UCRL-TR-224891

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September 2006 Monthly Report-ITER Visible/IRTV Optical Design Scoping Study

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October 1, 2006

This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

To: David W. Johnson
From: C.J. Lasnier, Lawrence Livermore National Laboratory
RE: September 2006 monthly report- ITER visible/IRTV optical design scoping study

LLNL received a request from the US ITER organization to perform a scoping study of optical design for visible/IR camera systems for the 6 upper ports of ITER. A contract was put in place and the LLNL account number was opened July 19, 2006. A kickoff meeting was held at LLNL July 26. The principal work under the contract is being performed by Lynn Seppala (optical designer), Kevin Morris (mechanical designer), Max Fenstermacher (visible cameras), Mathias Groth (assisting with visible cameras), and Charles Lasnier (IR cameras and Principal Investigator), all LLNL employees.

Kevin Morris has imported ITER CAD files and developed a simplified 3D view of the ITER tokamak with upper ports, which he used to determine the optimum viewing angle from an upper port to see the outer target. He also determined the minimum angular field of view needed to see the largest possible coverage of the outer target.

We examined the CEA-Cadarache report on their optical design for ITER visible/IRTV equatorial ports. We found that the resolution was diffraction-limited by the 5-mm aperture through the tile. Lynn Seppala developed a similar front-end design for an upper port but with a larger 6-inch-diameter beam. This allows the beam to pass through the port plug and port interspace without further focusing optics until outside the bioshield. This simplifies the design as well as eliminating a requirement for complex relay lenses in the port interspace. The focusing optics are all mirrors, which allows the system to handle light from 0.4 μm to 5 μm wavelength without chromatic aberration.

The window material chosen is sapphire, as in the CEA design. Sapphire has good transmission in the desired wavelengths up to 4.8 μm, as well as good mechanical strength. We have verified that sapphire windows of the needed size are commercially available.

The diffraction-limited resolution permitted by the 5 mm aperture falls short of the ITER specification value but is well-matched to the resolution of current detectors. A large increase in resolution would require a similar increase in the linear pixel count on a detector. However, we cannot increase the aperture much without affecting the image quality. Lynn Seppala is writing a memo detailing the resolution trade-offs.

Charles Lasnier is calculating the radiated power, which will fall on the detector in order to estimate signal-to-noise ratio and maximum frame rate. The signal will be reduced by the fact that the outer target plates are tungsten, which radiates less than carbon at the same temperature. The tungsten will also reflect radiation from the carbon tiles private flux dome, which will radiate efficiently although at a lower temperature than the target plates. The analysis will include estimates of these effects.

Max Fenstermacher is investigating the intensity of line emission that will be emitted in the visible band, in order to predict signal-to-noise ratio and maximum frame rate for the visible camera. Andre Kukushkin has modeling results that will give local emission of deuterium and carbon lines. Line integrals of the emission must be done to produce the emitted intensity. The model is not able to handle tungsten and beryllium so we will only be able to estimate deuterium and carbon emission.

Total costs as of September 30, 2006 are $87,834.43. Manpower was 0.58 FTE's in August, 1.48 in August, and 1.56 in September.