Journal of Physics: Conference Series

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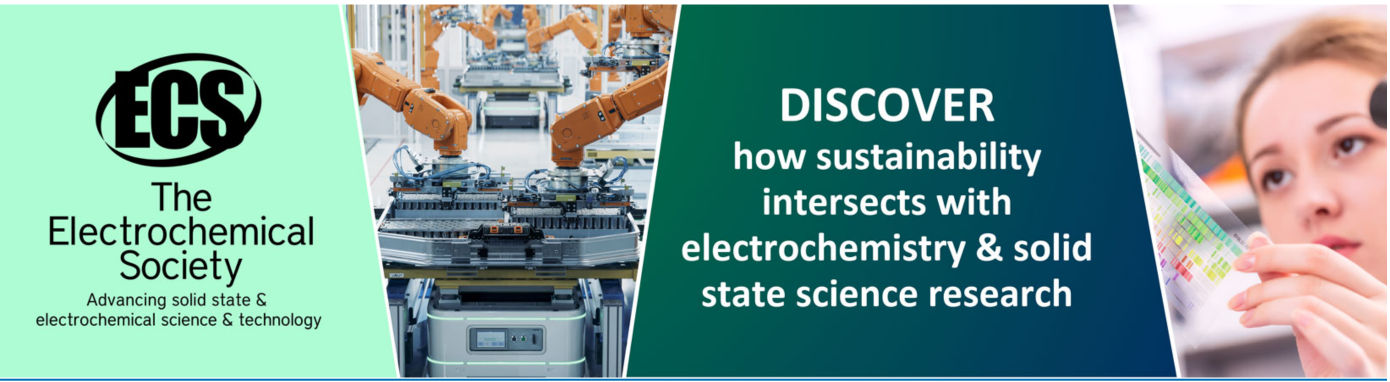

Journal of Physics: Conference Series **390** (2012) 012014 doi:10.1088/1742-6596/390/1/012014

Design, fabrication, and performance testing of a vacuum chamber for pulse compressor of a 150 TW Ti:sapphire laser

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Abstract. A vacuum chamber, to house the optical pulse compressor of a 150 TW Ti:sapphire laser system, has been designed, fabricated, and tested. As the intensity of the laser pulse becomes very high after pulse compression, there is phase distortion of the laser beam in air. Hence, the beam (after pulse compression) has to be transported in vacuum to avoid this distortion, which affects the laser beam focusability. A breadboard with optical gratings and reflective optics for compression of the optical pulse has to be kept inside the chamber. The chamber is made of SS 316L material in cuboidal shape with inside dimensions 1370x1030x650 mm^3, with rectangular and circular demountable ports for entry and exit of the laser beam, evacuation, system cables, and ports to access optics mounted inside the chamber. The front and back sides of the chamber are kept demountable in order to insert the breadboard with optical components mounted on it. Leak tightness of $9x10^{-9}$ mbar-lit/sec in all the joints and ultimate vacuum of $6.5x10^{-6}$ mbar was achieved in the chamber using a turbo molecular pumping system. The paper describe details of the design/ features of the chamber, important procedure involved in machining, fabrication, processing and final testing.

1. Introduction

In this paper, we report the design, fabrication and performance testing of a vacuum chamber, which is to be used to house optical pulse compressor of 150 TW Ti:sapphire laser system. The pulse compressor of this laser consists of two optical gratings and reflective optics. The chirp pulse from the system compresses the optical pulse in the time to get back the femto second laser pulse. After the pulse compression, the intensity of the laser pulse becomes very high and this results phase distortion in the laser beam due to air. Therefore, the beam has to be in vacuum to avoid this. The optical gratings and relevant reflective optics are to be mounted on a bread board, which is to be housed in bottom of the chamber. The optical gratings and relevant reflective optics are to be positioned with the help of vacuum compatible positioners to be operated from outside the chamber through feed-throughs. The chamber is meant for obtaining dry vacuum of the order of 10^{-6} mbar.

2. Features

The chamber has a cuboidal geometry having rectangular and circular demountable ports with an overall volume of approximate 930 litres. The chamber has seven demountable rectangular ports of size 250 mm x 500 mm with aluminum covers. The overall size of the chamber is 1420 mm (L) x 1200 mm (W) x 820 mm (H) which is made from SS 316L material. The available space inside the chamber is 1370 mm (L) x 1030 mm (W) x 650 mm (H). Front and back sides of the chamber can be opened (opening:1030 mm x 650 mm) in order to insert the breadboard of size 1250 mm x 950 mm duly optical gratings and other associated optical components mounted laterally from any side of the chamber. These optical gratings and other optics need to be aligned during operation. Both the sides are having demountable covers of aluminum in order to make them light weight, as these are to be handled manually. One side cover plate have entry beam port and three ports with DN 63 ISO-K flanges, which are to be used as feed-through ports for system control cables as well as to operate the positioners from out side the chamber. The other side plate have two measurement ports of 160 mm inside diameter ports and a small port for vacuum measurement. The exit beam port of 160 mm inside diameter has been provided at desired place at right angle to the entry of laser beam. The output laser beam is to be transported from this port to the Laser Plasma Interaction Chamber through 160 mm ID beam line. The top of the chamber has two demountable rectangular ports for the purpose of access to optics mounted on breadboard from top and one demountable evacuation port with DN 200 ISO-F flange to couple the TMP via high vacuum gate valve. The front and back sides are also having three and two demountable rectangular ports respectively of same size for the purpose of accessibility to optics etc. All the demountable joints are made with the help of Viton 'O' ring sealing of suitable cross section.

3. Design

The design of the chamber is based on theory of plates. The chamber is designed rigid enough to withstand the external pressure equal to atmospheric pressure as well as keeping deflection with in limit for sealing the demountable joints with the help of 'O' rings reliably. In this, we have designed separate plates using theory of plates with end conditions as fixed ends in order to keep conservative approach. The ASME code Section VIII, Div 1 has also been referred for design of ports / flanges as well as to cross check the design from stability point of view. Stiffeners are attached with walls of the chamber in order to reduce the wall thicknesses as well to keep deflections within desired limit. All the groves are designed very carefully with proper groove dimensions to fulfill the sealing requirements i.e, appropriate surface contact and surface finish of the order of 1.6 micron. All permanent joints are designed in such a way that no crevices are left, thus avoiding trapped volumes.

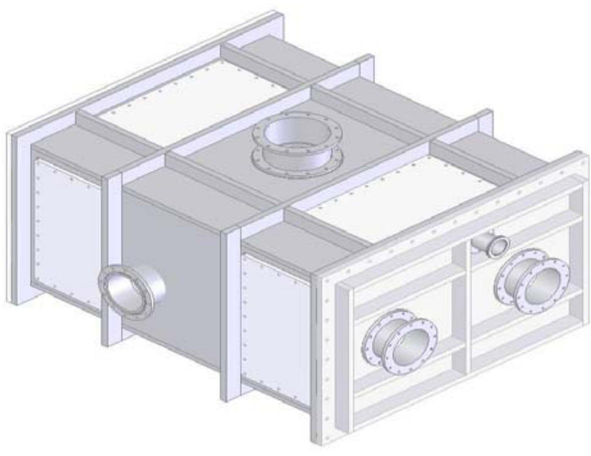

Fig. 1. 3-D view of the chamber

The vacuum pumping system had been selected to obtain vacuum better than 1 x 10^{-5} mbar within half an hour time after starting the same. The chamber was designed for a leak tightness better than 1 x 10^{-8} mbar lit./sec (He). The vacuum system was selected based on gas load in the chamber and ultimate vacuum requirement in stipulated period. A gas load of the order of 6 x 10^{-3} mbar lit./sec is calculated based on surface area exposed to vacuum and outgassing rate of construction materials. An additional gas load of 1 x 10^{-3} mbar lit./sec is expected due to out gassing of breadboard optical arrangement. A pumping system of 1250 lit /s speed was found suitable to evacuate the chamber into desirable vacuum within stipulated time considering conductance of connecting port and gate valve etc.

4. Fabrication

Manual GTAW welding process was used for welding using AWS 5.9 ER 316L filler wire and ultra pure argon gas under controlled RH (< 40%) in clean room. As higher coefficient of thermal expansion of austenitic stainless steel leads to unacceptable distortion during welding, the proper fixturing was used to avoid the same. The typical welding parameters used are as follows:

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% @ 22º C

Fig. 2. Photograph during welding

The chamber was machined on CNC Horizontal boring machine for its desired tolerances. Surface finish of the order of 1.6 micron 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 micron with no scratches and dents. All crevices in trapped volume had been removed to facilitate evacuation of the chamber. The stainless steel central chamber and other stainless steel parts are chemically cleaned and electro-polished in order to reduce the outgassing from them, while all aluminum covers plates are cleaned thoroughly to do the same.

5. Pumping system

The pumping system for the above Pulse Compressor Vacuum Chamber consists of combination of a turbo molecular pump with pumping speed of 1250 lit/sec and a dry backing pump with pumping speed of 50 M^3/Hr. 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.

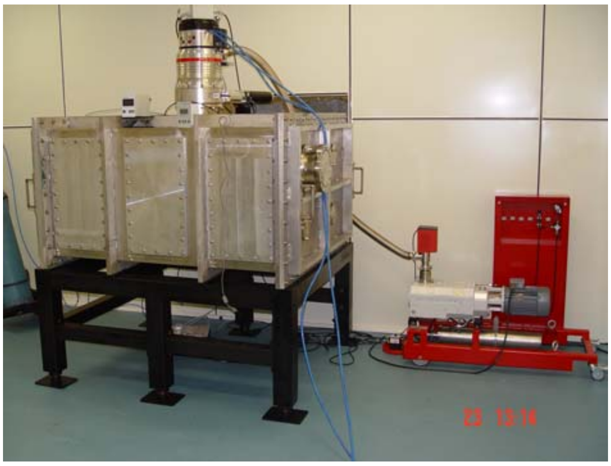

Fig. 3. Photograph of the chamber along with vacuum pumping system

6. Testing

Helium MSLD was used for carrying out leak testing. All permanent and demountable joints of the chamber have been tested and a leak tightness better than 9 x 10^{-9} mbar lit. per sec is found for all the joints. A vacuum of 6.5 x 10^{-6} mbar was achieved in less than two hours pumping time using a TMP of 1250 lit/sec pumping speed.

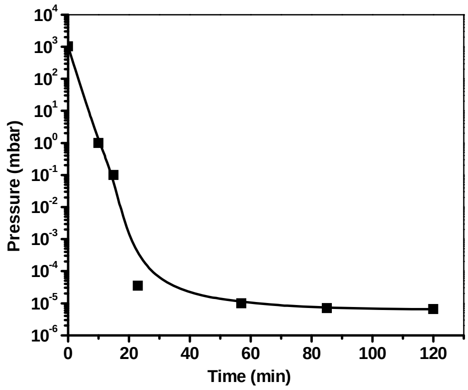

Fig. 4. Pump down curve

Acknowledgements

Authors sincerely acknowledge support and encouragement from Dr. P.A.Naik, Head, Laser Plasma Division. Thanks are due to Shri L.V.Thorat and Shri Sobhan Choudhary, ACDF Section, Shri P.Ram Sankar, CTF and Shri B.K.Sindal, UHV Division for drafting, fabrication, chemical treatment and leak testing work respectively. The authors are also thankful to other team members of ACDF Section for technical discussions and involvement in fabrication.

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