MECHANICAL DESIGN OF A COMPACT COLLINEAR WAKEFIELD ACCELERATOR*

CWA vacuum chamber module

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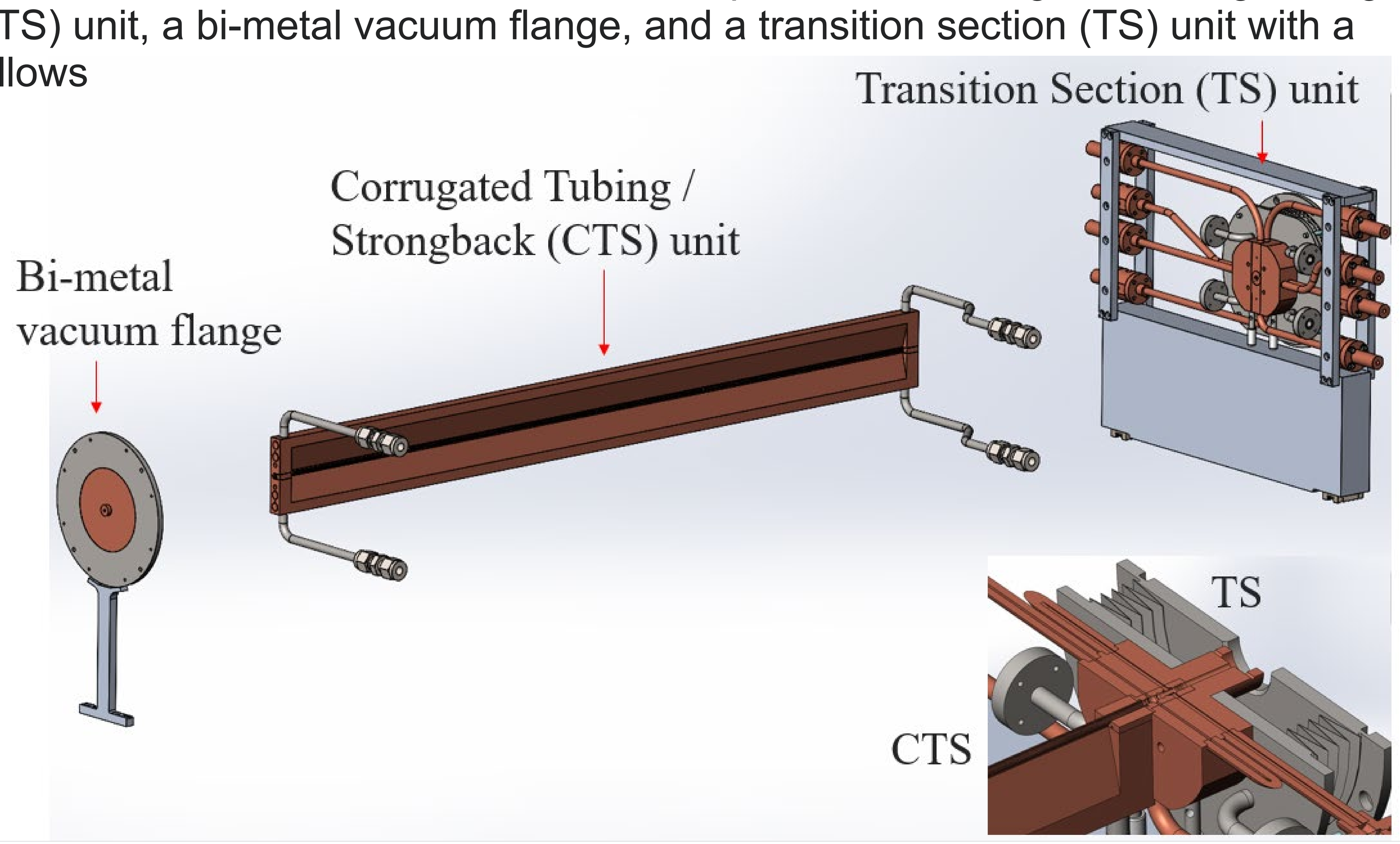
ABSTRACT

Argonne National Laboratory is developing a Sub-THz AcceleRator (A-STAR) for a future multiuser x-ray free electron laser facility. The A-STAR machine will utilize a compact collinear wakefield accelerator (CWA) based on a miniature copper (Cu) corrugated waveguide as proposed in [1]. The accelerator is designed to operate at a 20-kHz bunch repetition rate and will utilize the 180-GHz wakefield of a 10-nC electron drive bunch with a field gradient of 100 MVm^{-1} to accelerate a 0.3-nC electron witness bunch to 5 GeV. In this paper, we discuss specific challenges in the mechanical design of the CWA vacuum chamber module. The module consists of series of small quadrupole magnets with a high magnetic field gradient that houses a 2-mm diameter and 0.5-m-long corrugated tubing with brazed water-cooling channels and a transition section. The 45-mm-long transition section is used to extract the wakefield and to house a beam position monitor, a bellows assembly and a port to connect a vacuum pump. The CWA vacuum chamber module requires four to five brazing steps with filler metals of successively lower temperatures to maintain the integrity of previously brazed joints.

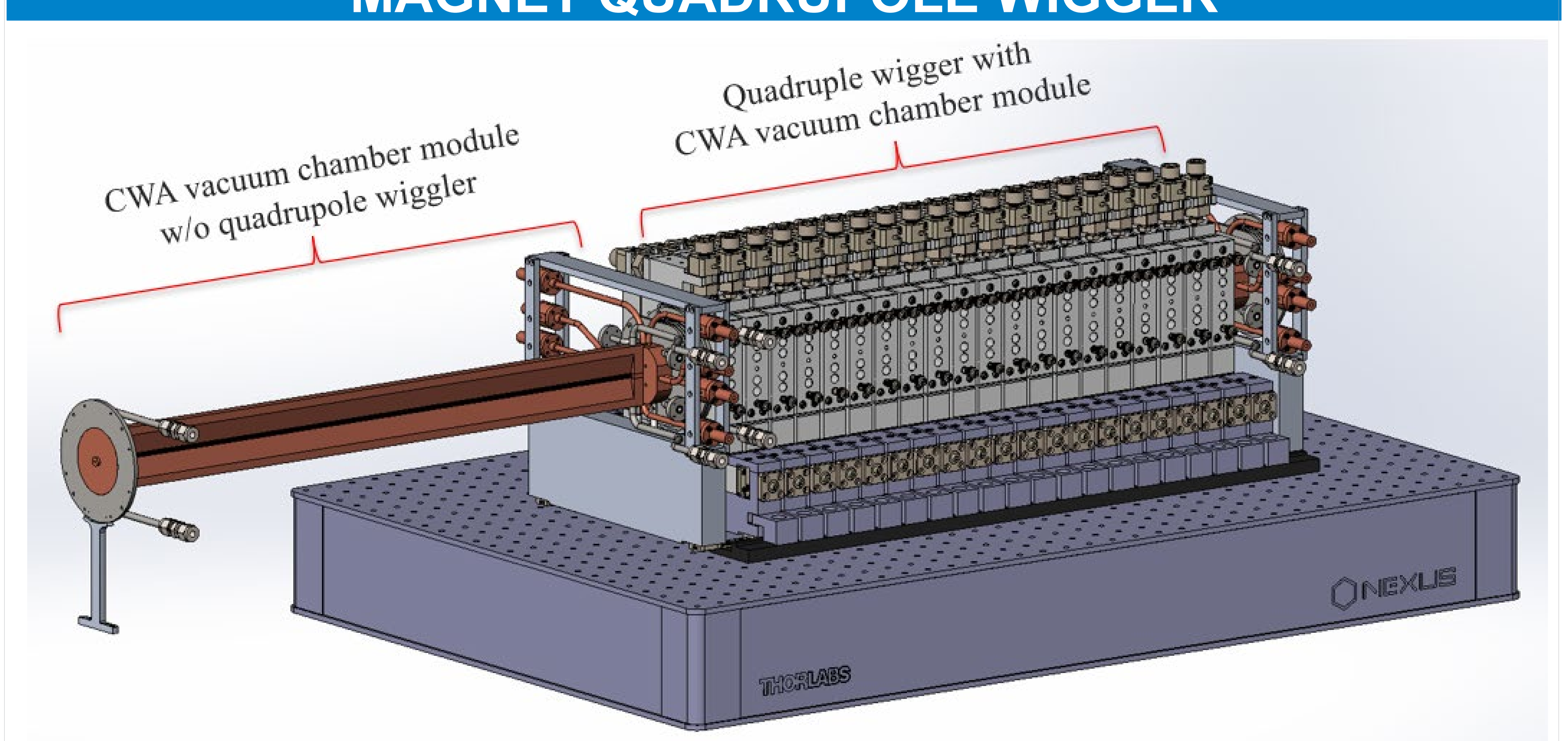
[1] A. Zholents *et al.*, "A conceptual design of a Compact Wakefield Accelerator for a high repetition rate multi user X-ray Free-Electron Laser Facility," in *Proc. IPAC2018*, Vancouver, BC, Canada, 29 Apr.-May 2018, pp. 1266–1268.

INTRODUCTION

The CWA vacuum chamber module is comprised of a corrugated tubing-strongback (CTS) unit, a bi-metal vacuum flange, and a transition section (TS) unit with a bellows

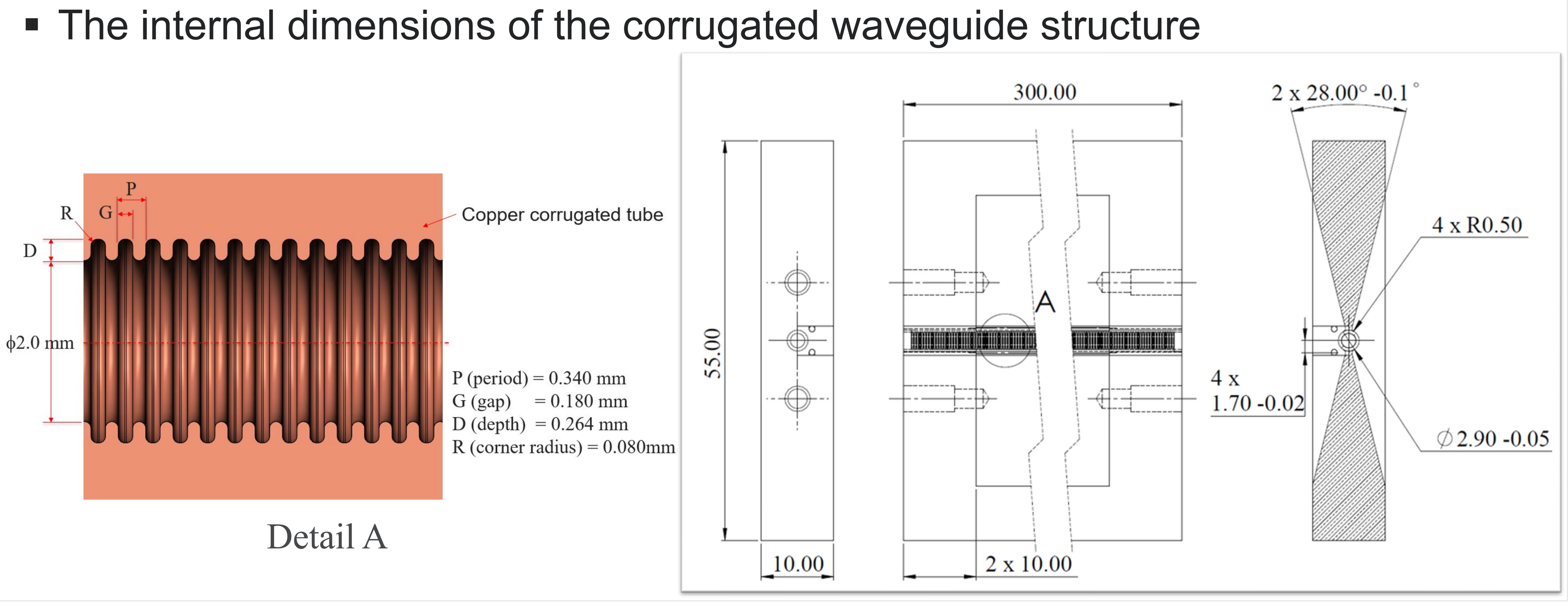


CWA VACUUM CHAMBER MODULES AND A PERMANENT MAGNET QUADRUPOLE WIGGER



SCHEMATIC OF CORRUGATION AND PROTOTYPE CHAMBER

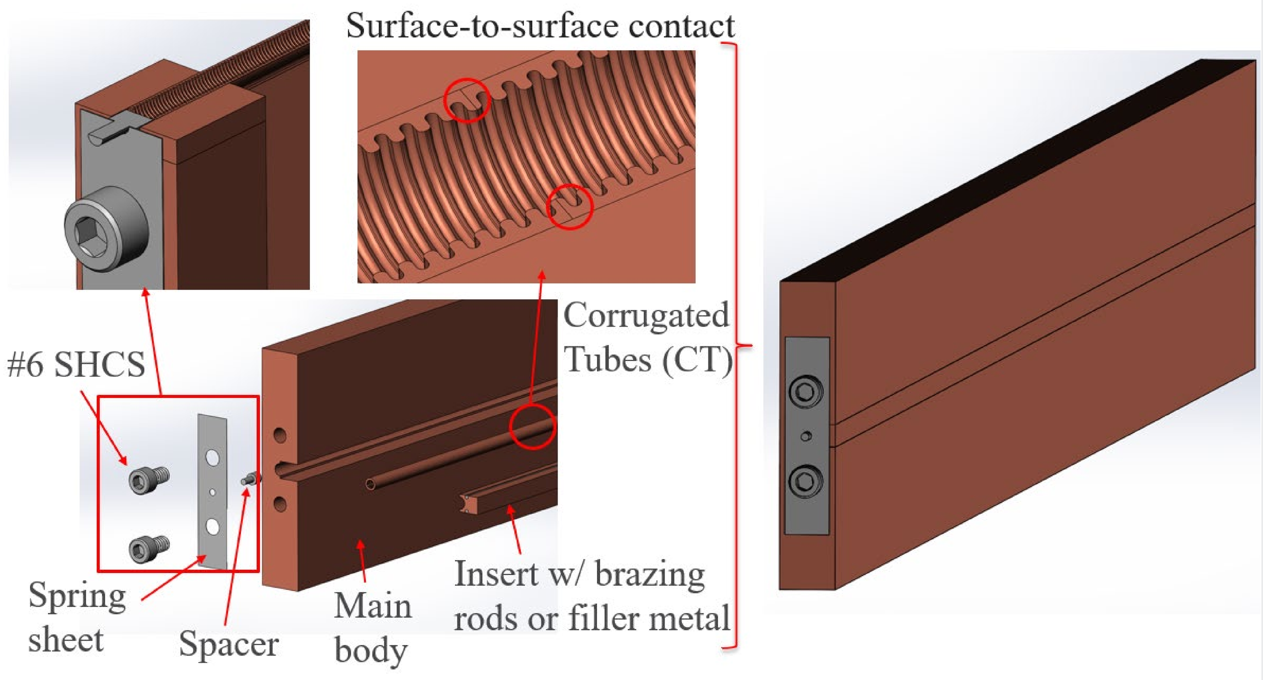
- The internal dimensions of the corrugated waveguide structure

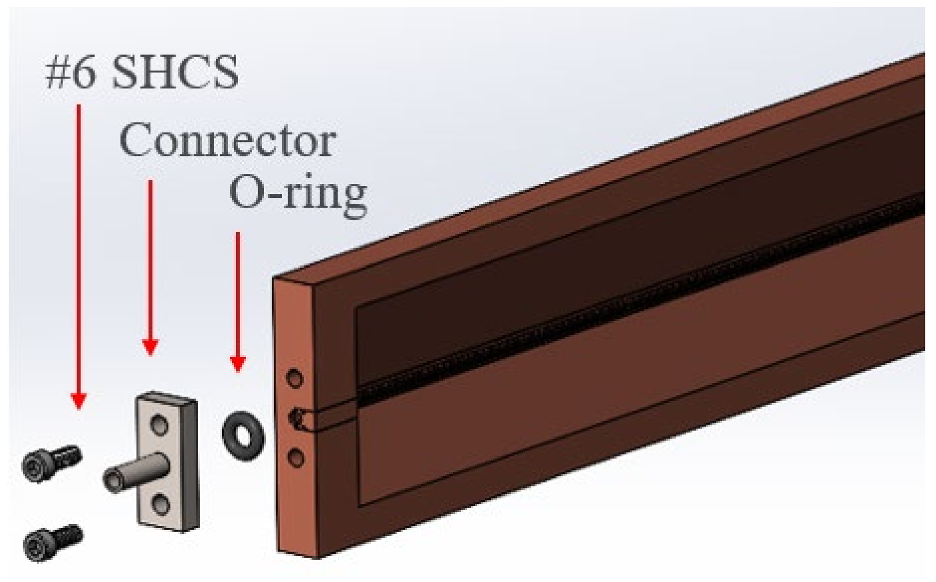


BRAZING PROCESS OF A CTS UNIT AND LEAK CHECK

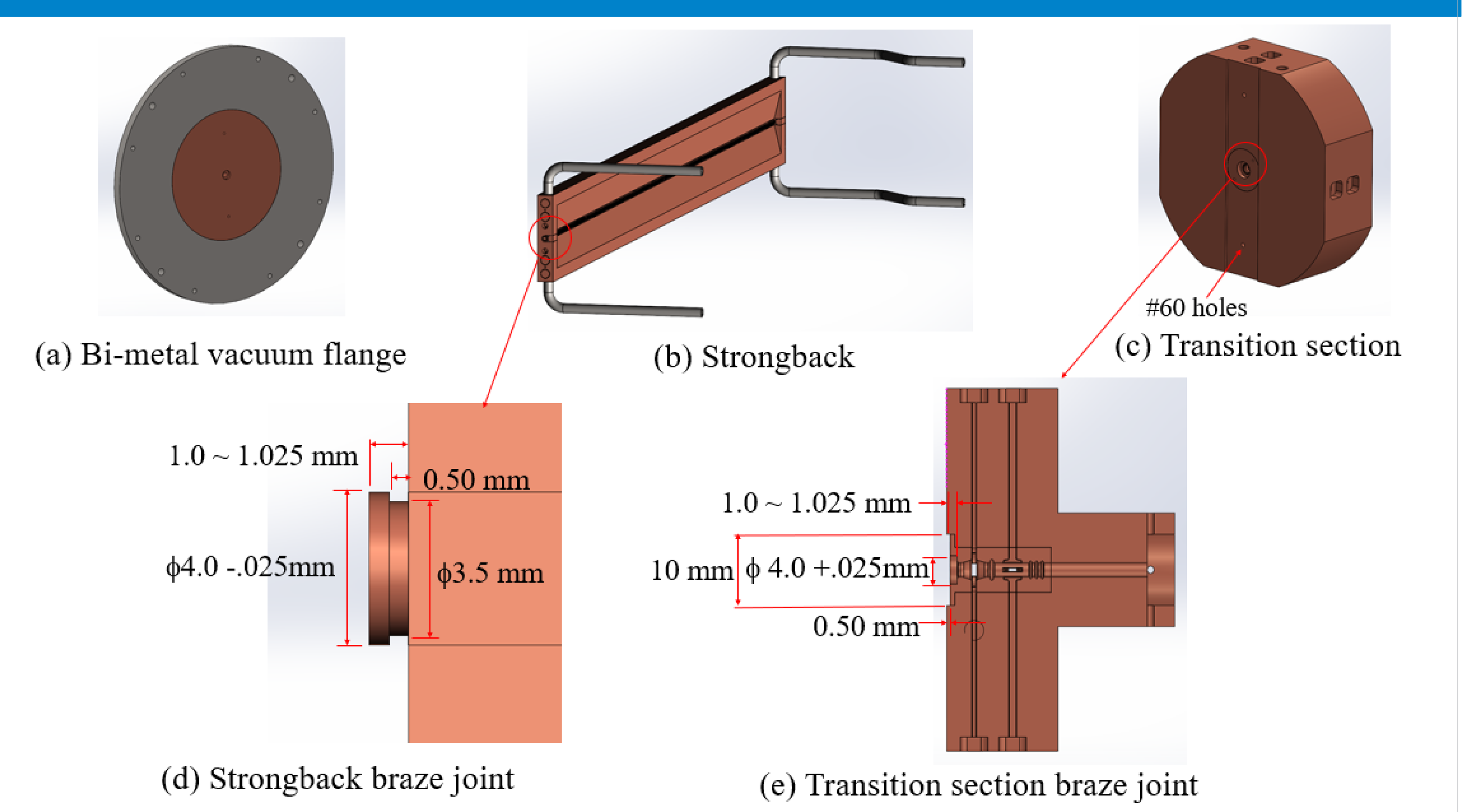
CTS components, brazing & leak checks

- Maximum length of the Al mandrel is ~100 mm;
- Use several corrugated waveguide segments.
- Inserted Cu strongback and secured by a Cu bar with braze filler metal spreading over the tubing surfaces.
- During brazing, compression force will be applied inwards along the length using spring sheets and spacers at both ends to maintain tight surface contact of the corrugated tubes. This will help to prevent filler metal from flowing inside the inner corrugation surface area. After the post-braze cleaning process, both end surfaces of the CTS unit are milled for vacuum leak testing





ELECTRO-FORMING PROCESS OF THE TRANSITION SECTION CORE



TECHNICAL CHALLENGES

- Maintain the integrity of previously brazed joints in brazing: Use suitable brazing filler metals of successively lower temperatures such as
  - BVAu-9, 35/65 Au/Cu (988, 1010, 1038-1066°C)
  - BVAu-4 (949, 949, 977-1004 °C)
  - BVAg-8 (779, 779, 779-835°C)
  - BAg-7 (618, 651, 679-707°C) (Solidus, liquidus, brazing temp. range low-high)
- Braze joint design for proper gap clearance: A clearance of 0.038~0.050 mm
- Surface finish on the joints for brazing: Maintain 32~64 RMS for flowing the filler metal into the joint and better capillary action
- Fixturing during brazing: Self-fixturing and self-aligning where possible
- Micro-machining process such as diamond-turning or micro-milling can be considered due to tight tolerances as tight as 0.001″ or less

CONCLUSIONS

- Proposed design parameters such as braze joint geometries, clearance gap, surface roughness, and brazing filler metals of successively lower brazing temperature and technical challenges in the brazing and micro-machining of the CWA vacuum chamber module.
- Future work will focus on further optimization of the joint geometries, brazing filler metals, process parameters, and machining tolerances and techniques in detail to produce the CWA vacuum chamber module prototype

U.S. DEPARTMENT OF ENERGY

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