NIRSPEC

UCLA Astrophysics Program | U.C. Berkeley | W.M. Keck Observatory

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NIRSPEC Optics Design Note 20.00
System Level Misalignments

1. Introduction

This document describes system level misalignments and their impact on system level design specifications. Misalignments in the context of individual optics and assembled modules are discussed in NODN0900. This document extends NODN0900 to include the Keck "system," i.e. the telescope optics and the DCS software/motion control. The image rotator (IROT) is taken to define NIRSPEC, so that all other alignment within NIRSPEC is assumed to be perfect.

2. Alignment Vectors

Misalignments can be resolved in terms of 6 components: offsets in x, y, z, and angular misalignments about the corresponding axes. Our coordinate system is defined in Figure 1. When looking at NIRSPEC from the side with light entering from the left, +x points away from us, +y points up, and +z points to the right. This coordinate system coincides with the global coordinate system used by Zemax.

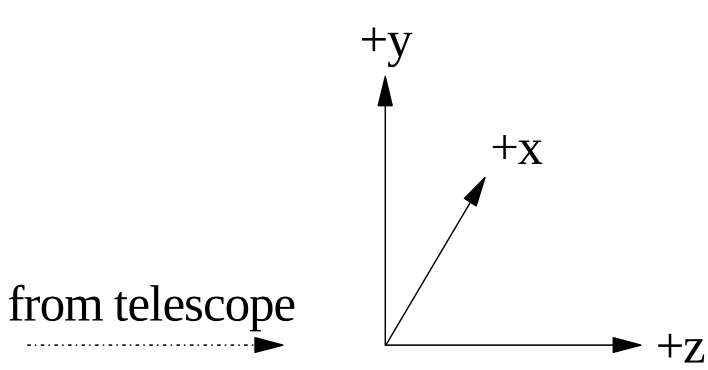


Figure 1. Global coordinate axes.

We can dismiss some system level misalignments because the system contains compensators which have been discussed elsewhere. Angular misalignments about the z-axis will be compensated by the IROT/DCS interaction which is discussed in NSDN0800. Translational misalignments along the z-axis will be compensated by focusing. Angular misalignments about the x or y axes produce the same results; the same is true for translational misalignments alonge these axes. So, the 6 original degrees of freedom can be reduced to just two. One is called “lateral” or “transverse” misalignment. This is when an element is misplaced in the plane perpendicular to the input beam. Another is called “angular” misalignment. This is the tilt of an element/module away from its nominal position as measured in a plane containing the z-axis. Figure 2 shows a module, represented by a vector, which is misaligned in lateral offset and angular direction. The lateral offset is *r, and the angular misalignment is *2.

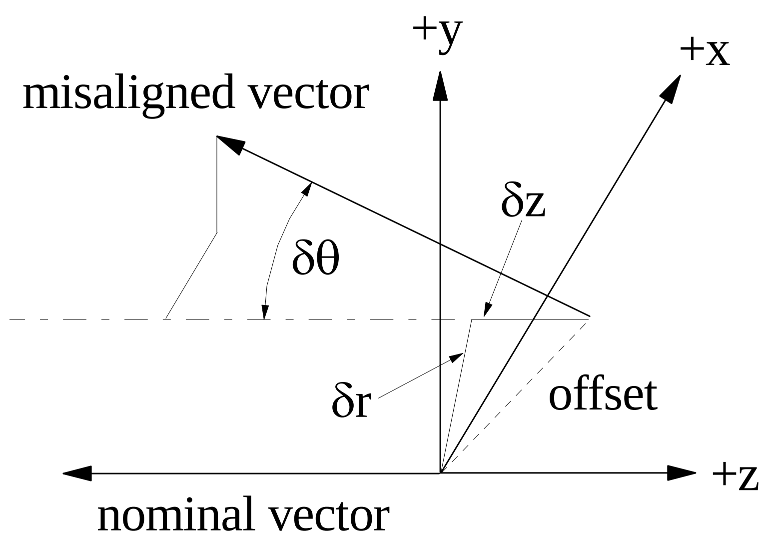
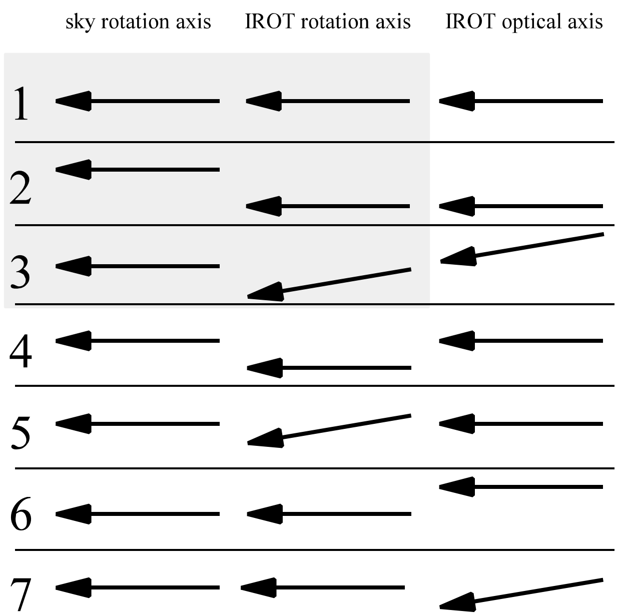


Figure 2. Misaligned module represented by a vector.

These two types of misalignments produce downstream manifestations which are truly decoupled, at least to first order. For instance, transverse misalignment between the sky rotation axis and the image rotator axis results in image wander at the slit focal plane. On the other hand, angular misalignment results in pupil wander at the Lyot stop.

3. Misalignment Matrix

Let’s consider 3 alignment vectors in the Keck/NIRSPEC system: the Keck rotation axis, the IROT rotation axis, and the IROT optical axis. We can simulate misalignments of each of these in turn and examine the effects on pupil and image wander. The results of these simulations are shown in the table. I have listed the results in the form of a “user’s guide” sheet which tells us what to do for any given type of misalignment. Notice that misalignments in the IROT optical axis have no effect on wander. In fact, there are only 3 truly unique cases, and they are shown in shade in the table.



Symptom	Solution
ALIGNED!	Finish with a slice of fruit and a decorative umbrella - Enjoy your data!
image wander at slit plane	translate NIRSPEC to restore to condition 1.
pupil wander	tilt NIRSPEC to restore to condition 1.
image wander at slit plane	same as for case #2
pupil wander	same as for case #3
no impact	same as for case #1
no impact	same as for case #1

4. Dynamic Considerations

If our considerations were limited to the above, it would be relatively easy to compensate for manufacturing offsets. For instance, we could simply position NIRSPEC, in offset and angle, until the sky and image rotator axes were coincident. We would only have to worry about whether the misalignments in the image rotator were so large as to throw the pupil image off the Lyot stop or the focal plane image off the reflective slits.

Unfortunately, we have to introduce the possibility that the alignment is a function of image rotator position. This can happen due to manufacturing irregularities in the bearing - in fact, this will always happen to some amount. We expect that a variable transverse offset will require some simple accounting in the Keck Drive and Control System (DCS). The DCS must have an accurate representation of the NIRSPEC boresight so that the telescope can be traslated as the image rotator is rotated. The system will then operate in unison so that image wander is minimized. The same trick cannot work in the case of a varying tilt between the IROT axis and the Keck axis. In this case, the precessing tilt will induce a pupil wander which cannot be eliminated. Remember that a static misalignment in tilt can be compensated by tilting the whole instrument so that the IROT and Keck vectors are coincident. There is no adjustment in the dynamic case, unless we build a mechanism which rocks NIRSPEC to counter IROT motion!

5. Recommendations

In this document, we have isolated the two general classes of misalignments which might affect system performance. From the discussion, it seems that static and dynamic transverse offsets can be compensated by properly positioning the instrument and by using a DCS model which includes IROT angle-dependendent boresight terms. It also seems that angular misalignments will be more troublesome. Static angular misalignments will require that we tilt the instrument and make a corresponding adjustment in transverse positioning of the Lyot stop. Dynamic misalignments will be the most troubling to compensate. In this case, we will have to live with pupil wander. Our best approach to countering this effect is to pay particular attention to IROT wobble in the acceptance and testing stage of our contract with Speedring, Inc.

We have ignored two aspects of this problem, and we should concentrate on them in the near future. One aspect is the measurement of these various misalignments. The misalignments produce small effects which are difficult to measure. How will we be able to measure them in order to reposition NIRSPEC and to pass along information to the DCS? The other aspect involves detailing the relationship of the DCS in the whole system. We can do this with the help of Keck support, and it will become much more important in the coming year and during the Keck integration phase.