

Development of VIRUS Alignment and Assembly Fixtures

Amanda D. Collins¹, Brian Vattiat², J. L. Marshall¹, Gary J. Hill², D. L. DePoy¹, Hanshin Lee²,
Richard D. Allen¹, Travis Prochaska¹, Steven Villanueva, Jr.¹

¹Department of Physics and Astronomy, Texas A&M University, 4242 TAMU, College Station, TX,
USA 77843-4242

²McDonald Observatory, University of Texas at Austin, 1 University Station, C1402, Austin, TX,
USA 78712-0259

ABSTRACT

The Visible Integral-Field Replicable Unit Spectrograph (VIRUS) Instrument is a set of 150+ optical spectrographs to support observations for the Hobby-Eberly Telescope Dark Energy Experiment (HETDEX). We plan to use a production line assembly process to construct the large number of VIRUS units. This allows each sub-assembly of a VIRUS unit to be interchangeable amongst all other VIRUS units. A production line manufacturing procedure will enable various sub-assemblies to be built and tested in parallel. Examples of alignment and assembly fixtures required for the VIRUS manufacturing process include a camera mirror alignment system, a collimator structure assembly device, a collimator mirror mounting tool, and a grating alignment system. In this paper we describe the design of these fixtures and their importance in the VIRUS assembly process.

Keywords: Telescopes: Hobby-Eberly, Astronomical instrumentation: Spectrographs—VIRUS, Spectrographs: Integral Field, Spectrographs: Assembly

1. INTRODUCTION

The VIRUS instrument is a set of at least 150 optical spectrographs that will support observations for the HETDEX¹ project. The HETDEX project² is aimed at looking for Dark Energy at high redshifts using the Hobby-Eberly (HET) telescope. As members of HETDEX, Texas A&M University is responsible for the manufacture, assembly, and testing of the 150+ VIRUS spectrographs.

This paper describes conceptual designs of the alignment fixtures that will be used to precisely and repeatably mount the optics in the instrument and assemble the structure of the instrument. These alignment fixtures are necessary to allow the 150+ unit spectrographs to be assembled in a timely fashion and in such a way as to maximize the throughput of the instrument and therefore produce the most science possible. The assembly procedure and plans for building the 150+ unit spectrographs are described elsewhere in these proceedings³.

1.1 Instrument Overview

The VIRUS instrument consists of between 150 and 192 simple fiber fed optical spectrographs. The unit spectrographs are assembled in pairs, and consist of a simple Schmidt spectrograph (referred to as the “collimator”) with an on-axis Schmidt vacuum camera. A volume phase holographic (VPH) grating provides a wavelength range of 350-550 nm. The detailed optical⁴ and mechanical⁵ designs of the instrument are described in more detail elsewhere in these proceedings. The VIRUS unit spectrographs will be mounted on the sides of the telescope structure; each spectrograph is fiber-fed from the focal plane of the HET. Figure 1 shows a drawing of a pair of VIRUS unit spectrographs.

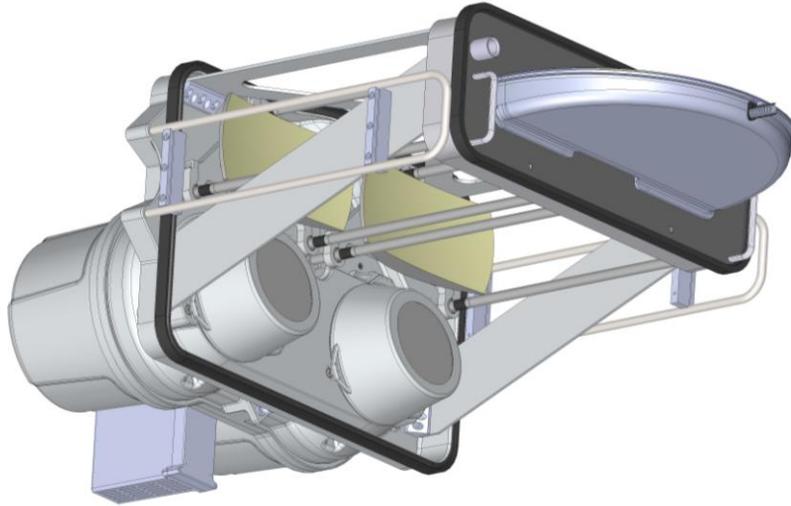


Figure 1: Drawing of a pair of VIRUS spectrographs. The cover for the fiber feed is shown on the top right. Light from the fibers enters the instrument and is collimated by the oblong spherical collimator mirrors (top center). The light is reflected by a folding flat located behind the fiber feed (not shown), and into the grating (lower center) which is mounted in front of the vacuum Schmidt cameras (lower left).

1.2 Optical Fixtures

The assembly process of the VIRUS unit spectrographs requires a precise alignment of certain mechanical and optical components. This precise alignment will be accomplished by mounting each optical component in its subassembly before incorporating it into the instrument. The main fixtures under development are used to accurately align optical components in their assemblies and include a grating alignment device, a camera mirror alignment tool, and a collimator mirror mounting device. This paper will describe the VIRUS assembly fixtures currently being designed and built in preparation for the assembly of the VIRUS spectrographs.

1.3 Instrument Assembly Fixture

The VIRUS spectrographs have been designed in such a way that the external structure of the instrument establishes the basis of the preliminary optical alignment for the instrument. As such, it is important that the mechanical structures of the unit spectrographs be assembled in a repeatable manner within the alignment tolerances. This paper describes a concept for accurately and repeatably assembling the external structure of the VIRUS units to allow the 150+ spectrographs to be aligned in a timely manner.

2. OPTICAL ASSEMBLIES

2.1 Grating Alignment Fixture

2.1.1 Design Requirements

The grating alignment fixture allows for the installation of the VIRUS grating substrate into the grating housing. It is necessary for the rotation of the grating substrate to be aligned within 0.1 degrees of the center plane of the grating housing. The tip and tilt of the grating substrate is machined into three mounting pads on the grating housing. The alignment device should allow the grating to conform to the tip and tilt of the mounting pads on the housing. The substrate must be epoxied into the grating housing after it is aligned. The clear aperture of the grating substrate should not be touched.

2.1.2 Design Solution

The overall design solution for the grating alignment device utilizes a concept which includes one structure used to align the grating rotationally, and a separate structure to lower the housing onto the grating to epoxy them together. The design features the use of a custom fiber optics to transmit a light source, an off-the-shelf CCD camera, and a precision rotary platform to adjust the grating. A fiber bundle has been designed to simulate the actual VIRUS light source as closely as possible. The alignment fixture and VIRUS optics both utilize 200 μm diameter fibers. In the grating alignment setup, the fibers are fed by an integrating sphere illuminated with white light. The precision rotary stage features a locking mechanism that will hold the grating substrate in place while it is being attached to the grating housing. We have chosen to use a system that utilizes gravity to hold the grating substrate onto three spring plungers. This would avoid having any objects interfere in the gluing process between the substrate and housing, as well as, limit the chances of touching the grating surface. The spring plungers would also allow the grating substrate to flex and conform to the mounting pads of the grating housing. The separate structure that holds the grating housing rests on a shelf attached to linear precision bearings that vertically lower the grating housing onto the substrate.

2.1.3 Alignment Procedure

- 1) The fiber optics will shine light through an achromatic lens which collimates the light.
- 2) The collimated light will go through the grating substrate. At the grating substrate the light will be bent 12.15 degrees per the optical design criteria.
- 3) The light will reflect off a mirror aimed parallel to the optical bench.
- 4) The reflected light enters a second achromatic lens where the light is focused onto the CCD detector.

Using the detector and the precision rotary platform the grating substrate will be rotated until it is in the proper position. When the grating is in the proper orientation, the rotary platform can be locked in place and the grating housing can be lowered onto the substrate. Figure 2 shows a picture of the grating alignment fixture device, with numbers outlining the alignment procedure.

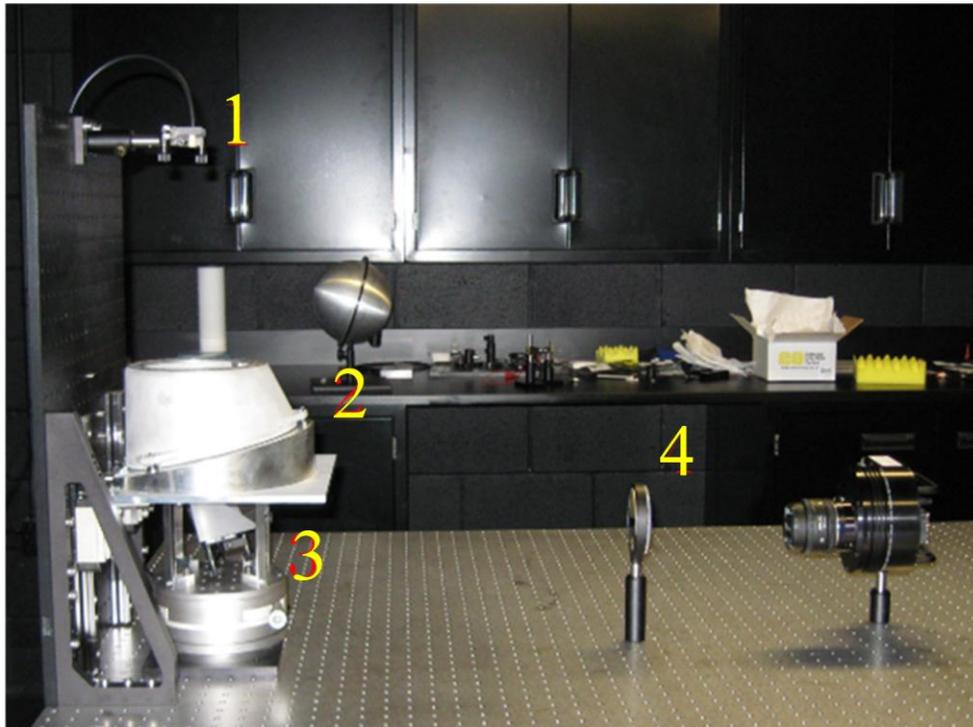


Figure 2: Picture of the grating alignment assembly with features indicated as follows: (1) Fiber head (note that the collimator lens is not seen in this photo). (2) Grating cell holding grating substrate mounted on alignment bracket. (3) Rotary stage. (4) Focusing mirror and CCD.

2.2 Camera Mirror Alignment Device

2.2.1 Design Requirements

The VIRUS camera primary mirror is attached to a camera mirror alignment (CMA) flexure (referred to as the “lollipop”) which allows for the adjustment of the tip and tilt of the camera mirror. It is essential to center the camera mirror onto the CMA lollipop within ± 1 mm in order to dial the correct tip and tilt into the mirror. The design is required to allow for the added thickness of the epoxy between the camera mirror and the CMA lollipop during the alignment process. Figure 3 shows a condensed view of the VIRUS camera unit with the vacuum housing cover, and a view of the VIRUS camera unit without the housing cover. In the camera view without the cover one can see clearly the CMA lollipop, camera mirror, and CCD.

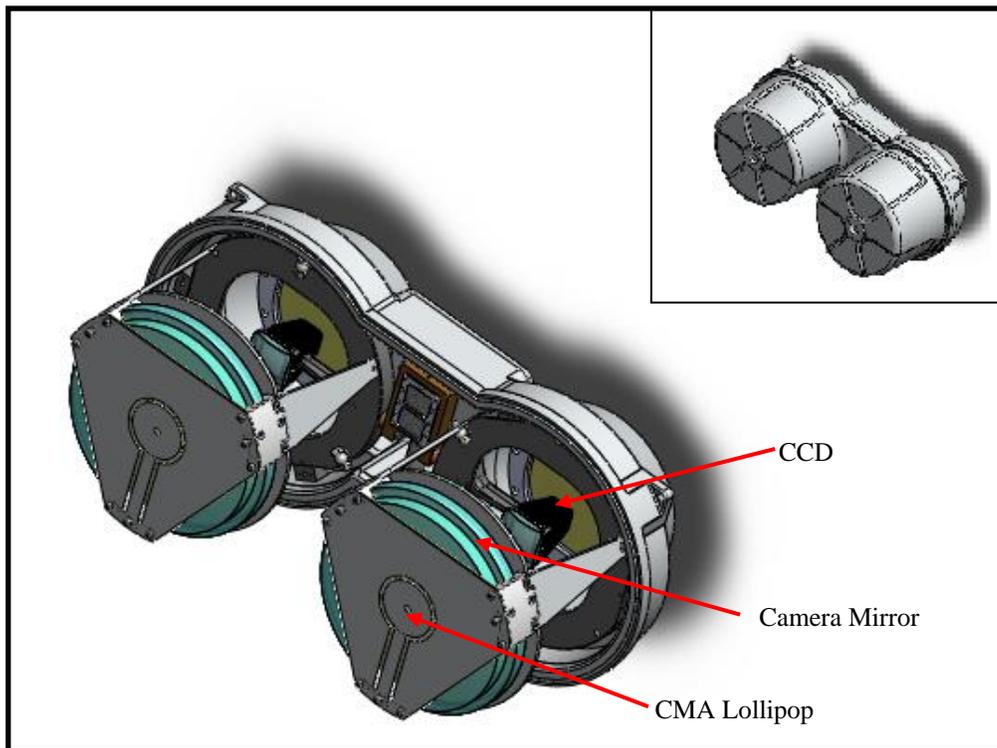


Figure 3: Drawing of the camera body showing the internal elements of the camera. In the large drawing, the external cover that forms the main portion of the vacuum vessel has been removed.

2.2.2 Design Solution

The design concept utilizes a guide made from machined aluminum. The CMA lollipop is placed in the alignment piece (note that the guide has a flatness specification so the CMA lollipop rests flat against the surface of the guide). The raised edge of the camera mirror is then placed into the alignment tool, centering both pieces within the specified tolerance. This simple alignment device can be built multiple times to allow for several camera mirrors and CMA lollipops to be assembled at once.

2.2.3 Assembly Process of the Camera Mirror Alignment Tool

1. Place the CMA lollipop inside the C shaped lip on the aluminum piece (shown below).

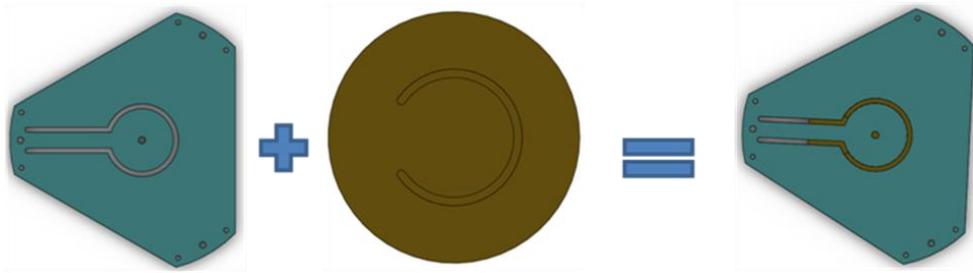


Figure 4: CMA lollipop alignment device

2. Place a predetermined amount of epoxy on the center of the circle of the CMA lollipop.
3. Insert the camera mirror center circle into the circle of the lollipop lip on the aluminum piece.
4. Press the mirror firmly onto the CMA lollipop and allow the epoxy to dry.
5. Remove and repeat with a new camera mirror.

2.3 Collimator Mirror Mounting System

2.3.1 Design Requirements

The collimator mirror reflects and collimates light from the fiber optics into the folding flat mirrors of the VIRUS unit. The collimator mirror will be glued to an aluminum puck which will allow it to be mechanically fastened to the collimator adjustment plate. The collimator mirror must be attached to the puck to within 0.5 mm concentricity and $\pm 0.1^\circ$ rotation.

2.3.2 Design Solution

To meet all rotational and translational requirements, the cylindrical and flat surfaces of the mirror will be used as the reference surfaces in the alignment fixture. As seen in Figure 5, two pins will be used along one cylindrical surface to define the mirror's X and Y position and a third pin is used along one of the flat sides to define the rotation. Clamps are also used on the other sides of the mirror to hold its position and rotation as defined by the pins. In the fixture assembly's current configuration the mirror's radius would have to deviate more than 0.46 mm from 147.5 mm to make the position out of tolerance. Likewise, the Y position of the referenced flat surface would have to deviate more than 0.20 mm from 65 mm to make the rotation out of tolerance.

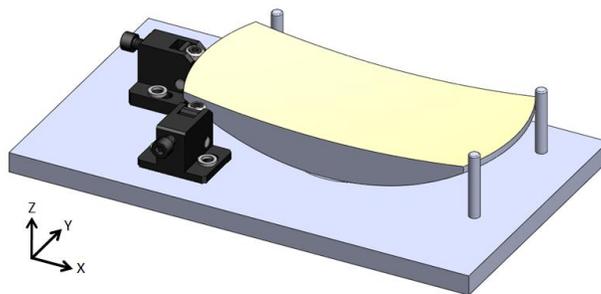


Figure 5: Collimator mirror and puck alignment fixture, assembled view.

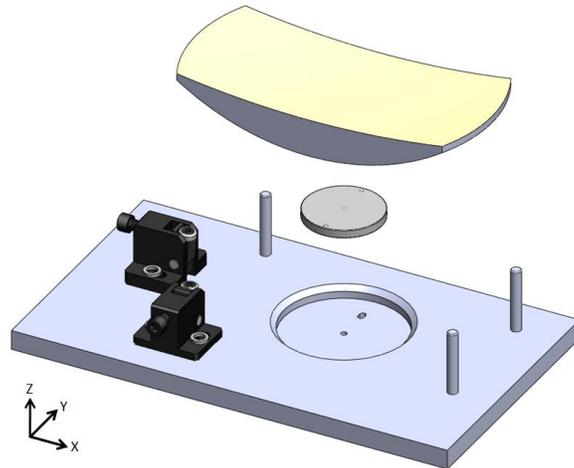


Figure 6: Exploded view of the collimator mirror and puck alignment fixture.

The puck is first aligned to the jig using two shoulder screws to constrain its position and rotation. The outer mounting hole on the jig is slotted to prevent the puck from being over-constrained, as seen in Figure 6. Next, a thin layer of epoxy will be applied to the collimator mirror and puck. With the clamps disengaged, the mirror is placed into the alignment fixture where the mirror can slide and rotate until the epoxy is evenly spread and level. The left clamp is tightened first until it has a light hold on the mirror, but the mirror should still be able to rotate about its center. The lower clamp is engaged next until it rotates the mirror into the third pin. Both clamps are then tightened until they have a firm grip on the mirror.

The weight of the mirror should provide enough compressive force to ensure the epoxy creates a proper bond, so no additional clamps or weights are needed to push down on the mirror. The epoxy may take a considerable amount of time to cure, so multiple collimator mirror fixture assemblies will be created to allow for more mirror and pucks to be bonded at the same time.

3. MECHANICAL ASSEMBLIES

3.1 Collimator assembly structure

3.1.1 Design Requirements

The collimator assembly fixture allows for the assembly of the collimator shell. The collimator shell is the frame on which the VIRUS optical components are mounted. The collimator shell assembly device must be able to support the load of a completed collimator assembly. The assembly structure should have a feature to allow for the easy removal and transport of the complete collimator shell. The alignment fixture should also be mobile for an easy assembly process in the Texas A&M facilities.

3.1.2 Design Solution

A proposed solution for constructing the collimator shell in a repeatable and precise manner is to use a tubular steel to build a custom frame to amass the collimator, as shown in Figure 7. The steel frame will be built in such a way as to allow the placement of the top and side collimator plates. Attached to the steel frame will be 4 swivel casters, 2 of which will be total locking. This will allow for mobilization of the fixture. A custom guide rail will be used on each side of the collimator to allow for an ease of removal from the frame. An IFU reference will be welded to the frame to prevent movement of the collimator head plate. With the collimator head plate fixed in place, the base plate can be translated until it is aligned to within 10 μm of the correct location from the base plate. Below is a picture of a completed collimator shell inside the assembly structure.

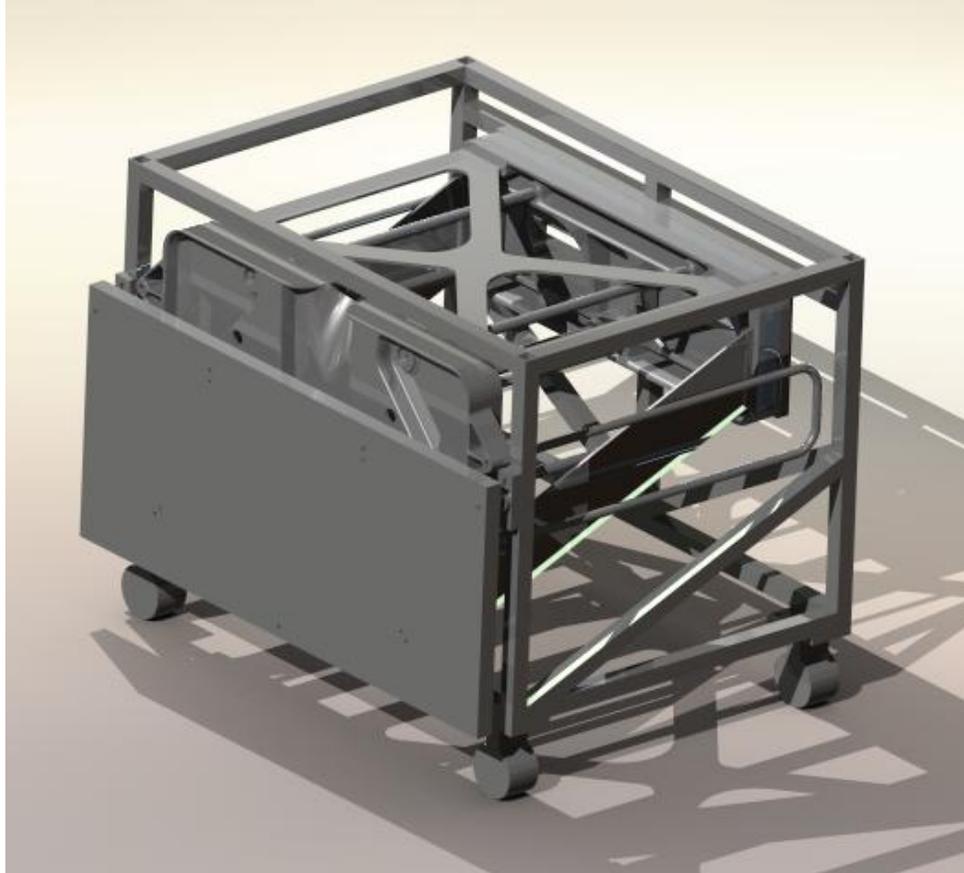


Figure 7: Collimator shell assembly fixture showing the collimator base plate (left, behind structure), collimator head plate (upper right), and side plates (connecting the two) mounted inside the assembly fixture. Once the head and base plate are positioned precisely using the assembly fixture, the remaining structure is attached to them.

Only the first “fiducial” collimator shell assembly needs to be aligned using a CMM. After the initial alignment the other VIRUS collimator shells can be simply placed in the pre-aligned frame and assembled. Creating an assembly fixture that only needs to be precision aligned once, in order to align all of the 150+ VIRUS collimators, greatly reduces the time and cost it will take to build each VIRUS unit. This is a large scale build; we have made an effort to take advantage of every opportunity to save assembly time and cost.

4. CONCLUSIONS

The alignment and assembly fixtures described here will aid in the rapid build process required for producing 150+ VIRUS units. Multiple optics alignment fixtures will be manufactured so that multiple identical VIRUS sub-assemblies can be produced at once. The collimator assembly structure will likewise enable quick assembly of the collimator structures of the unit spectrographs. All of these alignment pieces are designed to be simple to machine and to use, and should greatly reduce the time and effort required to build 150+ VIRUS units.

Texas A&M University is currently in the process of prototyping these fixtures along with the rest of the components of the unit spectrographs. Once the mechanical design of the spectrographs has been fully prototyped, by Fall 2010, we will begin production mode construction of the 150+ spectrographs. The instrument will be installed on the telescope about 18 months after production mode construction begins.

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