Design, fabrication, and performance testing of a Vacuum Chamber for Pulse Compressor of a 150 TW Ti:sapphire laser

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Contents

Introduction

- Purpose of the vacuum chamber - To house the optical pulse compressor of a **150 TW Ti:sapphire laser system.**
- **In pulse compression,** the **intensity** of the laser pulse becomes **very high.** ***When this high intensity laser beam interacts with air medium phase distortion of the laser beam takes place. The phase distortion affects the its focusability***. **Hence, the beam after pulse compression has to be transported in high *vacuum* to avoid this distortion.**
- Standard chamber from OEM was not suitable for our application & it was developed as per our requirement.

Introduction

Contd….

- **Vacuum Chamber - Cuboidal shape with rectangular & circular demountable ports for entry and exit of the laser beam, vacuum pumping, system cables, and ports to access optics mounted inside the chamber.**
- **Size of the chamber –**

  1420mmL x 1200mmW x 820mmH.
- **Vacuum Requirements - A clean vacuum better than 5×10^{-5} mbar is required for this purpose.**

Features

- A vacuum chamber to house the optical pulse compressor of a 150 TW Ti:sapphire laser system.
- Shape - Cuboidal as max. space available
- Volume - 930 liters approx.
- Space - 1370mm x1030mmx 650mm(LxWxH).
- Ports - Seven demountable rectangular ports of size 250 mm x 500 mm, Circular Ports of 160mm dia.

Features

- Access - **Front and back side, chamber can be opened from the sides (opening:1030 mm x 650 mm) to insert the breadboard**.

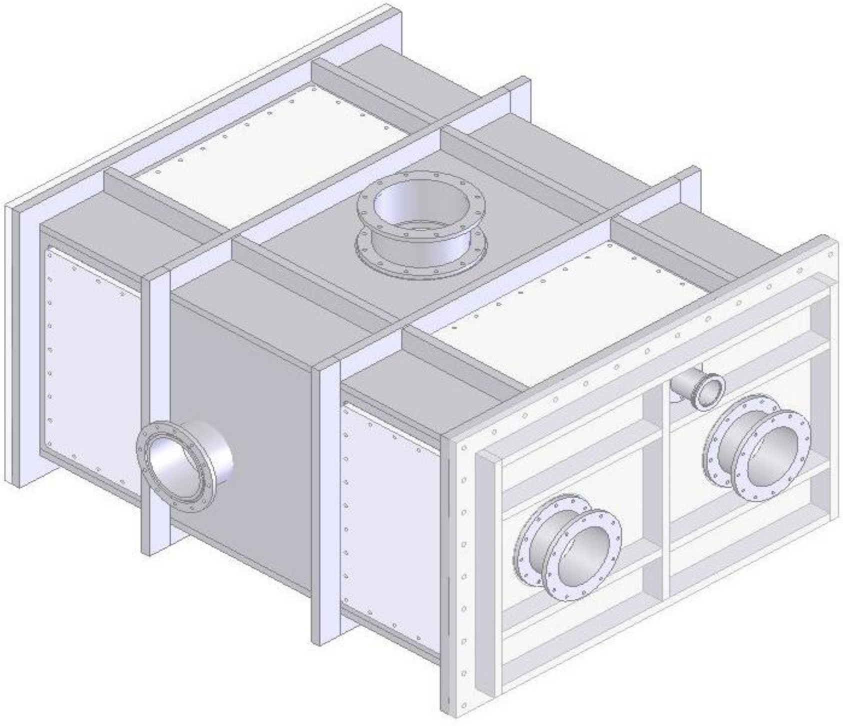
- Beam entry port and beam exit port each of 160 mm inside diameter at right angle.

- Two measurement ports of 160 mm inside diameter in one of the side cover plate.

- Three ports with DN 63 ISO-K flanges, which are to be used as feed-through ports for system control cables.

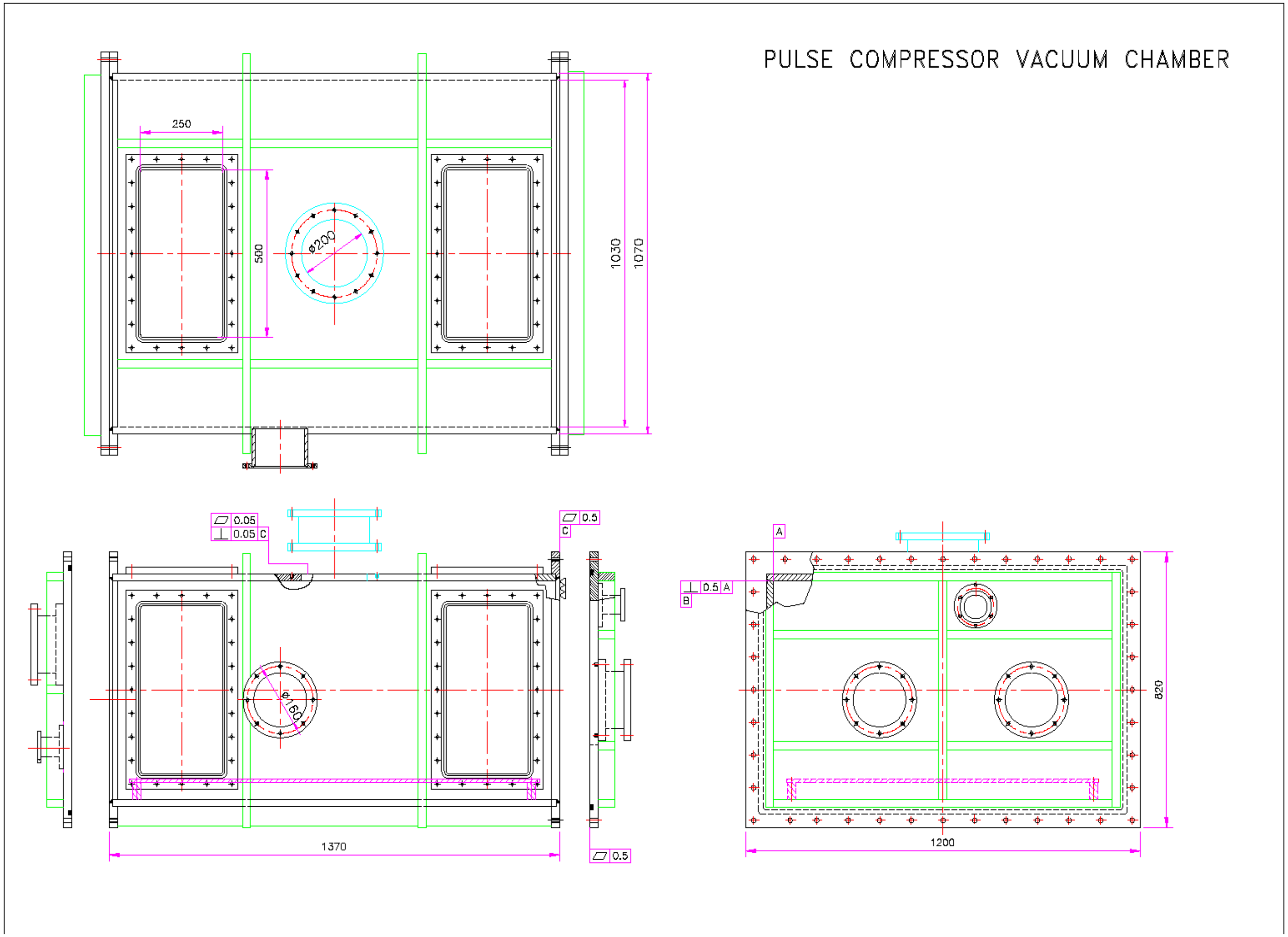
Mechanical Design

- Chamber design based on theory of plates.
- The chamber is designed rigid enough to withstand the external atmospheric pressure to keep deflection with in limit for sealing the demountable joints.



3-D view of the chamber

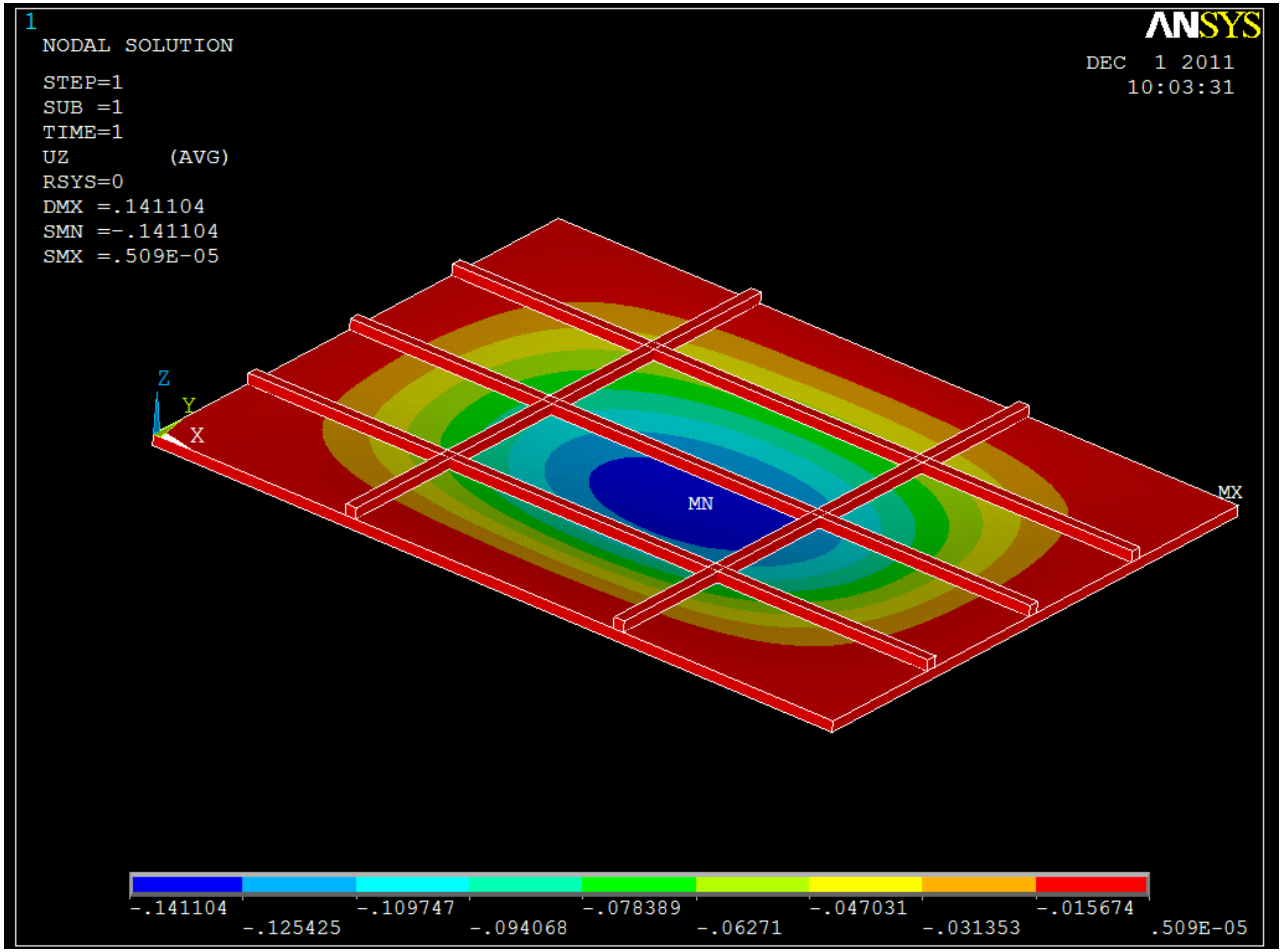
DESIGN



PULSE COMPRESSOR VACUUM CHAMBER
250
500
ø200
1030
1070
0.05
0.05 C
0.5
C
ø160
1370
0.5
A
0.5 A
B
820
1200

Mechanical Design

- **Stiffeners** are designed & welded to the walls of the chamber to Reduce and optimize the wall thicknesses & Keep deflections within the desired limit.
- Stiffners Cross Section- 25mmx60mm
- Bottom Plate Thickness- 20mm
- **O'ring grooves** are designed and fabricated to the required precision so that the grooves meet **sealing requirements**.
- **Groove Surface finish** is better than **1.6 microns with no scratch and dents on the sealing surfaces.**



FEM Analysis of Bottom Plate

Vacuum Design

- **Design of vacuum system** based on ***gas load*** in the chamber and ***vacuum*** requirement of the process.

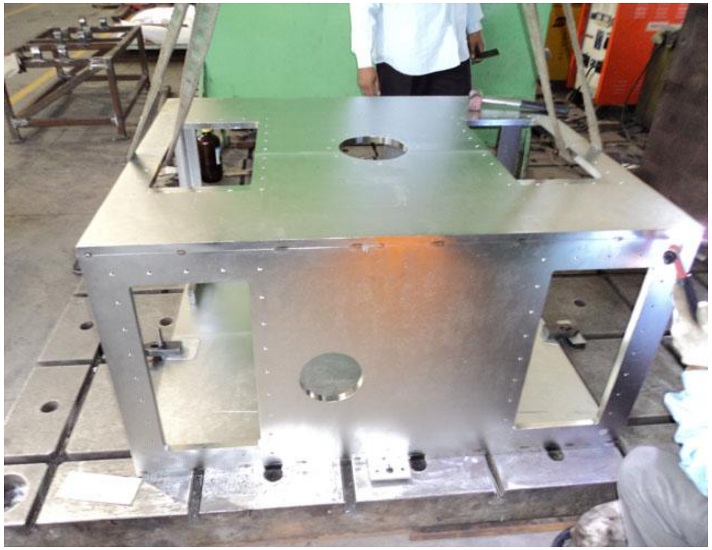
- **Gas load** of the order of **$6x10^{-3}$ mbar-l/s** is calculated based on surface area exposed to vacuum and **Specific Out-Gassing Rate (OGR)** of construction materials.

- **An additional gas load** of **$1x10^{-3}$ mbar-l/s** is expected **due to out gassing of breadboard & its optical arrangement.**

Fabrication

TIG welding used for fabrication of the chamber -

- In a **Clean Room** under **controlled RH** (< 40%),
- AWS 5.9 **ER 316L filler wire/rod thoroughly cleaned**
- **Ultra pure Argon gas for shielding & purging**
- **Proper fixturing** to avoid the ***distortion*** during welding.



Chamber during welding Stage

Welding Details

Typical **welding parameters** used are -

- Welding current : 120-150 Amps,
- Filler wire : ER 316L (dia. 2.5 mm and 3.15 mm.)
- Shielding gas : 99.999% pure Argon
- Shielding gas flow rate : 8 Ltrs./min.
- Relative humidity : 35-40% @ 22 to 25ºC

Fabrication

- The chamber was machined on CNC Horizontal boring machine for achieving the desired tolerances.
- Surface finish of the order of 1.6 microns was achieved on sealing surfaces of the components using pocket milling cycle on CNC machine.
- Surface finish of all the ‘O’ ring grooves is better than 1.6 microns with **no scratches and dents**.

Chamber machining at CNC Horizontal Boring Machine

Photograph of setup during measurement of deflection

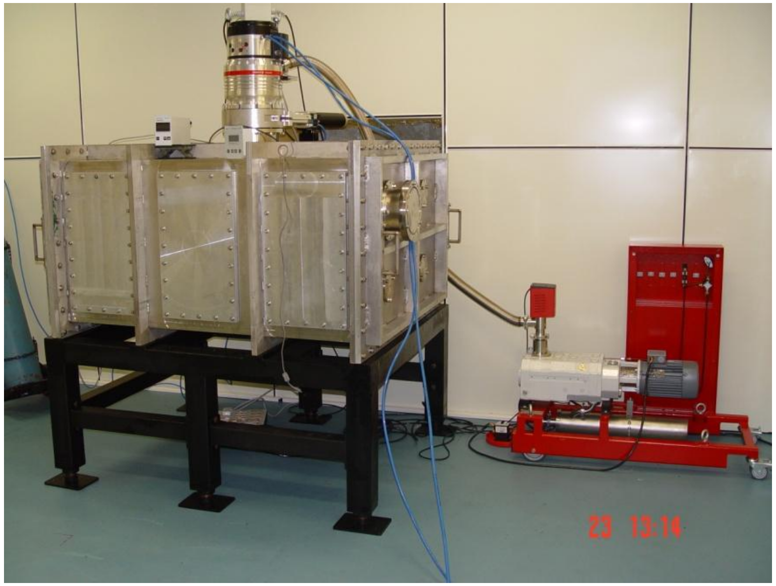
Fabrication

Chemical Cleaning

- **Main chamber** and other stainless steel parts chemically cleaned and electro-polished to reduce the out-gassing load from them, while all aluminum cover plates are soap cleaned thoroughly to make them vacuum compatible.

Pumping System

- The pumping system for the above Pulse Compressor Vaccum chamber consists of a TMP with a pumping speed of 1250 l/s. The above TMP was provided with a dry backing pump of 50 m^3/hr.



Photograph of the chamber with Pumping system

Pumping System

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- The TMP is mounted in the top of the chamber in the vertical orientation via pneumatically operated gate valve.

- The chamber was rigidly mounted on a Mild Steel stand with levelling provision.

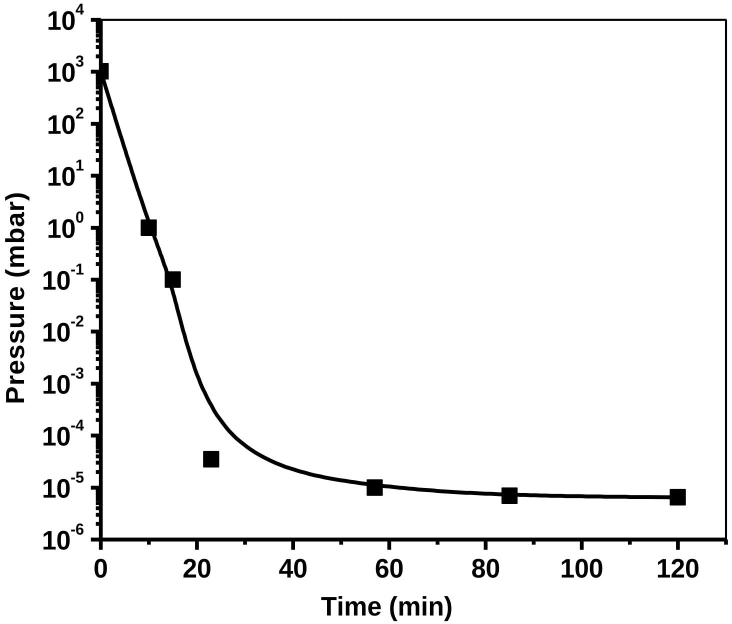
Vacuum & Leak Testing

- TMP & Dry Vacuum Pumps used for vacuum pumping.
- Helium MSLD was used for carrying out leak testing.
- A leak tightness of better than 9×10^{-9} mbar-l/s is found for all the joints.

Photograph of leak testing setup

Vacuum & Leak Testing

- **Vacuum achieved** - 10^{-5}mbar – 1/2 hour, 6.5×10^{-6} mbar less than two hours using TMP of 1250 lit/sec pumping speed and roughing pump of $50M^3$/hr pumping speed.



Pump down curve

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Thank you!!!