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Design of Diagnostics in the Steady State Environment of W7-X

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To facilitate long pulse, high power operation (with 10 MW cw heating power by ECRH) the first wall of W7-X is designed to withstand a steady state heat flux of up to 200 kW/m² from neutral particles and plasma radiation. The value for the targets and baffles of the divertor is even higher, up to 10 MW/m². A number of diagnostic components will be exposed to the same heat flux, since they have to be positioned close to the plasma because of the need for

- large viewing angles (divertor thermography),
- large variation of the observation direction (soft-X tomography),
- positioning between plasma and electrically conducting plasma vessel (e.m. diagnostics),
- positioning opposite of ports (interferometry reflectors),
- measurements with probes (Langmuir-probes).

One of the major concerns in the design of the diagnostics will be to keep their temperature from rising to unacceptably high values. The heat load on the diagnostic components situated close to the plasma therefore poses a twofold task for the design of these components:

(1) The heat flow from the plasma to the component must be minimized and (2) the remaining quantity must be balanced by active cooling.

1. Minimizing the Heat Flow to the Component

1.1 Shielding of Diagnostics

1.1.1 Full Covers

A number of electromagnetic diagnostics are being positioned between the plasma vessel and the first wall, which provides a complete shielding of plasma radiation (Fig. 1). This is only possible for magnetic measurements and is not possible everywhere due to spatial restrictions. A prototype is being set up.

1.1.2 Partial Covers

Part of the first wall will be raised to house the soft-X cameras for tomography with a slit for observation, lowering the heat load by partial shielding, but still allowing direct access to the plasma (Fig. 2). Due to spatial restrictions this is only possible in those poloidal planes where the plasma cross section is triangular, the viewing angle is limited in toroidal direction and cooling of the camera is mandatory. This development is in the conceptual design phase.

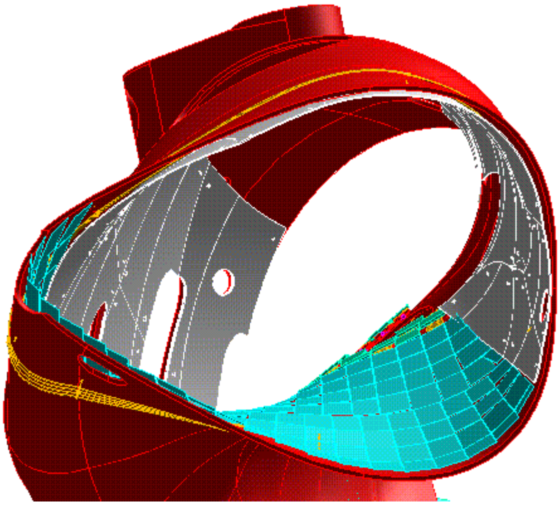

Fig. 1. Rogowski coil (yelow) between plasma vessel (red) and first wall (grey and blue).

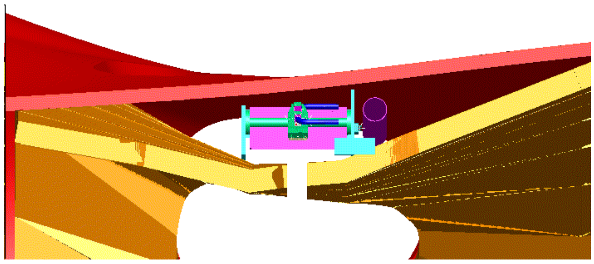

Fig. 2. Soft X-camera (green) between plasma vessel (red) and raised first wall with slit (yellow).

1.1.3 Grids (see also 2.2)

Grids will be placed in front of the reflectors for interferometry, lowering the heat load by partial shielding, while still allowing direct access through the holes. The heat conduction of the grid will be the limiting factor. This development is in the conceptual design phase.

1.1.4 Shutters (see also 2.3)

Shutters are widely used for temporarily shielding optics. However, spatial restrictions and the need for active cooling set severe limitations on the aperture.

1.2 Compact Design Solutions

Covers like the first wall or individual shields pose severe spatial restrictions to a number of diagnostics, requiring extremely compact design solutions.

Rogowski coils with high aspect ratio (1:10) rectangular cross sections are being positioned between the first wall and the plasma vessel and between the plasma vessel and the thermal insulation / field coils (Figs. 3 and 4). With 4 windings / mm the signal strength enables even long pulse e.m. measurements. A prototype is being set up.

1.3 Retractable Diagnostics

Pressurized air driven actuators enable repeated short measurements in the plasma edge with Langmuir probe arrays positioned between the divertor target tiles (Fig. 5). Limitations are speed, duration of measurement and lifetime. A prototype is being set up.

2. Active Cooling

Water cooling is the preferred solution, however, low heat conductivity of insulators (most notably windows) and movable parts in ultra high vacuum (e.g. reflectors, shutters) pose

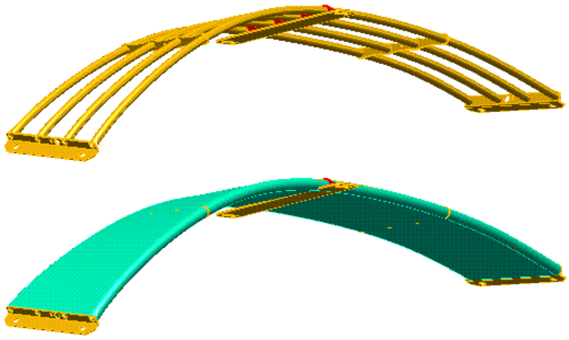

Fig. 3. Rogowski coil with high aspect ratio rectangular cross section (8 × 80 mm).

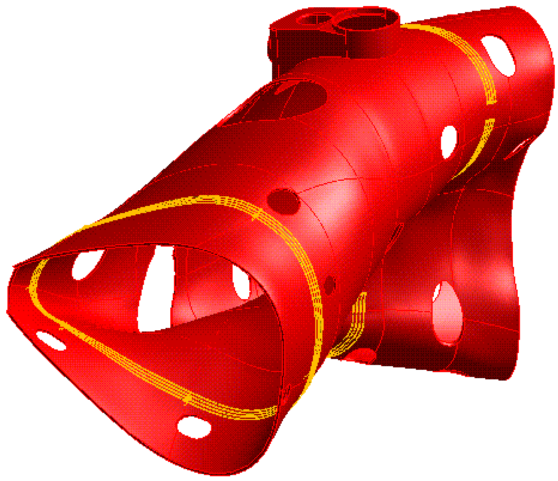

Fig. 4. Rogowski coil (yellow) inside and outside of the plasma vessel (red).

severe difficulties to water cooling. Prototypes will be set up to test the concepts and explore their limits.

2.1 Windows

Windows provide access for optical diagnostics in the visible and infrared wavelength region. Water cooling of the window edge and the flange will limit the window size and the viewing angle (Fig. 6). A prototype is under design and a test bed is being set up.

2.2 Reflectors

Corner cube reflectors precisely reflect visible and infrared laser radiation. They are cooled by embedding in an actively cooled first wall tile (Fig. 7). They are cylindrically shaped to

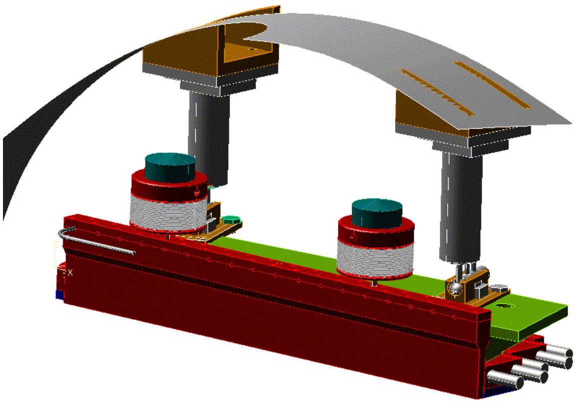

Fig. 5. Retractable Langmuir probe array in front of target tiles.

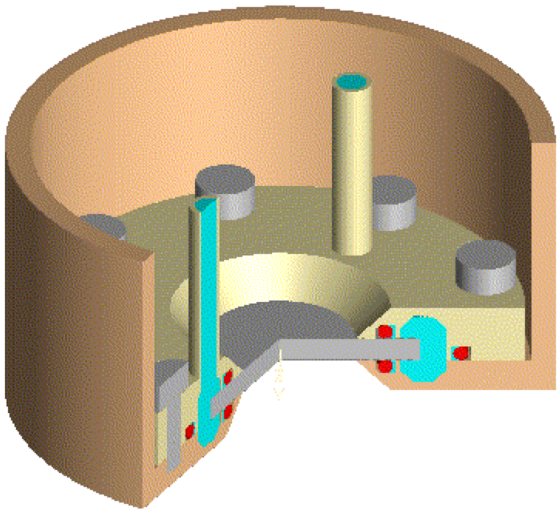

Fig. 6. Water cooled window at the end of a periscope.

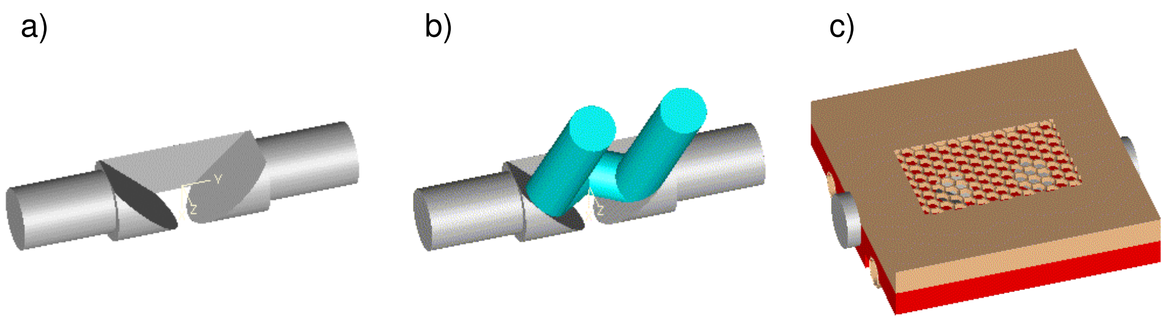

Fig. 7. Cylindrical corner cube reflector (a), reflected laser beam (b) and reflector embedded in a first wall tile with shielding grid (c).

be rotatable for protection during boronization and glow discharge. For a wall thickness of 28 mm the laser beam is limited to a diameter of 15 mm. The reflector is in the conceptual design phase.

2.3 Shutters

For protection of windows for visible and infrared observation during boronization, glow discharge and (temporarily) plasma operation a rotatable shutter is being designed. To provide active water cooling, a tube, a triangular box and a bellows extend the machine vacuum through the port. They house the shutter with stiff stainless steel cooling water tubing (Fig. 8). The design sets limits to window size and viewing angle. The cooled shutter is in the conceptual design phase.

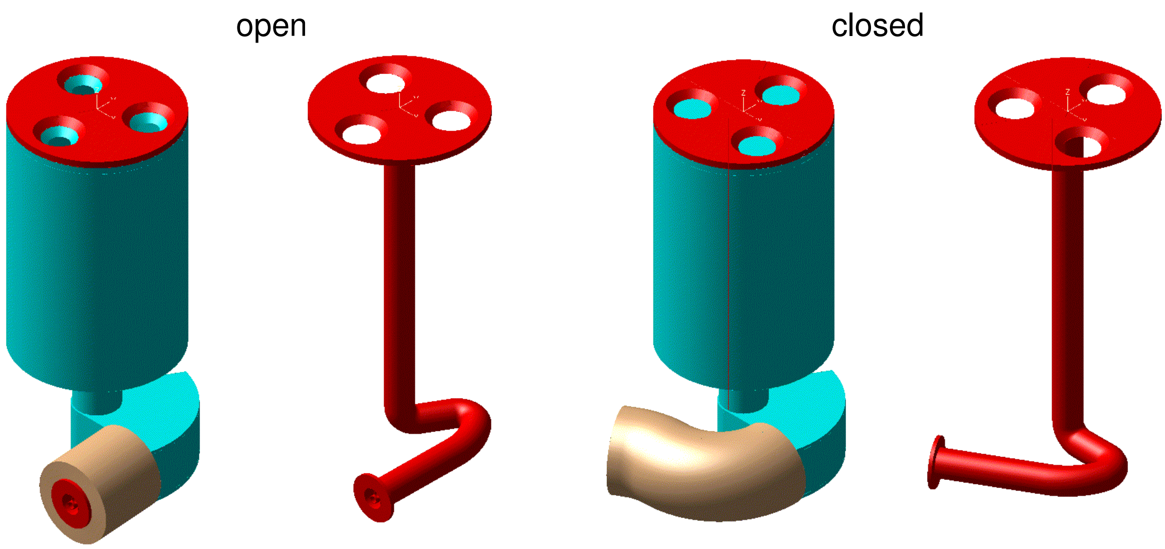

Fig. 8. 3-window periscope with rotatable, water cooled shutter.

Summary

Concepts have been developed to counter the problems raised by the heat load on diagnostic components during long pulse, high power operation. Test to verify these concepts and to lay out the design are being prepared.