Extruded Aluminum Vacuum Chambers for Insertion Devices

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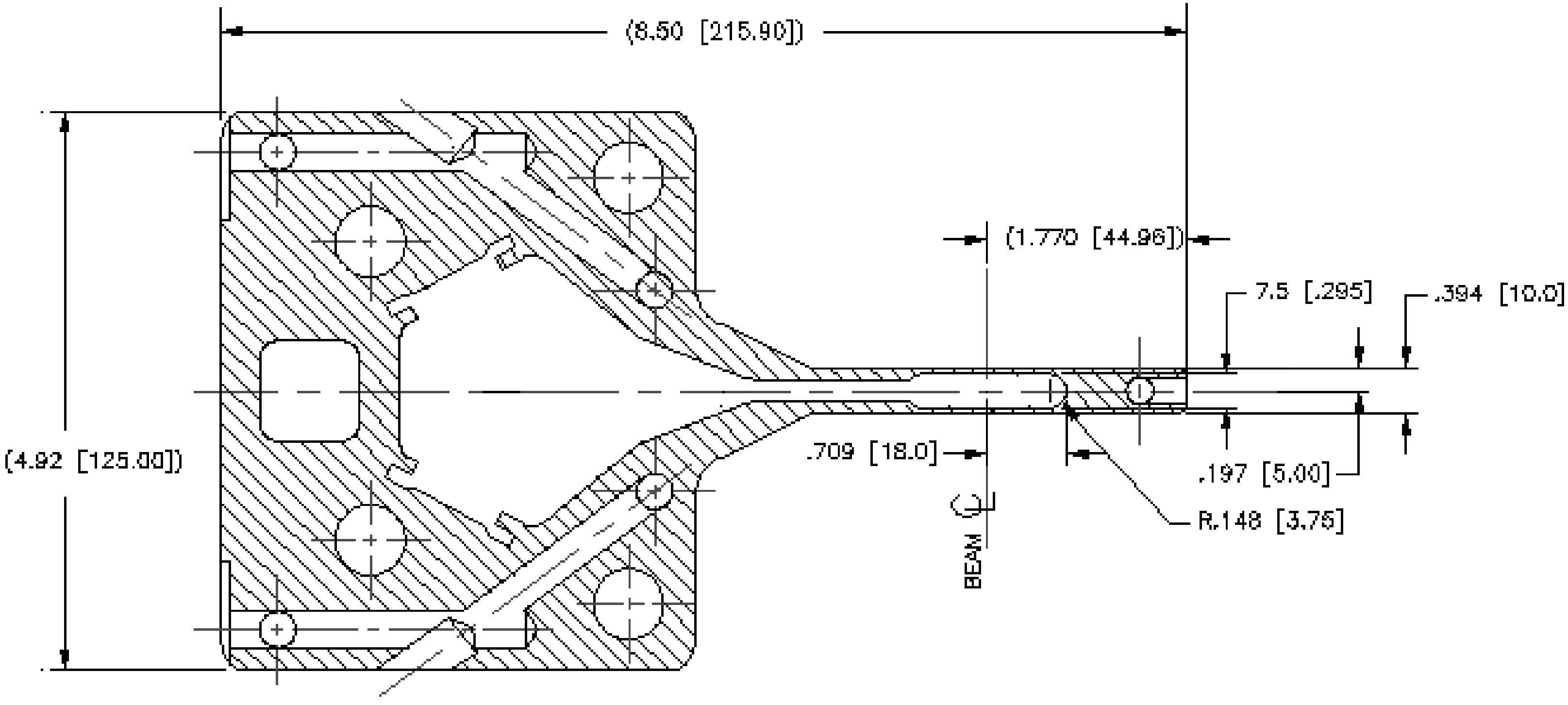
How to achieve pole gap in insertion devices as small as possible

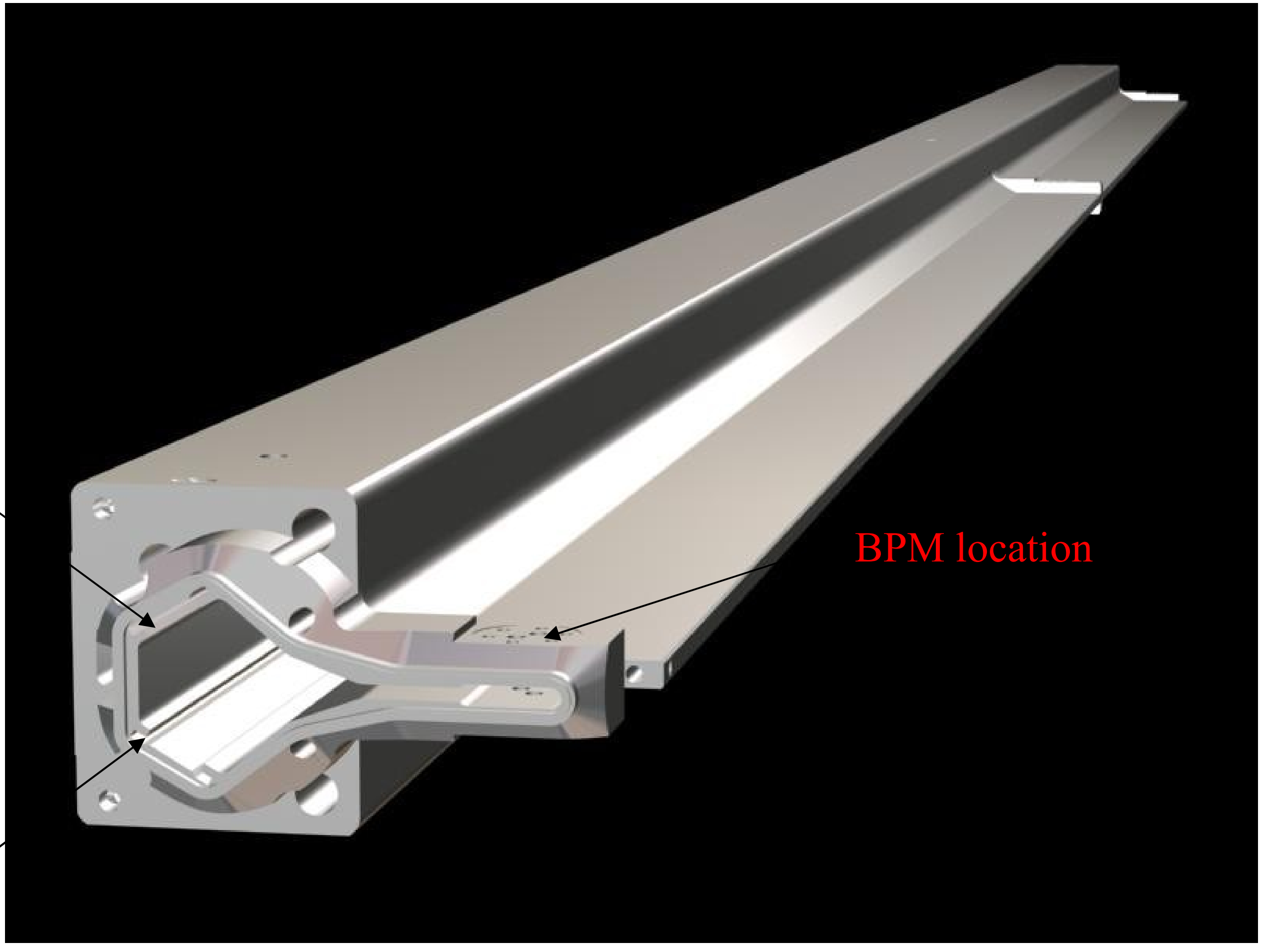
We know three ways to achieve this goal:

1. Use in-vacuum undulators and wigglers without a separate vacuum chamber (VC);
2. Use a small-aperture stainless steel vacuum chamber —usually with non-evaporate getter (NEG) coating for pumping;
3. Use a small-aperture extruded aluminum vacuum chamber with a thin wall.

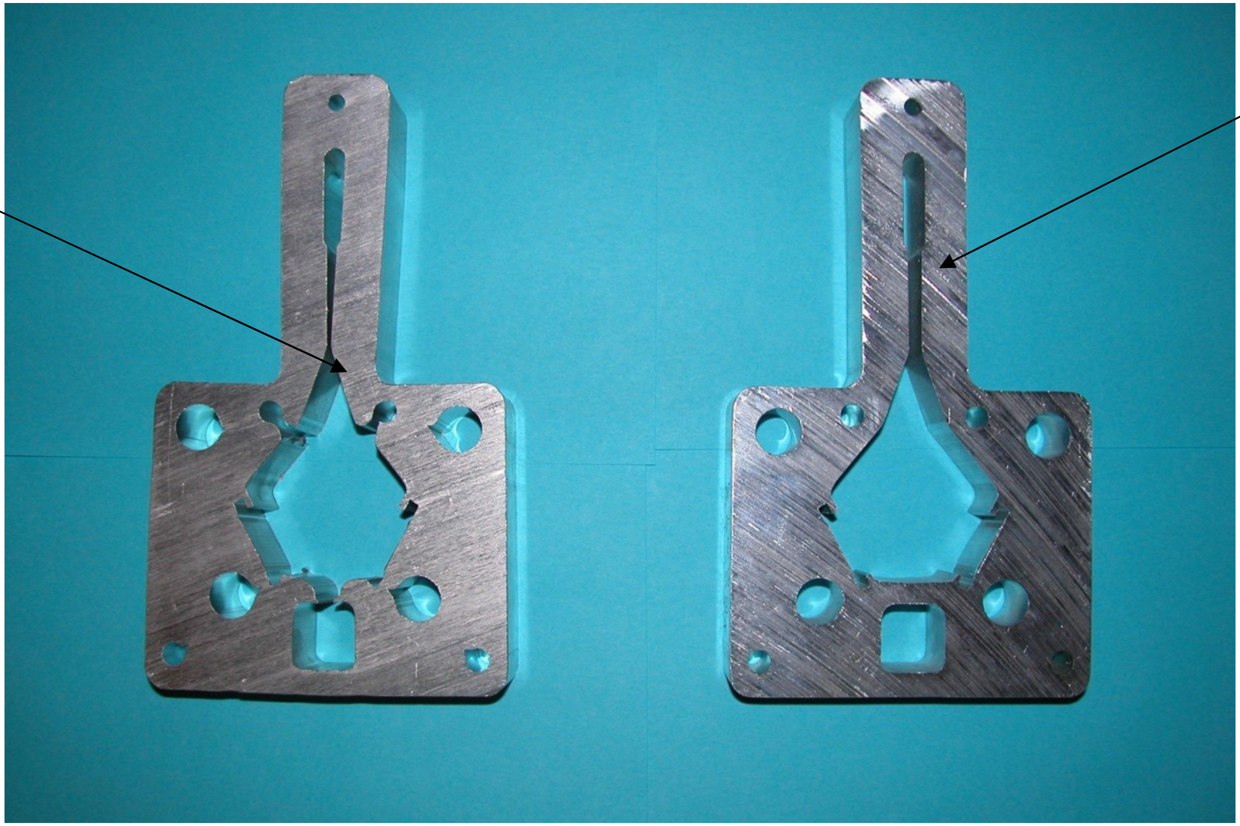
Latest APS ID Vacuum Chamber Cross Section



7.5 mm ID Vacuum Chamber



APS Latest ID Vacuum Chamber Extrusion Cross Section



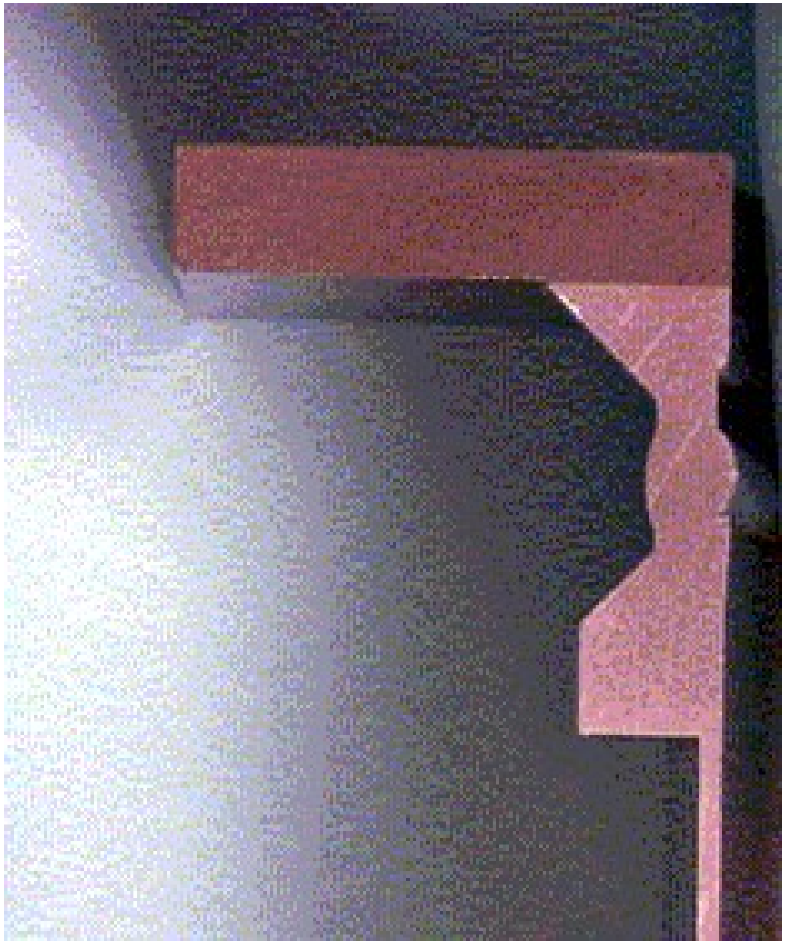
Each new extrusion is a puzzle to be solved

What technological challenges have we overcome (together with our vendors):

- High-quality long extrusion ("Taber Metal", "Cardinal Aluminum")
- Stretching of an extrusion to eliminate major waviness and twist ("Taber Metal", "Cardinal Aluminum")
- Additional straightening of the extrusion within ± 0.1 mm over 5 m length ("Ideal Tool Mfg.", "Hi-Tech LLC Mfg", "Dial Machine")
- Precise machining to the specifications ("Ideal Tool Mfg.", "Dial Machine", "Hi-Tech Mfg LLC"
- Vacuum-tight bimetal end components ("Atlas Technologies")
- Robotic TIG welding with full penetration and no under bead (in house)
- Ultra high vacuum cleaning and full assembly in a clean room (in house)
- Baking and vacuum certification (in house)

APS ID Vacuum Chamber on the CNC Machine

Welding Joint Cross Section



Welding should be performed with 100% penetration and without excessive underbead sticking out.

We have machined a small recess inside the vacuum chamber and its mating end plate to accommodate this minimum underbead.

Will thin chamber wall keep vacuum integrity?

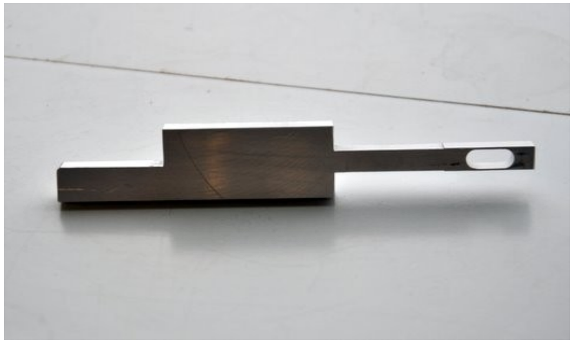
This was the first question which should be answered;
We have made multiple tests using extrusions from two different vendors;
DESY extrusion and LCLS prototype extrusion were used for the tests.

*Results of these tests were presented at PAC-2007 at Albuquerque, New Mexico

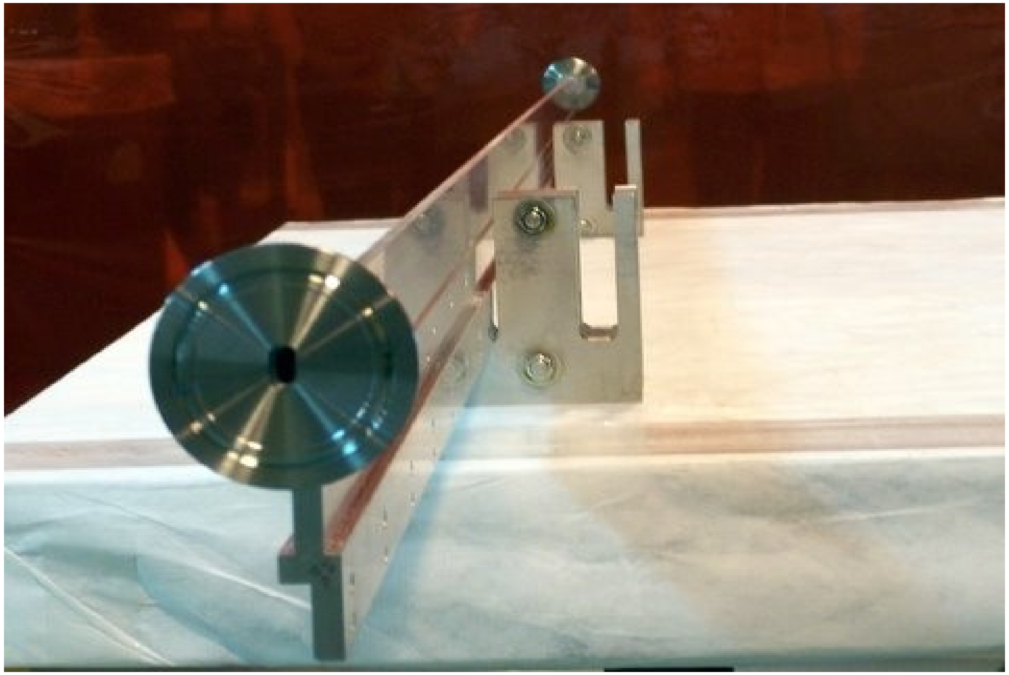
*Emil Trakhtenberg, Greg Wiemerslage. “A Study of the Minimum Wall Thickness for an Extruded Aluminum Vacuum Chamber“, PAC-2007, Albuquerque, New Mexico, June 2007, 1151 (2007).

LCLS extruded vacuum chamber

Section of extrusion



Section of machined chamber



Production chamber prepared for cleaning

Extrusion Surface Roughness (inside)

- We did such measurements for the VC for TTF FEL at DESY and Argonne.
- Samples were measured with a stylus profiler and optically.
- After extrusion, the RMS inner surface roughness was **~1.2 - 1.0 μ.**
- After electro polishing, the RMS roughness was improved to **~0.7 - 0.8 μ.**
- Optical measurements showed that the surface along the extrusion was almost two times better than in the transverse direction.
- **These numbers could be improved, if the die manufacturer will take special care of the surface finish of the inner part of the die. An additional wear-resistant coating of this part may also help.**

Abrasive Flow Polishing

- During preparation for extrusion the inner part of the die (mandrel) was additionally polished at the APS optical shop. It helped to improve surface finish initially to 600-700 nm.
- *Abrasive flow polishing process was proposed to be used to achieve surface finish around 150-200 nm.
- Special fixtures and technology were developed to apply this process to the 4m long extrusion with the ratio length/aperture ~700. The standard ratio for this process is 8-10*.
- Each chamber was polished from both ends using two different abrasive grits. Aluminum oxide was chosen as an abrasive material. Average polishing time was 50 hours per chamber.

*Ray Dargis. "'Non-Traditional' Goes Mainstream." http://www.pfonline.com/articles/020802.html

Abrasive flow polishing at "Engineered Finishing "

Abrasive Flow Polishing Process

Superconducting Undulator Vacuum Chamber

Vertical aperture	7.2 mm
Horizontal aperture	53 mm
Vertical aperture tolerance specified	±100microns
Vertical aperture tolerance specified	±15microns

Total price for twelve 3 m long extrusion ≤$10K including die production

What we have proven:

- It is possible to produce extruded aluminum vacuum chambers with vacuum tight walls with thickness (after machining) **0.5 ± 0.1 mm.**

- It is possible to routinely make ~5-meter-long vacuum chambers with flatness **better then ± 75μm along the whole length** after installation on three supports. This allows us to get a minimal undulator pole gap of **10.5mm** for a vacuum chamber with **10 mm** outside dimension in extreme case and **11mm** routinely.

- It is possible to routinely get certification pressure inside the ID vacuum chamber of better than 2•10 -10 Torr.

- It is possible to make an extruded aluminum vacuum chamber with a very small vertical aperture **(5 mm inside, 7 mm outside for APS , 5 mm inside, 6 mm outside for LCLS).**

What we have proven:
(continued)

- **Deflection of the thin wall in the center of an aperture is less than 100 μ per wall for all extrusion cross sections regardless of aperture size.**
- **No NEG dust problem at all for 707 “Saes Getter” material. We definitely would have seen it if such a problem existed inside our 5 mm ID vacuum chamber.**
- **It is very easy to activate NEG strips.**

NEGATIVE

- **This technology requires big up-front investments (robotic welding machine, clean room, cleaning tanks and so on).**
- **There are very few vendors that produce such an extrusion, and it takes 9-12 month from start to finish for the complicated extrusion shape.**
- **Most technological steps require a so-called “learning curve”, and not all vendors are eager to do that.**
- **Many operations are not forgiving – not too much room for mistakes.**
- **This technology looks reasonable only for the scale production.**

What we have made:

- **40 ID Vacuum Chambers for the "APS"- 32 installed (four different extrusion cross sections, seven different design types).**
- **16 ID Vacuum Chambers for the "BESSY - II" (two different extrusion cross sections, four different design types).**
- **4 ID Vacuum Chambers for the "SLS " (two different extrusion cross sections, two different design types).**
- **2 ID Vacuum Chambers for the "CLS " (two different extrusion cross sections, two different design types).**
- **13 ID Vacuum Chambers for the "TTF " (one extrusion cross sections, two different design types).**
- **1 ID Vacuum Chambers for the "ESRF "**
- **40 Undulator vacuum chambers for LCLS**
- **2 Vacuum Chambers for SCU and 4 short LCLS VC (in production)**

TOTAL 122 CHAMBERS!

Acknowledgements:

E. Gluskin, J. Noonan, S. Xu, J. Arko, J. Gagliano, K. Knoerzer, R. Otto, J. Attig, M. Erdmann, D. Capatina, O. Schmidt, B. Brajuskovic, L. Cokeley, T. Powers, *E. Sund

- Frank Bock ("Cardinal Aluminum Co.")
- Don Fulcher, Tom Inwood ("Engineered Finishing Co.")
- Simon Sorsher ("Hi-Tech LLC Mfg.")
- Eric Anderberg ("Dial Tool")

*Former President and Chief Engineer of "Ideal Tool Mfg."