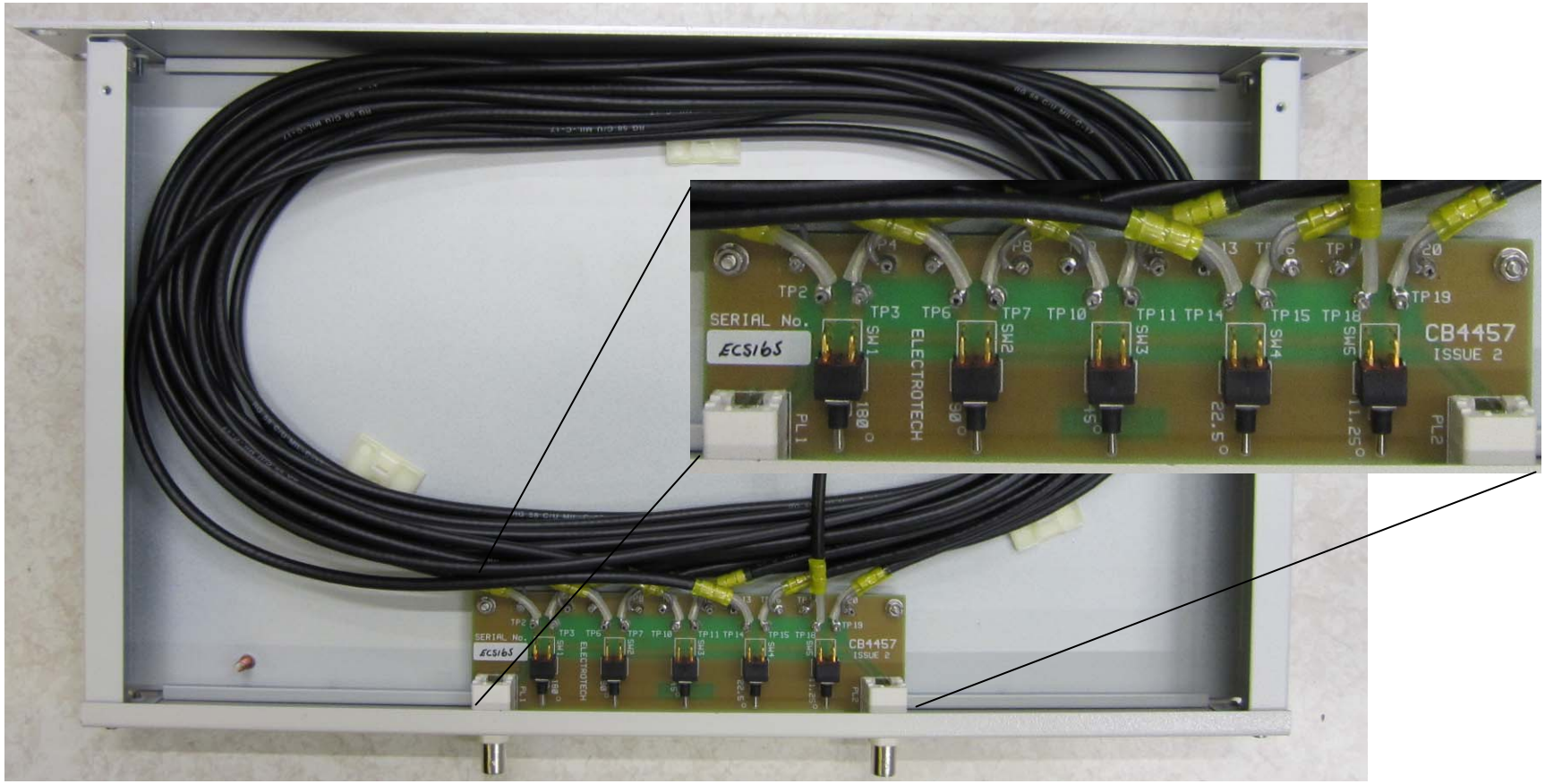
- The shown variance in the control signal referred to RF power output is directly transferred to the same phase variance at the chamber! *The tool offers adjustment in steps of 11°!*
- Any change of a generator can lead to a nonfunctional chamber as often experienced.

Measurement: Falling edge of power output to falling edge of control signal.



Generator influence on control signal

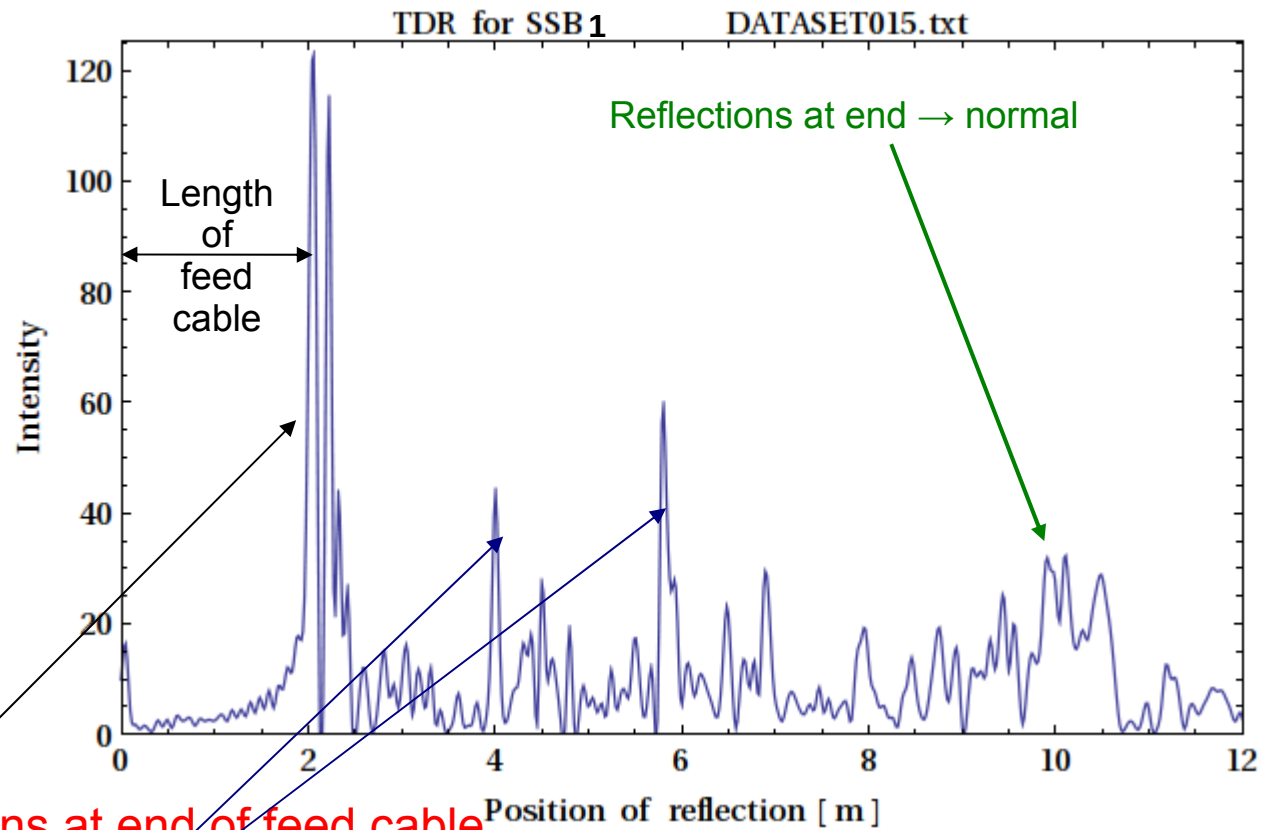
SSB = Synchron Switch Box



- The SSB is designed to delay the control signal (=phase shifter);
  - With dip switches cables of different length are combined
  - It offers adjustments in increments of 11,25°

Poor Transmission due to Signal Reflections at Switches inside the SSB 1 (= Synchron Switch Box 1)

Measurement:
Reflection with open end
Network analyzer
FSH 3 with VSWR
bridge FSH-22
(Rohde & Schwarz)

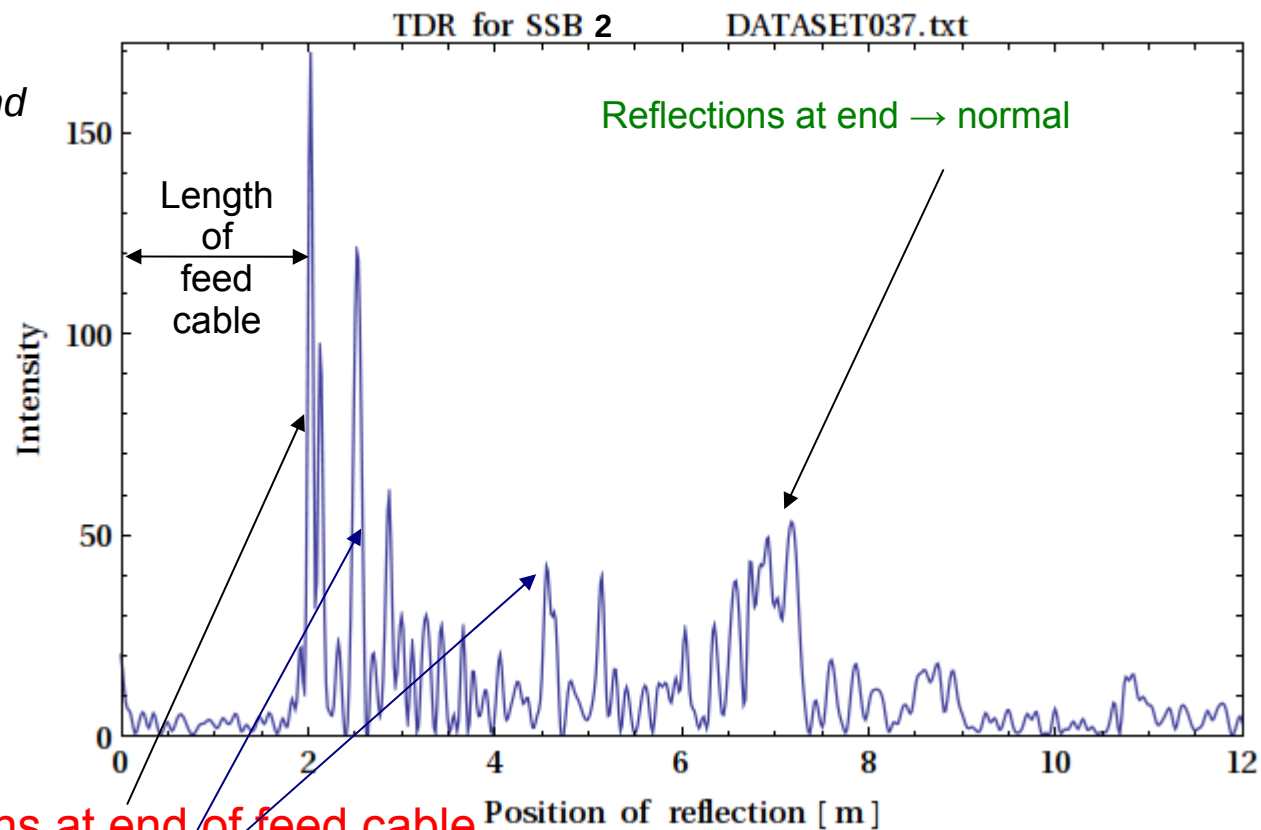


Issue:
Signal reflections at end of feed cable
and multiple ones inside at switches …

Reflections lead to bad signal transmission and so to phase deviations!

…. SSB 2 (= Synchron Switch Box 2)

Measurement:
Reflection with open end
Network analyzer
FSH 3 with VSWR
bridge FSH-22
(Rohde & Schwarz)



Issue:
Signal reflections at end of feed cable
and multiple ones inside at switches …

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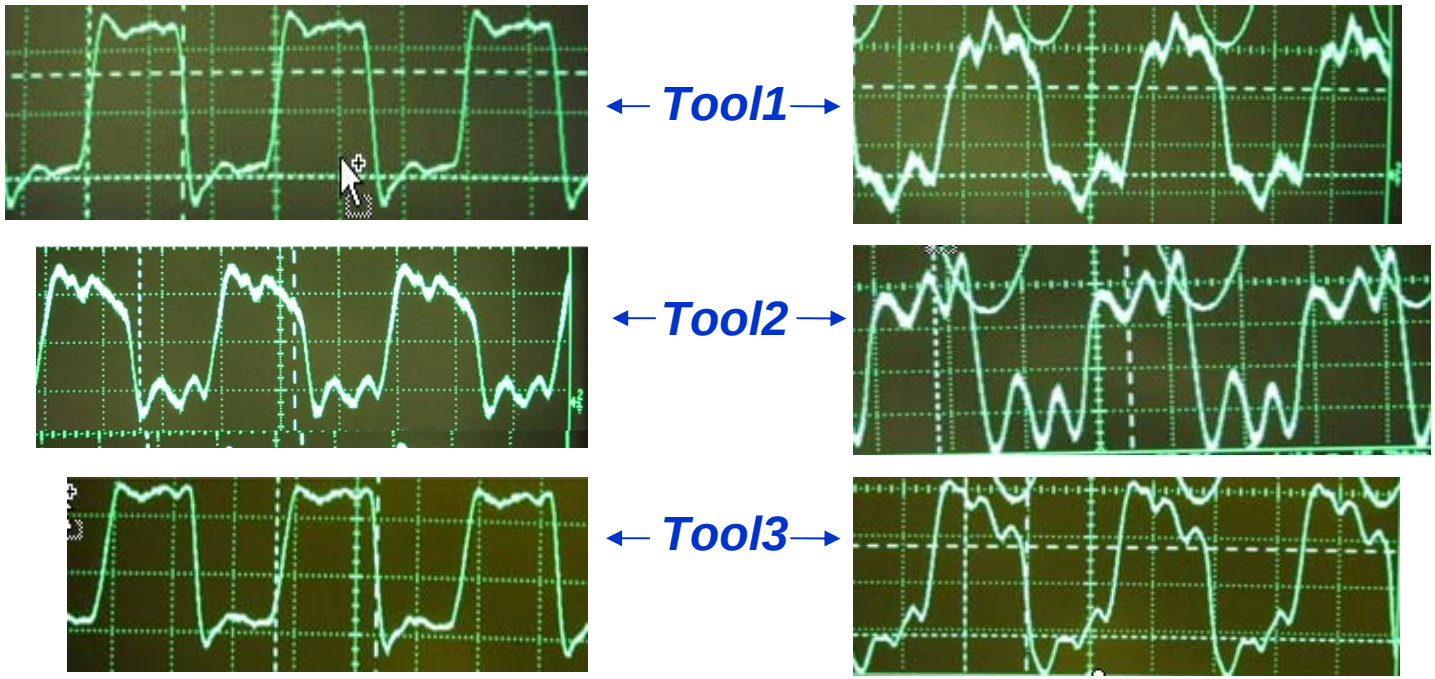
Control Signal before and after SSB

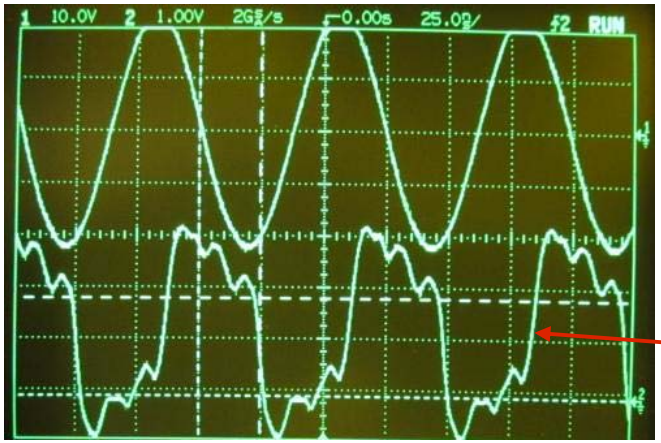
- Each SSB modulates the control signal differently !

Control signals

Before SSB: After SSB:

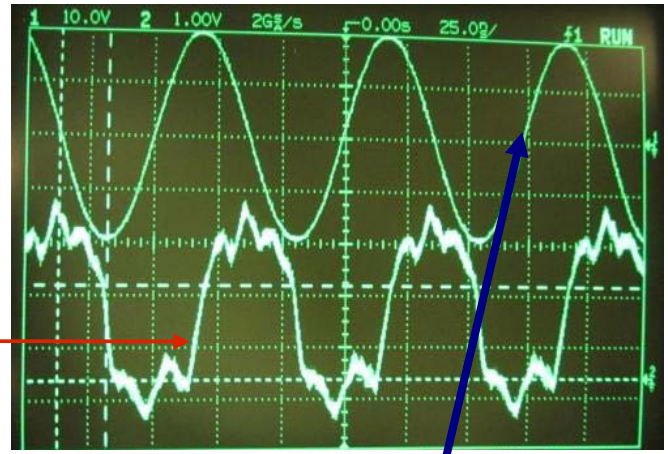


Worse Control Signals when SSB is connected to CEX OUT of Coil Generator



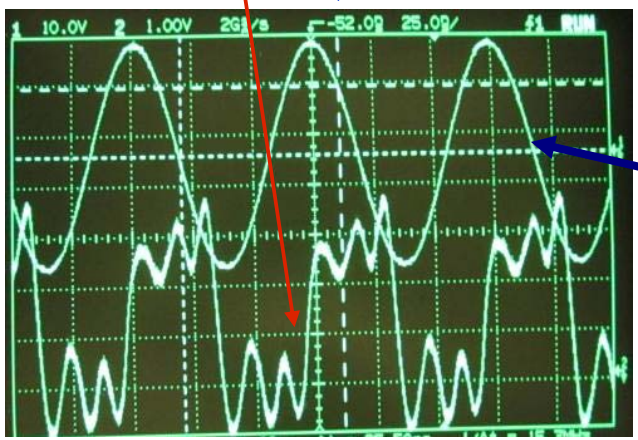
← *Tool1*

Tool2 →



control signal

Tool3



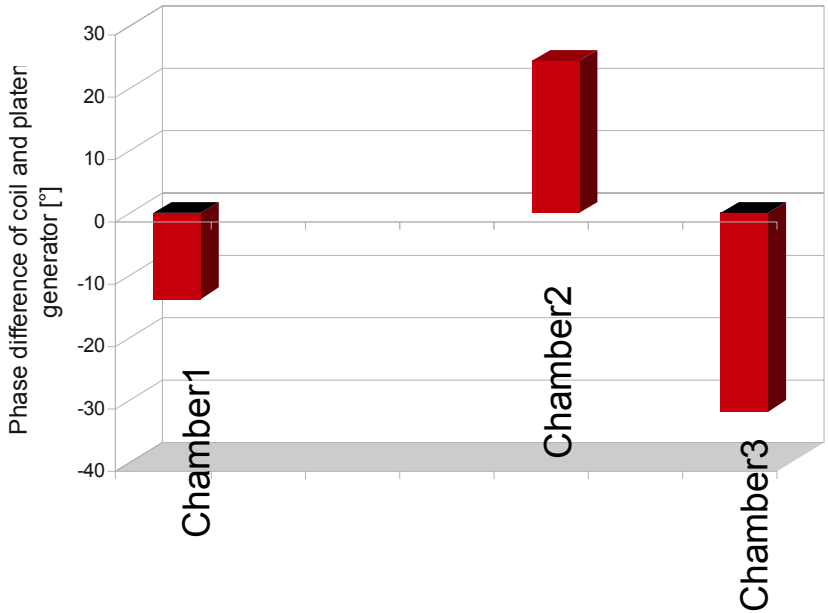
Δφ

Phase angle between coil control signal and Platen RF power output (falling edge to falling edge)

Platen RF power output

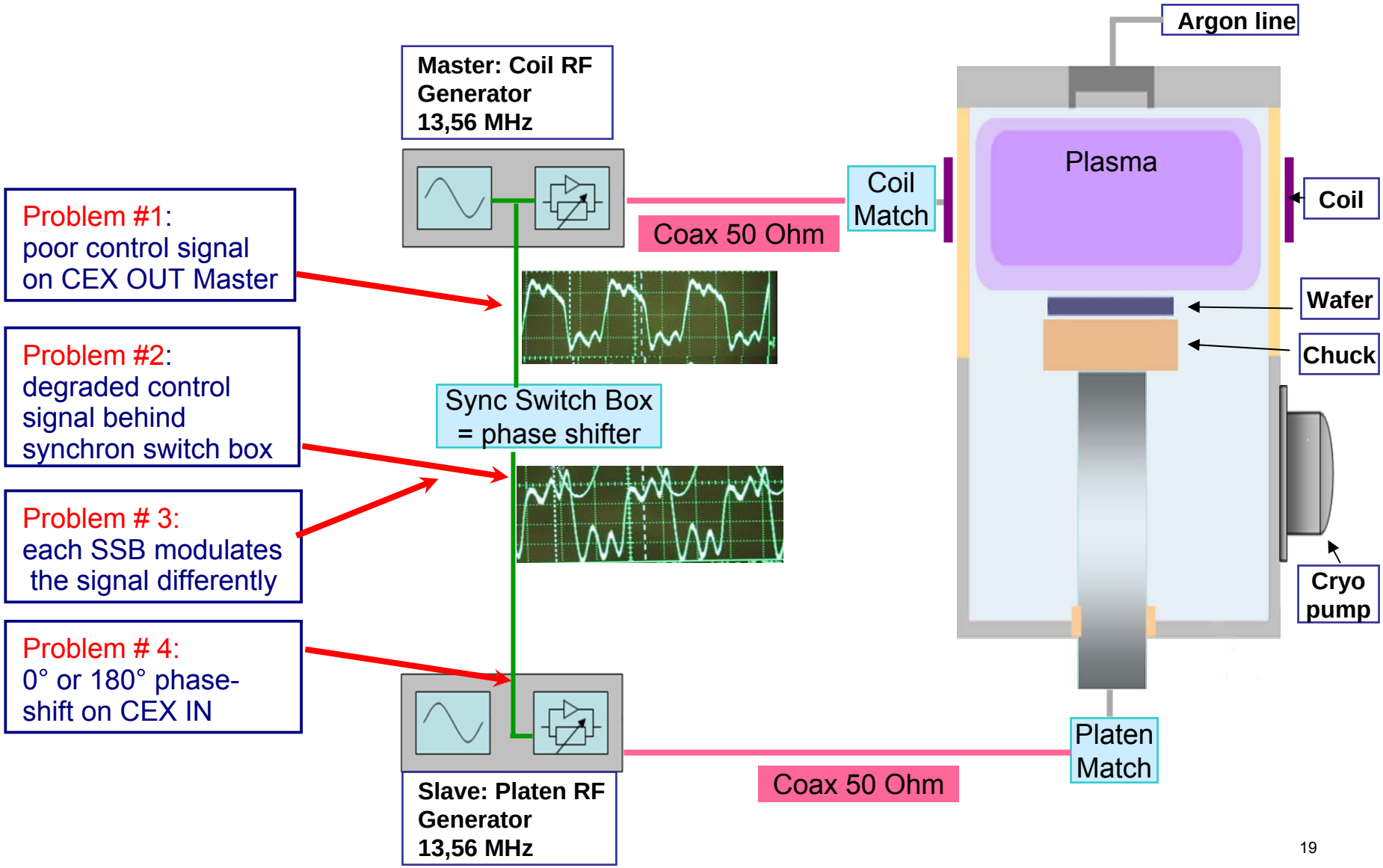
Total Phase Variance of three Chambers

- Phase deviations of Generators alone
- Total phase from two measurements = (control signal – output of coil generator) + (platen output – control signal)
- Test conditions:
  BKM recipe, 400W platen,
  300 W coil, Ar
- Range of phase error: 56°
- Can lead to different process results and unstable process (aborts).



Phase error finally depends on the combination of generator, SSB, and SSB adjustment.

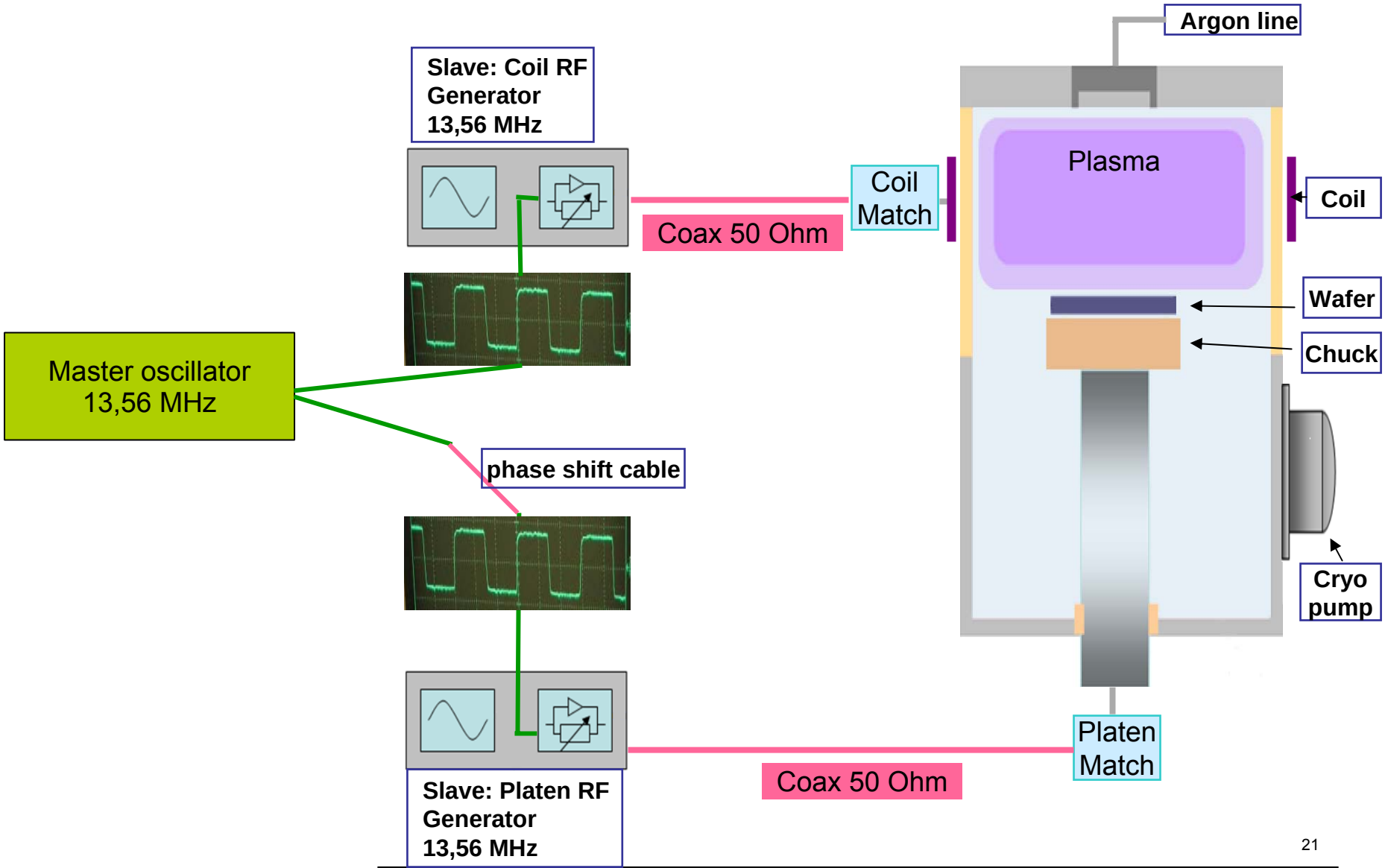
Baseline State – Failure Analysis (Summary)



Solution by Refurbishment of RF System

- Implementation of external Master Oscillator with stable and good shaped control signal
- Change the generator synchronization from Master/Slave to Slave/Slave
- Exchange of the SSB with fixed phase delay RF cable of defined length

Solution by Refurbishment of RF System



Pilot Chamber – Increased Stability

- **Current Status:** One chamber setup modified, comparing baseline to modification (on high utilization).

- **Baseline:** 115 warnings / 6 aborts in 8 weeks
  - mostly due to high reflected power.

- **Modified Chamber:** 0 warnings and 0 aborts in 8 weeks.

Summary

- **Issue:** Aging of generators, low quality of cables, and switches in phase shifter leads to unstable synchronization of coil and platen generator. Range observed at three chambers: 55°.
- **This results in risk of:**
  - Process aborts / scrap
  - Chamber down after generator is changed
  - Decreased uptime and OEE and increase of work load and costs of repair
- **Solution:**
  - Control by external master control signal generators
  - Replacement of all SSBs by customized cable set
  - Test method already verified