

RYTSI: A New Way to Do Speckle Imaging

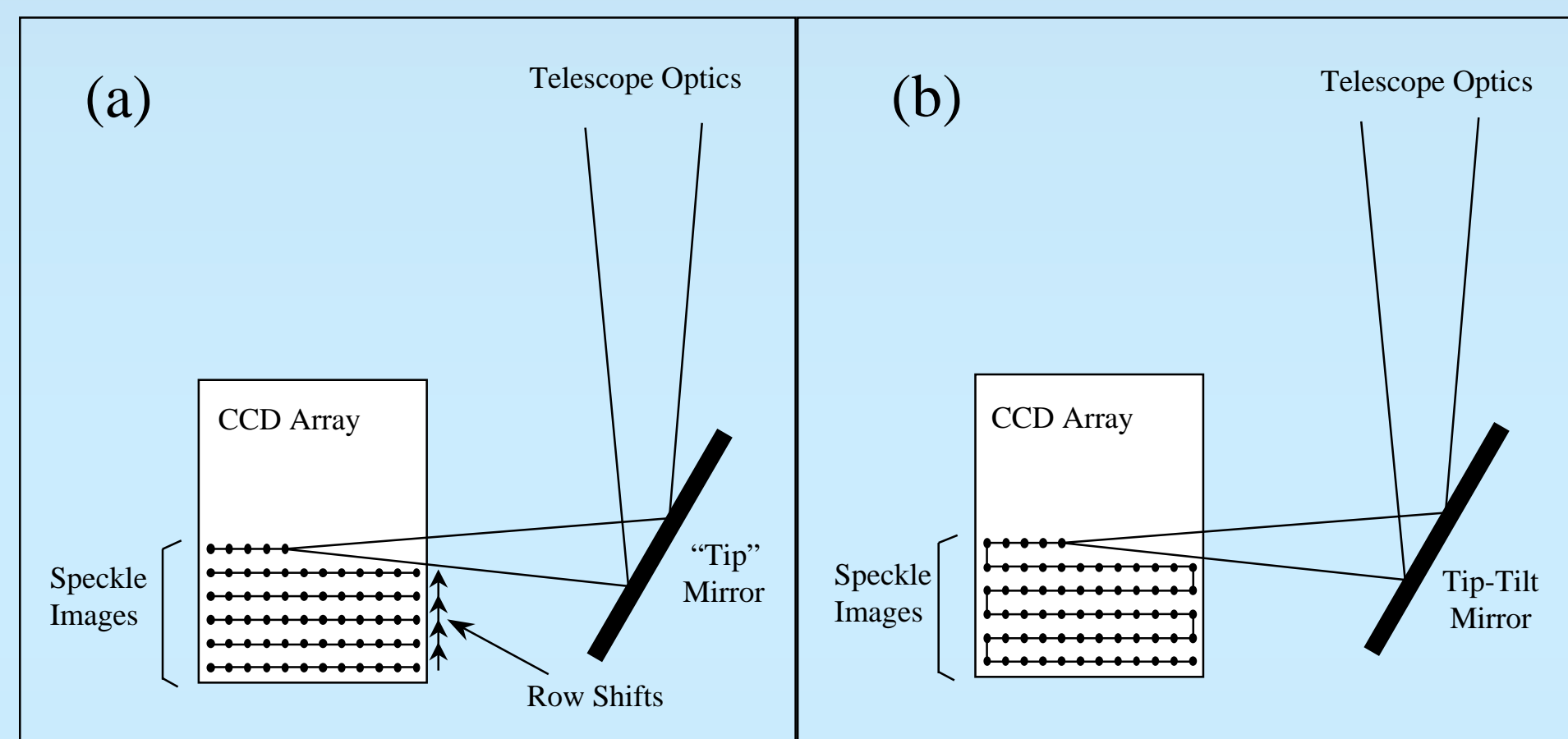
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ABSTRACT

The RIT-Yale Tip-tilt Speckle Imager (RYTSI) is a unique speckle imaging system that can use any large-format CCD as the image recording device. Short exposure images are created by moving the star image in a rapid step-and-expose pattern that covers the entire area of the chip. When this process is completed, all of the recorded images are read out together. The image movement is accomplished with a tip-tilt mirror system enclosed in a compact optics package that sits between the telescope and the CCD system. When used with the RIT 2048x2048 pixel CCD camera, approximately 256 (diffraction-limited) speckle images can be recorded in a 16x16 grid per full-frame read at a 4-m class telescope. As large-format, high-quantum-efficiency astronomy CCDs continue to improve in terms of readout speed and read noise, they compete very favorably with more traditionally used intensified-CCD (ICCD) systems in terms of signal-to-noise ratio obtainable per frame in speckle imaging applications. In addition, the linear performance of CCDs appears to allow for the possibility of reliable diffraction-limited differential photometry¹, something that has proved extremely difficult to do with ICCDs. Construction of RYTSI is now nearing completion at RIT, and the module is scheduled for use at the WIYN 3.5-m telescope for the first time later this year. The design and performance are discussed, as well as the future observational program with RYTSI at WIYN.

¹ Horch, E., Ninkov, Z. & Franz, O. G. 2001, AJ, 121, 1583

1. Tip-Tilt CCD Speckle



The idea: use a large format CCD to collect a grid of speckle images over the entire active area of the detector before full-frame readout. Shown above are two possible methods of filling the array.

(a) “typewriter mode” -- use the row-shift capability of the CCD to advance rows of star images toward the serial register. Rows are filled by moving the mirror in a direction parallel to the serial register.

(b) “raster mode” -- tiltable mirror(s) deflect the star image in both imaging dimensions (serpentine step pattern).

2. System Design

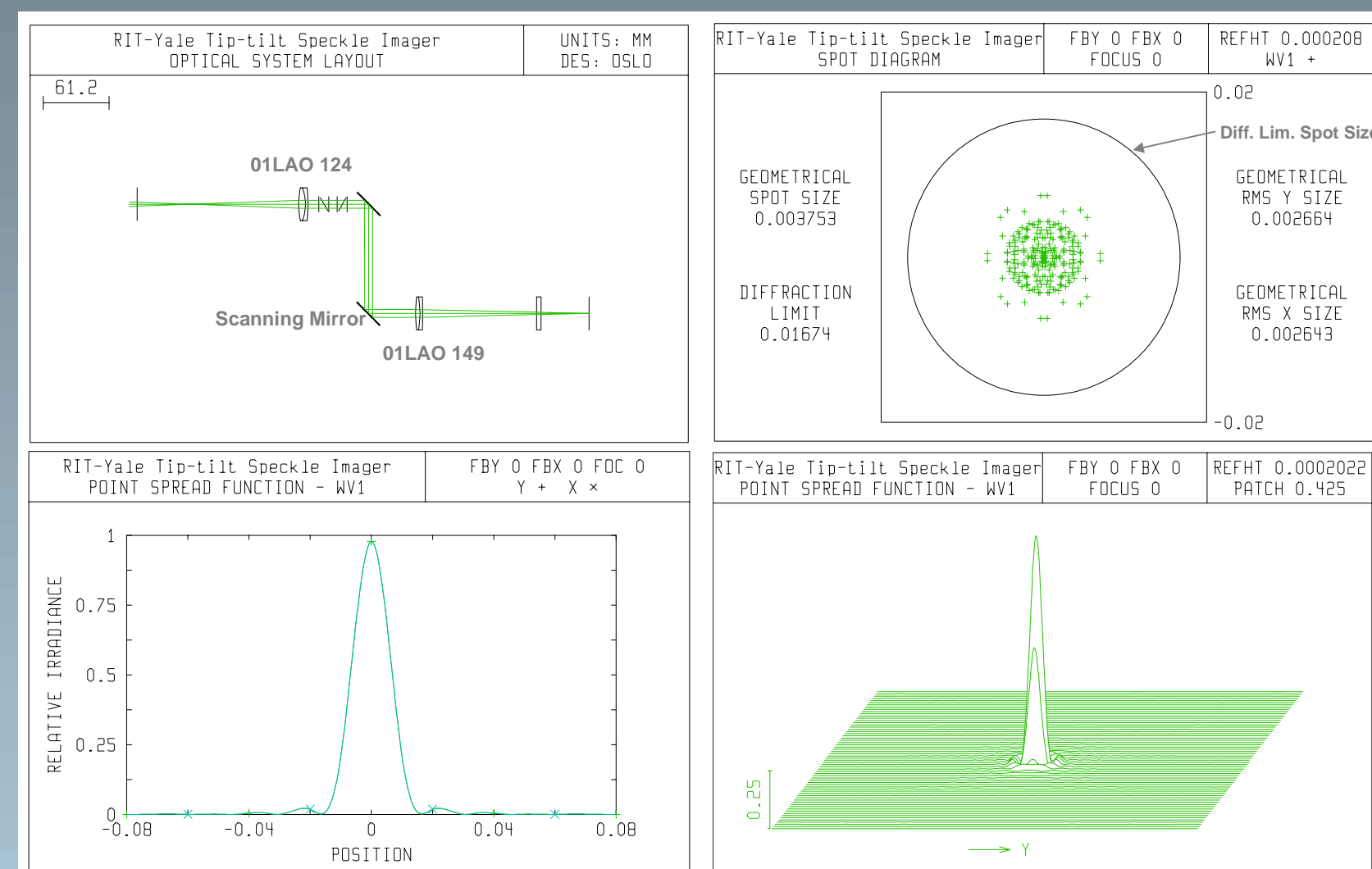
Optical design of the system was carried out with the OSLO SIX ray tracing software. The design goal was to create a simple, compact, flexible prototype to demonstrate the “tip-tilt speckle” idea. For example, we will use Melles Griot catalogue lenses and off-the-shelf galvanometric scanning mirrors (from Laserworks, Inc.). A double filter wheel is also being purchased from ISI Systems and will be simply “inserted” into our optics box. Risley prisms (for atmospheric dispersion) will be custom made later this year, but will be rotated with off-the-shelf stepper motors. The ray tracing shows that we will have reasonable optical performance over the entire field of view at WIYN.

Why CCD Speckle at WIYN?

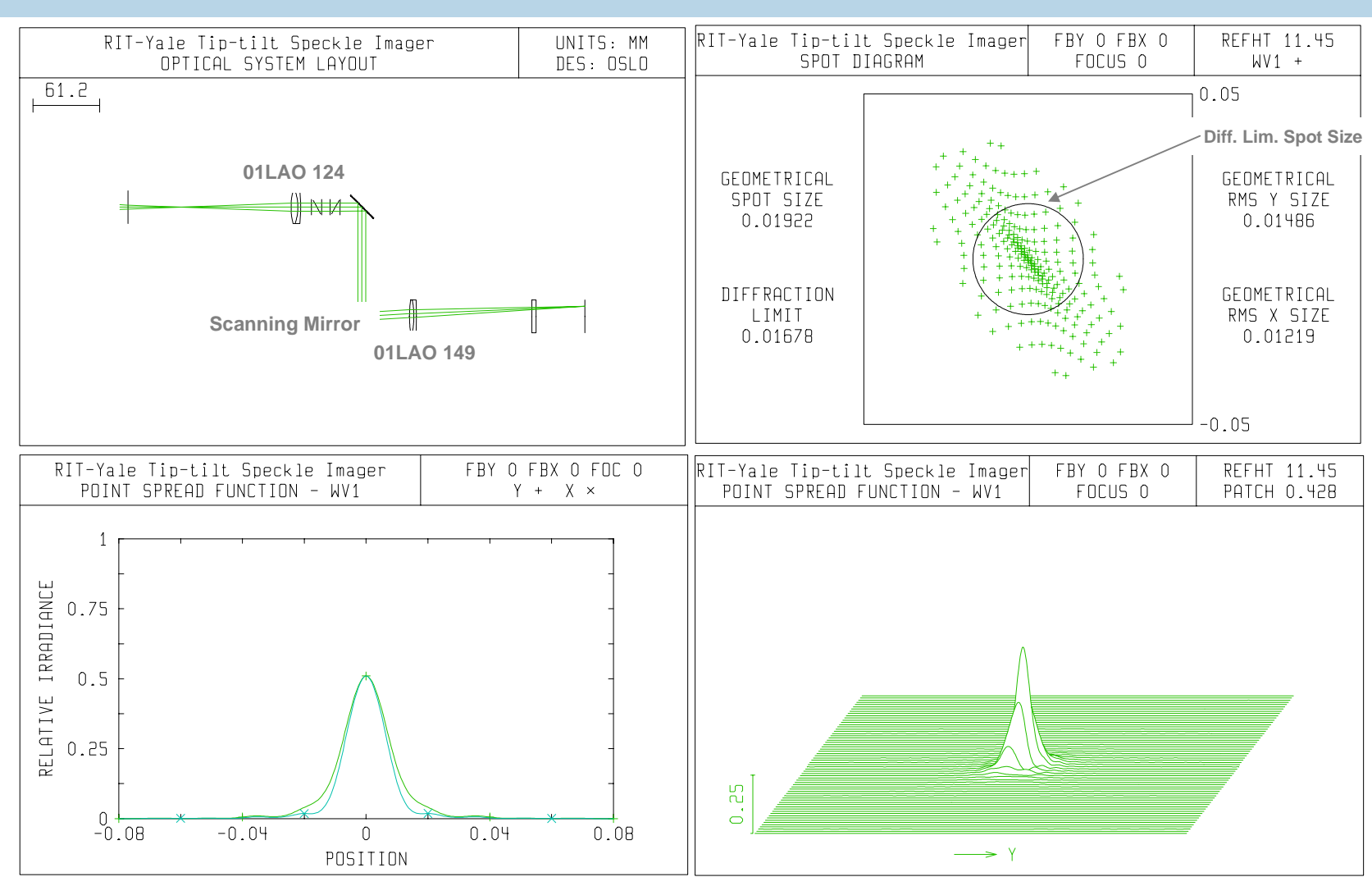
- Speckle remains a fundamental tool in determining binary star orbits and stellar masses.
- CCDs have improved dramatically in readout speed and read noise in the last few years and will most likely continue to do so. In the limit of zero read noise, a CCD is a *linear* photon-counting detector of very high quantum efficiency. Meaning:
 - > Fainter limiting magnitudes.
 - > Reliable diffraction-limited photometric information.
- Hipparcos has identified ~3400 previously unknown doubles. With distances already known, we seek to identify which are gravitationally bound and determine orbits *as well as component magnitudes and colors*.
- WIYN has outstanding median seeing conditions and superb optics, meaning higher signal-to-noise in the speckle patterns.
- See Sally Robinson’s poster tomorrow (47.06) for more information on what we’ve done so far with CCD speckle at WIYN and where we are going.



Below: a ray trace to the detector center, using the WIYN Cassegrain port optics. We expect diffraction-limited performance at this location.



Below: a ray trace to the detector corner, using the WIYN Cassegrain port optics. Here, the spot size is influenced by geometrical aberrations, but will be sufficient for demonstration purposes. Eventually, we will replace the catalogue achromats with aspherics.



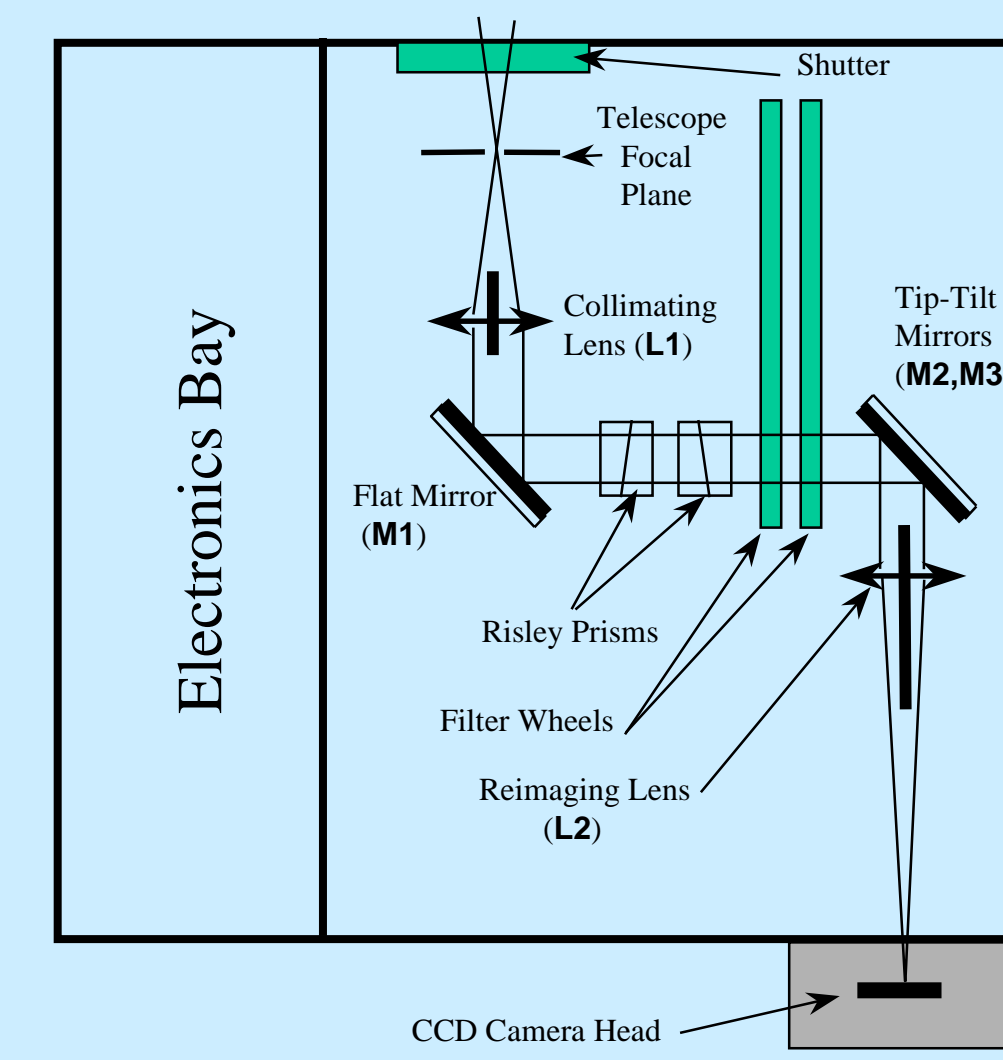
At the top of the next column is the final block diagram for the instrument. Both the collimating and reimaging lenses will be mounted on tracks to enable different lenses to be used for different telescopes, depending on the magnification needed, the size of the CCD pixels, and so on. The optical quality will vary slightly depending on the telescope and lenses used in RYTSI, but in general will be diffraction-limited. The table below shows typical observing parameters for three Kitt Peak telescopes, as examples.

Once RYTSI is working well with the current RIT CCD, we would like to try to couple the optics box with a back-illuminated, low read noise CCD. We expect that we could reach ~12th magnitude at WIYN in that case.

Parameter	0.9-m	2.1-m	WIYN 3.5-m
<i>f</i> /ratio	13.5	7.5	13.6
magnification needed*	1.6	3.0	1.6
pixel scale (mas/pix)*	95.5	39.3	24.4
tilt range (deg)* (single axis)	±1.65	±1.46	±1.65
mirror steps (deg)*	0.052	0.11	0.21
images per full frame*	4096	729	256
effective frame rate* (30ms exposures, 3ms mirror motion)	28.5	22.5	15.2

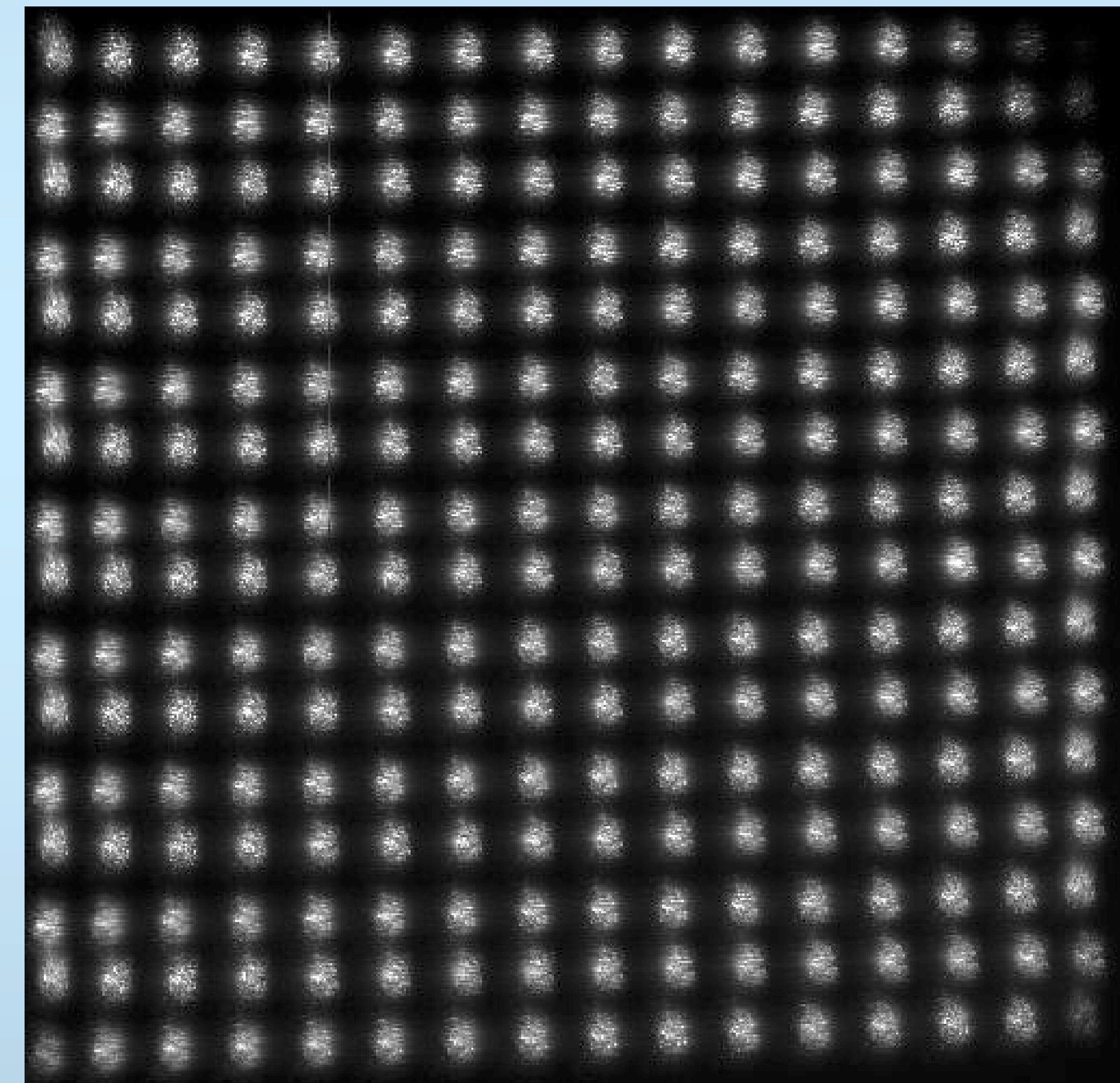
*assumes use of the RIT 2Kx2K 500kHz readout CCD (9 micron square pixels).

RYTSI Block Diagram/Top View



3. Testing and Fabrication

The scanning mirror system has been tested in the laboratory, and the step-and-expose capabilities appear to be more than sufficient for the speckle imaging application. Below is an example of a laser speckle spot created in the lab and imaged with the RIT 2048x2048 CCD, using a lens system and the scanning mirrors set up on an optical bench. Backlash occurs in the mirror motion when reversing directions, but we have been able to compensate in the mirror control software.



Machining of the optics box has begun in Rochester at ModelMax, Inc. The work should be completed in mid June. Below is a photo taken on May 31, 2001, showing the box with the electronics bay on the right. The lens holders for L1 and L2 from the above block diagram are shown in their approximate locations on the track mounts. The system is planned for use at WIYN this summer.



RYTSI Related Publications:

- 1) Horch, E., Ninkov, Z. & van Altena, W. F. 1998 Proc. SPIE, 3355, 777
- 2) Horch, E., Ninkov, Z., van Altena, W. F., Meyer, R. D., Girard, T. M. & Timothy, J. G. 1999, AJ, 117, 548
- 3) Horch, E., Ninkov, Z. & van Altena, W. F. 1999, BAAS, 31, 837