Externally Dispersed Interferometer: Implementation on a 2d Echelle Spectrograph

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Abstract: A fixed delay interferometer is placed at the slit of the Lick Obs. 2d-echelle spectrograph to imprint a periodic sinusodial fringe comb against the input spectrum. This boosts the effective resolution by a factor of 2-3.

OCIS codes: (300.6300) Spectroscopy, Fourier Transform; (300.6310) Spectroscopy, Heterodyne

An implementation of an externally dispersed interferometer (EDI) at the Lick Observatory 2d-echelle spectrograph is discussed. Demonstration of a resolution boosting effect capable of increasing the effective resolution beyond the Nyquist frequency of the spectrograph CCD is shown using the telluric lines of the solar spectrum. The phase of the interferometer fringe is uniform across the area of the spectrograph slit, allowing minimal height beams and 1d imaging applications. The mathematical basis and references for this technique are described in a companion presentation by this author at this conference.

The echelle data was taken with the assistance of Jerry Edelstein, Barry Welsh, Michael Feuerstein and Tim Erskine. Shauna Sallmen assisted in data reduction. We are grateful for the Lick Observatory and staff for use of their facility. Reference solar spectra were provided by Kitt Peak/NOAO. Work was partially supported by CalSpace/Lockheed, and NASA SARA research grants NAG5-9091 and NAG5-3051. This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

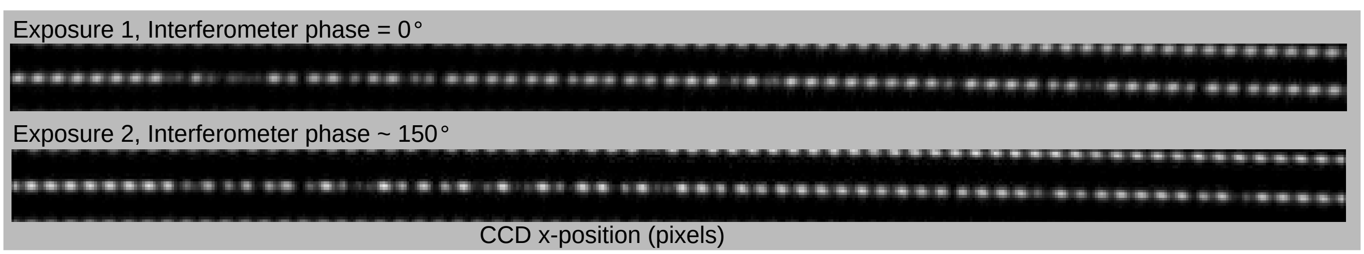

Fig. 1. Two exposures of the telluric line order (near 6868 Å) of star epsilon-Leo taken April 2002 with the Lick echelle spectrograph and a 11 mm fixed delay interferometer at its slit. The interferometer delay was changed by 150 degrees (0.4 λ) between the two exposures. The spacing of sinusoidal interferometer fringes is 1/delay = 1/1.1 cm = 0.9 cm^{-1}. (Data was also taken with a $\sim$30 mm delay and shown in the next Figure.) Note the difference in the Moire patterns, which manifests interaction between sinusoidal interferometer spectrum and features in the stellar spectrum having similar width as 0.9 cm^{-1}. Three such exposures at minimum are needed to fully isolate the fringing Moire signal from ordinary spectrum. Taking the difference between the phase step exposures isolates the fringing component, taking the sum isolates the nonfringing. Only one order of about 70 orders spanning from 4000 to 8000 Å is shown.

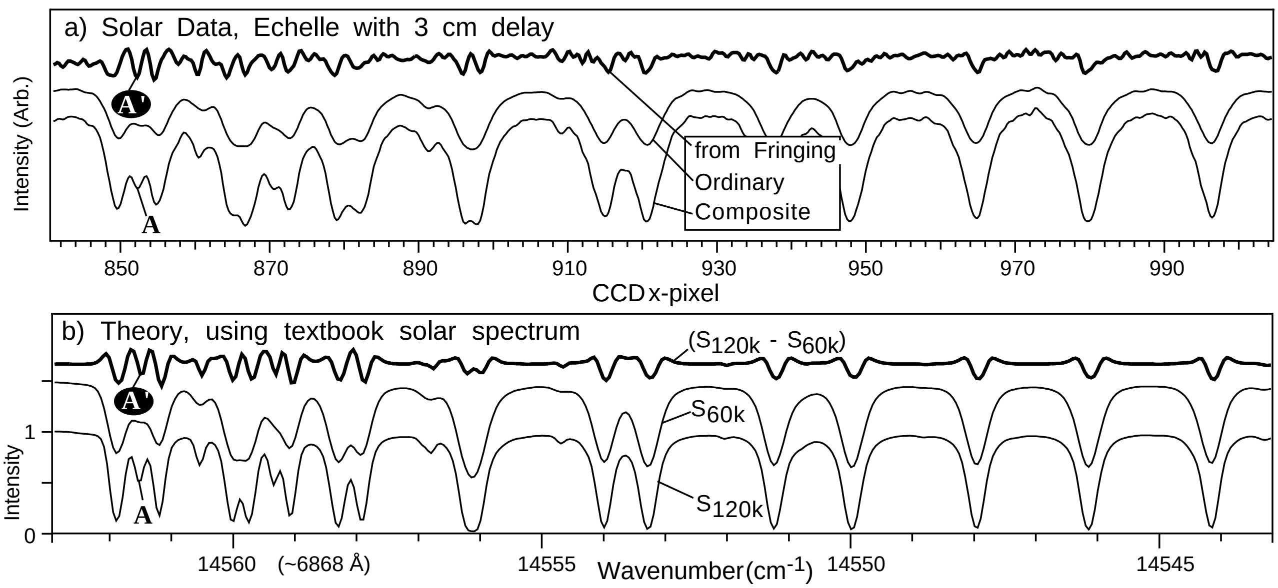

Fig. 2. Demonstration of a $\sim 2\times$ EDI resolution boosting effect on the Lick echelle grating spectrograph using a $\sim$3 cm fixed delay interferometer and observing the telluric lines of the solar spectrum. a) The ordinary resolution (without the interferometer) of the spectrograph is about $R = \lambda/\Delta\lambda$=60 k (upper thin curve). The telluric lines have a few narrow peaks in between the deeper peaks, such as indicated by "A", that cannot be resolved at R =60 k without the interferometer, but are resolved in the composite EDI signal (lower thin curve). The bold curve is the fringing component of the data after the heterodyning effect is reversed numerically. Adding it to the ordinary nonfringing component produces the composite spectra having boosted effective resolution. The analysis is preliminary because an equalization step where the relative weights between fringing and nonfringing components is adjusted has not yet been applied. The theory spectra of panel b) were measured at $R \sim 500$ k by the Kitt Peak FTS and artificially blurred to R=120 k (lower thin curve) and R =60 k (upper thin curve) resolutions. The difference curve (bold) agrees approximately with the measured fringing curve of panel a). The resolution boosting analysis can be applied to each order of the echelle format to cover a bandwidth from infrared to ultraviolet.