Background and Objectives

- The main function of the Impurity Influx Monitor (divertor) is to measure the parameters of impurities and isotopes of hydrogen (tritium, deuterium and hydrogen) in the divertor plasmas using spectroscopic techniques in the wavelength range of 200 - 1000 nm.
- The Japanese Home Team (Japan Participant Team) had designed the Impurity Influx Monitor (divertor) during the EDA and CDA phases.
- Because the machine size of ITER was reduced after EDA phase, interfaces between ITER and the monitor changed. In order to install in the present ITER, changes in the design of the monitor are required.
- Optical design of this monitor and mechanical design of front end optics are carried out to realize the measurement in the harsh environment for diagnostic components such as high magnetic field, high vacuum condition and high radiation field.

ITER Environment
- Neutron Flux : 1015 m-2s-1
- Neutron Shielding Power Density: 0.2 ~ 2.7 MW/m3
- Base Pressure <10^-5 Pa
- Magnetic Field: 3~5 T
- Temperature: Operating Temp: 100°C (in Vessel Components) 20°C (in Vacuum Vessel) Baking Temp: 200°C (Vacuum Vessel) 240°C (in Vessel Components)
- Vacuum: Leak Rate < 5.0×10^-9 Pa m3/s
- Radiation Field: 20~40 mSv/hr
- Spatial Resolution of Central Optics in Divertor: 7.35 mm
- Spatial Resolution of Other Port: 35 mm

Design Process
- Optical Design for Each Viewing Fan
- Mechanical Design of Front End Optics
- Heat Analysis for Nuclear Heating
- EM Analysis for Plasma Disruption
- Nuclear Analysis for Shielding

Results of analysis is feedback to the mechanical design and/or the optical design.

Optical Design
- Ray trace analysis of each viewing fan has been carried out by using optical design code Code Y and ZEMAX.
- Micro lens array is placed on the imaginary plane of Cassegrain telescope (before fiber bundle).
- The optics designed here will meet the ITER requirement for spatial resolutions (< 50 mm).

Mechanical Design of Front End Optics of Upper Port
- Five mirrors are necessary to avoid the interaction with other diagnostic equipments such as radial neutron camera, MSE and IR TV.
- Three mirrors are made of stainless steel 316 and mirror holders are made of copper alloy.
- Each mirror module has many cooling channels to remove the heat load by the nuclear heating.
- The neutron shield is not considered in the present design to install in the narrow space.
- The micro lens array is made of silica.
- The micro lens array is piled up many micro lenses, which is thin spherical lens with height of 0.25 mm, thickness of 7.35 mm and effective width of 2 mm.

Development of Impurity Influx Monitor (Divertor) for ITER
H. Ogawa, T. Sugie¹, S. Kasai, A. Katsunuma², H. Harada and Y. Kusama
JAEA, ITER-JT, Nikon Co., Toyama Co., LTD.
Heat Analysis

- **Analysis Code**: ANSYS Design Space Ver.9.0 (Steady State Analysis), Ignore Radiation and a Slit on the Boundary of Each Component

  **Assumptions**
  
  - Nucleating Heating: Constant for Different Materials
  - Initial Temperature: 150°C
  - Cooling Water Pressure/Flow Rate: 4MPa Constant
  - Cooling Water Temperature: 10°C Constant

- **Materials**
  
  - M1 (Plasma Facing Mirror): Mo
  - M2~M5: Al alloy
  - Mirror Holder: SS 316/Cu Alloy

- **Model C-1**
  
  - Mirror Holder: SS 316/Cu Alloy (Young's module of copper decreased as increasing temperature up to 200°C)
  - Mount Module: SS 316
  - M1 Mirror: Mo
  - M2~M5 Mirrors: Al alloy

- **Model C-2**
  
  - Mirror Holder: SS 316
  - Mount Module: SS 316
  - M1 Mirror: Mo
  - M2~M5 Mirrors: Al alloy

- **Model C-3**
  
  - Mirror Holder: SS 316
  - Mount Module: SS 316
  - M1 Mirror: Mo
  - M2~M5 Mirrors: Al alloy

Temperature Profile on the Mirror and Mount Module in Upper Port

- **Model A**
  
  - M3: 150°C (Flat)
  - M2, M4, M5: 220°C
  - M1: 232°C

- **Model B**
  
  - M3: 150°C (Flat)
  - M2, M4, M5: 224°C
  - M1: 244°C

- **Model C**
  
  - M3: 150°C (Flat)
  - M2, M4, M5: 226°C
  - M1: 246°C

Heat Analysis – Effect on the Optical Properties

- In order to estimate the effect of the heat distortion to the optical property, ray trace calculation is carried out by using ZEMAX code. In this calculation, it is assumed that the thermal deformation of mirror surface changes the tilt angle of each mirrors and thermal deformation of the mount module changes the angle of the light to the vacuum window.

Summary

1. Ray trace analysis for each viewing fan indicates that the optics designed here will meet the ITER requirement for spatial resolutions (< 50 μm).
2. The mechanical design of front end optics in the upper and equatorial port is carried out based on the optical design mentioned above.
3. The heat analysis indicates that it is possible for mirrors to be cooled by the thermal conduction using the mirror holders made of a copper alloy and making many cooling channels on the mount module.
4. The effect of thermal deformation to the optical properties is also calculated by using the optical design code ZEMAX. In the optics on the upper port, it is small. But in the equatorial port, the measured position near the divertor region is displaced about 150 mm by the thermal deformation.
5. In the point of view of the cooling, the monolithic structure such as the front end optics of the upper port is favorable.

Future Plan

1. Design of mount module and mirror holder in the divertor port
2. Designs of the interface between a mount module and a pipe and/or a port plug (mounting method, route and connection of cooling water, etc.)
3. Design of the remote mirror adjustment system including the actuator and the driving method
4. Design of the actuator for shutter
5. Electro-Magnetic analysis to protect the front end optics during disruption
6. Neutron analysis to determine the thickness of the neutron shield after the front end optics.