ISBN: 978-3-95450-214-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2021-WEPAB335

ALUMINUM VACUUM CHAMBER FOR THE SIRIUS DELTA 52 UNDULATOR

T. M. Rocha†, R. M. Seraphim, F. Rodrigues, R. F. Oliveira, B. M. Ramos, P. P. S. Freitas, O. R. Bagnato, D. R. Silva, G. R. Gomes, H. G. Filho, M. B. Silva, P. H. Lima, R. O. Ferraz
Brazilian Center for Research in Energy and Materials (CNPEM), Campinas, Brazil

Abstract

Sirius is a 3 GeV, 4th generation synchrotron light source under commissioning by the Brazilian Synchrotron Light Laboratory (LNLS). Sirius will have a 0.25 nm.rad emittance storage ring based on 20 cells of a highly compact lattice – 5 bend achromat (5BA). Delta Undulators with magnetic aperture of 13.6 mm, and period of 52.5 mm will be used for the generation of soft X-rays to photoemission spectroscopy and X-ray absorption experiments. An extruded aluminum vacuum chamber having a small inner vertical aperture of 7.6 mm and inner horizontal aperture of 13 mm is proposed. This paper details the design and manufacturing processes of a complete chamber. Challenges regarding the TIG welding for aluminum and NEG coating for the small aperture chamber will also be presented.

INTRODUCTION

To reduce the horizontal emittance to a sub-nm.rad value, the Sirius storage ring has a circumference of 518 m comprising 20 achromats cells that are based on a 5-bend achromat (5BA) lattice [1].

Delta Undulators can be considered an adjustable phase device able to produce full polarized radiation [2] trough the displacement of magnetic arrays while maintaining the gap fix. This model of undulator can provide higher magnetic fields than conventional planar undulators [3]. However, the limited aperture in the cross section induces engineering challenges to the design of vacuum chambers.

Sirius has 15 low beta straight sections, where the horizontal and vertical Beam Stay Clear (BSC) apertures, in the center, are +/- 3,2 mm and +/- 1,9 mm, respectively [4]. The small BSC values provides an opportunity to consider the Delta undulators at Sirius and use the produced intense and coherent photon beam to demanding experiments in beamlines.

At this moment, one Delta 52 Undulators is planned to be installed at Sirius. Their main characteristics are presented in Table 1.

Table 1: Delta 52 Undulator Parameters

Period	52.5 mm
Number of Periods	63
Maximum Total Length	3.6 m
Magnetic Gap	13.6 mm
Magnetic Field Amplitude	1.2 T
K Maximum	5.85

The length of the first undulator to be installed will be 1.2 meters to validate engineering and scientific concepts, enabling the production of a 3.6 m version in the future.

VACUUM CHAMBER'S DESIGN

Material Selection

Due to the characteristics of the Delta 52 undulator magnets, a vacuum chamber with narrow cross section and 1.3 meter length is proposed. To achieve the necessary cross section geometry, mechanical strength, and vacuum requirements, a custom 6063-T6 extruded aluminum profile was selected for the chamber. The extruded profile was manufactured in bars of 4.5 – 6 meters by the Hydro Extrusion company located at the city of Santo André, Brazil. Figure 1 illustrates de extruded profile as received.

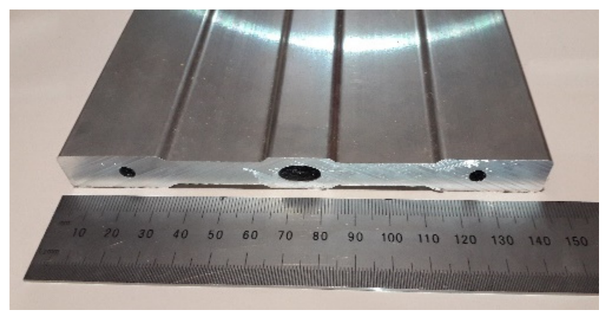

Figure 1: 6063-T6 aluminum extruded profile as received.

Tight tolerances were demanded for the extrusion company. The center of the elliptical profile has only 0.2 mm acceptable deviation in position. Linear dimensions for the ellipse's axes have +/- 0.2 mm tolerance. Requested flatness for the profile was 0.5 mm for 6 meters of extruded bar.

As part of the quality control of the extruded profile, metallographic analysis were conducted to evaluate grain refinement as illustrated by Fig. 2.

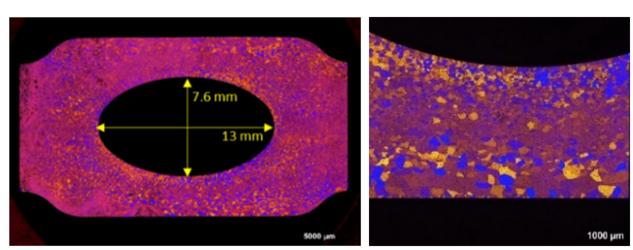

Figure 2: Metallographic image from the central part of chamber's cross section.

† thiago.rocha@cnpem.br

ISBN: 978-3-95450-214-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2021-WEPAB335

Structural and Thermal Design

Aiming a safe performance for the chamber in accelerator environment under ultra-high vacuum, structural and thermal analysis were done using the software Ansys Mechanical.

Structural analyses results show a minimum deformation due to atmospheric pressure and a von Misses stress in the order of 3 MPa which is far bellow the Yield Strength of aluminum 6063-T6 of 170 MPa [5].

Thermal analysis considered RF induced heating due to image current and synchrotron radiation heating from the upstream dipole. The total heat load for the 1.3 meters vacuum chamber is 185 Watts. A 1 Liter per minute water flow was considered at the 5 mm diameter cooling channel, resulting in 29.8 °C maximum temperature, which is satisfactory. Figure 3 shows temperature distribution.

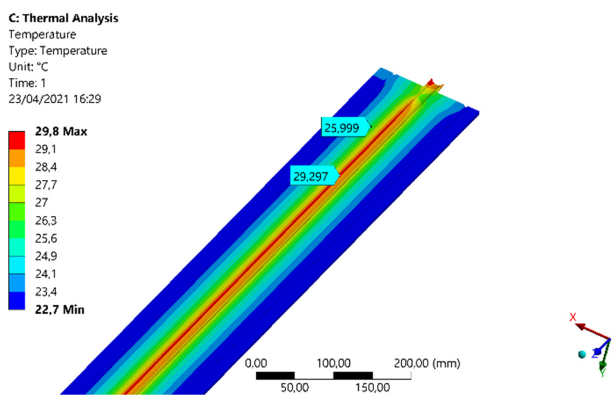

Figure 3: Temperature distribution in the chamber due to image current induced heating and Synchrotron Radiation from the previous dipole.

FABRICATION

The sequence of manufacturing processes for a complete chamber is illustrated by Fig. 4.

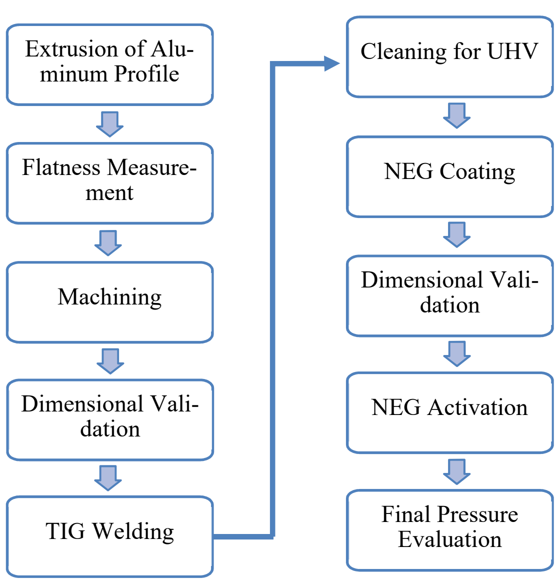

Figure 4: Sequence of processes to fabricate a complete chamber.

Machining

A vacuum chamber prototype was machined at CNPEM using a high precision CNC milling machine. To minimize deformation of chamber induced by machining, an aluminum support was developed to fix the chamber at the machine. The same concept was successfully used in the machining process of the chambers for the planar undulators [6].

Figure 5 illustrates the vacuum chamber assembled at the support. The support is also used in other process such as, dimensional validation, cleaning for ultra-high vacuum and NEG deposition. The chamber is only disassembled from the support when it is installed in the undulator. This procedure is used to guarantee the chamber's tight tolerances through all the fabrication process.

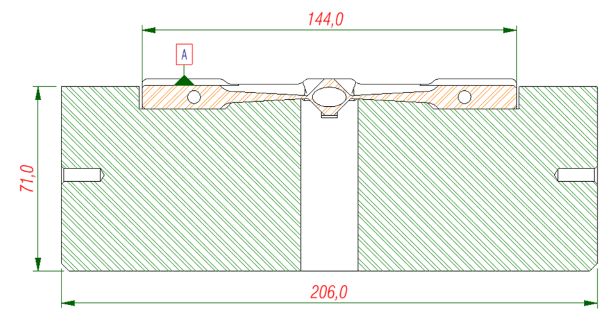

Figure 5: Vacuum chamber assembled to the support.

Dimensional Validation

After machining, a complete dimensional measurement was carried out to assure the chamber's conformity. The chamber was kept assembled to the support during measurements, as illustrated in Fig. 6.

The measured values were 0.1 mm for flatness and parallelism for "surface A", which is the top surface of the chamber, as indicated at Fig. 5.

Figure 6: Vacuum chamber measurement.

Vacuum Flange

The vacuum flanges were fabricated from special developed bimetal blanks of 6061 aluminum alloy-316L stainless steel produced in-house by using diffusion bonding process [7]. The chosen knife edge geometry is very similar to the one used in Sirius vacuum chambers [8] and planar undulator chambers [6], which are already installed and proven in the storage ring of Sirius.

ISBN: 978-3-95450-214-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2021-WEPAB335

Figure 7 shows one of the vacuum flanges already machined and ready to be welded to the vacuum chamber.

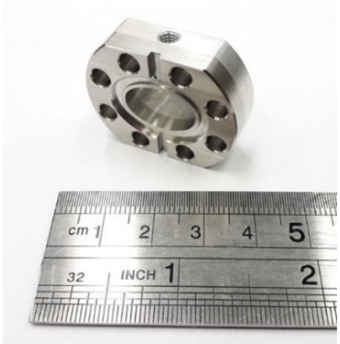

Figure 7: The vacuum flange developed for the aluminium vacuum chamber.

TIG Welding

Aluminum samples were machined to evaluate various welding parameters sets aiming to achieve a leak tight and low porosity UHV compatible welding beads. The weldings were performed manually using a 4043 aluminum filler metal. An automated welding in a robotic arm is being developed to increase process repeatability.

Figure 8 illustrates the special flange welded to the vacuum chamber, while Fig. 9 shows a metallographic analysis for one of the samples, with porosity bellow 1%, the maximum adopted limit.

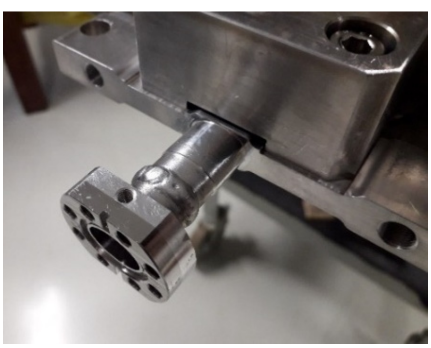

Figure 8: Vacuum flange welded to the chamber.

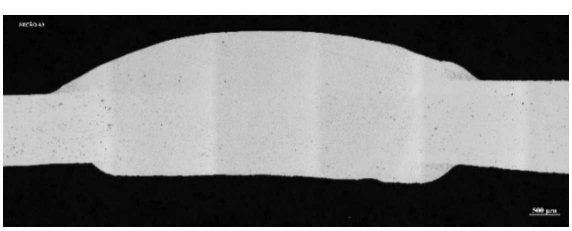

Figure 9: Metallography analysis indicating 0,2% porosity.

Cleaning

The cleaning procedure used on chamber prior to the NEG coating consisted of two steps of 5 minutes immersion in a water solution of 3% alkaline detergent at ultrasonic bath, rinsing with demineralized water, 10 minutes immersion in a solution of 10% citric acid, rinsing with demineralized water and drying with ionized Nitrogen.

NEG Coating Process

To achieve UHV pressure in a vacuum chamber with narrow cross section, NEG coating is mandatory since the conductance is very small. CNPEM has a license agreement with CERN to develop and apply NEG coating technologies for Sirius vacuum chambers [8].

The prototype was coated aiming a film thickness of 0.6 µm. One cathode made from intertwisted 0.5 mm diameter Ti, Zr, V wires was submitted to a linear power density of 15 W/m, a magnetic field of 600 G and a vacuum pressure of 1.10^{-1} mbar. Cathode centering is critical for NEG coating of narrow gap chambers. In this way, cathode's centering ceramics were installed at the extremities of the chamber. The coating was visually inspected and no peel off or other defects were found.

After NEG activation, the pressure was validated trough a measurement bench and the value of 5.10^{-10} mbar was achieved at sensor P3, as illustrated by Fig. 10.

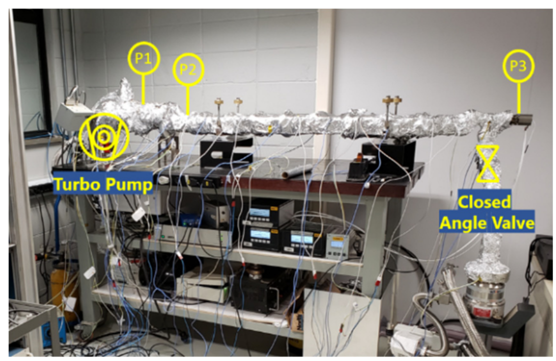

Figure 10: Set up for NEG activation tests.

CONCLUSION

A vacuum chamber prototype for the Delta 52 undulator was built by CNPEM. The technological opportunity, mechanical design and manufacturing processes were presented and illustrated. The machining procedure resulted in a chamber with approved dimensional that would fit the undulator and beam stay clear requirements. The manual aluminum TIG welding process was developed, but further refinement is still needed. To increase repeatability, an automated process is under development. The first prototype has presented a good pumping speed from NEG coating. A coating without defects and with good adhesion was achieved.

A second chamber is being built and will serve as the vacuum chamber for the application at the Sirius Storage Ring.

ACKNOWLEDGMENTS

The authors would like to thank Johnny Santos for the machining of the chamber, Pedro Freitas for the mechanical drawings and Ulisses Sposito for the dimensional validation.

REFERENCES

[1] L. Liu, N. Milas, A. H. C. Mukai, X. R. Resende, A. R. D. Rodrigues, and F. H. de Sá, "A New 5BA Low Emittance

ISBN: 978-3-95450-214-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2021-WEPAB335

Lattice for Sirius", in *Proc. 4th Int. Particle Accelerator Conf. (IPAC'13)*, Shanghai, China, May 2013, paper TUPWO001, pp. 1874-1876.

[2] L. N. P. Vilela, L. Liu, X. R. Resende, and F. H. de Sá, "Studies of Delta-Type Undulators for Sirius", in *Proc. 8th Int. Particle Accelerator Conf. (IPAC'17)*, Copenhagen, Denmark, May 2017, pp. 3045-3047. doi:10.18429/JACoW-IPAC2017-WEPIK053

[3] A. B. Temnykh, "Delta undulator for Cornell energy recovery linac", *Physical Review Special Topics – Accelerators and Beams,* vol. 11, p. 120702, 2008. doi:10.1103/PhysRevSTAB.11.120702

[4] L. Liu, X. R. Resende, and F. H. de Sá, "A New Optics for Sirius", in *Proc. 7th Int. Particle Accelerator Conf. (IPAC'16)*, Busan, Korea, May 2016, pp. 3413-3416. doi:10.18429/JACoW-IPAC2016-THPMR013

[5] Technical datasheet from Hydro extrusion company, https://www.hydro.com/Document/Index?name=Alloy%206063.pdf&id=560719

[6] B. M. Ramos *et al.*, "Aluminum Vacuum Chamber for the Sirius Commissioning Undulators", presented at the 12th Int. Particle Accelerator Conf. (IPAC'21), Campinas, Brazil, May 2021, paper WEPAB336, this conference.

[7] R. L. Parise *et al.*, "Development of Diffusion Bonded Joints of AA6061 Aluminum Alloy to AISI 316LN Stainless Steel for Sirius Planar Undulators", presented at the 12th Int. Particle Accelerator Conf. (IPAC'21), Campinas, Brazil, May 2021, paper WEPAB334, this conference.

[8] R. M. Seraphim *et al.*, "Vacuum System Design for the Sirius Storage Ring", in *Proc. 6th Int. Particle Accelerator Conf. (IPAC'15)*, Richmond, VA, USA, May 2015, pp. 2744-2746. doi:10.18429/JACoW-IPAC2015-WEPMA003