Advancements in Satellite-Ground Laser Time Transfer at the Shanghai Astronomical Observatory

zhibowu

The laser time transfer technique provides critical insights into time and frequency metrology as well as space geodesy, supporting the calibration and validation of microwave systems, the analysis of clock behavior, and clock comparisons across remote observatories. The Shanghai Astronomical Observatory first achieved laser time transfer between Beidou satellites and ground stations in 2007, reaching a measurement precision of 300 ps and stability better than 20 ps over 500 seconds.

Following over a decade of technological advancements, including significant improvements in the performance of single-photon detectors, event timers, and laser retroreflector arrays, a new generation of laser time transfer payload (CLT) was launched aboard the Chinese space station in 2022. The CLT payload measures 230 × 190 × 169 mm, weighs 6 kg, and consumes approximately 24 W, with power fluctuations depending on the operational mode. Ground-based laboratory tests have demonstrated that the CLT payload achieves a timing precision of 23 ps, with an instability of less than 0.5 ps over 24 hours and 0.09 ps over 300 seconds.

Ranging experiments using the CLT laser retroreflector array have been conducted by satellite laser ranging systems in Shanghai, Xi'an, and Beijing. Furthermore, dedicated CLT ground stations in Xi'an and Beijing carried out satellite-based laser time transfer measurements. The results indicate that the ranging precision at the Xi'an and Beijing ground stations is approximately 4 mm, while the clock bias measurement precision is around 22 ps, with a measurement stability of about 0.2 ps over 20 seconds.

In 2024, we plan to extend satellite-ground laser time transfer to Earth-Moon space, with relevant payload tests currently progressing in stages. The Shanghai Astronomical Observatory has successfully conducted laser time transfer in high orbit, low orbit, and Earth-Moon space, with future efforts focusing on deep space applications and further enhancements in performance