# Requirement Specification for Rig3 optimised scan and pointing driver code PK, GE, NS 16/5/2014 v1

## Introduction

This document is to capture recent discussions and clarify the requirementspecification for the new software driver for AOL control. The new requirements include being able select a pixel on a high speed scan image and point to it or zoom onto it with a miniscan subsequently with better than 1/500 FOV (Field of View) precision is a new target that is quite conceptually and practically challenging. The aim is to minimise the non-understood fudge factors used to date to achieve alignment and good imaging. The starting point is to define the requirement.

In addition it will greatly speed up our progress if we use a software test bench to prove that the driver achieves the objectives, at least with an idealised paraxial model of the AOL and microscope. The verified driver can then be used on the real microscope and with more refined AOL simulators to progressively improve our understanding of precision AOL control. Geoff’s current sophisticated AOL simulator shows about 1/140 precision over a 20mrad FOV between pointing and scanning and a similar precision circle of confusion around each focal point. We do not know if this imperfection is caused by bugs in the program, --tested now and is due to differences between the lambda F / V and the Xu and Stroud model-- conceptual discrepancies with reality or represents what you in fact get in reality. I believe that to avoid getting into a loop of un-understood fudge factors on the microscope it is important to first verify that the driver code without fudge factors does give near perfect results with an idealised test bench on Matlab. This test bench will use an idealised numerical model of the AOL using zero thickness AODs and deflection = F\*lambda/V.

## Specification

### User requirements

The driver inputs are :- normalised input Xn Yn Zn and scan rates deduced from e.g Xn start –Xnstop and voxel dwell time as defined already by the existing driver

1. That a Z stack has no skew of magnification distortion with Z to a precision of 1/500 of FOV . i.e. The focal spot scans parallel to the Z axis when Z is stepped sequentially at constant Xn Yn coordinates. Importance 10
2. That when building up a volume image the out of focus Z planes are lined up with the in focus planes to a precision of 1/200 of FOV?. This requires that, the illumination ray bundle chief ray is parallel to the axis, and when Z is varied the focal point moves parallel to the axis. The main requirement for this is that the XY=0 input beam is central to the microscope objective and its chief ray is parallel to the Z axis. Since the X and Y iris planes where the scanning beam appears to originate from are not coincident this requirement cannot be met perfectly. Importance 7?

Therefore to test these :- Add a single following telecentric projection lens imaging the output of the idealised AOL model from a fixed reference iris plane in the AOL (I suggest the centre) to a focal plane a distance of one focal length in front at Zn=0. The ideal XYZ field of view would be a parallelepiped with constant measured XY deflection of the focal point as Zn is varied at constant normalised Xn Yn coordinates input to the AOL driver software.

1. When imaging in the scan mode changing the speed of scan does not affect image position to a precision of 1/500 of FOV Importance 10
2. When selecting a point in scan mode and using that selected point to define a smaller zoomed imaging area or a stationary pointing mode spot the centre of the zoomed area or the position of the pointing beam are accurately aligned to a precision of better than 1/500 FOV Importance 10

In the test model, using a specified delay after the start of ramp for starting imaging in each line or point check that these requirements are met

## Issues and difficulties in achieving these requirements

As discussed yesterday, in the pointing mode it is possible to arbitrarily vary the ratio ‘*r*’ of deflection from the first and second AODs. As the point is step scanned to build up a grid image the apparent iris plane from where the rotating bundle of rays leaving the AOL appears to originate varies dependent on *r* .

In scanning mode however there is only one value of *r* --if r is defined as the fraction of deflection by the first over the second on the base ray at t=0 then r is still arbitrary, if you mean something else then I’m not sure but there’s still an arbitrary constant that we can play with— that enables scanning and focussing. A scanned beam therefore has a fixed iris plane that I now have the equation for and a 2D idealised model.

I have not modelled a complete AOL microscope system. I assume in my earlier AOL drive equations that angle from the reference point chosen as the centre of an iris plane –the iris plane is not a good way to proceed on this because the planes are different for x and y, it’s much better to use the focus and work backwards-- on the final AOD to the focal point is the only parameter that affects the X and Y displacements in the final imaging field irrespective of Z or scan rate. I ignore possible effects of the iris from which the ray bundle appears to originate. We need to check this assumption to clarify our understanding of the importance of iris plane movement. The scanning iris planes positions are a function of both Zn and scan rate. So if there are even slight variations of X and Y coordinates with these parameters we need to understand why and correct for it in the driver. To test this therefore we should test these parameters with e.g. idealised telecentric projection lens as before but vary its focal length to check these issues. We could then check with a complete idealised model of the microscope lenses. If my initial assumption is not correct, and iris plane movement does slightly affect X Y position in the image field even for fixed first image from the stand alone AOL then it means that for eliminating the not understood fudge factors we would need to incorporate a more comprehensive model of the complete optical train into the driver model

Because my modelling of the scanning iris planes shows that averaged over all cases the X and Y iris planes are symmetrical about the centre of the AOL not the final AOD, we will have less displacement of these iris planes with respect to the reference point if we move the reference point to the centre of the AOL. I speculate that the primary cause of the unexplained XZ skew displacement of current AOLs is the use of this wrong reference point. I also believe that this may be causing a significant magnification distortion of the field of view, which we are compensating with our optics. If modelling proves this right, I therefore now believe that we should from now on set up the microscopes with the first projection lens centred on this new reference point. This may require making this first lens e.g. 150mm focal length rather than the current 100mm.

In order to meet the scanning/pointing alignment precision requirement do we need for instance to define the offset equations for the pointing beam or the midpoint of a miniscan so that the *r* value and hence iris plane is not changed by the scan rate change. Or is it sufficient for instance to have one set of pointing mode offset equations that assumes that the ‘fixed point iris plane’ is coincident with the new reference point at mid AOD. I favour starting with that assumption.