BUILDING A 12 GHz TRAVELING WAVE ACCELERATING STRUCTURE BRAZED THROUGH IRISES

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Abstract

Accelerating structures are usually manufactured by precision turning of individual cells combined with precision milling for complex parts such as rf power couplers. These multiple parts are staked and brazed into a complete structure. We consider an alternative approach: precision milling of multiple cells and couplers into metal blocks that comprise halves or quadrants of the complete structure. We successfully produced a 12 GHz Compact Linear Collider (CLIC) main linac accelerating structure prototype using this method. A previous prototype was designed as an open structure with a gap between cell irises. Here we describe a different approach, an accelerating structure which is brazed through irises. It is based on a multi-cell traveling wave structure designed at CERN for PSI, so called *T24 PSI 12 GHz*. This brazed-through irises structure was built at SLAC for high power tests at CERN. Here we describe the details of this process.

INTRODUCTION AND MOTIVATION

Accelerating structures of normal conducting linacs are typically built from a multitude of precisely machined cells. Examples are X-band structures of linear colliders [1] or S-band cavities of medical accelerators [2]. The cells are joined using high-temperature brazing or diffusion bonding into a complete structure. An alternative approach has been used for making structures from two halves at W-band [3–6] and X-band [7–10], quadrants [11,12] or octants [13]. These halves, *etc.* are made by precision milling and then joined together either by clamping [11,13] or brazing [7,8,12]. All these structures were designed with gaps between irises: a small, difficult to control gap [11]; small, controlled gap [12]; and a large gap on the order of a millimeter [3–10,13]. High power tests of these structures have shown that structures with controlled gaps performed satisfactorily [9,12].

Here we present an alternative approach to build a constant gradient traveling wave accelerating structure from halves [14]. We braze the halves through irises thus eliminating both rf field enhancement caused by a controlled gap between irises and degradation of high gradient performance attributed to uncontrolled gaps. The geometry of this structure is practically identical to a structure made of discs but with several advantages. In the case of halves, the machined surface area is smaller and number of precision parts to handle is fewer thus reducing fabrication costs.

More advantages come from the absence of rf current flow through the joints between the halves. This makes prebrazing rf cold test practical and useful, and reduces risk of arcing or erosion in small, uncontrolled gaps between cells. In cases of structures made from stacked cells rf currents cross these gaps. The gaps could be caused by joints starved for alloy in brazed structures or uneven bonding pressure in diffusion-bonded structures.

DESIGN AND MANUFACTURING

Design

The geometry of our structure is based on the so called *T24 PSI 12 GHz* which was designed at CERN for PSI [15] and was successfully built and high power tested [16]. The rf parameters of this structure are presented in [16] and should be practically identical to our structure. The original structure is made out of symmetric cells with rounded outer diameter. This cells geometry is suitable for manufacturing by milling into halves. Meanwhile the rf couplers (mode launchers) of the *T24 PSI 12 GHz* were brazed of separate milled parts and had to be re-designed both electrically and mechanically. We report this work in [17]. We show a solid model of the mode launcher from [17] in Fig. 1b). With a new coupler the electrical re-design was complete.

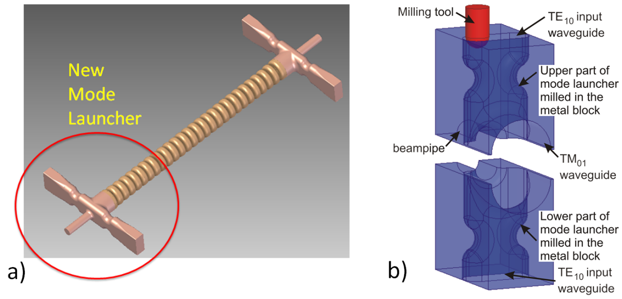

Figure 1: a) Solid model of RF envelope with re-designed mode launcher as imported into Solid Edge from HFSS [18], and b) solid model of the mode launcher, with detail of 8 mm diameter milling tool [17].

Manufacturing

In manufacturing of previous, open structure made of halves [7] we have validated an approach where we built a solid model directly from the electrical model. This electrical model was imported into Solid Edge [19] from HFSS [18]. After mechanical design was finished, the resulting solid model was used to generate the milling machine control program. No interim drawings were utilized for the

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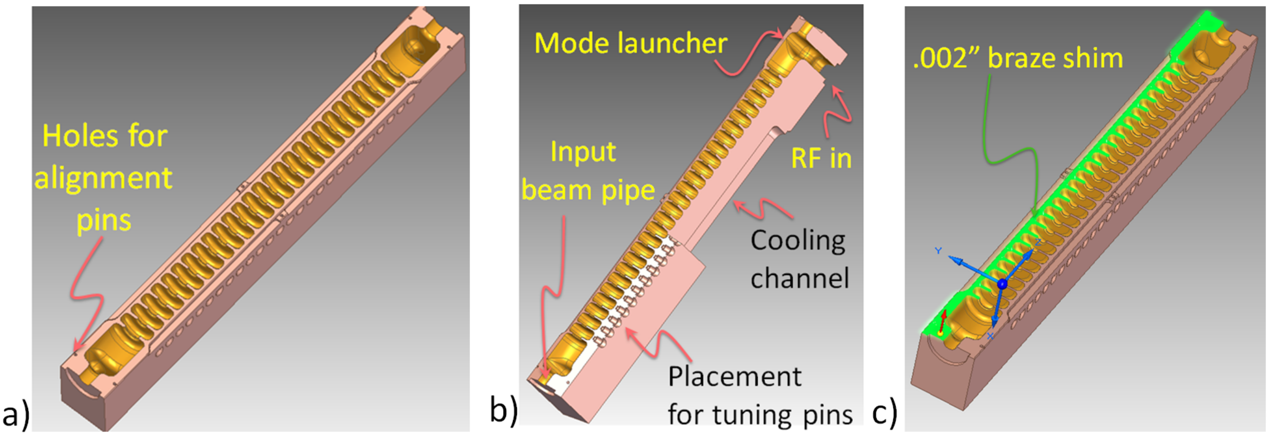

Figure 2: a) Solid model of half cavity. b) Cutaway of the half. c) Braze shim.

mill programming. Here we used the same approach. We show solid model of the imported geometry in Fig. 1a). This model was adapted to be milled out of halves with added cooling, flanges, tuning pins, *etc.* We show solid model of a half in Fig. 2a), cutaway of the half with visible holes for tuning pins and a cooling channel in Fig. 2b), and a design of 0.002 inch braze shim in Fig. 2c).

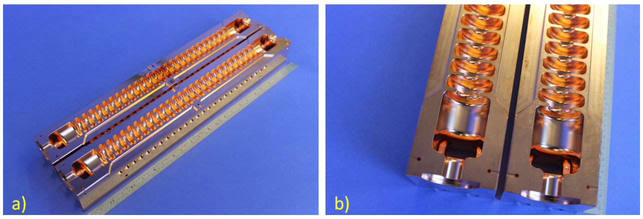

Figure 3: a) Two halves of the accelerating structure after machining. b) Input part of the structure zoomed on integrated milled-mode-launchers.

We planned to fabricate the structure using the following steps: machine halves from imported solid model; then clamp halves with instrument flanges and perform pre-brazing microwave cold measurements on our bead-pull setup; clean then braze; followed by final tuning and vacuum firing. We show milled halves in Fig. 3, and parts prepared for brazing in Fig. 4b).

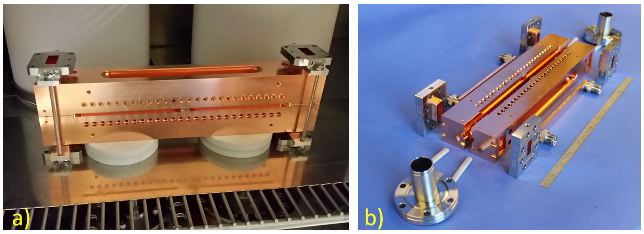

Figure 4: a) Structure clamped for pre-brazing microwave cold-test measurements. b) Structure parts before brazing. Tuning pins are not shown.

Pre-brazing Rf Measurements

We have included per-brazing bead-pull measurement into the fabrication procedure to reduce the risk of finished, brazed structure being outside tuning range. For the measurement of rf phase and amplitude along the structure we use non-resonant perturbation method [20]. We show the structure assembled for the pre-brazing bead-pull test in Fig. 4a). To simulate separation between halves due to melted brazing alloy we have put a 0.0011 inch shim between them. Results of the pre-brazing bead-pull have shown that beam-synchronous frequency is 23 MHz higher than the operating frequency of 11.994 GHz. For our tuning pins this frequency shift is at the limit of the tuning range. The cause of this frequency shift was traced to a machining error. At that point we decided to machine a shallow, 75 µm deep pocket at outside cavity diameter of every cell to drop the frequency by 23 MHz. After the machining we performed dimensional quality control to verify that the sizes of the machined pockets were acceptable and then proceeded to brazing, without additional microwave testing.

Final Tuning

For the tuning of the structure we used a method first published in [21] and refined in [22]. Our bead-pull setup with a tuned structure is shown in Fig. 5. Input reflection of the

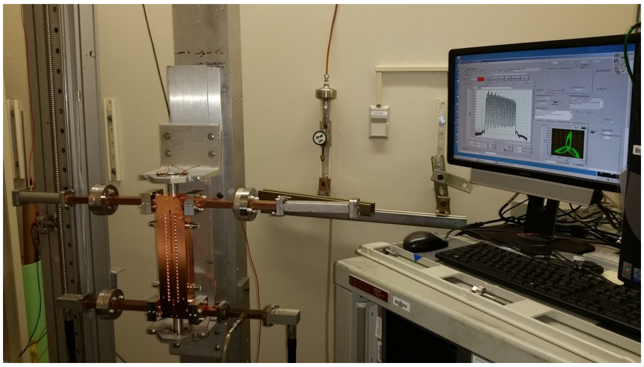

Figure 5: Final bead-pull measurements.

tuned structure is shown in Fig. 6 with -39 dB at operating frequency. Measured amplitude of on-axis field is shown in Fig. 7a). Phase deviation from beam-synchronous 120 deg. per cell is shown in Fig. 7b). Accumulated phase advance between first regular cell and penultimate regular cell is about 1 deg. Phase variations of about +/- 5 deg. for cells 15-25 are caused by a small reflection from output coupler. As brazed the beam-synchronous structure was 15 MHz lower than the operating frequency. This 15 MHz is comfortably within the tuning range. At the moment of publication the cause of this frequency shift is not understood. Possible reasons are miscalculation of the shape of frequency-correcting milled pocket or a manufacturing error.

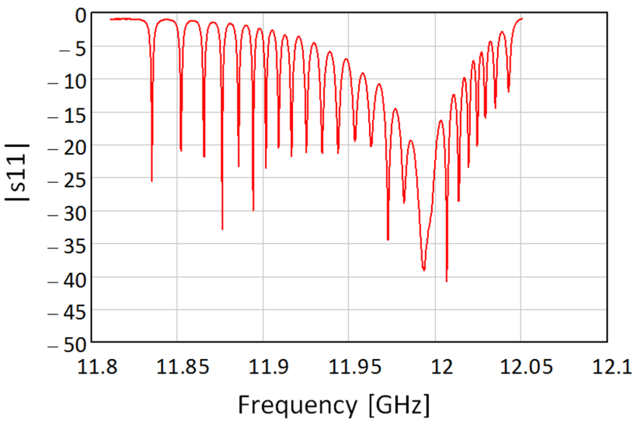

Figure 6: Input S11 of tuned structure with -39 dB at operating frequency.

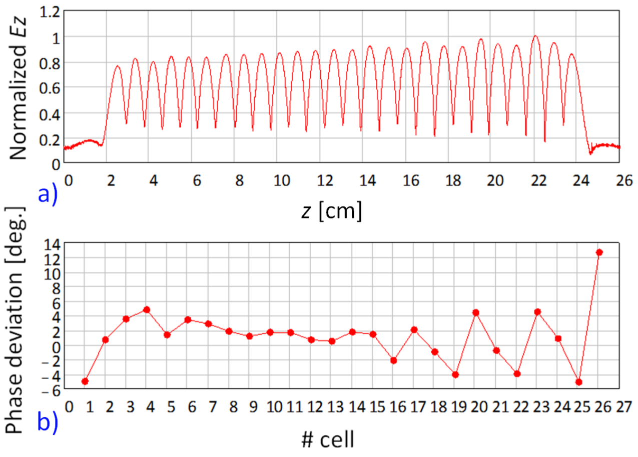

Figure 7: Results of bead-pull measurements made from an input port, input on the left: a) on-axis electric field normalized to peak value; b) deviation of rf phase from nominal 120 deg. per cell.

SUMMARY

We continue developing manufacturing techniques for high gradient accelerating structures. As part of this work, we built a 12 GHz traveling wave structure made of precisely milled halves. At the time of this publication the structure is being shipped to CERN for high power tests. Novelty of this structure is that it is brazed through irises unlike our previous made-of-halves-structures which have an open geometry with a controlled gap between iris halves. Once perfected, this method could reduce cost of linacs for scientific, medical and security applications.

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