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FABRICATION OF THE CERN/PSI/ST X-BAND ACCELERATING STRUCTURES

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Abstract

In a collaboration between CERN, PSI and Sincrotrone Trieste (ST), a multi- purpose X-band accelerating
structure has been designed and fabricated, used for high gradients tests in the CLIC structure testing program and in the FEL projects of PSI and ST. The structure has 72 cells with a phase advance of 5 pi/6 and includes upstream and down-stream wakefield monitors to measure the beam alignment. The SLAC mode launcher design is used to feed it with RF power. Following the CERN fabrication procedures for high-gradient structure, diffusion bonding and brazing in hydrogen atmosphere is used to assemble the cells. After tuning, a vacuum bakeout is required before the feedthroughs for the wake field monitors are welded in as a last step. We describe the experiences gained in finishing the first two structures out of a series of four and present the results from the RF tuning and low level RF tests.

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In a collaboration between CERN, PSI and Sincrotrone Trieste (ST), a multi- purpose X-band accelerating structure has been designed and fabricated, used for high gradients tests in the CLIC structure testing program and in the FEL projects of PSI and ST. The structure has 72 cells with a phase advance of 5 pi/6 and includes up-stream and down-stream wakefield monitors to measure the beam alignment. The SLAC mode launcher design is used to feed it with RF power. Following the CERN fabrication procedures for high-gradient structure, diffusion bonding and brazing in hydrogen atmosphere is used to assemble the cells. After tuning, a vacuum bakeout is required before the feedthroughs for the wake field monitors are welded in as a last step. We describe the experiences gained in finishing the first two structures out of a series of four and present the results from the RF tuning and low level RF tests.

INTRODUCTION

Currently an X band travelling wave accelerator structure is under development in collaboration between CERN, PSI and ELETTRA. At PSI and ELETTRA, it will serve for longitudinal phase space compensation at the respective FEL projects, where CERN will use it to test break down limits and rates in the high gradient regime. The design employs a large iris, $5\pi/6$ phase advance geometry, which minimizes transverse wake field effects while still retaining a good efficiency. In addition, we plan to use an active monitoring of the beam to structure alignment and to include two wake field monitors coupling to the transverse higher order modes.

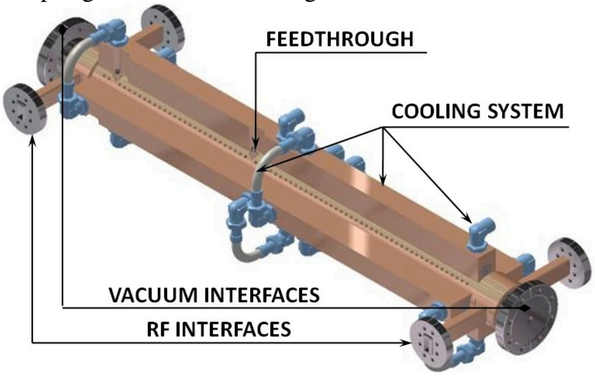

Figure 1: General view of the accelerating structure.

The accelerating structure is 965-mm long and its weight is approximately 62 kg. Two CF63 flanges at the extremities of the structure and four X-band WR90 RF waveguide vacuum flanges on the couplers are used as vacuum and RF interfaces. Figure 1 shows the structure and figure 2 gives a detailed view of the wake field monitor region. Table 1 gives the fundamental RF specifications.

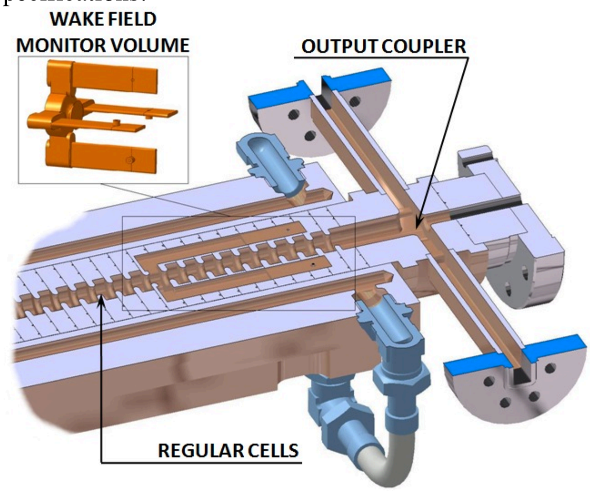

Figure 2: Wake field monitor region.

Table 1: RF Parameters

Reference frequency at 40 ^{O}C	11.9934 GHz
Beam Voltage	30 MeV
Max. Power	29 MW
Iris diameter	9.1 mm (avg.)
Wakefield monitors	up/downstream
Operating temperature	31-49 ^{O} C
Fill time	100 ns
Repetition rate	100 Hz

FABRICATION AND ASSEMBLY

Copper Disk Machining, Qualification Control and Assembly Preparation

The structure consists of two coupler subassemblies and 73 disks. 19 disks are specially designed to host the wake field monitor. All parts are fabricated by VDL ETG [3] using ultra-precise turning and milling processes.

The rough machining is performed all over the surface with an undercut of 0.1 mm. Then the annealing is performed at 500°C for 2 hours, followed by a mid cycle

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turning to make the reference surface for milling. The milling is then performed to its final design position.

The shape tolerance of 4 µm in the iris and cavity regions is achieved by single-point diamond turning. Flatness of the coupling faces of the disk is defined with a tolerance of 1 µm in order to fulfil the bonding requirements. The surface roughness of internal disk surfaces is 0.025 µm and 0.8 µm on the external ones.

All the final machining operations are executed with use of the hydrostatic guide based equipment providing a high rigidity and stability of the technological system.

The dimensional and shape accuracy measurements are performed by using the 3D coordinate measurement machine Zeiss UPMC 850 Carat. The surface roughness is controlled by means of a non-contact Scanning White Light Interferometer Zygo NewView 5032.

The fabricated cells were prepared for the assembly following the SLAC developed procedure. The process includes vapour degreasing, alkaline soak cleaning, chemical etching, ultrasonic in de-ionized water and alcohol cleaning. The parts were stored in a clean alcohol and dried with filtered nitrogen just prior to diffusion bonding. The cells should not be stored in alcohol for more than one day [4].

Assembly of the Accelerating Structure

To avoid possible misalignment between regular cells due to large quantity of them it was decided to split the structure in three separate stacks.

The assembly includes several steps (Fig. 3):

- Aligning the cells of each stack in a dedicated V-shaped support with accuracy better than 5 µm (Fig. 4)

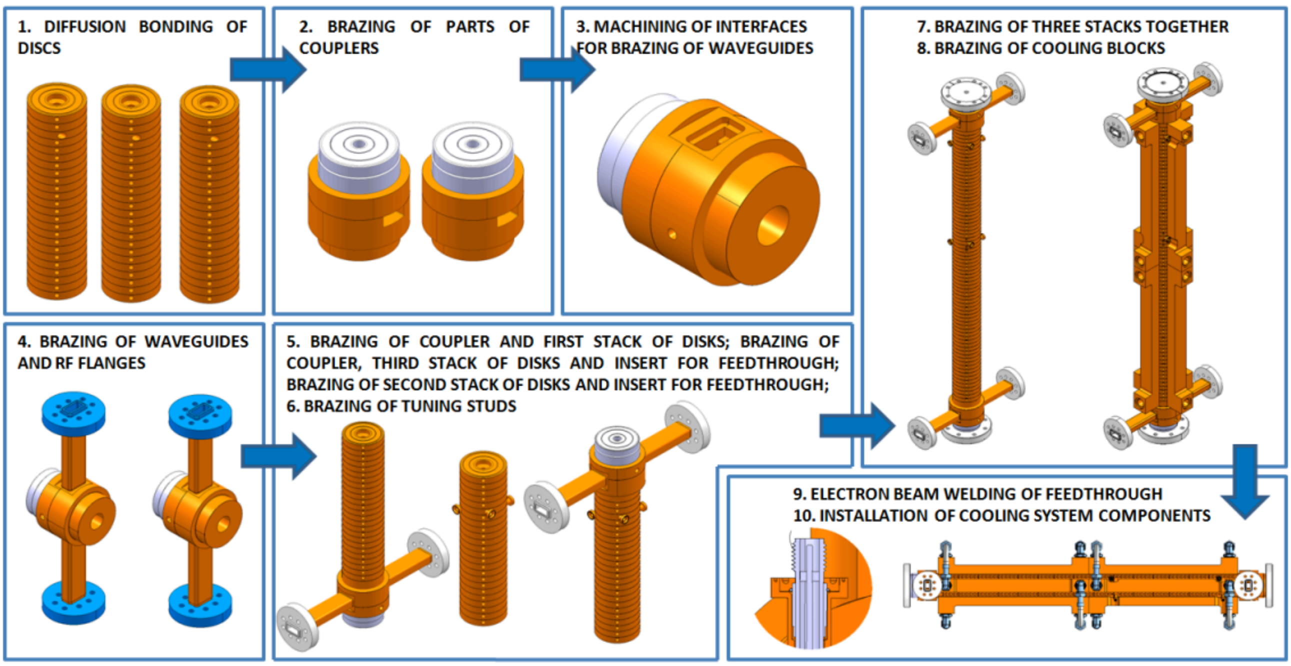

Figure 3: Assembly of the accelerating structure.

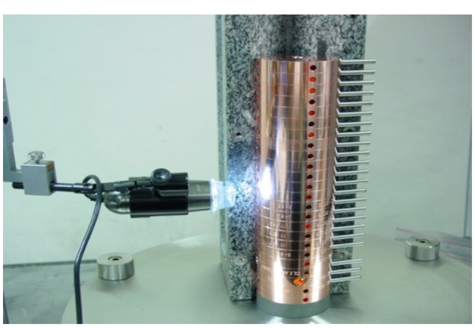

Figure 4: Assembly and alignment of stack.

- Diffusion bonding of the discs under hydrogen at 1040°C. Fig. 5 shows the installation of the stack in the furnace before bonding.
- Brazing of parts of couplers together at 1040°C with brazing alloy 25Au/75Cu.
- Machining of interfaces for brazing the waveguides to the couplers.
- Brazing of waveguides on couplers at 1040°C with brazing alloy 25Au/75Cu.
- Brazing of coupler and first stack of disks; brazing of coupler, third stack of disks and four inserts for feedthrough; brazing of second stack of disks and

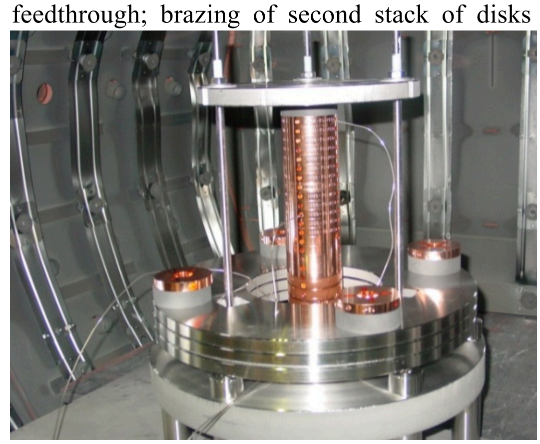

Figure 5. Bonding of a disk stack.

four inserts for feedthrough at 1020°C with brazing alloy 35Au/65Cu.

- Brazing three sets: coupler and first stack of disks; coupler, third stack of disks and four inserts for feedthrough; second stack of disks and four inserts for feedthrough; each at 1020°C with brazing alloy 35Au/65Cu.
- Brazing of tuning studs at 1020°C with brazing alloy 35Au/65Cu.
- Brazing of three stacks together at 980°C with brazing alloy 50Au/50Cu.

After each brazing, the assembly is checked for leaks. At this point the structure is ready for RF check, tuning and characterization described in the next section.

After brazing the stacks for the first structure, major lateral offsets between stacks of 350 μm and 50 μm developed, whose cause is as yet unknown. To eliminate that problem, additional copper sleeves interlocking the stacks were introduced for the second structure, which turned out fine with an inner alignment better than 18 μm.

Manufacturing steps to be done after tuning are:

- Brazing of cooling blocks at 820°C with brazing alloy 68Ag/28Cu/5Pd.
- Hydrogen bake out in vacuum at 650°C for at least 10 days (Fig. 6)
- Electron beam welding of eight feedthroughs for the two wake field monitors
- Installation of the cooling system components, such as connectors and flexible pipes.Installation of the cooling system components, such as connectors and flexible pipes.

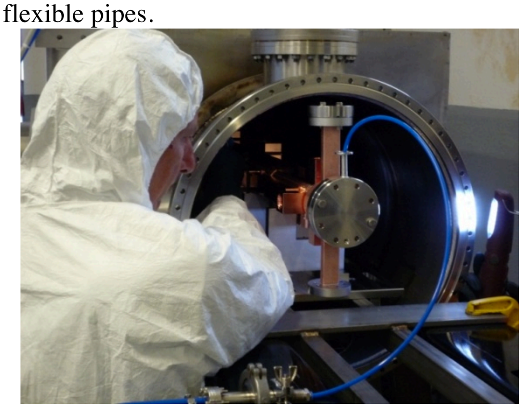

Figure 6: Preparation for baking of the accelerating structure at COMEB in Rome.

RF TUNING

The RF tuning system consists of four radial tuning holes per disk, each equipped with a special tuning stud brazed to the bottom of the hole. Tuning is done via push-pull. It allows to either increase or decrease the equivalent outer diameter of each cell by deforming the cell's wall and thus changing the cell RF frequency.

The steps of the tuning procedure are [5]:

- Measure the field distribution using the "bead-pull" method.
- Calculate the local reflection of each cell.
- Calculate the global reflection change (|ΔΓglobal| or |ΔS11|) due to local reflection correction.
- Tune cell-by-cell while monitoring |ΔS11| on the network analyzer to the target calculated in the previous step.

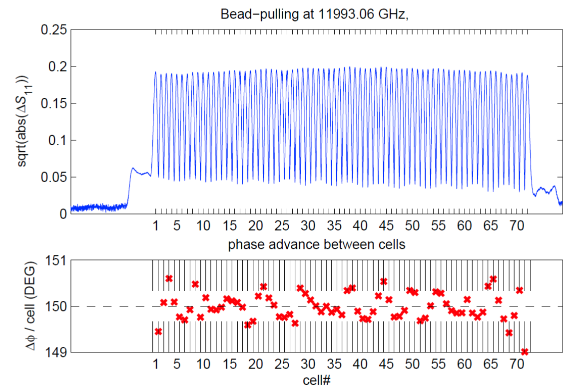

Figure 7: Field flatness and phase advance after tuning.

The overall procedure was iterated four times. The field flatness and the phase advance (measured at the target frequency) after tuning are shown in Figure 7. At the operating frequency, the phase advance per cell is 150°+/-0.7°. No major difficulties showed up. Even for the first structure, the inner offsets did not have any effects on field flatness and phase advance.

SUMMARY

Two out of a series of four X band structures to be used in fourth generation light sources have been fabricated and successfully tuned. The very first structure showed an internal alignment out of specification, whose effect on the suitability for single bunch operation is still under investigation. The second structure fully complies with an overall straightness after assembly lower than 18 μm. RF tuning was done for both structure using the standard procedure at CLIC and gave excellent results.

Assembly, brazing and tuning of the second pair of structures will start in September and should be finished by the end of the year. With the experience gained in the fabrication of the first pair of structures and the minor design changes required, we do not expect major problems for the completion of the second pair.

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