

Spectrograph point spread function characterization using a sine comb generator: testing on the Keck Planet Finder spectrograph

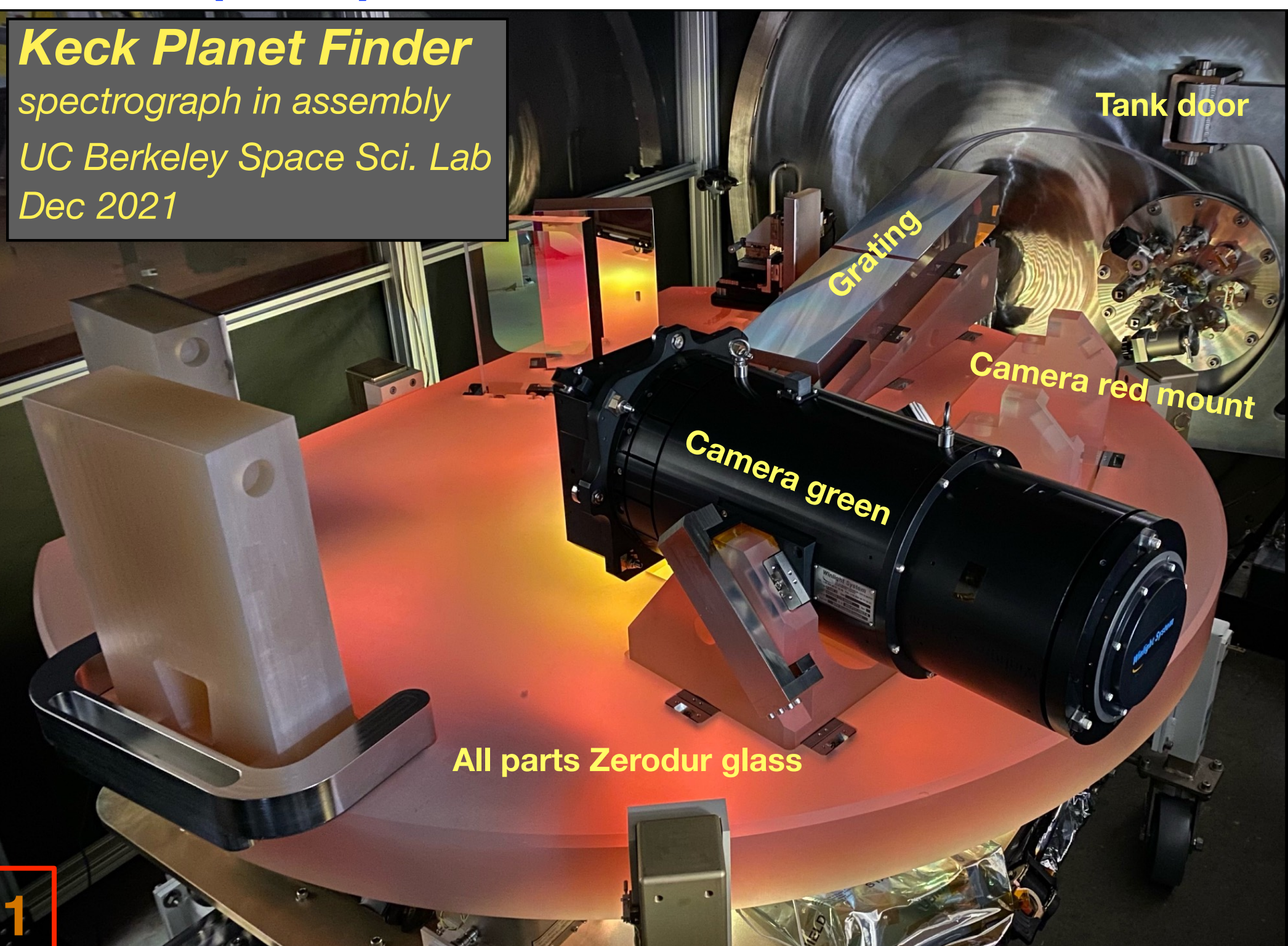
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Method called "MTF" or "Sine Comb Visibility"

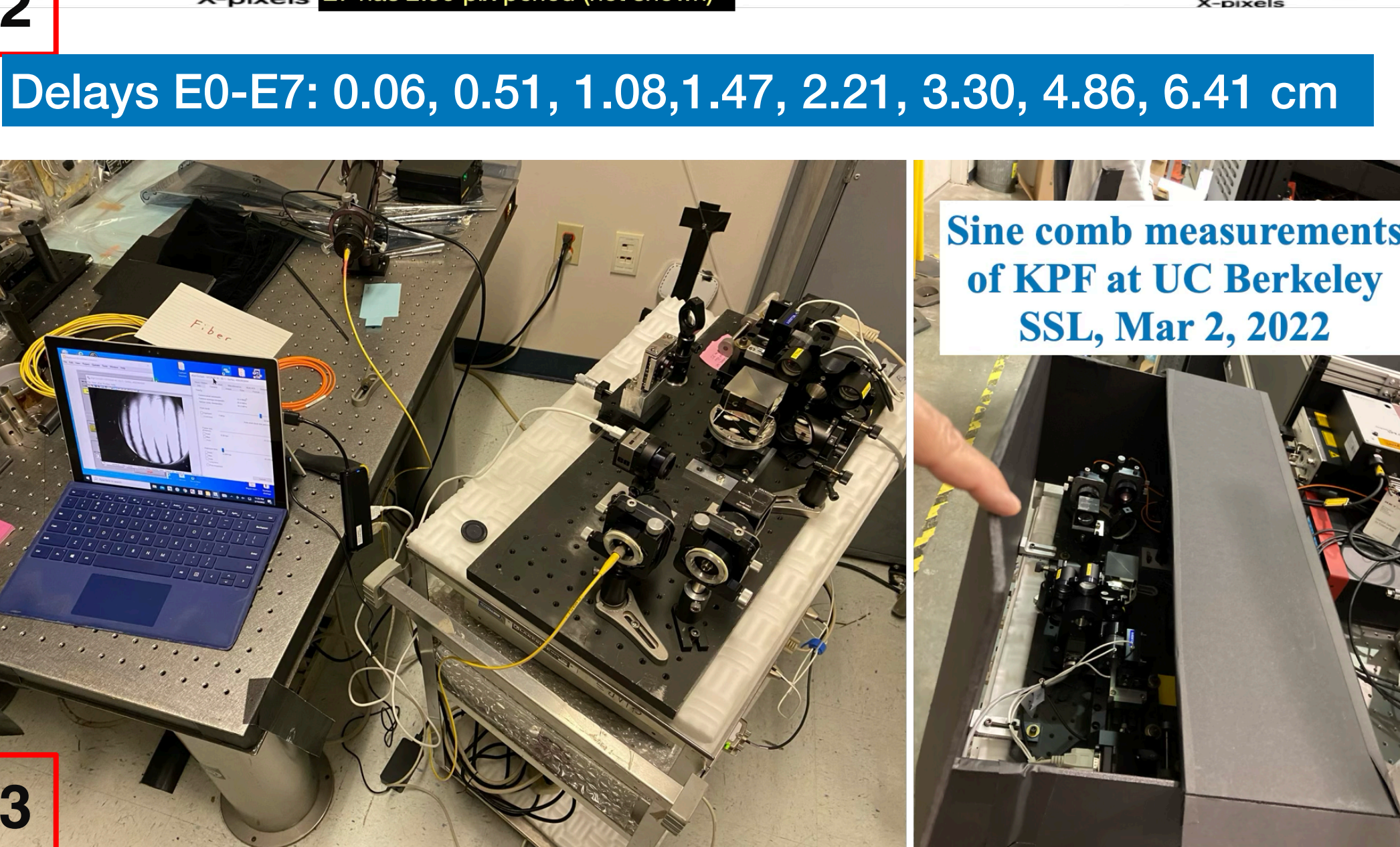
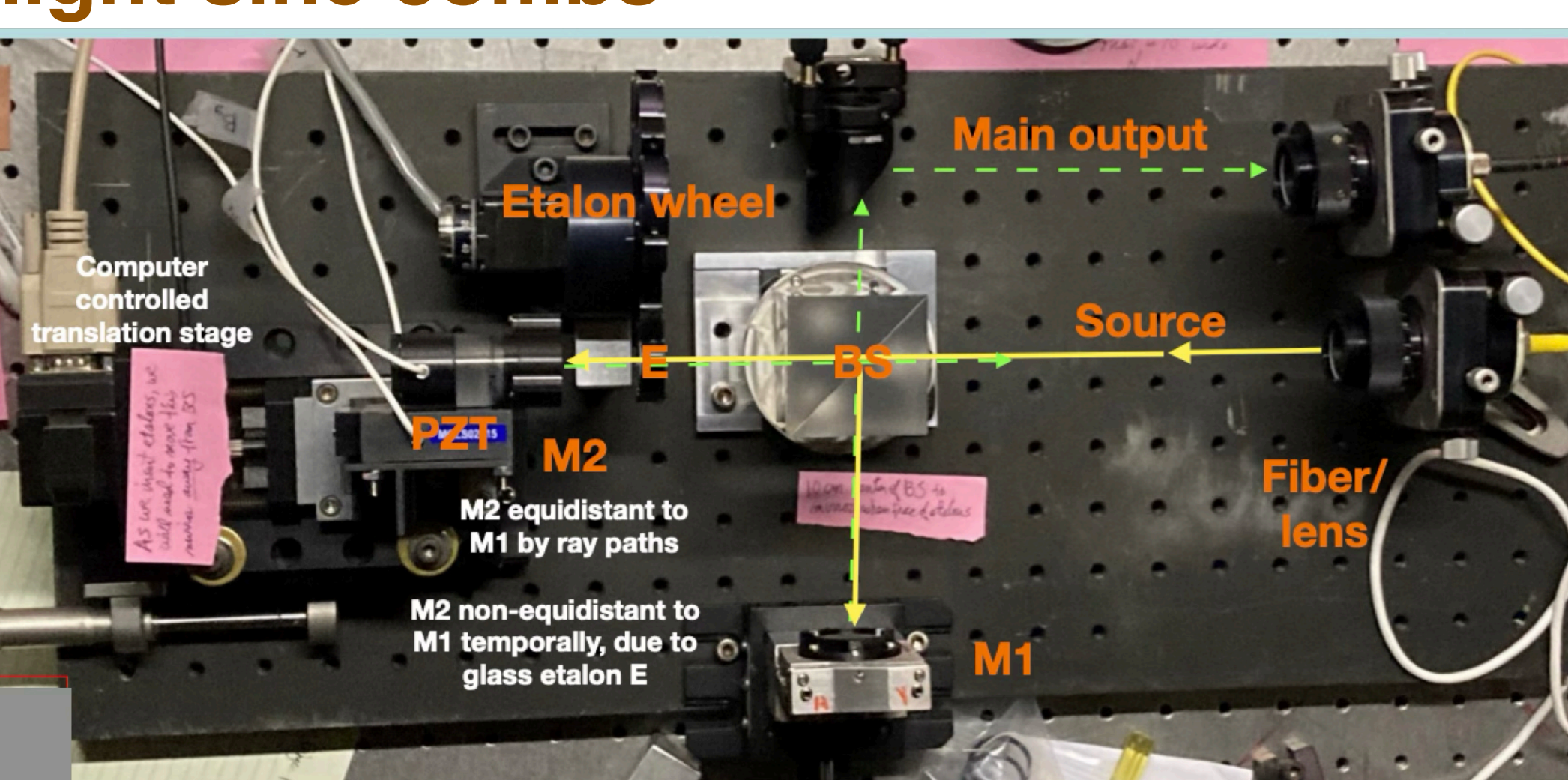
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-- During KPF assembly at UC Berkeley, PSF needed quickly. But, Laser Freq. Comb (LFC) unavailable

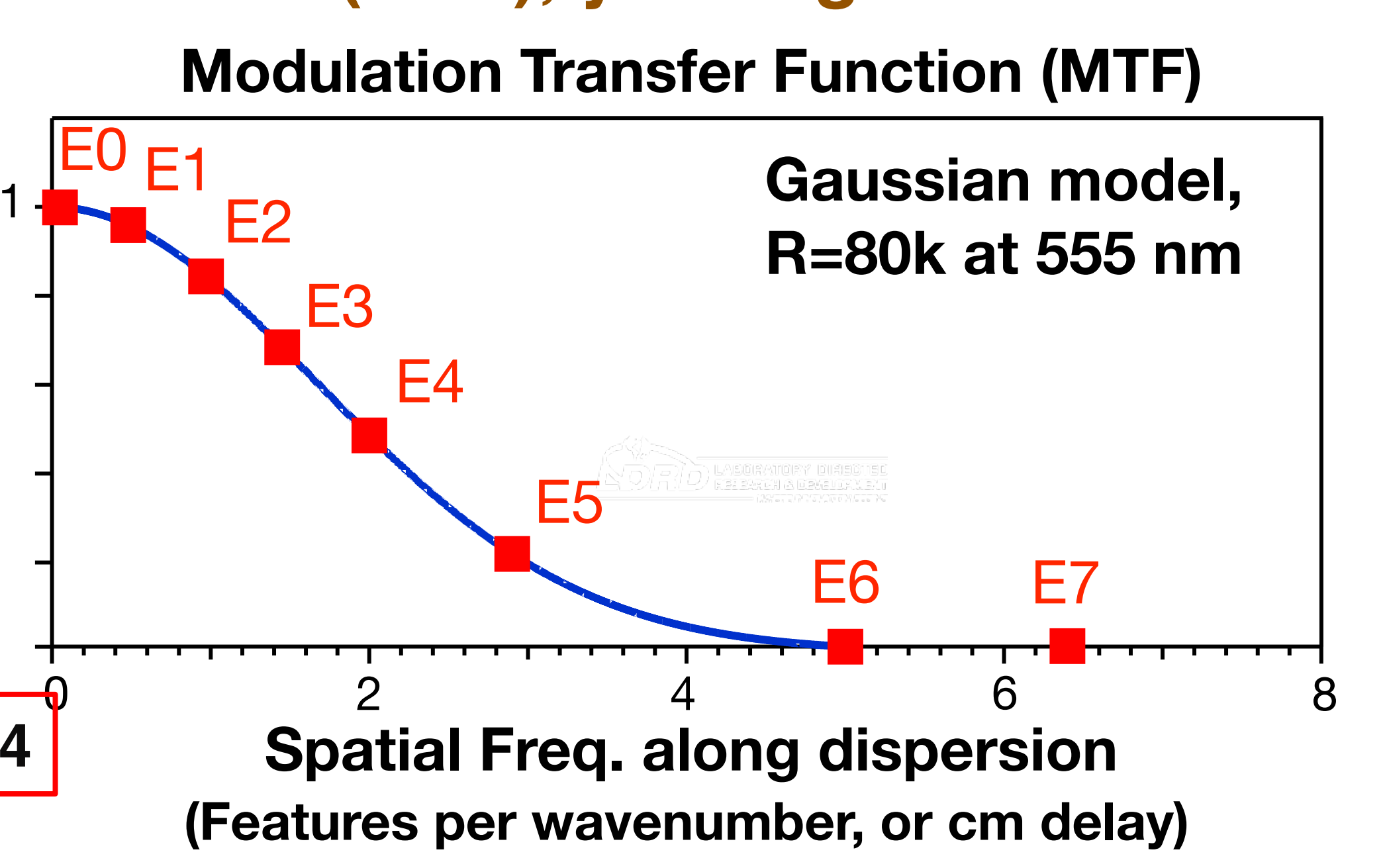


Supply chain delayed delivery of KPF Laser Frequency Comb in spring 2022. Proper alignment of KPF optical elements required finding point spread function (PSF) and its variation across detector chip, prior to summer shipping date to Hawaii.

-- Solution: Michelson interferometer with selectable delay creates white light sine combs



--Sine fringe visibility on spectrograph measures the Modulation Transfer Function (MTF), yielding PSF width.



--We did not use stabilized sine combs

We did not use a stabilized interferometer to generate sine combs, for expediency, cost, and since not necessary due to short exposures.

-- Background notes

The authors gained valuable insight into white light interferometers and sine combs in the 1990's[1-3]. Further insight gained in 2000's[4-7].

Ref. [8] describes Keck Planet Finder (KPF) design.

Other researchers have developed stabilized white light interferometers making sine combs for spectroscopy[9-11].

-- Advantages of MTF method

- White light lamp extends past **blue limit** (480 nm) of KPF Laser Frequency Comb
- Measures every pixel (**no gaps** as in a spectral lamp)
- Can measure high or low res, since selectable delay
- Inexpensive: built from **hand-me-down parts**
- Portable, fiberoptically connected to spectrograph

• **Intrinsic linewidth W_0 of calibrant not needed** as in Eq. 1 for conventional method convolving FWHM of calibrant and instrument in dispersion space

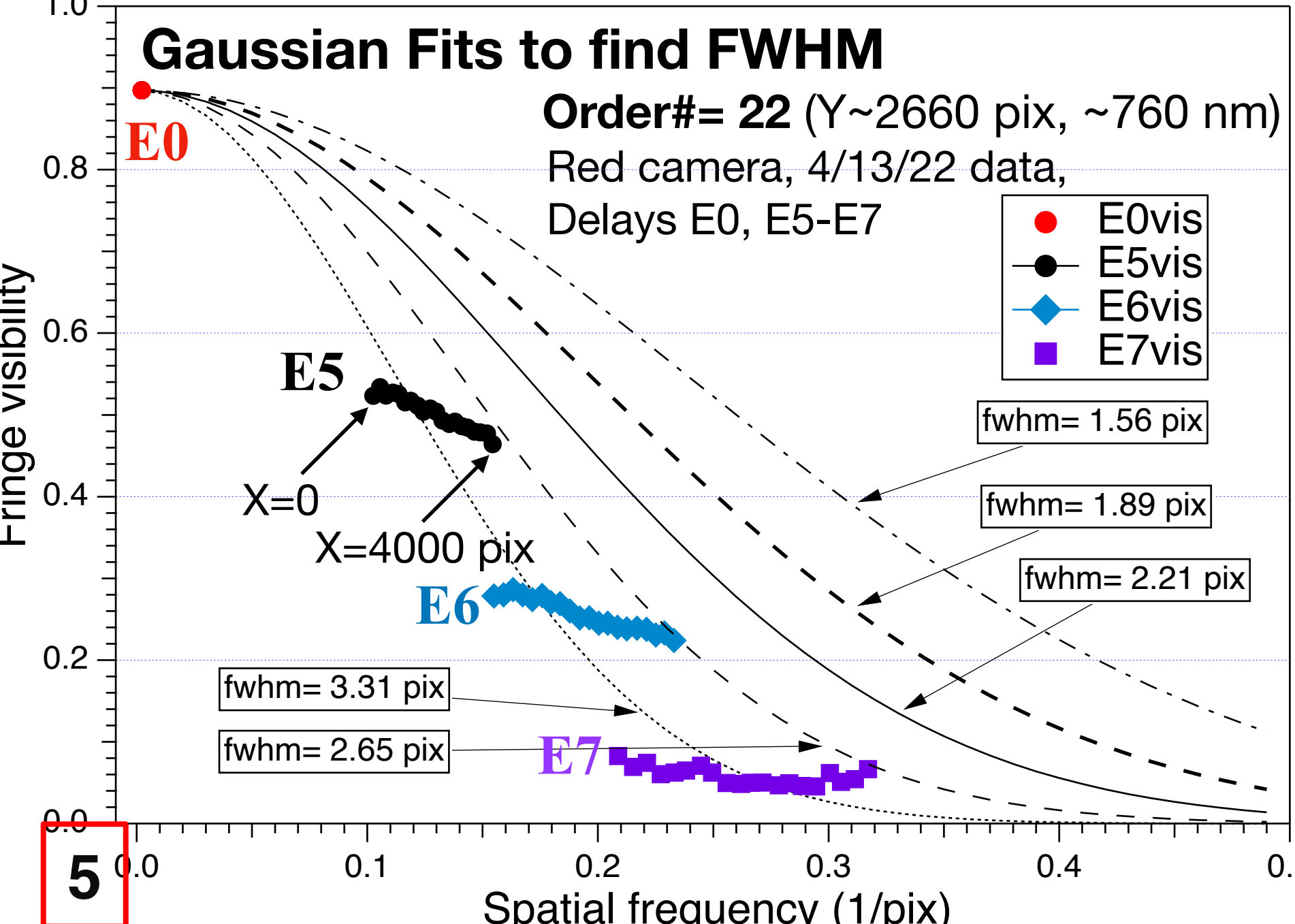
$$W_{instrm}^2 = W_{msrd}^2 - W_0^2. \quad \text{Eq 1}$$

-- Task: measure PSF as soon as possible

Measuring point spread function (PSF) and its variation over the detector was our task. The goal was to assist alignment of KPF optical elements during assembly.

Others were calibrating the KPF spectrograph for precision wavelength.

-- Example results for red camera



Comb spatial frequency changes across detector X=0 to X=4000 pix, mainly due to spectrograph

E0 delay (quasi-zero fringe frequency) establishes Gaussian model height.

Each individual delay visibility (E5, E6, E7) yields a value for FWHM when compared to E0, using simple Gaussian model. Plotted in maps Fig. 6-8.

-- References

[1] D.J. Erskine and N.C. Holmes, "White Light Velocimetry," Nature 377(6547), 317 (1995); <https://doi.org/10.1038/377317a0>

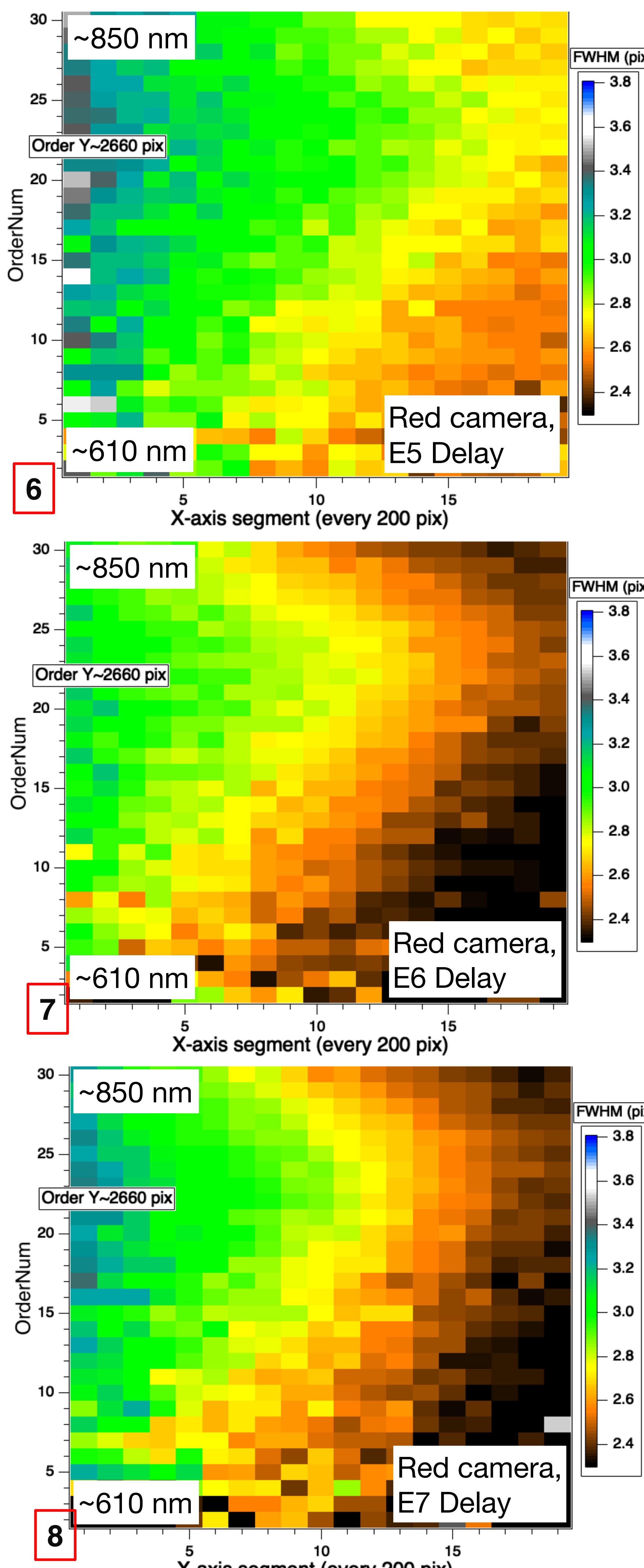
[2] D.J. Erskine and N.C. Holmes, "Imaging white-light VISAR," in 22nd Intnl. Congress on High-Speed Photography and Photonics, D.L. Paisley, Ed., SPIE 2869, 1080 (1997); <https://doi.org/10.1117/12.273416>

[3] D. J. Erskine, "Techniques in broadband interferometry," Tech. Rep. UCRL-TR-201695, Lawrence Livermore Nat. Lab. (2004); <https://doi.org/10.2172/15009760>

[4] D.J. Erskine and J. Ge, in Imaging the Universe in Three Dimensions, W. van Breugel and J. Bland-Hawthorn, Eds., ASP Conf. Series 195, 501 (2000); <http://digital.library.unt.edu/ark:/67531/metadc780974/>

[5] D.J. Erskine, "An Externally Dispersed Interferometer Prototype for Sensitive Radial Velocimetry: Theory and Demonstration on Sunlight," PASP 115, 255 (2003); [doi:10.1086/345995](https://doi.org/10.1086/345995).

-- PSF FWHM (pix) vs X,Y position on detector



For simplicity, sine visibility was analyzed in 200 pixel groups in dispersion (X) direction. Y-axis shows order#.

-- Take-away thoughts

Results for the three delays E5, E6, E7 are **independently determined, yet consistent** with each other.

Funding for this task was very brief. Furthering this **preliminary** work would make an interesting project useful to the spectroscopy community.