PRODUCTION STATUS OF ACCELERATOR COMPONENTS

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Abstract

Mitsubishi Heavy Industries, LTD. (MHI) has been delivered various kinds of accelerator components to multiple FEL facilities. Recently we completed production of S-band accelerating structures for PAL-XFEL. Currently we are manufacturing C-band waveguide network for SwissFEL. Production status and results of above-mentioned products are reported in this paper.

INTRODUCTION

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 network prototype (CWNP) for SwissFEL project [5] in June 2014 and has been already delivered to PSI in December 2014 [6]. MHI also has been accepted order of 26 C-band waveguide network series (CWNS) and the production of them is in progress now.

S-BAND ACCELERATING STRUCTURES FOR PAL-XFEL

Mass-production of the S-band 3 m long accelerating structure [7-8] started in June 2012 and finished at March 2015. Totally 120 structures has been delivered to PAL. Appearance of the structure is shown in Fig. 1 and main parameters are shown in Table 1.

Results of LLRF measurement after tuning are shown in Fig. 2. It shows excellent performance of production.

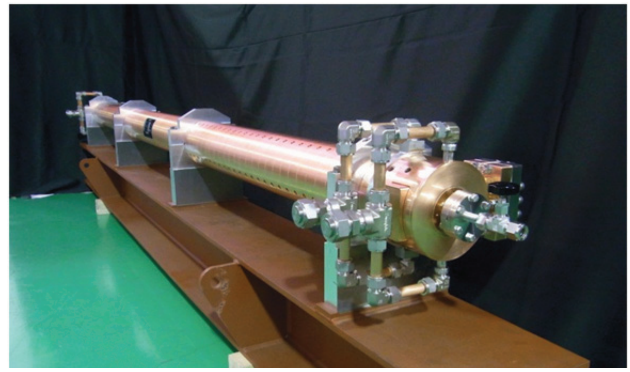

Figure 1: Appearance of the S-band accelerating structure for PAL-XFEL.

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	$2\pi/3$
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

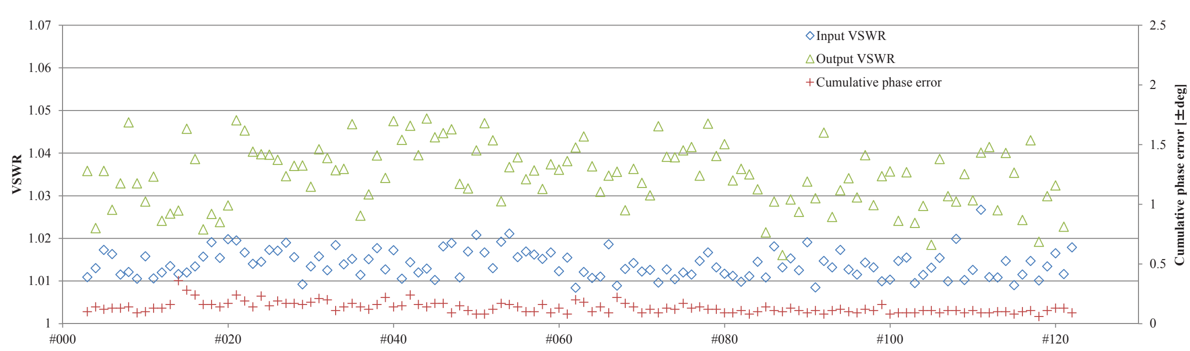

Figure 2: Input / Output VSWR and cumulative phase error of 120 S-band structure for PAL-XFEL after tuning.

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C-BAND WAVEGUIDE NETWORK FOR SwissFEL

The prototype waveguide (CWNP) has already installed by PSI in the test facility and high power test by PSI is planned. Additional 26 units (494 waveguides) will be delivered as a plan of series production (CWNS). 4 units of the CWNS have been already delivered to PSI in August 2015. Factory acceptance test results of the CWNP and first 4 units of the CWNS are shown below.

Overview of the waveguide network for LINAC 1 of SwissFEL is shown in Fig. 3. One waveguide network 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 splitters and nine vacuum ports are included in one waveguide network. 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
RF leak to vacuum manifold	< -85 dB
Residual gas analysis (RGA)	The RGA spectrum must show no evidence of hydro carbons and the peaks > 40 Amu (excluding peak 44) should be < 0.1%
Outgassing rate	< 1.0x10^{-7} Pa・m^3/(s・m^2)

*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.

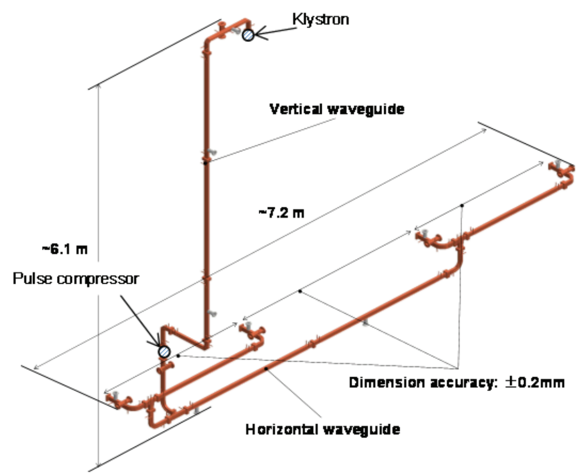

Figure 3: Overview of the C-band waveguide network for SwissFEL LINAC 1.

Directional Coupler for RF Monitor

Schematic of the directional coupler is shown in Fig. 4. Type of the monitor is a side-wall bidirectional coupler. Result of the LLRF measurement of coupling and directivity is shown in Fig. 5. All manufactured RF monitor complied with LLRF specification described in Table 2. Definitions of the values are as follows.

Coupling: S31 (-60 +/- 2 dB)
Directivity: S31 – S32 (> 25 dB)

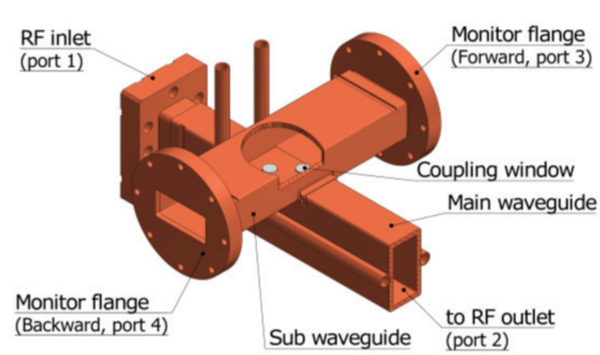

Figure 4: Schematic of the RF monitor.

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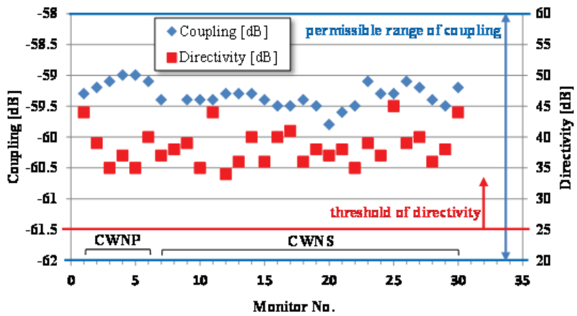

Figure 5: Coupling and directivity of RF monitors.

RF Splitter

RF Splitter divides RF power from inlet flange into 2 outlet flanges. Schematic of the H splitter is shown in Fig. 6. Two H splitters and one E splitter are included in one waveguide network unit.

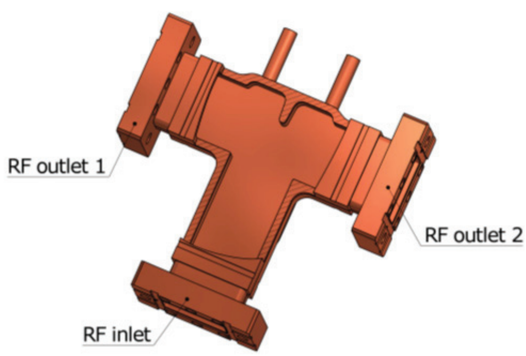

Figure 6: Schematic of the H splitter.

Result of the LLRF measurement of symmetry error is shown in Fig. 7. All splitters complied with LLRF specification described in Table 2.

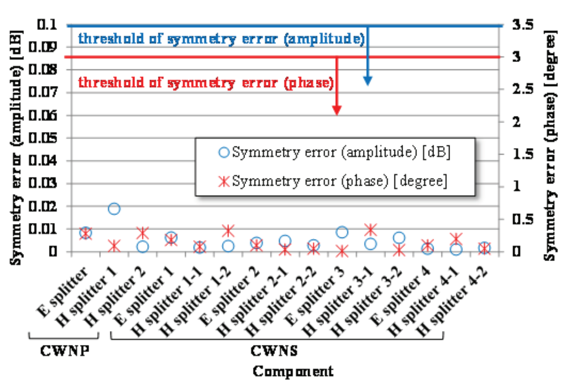

Figure 7: Symmetry error of splitters.

Residual Gas Analysis (RGA) and Outgassing Rate Measurement

RGA and outgassing rate measurement were carried out for the waveguide network. Regarding the CWNP, whole waveguide unit was divided into one vertical part and two horizontal parts then measured. Regarding the CWNS, one waveguide piece from each unit is picked up and assembled into one waveguide unit using 4 waveguide pieces then measured. Result of the RGA is shown in Fig. 8. There is no evidence of the hydrocarbons in mass spectrum.

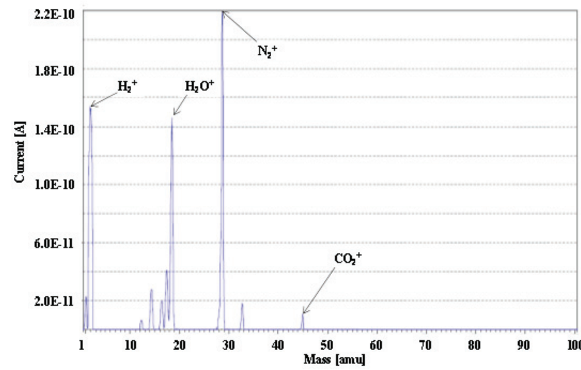

Figure 8: Residual gas analysis of the waveguide unit of CWNS (1st shipment).

Result of the outgassing rate is shown in Fig. 9. All results of the outgassing rate complied with the specification described in Table 2.

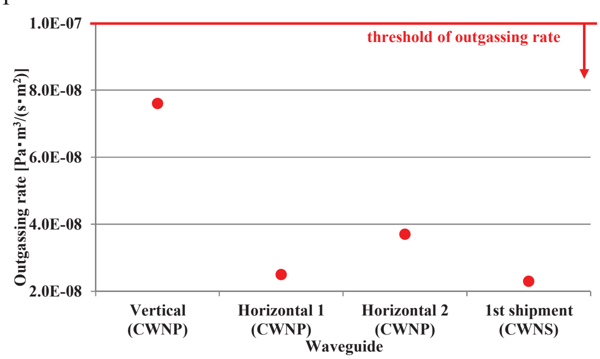

Figure 9: Outgassing rate of the CWNP and the CWNS.

CONCLUSION

Production status and result 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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