Window and Coupler Testbench at ELBE

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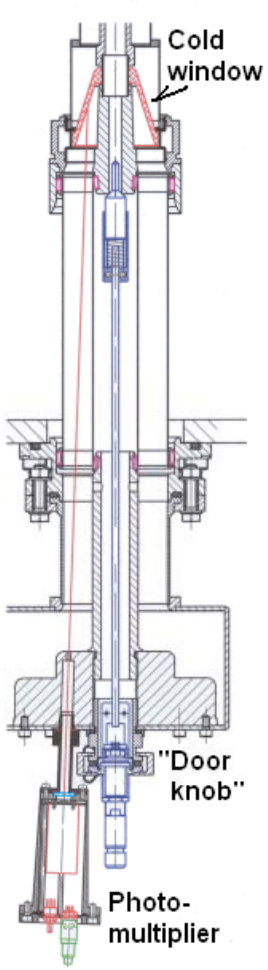
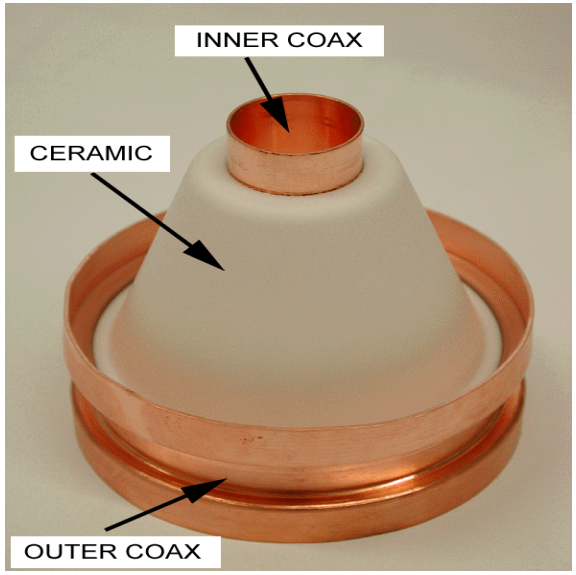
FZ Dresden-Rossendorf e.V.

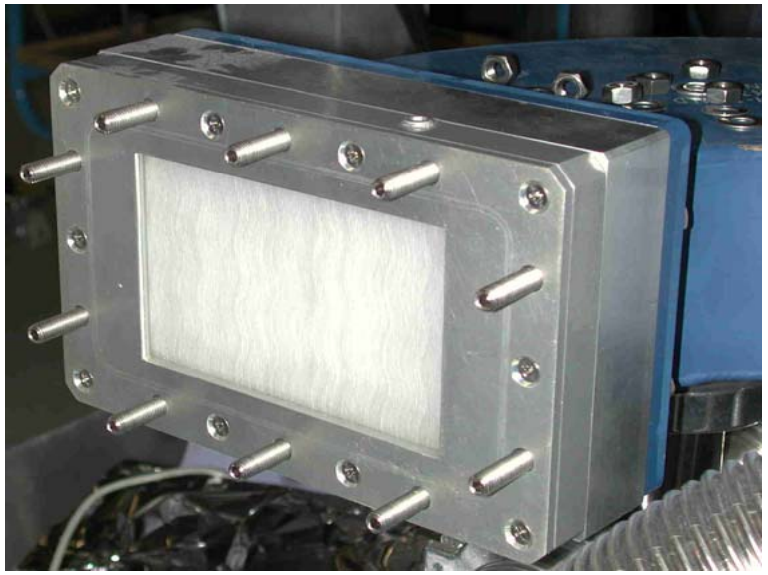
Introduction – Tested Parts



RF coupler with cold window and door knob transition.



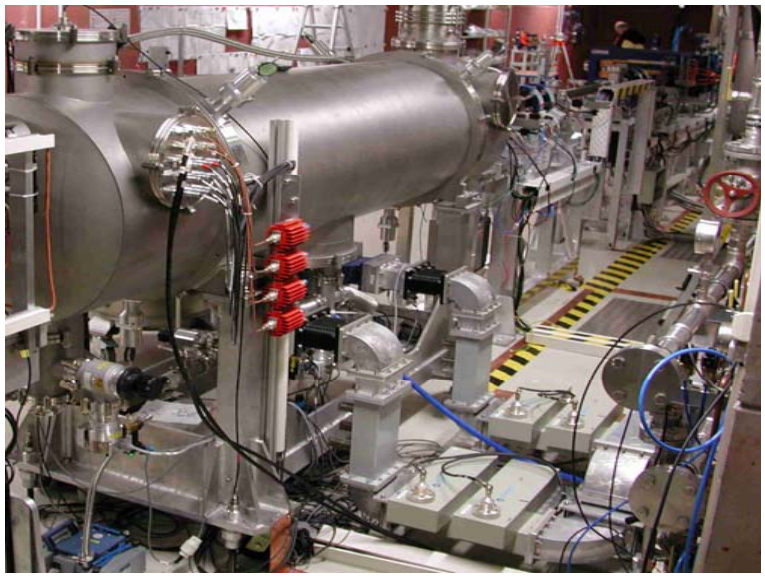
Disassembled cold window.



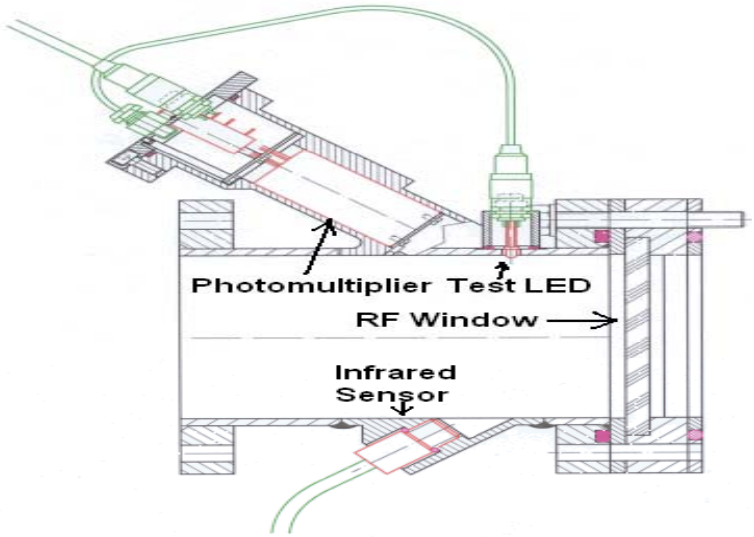
Warm window at the opened waveguide.

- ELBE RF-coupler has a fixed antenna tip length,
- operational bandwidth of 114 Hz,
- loaded quality factor QL of $1.2*10^7$.

Experience from normal Operation

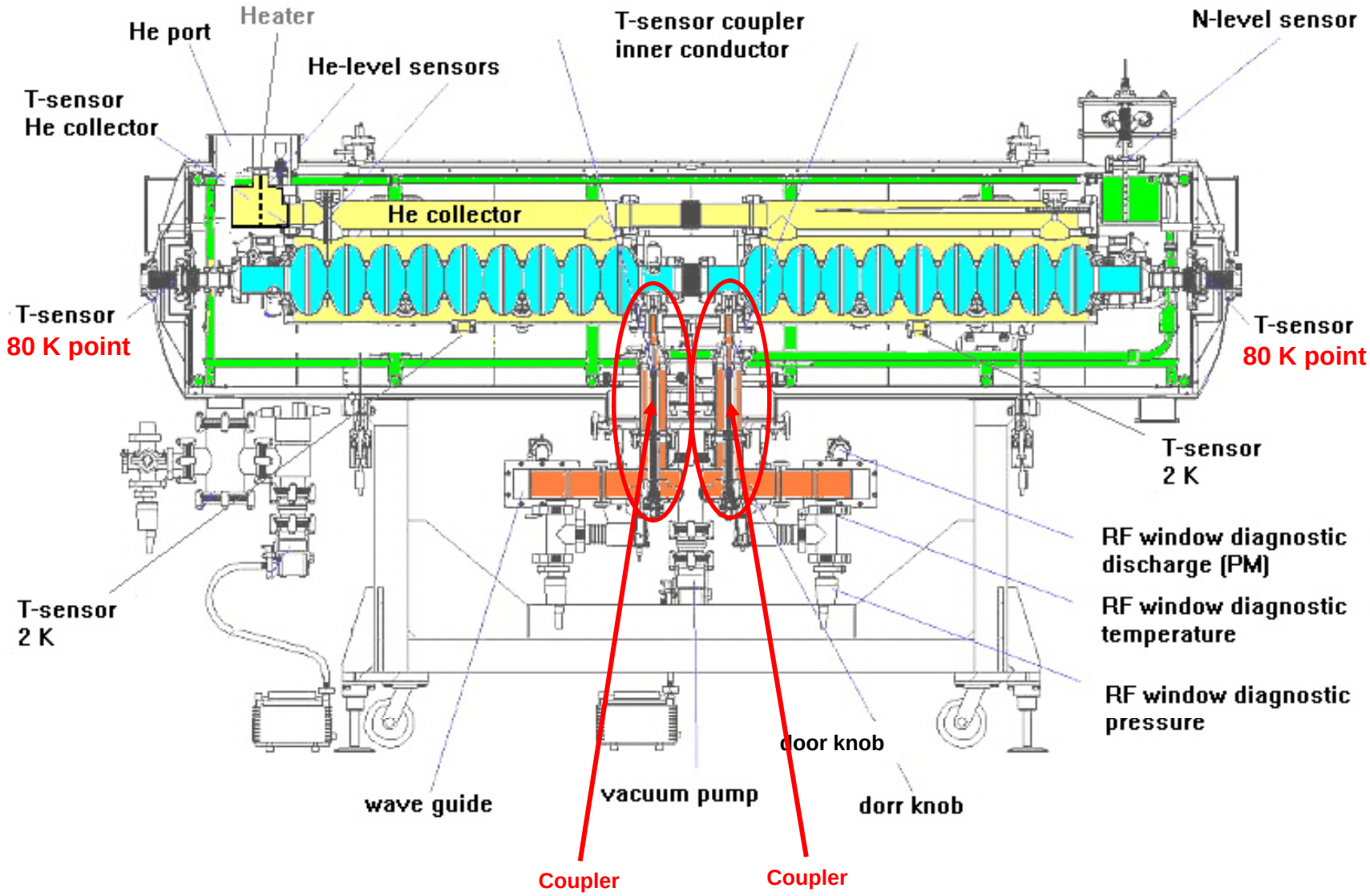


ELBE cryomodule with 2 RF-feeds.

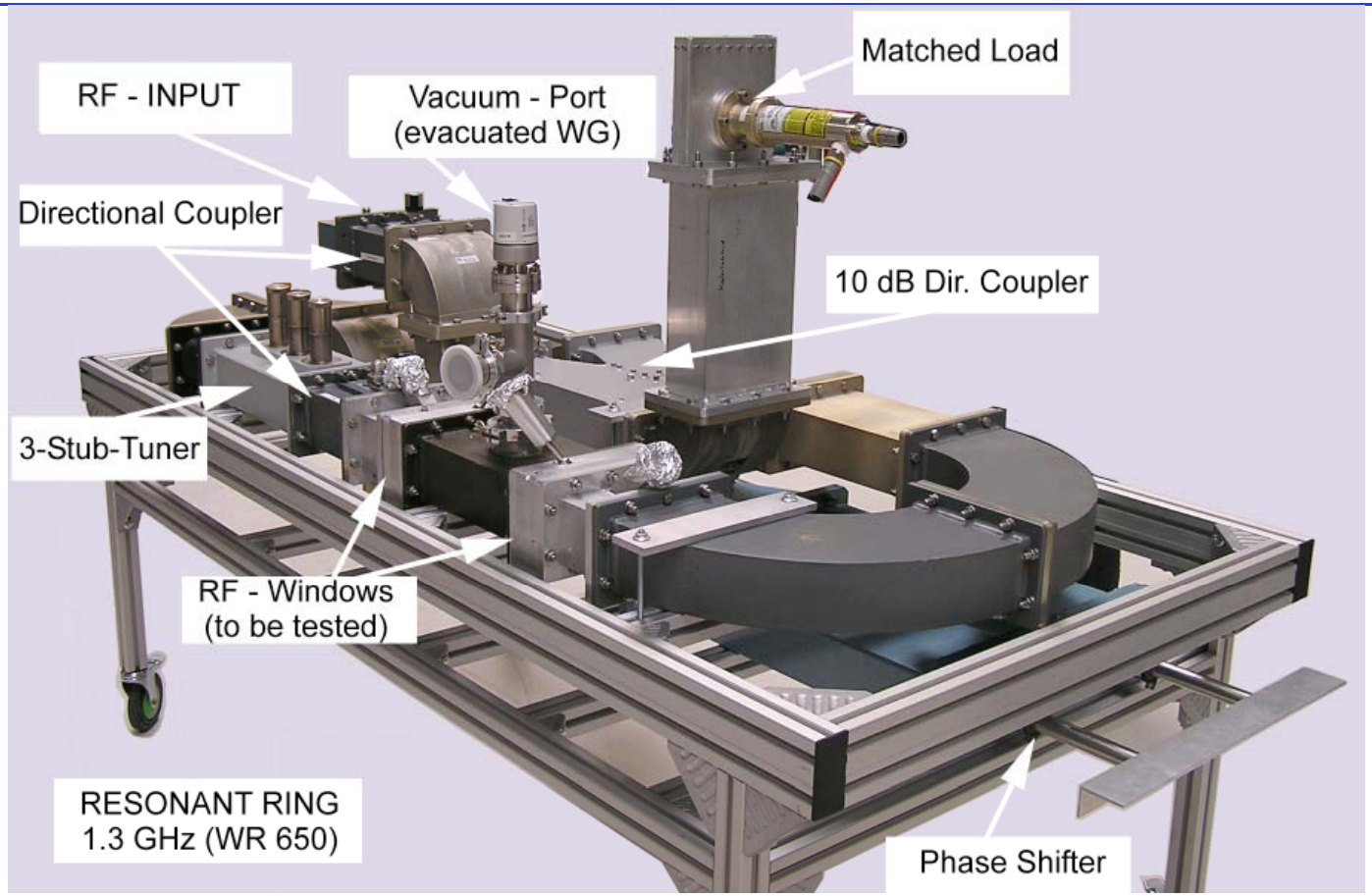


Waveguide warm window with sensors.

- Two Modules each contains two cavities used at ELBE.
- All couplers are identical,
- REXOLITE waveguide window with viton rubber sealings,
- Normal operation without problems at 8.5kW RF power.

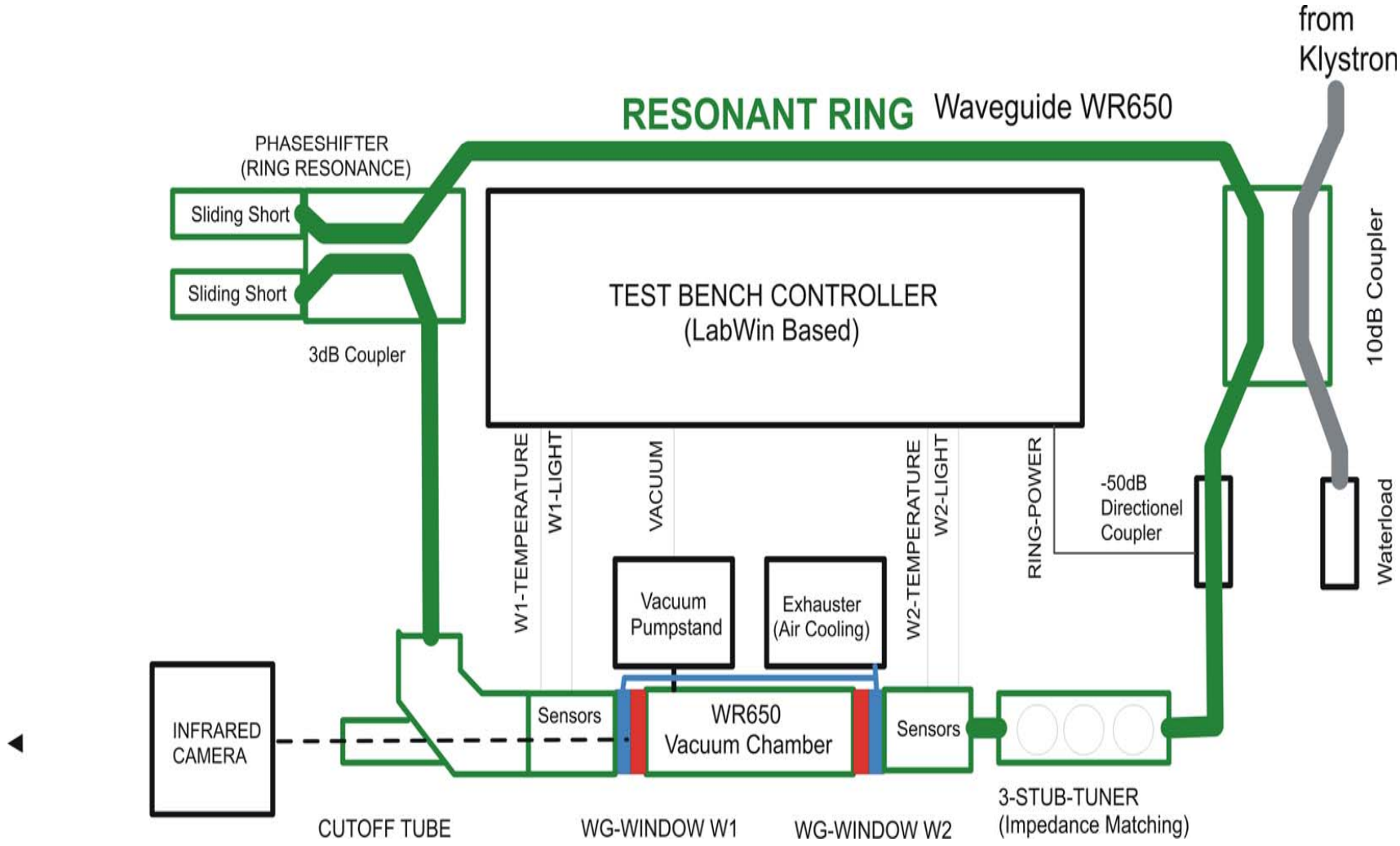

He port
Heater
He-level sensors
T-sensor coupler
inner conductor
N-level sensor
T-sensor
He collector
He collector
T-sensor
80 K point
T-sensor
80 K point
T-sensor
2 K
RF window diagnostic
discharge (PM)
RF window diagnostic
temperature
RF window diagnostic
pressure
T-sensor
2 K
door knob
wave guide
vacuum pump
dorr knob
Coupler
Coupler

The Resonant Ring

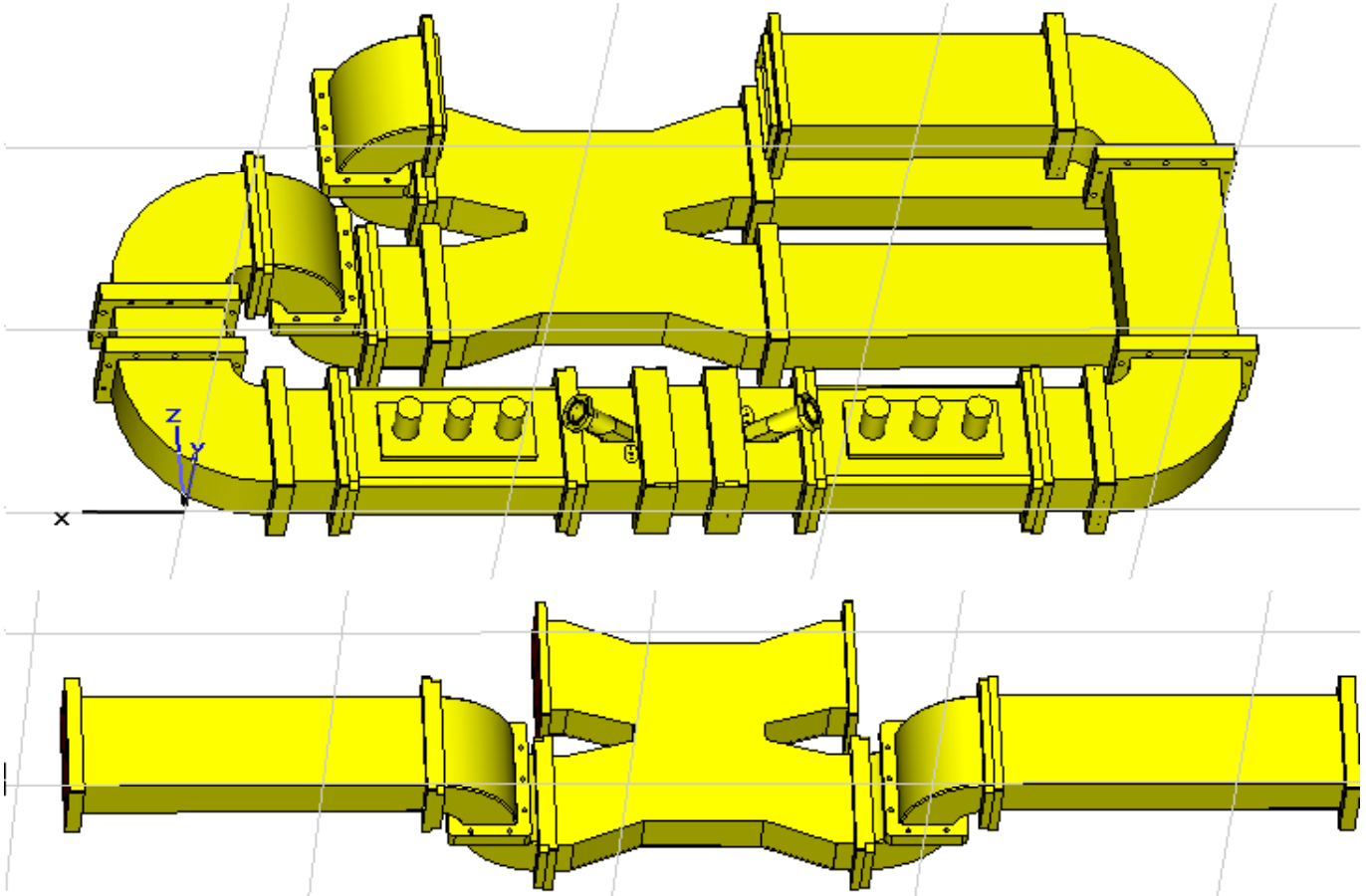


- Ring is driven by a 10 kW klystron VKL7811St (CPI),
- Waveguide phase shifter used to bring the ring into resonance.

The Resonant Ring – Block Diagram

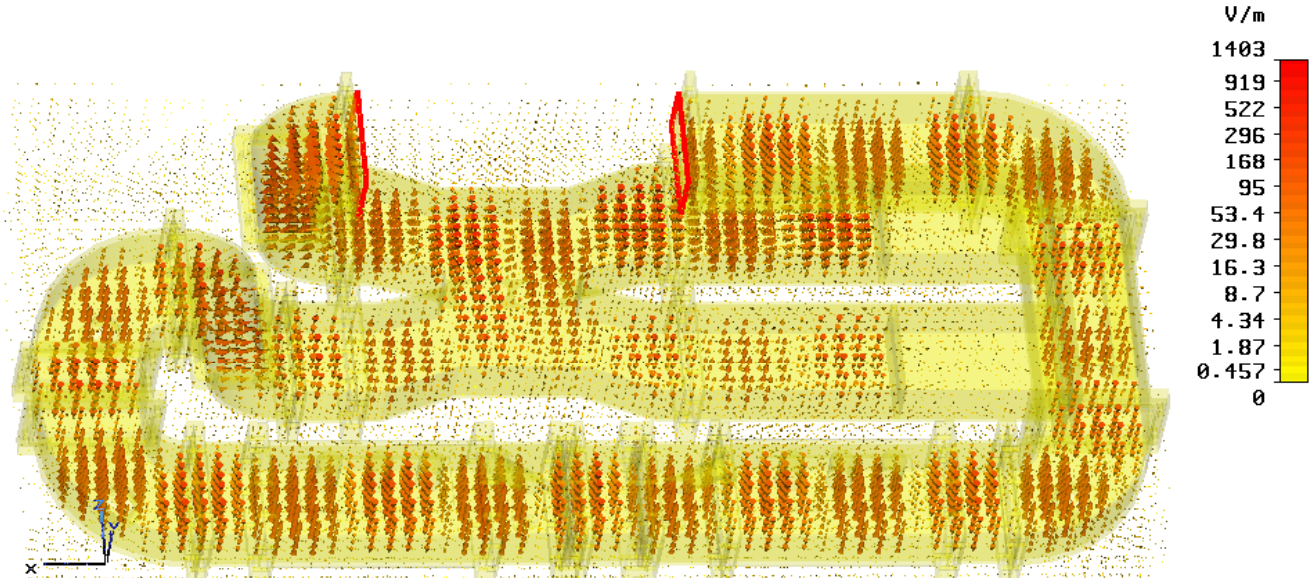


Simulation of the Resonant Ring



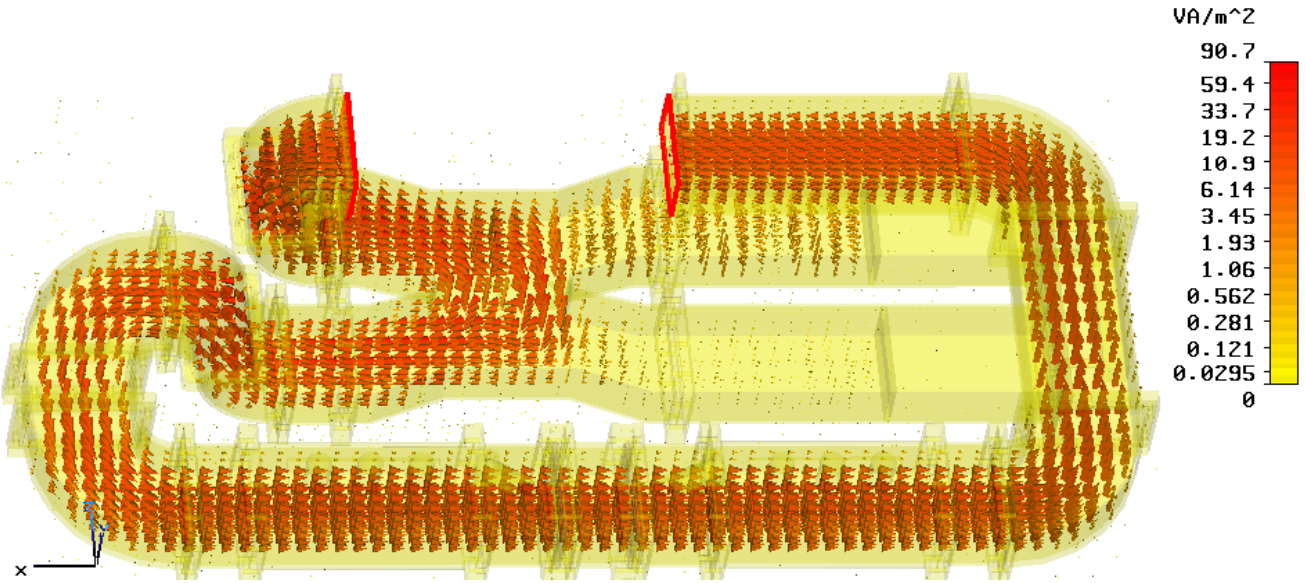
- Simulation with CST Microwave Studio,
- The resonant ring was split in two parts.

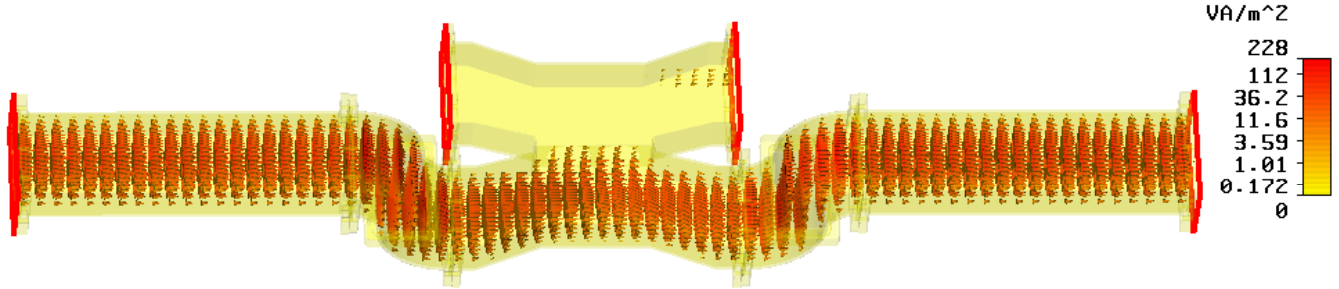
Electric Field in the Resonant Ring




```
Type         = E-Field (peak)
Monitor      = e-field (f=1.335e+009) [1]
Maximum-3d   = 920.54 V/m at -249.4 / 236.094 / 514.575
Frequency    = 1.335e+009
Phase        = 0 degrees
```

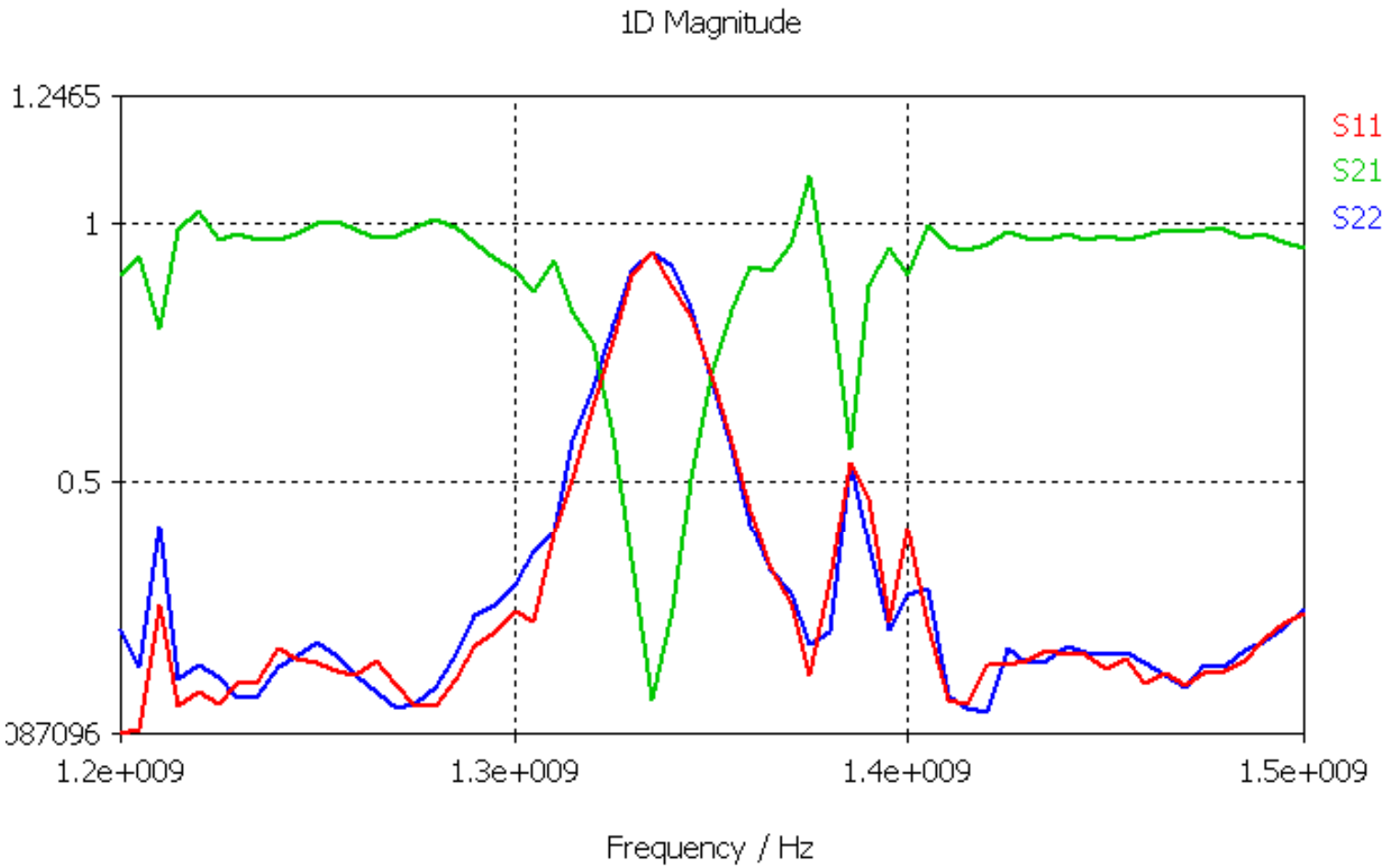
Power Flow in the Resonant Ring



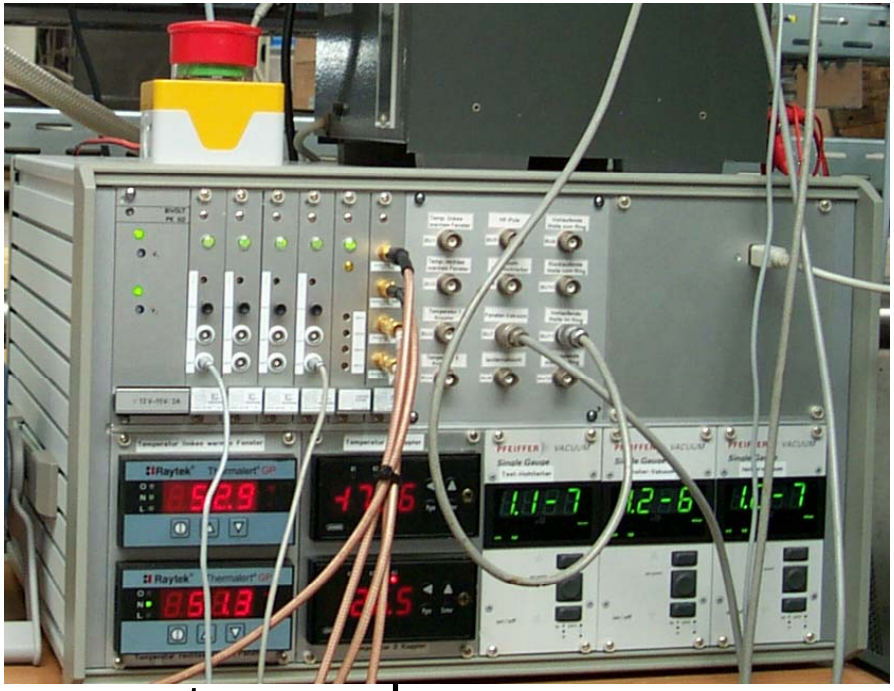



```
Type        = Powerflow (peak)
Monitor     = power (f=1.335e+009) [4]
Maximum-3d  = 227.662 VA/m^2 at 350.485 / 233.094 / 510.075
Frequency   = 1.335e+009
```

S-Parameter of the whole Resonant Ring

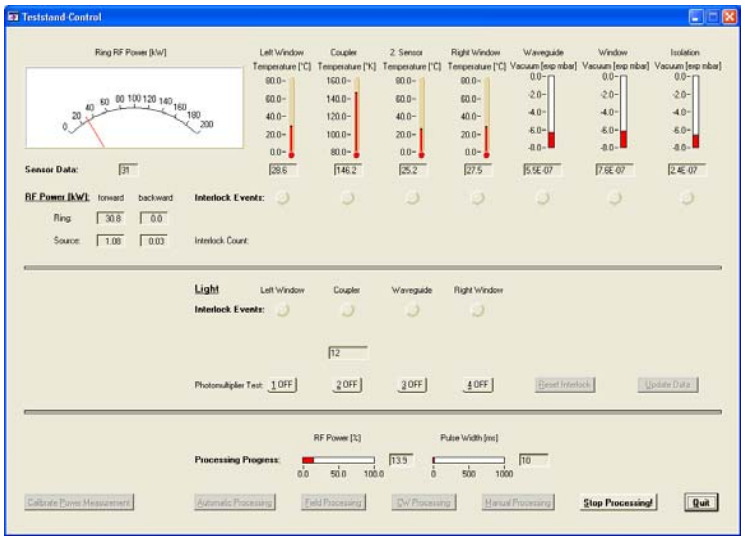


Resonant Ring Control Hardware



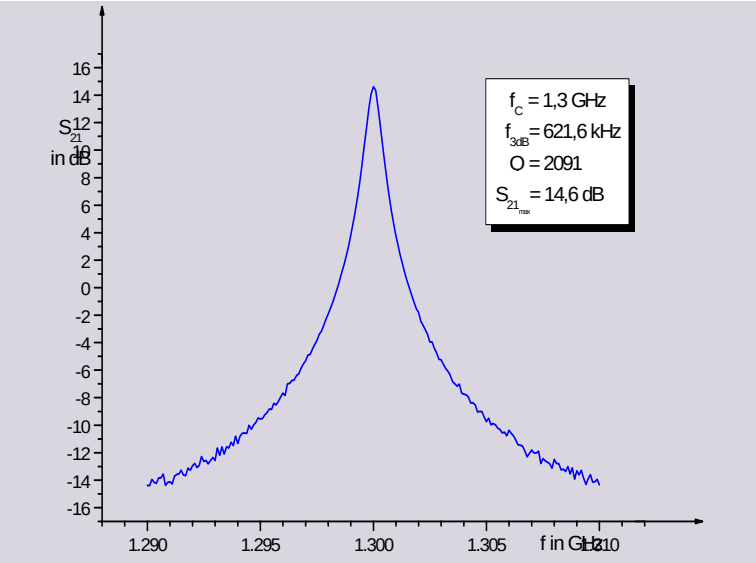
- Monitoring temperature and vacuum,
- Processing light signals from the photomultipliers,
- RF level measurement with 4 channels,
- processes 16 interlock signals in hardware and is used for controlling the RF power amplifier (e.g. klystron).

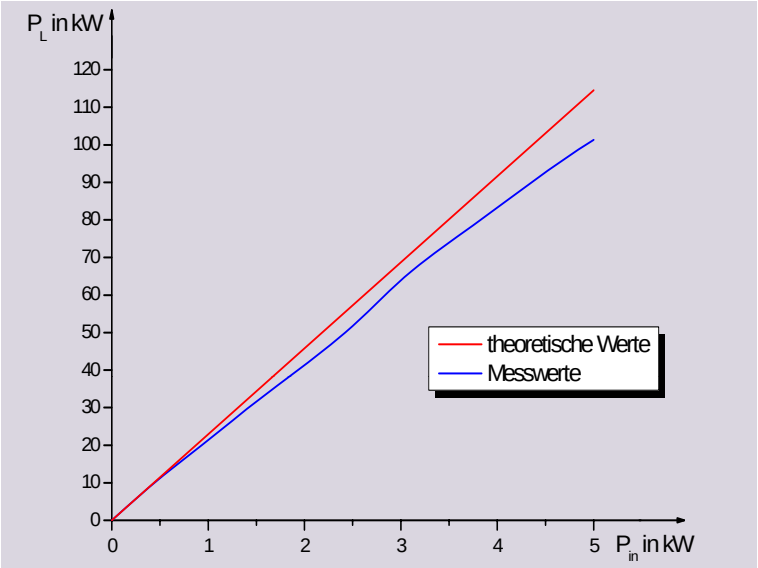
Resonant Ring Control Software



- Field processing with low thermal load, pulses of 10ms / 300ms repetition rate,
- Thermal tests are done with constant CW-power. Any Interlock (light, vacuum or temperature) stops processing,
- Mixed Mode with pulse trains from 1ms (10 times) to 1s (10times) is a combined test procedure to apply high gradients as well as significant thermal load. Interlocks reduce repetition rate as well as power.

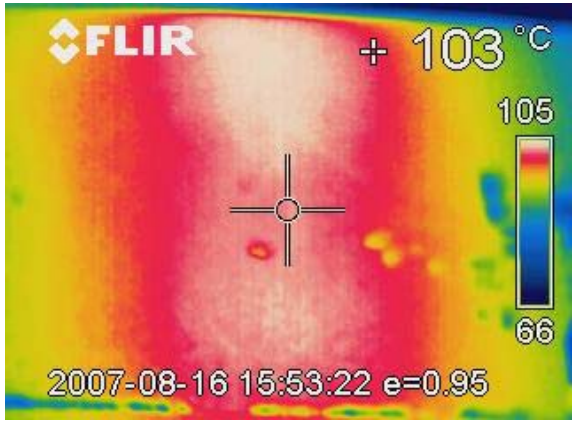
Resonant Ring Measurements



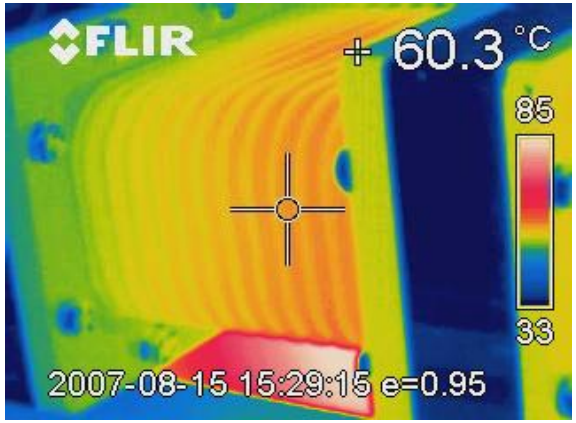


- At low power (approximately up to 50 kW) the ring behaves like a travelling wave resonator,
- At higher RF power surface losses of the waveguide become dominant and decrease its gain,
- At 90 kW operation the gain was reduced from 25 to 6 and could not be compensated by retuning the ring with the phase shifter.

Resonant Ring Measurements



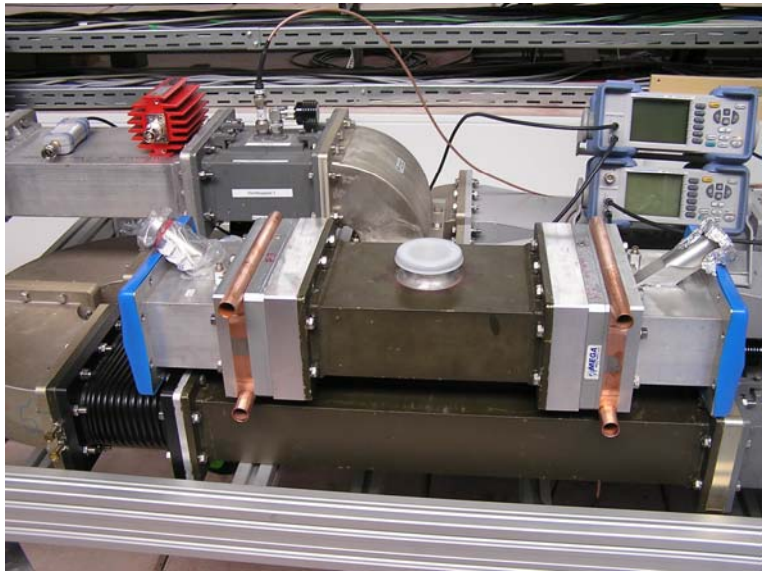
Phase shifter hot spot.



Flexwell waveguide hot spot.

- Some of the components used for the resonant ring have problems to handle the really big power in CW operation.
- In the meantime the Flexwell waveguide was changed and the phase shifter was repaired.
- Maximum Q of the Ring was 29 without resp. 19 with insertions as windows or couplers. Therefore for the tests in maximum 190kW CW reachable.

Warm Window Tests

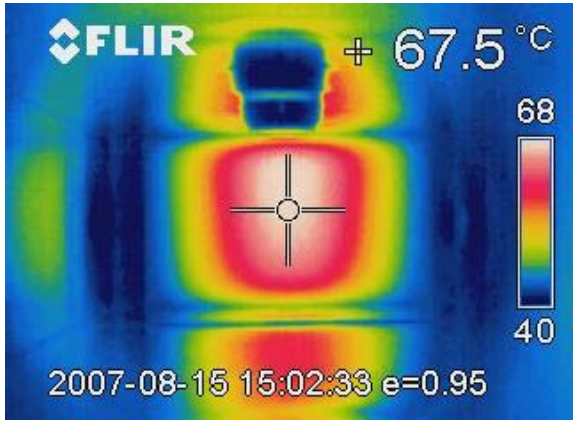


Setup of two air-cooled waveguide windows before assembling.

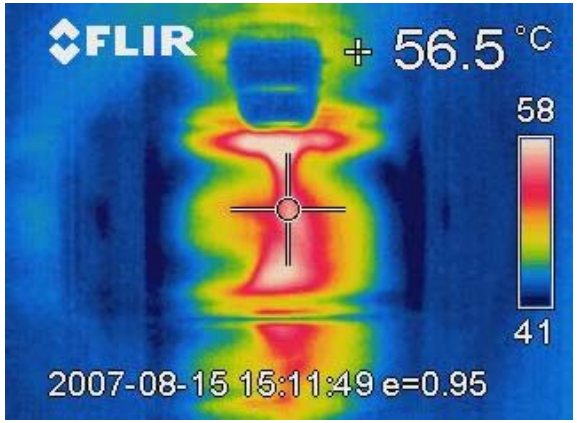
IR-camera to measure the surface temperature of the warm window.

- Setup consist of two warm windows and evacuated waveguide.
- IR-camera was used to measure the surface temperature of the waveguide window during operation by using a cut-off tube in of the bends of the resonant ring.

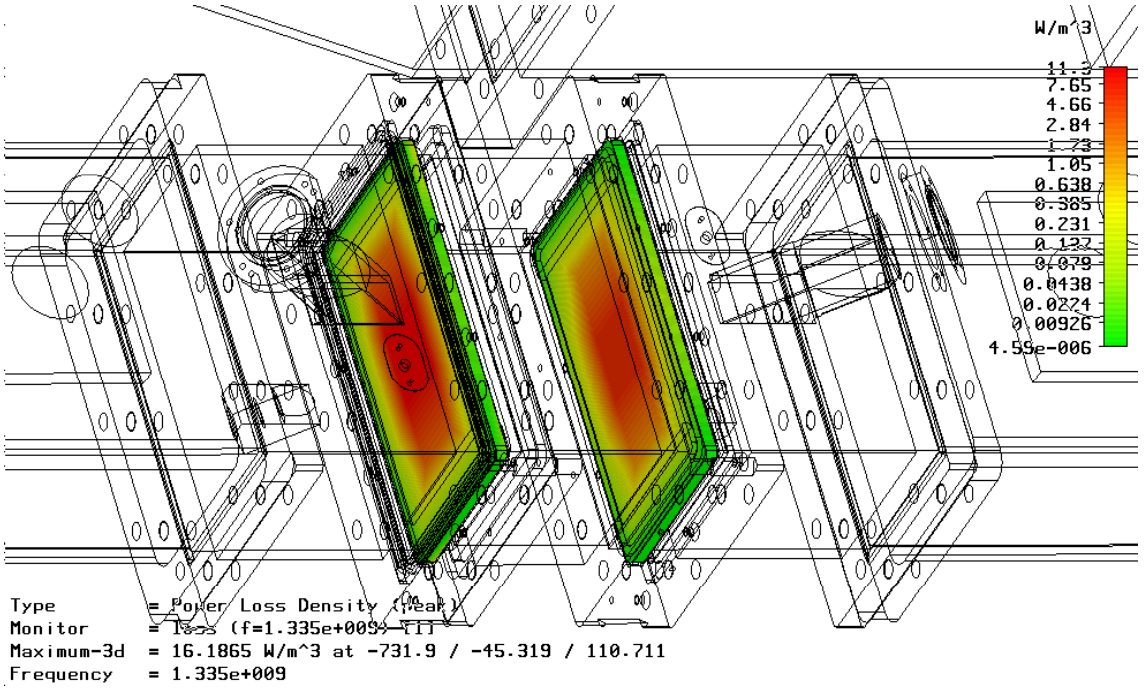
Resonant Ring Measurements



19kW CW without air cooling.

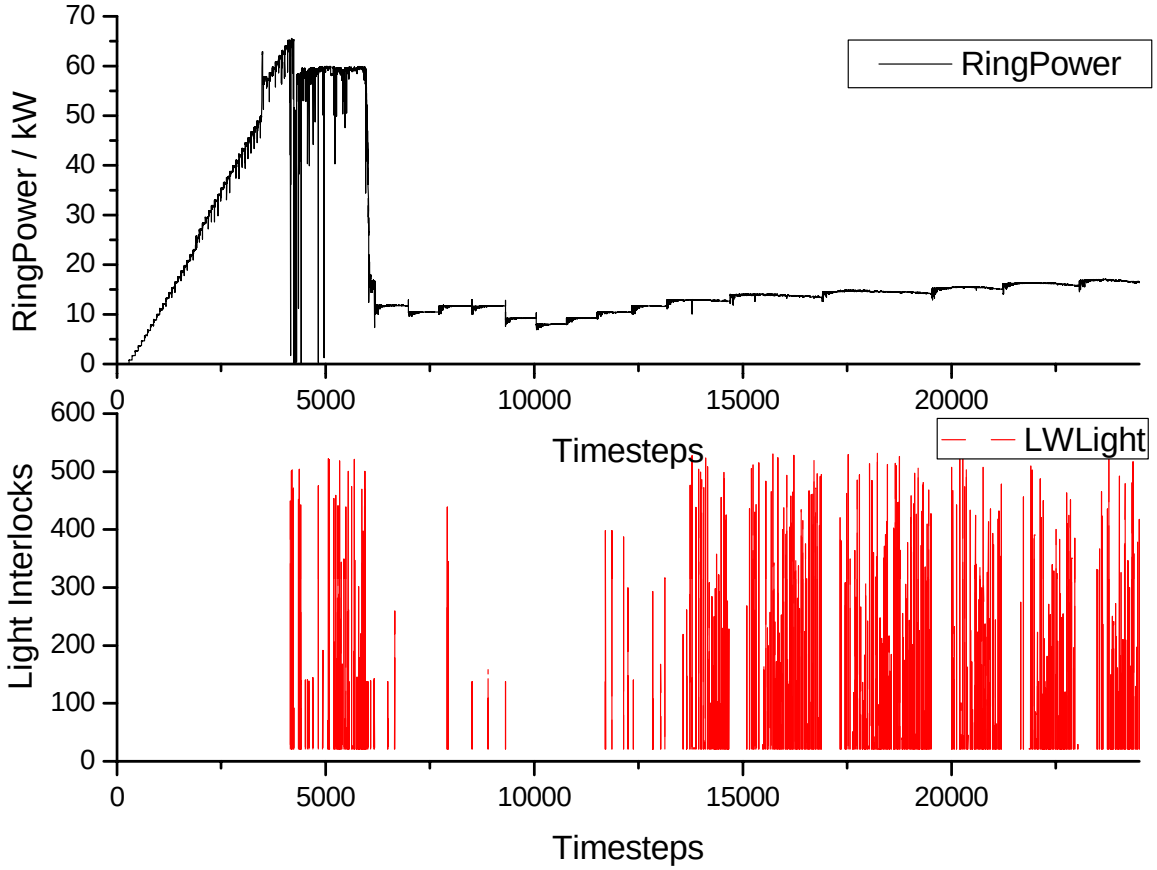


55kW CW with air cooling.



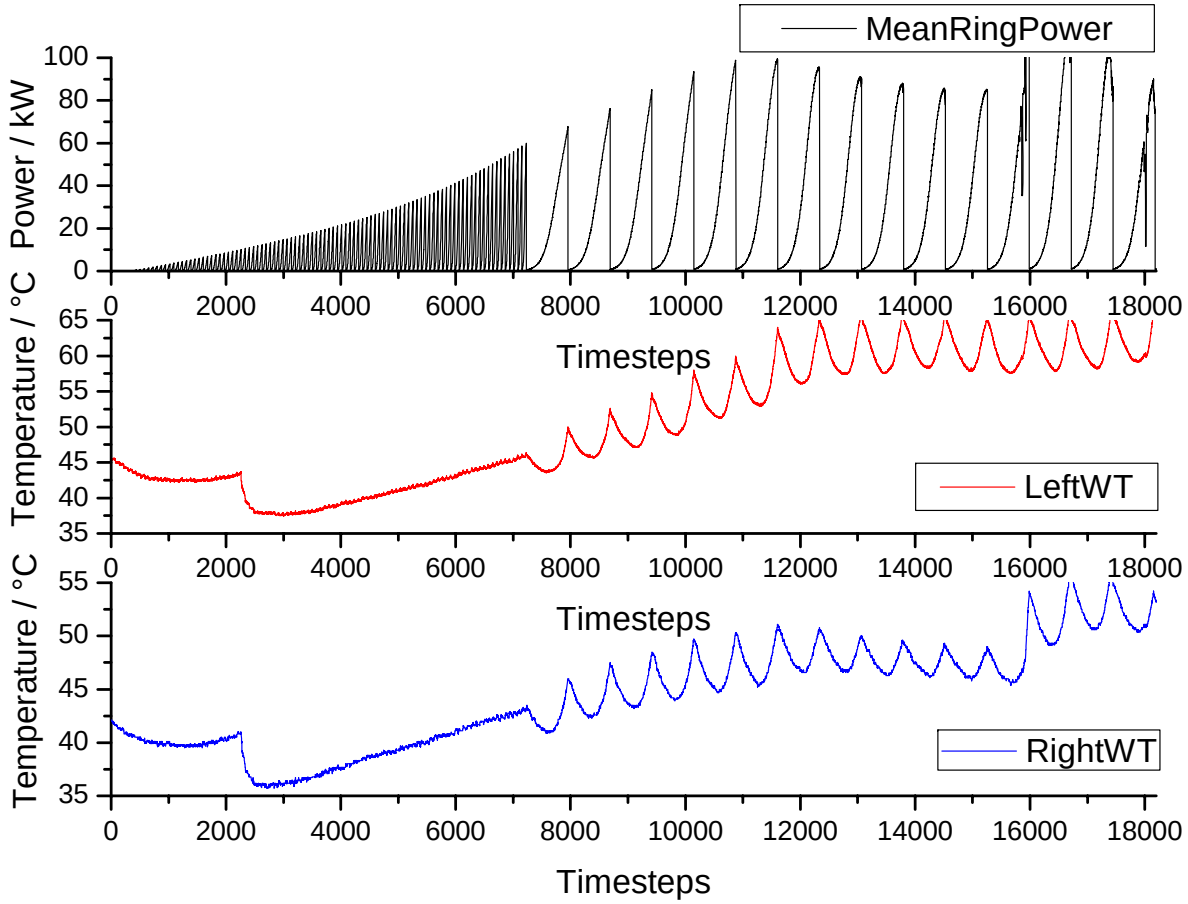
- Thermogram at 19 kW CW without resp. at 55kW CW with air-cooling.
- CST Microwave Studio simulation of the Power Loss Density in both warm windows.

Warm Window in Pulsed Operation



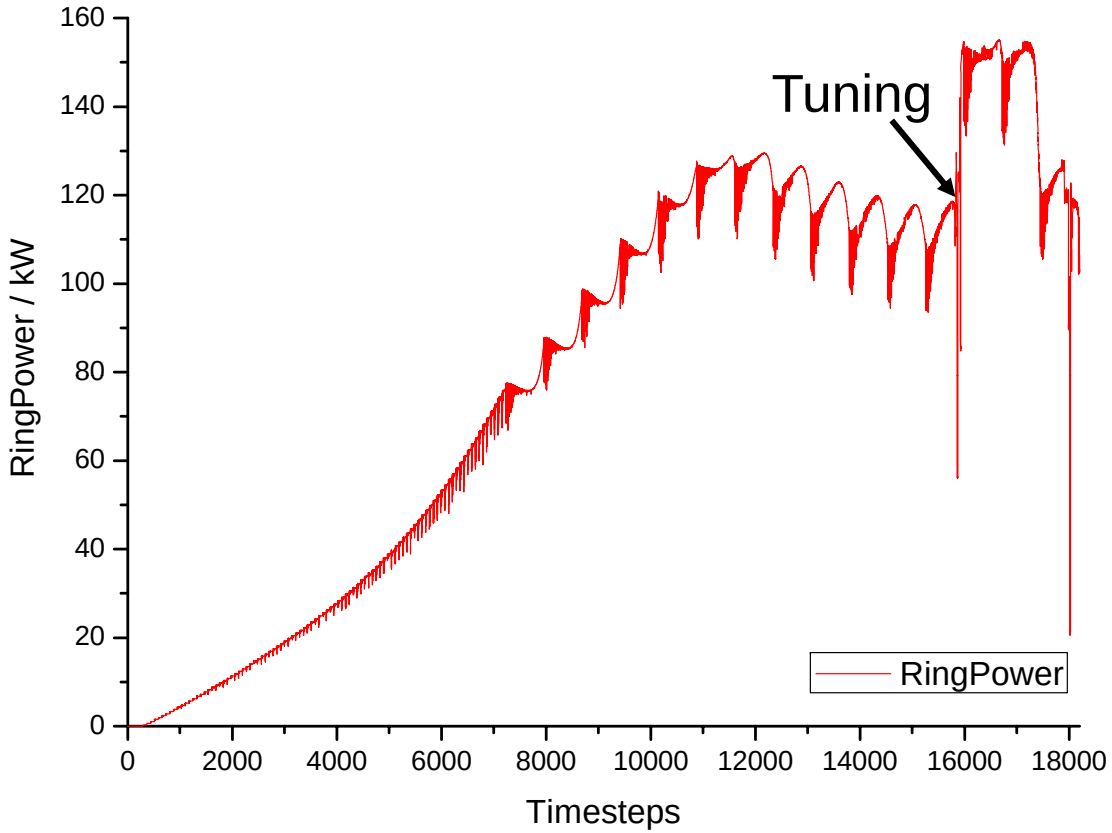
- First light interlocks occur above 70 kW, thereafter the achievable RF power is only 30 kW without interlocks.

Warm Window Heating



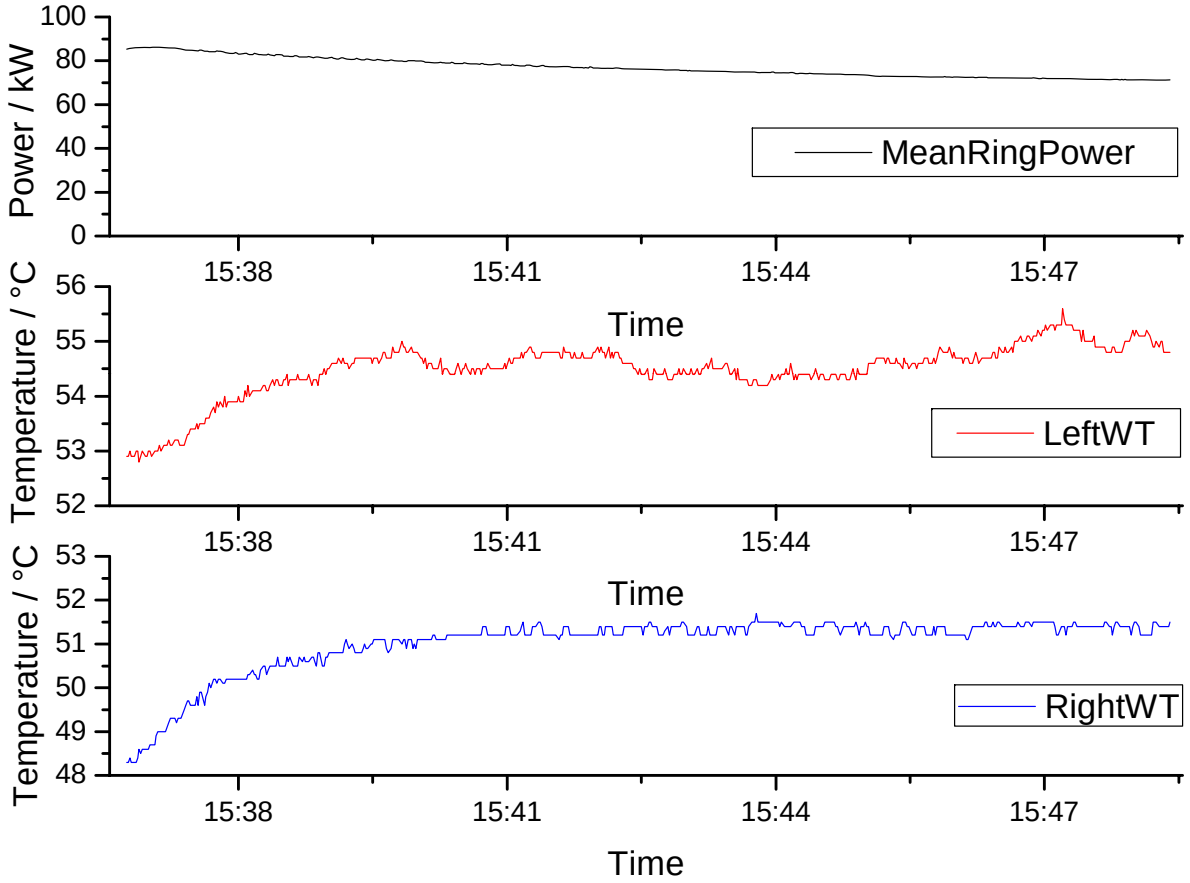
- Over the time the warm windows are heated up. The shown results are measured with air cooling on one window side.

Resonant Ring Thermal Drift



- Heating up the resonant ring leads to a lowered power amplification. This can be manually tuned (see arrow).

Warm Window in CW Operation

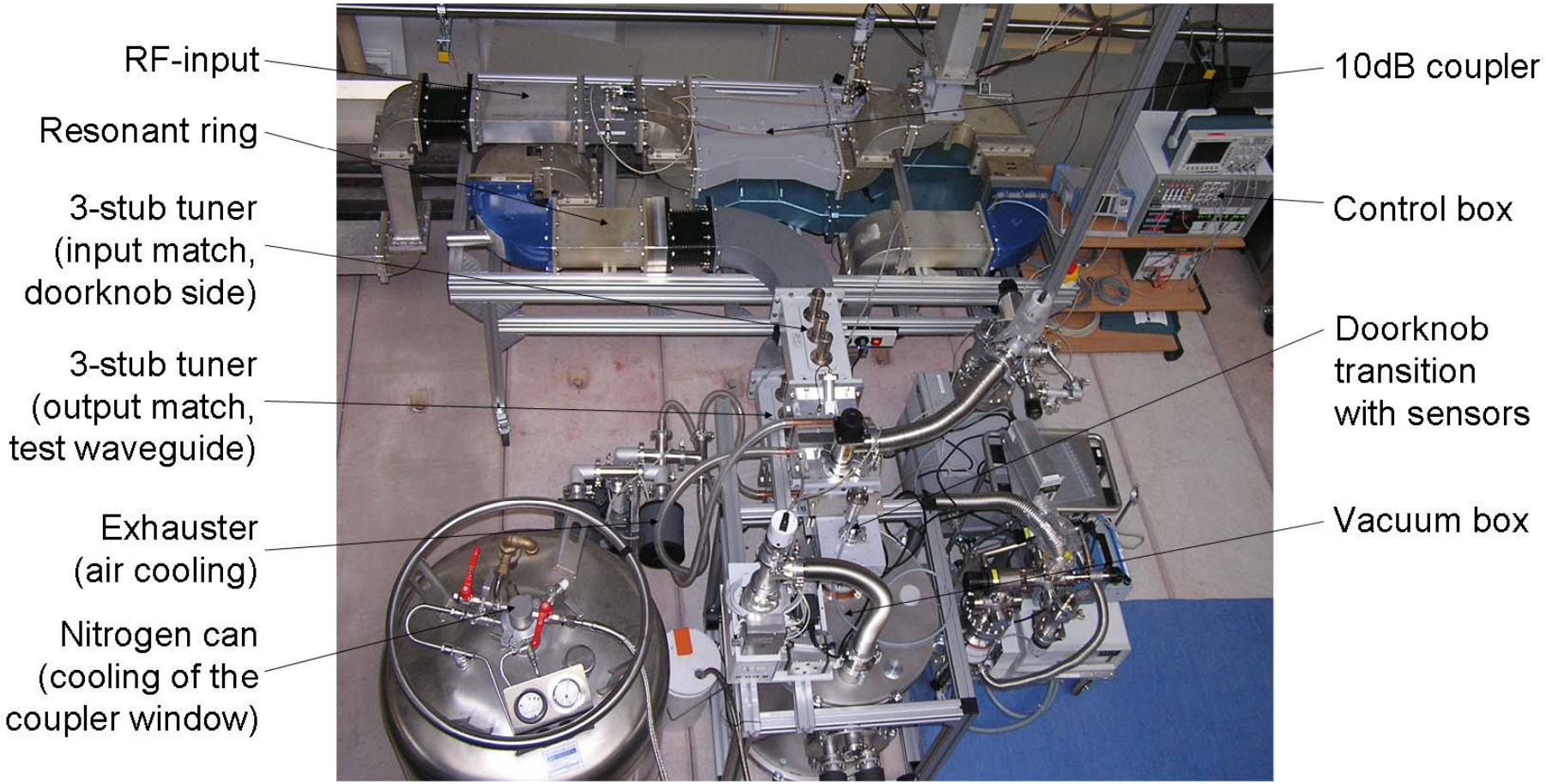


- Even more as in pulsed operation in CW operation the windows are heated up.

Warm Window Summary

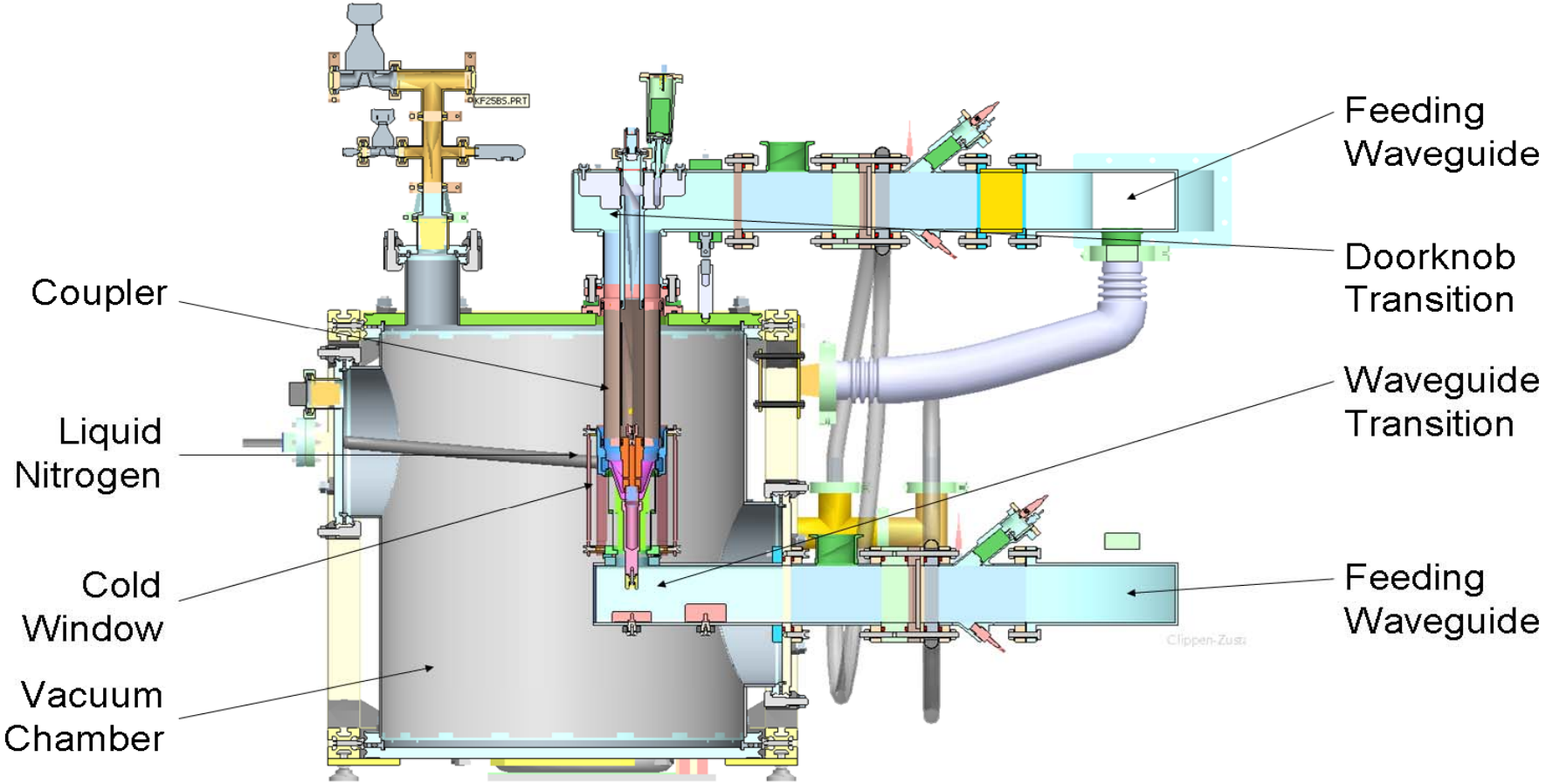
- In CW-operation the tested REXOLITE plastic warm windows are capable up to 50 kW power with air-cooling and up to 17 kW without.
- First light interlocks occur above 70 kW, thereafter the achievable RF power is only 30 kW without interlocks.
- There was no improvement over a long time, no training effects are detected.
- Starting the procedure one day later the same effect was observed. It is hoped, but not understood yet, that this effect is vacuum related.

Resonant Ring with Coupler Test Bench



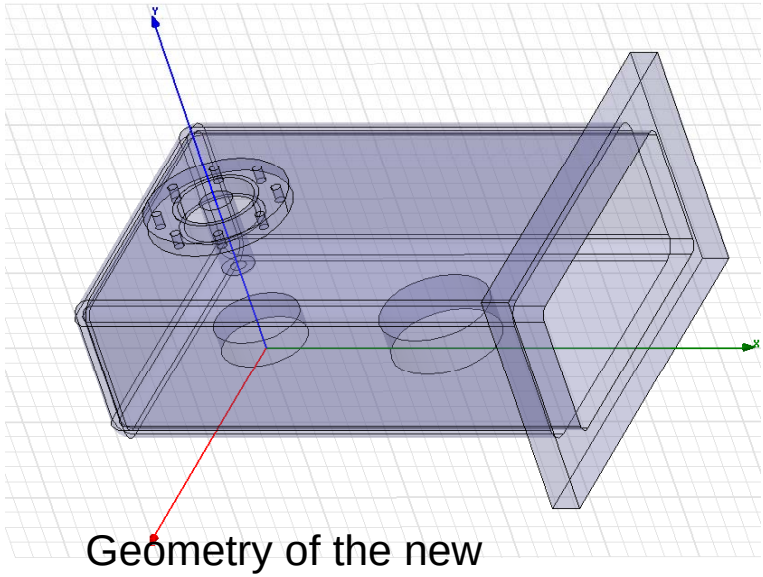
- Coupler test stand was inserted in the resonant ring.

Explosion Drawing of the Vacuum Box

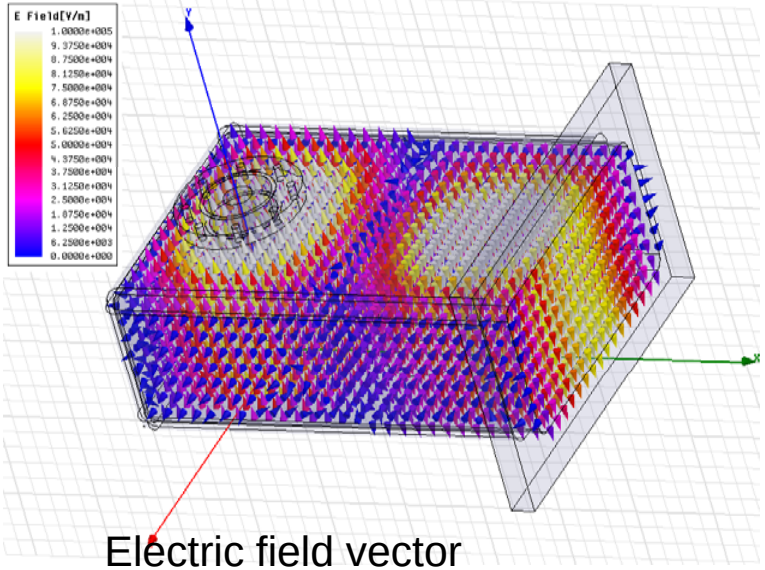


- Vacuum chamber with coupler and waveguide transitions.

Waveguide to Coupler Tip Transition



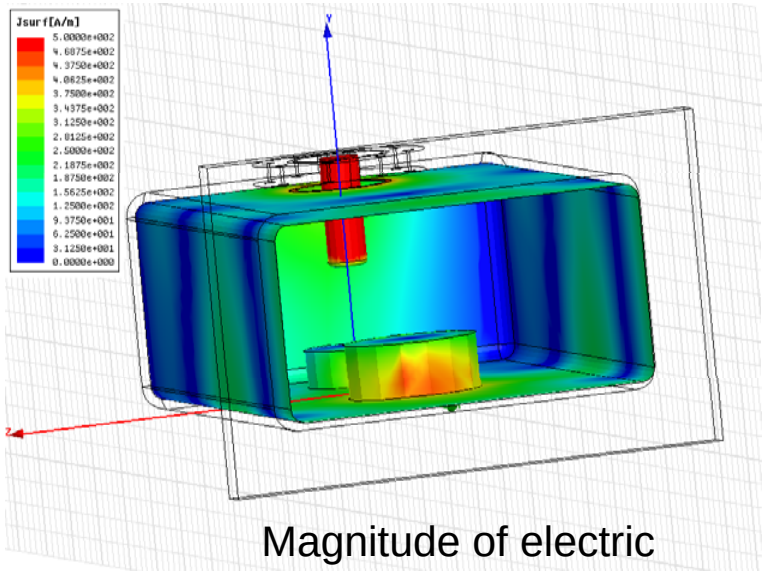
Geometry of the new Waveguide transition.



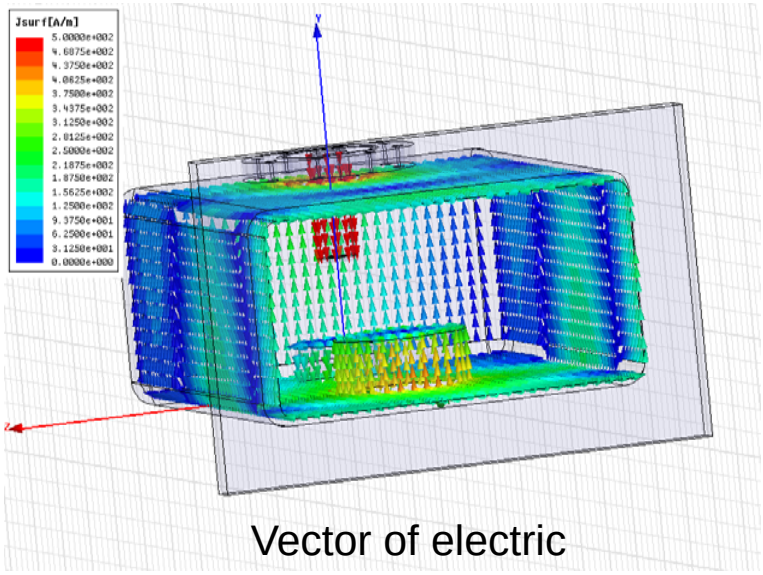
Electric field vector distribution in the transition.

- Simple transition for a wide range of coupler tip lengths.
- Easy adaption to new coupler tip geometries.
- Electric field distribution very similar to the later application.

Waveguide to Coupler Tip Transition



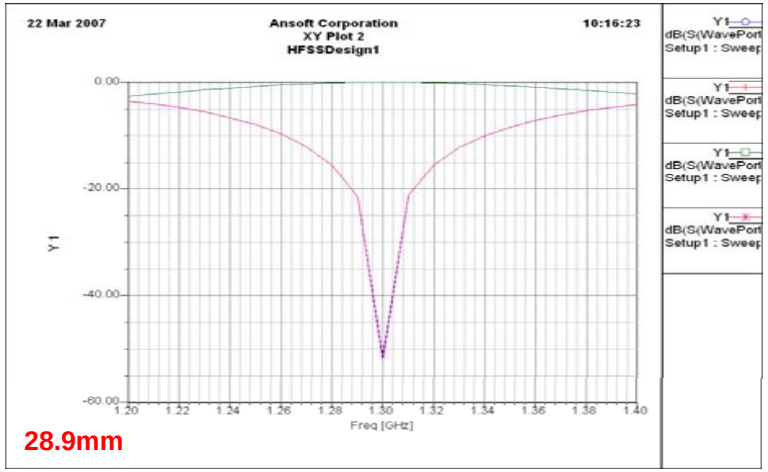
Magnitude of electric surface current density.

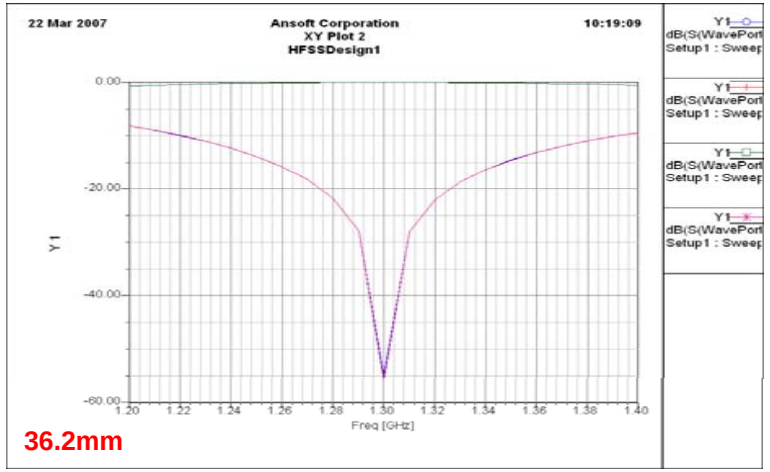


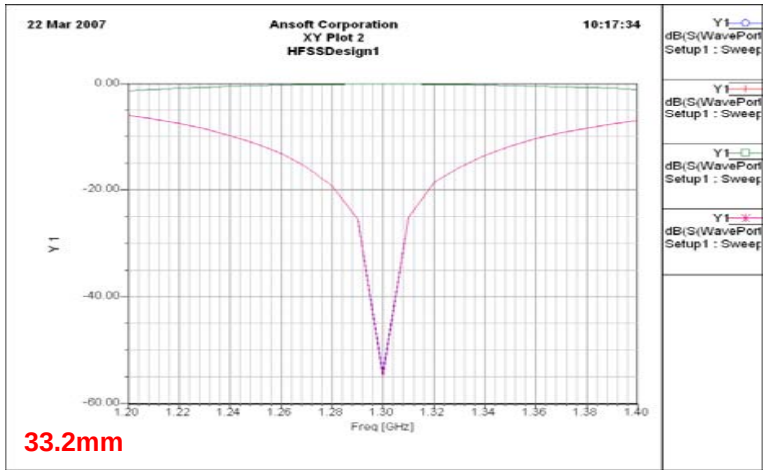
Vector of electric surface current density.

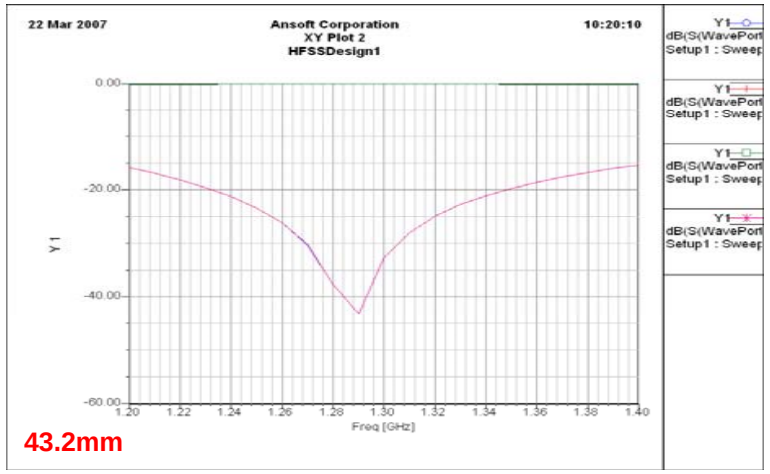
- Highest electric surface current densities on the coupler tip.

Waveguide to Coupler Tip Transition



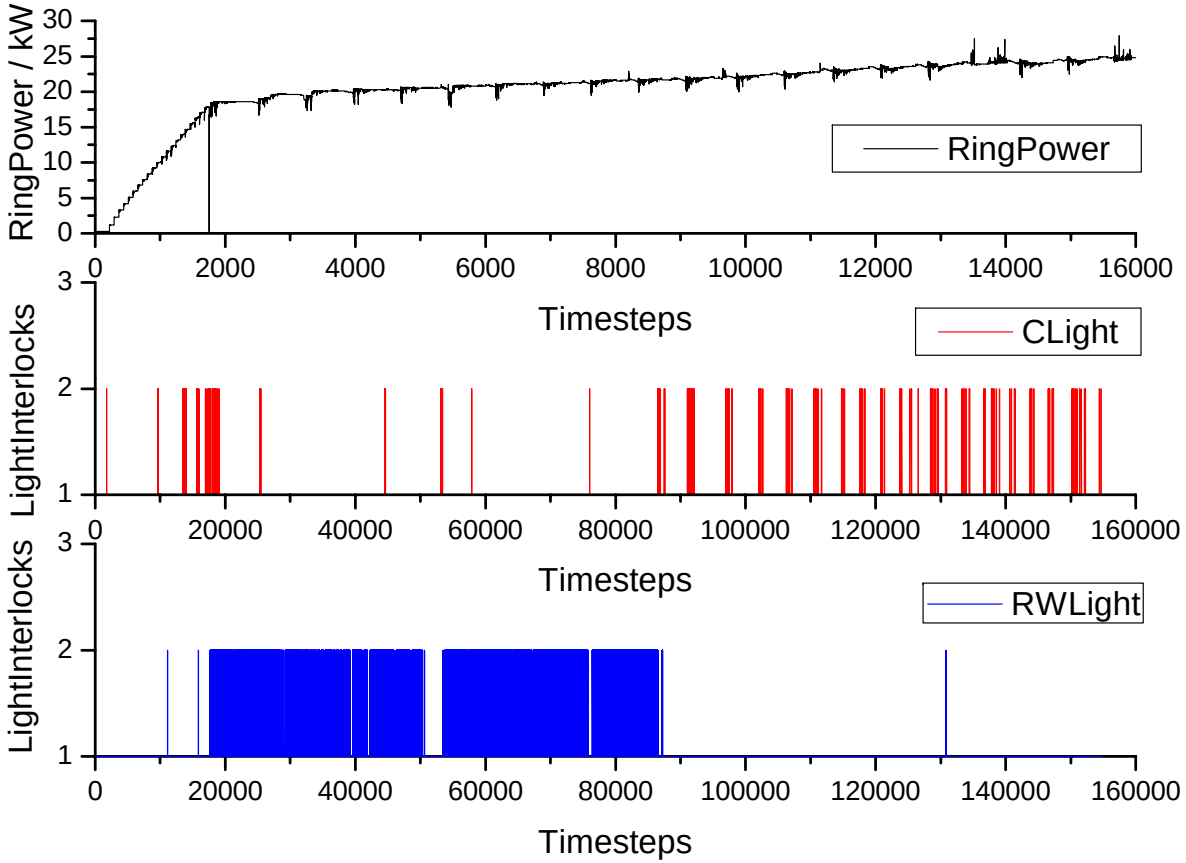






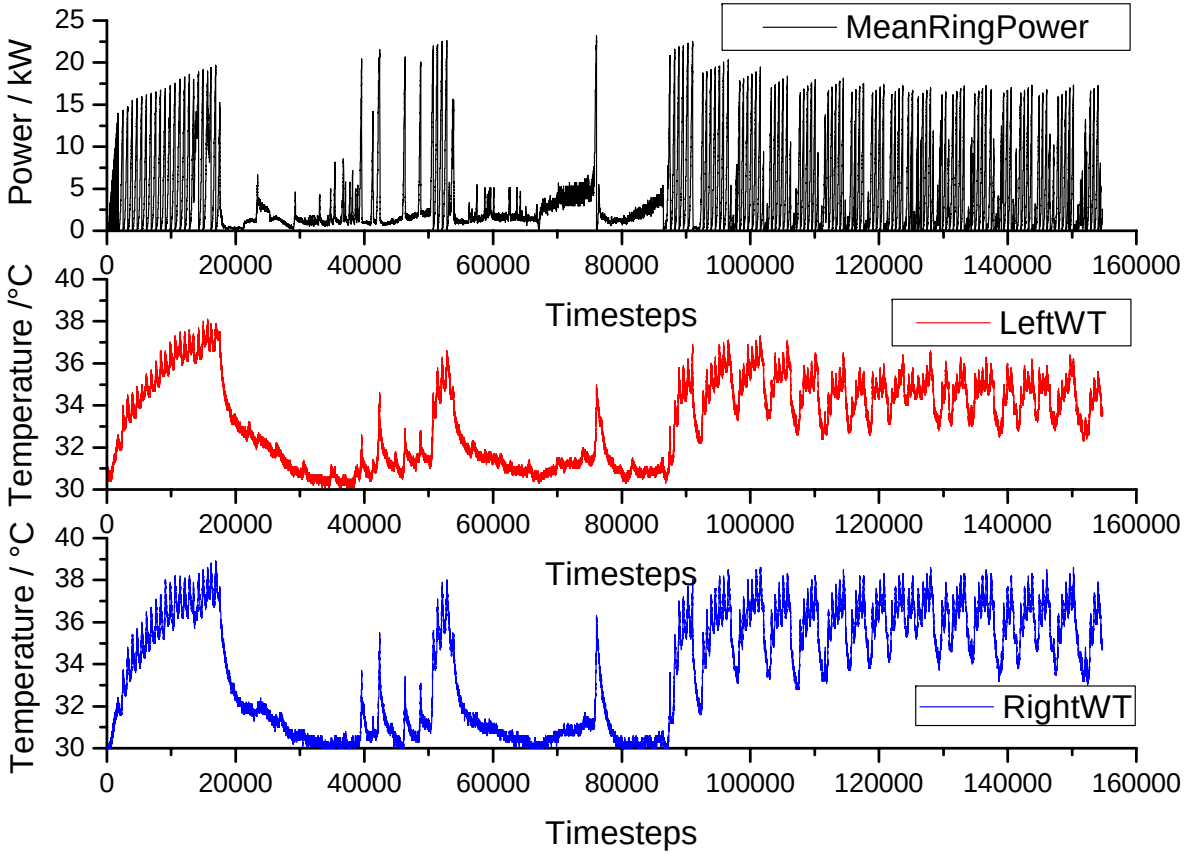
- Variation of coupler tip length from 28.7mm up to 43.2mm.

Coupler in Pulsed Operation



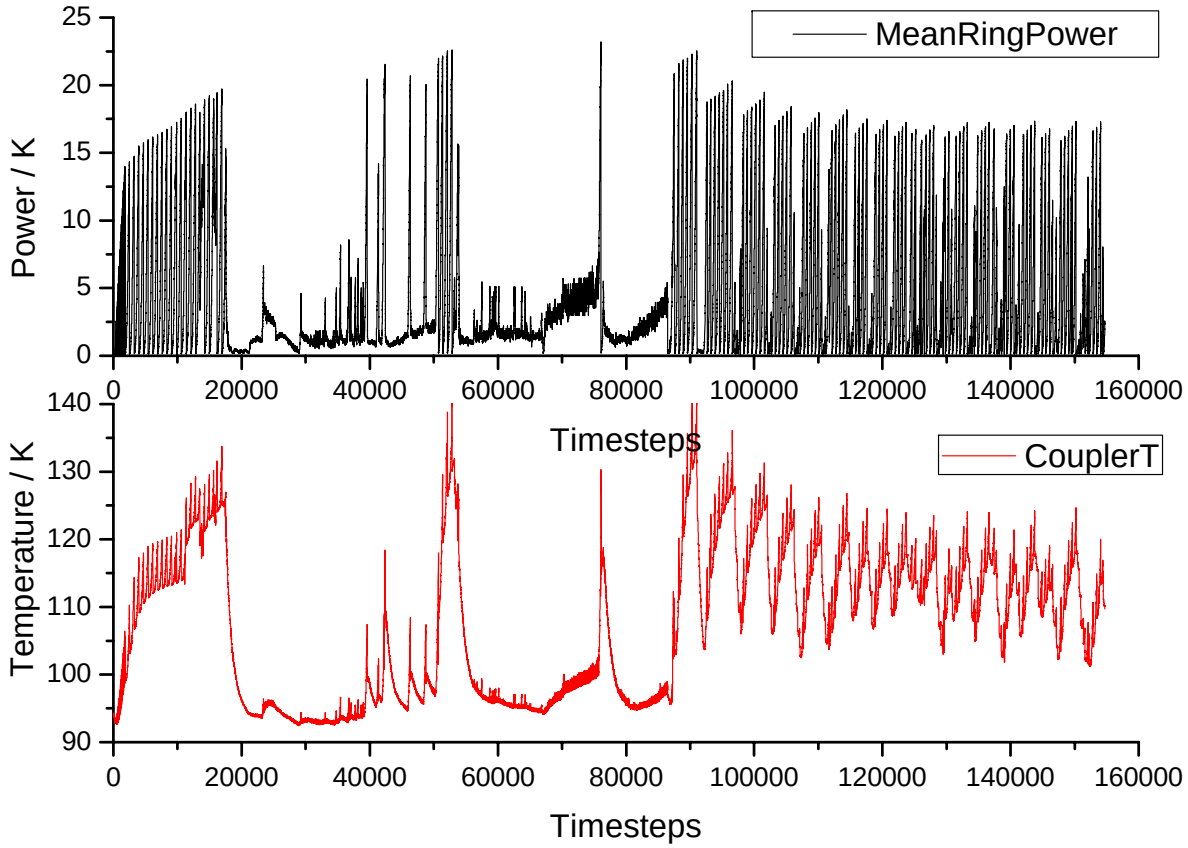
- In the coupler test bench different sources for light interlocks exists. Sometimes the light from the cold or warm window disappear.

Warm Window Heating



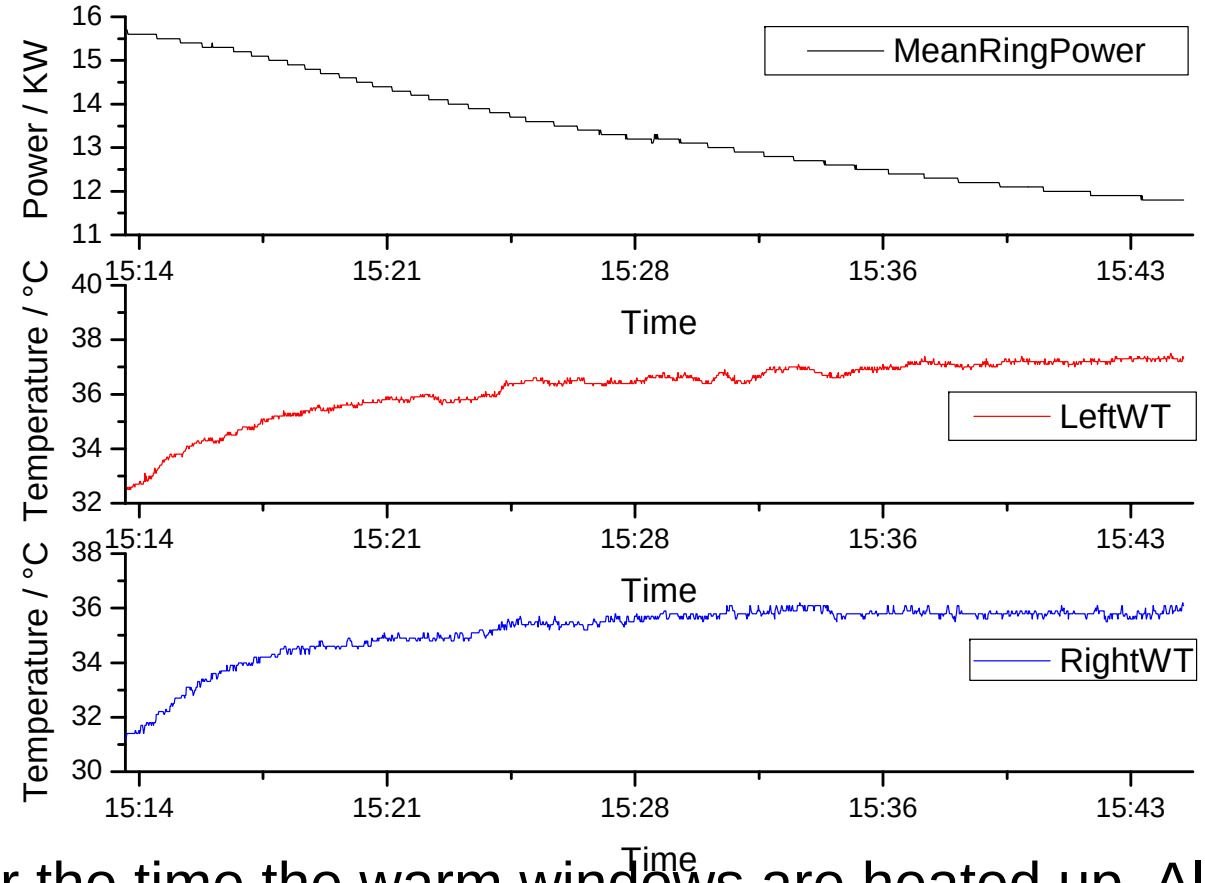
- Over the time the warm windows are heated up. The shown results are measured with air cooling on one window side.

Cold Window Heating



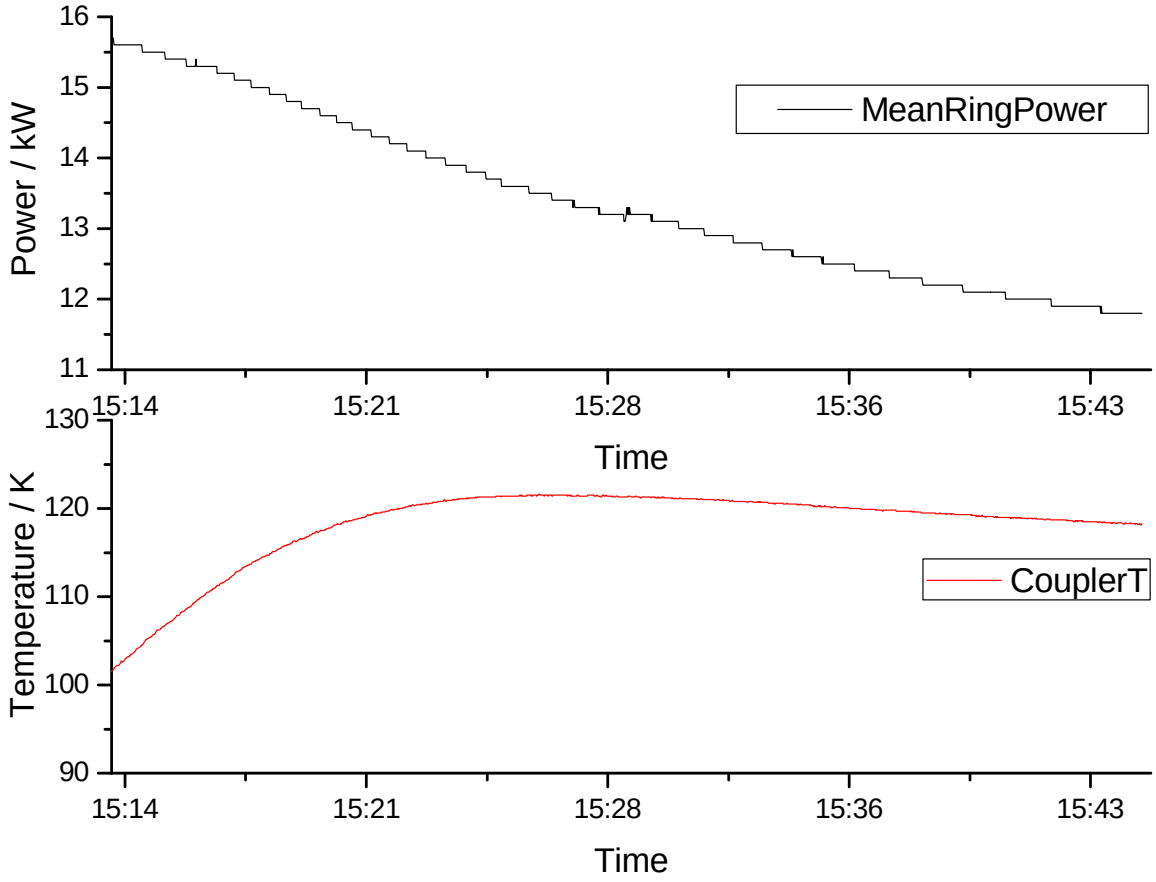
- Also the cold window are heated up.

Coupler in CW Operation



- Over the time the warm windows are heated up. Also shown: drift of the ring amplification.

Coupler in CW Operation



- Also the cold window was heated up.

Coupler Test Preliminary

- Caused by an assembly error at the beginning of the tests the contact spring was melted and some parts drops on the cold window. Therefore all tests are preliminary.
- Maximum power level reached in the coupler test stand is 15kW in CW-operation for 8 hours of continuous operation and 30kW in pulsed operation.
- The maximum power in CW-operation is mainly limited by thermal problems caused by contact limitations of the coaxial line between the coupler and the doorknob transition.
- Pulsed operation power is limited by light interlocks mainly from the coupler cold window sensor. Sometime this effect disappears and therefore it is supposed that's it can be healed.

Polluted Cold-Window

- Parts of the melted contact spring on the cold window surface.

References

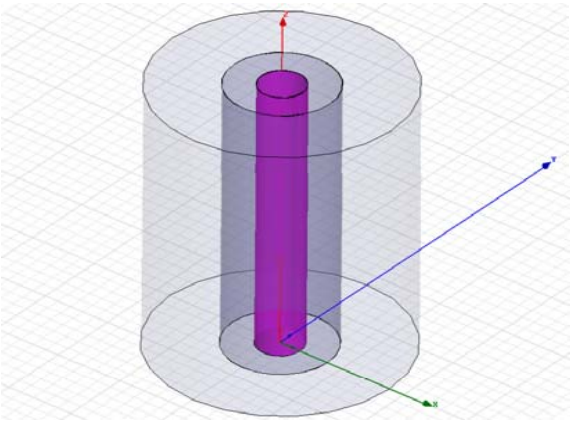
(1) A. Büchner, H. Büttig, J. Stephan: RF Window Diagnoses and Training for the Elbe SC Acc., Workshop on High-Power Couplers for SC Acc., J-Lab, 2002.

(2) H. Büttig, A. Büchner, M. Krätzig: FZD-473 2007, p. 29, FZ-Dresden-Rossendorf 2007

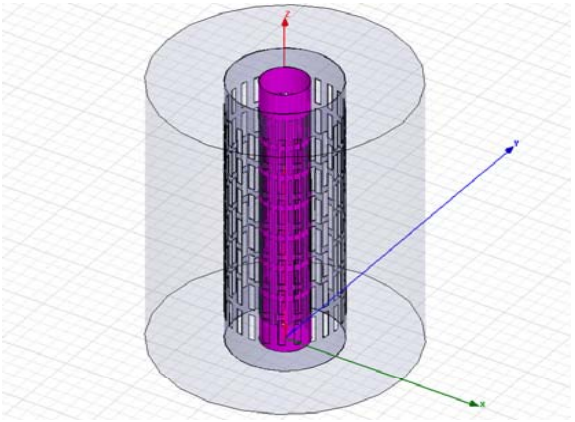
(3) C. Balanis: “Antenna Theory, Analysis and Design”, pp.352-388, 2nd ed., John Wiley and Sons, New York, 1997.

(4) G. L. Matthaei, L. Young, E.M.T. Jones: “ Microwave Filters, Impedance-Matching Networks and Coupling Structures”, pp. 255-353, Artech House, Norwood, 1980.

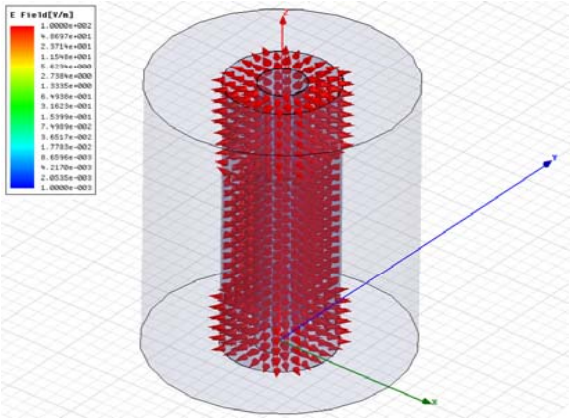
Modifications



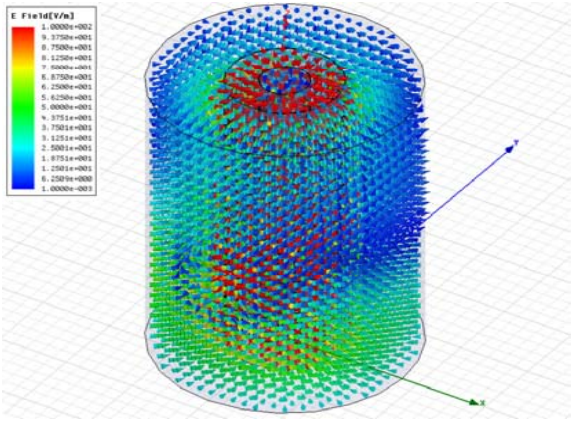
Original coaxial line



Modified coaxial line



Electric field distribution
for 10kW power



Electric field distribution
for 10kW power

Modifications