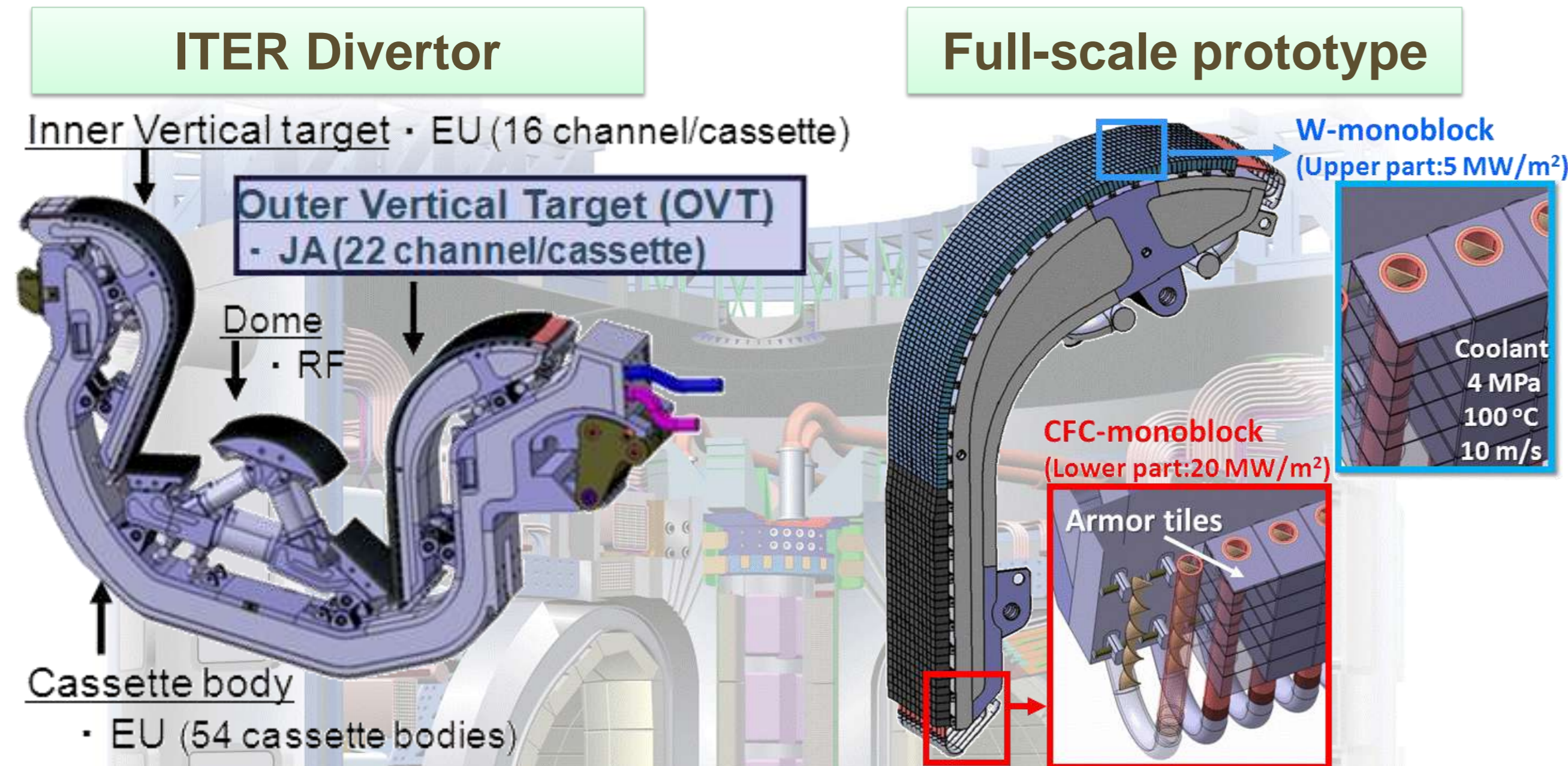


# Progress of Manufacturing and Quality Testing of the ITER Divertor Outer Vertical Target in Japan

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## 1 The design of ITER divertor



Japan Domestic Agency (JADA) has started manufacturing 11 plasma facing units (PFUs) of a full-scale prototype which is corresponding to a half cassette of an outer vertical target (OVT) in the ITER divertor. This PFU, which is based on the present design proposed by the ITER organization (IO), consists of carbon fiber composite (CFC) monoblocks, tungsten (W) monoblocks and CuCrZr tubes. At the beginning of this activity, **a joining technology and quality control for an interface between plasma-facing material and heat-sink material are key issues in the manufacturing process of the PFUs.**

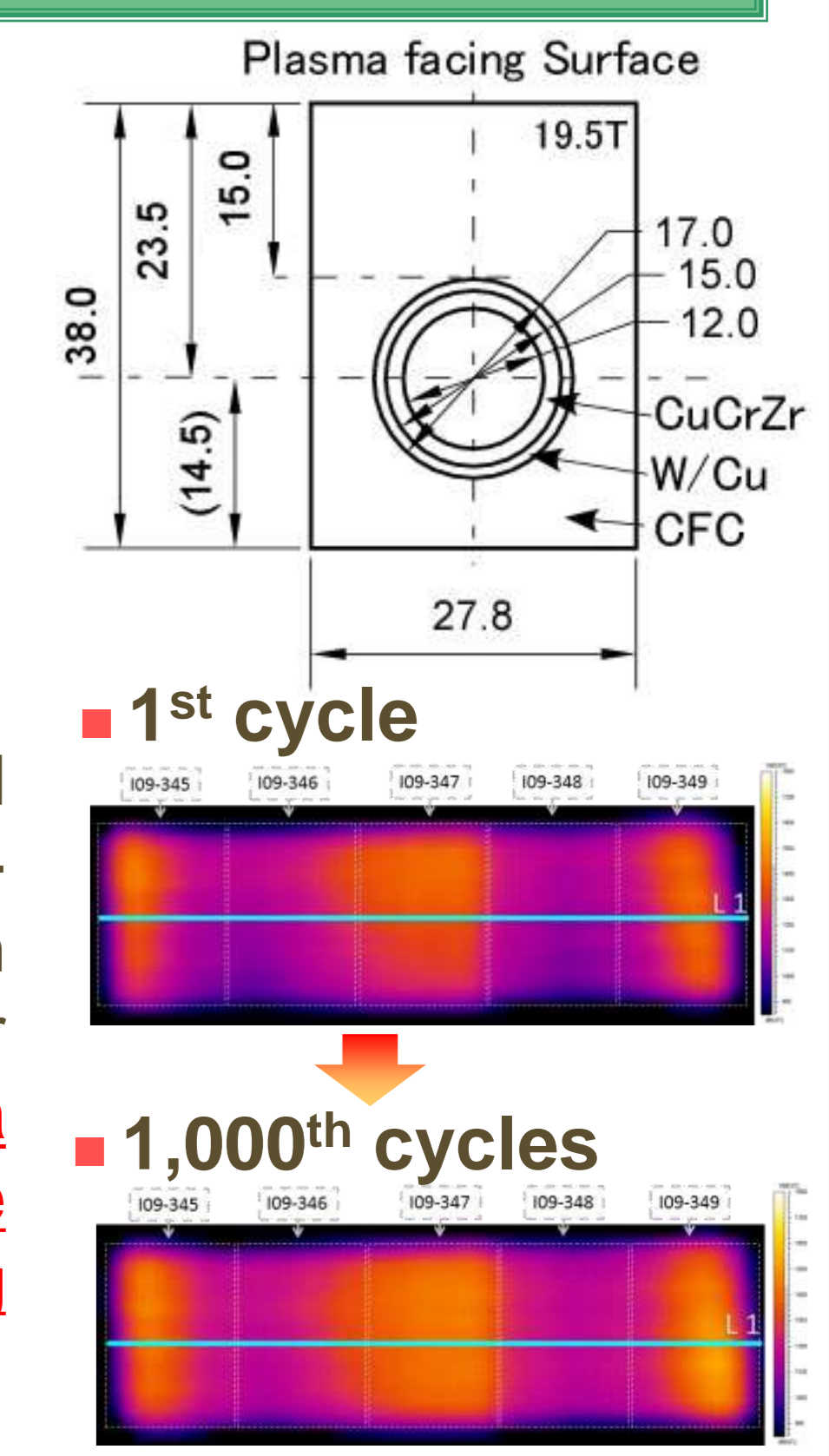
## 2 Material selection and procedure for Quality of jointing

### To improve wettability,

**Titanium-coating** was applied to metalize the CFC joint surface. **Thickness of the coating should be strictly controlled to minimize assembly gap**, because the gap between the CFC monoblock and the buffer layer is a key parameter for the high temperature brazing.

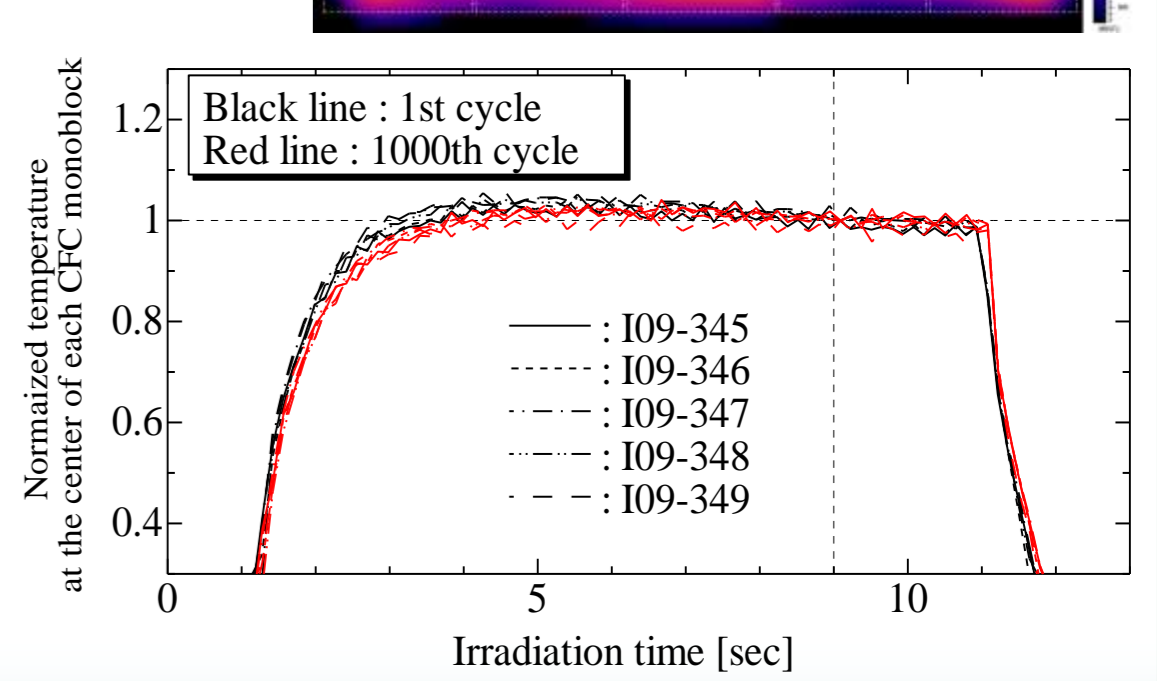
### As a buffer layer

An **interlayer collar of the W/Cu** instead of the Cu was inserted in between the CuCrZr tube and the CFC with braze fillers of Ni-Cu-Mn. The W/Cu has intermediate value of thermal expansion coefficient between the CFC and the CuCrZr tube, and higher mechanical strength than Cu. It was employed **to decrease a deformation amount of CFC monoblock caused by shrinkage and recovery of mechanical strength of the CuCrZr tube during the heat treatment processes.**



### HHF test of 20 MW/m<sup>2</sup> for 1,000 cycles

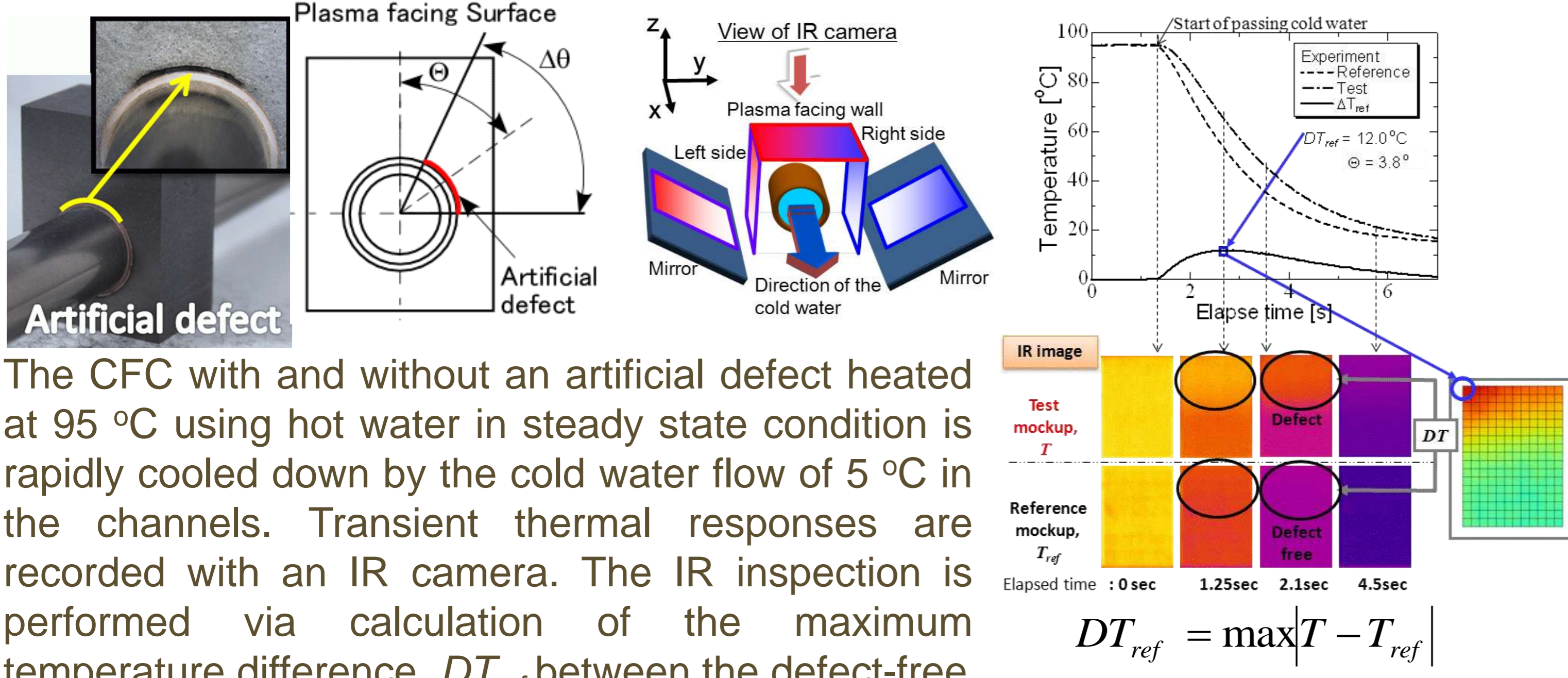
JADA demonstrated that three mock-ups fabricated by using the joining process **withstood the cyclic heat load of more than 20 MW/m<sup>2</sup> for 1000 cycles** before the manufacturing of the full-scale prototype. This shows positive prospects for manufacturing of PFU.



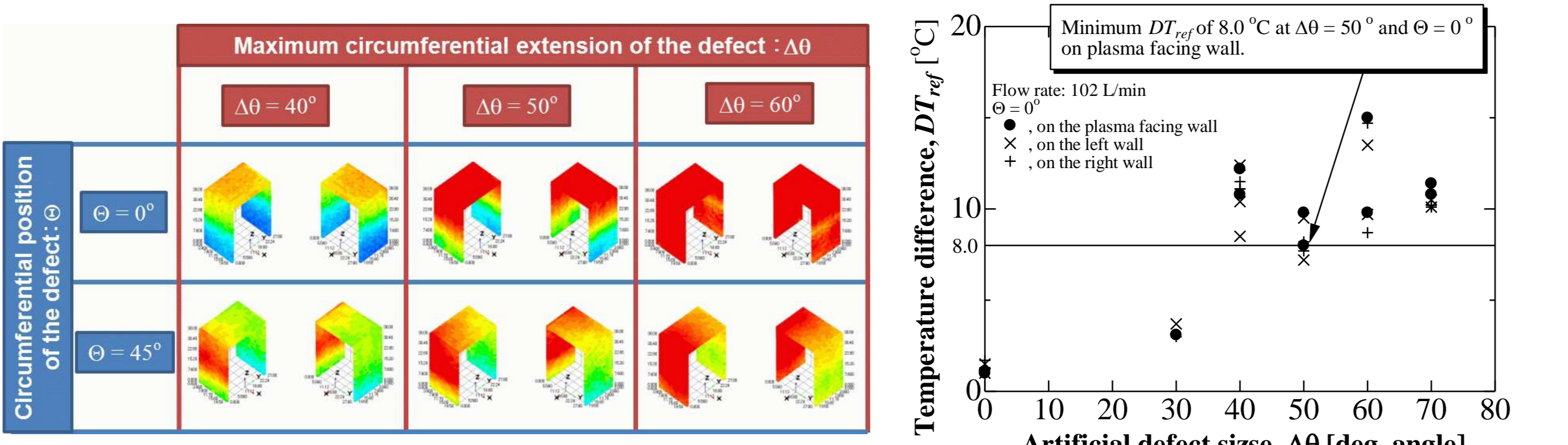
## 3 IR inspection for quality control

### Facility of Infrared NDE for Divertor: FIND

FIND can detect the integrated defects in the CFC and its joint interface.



The CFC with and without an artificial defect heated at 95 °C using hot water in steady state condition is rapidly cooled down by the cold water flow of 5 °C in the channels. Transient thermal responses are recorded with an IR camera. The IR inspection is performed via calculation of the maximum temperature difference,  $DT_{ref}$  between the defect-free and a test mock-up. Two mirrors are mounted at a side of each channel in FIND. The temperature on three surfaces of the CFC monoblock can be simultaneously monitored in FIND.

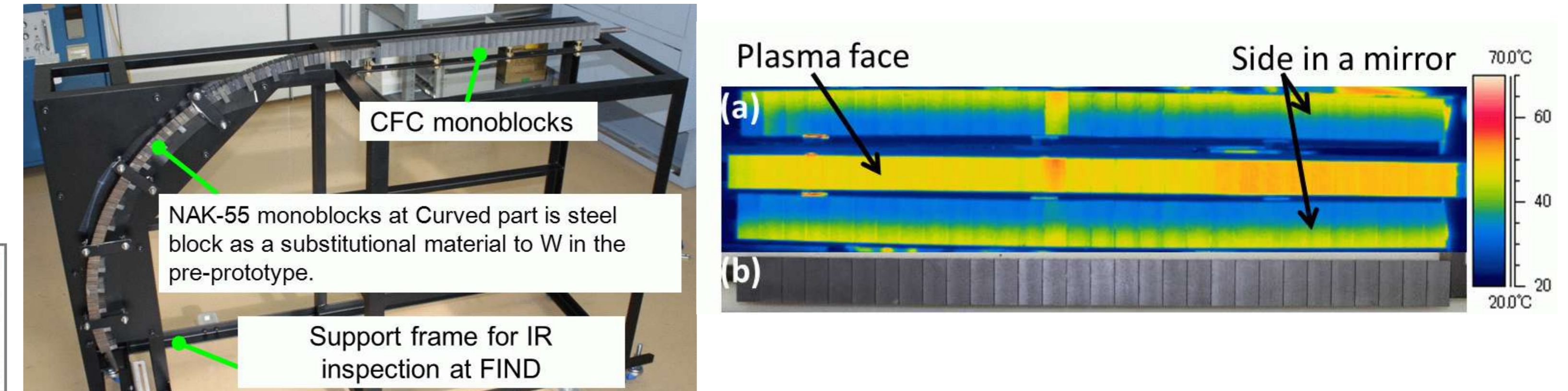


JADA applies the criteria of IR inspection in accordance with the procurement arrangement between the IO and JADA. The present criteria are that none of the CFC/Cu joints shall have defects with  $\Delta\theta > 50^\circ$ . The criteria were obtained by the experiment in FIND. JADA keeps applying the criteria of the IR inspection until new criteria will be confirmed by a use of data of high heat flux testing.

## 4 Manufacturing status of OVT full-scale prototype

### Pre-prototype of PFU

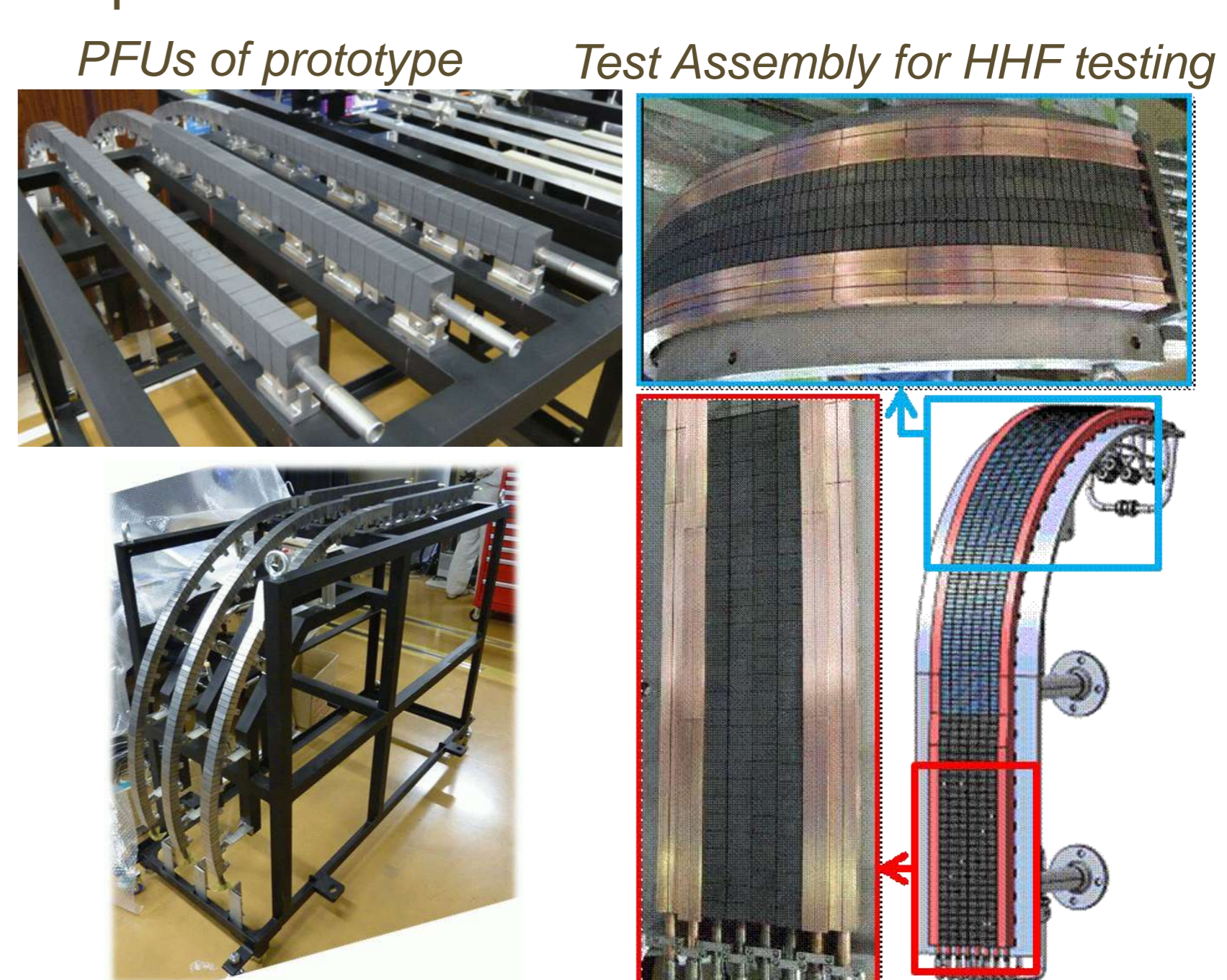
The pre-prototype of PFU was manufactured as a final exercise toward manufacturing the PFUs of the full-scale prototype. The result of the IR inspection indicates a good performance except for a central armor tile.



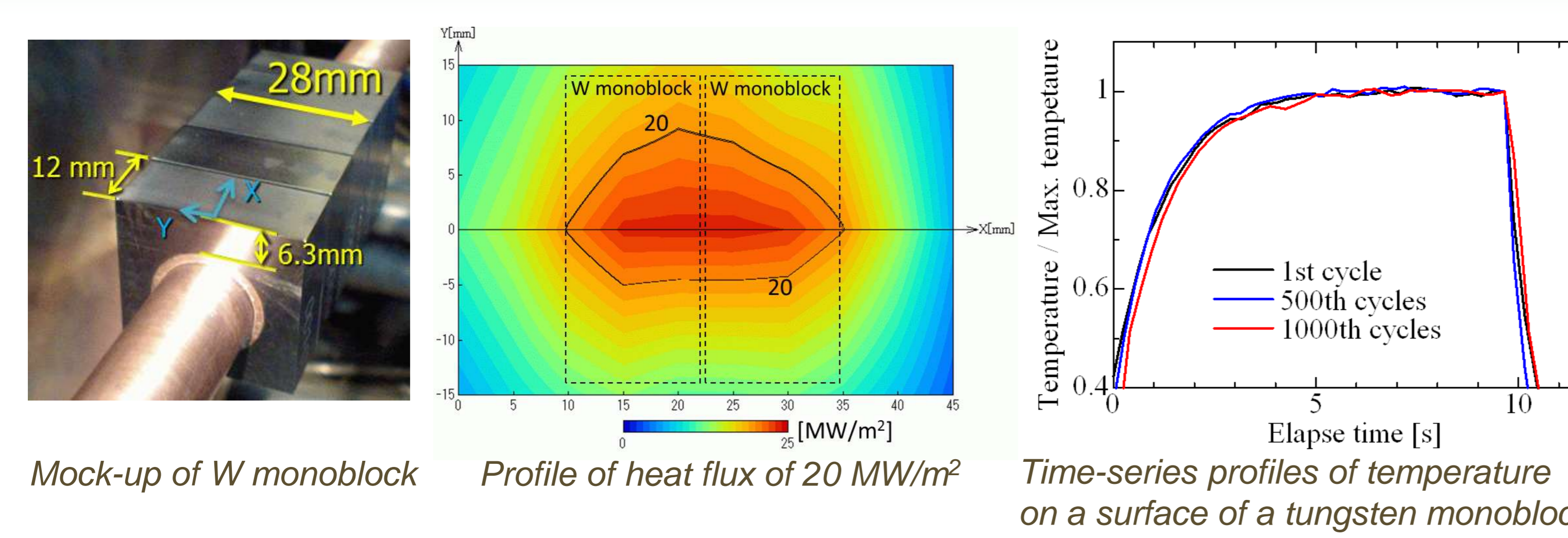
The defect of the central tile was caused by excessive restraint of a longitudinal thermal elongation of the CuCrZr tube with brazing jigs during the heat treatment. After this experience, JADA improved the jig to allow the longitudinal thermal elongation of CuCrZr tube due to thermal expansion.

### PFUs

Based on the result from the pre-prototype of PFU, the first 6 PFUs were manufactured by the end of June 2012. High heat flux (HHF) testing for the 6 PFUs, which are mounted on a test frame of a test assembly, will be started at IDTF of Russian Federation Domestic Agency from October 2012. Moreover, the manufacturing of the other 5 PFUs is scheduled in 2013.



## 5 R&D of W monoblocks



JADA has started R&D of the W monoblocks to support the IO design activity for full-W PFU without PFU, which is to be determined by Autumn 2013. Two mock-ups with the W named "S-TAN" were manufactured by using a non defect bonding (NDB) for the joint between the W and a buffer layer of Cu. "S-TAN" which is produced by using HIP process has isotropic microstructure. **JADA successfully completed the HHF testing of two mock-ups for 1,000 cycles at 20MW/m<sup>2</sup>** under a constant cooling ratio from stopping the irradiation. The soundness of NDB is sufficient against **the cyclic heat flux except for the recrystallization of W.**

## 6 Conclusions

- Material selection and IR inspection for Quality of jointing**  
JADA developed the quality control procedure for the joint interface.
    - To improve wettability, Ti-coating was applied to metalize the CFC joint surface.
    - The gap between the CFC and the buffer layer was strictly controlled.
    - In the IR inspection using FIND, the temperature on three surfaces of the CFC is able to be simultaneously monitored by two mirrors. It provides quick feedback during the manufacturing process about a defect in the joint.
  - Manufacturing status of OVT full-scale prototype**  
Based on the result from the pre-prototype of PFU, the first 6 PFUs were manufactured by the end of June 2012.
  - R&D of W monoblocks**  
JADA successfully completed the HHF testing of two mock-ups for 1,000 cycles at 20MW/m<sup>2</sup>.
- Next ... We will manufacture the other 5 PFUs and a steel support structure for full scale prototype of ITER divertor.**