SLAC/FNAL TTF3 Coupler Assembly and Processing Experience*

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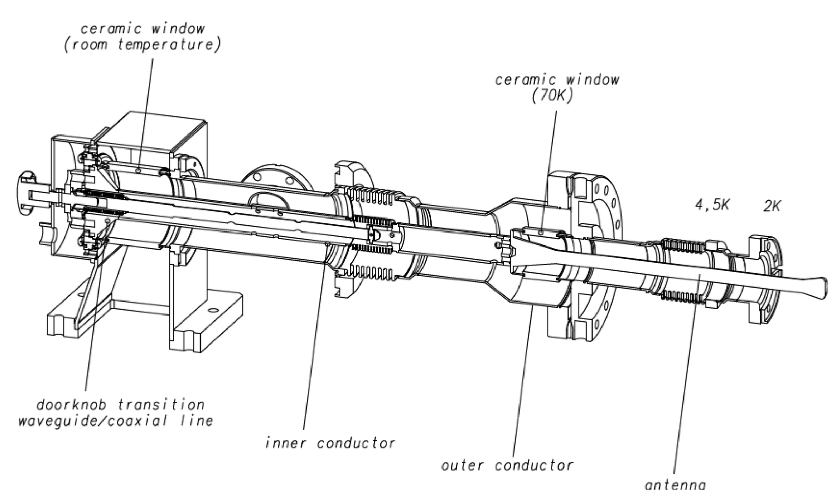
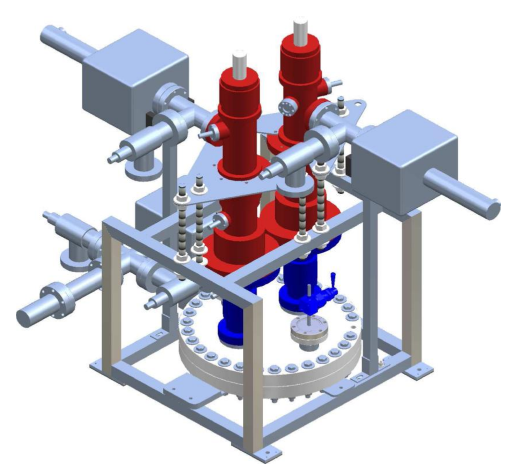
Abstract: The TTF3-style coupler is typically used to power 1.3 GHz TESLA-type superconducting cavities. For the US ILC program, parts purchased in industry for such couplers are received at SLAC where they are inspected, cleaned, assembled as pairs in a Class 10 cleanroom, pumped down, baked at 150 degC and rf processed. The pairs are then shipped to FNAL and installed in cavities that are tested at input power levels up to 300 kW. This paper describes the coupler results to date including improvements to the preparation procedures and efforts to understand problems that have been encountered.

Introduction

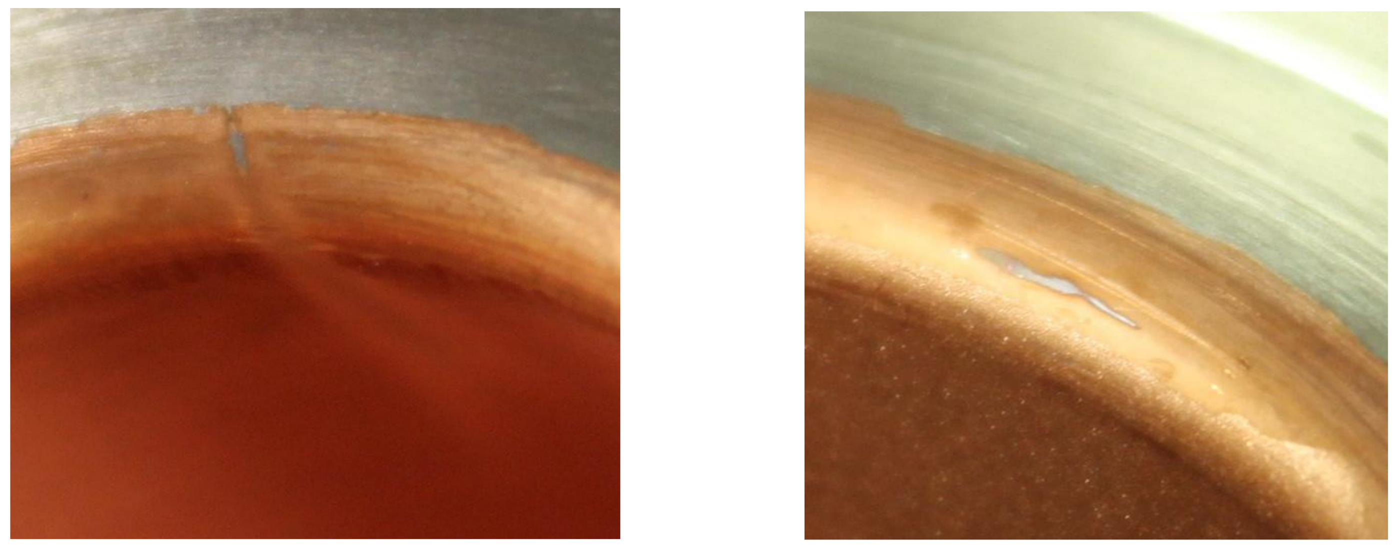
The TTF3 coupler (below, left) was developed by the TESLA Collaboration and is being used for ILC cavity R&D in Europe and the US, and for the European XFEL project. The cryomodule program for the US ILC effort is centered at FNAL and SLAC is providing TTF3 couplers for the cavities that are being 'dressed' there. So far, all couplers have been purchased from one vendor. They were fabricated using brazing and e-beam welding techniques, and then shipped to SLAC where they were inspected, cleaned, assembled in a Class 10 room, pumped down, baked at 150 degC and then rf processed in pairs (the setup for doing this is shown below, right).





Processing History

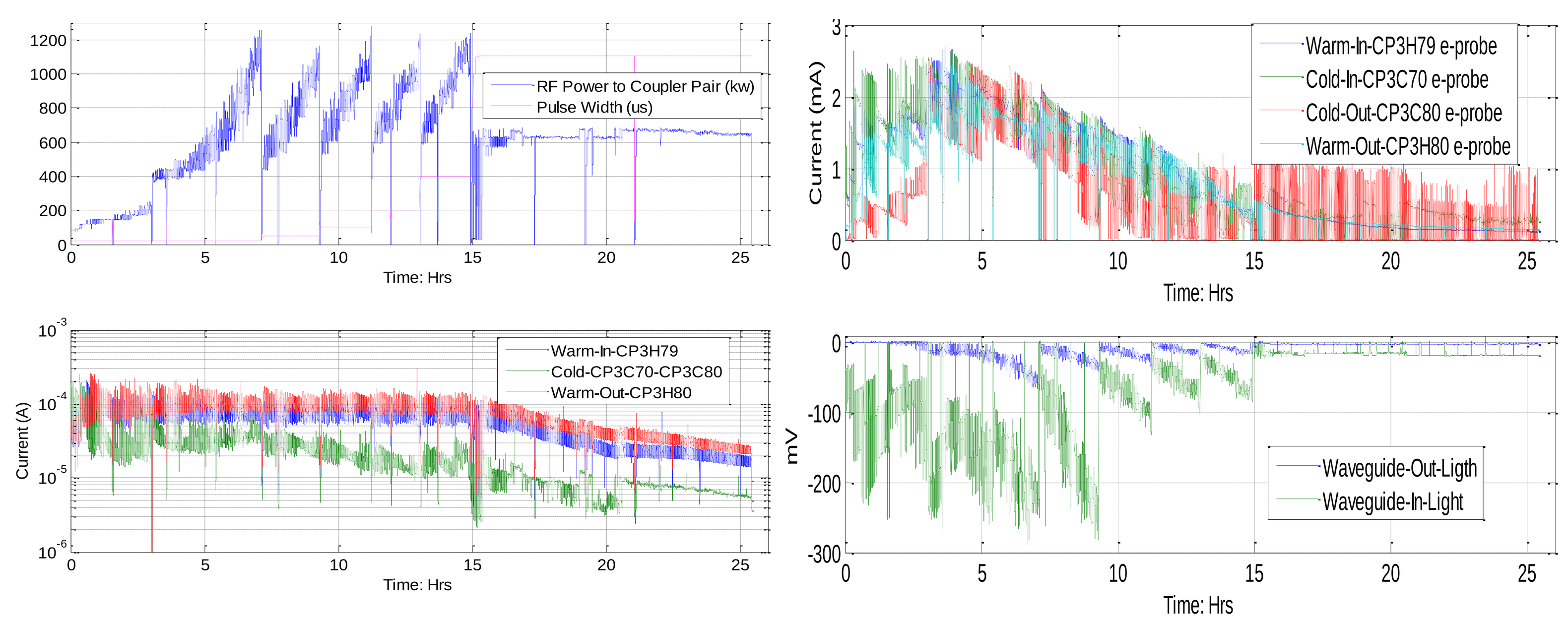
To date, 18 couplers have been prepared at SLAC and shipped to FNAL where 16 have been installed in cavities that have been tested in their Horizontal Test Stand (HTS). For two of the early cavities, the rf processing was clearly limited by the cold coupler sections. Both of these sections had been returned to the vendor for repair. In one case (below, left), a few mm strip of plated copper had come off near the flange that attaches to the cavity, and the copper was vaporized by the rf. The vendor had been asked to remove excess copper on the flat region just outside this area, which apparently weakened it on the curved region as well. For the other failure (below, right) the copper in the rounded region was smoothly eroded around the entire circumference, leaving several patches where the underlying stainless steel can be seen. The vendor had masked this area when bead blasting the plated copper, and perhaps the masking introduced contaminants that led to multipacting in this area. Such erosion has not been seen again.



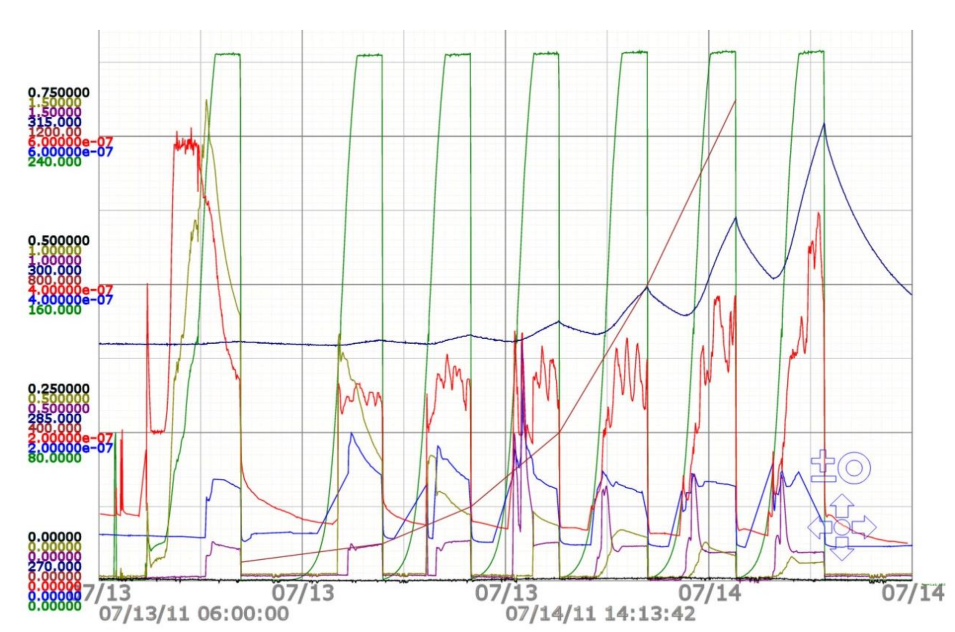
Copper removal observed near the output flange in two coupler cold sections after rf operation at FNAL.

Processing Results

For the rf processing at SLAC, the input power is slowly increased up to 1.3 MW, paced by the outgassing level (limited to 1e-6 Torr), at progressively longer pulses (20, 50, 100, 200, 400, 800 and 1050 us). At 800 us and 1050 us, the power is kept below 650 kW to limit average heating, although for the most recent pair, the repetition rate was lowered to 1 Hz for the 1050 us operation and the power ramped to 1.3 MW to better match the long pulse SW operation at FNAL. The integrated periods of power-ramping were typically 10-20 hours for the nine pairs, although they are operated up to 50 hours including fixed power periods to verify that the monitored signals (vacuum, light in the air-filled waveguide and electron probes in the coupler vacuum) continue to decrease over time. Shown below is an example of the recorded signals.



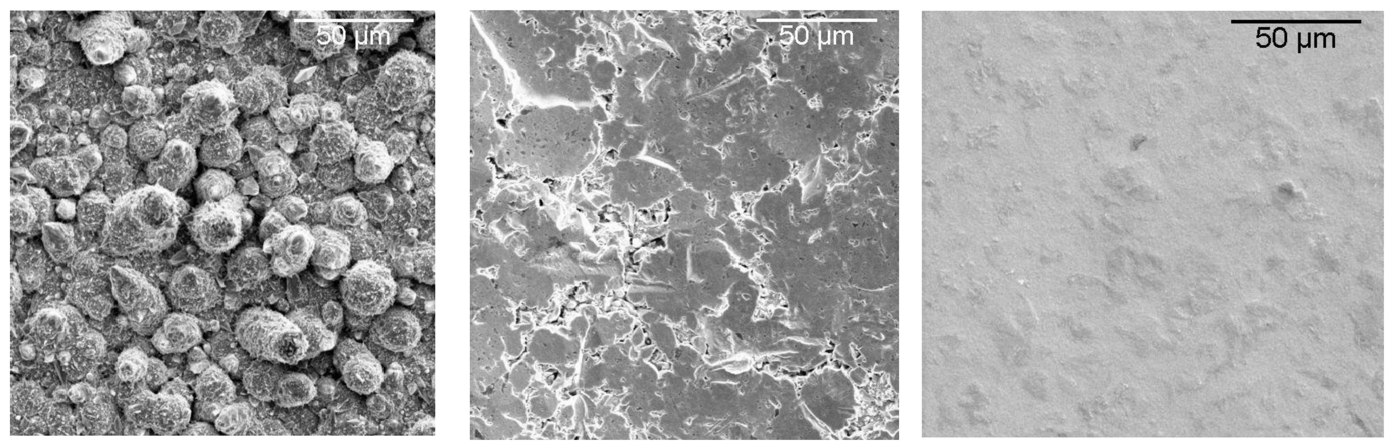
At FNAL, the couplers need to be rf processed again after installations on the cavity (cold section) and in the HTS (warm section), as the inner surfaces are exposed to air. This is first done at room temperature where the rf power is fully reflected. A similar conditioning protocol as that described above is used, except that the power is limited to 280 kW, the maximum pulse length is 1.3 ms and all operation is at 2 Hz. It usually takes 25-40 hours to complete the processing. An example data set is shown below.



The result of room temperature rf processing of a coupler at FNAL. The green curve is the forward RF power [kW], deep blue is the coupler temperature [K], red and blue are the coupler and cavity vacuum [Torr], deep red is the rf pulse length [μs], pink and yellow are the signals from e- probes near the 4 K and 80 K flanges [mA].

Plating Issues

Given the issues with the two couplers noted above, the effect of ultrasonic cleaning on particle generation was examined. This study was also motivated by the change in the post-plating treatment of the copper by the vendor. Instead of using a brushing process to remove general discoloration, which leaves scratches, bead blasting was used to clean the entire surface. For the study, the vendor and SLAC produced flat test coupons to mimic the coupler copper plated inner stainless steel surfaces – SEM images are shown below. The smoother SLAC coupon surface probably results from the periodic-reverse polarity changes made during the plating.



SEM photos of the copper coupon plating: (left) vendor non bead blasted, (middle) vendor bead blasted and (right) SLAC non bead blasted

To test the coupons for flaking, each one was ultrasonically cleaned three times for 15 minutes at the nominal transducer power setting of 1.6 kW, 40 kHz with no frequency sweep. Filter sampling was done after each ultrasonic bath, then a one square mm region was photographed and particles were counted (up to 50) by size. The results averaged over both the three ultrasonic baths and the coupons of a given type are listed below.

Coupon Sample	Avg. # Particles > 25 μm per mm²	Avg. # Particles 10-25 μm per mm²	Avg. # Particles < 10 μm per mm²
Vendor Bead Blasted	12	40	47
Vendor Non Bead Blasted	3.2	14	30
SLAC 30 μm plating	0.55	2.3	3.0
SLAC 10 μm plating	0.46	1.8	2.6

Outlook

Although the vendor plating with or without bead blasting produces copious copper flakes during ultrasonic cleaning, subsequent water rinses do not show further copper removal. Also, after rf processing one of the coupler pairs, the two cold ends were removed and no particles were detected with an air sampler.

Given that five recent cavities with bead blasted couplers achieved gradients greater than 33 MV/m at FNAL suggests that the plating is a not major issue, although some of the cavities showed X-ray bursts. Nonetheless, the plating should be improved to reduce the possibility of cavity contamination.

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