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MHI'S PRODUCTION ACTIVITIES OF ACCELERATOR COMPONENTS

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Abstract

Mitsubishi Heavy Industries (MHI) is manufacturing various types of accelerator components. As examples of recent production activities result of a mass-production of S-band accelerating structure for PAL-XFEL and a status of series production of C-band waveguide network for SwissFEL will be reported in this paper.

INTRODUCTION

Mitsubishi Heavy Industries (MHI) has started manufacturing of accelerator components such as accelerating structures in 1960s. For example, in a field of normal conducting accelerator, in recent years, MHI had handled mass production of C-band choke-mode accelerating structures and SLED for Riken SACLA, production of DTL, SDTL (Separated DTL), ACS (Annular Coupled Structure) for JAEA/KEK J-PARC [1]. In latest years, MHI manufactured over 120 S-band accelerating structures for PAL-XFEL project [2-4] and shipment has completed in March 2015. In addition, MHI has accepted order of C-band waveguide for SwissFEL project [5] in June 2014. One set of prototype waveguide has been already delivered to PSI in December 2014 and series production is in progress now.

S-BAND ACCELERATING STRUCTURES FOR PAL-XFEL

Mass-production of the S-band 3 m long accelerating structure [6-7] started in June 2012 and finished at March 2015. Totally 120 structures has been delivered to PAL. Appearance of the structure is shown in Figure 1 and main parameters are shown in Table 1.

Result of LLRF measurement after tuning shown in Figure 2. It shows excellent performance of production.

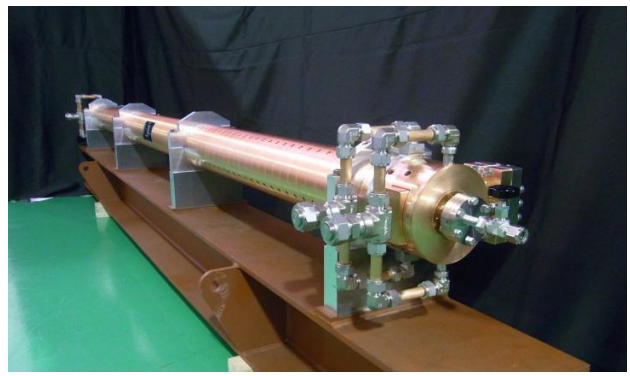

Figure 1: Appearance of the S-band accelerating structure for PAL-XFEL.

Table 1: Main Parameters of the S-band Accelerating Structure for PAL-XFEL

Item	Value
Operating frequency	2856 MHz
Accelerating type	C. G.
Phase shift per cavity	2π/3
Unloaded Q	13,000
Attenuation constant	0.56
Input / Output VSWR	< 1.05
Phase error	< +/- 2.5 degree
Number of cells	82 + 2 coupler cells
Filling time	0.84 μs
Length	3 m
Coupler type	Quasi-symmetrical

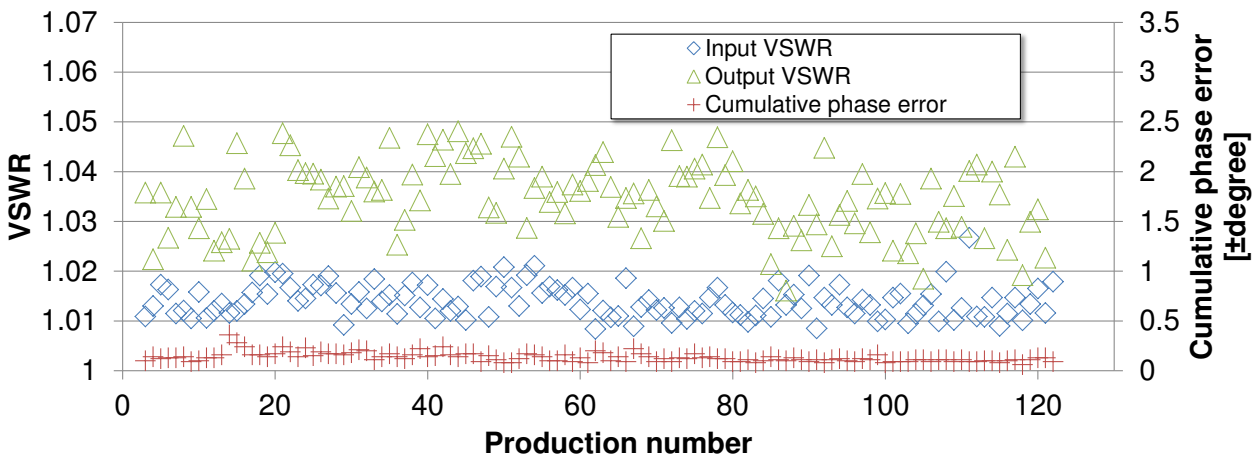

Figure 2: Input / Output VSWR and cumulative phase error of 120 S-band structure for PAL-XFEL after tuning.

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C-BAND WAVEGUIDE NETWORK FOR SwissFEL

Overview of the waveguide network for LINAC 1 of SwissFEL is shown in figure 3. One waveguide network module provides RF power from one klystron to four accelerating structure. Waveguide network for LINAC 1, 2 and 3 slightly differ from each other but basic configuration is common. Six directional couplers for RF monitor, three RF splitter and nine vacuum ports are included in one module. Specification of the waveguide network is shown in Table 2.

Table 2: Specification of the C-band Waveguide Network for SwissFEL

Item	Value
Bandwidth	5712 MHz +/- 20 MHz
Peak power	320 MW*
Average power	15 kW
Pulse repetition rate	1 – 100 Hz
VSWR	< 1.04
Operating pressure	< $1x10^{-6}$ Pa
Waveguide size	WR187
Flange type	C-band A-DESY
Coupling of the RF monitor	-60 +/- 2 dB (5712 +/- 3 MHz)
Directivity of the RF monitor	>25 dB (5712 +/- 20 MHz)
RF symmetry error of splitters	< 0.1 dB in amplitude < 3 degree in phase

*Maximum power in between the pulse compressor and the 1st splitter

Main part of the waveguide body is made from extruded ASTM class 2 oxygen-free copper (OFC). Waveguide flange is C-band A-DESY type. FUAR48 flanges are used for monitor ports. CF40 (ICF70) flanges are used for vacuum ports. Material of the each flange is SUS316L. RF flanges are copper plated.

Waveguide bodies, flanges and cooling pipes are assembled using vacuum brazing method.

In order to precisely fit to input flange of each accelerator structure, dimension accuracy between four interface flanges are +/- 0.2 mm.

Figure 4 shows situation of a vacuum test of the vertical waveguide at factory. One prototype module had been already delivered to PSI in December 2014 and has already installed in the test facility as shown in Figure 5.

High power test of the prototype module by PSI is planned. Additional 26 modules will be delivered as a plan of series production. Production of approximately 500 waveguides has been started. First delivery of the series waveguide is planned in summer 2015.

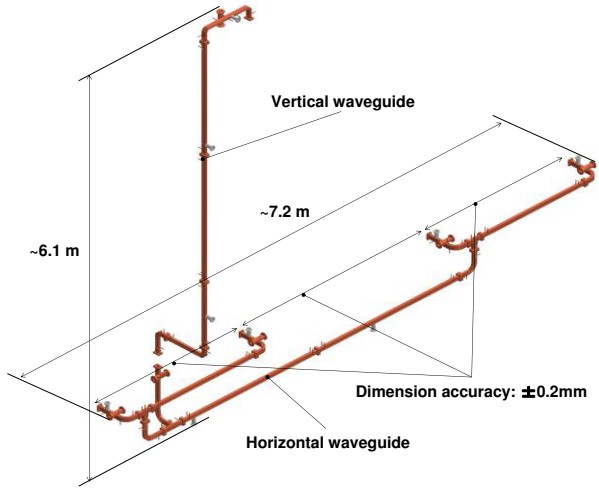

Figure 3: Overview of the C-band waveguide network for SwissFEL LINAC 1.

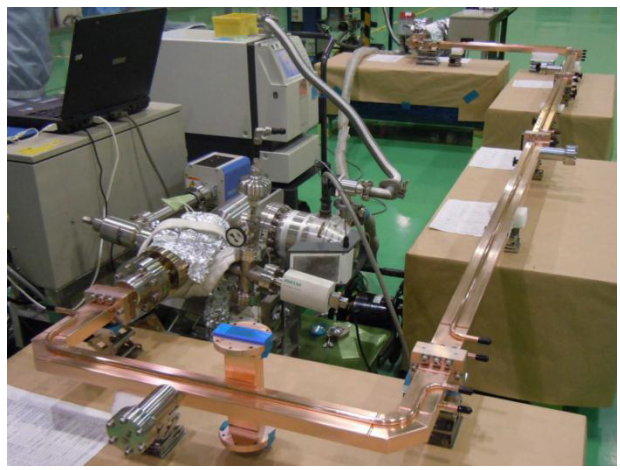

Figure 4: Vacuum test of vertical waveguide at MHI factory.

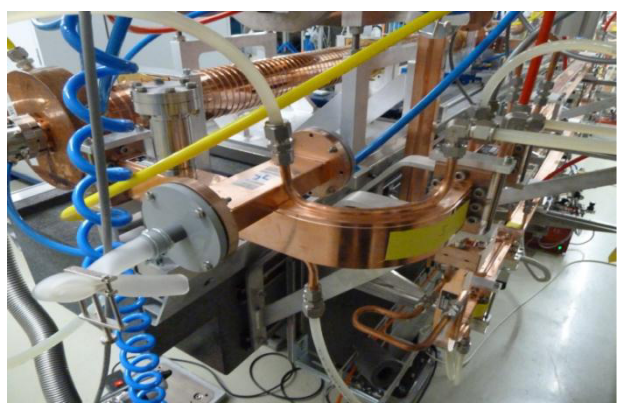

Figure 5: Horizontal waveguide installed in the PSI test facility.

Directional Coupler for RF Monitor

Schematic of the directional coupler is shown in Figure 6. Type of the monitor is a side-wall bidirectional coupler. Six RF monitors are included in the prototype module. Result of the LLRF measurement of coupling and directivity is shown in Figure 7. All manufactured RF monitor complies with LLRF specification described in Table 2. Definitions of the values are as follows.

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Coupling: S31
Directivity: S31 – S41

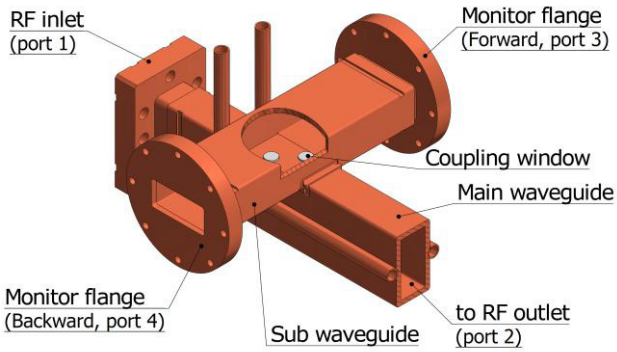

Figure 6: Schematic of the RF monitor.

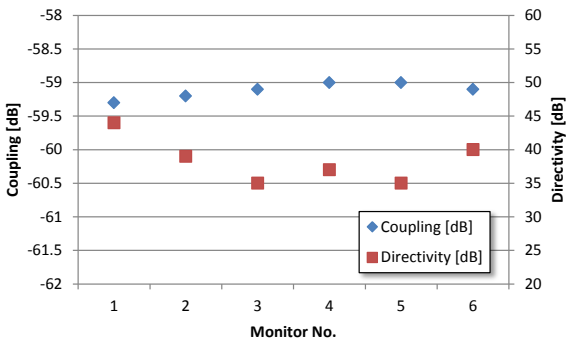

Figure 7: Coupling and directivity of RF monitors in the prototype module

RF Splitter

RF Splitter divides RF power from inlet flange into 2 outlet flanges. Schematic of the H-plane splitter is shown in Figure 8. Two H-plane splitters and one E-plane splitter are included in the prototype module.

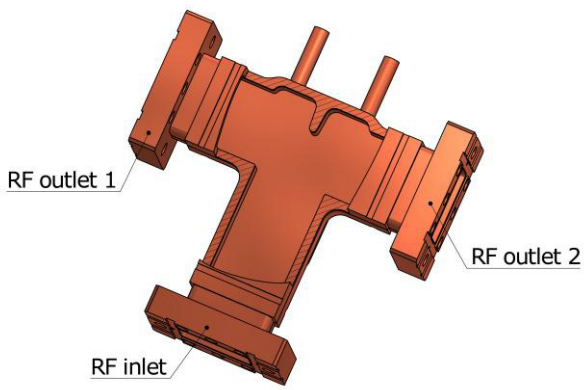

Figure 8: Schematic of the H-plane splitter.

Result of the LLRF measurement of symmetry error is shown in Figure 9. All splitter complies with LLRF specification described in Table 2.

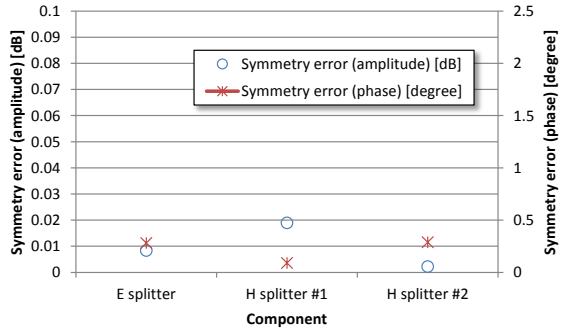

Figure 9: Symmetry error of splitters in the prototype module.

Production Status and Plan

Production of approximately 500 waveguides has been started in early 2015. First delivery of the series waveguide modules is planned in summer 2015. The rest will be delivered in series by spring 2016.

CONCLUSION

Production result and status of two types of accelerator components are described in this paper. MHI keep contributing to the advance of the accelerator technology.

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