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Enhanced exoplanet biosignature from an interferometer addition to low res spectrographs

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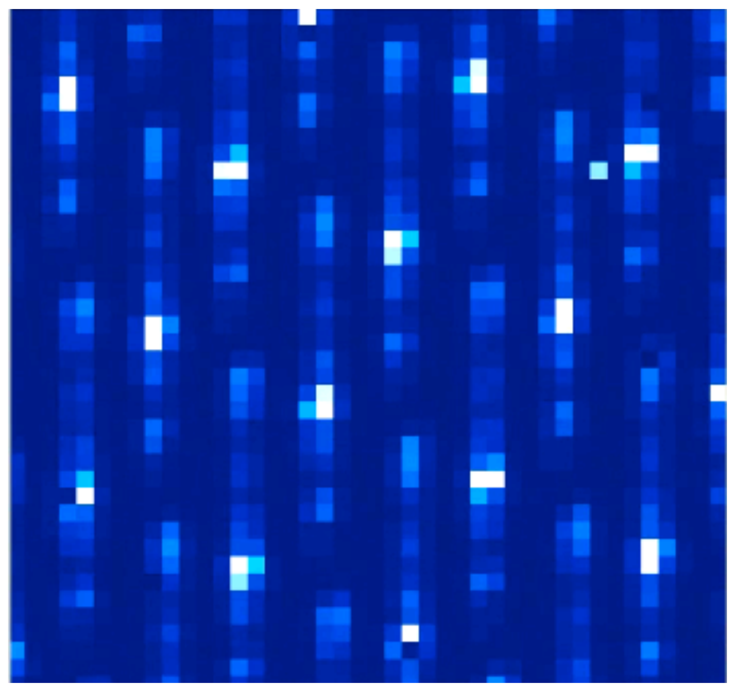
INTRODUCTION

Exoplanet atmospheric molecules (water, CO2, methane etc) vibrational spectra normally require high resolution (R) to detect, 50x higher than the R~70 that the Gemini Planet Imager (GPI) integral field spectrograph can supply. But because the physics of vibrating molecules creates a nearly *periodic* set of 30-40 absorption lines, detection is easier by a moire effect. We model how a small (6mm delay) interferometer, which has similar periodic transmission spacing as these lines, added in series to a low res spectrograph creates moire patterns. These are detected having a photon limited sensitivity similar to a R~4000 spectrograph.

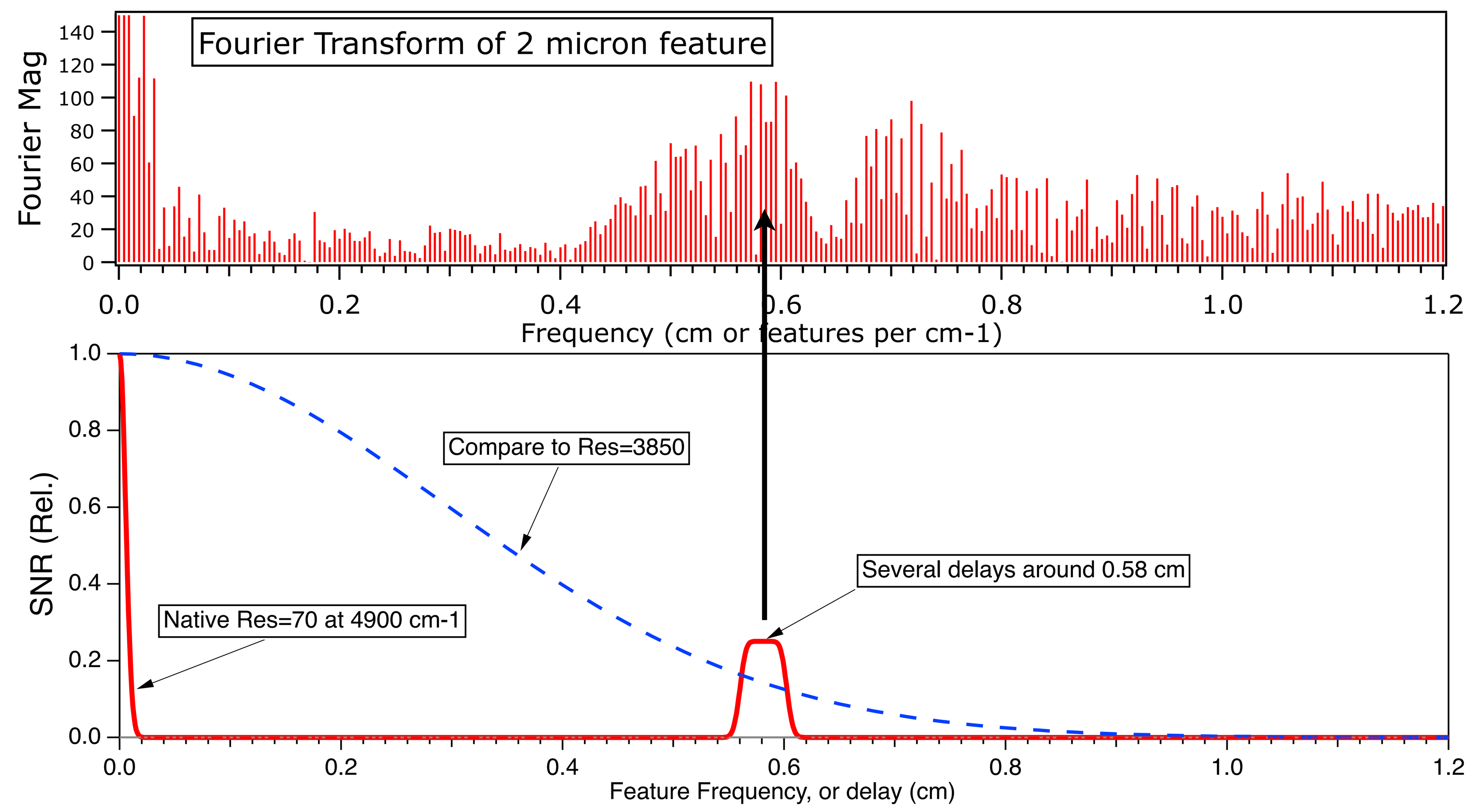
The technique is called Externally Dispersed Interferometry (EDI) and has been demonstrated on a number of astronomical spectrographs, but not yet on an IFS system.



Integral Field Spectrographs (IFS) are severely pixel limited. Here are small rainbows for each section of target spatial image made by a lenslet array– small because they cannot overlap. We use the Gemini Planet Imager IFS resolution as a concrete example, even though it may lack the aperture to collect the needed photons from small exoplanets.

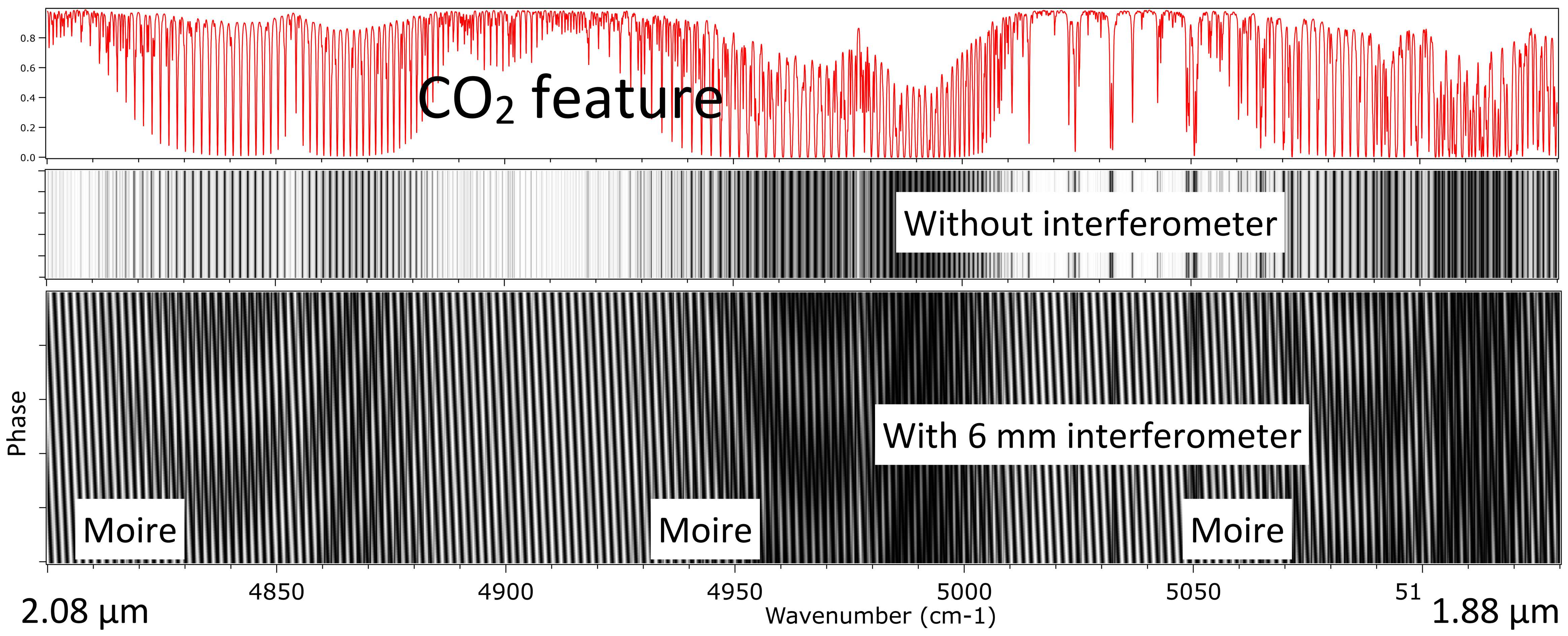
METHOD: Externally Dispersed Interferometry

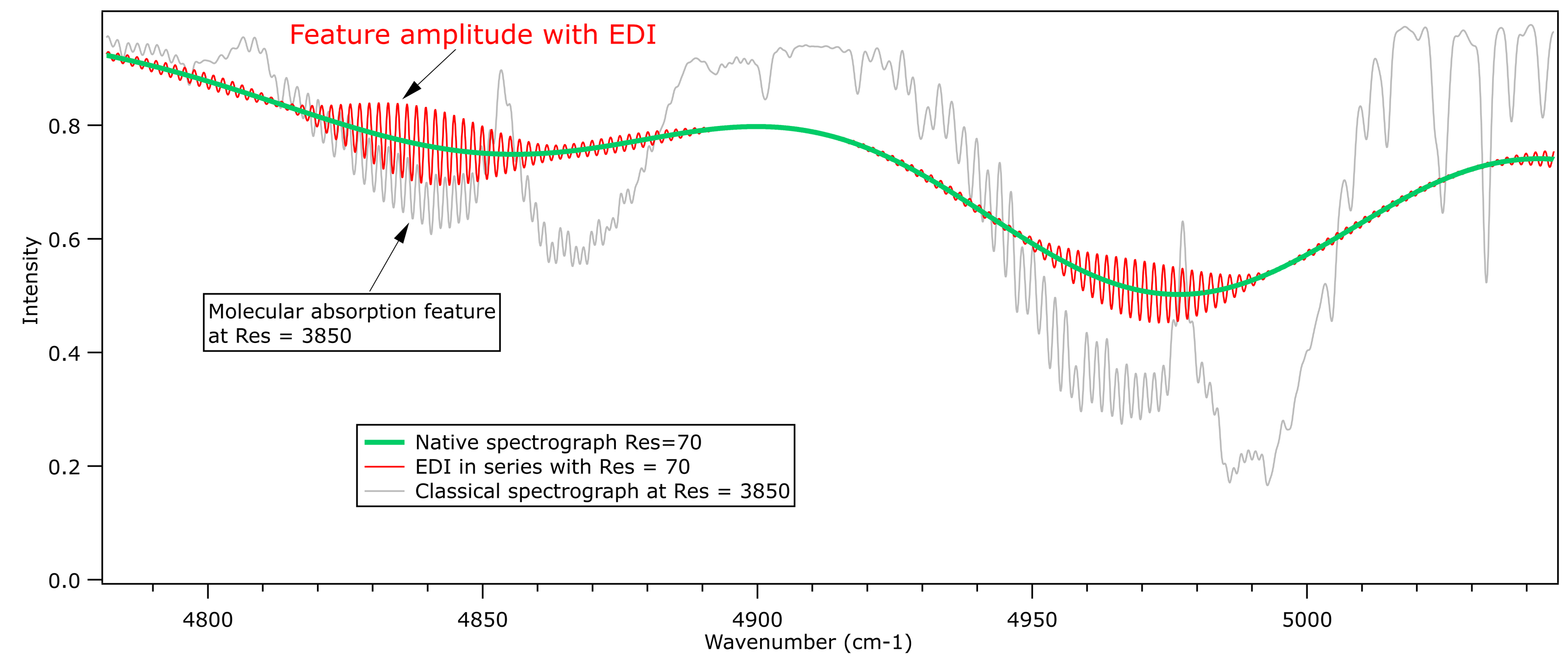
Fourier transform shows concentration of CO2 feature at high frequencies. Horiz axis is in units of interferometer delay (cm). We pick the 6 mm region for the delay since it is fertile.



(Bottom graph) Conventional spectrograph photon limited sensitivity having 3850 resolution shown in blue dashes. Wider in frequency space means better resolution in wavenumber space. Performance of EDI is the red peak at 5.8 mm. Key point: it is not necessary to measure all frequencies to detect a CO2 feature, we can place the EDI sensitivity peak at a strategic place. Hence R=70 has been boosted to R~4000 for detecting this feature.

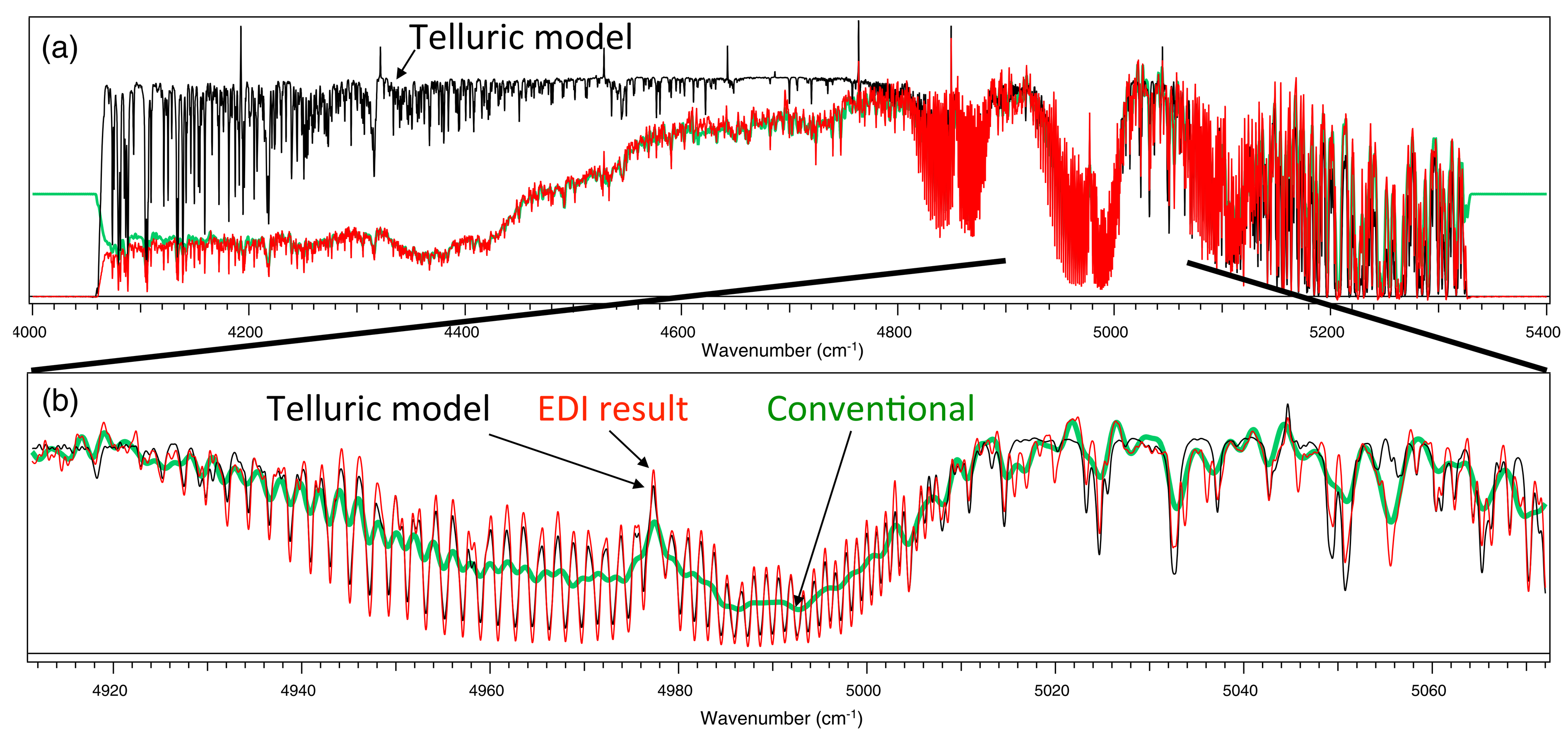
CO2 line spacing nearly periodic, hence strong moire patterns produced passing through interferometer comb



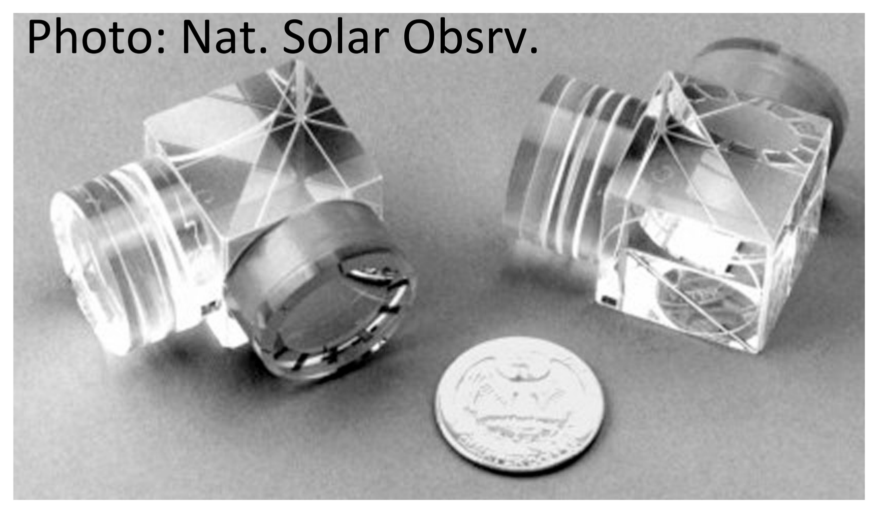


Moire intensity fluctuations measured by dithering delay by ½ wave

Demo on Mt. Palomar 5m NIR TripleSpec, measured CO2 feature at 5000 cm-1 with 2700 native resolution boosted 4x to 11000 by several contiguous delays up to 2 cm. The proposal here is to economize by using only the delays near 0.6 cm, since the CO2 feature shape is already known. Also, a lower resolution (70 instead of 2700) native disperser would be used.



Compact prism interferometers can be inserted into beam like a filter



Delay is dithered with a voltage

"**High-resolution broadband spectroscopy using externally dispersed interferometry at the Hale telescope: Part 1, data analysis and results**", D.J. Erskine, J. Edelstein, E. Wishnow, M. Sirk, P.S. Muirhead, M.W. Muterspaugh, J.P. Lloyd, Y. Ishikawa, E. McDonald, W. V. Shourt, and A. M. Vanderburg, J. Astr. Tele. Instrm. Sys. 2(2), 025004 (2016), doi: 10.1117/1.JATIS.2.2.025004.

http://spectralfringe.org/EDI/MyPubs4/TediTenxPart1gen.pdf

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