Warm Test of a Modified TTF-III Input Coupler up to 10 kW CW RF-Power

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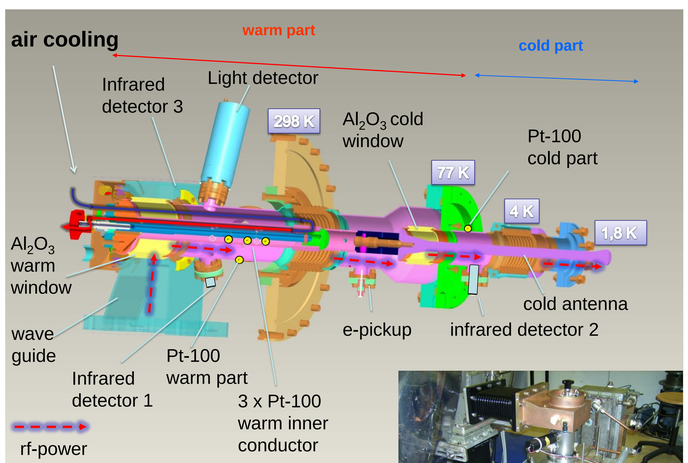
Abstract

The TTF-III input coupler was designed for pulsed operation at average power levels up to 5 kW. For CW-applications, higher power levels are desirable. Previous investigations have identified the inner conductor bellows as the bottleneck for the maximum usable power level. We have modified this section of the coupler by including a gas cooling. This setup was tested in a coupler-test-stand at room temperature. We have achieved stable operation at power levels up to 10 kW which is sufficient for the field levels that are to be reached in the BerlinPro ERL (s. TUPPO017). The results can be regarded as a worst case scenario, since the heat conductivity of all involved materials is rising significantly upon cooling to operating temperatures.

Experimental setup

One significant modification was made to the original TTF-III version of the coupler: The inside of the inner conductor has been sealed off from the RF-volume. Gas connectors were attached at the outside next to the manipulator, allowing for coolant gas to flow into the inner warm section of the coupler. At the far end of the hollow support rod for the cold antenna, a number of holes were drilled into the rod to provide backflow of cooling gas. The tuning knob needs to be removed for the rod to function as a gas exhaust (Fig. 1).

The coupler was equipped with three infrared temperature sensors monitoring the warm antenna, the cold antenna and the warm ceramic window. Emissivities of these sensors were set to 0.9 for the ceramic window, and 0.3 for copper surfaces. Three Pt100 thermocouples were attached to the warm antenna, two Pt100 were used to monitor outside temperatures.



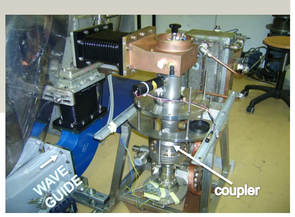


Fig 1: 3D model of the modified coupler (above) and picture of the coupler test-stand (right)

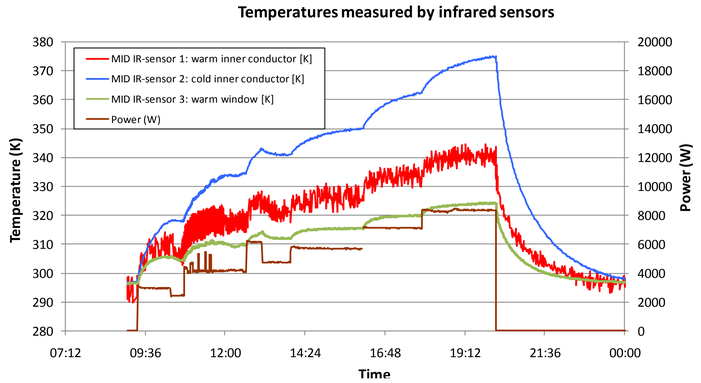


Fig 2: Typical thermal behavior of the coupler at different power levels.

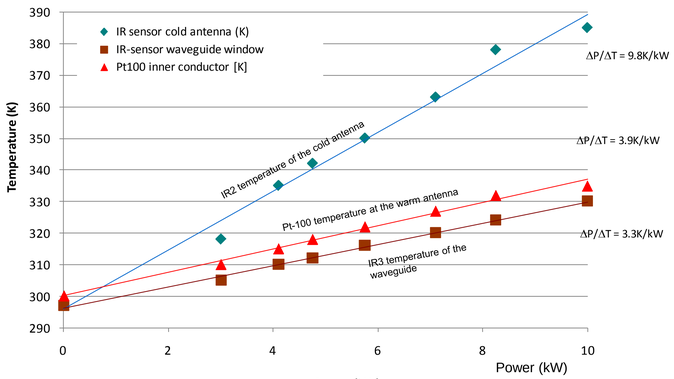


Fig 3: Equilibrium temperatures in traveling wave mode at 35 l/min gas flow

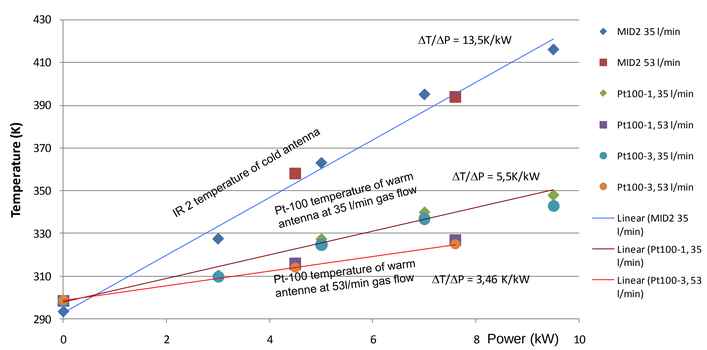


Fig 4: Equilibrium temperatures in standing wave mode at different power levels

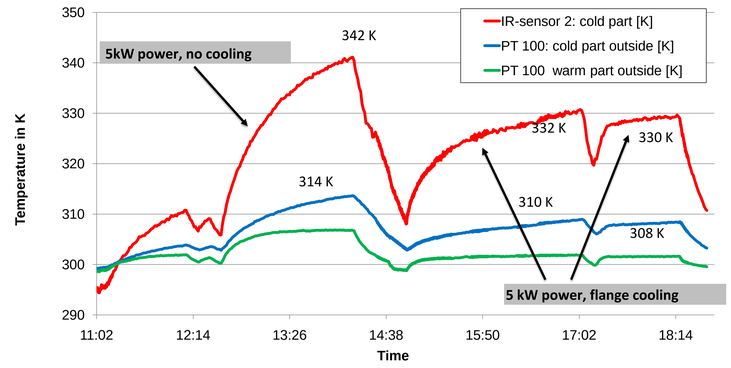


Fig 5: Influence of a LN2 heat sink at the 80 K flange on the temperature behavior in the cold and the warm part at 5 kW CW-power

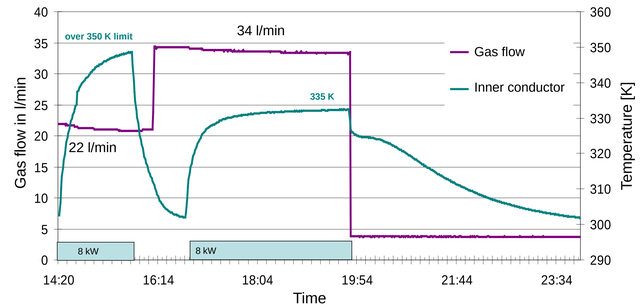


Fig 6: Influence of the gas flow on the temperature of the warm inner conductor

Results

Stable long term operation at 10 kW of CW power was demonstrated in warm tests of the modified air-cooled TTF-III input coupler in travelling and standing wave mode (Fig. 2-4). Higher power levels eventually led to interlock events, mostly due to discharge detected by the electron pickup at the cold antenna and excession of the vacuum threshold of $3 \cdot 10^{-7}$ mbar.
The highest temperatures were measured at the cold antenna. A possible explanation for this is the reduced thermal conductivity of the cold ceramic at room temperatures. Since the alumina thermal conductivity increases drastically upon cooling (reaching the same order of magnitude as copper at LN_2 temperatures) and the involved temperature gradient is higher, heat transfer through the ceramic can be expected to increase under cryogenic operating conditions resulting in an improved performance. This is also suggested by the measurement in Fig. 5. We found that the gas flow rate has a big impact on the equilibrium temperatures of the coupler during operation (Fig. 6).
A number of issues is still unresolved and will be dealt with next: ε=0.3 for the emissivity of the cold antenna may be large overestimated. Smaller values mean higher temperatures at the antenna tip. Measurements of the true ε are underway.
Also, true cold tests with will be performed in the near future.

(1) M. Dohlus, et al. „TESLA RF power coupler thermal calculations“ Proc. LINAC 2004, Lübeck, Germany

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