MECHANICAL ENGINEERING FOR THE FRONT END TEST STAND

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Abstract

The RAL Front End Test Stand (FETS) is being constructed to demonstrate a chopped H^- ion beam of up to 60 mA at 3 MeV with 50 pps and sufficiently high beam quality for future high-power proton accelerators (HPPA). This paper details the mechanical engineering components related to ion source high voltage cage, the post acceleration electrode and the laser based beam diagnostics that immediately follow the ion source.

INTRODUCTION

FETS will consist of a high power ion source mounted on a 70 kV high voltage platform, a 3 solenoid Low Energy Beam Transport (LEBT) including a laser based profile measurement system, a 3 MeV 324 MHz Radio Frequency Quadrupole (RFQ), and a Medium Energy Beam Transport (MEBT) line including a chopper and diagnostics. A status report for the FETS is given in [1] and more detailed information is given in [2] and [3].

The mechanical engineering for FETS has covered a broad range of expertise from design conception through finite element analysis, detailed manufacturing drawings, to construction, installation, alignment and testing.

HIGH VOLTAGE PLATFORM AND CAGE

Figure 1: High voltage platform installed.

The high voltage platform measures 2000mm x 3000mm, and at 50mm thick allows for a suitably sized corona shield along its outer edges. Care was taken during the welding stage to achieve a working area flatness of within 2mm per m^2. The electrical equipment when installed on the platform will weigh 1000kg (see Fig. 1).

Figure 2: High voltage cage completed.

A grounded aluminium sheet floor was put in place as a safety feature through which the high voltage platform is bolted to the floor. The insulators supporting the platform were sourced from Georg Jordan [4] and are 630mm high. The personnel interlocked cage was erected to provide a safety barrier from the high voltage equipment inside.

POST ACCELERATION ELECTRODE ASSEMBLY

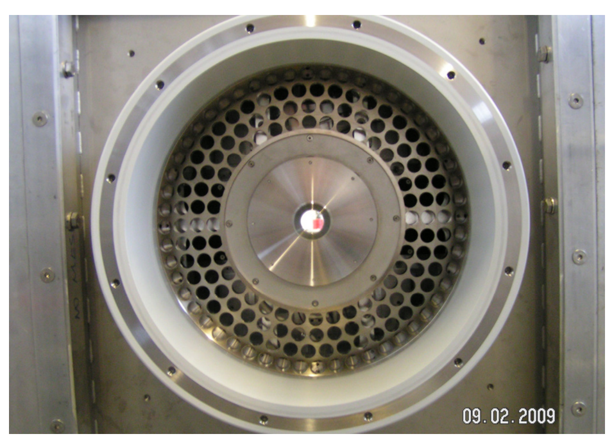

Figure 3: Post acceleration electrode assembly.

This proved to be a challenging but rewarding project for both engineer and scientist. The insulator was manufactured from TECANYL GF 30 in two pieces and bonded together due to the unavailability of the right size bulk material. Many requirements were needed for the spacer, firstly having enough mild steel to provide magnetic shielding, a magnetic bridge was designed to direct the stray field from the ion source both away from the sensitive dipole magnet inside the diagnostic tank and around the current transformer toroid. Secondly enough holes to allow efficient vacuum pumping and lastly a method to support the electrodes, toriod and mu-metal shielding. The electrodes have a 6mm degree of adjustment (in 1mm increments) allowing for different post accelerating gaps to be achieved.

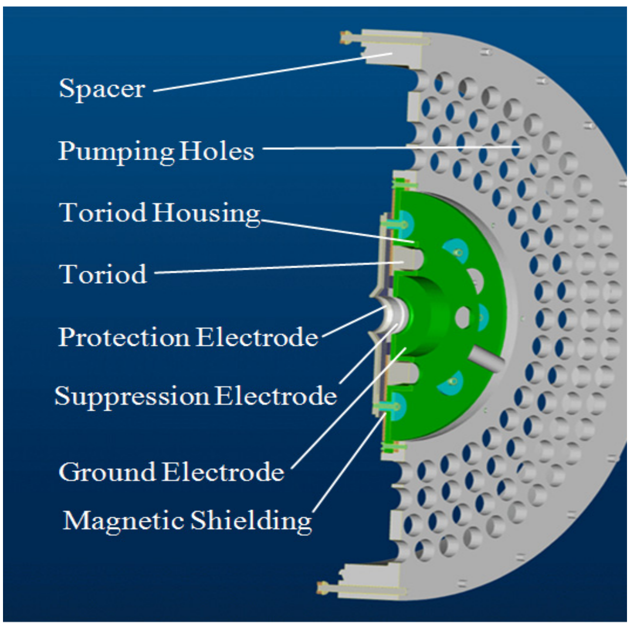

Figure 4: Sectional view of assembly.

The Ion source flange bolts directly to the insulator. In addition the ion source is supported with a frame coming from the high voltage platform to provide dimenional stablity during it's operational life. The post acceleration assembly is then directly bolted to the first vessel described below.

LASER BASED BEAM DIAGNOSTICS SYSTEM

The laser based beam diagnostics are designed to measure beam profile by the method of photo electron detachment [5]. The diagnostics occupy the space immediately after the ion source and before the LEBT. The engineering brief was to produce a system that allows a laser beam to pass through the axis of the ion beam at a wide sweep of angles, to occupy no more than 200mm in the beam direction (to minimise beam emittance growth), to incorporate a detector and to be housed in a vacuum vessel. Furthermore the vacuum vessel must allow for mounting the ion source, must be accessible for maintenance and alignment puropses and must allow for vacuum pumping totalling approximately 3000 l/s.

Initially two engineering design concepts were investigated. The first concept design considered revolving the laser around the axis of the ion beam. This system has the advantage of minimising the number of moving parts inside the vacuum vessel but introduces problems of stability due to the laser movement and the problem of maintaining a revolving vacuum-tight seal. The second concept design and the one chosen for the FETS uses a fixed laser and employs moving mirrors to guide the laser beam through the ion beam.

The chosen system uses four mirrors, each mounted to an ALIO Industries [6] AI-40R rotary stage which in turn are mounted to an ALIO AI-HR4-20000E linear stage. Two pairs of the mirror/stage assembly are then mounted in the horizontal position and two are mounted in the vertcial position. Figure 6 demonstrates the concept with the mirrors shown arranged in three different positions, providing three laser beam deflection paths. From left to right these three positions show a vertical laser beam, a horizontal laser beam and a 45 degree laser beam.

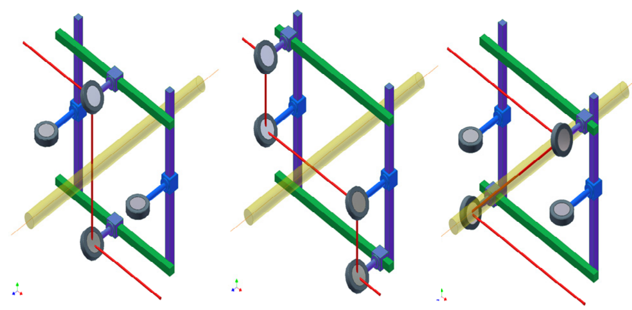

Figure 5: Laser movement concept.

Several design iterations led from the concept to the development of the final engineering design for the mirror/stage and detctor mounting chassis (see figure 7).

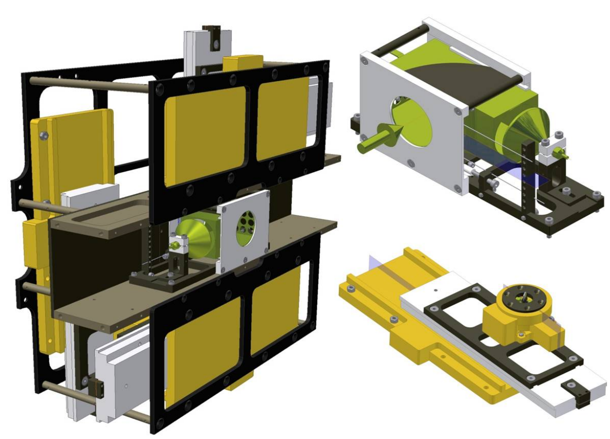

Figure 6: One mirror/stage assembly (bottom right), detector (top right) and complete 4X mirror/stage chassis including detector (left).

A vacuum vessel was required to house the stages and detector that had to withstand both the vacuum loading plus the possiblity of loading to an over pressure of 1.5 to 2.0 bar during routine operation.

The first design step was to perform hand calculations to define the material wall thickness. Calculations for the worst case vacuum loading revealed a stress of 130MPa and a deflection of 2mm for 10mm thick grade 304 stainless steel. Due to the requirement for a stable mirror and laser system and because the upstream wall of the vessel is the mounting face for the ion source it was decided to fabricate the vessel from 20mm thick stainless steel which shows a stress of 28MPa and a deflection of 0.3mm. ANSYS calculations were performed to verify hand calculations and to observe the effect of adding ports and features into the structure.

Figure 7 shows the vessel at an early stage of manufacture. The vessel walls have been stitch welded on the outside and a 2mm continuous fillet weld has been made on the inside. The ion beam ports in the upstream and downstream faces have not been added at this stage. They are made following the weld process to ensure their concentric alignment of +/- 0.5mm.

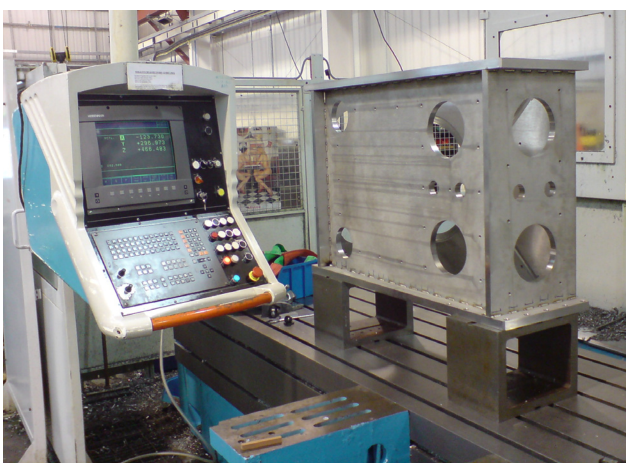

Figure 7: The vacuum vessel during manufacture.

The final vacuum vessel design was fabricated and installed successfully on the rail system. Alignment of the vessel with respect to the beamline was conducted using a laser system. The internals were mounted to the heavy duty telescopic ball slides and the electrical feed-through connections were made. Initial pumping using three Oerlikon [7] TURBOVAC MAG 830 pumps was slow due to the large surface areas outgassing but vacuum pressures in the 10^{-6} mbar range were quickly achieved. An uncooled faraday cup assembly has been added to the downstream vessel wall to act as a low power (<1% duty cycle) beam stop and current measurement device. All of the above items are under commissioning and first beam is expected this Spring.

An enclosure was fabricated to allow for safe operation of the laser and then mirror alignment tests were performed at the full range of linear stage travel (+/- 100mm).

Figure 8 shows a CAD model of the final vessel design. The side door is shown half open to enable the internals to be seen.

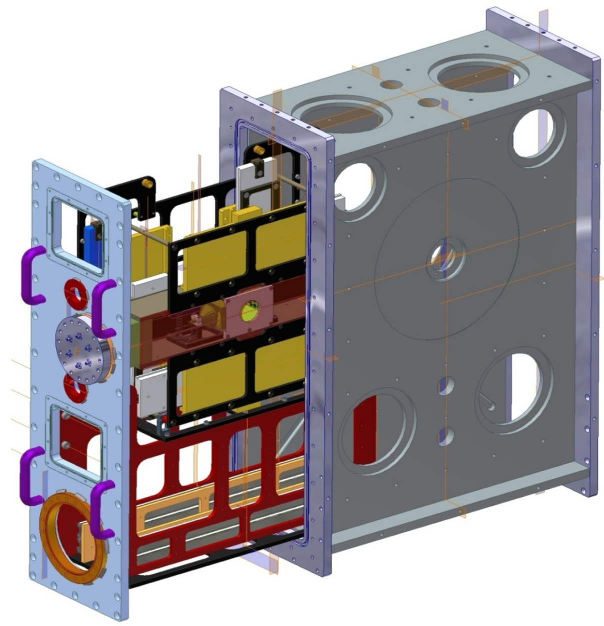

Figure 8: The complete vessel including internals.

OUTLOOK

There are numerous engineering challenges to come before completion of the FETS. The LEBT beam pipe sections have been manufactured and will be installed in the near future and the associated LEBT diagnostics will be designed. A pepperpot based multi-position diagnostic vacuum vessel will be ready for use on the FETS. The RFQ engineering design has begun and is scheduled for completion at the end of 2009. Looking further into the future the MEBT which includes the chopper will need engineering design effort. At the time of writing the ion source installation is nearly complete and the laser-based beam diagnositcs have been tested. First beam should be produced in May 2009.

REFERENCES

[1] A. Letchford et al., EPAC'08, THPP029

[2] D. Fairlocth et al., PAC'09, MO6RFP040

[3] J. Back et al., PAC'09, TU6PFP101

[4] Georg Jordan., http://www.jordan-siegburg.de/

[5] D. Lee et al., ID 2681, PAC'09

[6] ALIO., www.alioindustries.com

[7] Oerlikon., http://www.oerlikon.com/