# INEXPENSIVE BRAZELESS RF ACCELERATOR

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*Abstract*

A simple, inexpensive way to manufacture a standard radio frequency (RF) driven particle accelerator is presented. The simplification comes from two innovations: utilization of LCLS gun - type RF design to avoid an expensive brazing process and copper plating of stainless steel that further reduces manufacturing cost. This is realized by a special structure design where accelerating structure cells are made out of copper plated stainless steel with knife edges and structure irises - copper disks acts also as gaskets for vacuum and RF seal. Besides the reduced cost, brazeless assembly allows integration of effective cooling and magnet optics elements into accelerator cells.

## INTRODUCTION

Particle accelerator is an array of accelerating cavities (cells) made out of copper separated by "irises" which are brazed together for vacuum and RF contact. This process is rather expensive due to usage of copper and the need for brazing of large structures. Brazing is an expensive process prone to errors that reduces production yield. Moreover, thermal stress experienced by copper during brazing increases the probability of a breakdown. In this paper we present an inexpensive brazeless design that can be utilized in moderate gradient industrial accelerators.

## BRAZELESS RF ASSEMBLY

High power RF components, cavities, and waveguide lines must be UHV vacuum tight. The vacuum seal can be successfully achieved with the now classical Varian conflat-type flange connection. Such joints, however, are not RF friendly. In high power vacuum RF transmission lines, so-called SLAC-flanges or similar CLIC-flanges are used. A square tooth instead of knife, placed right at the edge of the waveguide opening, ensures that there is no radial gap. A small amount of bulging of copper into the waveguide is possible, but can be tolerated in RF transmission operation. However, resonators, and especially accelerating waveguides (arrays of resonators), must generally all be brazed together.

The main contribution to brazeless designs was done in the development of high gradient photoinjectors. Naturally, electron guns require periodic replacement of the cathode. For that reason, most photoinjectors are designed so that the RF joint and vacuum joint are separated. For example, in the AWA gun, the cathode plug is attached to the gun body via copper-beryllium coil [1].

In the quest for low emittance and reduced dark current, following the design of the BNL/SLAC/UCLA gun [2], many RF electron guns adopted a design in which the whole back wall of the gun is a replaceable cathode [3, 4]. After several iterations, the LCLS gun solution with a shallow sloped knife edge at the RF joint, followed by a vacuum joint, provided a brazeless breakdown-free joint for high gradient operation. An important point about the RF joint knife edge is that it is made out of stainless steel, and copper plated on the inside [4].

In a recent development, a complete electron gun structure was proposed in a brazeless design [5]. The key is a special gasket design. Copper parts of the structure are used to crush an annealed and slightly softer copper gasket. In a sense, the complexity of the brazing step is replaced by a rather complex mechanical design. The intended gain of such a design is not cost reduction, but the potential for improved high gradient operation, since thermal heating in a brazing cycle is believed to reduce the copper breakdown strength.

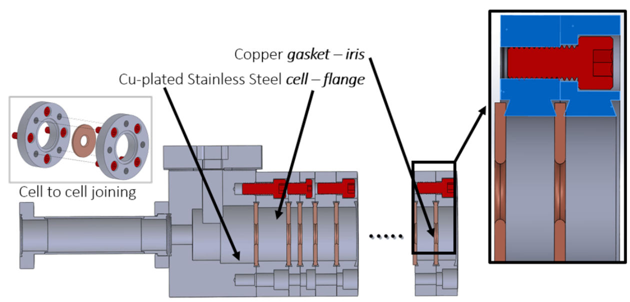


Figure 1: Brazeless design of the accelerating structure, as proposed here. The LCLS-like joint consists of a copper plated cell-flange, which bites into the copper gasket–iris. The gasket is thus a functional part of the resonator.

We present here a novel brazeless design for an accelerating structure (Figure 1). In a sense, it is evolutionary from the LCLS gun, and applied here to the design of iris-loaded accelerating structures. The major difference from the brazeless design of [5] is that the gasket of the RF and vacuum joint is a part of the resonator assembly, namely the iris. We further refer to it as iris-gasket in the text. We use stainless steel flanges that act as the resonator body, or cells in the accelerating structure. We will refer to them as flange-cells further in the text. Just like in the LCLS gun, stainless steel-cells are copper-plated, to provide the best RF performance. From the standpoint of RF design, the resulting structure is fully equivalent to a brazed all-copper accelerating structure. Remarkably, the complexity of the proposed assembly is not much different from the reliable and inexpensive conflat flange technology. The flange-cell is a stainless-steel part with a knife edge similar to that in the LCLS gun. The copper gasket-iris is indeed very similar to a blank conflat flange gasket. Conflat gaskets are stamped



ISBN 978-3-95450-182-3 

and, being a beamline commodity item, are cheap. For high gradient operation, one may elect to machine the copper gaskets, which will increase the price. However, for industrial gradients of 20–40 MV/m, it may be possible to do away with machined gaskets, bringing the price further down. Figure 2 shows a comparison of standard conflat flanges, gaskets, flange-cells and gasket-irises of the proposed brazeless assembly.

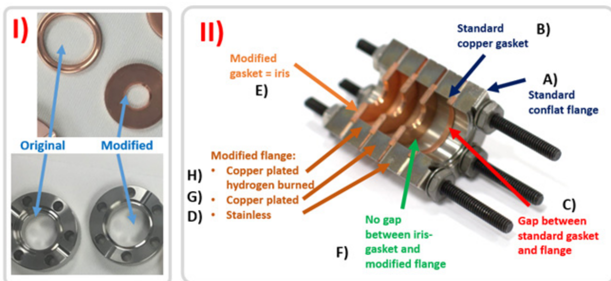


Figure 2: I) Original conflat flange and gasket, compared to modified conflat flange-cell and gasket-iris for brazeless assembly. II) Cut assembly of standard and modified conflat parts for comparison. Standard conflat flange A) with standard conflat gasket B) produce a micro gap C). Modified flange with modified gasket indeed produce an accelerating waveguide-like structure without gaps at the vacuum-RF contact. Some flanges are copper-plated, and some of them are hydrogen burned (bright copper).

## FIRST PROTOTYPE

We used a standard 1.33" conflat flange to test the idea. The double-sided flange bore was enlarged, so that the knife edge was right at the inner diameter line of the opening. These flanges were copper plated with a ~100-µm layer of copper. We also produced custom copper gasket-irises. We assembled a 5-cell structure with blank 1.33" cells that hosted coaxial couplers for RF measurement.

This test structure has successfully demonstrated the following:

1. Vacuum seal: a 5-cell structure was assembled and vacuum tested successfully. Then, it was disassembled and reassembled with new gasket-irises – 7 cells, which also were vacuum sealed.

2. Copper plating surface quality had been confirmed by a hydrogen burn test, in which a copper-plated cell had been heated up to 500 C, and no delamination of the plated copper had been observed. Copper-plated stainless steel is used in high power RF components like SLAC and CLIC flanges (inner waveguide surface plating) and in the LCLS gun back wall-cathode assembly.

3. Finally, the RF seal and quality of the copper plating was tested in RF measurements. The S11/S21 measurement (Figure 3) was equivalent to that of a structure fully made out of copper and brazed together. We performed this measurement before and after copper plating. In a zero-coupling S21 measurement, one can see how quality factor of resonant modes improved after copper plating, theoretical values for mode Q-factors were achieved.

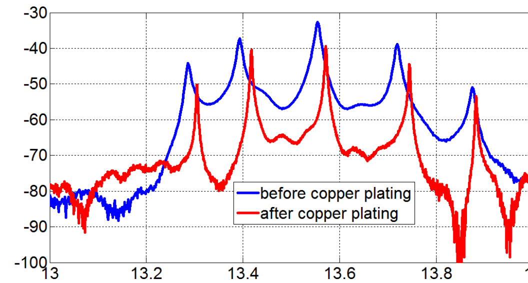


Figure 3: Network analyzer 5-cell (= 5 mode) standing-wave structure quality factor measurement with "zero" coupling. Blue – before copper plating, and red – after copper plating.

## SUMMARY

We presented an inexpensive method of accelerating waveguide production for industrial gradients [6]. By replacing the brazing step with a brazeless RF-mechanical design one can achieve a significant reduction in accelerator cost. A proof-of-principal prototype had been manufactured and tested. It successfully demonstrated that brazeless, vacuum-tight device is possible, copper plating does not delaminate with thermal cycling to 500C and RF properties of the device are equivalent to the all-copper structure.

## ACKNOWLEDGEMENT

This project was partially supported by Small Business Innovative Research phase II grant DE-SC0009571.

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