ENGINEERING DESIGN OF THE JET EDGE THOMSON SCATTERING SYSTEM

D. J. Wilson, P. Nielsen, C. W. Gowers, R. J. Eagle
Jet Joint Undertaking, Abingdon, Oxon, OX14 3EA, UK.

ABSTRACT

A new Thomson Scattering System has been designed to measure electron temperature and density in the Jet plasma, near the last closed flux surface with high spatial resolution. The design overcomes the severe access restrictions around this region.

1. INTRODUCTION

Simultaneous measurements of temperature and density at the plasma boundary are important for understanding of both the Scrape Off Layer and the limiting gradients at the main plasma edge (Ballooning Limits). The spatial resolution required in this region of the plasma is ~1 cm or less perpendicular to the surface. These measurements can be made using reciprocating probes, but these are restricted in the penetration depth and are of a much higher risk. Thomson Scattering can in principle provide these measurements, given enough laser energy and solid angle of collection. Better spatial resolution can be obtained from a conventional scattering geometry, if the measurements are made in a region with some flux expansion and/or if the laser light path is at a small angle to the flux lines.

2 THE THOMSON SCATTERING SYSTEM DESIGN

The system uses two inner vertical ports in the C-Sector of Octant 2 as per Figure 1. The laser passes into the plasma vertically from the outer port, with the collection optics located in the innermost port. In this region the plasma tends to span the last closed flux surface. Twelve scattering locations along the laser path are each imaged onto 2mm nom. diameter quartz fibres. Taking account of the flux expansion in this region the system has an equivalent spatial resolution of 1 to 2 mm at the equatorial midplane.

The light emerging from the fibres is relayed to the ceiling of the torus hall (~ 10 m) by a cassegrain telescope (F/2). In the ceiling the light is relayed through a labyrinth to the spectrometer and detector. The telescope is mechanically linked to the fibre optics periscope which is inserted into the vessel during a pulse.

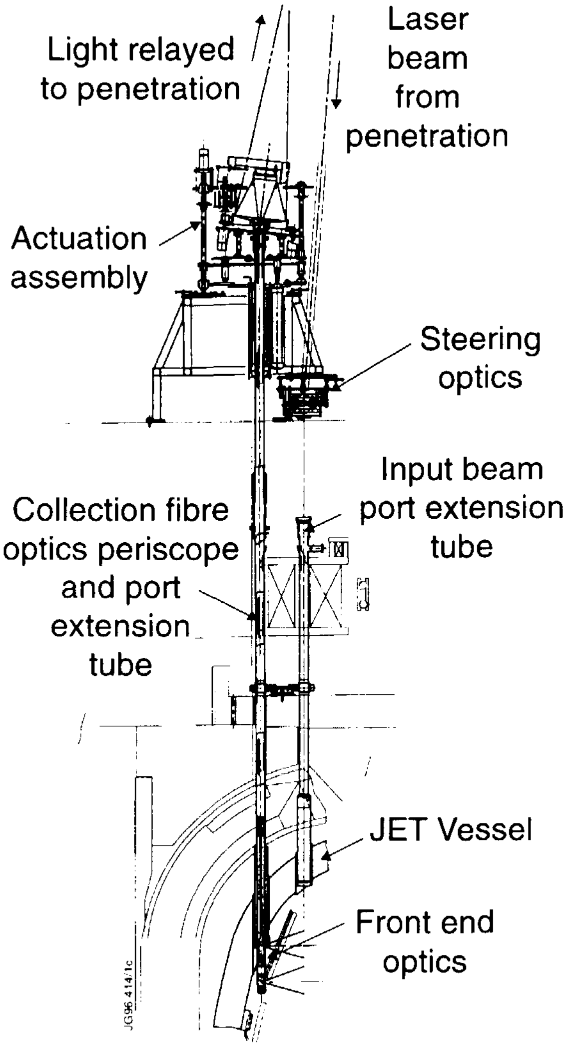


Figure 1 General Layout

An adjustable stroke between 200 and 400 mm with an insertion and withdrawal time of less than 1 second has been adopted. In order to protect the front of the gold coated mirror from plasma deposits, the periscope is pneumatically inserted only during periods of measurement. The length of the downward stroke and hence the selection of scattering positions is controlled by an adjustable stop.

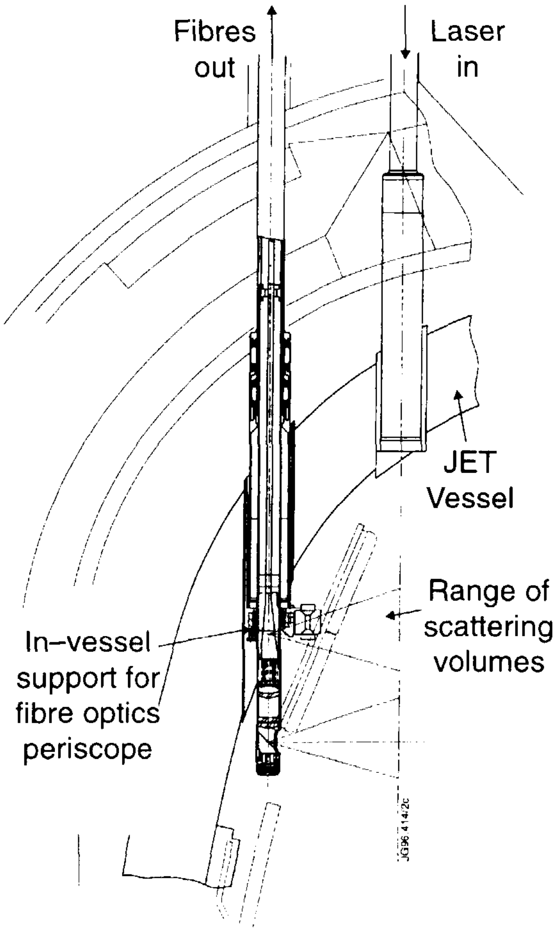
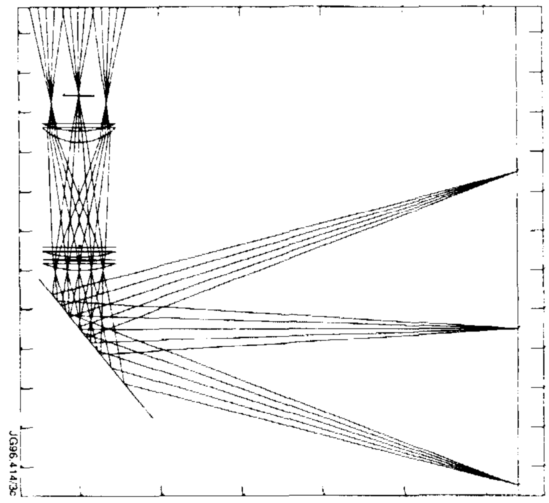


Figure 2 In-Vessel Assembly in fully inserted position, showing range of scattered volumes.

Access restrictions around the Torus ports have made it necessary to extend the vacuum boundary up to the top of the limbs, so that a more substantial structure can be erected. Double bellows have been used as a general policy with regard to maintaining vacuum integrity. The lower bellows are used to provide the flexibility between the heated vacuum vessel and the cold mechanical structure. They also provide the necessary isolation from vessel movements, during plasma disruptions. The upper edge welded bellows provide the necessary stroke for the internally mounted fibre optics collection assembly.

3. IN-VESSEL ASSEMBLY

Figure 2 shows the collection assembly located in-vessel inside a graphite support ring. This support is necessary as high forces are possible during collapsing halo currents. The collection assembly normally rests inside the small circular port, out of view of the plasma. At no point does this assembly enter the plasma and is protected behind the relevant inner wall tiles.



Figures 3a Ray tracing diagram showing performance of telecentric lens

The collection system uses a fibre optics periscope constructed using sixteen fibres. Four fibres are used for alignment and are mounted on both sides, of the line of 12 collecting fibres. The scattering volumes are imaged onto the fibre ends by a three element telecentric sapphire lens as per Figure 3a. The effective scattering length is 10mm with F/10 collection. The image is deflected through 90 degrees by a gold coated copper mirror at the front of the periscope. All these components are located inside the vacuum vessel and can be heated to 350 °C.

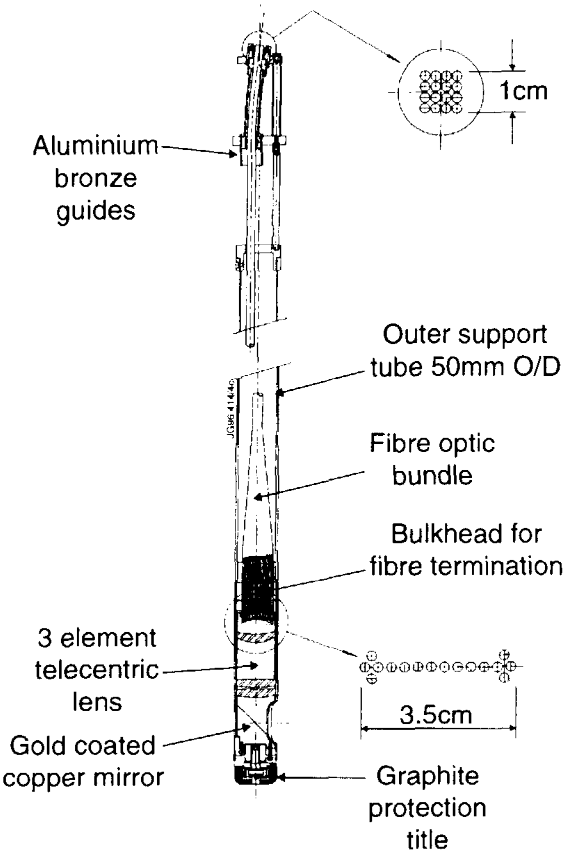


Figure 3b The Fibre Optics Periscope. Inserts show layout of fibres at each end.

4. THE FIBRE OPTICS PERISCOPE

Figure 3b shows the periscope with its collection optics and the fibre bundle at the top of the vacuum assembly just below the double fused silica window. The periscope is approximately 6 m long and clears both the toroidal field coils and vessel support structures. In this space the transition between the fibre optics to conventional mirror optics is made. Two cam shaped bolts lock the periscope into its correct angular position, using two knurled pressure plates inside the vacuum tube. Thermal expansion of the outer structural tube is downwards at this point. The fibres are attached to a bulk head at the collection optics end of the assembly. Thermal expansion of approximately 5 mm at the window end is achieved with the fibre bundle sliding in a aluminium bronze guide and on three sprung loaded pillars.

The fibres used are aluminium clad quartz, of approximately 2.6 mm outside diameter. These were selected for vacuum compatibility, maximum radiation hardness and good mechanical strength properties. The ends were cleaved to within 2mm of final length, hand dressed down, then finally polished using a conventional fibre polishing machine. Small ferrules were attached to the lower end so that after final positioning within the bulk head with respect to the lens, the fibres were potted in a Ceramabond 571 ceramic compound. After curing, this joint is vacuum compatible and is a useful technique for bonding in these situations. At the top end the fibres are closely packed in a 4 x 4 matrix. This end is also potted in ceramic compound.

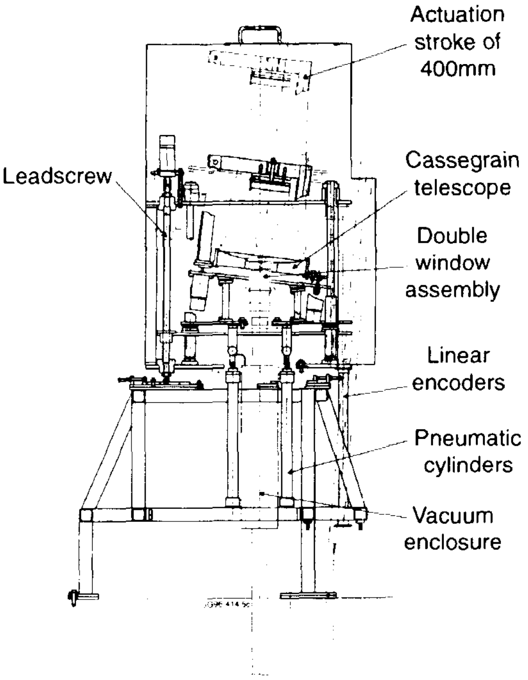


Figure 4 Actuation Assembly with Cassegrain telescope shown in the fully inserted and in the Stand-by positions.

5. ACTUATION ASSEMBLY AND CASSEGRAIN TELESCOPE

Figure 4 shows the layout of the cassegrain telescope mounted inside the actuation assembly. Although rather complicated looking its operation is simple. The vacuum tube and hence the fibre optics assembly is pneumatically driven up and down between a fixed top plate and a variable bottom plate. The position of the bottom plate is set using a dc motor driven lead screw, which determines the depth to which the collection assembly reaches. Linear encoders are used to measure the position of the bottom plate as well as the driven plate. Constant force shock absorbers are mounted in pairs in both directions and smooth out the motion, together with flow restriction of the pneumatic cylinders. Access to the double window for remote handling replacement, is achieved by the removal of the cassegrain telescope sub-assembly. The two mirror elements are spaced apart accurately using a three legged frame that gives minimal blockage to the collected light. Mounted off the support frame is the laser steering assembly, consisting of two counter-rotating wedges. Minimising the effects of reflected laser light is implicit in this design.

6. PENETRATION OPTICS

Figure 5 shows the penetration assembly. The spectrometer and detection system are mounted inside of a removable tubular insert. This in turn sits over another insert which contains a conical cavity for the F/10 optics. A 250 mm diameter lens is mounted at the very end of the lower insert and aligns the axes of the penetration with the torus mounted optics. This arrangement was adopted as it minimised the amount of radiation shielding required above the floor level of the roof penetration. All inserts are double skinned so that they can be filled with shielding material. In order to achieve sufficient spatial resolution we have opted for a conventional ruby laser system. The ruby laser provides 2 joules in 1.2 ns pulses at 4 Hz operation.

The square image of the 16 fibres is divided into four spectral channels by dichroic filters. All four channels are imaged onto the same image intensifier - CCD camera detection system. The image intensifier can be gated to 5 nsec. With the short laser pulse it may be possible to gate out laser stray light pulses!

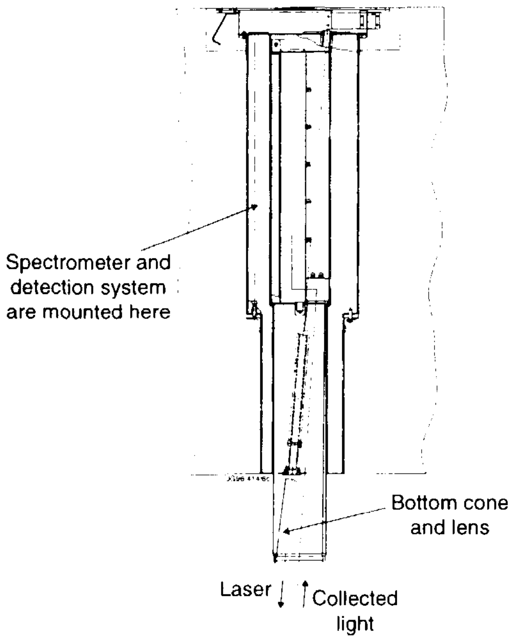


Figure 5 Insert in biological shield above Torus showing the optical layout for the spectrometer/detection system.

7. SUMMARY

An engineering solution for the new Edge Thomson Scattering System has been made. Operation of these components is required to be both accurate and reliable in an ultra high vacuum and high temperature environment. The spectrometer and detection system for this diagnostic, where the scattered light will be analysed, will be installed in the penetration by the end of 1996.