Split Relay Tip/Tilt Stability

Don Gavel, Brian Bauman, Chris Lockwood
August 8, 2007

This memo summarizes a mini-study of the pointing stability issues that arise due to the non-common path error in the split relay architecture. This architecture separates the tip/tilt sensors, which would be located on the turret of the d-NIRI instrument, from the focal plane of the narrow field science instrument. The non-common path consists of the tip/tilt splitter, ADC, K-mirror derotator, and narrow field relay optics. Stability is only an issue in narrow field science mode, but this is when the tip/tilt requirements are the strictest, with a science case driven error budget of 15 milli-arcseconds.

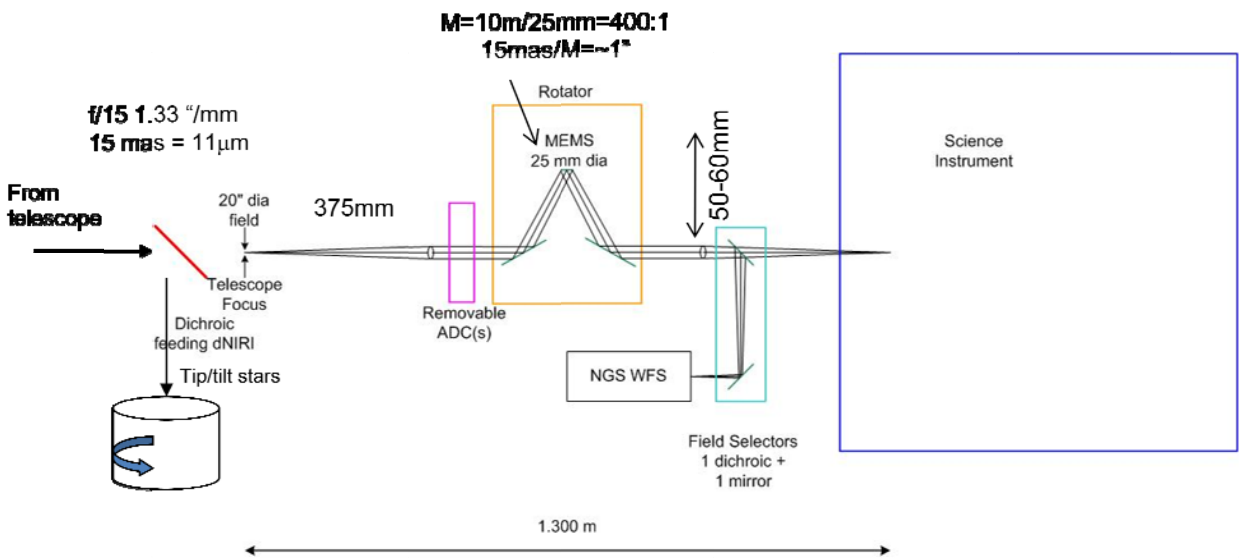

Figure 1. Layout of Split Relay Architecture, with my annotations

There is no inherent difficulty with positioning or pointing along beam lines, or with nutation. The tolerances are rather lax (a few microns in positioning) and any decenter, nutation, or rotation error can be calibrated out. There is a very difficult problem with the 3 mirrors in the K-mirror scheme as shown however. The 15 mas tolerance on tip/tilt can easily be destroyed by the smallest of wobble or vibration of the 2^{nd} mirror in the derotator (the MEMS in this picture) which is located at a pupil. In spite of the pupil demagnification of 400:1 working in our favor, this is still a very tight mechanical tolerance. It allows only 0.015 x 400 = 6 arcseconds of physical motion of M2 with respect to M1 or M3 in the K-mirror. There are probably similar tolerances on the tilt of either of the other two mirrors with respect to each other or with respect to the beam line, since they are also both near the pupil. For perspective, assuming a 1 inch M2, this allows one edge of the mirror to move only 0.375 µm with respect to the center, a motion that might easily be induced by bench vibrations or air in the path. This motion is of course present in all the architectures, and M2 could in fact be on a fast tip/tilt correction stage, but this is the only architecture where the tip/tilt *sensing* is upstream and hence blind to the disturbance.

There are three solutions to the above difficulty which all seem feasible (aside from being very careful not to induce vibration and move these mirrors with extremely repeatable action):

1) Use a metrology system. Propagate an artificial tip/tilt guide star starting at the center of the d-NIRI field, and using a retro mirror behind the dichroic, send it down the center of the AO relay into the sensor labeled here NGS WFS. Use a wavelength that would be blocked by every science filter. This would essentially give the same advantage enjoyed by the other architectures, i.e. the tip/tilt star (in this case artificial) probes the non-common path, particularly the troublesome K-mirror.
2) Put the K-mirror ahead of the d-NIRI split. This would but its problems in the common path, and would have a side benefit of eliminating the need to rotate d-NIRI. Disadvantages are the K-mirror would now have to pass the full 150 (180?) arcsecond field of view, and it would also need to be ahead of focus, well inside the elevation bearing.
3) Brian Bauman has suggested the use of a dove-prism in place of a 3-mirror K design. This is a single piece of fused silica glass (illustrated in concept in Figure 2 below) that would use total internal reflection for M2 and refractive bending to substitute for M1 and M3. The dove-prism can be made rather small given the small science field, and located at the same position as the K-mirror in the split relay. The induced pointing wander is insensitive to the prism's centering and tilt with respect to the nominal beam line. For example, if we imagine 1/10 of a subaperture being the allowable tolerance of beam wander at the pupil, then beam wander can be as much as 25mm/640 = 40 microns, rather easy to achieve mechanically. Optically, there is an issue with lateral color shear of the pupil with this refractive solution, but the amount of shear, calculated by Brian, is less than 10 μm across H band and 13μm across the K' band.

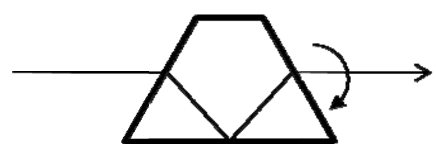

Figure 2. Dove-prism field derotator

In summary, the split relay architecture can still be feasible for precise tip/tilt tolerance, but will need either metrology or a different derotator solution than originally envisioned.

DG