Movable Sample Holders

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1. Objective

Exposing samples to the LHD plasma periphery or the position of the vacuum wall for investigating plasma-material interactions. This device can be used for movable electron guns for magnetic surface measurements, magnetic/electrostatic probes for peripheral plasma parameter measurements, an electrode for electric bias experiments, and so on.

2. Apparatus

2.1. Movable sample holder (4.5-L)

2.1.1 Overview

Two movable sample holders are installed in two lower ports (4.5-L and 10.5-L), which can vertically insert the samples into the LHD vacuum vessel up to near the equatorial plane (see Figure 1). These devices are vertically mounted on a middle stage in the LHD basement hall. Figure 2 shows a side view of the configuration of the movable sample holder installed in 4.5-L port. The length of the stroke for the vertical movement is about 4m. The device consists of a movable rod, an upper vacuum chamber, welded bellows, a lower vacuum chamber and a driving gear (air motor). The device is electrically disconnected to the LHD vacuum vessel by an insulator inserted at the top of the upper chamber. Four network cameras monitor the device for the safe operation. The cameras are controlled from the LHD control room via Web browsers on personal computers. A CCD camera (NTSC video signal output) is also set at the front of a remote control system on the middle stage for real-time monitoring. Most of gate valves and vacuum gauges are remotely controlled from the LHD control room. The movable rod inserted in the vacuum vessel is routinely monitored with a plasma monitor camera mounted in an upper port (4.5-U). One can insert the movable rod to near the equatorial plane because of no lower/outer divertor leg plasma at the position of the rod. This is because the divertor leg is intersected by divertor plates in closed helical divertor components near the lower port (4.5-L).

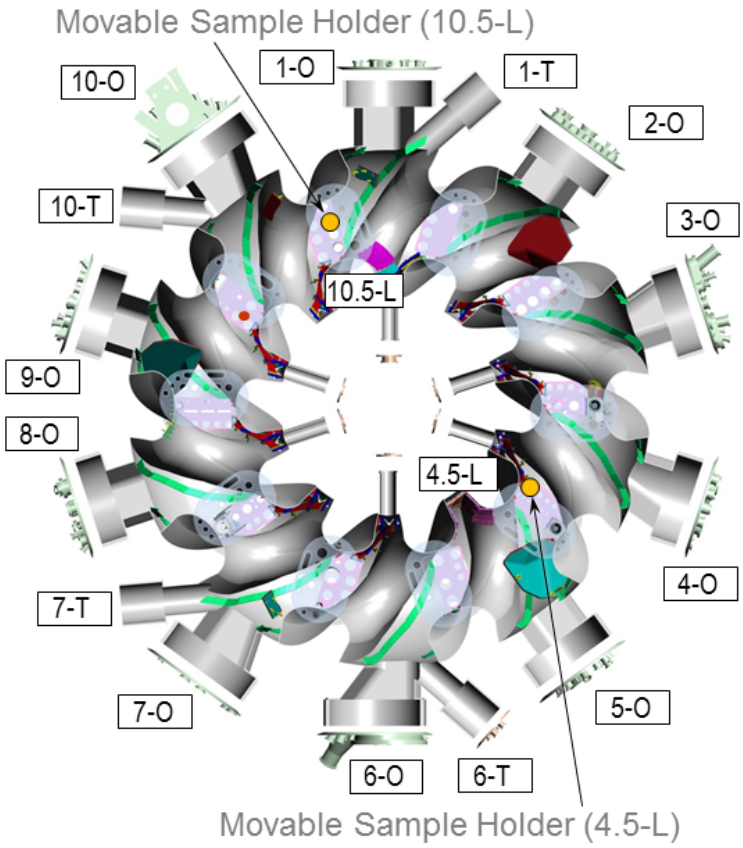

Fig. 1. Top view showing the positions of the movable sample holders installed in 4.5-L and 10.5-L ports.

2.1.2. Movable rod

By inserting an insulator on the top of the movable rod, one can electrically bias the samples. The central part of the rod (tube) is rotatable on the axis of the rod, which can be used as mask for controlling exposed areas of the samples and so on (see Figure 3). The rotation angle is controlled with a pulse motor mounted at the bottom of the lower vacuum chamber. The length of the vertical movement and the rotation angle of the tube are controlled by a personal computer in the control room via optical fibers, a media convertor, and a four port RS-232 serial device servers (NPort 5410). Two power supply cables (φ1.7mm×2), eight general-purpose cables (φ0.5mm×8), and eight thermocouples (K-type, φ1.6mm×8) are mounted at the top of the rod for experimental use. Two cooling pipes pass through the inside of the rod in order to cool down the top of the component.

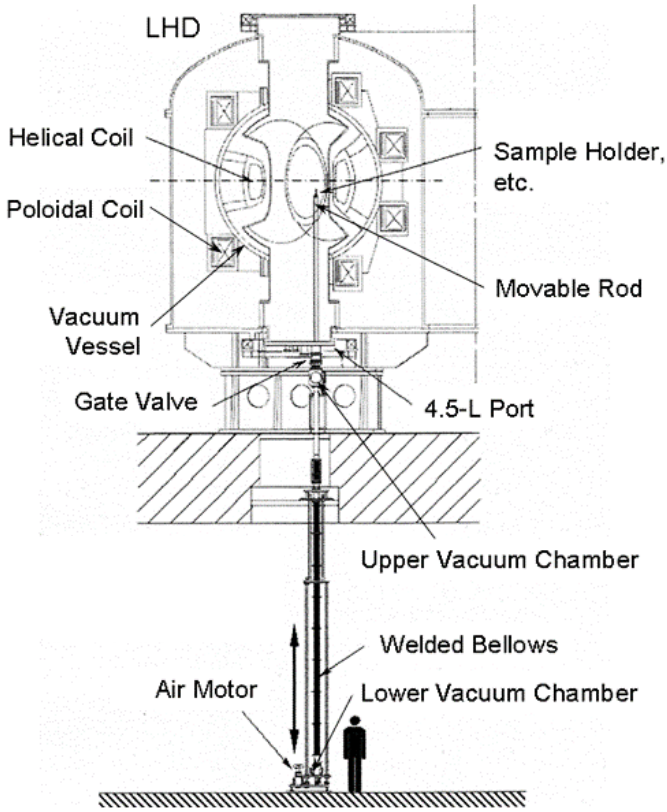

Fig. 2. Side view of the configuration of the movable sample holder installed in 4.5-L port.

2.1.3. Upper vacuum chamber

The samples mounted on the top of the rod can be replaced by opening flanges (ICF305) in the upper vacuum chamber. At the replacement of the samples, a specially designed flange and manipulator are mounted on the flange, which enable to check the residual tritium and to replace the samples quickly. The samples mounted on the top of the rod can be seen through a view port on the upper chamber. A cyopump (the pumping speed is 500l/s) is connected to the chamber via a remotely controlled gate valve. A turbo molecular pump (the pumping speed is 350l/s) is also connected in the chamber via a gate valve.

2.1.4. Lower vacuum chamber

The lower vacuum chamber is vertically moved by the driving gear with the air motor. The electrodes for the power supply and the cables are mounted at the side of the chamber. At the initial vacuum pumping phase, a turbo-molecular pump (the pumping speed is 550l/s) with a flexible tube has to be connected to the chamber for efficient residual gas pumping.

2.1.5. Driving gear (air motor)

The driving gear is drove by an air motor which is controlled by a control unit in the remote control system installed on the middle stage in the basement hall.

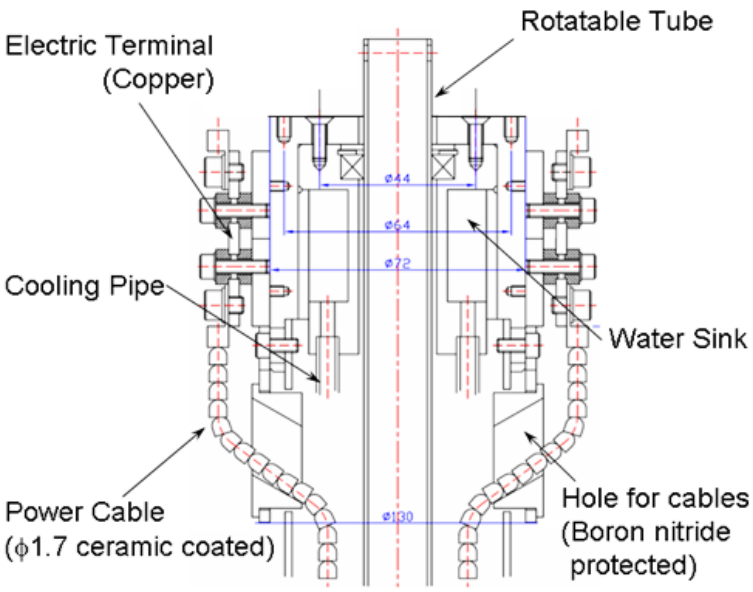

Fig. 3. Side view of the configuration of the top of the movable rod installed in 4.5-L port.

2.2. Movable sample holder (10.5-L)

2.2.1 Overview

The movable sample holder installed in a lower port (10.5-L) can also insert the samples into the LHD vacuum vessel to near the equatorial plane. The structure of this device is almost as same as that in the sample holder (4.5-L) (see Figure 4). Four network cameras monitor the device for the safe operation. The movable rod inserted in the vacuum vessel is routinely monitored with a plasma monitor camera installed in an upper port (10.5-U). It should be noted that a lower/outer divertor leg plasma intersects the side of the movable rod, which can damage the rod in plasma discharge operation. It is recommended that this device is used for exposing the samples to the divertor plasma or at the position of the vacuum vessel surface except for low power plasma discharge operation.

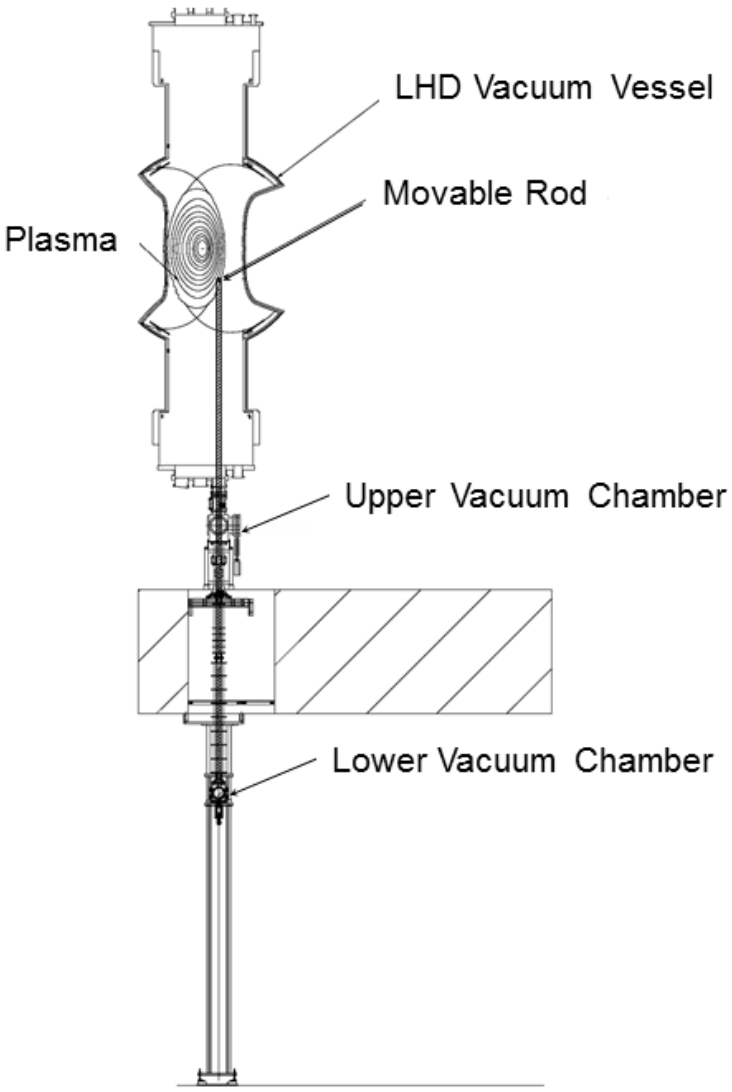

Fig. 4. Side view of the configuration of the movable sample holder installed in 10.5-L port.

2.2.2. Movable rod

The structure of the top of the movable rod is illustrated in Figure 5. In the same as that in the sample holder (4.5-L), the central part of the rod (tube) is rotatable. The rotation angle is controlled with a pulse motor mounted at the bottom of the lower vacuum chamber. The length of the vertical movement and the rotation angle of the tube are controlled by a personal computer in the control room via optical fibers, a media convertor. Two power supply cables, ten general-purpose cables, and six thermocouples are mounted at the top of the rod. Two cooling pipes pass through the inside of the rod in order to cool down the top of this component.

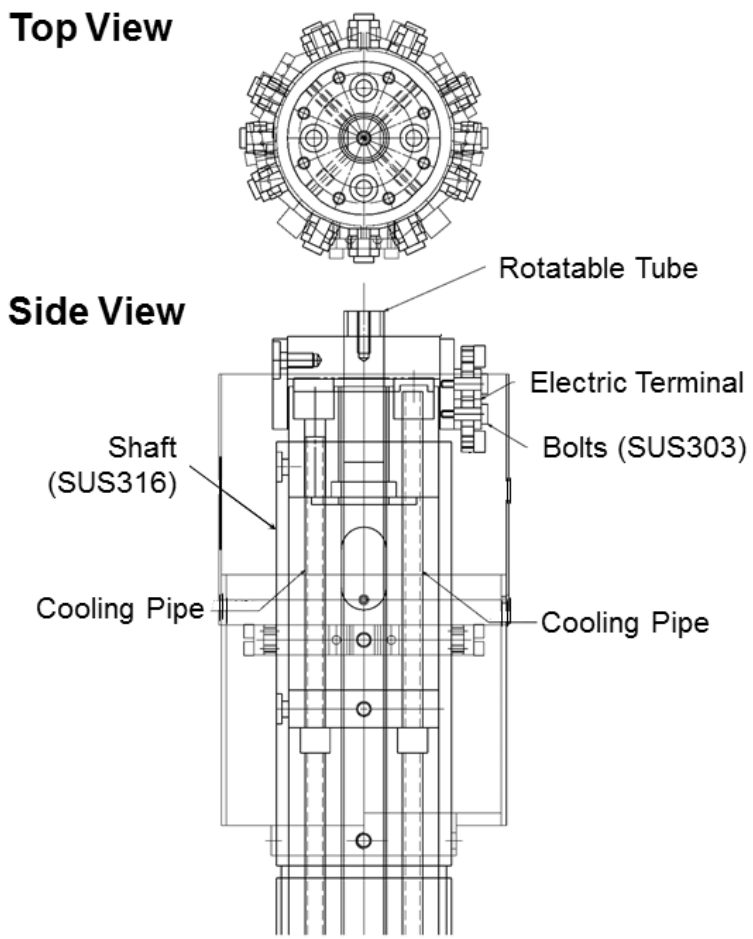

Fig. 5. Top view and side view of the configuration of the top of the movable rod installed in 10.5-L port.

2.2.3. Upper vacuum chamber

The samples mounted on the top of the rod can be quickly replaced by a specially designed flange and manipulator. A cyopump (the pumping speed is 800l/s) is connected to the chamber via a remotely controlled gate valve. A turbo molecular pump (the pumping speed is 300l/s) is also connected in the chamber via a gate valve.

2.2.4. Lower vacuum chamber

The lower vacuum chamber is vertically moved by the driving gear with the air motor which is same as that used in the sample holder (4.5-L). The electrodes for the power supply and the cables are mounted at the side of the vacuum chamber.

2.2.5. Driving gear (air motor)

The driving gear is drove by an air motor which is controlled by a control unit in the remote control system installed on the middle stage in the LHD basement hall.

3. Specification

- The precision of the vertical movement of the rod is ±1mm.
- The precision of the rotation angle of the tube at the top of the rod is about 0.1° (4.5-L) and 0.01° (10.5-L), respectively.

- The rotation speed of the tube at the top of the rod is about 18°/sec.
- The speed of the vertical movement of the rod is about 150mm/min.
- After venting to the air, it takes about one day to evacuate the chamber to 1.0×10^{-5}Pa which is necessary pressure to open the gate valve connecting the LHD vacuum vessel.

4. Remarks

In near future, infrared cameras will be installed in 4.5-U and 10.5-U ports for monitoring the temperature of the surface of the samples mounted at the top of the rod. In opening the flange on the chambers after exposure of the samples to the plasmas, residual tritium has to be measured in the chamber. Time for completely taking out the rod to the outside of the LHD vacuum vessel is about 25minutes (in the case where the position of the top of the rod is the equatorial plane). When the samples are exposed to plasmas at the vertical positon beyond the level of the vacuum vessel surface during the LHD plasma discharge operation, an approval of a special experimental proposal by the LHD experimental board is necessary.

References

[1] M. Tokitani, et al., Journal of Nuclear Materials 463 (2015) 91.
[2] M. Tokitani, et al., Nucl. Fusion 51 (2011) 102001.