2) C. J. Oh, et. al., “Alignment of 4-mirror Wide Field Corrector of the Hobby-Eberly Telescope”, Proc. SPIE, 8844, 884403 (2013) (College of Optical Sciences, University of Arizona)

In order to align the CGH optical axis with the optical axis of the mirror the set up in the Figure 3 was used. As shown in the Figure, the set up consists of a precision air-bearing, an interferometer and CGH to evaluate the wavefront of the optical surface and a point source microscope to monitor the CGH in the center reference fixture. The general procedure to register the CGH to the optical axis of the mirror is given below.

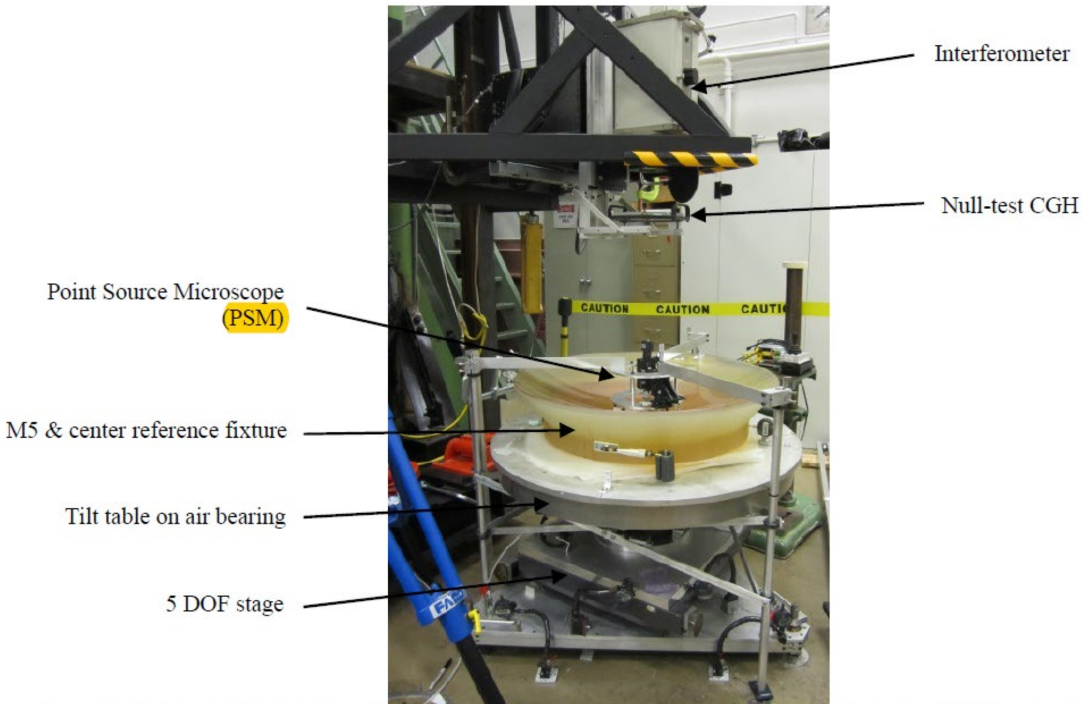

Figure 3. Center reference fixture alignment with the optical axis of M5 using null CGH test and PSM on a rotary air bearing.

3) H. Lee, et. al., "Delivery, Installation, On-sky Verification of the Hobby Eberly Telescope Wide Field Corrector", Proc. SPIE, 9906, 990646 (2016) (McDonald Observatory, University of Texas at Austin, Austin, TX)

Figure 9-(G) shows a CR with three ½-inch tooling balls on the SMR mounts being registered to the CR under the PSM mounted to a precision Coordinate Measuring Machine (CMM). The centers of the tooling balls should be very close to those of precision ½-inch SMRs. Once this registration is completed, it is possible to use a Laser Tracker (LT) in order to accurately locate the center of the CR in the 3-dimensional space and this facilitate the initial alignment of the mirrors within the capture ranges of the subsequent optical alignment instruments. Also possible is to determine the *z* location of the CR with respect to the vertex of the mirror surface.

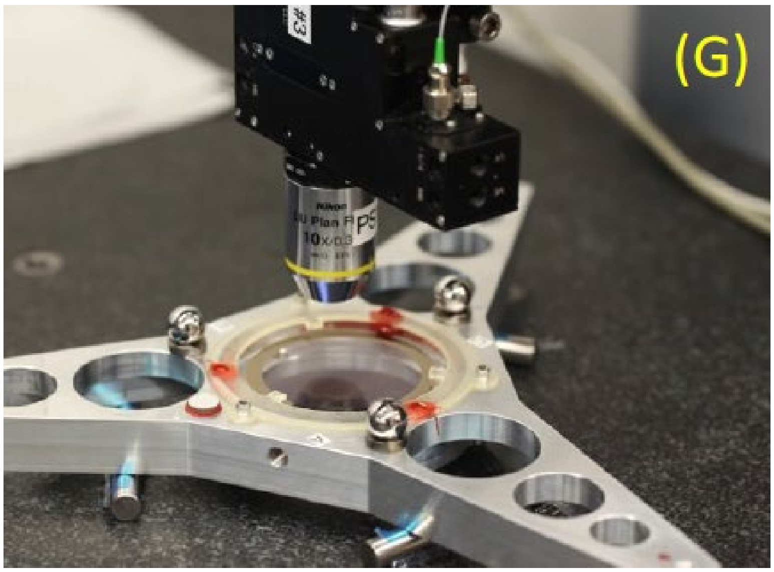

Figure 9 The Center reference to mirror registration procedures.

7) E. Winrow, et. al., “The Design and Build of a Zoom Telescope Utilizing Additive Manufacturing”, in *Optical Design and Fabrication 2019 (Freeform, OFT)*, OSA Technical Digest (Optica Publishing Group, 2019), paper OT3A.1 (Sandia National Laboratories, Albuquerque, NM)

The secondary mirror was aligned directly to the axis of an autocollimator on a precision linear stage using the reflected return of the mirror and a precision fiducial at the center of the mirror. In aligning the primary mirror, a double -pass system was used with the secondary and a 12” flat mirror. A point source microscope (PSM) projected a focused laser out through the nominal focus of the two -mirror system to the flat mirror and back [2]. The primary mirror was then positioned in six degrees of freedom to minimize the spot size and aberrations.

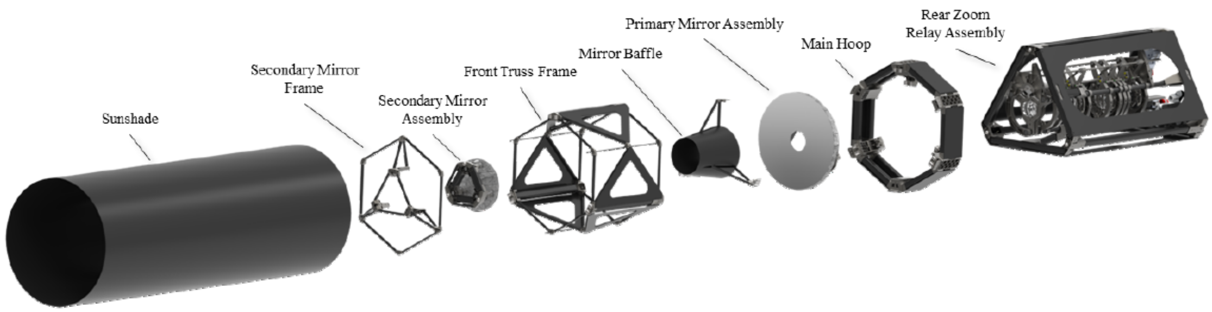

Figure 1. Telescope major subassemblies

25) J. Ashcraft, et. al., The Space Coronagraph Optical Bench (SCoOB): 1. Design and Assembly of a Vacuum-compatible Coronagraph Testbed for Spaceborne High-Contrast Imaging Technology, Proc. SPIE, 12180, 121805L (2022)

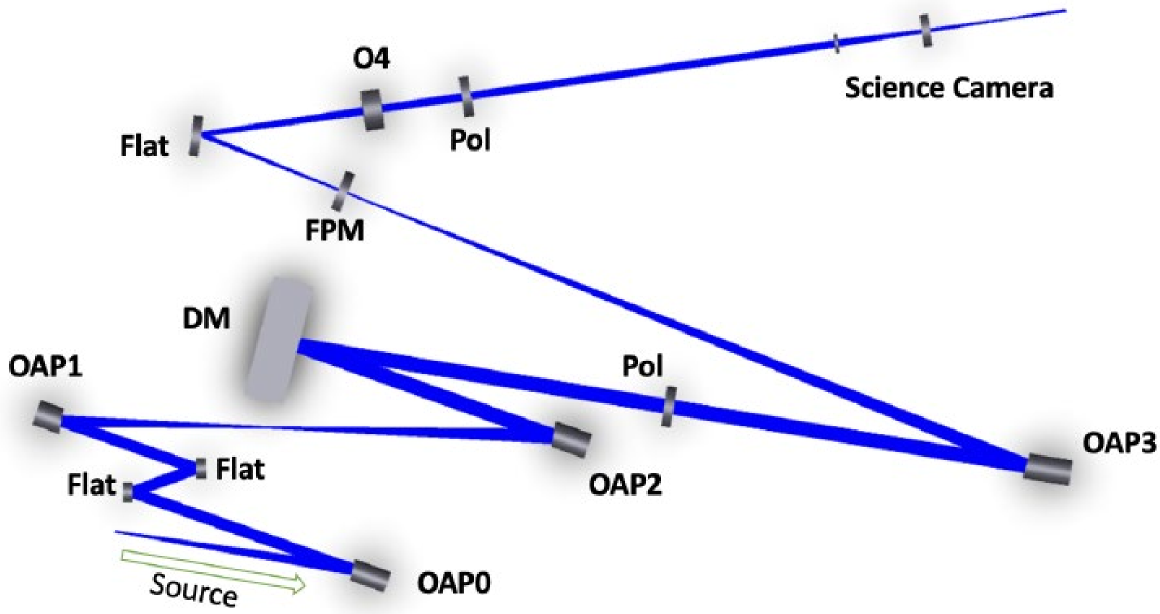

Figure 1. Raytrace model of SCoOB in Zemax OpticStudio. The optical path begins on the bottom left where a source simulator generates an isotropic point-source before OAP0. Light then propagates through the coronagraph into the science camera.

The optical path (shown in figure 1) begins with a source simulator. Most experiments were conducted using a point-source microscope to illuminate a small (15um diameter) pinhole at this location, but recently this was switched to a single-mode fiber tip with a sufficiently small mode field diameter ($< 5um$) to act as a point source.

48) A. Qichang, et. al., Alignment for sparse aperture telescope with serial robot arm, Infrared and Laser Engineering, 47(8) 2018

Abstract: In order to align large sparse aperture telescope, the application of screw theory for assembling by the serial robot arm was investigated. Firstly, the basic principle of the serial robot arm alignment for large sparse aperture telescope was analyzed by screw theory. Secondly, based on the screw theory and geometric relation, the principle of the sparse aperture telescope assembling was analyzed and the error analysis was carried out. After that, the feasibility of the installation of point source microscope(PSM) on serial robot arm was analyzed and tested. It was proved that PSM on robot arm was similar to the case in laboratory environment for image stability. In the end, the application of serial robot arm combined with PSM in the large sparse aperture telescope alignment was analyzed.

将 PSM 安装于机械臂之上，驱动机械臂，将 PSM 的焦点对准相同的靶球，将靶面上的光斑调节至最小后记录若干幅图像。通过统计靶面像点光斑大小的变化，可以评价机械臂的夹持是否满足实际工程试验中的稳定性要求。串联机械臂及 PSM 如 图所示。

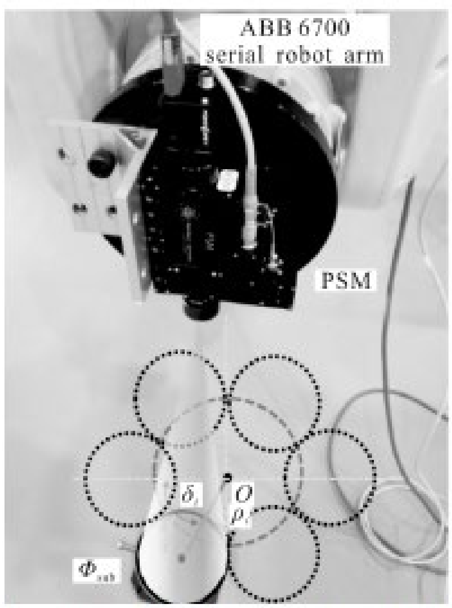

图 4 串联机械臂以及 PSM

Fig.4 Sketch of serial robot arm and PSM