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A Caltech Submillimeter Observatory Active Optics System

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Abstract. Active surface correction of the Caltech Submillimeter Observatory (CSO) primary mirror has been accomplished. The Dish Surface Optimization System (DSOS) has been designed and built to operate at the CSO, on Mauna Kea, Hawaii. The DSOS is the only active optics system of its kind in the world. There are 99 steel rod standoffs that interface the dish panels to the telescope backing structure. Each standoff is now fitted with a heating/cooling assembly. Applying a controlled potential to each of the 99 assemblies adjusts the surface of the dish. Heating elongates and cooling shortens the standoffs, providing the push or pull on the primary's panel surface. The needed correction for each standoff, for a given elevation, is determined from prior holography measurements of the dish surface. Without the DSOS the optimum surface accuracy was 25 μm RMS, yielding a beam efficiency of 33% at the 350 μm wavelength range. With the DSOS, this has been improved to 10 μm RMS. The best beam efficiency obtained is 56%, with an average beam efficiency of 53%. The DSOS has been in operation on the CSO since February 2003. Observers using SHARC-II (Dowell et al. 2003; a 384 pixel submillimeter high angular resolution camera) and the 850 GHz heterodyne receiver, have been able to detect new weak and/or distant objects with the help of this unique active optics system.

1 DSOS Performance

The DSOS had 92 out of 99 operating channels in May 2004. Figure 1 displays improvements in the SHARC-II maps. These are images of Ganymede, one of Jupiter's moons. The FWHM improved 18% from 10.4 arcsec to 8.8 arcsec. Peak signal power increased 50% from 64.6 Jy/beam to 129 Jy/beam. The zenith angle range is from 11 to 15 degrees.

Woody et al. (1998) derived the RMS surface of the CSO and predicted that the best RMS value that can be obtained, considering the primary mirror's small-scale surface errors, is slightly more than 10 μm at a zenith angle of 20 degrees. The April 2005 holography run was performed with a correction table compiled with the addition of recent holography data. All 99 channels were operating. Figure 2 compares holography maps taken in September 2002, DSOS off, to those taken in April 2005, DSOS on, at similar elevations. The contour level is 10 μm/line. One can clearly see that the deformations were reduced significantly. With the DSOS on, an average of 10 μm RMS over a zenith angle

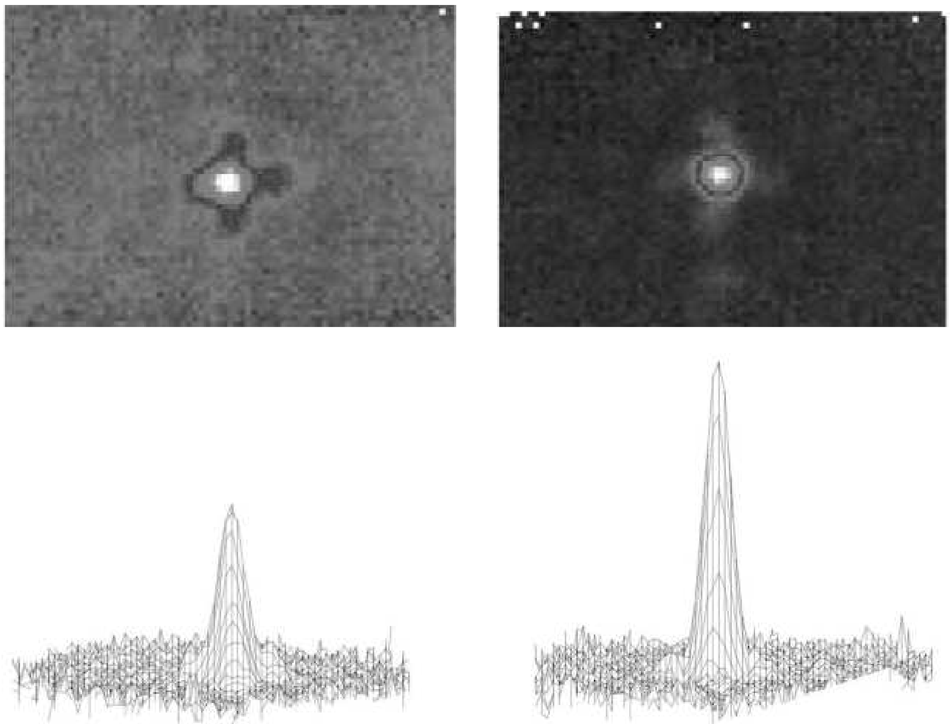

Figure 1. SHARC-II Images of Ganymede. Power and 3-D Maps with DSOS Off (left) then DSOS On (right).

range of 22 to 63 degrees was achieved. This, in the least, meets the best surface value predicted.

From these holography results, verification in the 350 μm wavelength range was warranted. The 850 GHz Heterodyne Receiver was used to measure the improvements in efficiency. The best percent improvement was as high as 71% with an average of 60% improvement. Figure 3 shows the percent improvements of the two corrections tables.

All these measurements were taken with the instruments located on the CSO's cassegrain platform mount. In recent years, there has been an increase in available instruments, resulting in a larger number of mounting locations. A second Nasmyth position (N2) to the right of the telescope was made available to accommodate for two more instruments. The results meant that SHARC-II and the 850 GHz receiver were to be mounted on this new platform. With a new optical path, the performance improvement from the DSOS was lessened. Presently the reasons are unknown. A possible explanation is that the optics to the Cassegrain platform are well measured and characterized. The second Nasmyth optical path, being newer, needs time to become well measured and characterized. There is still appreciable improvement seen by SHARC-II, however, the full benefits on N2 have not been materialized yet.

In February 2006, steps have started optimizing the DSOS correction tables to accommodate the new optical path. Early results indicate a straightforward revision. This needs to be verified with further engineering runs. Figure 4 shows

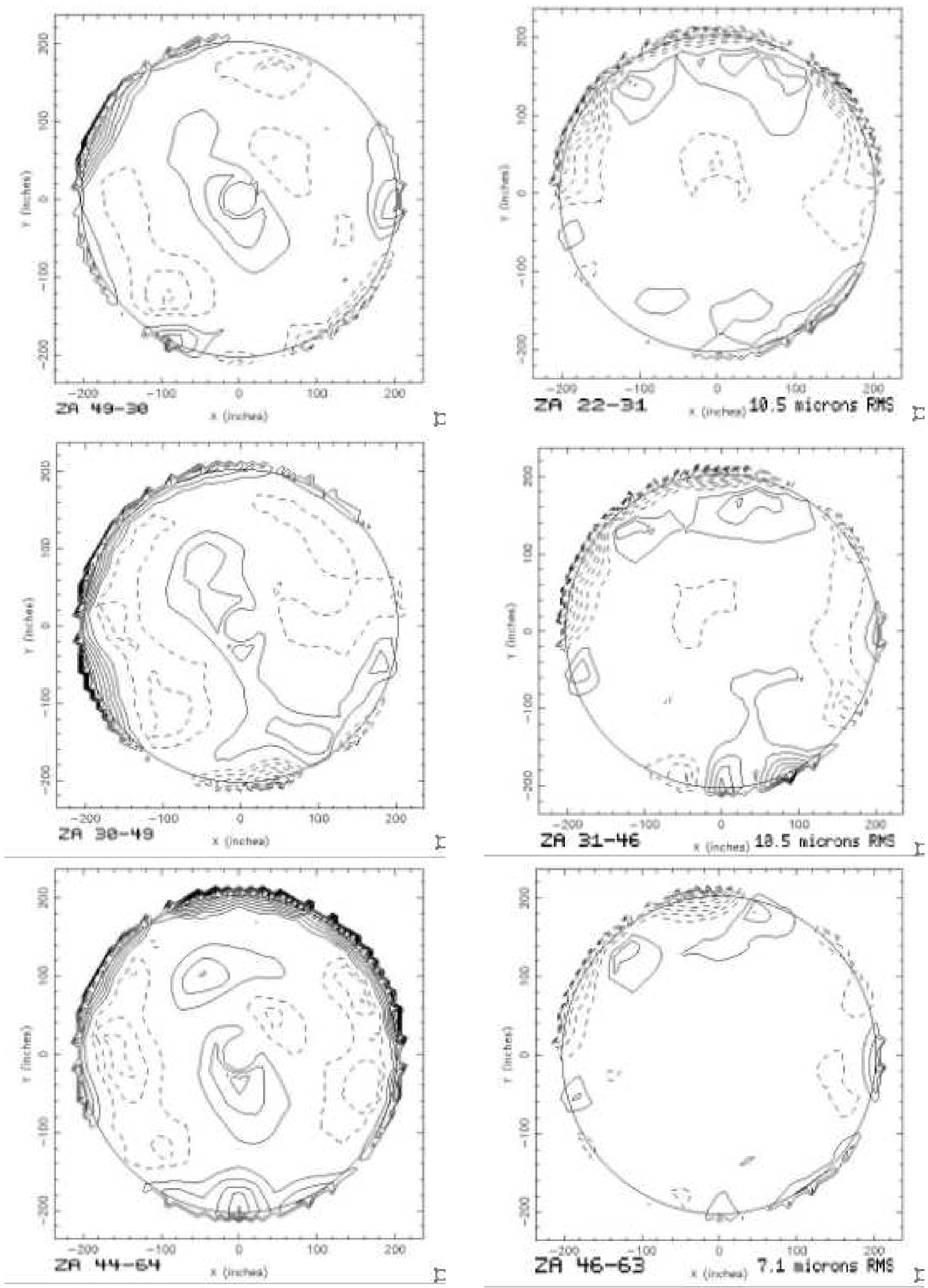

Figure 2. Improvements in holography maps. September 2002 (left) vs. April 2005 (right) at similar elevations.

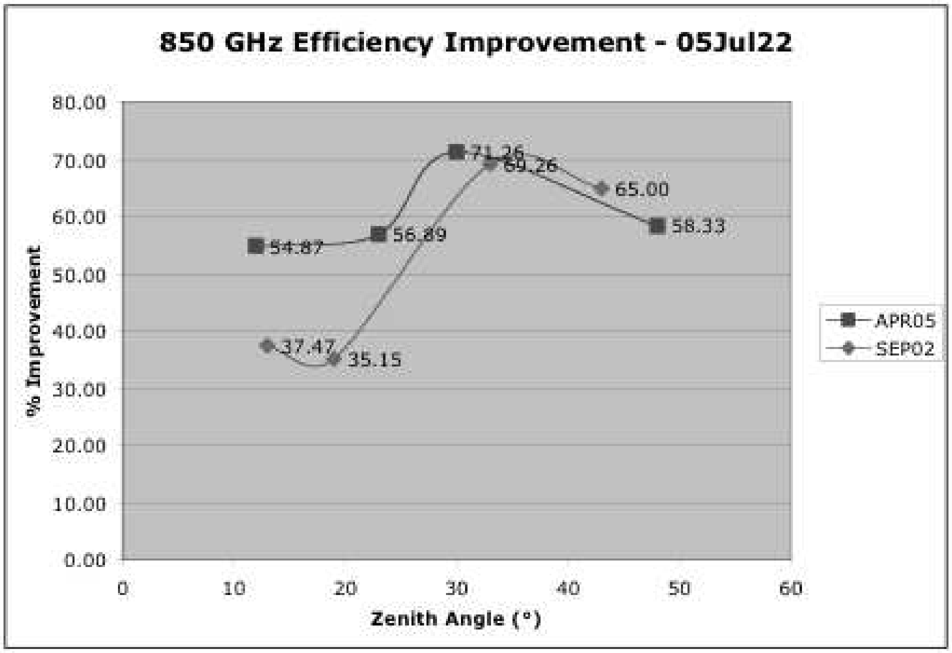

Figure 3. Percent improvement in efficiency. Original zenith-angle lookup table vs. updated zenith-angle lookup table.

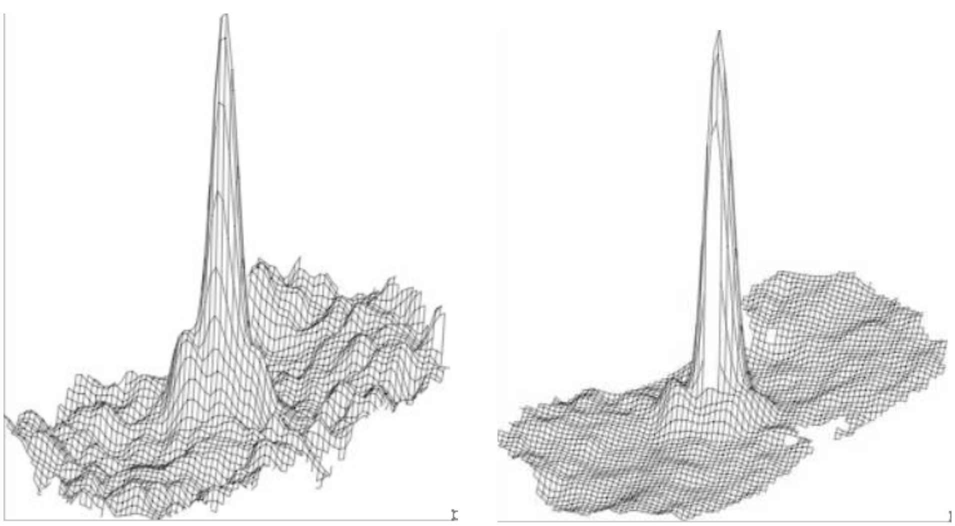

Figure 4. Preliminary N2 optimization results. DSOS On (left) then DSOS On with enhanced channels (right).

a visible improvement in the signal received from Ganymede, seen by SHARC-II with the DSOS on, then with several DSOS channels enhanced.

2 Summary

The DSOS has proved to provide worthwhile improvement in the performance of the CSO. It is a unique active optics system for a unique telescope. The DSOS has resulted in significant improvements in signal power and beam shape in the 350 μm wavelength range. It has been in use for scientific observations since February 2003. With the help of the DSOS, the SHARC-II Bolometer Camera and the 850 GHz Heterodyne Receiver are able to detect new weak and/or distant galaxies at the CSO.

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