# PhoSim (Photon Simulator) Reliability Test for Confocal Off-Axis System

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**Comprehensive optical simulation is important for avoiding risks when running the system for high accuracy observations. Photon simulator (PhoSim), which was developed for Large Synoptic Survey Telescope, considers not only the ray tracing based optical effects but also the physics that affect the image quality, such as electrostatic movements of the electrons converted from the photons in detector. However, the reliability of PhoSim for the confocal off-axis system application has not been confirmed. We simulate an on-axis and a confocal off-axis Cassegrain telescope with an identical aperture size and focal length. We confirm how well the PhoSim applies the confocal off-axis optical configuration. Also, we present the diffraction analysis results of the on-axis Cassegrain design using point spread function simulation.**

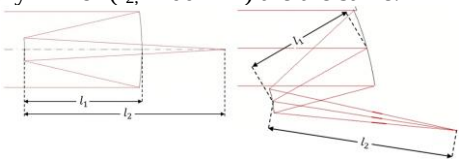
## I. Introduction

Photon Simulator (PhoSim) was developed for the Large Synoptic Survey Telescope, which is specialized for realistic optical simulation as it considers physical effects in atmosphere, detector, and so on [(1)(2)]. Such realistic simulations can be a powerful tool to model and predict high accuracy astronomical observations of low surface brightness objects [(3)]. One of PhoSim simulations, which returns an expected image based on input image and a given optical system, can be utilized for an imaging system whose resolution over the entire field matters, such as optical system of unmanned aerial vehicles.

The obscuration from a secondary mirror, which generates severe diffraction effects at the focal plane, is one of the primary issues of high accuracy observations. Off-axis optical systems solve the obscuration issues, but linear astigmatism aberration, which only occurs in off-axis systems, degrades the overall optical performance. By letting the mirrors share their foci, the confocal off-axis configuration can eliminate the linear astigmatism [(4)]. Confocal off-axis designs have been widely used because of their superb optical performance over the large field of view [(5)(6)]. However, the confocal off-axis configuration has not yet been applied and confirmed with PhoSim.

## II. PhoSim Simulation Setup

For reliability test of the confocal off-axis system using PhoSim, we simulate and compare a confocal off-axis and an on-axis Cassegrain telescope with the same entrance pupil diameter (1000 mm) and effective focal length (8000 mm). The optical layouts of the Cassegrain telescopes are shown in Figure 1. The distance between the mirrors ($l_1$, 1400 mm) and the distance between the sensor and the secondary mirror ($l_2$, 2400 mm) are the same.




[Fig.1] Optical layouts of the on-axis (left) and the confocal off-axis (right) telescopes

Optical diffraction effect due to the obscuration of the secondary mirror in PhoSim is investigated through analyzing the outer region of the point spread function (PSF) in detail. PhoSim simulation results are compared to those from the previous work which analyzed the optical performance of the same optical systems using CODE V[(7)].

## III. Results and Discussions

The PSF to see the diffraction effect of PhoSim is simulated and cross-check with CODE V as reference. A line profile of the PSF in log scale is compared in order to check both the overall shape and fine details.

We are planning to utilize PhoSim for the future analysis and development of the three mirror confocal systems based on this Cassegrain confocal off-axis system case study result [(8)]. Especially, as the accurate and realistic PhoSim framework can model and predict high precision optical performance, it will play a critical role during the optical alignment process [(9)].

## References

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