§35. Camera Systems for Monitoring Deuterium Plasmas in LHD

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In the first campaign for starting deuterium plasma experiments in LHD from March in 2017, the plasmas will be monitored with six CCD cameras (Toshiba IK-CU44 and IK-C44H) by mounting optical zoom lenses at four outer ports and a tangential port (2-O, 4-O, 6-O, 10-O×2 and 6-T). In order to protect the cameras from high-energy neutrons released from deuterium plasmas, the CCD cameras are installed in the inside of specially designed 19-inch racks (600×750×1250mm) which are arranged on the middle stage at least 10 meters apart from the LHD center location for reducing the influence by the neutrons. Six radiation resistant bundled image fibers (Fujikura FIGR-30) are used for transmitting the plasma images to the cameras. The position of the 19-inch racks, optical lenses and the laying routes of the image fibers are described in Figure 1. Analog video signals (NTSC) from the cameras are converted to optical signals by media convertors, which are transferred to the control room via common optical fibers. The video signals are captured by an existing Video On Demand (VOD) system and stored to RAID disks.[1)]

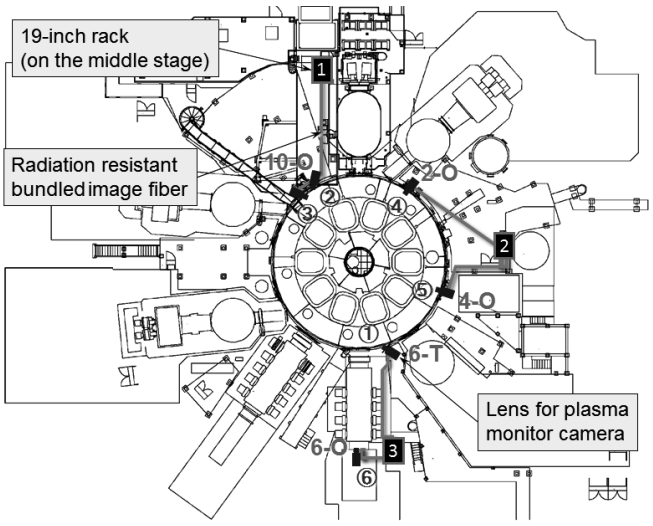

Fig. 1. The top view of the arrangement of the 19-inch rack and optical lenses for six camera systems for monitoring deuterium plasmas in LHD.

The specially designed 19-inch racks consist of a shield box and a polyethylene cover surrounding the shield box as indicated in Figure 2. The shield box (260×215×320mm) is made of lead plates (~15mm in thickness) for protecting the cameras, the media convertors and communication devices from gamma rays induced by neutrons. Four slit holes are opened on the bottom plate for an air intake for cooling down the internal devices. A bended slit hole is opened on the top plate for the outtake of the air and bringing some electric cables, optical fibers and bundled image fibers into the shield box. The curvature of the bended slit hole is set by the allowable minimum bend radius of the image fibers (R=400mm). In an area in the interior of the shield box where can seen from the outside of the box through the hole, relay lenses for connecting the terminal of the image fibers to the inlet of the cameras are mounted. Though the lenses are directly exposed to the gamma rays from outside of the box, it will not be a problem for the camera systems because the lenses mainly consist of quarts and aluminum having strong tolerance to the radiation. Up to four CCD cameras can be installed in the inner part of the shield box where is not directly seen from the outside through the hole. The top plates can be separated into two parts at the bended slit hole, which is for the easy maintenance and the change of the internal devices.

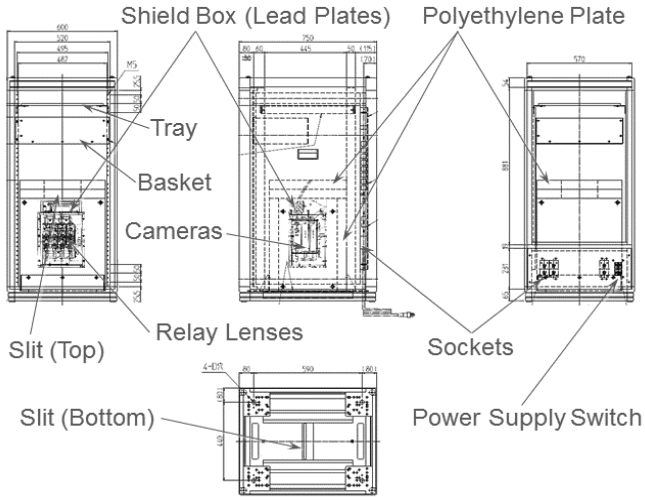

Fig. 2. A drawing of the specially designed 19-inch racks for protecting the camera systems from high-energy neutrons by deuterium plasmas.

The shield box is covered with polyethylene plates (10% boron is blended, 100mm in thickness) which is for reducing the intensity of the high energy neutrons by converting it to gamma rays by interaction with protons in polyethylene plates. Two inclined slit holes are opened in the bottom and top of the polyethylene plates for air ventilation and bringing the cables and the image fibers into the shield box, etc. The inclined slit holes are composed of two polyethylene plates with the slits which angle of inclination is a little bit different from each other. It is for preventing the neutrons from directly reaching the shield box from outside of the polyethylene cover. The top plates of the polyethylene plates can be also separated into two parts at the slit hole for easy maintenance and change of the internal devices in the shield box.

In the upper half part of the 19-inch rack, a cable tray and a basket are equipped for keeping the spare length of the cables and the image fibers, etc. Some AC/DC adaptors and accessories for internal devices are put in the basket, which is for saving the limited space and minimizing heat sources inside of the shield box.

1) Shoji, M. et al.: J. Plasma Fusion Res. SERIES **3** (2000) 440.