LOWL - AN INSTRUMENT TO OBSERVE LOW-DEGREE SOLAR OSCILLATIONS

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ABSTRACT The High Altitude Observatory (HAO) of the National Center for Atmospheric Research is constructing an instrument optimized to observe solar oscillations of low degree (LOWL). The primary goal of this instrument is to measure the frequency splitting of the low-degree modes in order to determine the rotation rate of the solar core. The LOWL is a doppler imager based on a Potassium Magneto-Optical Filter (MOF) and employs a two-beam technique which allows the simultaneous observation of solar images in the red and blue wings of the absorption line. The atomic vapor of the MOF makes the instrument very stable against drifts in the wavelength zero-point, while the two-beam design makes the instrument insensitive to noise sources due to image motion and scintillation and allows a doppler analyzer with no moving parts. The instrument will be deployed at HAO's observing station on Mauna Loa, Hawaii in mid-1993 and will operate for a period of at least two years.

INTRODUCTION

Over the past two decades, the solar acoustic oscillations have emerged as a powerful probe of the solar interior. Observations of the low-degree oscillation modes are critically important since they penetrate most deeply into the solar core. Integrated light instruments, based primarily on atomic resonance techniques, provide excellent measurements of the low-degree modes. Unfortunately, the optical averaging of these methods does not allow the unambiguous separation of modes with different azimuthal orders, which is required to measure rotational frequency splittings. Spatially resolved

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observations of the oscillations have been made by many groups employing different techniques. However, none of these efforts have been able to measure the frequency splittings of low-degree ($\ell < 10$) modes with sufficient accuracy to constrain the solar rotation rate interior to $0.4 R_\odot$. We believe that these imaging experiments have failed in this regard for two reasons. The first is fluctuations in the velocity zero-point of the instruments, which should be kept below 1 m/s rms. The second is the lack of sufficient duration of the observations which is set at $\sim 1$ year by the realization noise limit. These and other requirements of an experiment to observe the low-degree oscillations are described in more detail elsewhere in these proceedings (Veitzer, et al., 1992).

INSTRUMENT DESCRIPTION

The LOWL uses a Magneto-Optical Filter (MOF) which combines the wavelength stability of atomic resonance methods with the ability to image the sun. A block diagram of the instrument is illustrated in Figure 1. The weatherproof instrument will sit outside in proximity to the existing dome of HAO’s Mauna Loa Solar Observatory (MLSO) and will operate whenever the sun is above the horizon. Some of the instrument electronics are located in a bay below the optics section, with the remainder of the electronics and the control computer located in a rack in the observatory.

Figure 1. LOWL block diagram showing the location of sub-assemblies. The components to the right are located outdoors in the instrument housing, while those to the left are located in the MLSO observing room.
A heliostat light feed, which comprises the only moving part of
the instrument, will direct the solar beam down the polar axis. It has an
elliptical flat mirror driven by two Compumotor servomotor systems. Each
of the servo motors has its output reduced by a harmonic drive speed reducer
of 200:1 ratio. Due to the modest spatial resolution needed to observe low-
degree modes, no high speed active image compensation is required. A
portion of the beam is directed to a quad cell photodiode to aid in image
acquisition and to correct slow drifts in the heliostat guiding. The heliostat
box is sealed with an entrance window of Schott RG9 which also provides
heat rejection.

The MOF doppler analyzer filters the solar light and forms solar
images on a CCD detector at the back of the optics section. The MOF
will employ a Potassium vapor and observe the solar line at 769.9 nm.
The configuration of the MOF doppler analyzer is shown schematically in
Figure 2. The input light initially passes through a linear polarizer and
into the first atomic vapor in a longitudinal magnetic field. The circular
dichroism (Zeeman effect) and circular birefringence (Faraday effect) of the
vapor modify the polarization of the light near the wavelengths of the sigma
components allowing transmission through a second linear polarizer which
has its transmission axis perpendicular to the first. The Zeeman effect of
the second vapor in a longitudinal magnetic field will convert the linearly
polarized light into opposite circularly polarized light in opposite wings of
the line.

Solar images in the wavelength bands in the wings are physically co-
spatial but are encoded by circular polarization state. They are converted to
orthogonal linear polarizations by a quarter-wave plate and then separated
spatially by a calcite rhomb. This allows solar images in the blue and red
wings to be formed simultaneously on a CCD detector. Note that the doppler
analyzer has no moving parts, and that the two beams are not physically
separated until immediately before the CCD camera.

The atomic vapor provides a stable zero-point reference for the
velocity measurements. Any variations of the imposed longitudinal fields or
vapor optical depths will produce velocity variations to only second order.
Temperature stability of the atomic vapor of 0.1 K is sufficient to stabilize
the measured velocity to better than 1 m/s.

The dual-beam technique allows for the simultaneous recording of
solar images in the red and blue wings of the absorption line. This makes
the measured velocities insensitive to noise arising from non-solar temporal
intensity variations, atmospheric and instrumental image motion, and
wavelength chopping.

Data acquisition and instrument control functions are performed by an
industrial grade PC computer. Each image is sampled with approximately
80x160 pixels by a COHU series 6400 CCD camera at a frame rate of 15
Hz. Frames are digitized to 8 bits and summed in real time with a DIPIX
Power Grab board. Every 15 seconds the summed images are recorded on
one of two Extabyte 8200 tape drives through a SCSI interface board in the
PC. Control of the heliostat tracker servomotors is accomplished by the PC
via RS-232. The time base for the experiment is maintained by a WWV
receiver board plugged into the PC. Bias and gain images will be acquired
automatically throughout the day.
Figure 2. Schematic of MOF operating principle. Optical components are shown to the left, while the evolution of the transmission profile is shown to the right. Polarization states are indicated by the arrows above the transmission profiles.

SUMMARY

Despite considerable effort, observations of the frequency splitting of low-degree solar oscillations have been elusive. This indicates the difficulty in performing these observations and points toward the need for an instrument optimized for this task. The two-beam MOF is ideally suited for these observations due to its wavelength stability and suppression of noise sources due to image motion and scintillation. In addition, the instrument is compact and very cost effective, with total costs of parts and labor estimated at about 200 k$. Construction of the instrument is proceeding and we expect deployment sometime around mid-1993.

REFERENCES