ENGINEERING OF MULTI-DIAGNOSTIC PORT-PLUG FOR COMPASS

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Abstrakt *:* The paper generally outlines a design of new multichannel optical diagnostics for the COMPASS (COMPact ASSembly) tokamak. The final design of a port plug for a multispectral diagnostic tool is introduced and its evolution taking into consideration spatial and other technical restrictions is reviewed.

Key words : tokamak, optics, diagnostics

1. Introduction

The COMPASS, a divertor tokamak with a clear H-mode and ITER-like geometry (1:10 to the ITER plasma size, R=0.56 m, a=0.23 x 0.38 m, I_p=200-400 kA, B_T=1.2-2.1 T and pulse length up to 1 s), is being re-installed in IPP Prague after its transport from UKAEA, Culham Science Centre, UK. Several new diagnostic tools are being built to address aims of the COMPASS scientific program focused on H-mode physics and pedestal investigations [1].

In the second section of the paper the design of new multichannel optical diagnostics port plug is described. An integrated optical system for visible plasma radiation from 400 nm to 800 nm, soft X-ray, and bolometric measurements has been designed and will be used to obtain information on hydrogen and impurity emission and its evolution during discharges [2]. As a result, neutral atoms density, impurity inflow, recycling processes, and rough estimation of particle confinement time can be derived. Effective ionic charge Z_{eff} will be evaluated from a line free region slightly above the 520 nm comparing to pure hydrogen plasma *bremsstrahlung* using known plasma density and temperature. This optical system will be installed in the sector 6/7 of the COMPASS tokamak (see Fig.1). This contribution addresses port integration issues imposed by a significantly constrained available space. A diagnostic port plug with an inside diameter of 97 mm will be used for two arrays of the AXUV-based bolometers (twenty channels each), thirty-five channel soft X-ray semiconductor sensor, and thirty-five channel visible light diagnostic, all of them integrating radiation along vertically stepped lines of sight with a spatial resolution of about 10 mm. Furthermore, this port plug will also be equipped with a shutter to prevent detectors and optics from an impurity layers deposition during cleaning glow discharge, and with an internal cooling to prevent detectors from overheating during vacuum vessel baking. The same spectroscopic system will be installed into a similar port located at the same poloidal cross-section below midplane in the same manner as mentioned above.

2. Port design for integrated optical system

A basic design was developed relating to the demand to integrate all above-mentioned spectroscopic systems together with both a cooling channel and a shutter in the limited port area. Therefore, this port plug is assembled from two pieces. The first is an inset which holds detectors, air slits, shutter, and also includes a cooling channel. The second piece is the NW100 flange. This flange contains two electrical feedthroughs, each equipped with 41 pins, one hole for a rotary feedthrough (NW16 flange) intended as a shutter manipulator, and the second hole for the NW35 viewport. The NW35 vacuum window will be made of UF- fused silica. This optical material fully meets tokamak requirements, such as high vacuum tightness (~10^{-6} Pa), immunity to heat loads during baking of the vacuum vessel (150ºC), resistance to neutron fluxes, and high transparency for a measured spectral range.

The inset design was developed from a placement scheme of detectors taking into account required observation angles (see Fig.1), and retaining the alternative of easy assemblage of the whole port plug. At the beginning, there were two possible ways of designing a part holding detectors. The first one was to make a separate case for each detector. This option is advantageous in a relatively simple construction and easy connection between detectors and electrical feedthroughs. However, it would be complicated to connect the cooling to more than one case inside a limited port area. The other option was to make a detectors holder as one monolithic inset. This inset is difficult to manufacture, but it has the advantage of compactness. Therefore, this option was chosen. In this case, the cooling channel is drilled through the inset, and holes on the vacuum side are sealed by threaded stoppers and welded. Both the presence of this drilled channel and the requirement to assemble the whole diagnostic port plug “on the table,” before the final connection to the tokamak, resulted in a double flange structure of the inset. One flange which contains input and output of the cooling channel allows assembling the port plug to the tokamak flange; the second is used to connect the NW100 flange to the inset.

During the inset design phase, the placement of detectors was slightly shifted against original scheme. This was done mainly to fit detector sockets, which are bigger than the detectors themselves, inside the inset. Then, a free area was used to fit in the visible light diagnostic system of the largest possible diameter. Moreover, enough space for a cooling channel of 6 mm diameter had to be kept.

In the visible light diagnostic system, light transmitted through the first optical component (the objective located on the vacuum side in the frame of the port plug) is collimated into a parallel beam. The throughput of the detection system is restricted by a maximum possible diameter of the viewport on the NW100 flange, i.e., the NW35 viewport. This viewport should be in-line with the objective, which is the main restriction for a layout of parts on the NW100 flange. Position of the rotary feedthrough is given by a free area left on the inset, the only place large enough for a shutter controller. Then, the electrical feedthroughs are placed. Their positions were chosen considering the electrical plug size and size of the NW35 viewport. Behind the NW100 flange, the parallel beam of light is collected by a set of optical fibers [2]. Each fiber corresponds to one spatial channel. Twenty-meter long optical cables will be used and their output will be connected to a multi-channel detector or to spectrometer, depending on the purpose of measurement. Detectors will be located far away from the tokamak because they are sensitive to the X-ray radiation from plasma. Moreover, an easy adjustment of the system will be possible in this case.

Thanks to the double flange structure of the inset, detector sockets for bolometric and soft X-ray measurements can be connected to the electrical feedthroughs before a final assemblage of the inset and the NW100 flange. Then, the NW100 flange will be bolted to the inset, and sockets will be bolted to the inset through a mounting hole. The mounting hole will be closed subsequently. Afterwards, detectors will be mounted from the front side and covered by an air slit holder (Fig.2). The air slit holder is used for movement of the slit against the detector centre, if a change of observation angle is required.

As a collimating element for the bolometers and a soft X-ray detector, the 0.1 mm wide and 2 mm long air slit together with the second, exactly the same air slit in a perpendicular direction will be used. The air slits are replaceable allowing an independent change of the vertical and toroidal spatial resolutions by the modification of air slit width. Changing the toroidal resolution, mainly the throughput will be influenced due to a toroidal symmetry of observed plasma. In the case of soft X-rays, a thin beryllium foil (a few micrometers) will be used to filter VIS and UV radiation. To prevent air slits and foils from rupturing during a chamber pumping or refilling, pressure relieve holes were added into the inset.

The cut through the port plug and the final design of the assembled diagnostic port are shown in Figs.3 and 4.

In these days the port plug is being mounted to the tokamak vessel. The photo of port plug during assembly is shown in Fig.5.

The results from port plug cooling test can be seen in the Graf 1. During this the port plug was mounted on the small vacuum chamber. This chamber was heated up to 100°C. The temperature of port plug was measured by two Pt 100 thermocouples. First thermocouple was placed on the far side of the port plug (behind the soft X-ray detector), the second thermocouple next to the cooling channel. When the temperature of the port plug was settled, the cooling water was introduced to the cooling channel (this cooling channel is placed between bolometers). When cooling started (at 13:30), the temperature of vacuum chamber dropped bellow 100°C what is considered to be minimal baking temperature for the vacuum vessel. For this reason the heating input power was raised to maximum value. Thank to this, the temperature of vacuum chamber raised to 110°C. However the temperature of the port plug did not exceed 60°C what is considered to be the maximum operational temperature for used detectors.

Conclusion

The final design of the port plug for the multispectral diagnostic tool for the COMPASS tokamak and its evolution was reviewed, taking into account spatial and other technical restrictions. In spite of the relatively complex double flange design, the observing system remains as flexible as possible and easily fabricated and settled.

The vacuum and cooling tests were done with satisfactory results.

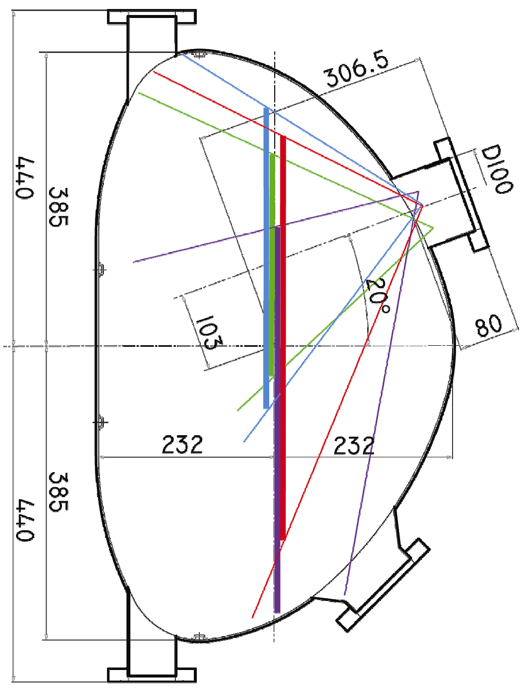


Fig.1 - Scheme of the poloidal cross-section of COMPASS tokamak in sector 6/7. Observation angle of visible light diagnostic is shown - visible light diagnostic view (green), first (violet) and second (blue) bolometric view, soft X-ray detection view (red)

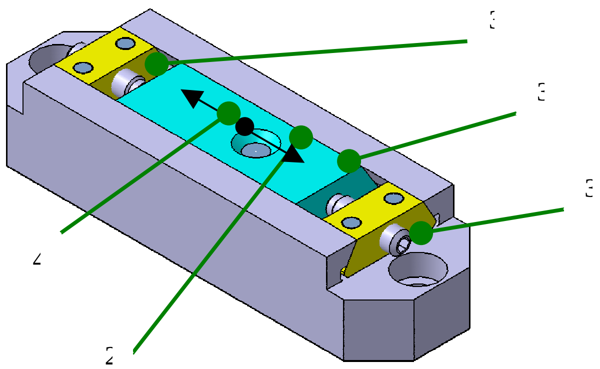


Fig.2 - Air slit holder (1-gliding stone, 2-air slit, 3-fly screw, 4 - movement of gliding stone)

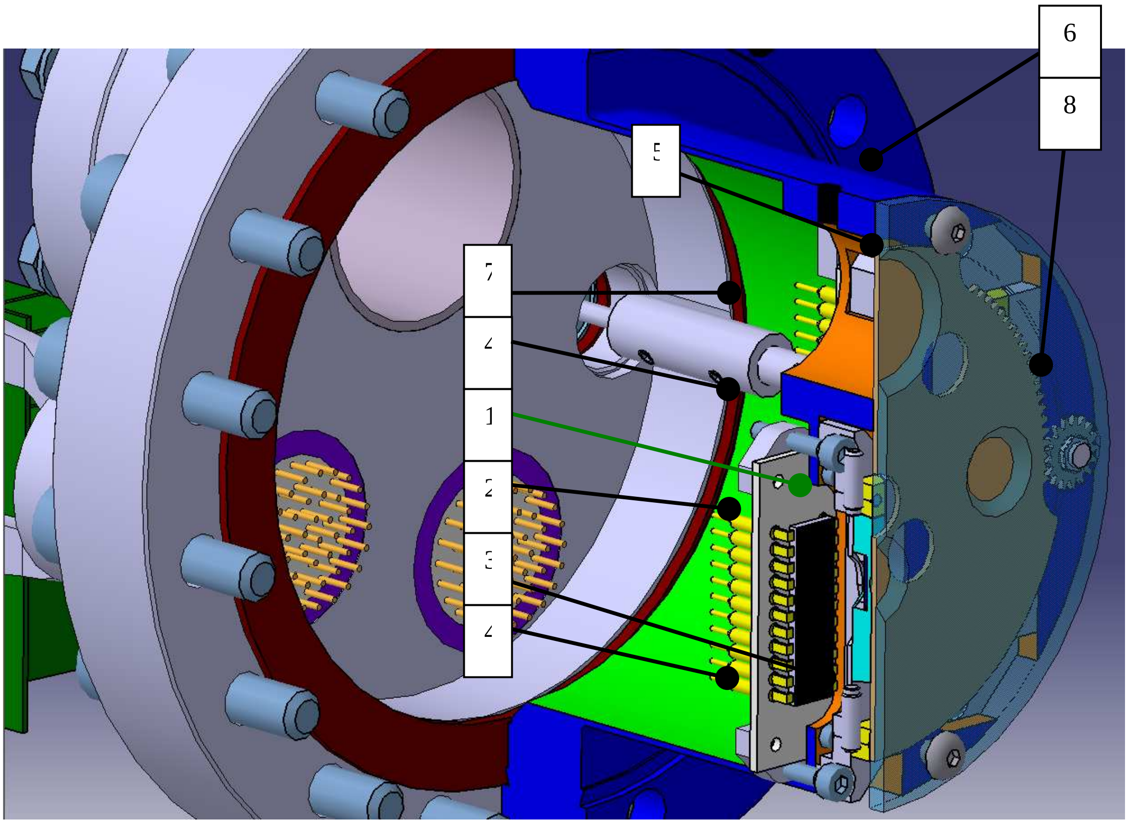


Fig.3 - Port cut through (1-detector, 2-detector socket, 3-air slit holder, 4-nut, 5-shutter, 6-hood (holds the shutter), 7-connection shaft (links shutter jack and rotary feedthrough), 8-shutter jack)

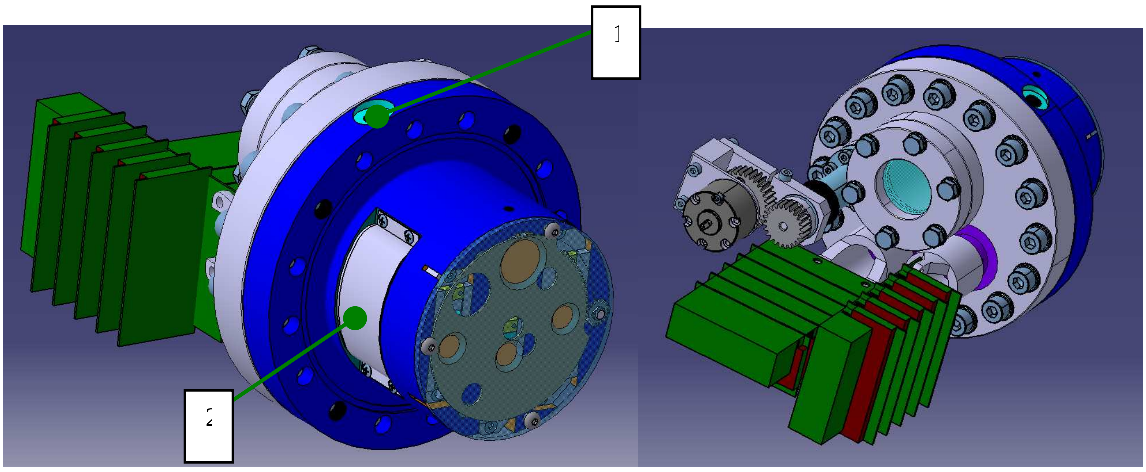


Fig.4 - 3D view of the assembled port (vacuum side – left picture, atmospheric side – right picture, 1-Cooling channel inlet, 2- Mounting hole)

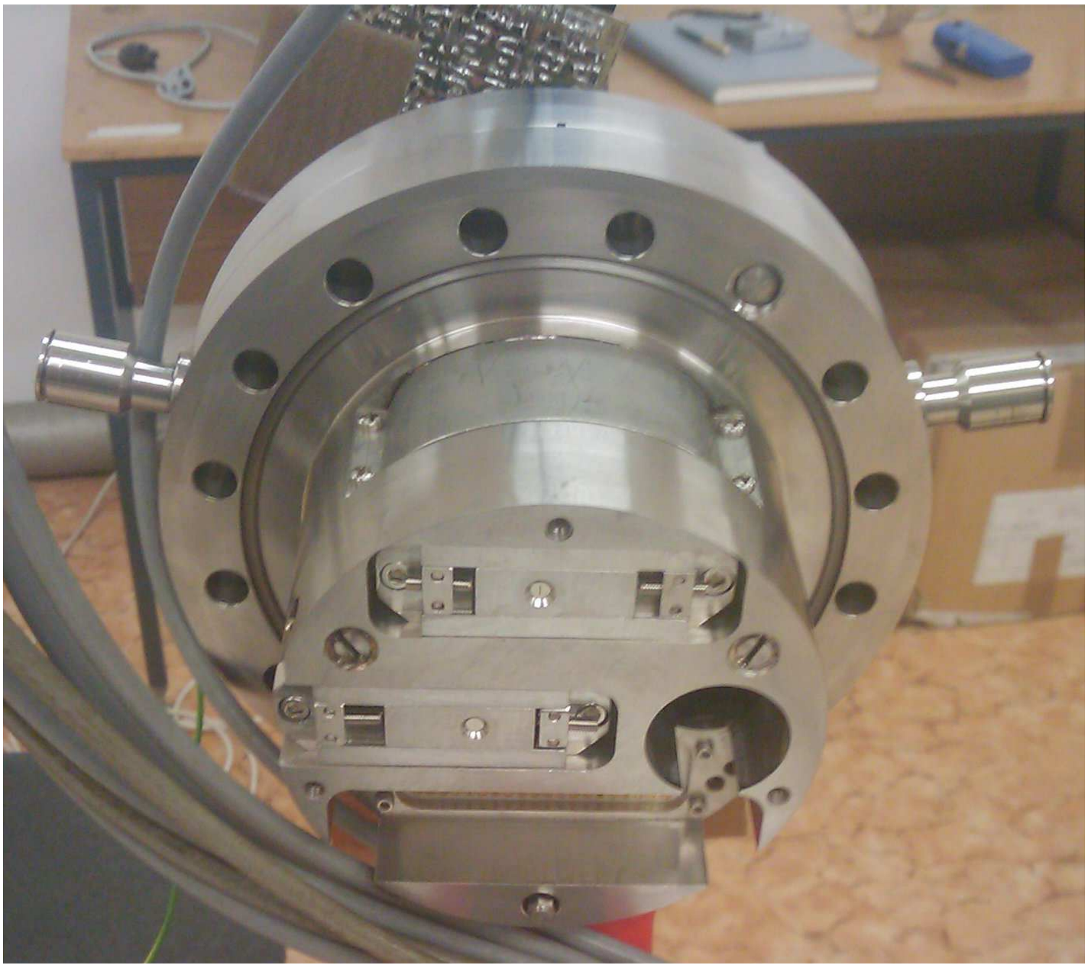
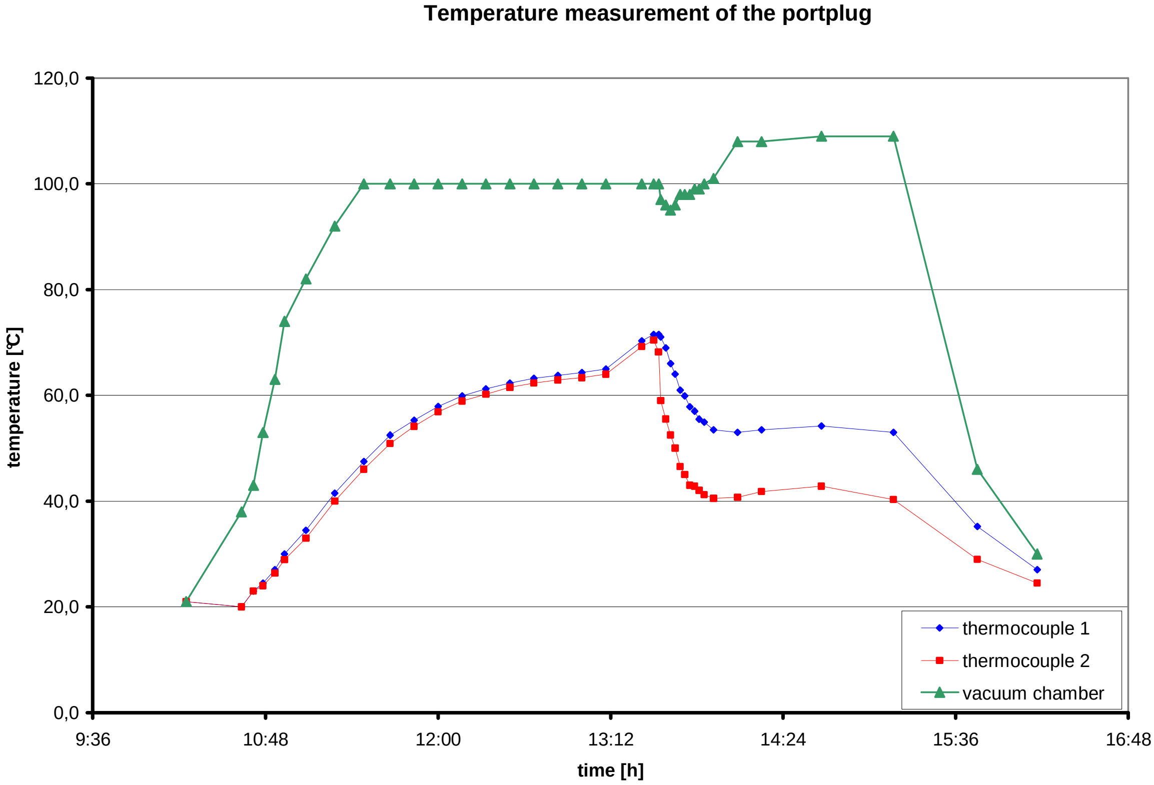


Fig. 5 – Photo of the port plug during assembly. Bolometer air slits are in the position, Soft X-ray air slit is missing.



Graf 1 – temperature measurement of the port plug

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References

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