TESTS OF AIR COOLED 1.3 GHZ WAVEGUIDE WINDOWS USING A RF-COUPLER TEST BENCH BASED ON A RESONANT RING

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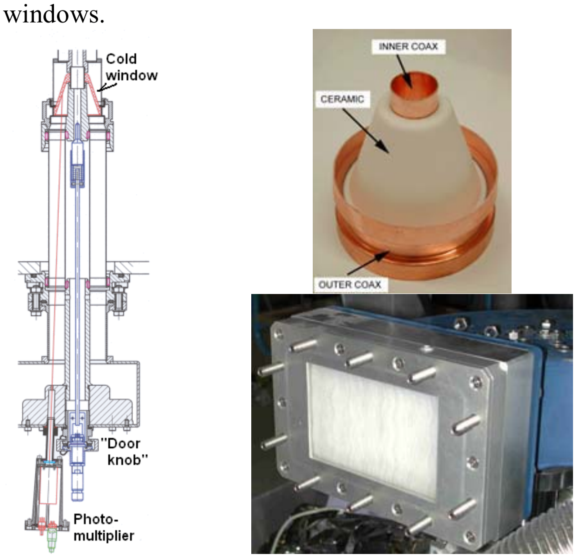
Abstract

A new coupler test bench based on a resonant ring has been built at ELBE in Dresden-Rossendorf to run window as well as coupler tests with RF power up to 100 kW. The ring is driven by a 10 kW klystron. This test bench includes also liquid nitrogen cooling of the ceramic cold window of the RF-coupler which allows testing under almost real conditions. A special waveguide was designed to match couplers with different antenna tips. In a first step the waveguide window has been equipped with additional air-cooling and tested.

The design of the test bench and the gained experience with warm window tests at the resonant ring as far as it could be collected within a short time of operation will be reported.

INTRODUCTION

The ELBE RF-coupler has a fixed antenna tip length, optimized for an operation bandwidth of 110 Hz, corresponding to a loaded quality factor Q_L of 1.2 10^7. Figures 1, 2 and 3 illustrate the RF-coupler with both windows.



Figures 1, 2, 3: The ELBE RF-coupler with cold (LN_2-cooled) ceramic window and warm waveguide window.

EXPERIENCE

The RF coupler setup shown above has been used since 2001 at ELBE (fig.4). Two cryomodules with two cavities each equipped with identically couplers. For carefully matching of Q_L 3-stub-waveguide tuners are used. These waveguide tuners allow to vary the bandwidth of the superconducting TESLA cavities between 50 and 300 Hz. To avoid damage vacuum, temperature and light are monitored at all windows /1/.

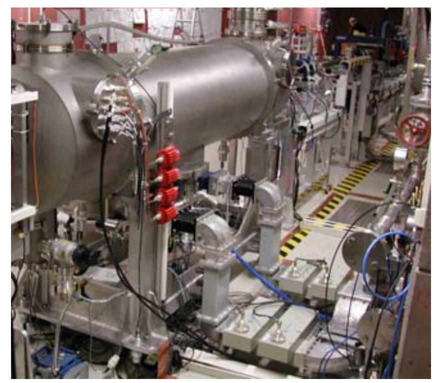


Fig. 4: ELBE cryomodule with 2 RF-feeds

The ELBE waveguide window is made from polystyrene (REXOLITE, part: OG9Y7-10073-702, WR650 Mega Industries). This requires the use of “viton” (rubber) sealings and limits the achievable vacuum at the waveguide window. Approved interlock set points at ELBE waveguide windows are:

-vacuum: $1x10^{-6}$ mbar, -light: 0.5 lx, -temperature: 70C

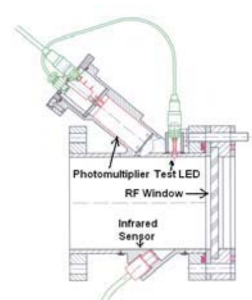


Fig.5: Waveguide Window with sensors attached

The experience at ELBE has shown safe operation up to the maximum available klystron power of 8.5 kW using this very low-loss “plastic” waveguide window. The achievable vacuum seems to be the most critical limitation for applying more RF power.

Since the available klystron power (CW) is limited a resonant ring has been built.

THE RESONANT RING

Within the EUROFEL framework a resonant ring has been built at ELBE to study the behaviour of coupler as well as waveguide windows with RF power above 10 kW in CW operation. The schematic diagram is presented in fig.6. A picture of the basic ring that has been built in the framework of a diploma thesis by Marko Kraetzig /2/ is shown in fig.7.

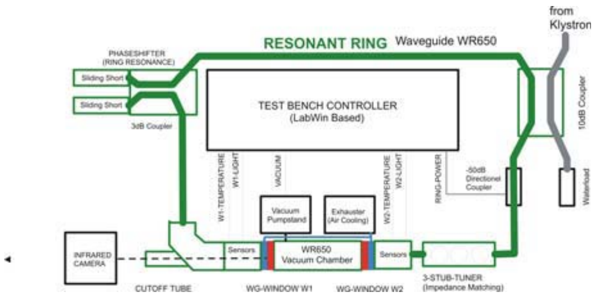


Fig.6: Blockdiagram of the Resonant Ring

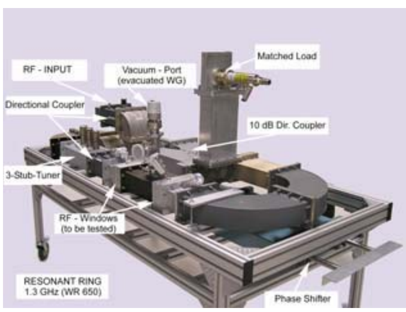


Fig.7: Resonant Ring at ELBE

The resonant ring is driven by a 10 kW klystron VKL7811St (CPI). The gain of the ring without insertions is 25. A waveguide phase shifter enables flexibility to bring the ring into resonance because different components change the electrical length.

BEHAVIOUR OF THE RING

At low power (approximately up to 50 kW) the ring behaves like a travelling wave resonator (fig.8). The s_{21}-characteristics are quite linear (fig.9).

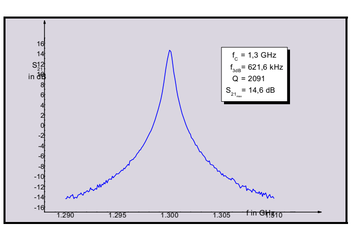


Fig.8: Resonance curve of the tuned resonant ring

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.

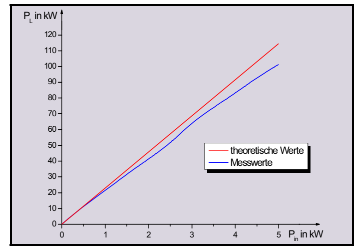


Fig.9: Gain of the resonant ring without insertions

The power density in the ring was simulated with CST (fig. 10). Thermograms of several ring components are presented in fig. 11.

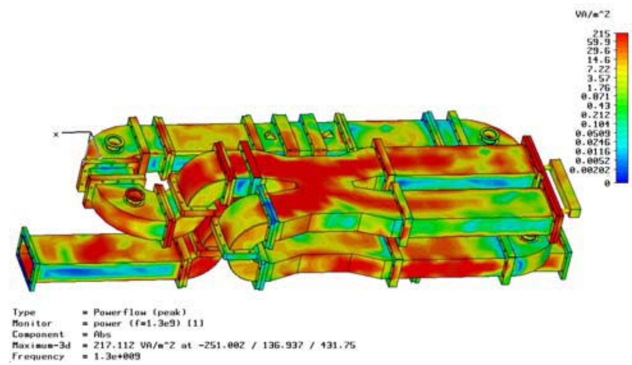


Fig.10: RF power density in the resonant ring

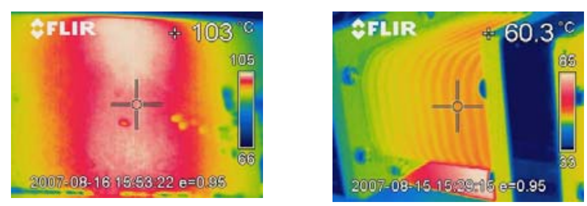


Fig.11: Hot spot on the upper arm of the phase shifter and on a flexwell waveguide.

TEST PROCEDURES

A PC-based control (LabWin) and data acquisition software was written. The following 3 processing modes are foreseen:

Field processing implies low thermal load at the device under test and is done with pulses of 10ms pulse / 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.

Generally the output power of the klystron is stabilized with its own control loop. The gain was chosen that a power step of +50W at the klystron is about +1 kW in the ring.

WAVEGUIDE WINDOW TESTS

The setup of two air-cooled waveguide windows before assembling (middle part: vacuum-waveguide, left and right: sensor boxes) is shown in fig.12.

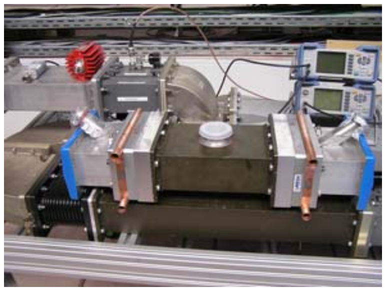


Fig.12: Waveguide window arrangement

A cutoff tube welded into a H-bend was used to apply infrared measurements. The RF-attenuation was estimated using CST and determined to be better 120 dB. RF-radiation measurements at 100 kW confirmed the calculation. The camera setup is shown in fig.13.

Fig.13: IR-camera to measure the surface temperature on the waveguide window during operation.

The effect of air-cooling during operation (steady state after 20 min.) with 50 kW RF power in the ring was measured to be 15…20 deg. This was done by using the IR camera on the left side of the window and a pyroelectric sensor on the other side, respectively. The power density distribution (simulated with CST) on the waveguide window is shown in fig.14. The cooling effect is demonstrated in fig. 15.

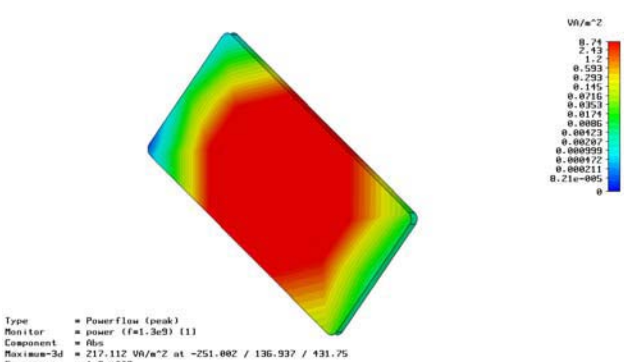


Fig.14: Simulation of the power density of the Rexolite waveguide windows using CST.

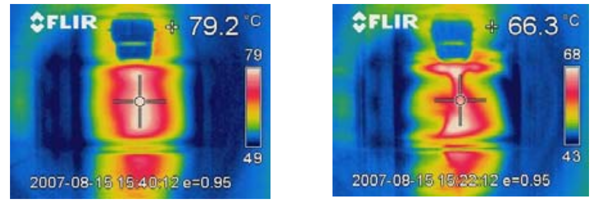


Fig. 15: Thermogram at 50 kW (CW) without (left), and with (right) air-cooling.

A typical "training"-curve is shown in fig.16. As seen first light interlocks occur above 60 kW, thereafter the achievable RF power is only 20...30 kW without interlocks. There was no improvement over a long time. Starting the procedure one day later the same effect was observed. It is hoped, but not understood yet, that this effect is vacuum related.

Fig.16: Typical training diagram of a Rexolite window

SUMMARY

The WR650 Rexolite warm windows can be safely operated up to 50 kW CW. For ELBE-like RF systems with individually driven cavities and RF power sources of 10 or 16 kW the Rexolite "plastic" waveguide window is a cost-efficient solution.

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.

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ACKNOWLEDGEMENT

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