A Ground Based Multiline Spectrometer for the Analysis of Solar Atmospheric Waves

J. Staiger
Kiepenheuer-Institut, 79104 Freiburg, Schönneckstrasse 6, Germany
joe@kis.uni-freiburg.de

Abstract. The presence of magnetic fields may influence the propagation characteristics of acoustic waves in the solar atmosphere. Investigating amplitude and phase properties may thus help to reveal the 3D geometry of magnetic fields above sunspots and activity regions. The height resolution of this type of measurements was limited in the past by the limitations of existing spectrometers. We have developed a double-etalon based spectrometer allowing us to observe solar velocities with an unprecedented number of spectral lines. A test version of this instrument has been installed at the Vacuum Tower Telescope of the Kiepenheuer-Institut at Tenerife in July 2009 for the first time. 16 spectral lines were observed at a cadence of 60 secs over a period of 4 hours. The field of view was 100”x100”. The multiple diagnostic diagrams resulting from these observations clearly reveal the simultaneous p-mode ridge structure at every height level from the deep photosphere (538.0 nm C I) to the chromosphere (656.3 nm H-alpha). We are confident that individual acoustic modes may be vertically traced through the atmosphere at yet unsurpassed height resolution in the future.

1. Introduction
A consistent observational picture that would explain the energy transfer between the solar surface and the hot outer layers of the solar atmosphere currently does not yet exist. Tunneling of evanescent P-Modes through the photometric barrier and subsequent shock formation have long been suggested as a means to heat the solar chromosphere. Yet there is still a lack of experimental evidence for this type of conversion. Primary observational tools currently are etalon-based spectrometers as pioneered by Cavallini et al. [1] and Bonaccini et al. [2]. We suggest that overcoming the limitations of existing spectrometers with respect to their multiline capabilities may improve this situation.

We have designed a Fabry-Perot based device allowing us to observe velocities and intensities simultaneously across a large field-of-view with a high number of spectral lines. We hope that we will be able to contribute to a better understanding of chromospheric heating with this instrument.

2. Optical Layout
The core elements of an etalon based spectrometer are a narrowband filter selection unit (see below, at image center) followed by two Fabry-Perot etalons arranged in a tandem configuration. During our experiments we used a collimated beam environment where the etalons were placed within the parallel beam section in front of the CCD camera (shaded box outlines spectrometer bounds).
3. Matrix Filter Shifter

We have designed a new type of filter mount allowing us to change narrowband pre-filters with high speed and accuracy. This unit removes one of the primary temporal bottlenecks of existing spectrometers with respect to multiline capabilities. More spectral lines can be observed in a quasi-simultaneous mode than previously possible. 16 filters may be mounted to a grid-type pattern which will be shifted through the instrument’s main beam by a Cartesian two-axis stepper drive.

4. VTT Experimental Setup

All experiments with the new spectrometer were carried out at the Vacuum Tower Telescope within the Teide Observatory at Izana, Tenerife. The etalons of the GFPI device (GFPI: Göttingen Fabry Perot Interferometer) which had been installed at the VTT in recent years were used as test etalons (see below, at image center).
Figure 3. VTT laboratory setup.

Setup Specifications:
- CCD Camera: DALSA 1M30
- Chip Size: 1024 x 1024
- Binning: 2 x 2
- Etalons: IC Optical Ltd, 70 mm
- Spectral Range: 560 nm - 860 nm
- Field-of-View: 100” x 100”
- Exposure Times: 5 ms
- Resolution Limit: 0.2”

5. Test Observations
During an observational campaign in July 2009 the spectrometer was tested for the first time. 16 spectral lines were observed simultaneously. We achieved a cadence of 60 secs over a time span of 4 hours. Exposure times were of the order of 5 ms. The following table gives an overview over the spectral lines and the number of scansteps.

| Wavelength | Element       | Scansteps |
|------------|---------------|-----------|
| 517.2 nm   | Mg I          | 20        |
| 538.0 nm   | C I           | 15        |
| 538.1 nm   | Fe I          | 15        |
| 538.2 nm   | Ti I          | 15        |
| 543.4 nm   | Fe I          | 10        |
| 557.6 nm   | Fe I          | 20        |
| 589.0 nm   | Na D2         | 30        |
| 589.6 nm   | Na D1         | 30        |
| 630.1 nm   | Fe I          | 20        |
| 630.15 nm  | Telluric      | 15        |
| 630.2 nm   | Fe I          | 15        |
| 632.8 nm   | He-Ne Laser   | 15        |
| 656.3 nm   | H-Alpha       | 50        |
| 709.1 nm   | Fe I          | 20        |
| 777.1 nm   | Fe I          | 20        |
| 777.2 nm   | Fe I          | 10        |
6. Test Observations
The operating software contains quick look tools which allow us to judge the quality of an observation shortly after the end of the measurements. The following screen dump displays such spectral data for 8 of the 16 observed absorption lines. Shown here are simultaneous multiple p-mode diagrams taken from the low photosphere (upper left, 538.0 nm, C I) to the chromosphere (lower right, 656.3 nm, H-Alpha).

![Multiple p-mode diagnostic diagrams](image_url)

**Figure 4.** Multiple p-mode diagnostic diagrams.

7. Conclusions.
We have constructed and tested a multiline spectrometer which is able to handle 16 spectral lines in a simultaneous observation mode. We expect to get detailed information about amplitude and phase properties of solar atmospheric waves at a height resolution not achieved before.

8. Acknowledgements.
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References
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