Summary of development a telescope for ILOM (In-situ Lunar Orientation Measurements) and results of experiments, and future prospects

*Hideo Hanada[1,2], Seiitsu Tsuruta[1], Kazuyoshi Asari[1], Hiroshi Araki[1,2], Hirotomo Noda[1,2], Shingo Kashima[1,4], Ken-ichi Funazaki[3], Atsushi Sato[3], Hideo Taniguchi[3], Hiromasa Kato[3], Mamoru Kikuchi[3], Hirokazu Sasaki[3], Tomoyasu Hasegawa[3], Taihei Yano[4], Naoteru Goda[4], Yukiyasu Kobayashi[4], Yoshiyuki Yamada[5], Takahiro Iwata[6]

1. RISE Project, National Astronomical Observatory, 2. Department of Astronomical Science, SOKENDAI , 3. Graduate School of Engineering, Iwate University, 4. JASMINE Project, National Astronomical Observatory, 5. Graduate School of Science, Kyoto University, 6. Institute of Space and Astronautical Science, JAXA

There are possibly information suggesting a liquid core or a partial melting zone in lunar rotational fluctuations, and we can get them if observe the lunar rotation with an accuracy of better than 1 milli-arc second. We developed a small telescope like Photographic Zenith Tube (PZT) for observations of lunar rotation and made some experiments in a laboratory and outside using a Bread Board Model (BBM) in order to check the total system of the telescope and the software.

In the laboratory experiments, which were made in August of 2014, 4 star images were recorded on a video camera at the rate of 30 frames/s. We found that the long periodic variations of centroid position of 4 stars in the field of view are similar, and the amplitude of the variations is reduced by subtracting the mean variation from each record, and only the random noises are remaining, which is regarded as the accuracy of centroid estimation. This suggests that the effects of vibrations are almost common to all the stars in the field of view. The variations have strong peaks in the frequency bands of 0 to 0.5 Hz and 5 to 6 Hz, which are confirmed to be stemming from vibration of the mercury surface. We can almost completely remove the effects of vibrations by subtracting the mean variation from each data.

The field observations, which were made in September of 2014 at Mizusawa VLBI Observatory of NAOJ, detected 6 stars of magnitude of 7 to 8, and they were recorded on a special CCD camera every 2s. The centroid position varies more largely than the case of the laboratory experiments. There were seen also common variations although it is not obvious. The scatter of the variation is reduced by subtracting the mean variation from each record, but it does not become as small as the case of the laboratory experiments
.
We calculated SNR in order to know the reason why the variation of centroid position in the field observations is larger than that of laboratory experiments. The SNR is here defined as the ratio of the maximum brightness of a star image to standard deviation (SD) of dispersion of brightness in the background around the star image. The SD of variation in measured centroid position is inversely proportional to SNR as shown in the Figure. The results of centroid experiments by JASMINE (Apr. 1, 2015) as well as those of the laboratory and field experiments are shown here. We can say that the less centroid accuracy in the field observations is due to lower SNR.

In summary,
1) The experiments show that 1 mas accuracy is possible if SNR is high enough (~1000).
2) Accuracy of several arc-seconds was attained in the field observations.

3) The difference can be explained mainly by the difference in SNR of stellar images.
4) The variations of centroid position of stellar images are mainly stemming from the vibration of mercury surface, and they are almost common to stars in the same view.

And for the future,
5) To develop a small sized instrument is also important in order to increase opportunities of boarding.
6) We started to investigate a new method to keep a tube in vertical direction.

Keywords: Lunar rotation, Small telescope, PZT, centroid