

HMI Filter Calibration



Purpose:

to make sure we can characterize the transmission profile (transmittance) of the HMI filter system through accurate enough measurements

Data needed:

•maps of the relative phases \emptyset and contrasts *B* of the 5 Lyot + 2 Michelson elements, in Obsmode and Calmode, and as a function of incidence angle and temperature {*T*(*l*) = [1+ *B* cos(2 π *l* / FSR + \emptyset)] / 2}

•maps of amplitudes and phases of the fringes produced by the front window and the blocker filter, and as a function of temperature

•throughput of the instrument to determine exposure time

Analysis not performed at all yet: temperature dependence (planned for the vacuum tests)



Requirements, Specifications, and Precision



Noise on the Doppler velocity determination (requirement):
25 m/s in quiet Sun for a dynamic range ±6.5 km/s (IPD)

Precision to reach on the fringes (requirement): ripples in the front window and blocker filter should have an amplitude <1% of the maximum transmittance (IPD)</p>

Field of view (specification): 2000" (CPS)

Impact of the precision on the contrasts: a 10% error produces a zero-velocity offset < 1m/s and an increase in Doppler velocity noise <7.8% (with averaged MDI-like algorithm, 6 positions)</p>

Impact of the precision on the phases: 0.25° error produces a zero-velocity error <4.4 m/s and an increase in Doppler velocity noise <0.05% (idem)</p>



Light Source:Sun through the heliostat

·Objective:

to learn how to co-tune HMI by obtaining relative phase maps for the tunable elements (+ maybe characterize the fringes on the front window and blocker filter at the same time)

•Procedure:

in Calmode, we take a 27-position detune sequence. We fit —leastsquares— for: relative continuum intensity, solar line width, solar line depth, 3 phases (E1, NB, WB) (+ maybe 6 Fourier coefficients of the fringe pattern). Solar line central wavelength assumed to be 6173.3433 A (in air including gravitational redshift) in frame at rest, and corrected for Earth orbital and rotational motions. Nothing done in Obsmode



Wavelength and Spatial Dependence (I)



-Assumptions:

•we use an averaged blocker filter+front window transmission profile

•we assume phases=0 and contrasts=0.98 for the non-tunable elements

- •we use measured values of FSRs
- •solar line is approximated by a Gaussian profile

 What has already been analyzed: in Feb., 6 detune sequences in Calmode with sunlight taken at different days (only 3 useful)
Phase maps obtained with the different detune sequences give more -or-less similar results (more problems for the NB Michelson)
In June, several detunes but major problem: linewidths too large and poor reconstruction

Problems encountered

bad exposures, overscans, "shadows" (vignetting ?) on the images, clouds in the sky





Lyot Element E1 120 70.0 69.5 100 69.0 Phase 80 68.5 Ē 68.0 60 degrees) 67.5 40 67.0 66.5 20 66.0 0 20 40 80 80 100 120 0



Transmission Profiles of the Mk I and the Mk II Lyot

The newer Lyot has higher quality calcite in the two thickest elements (E1 and E2). These curves show only the effect of Elements E2 through E5 since E1 doesn't have a exit polarizer. The orange curves are the ideal theoretical transmission. The dip in the center is the solar 6173.35A line (these were done with sunlight).





Light Source:

dye Laser +stimulus telescope +circular target ($\emptyset = sun$) in focal plan of stimulus telescope +diffuser

·Objective:

to obtain phase and contrast maps for the tunable elements

Procedure:

in Calmode, we take a 27-position detune sequence, we analytically derive the phases and contrasts (E1, NB, WB) {Using the fact that $cos(a)+cos(a+2\pi/3)+cos(a+4\pi/3) = 0$ } Idem in Obsmode

Assumptions:

laser emission profile is a Delta function with a linewidth < 1 mA Laser intensity constant throughout the detune sequence we use measured values of FSRs



What has already been done:

we have several detune sequences taken at different days In Feb., the phase and contrast maps obtained with the different detune sequences are not consistent with each other except for E1 (contrasts > 1 sometimes)

In June: phase maps roughly consistent with each other, but major problem low contrast for NB (0.9 on average)

Problems encountered

difficulty to remove dark frame, some bad exposures and overscans (corrected in June)

wavemeter off (main problem)

laser wavelength unstable (main problem, will be monitored)

laser intensity unstable (will be monitored)



Lyot Element E1 Narrow-Band Michelson 0.95 -165.0120 120 -166.0 0.94 -166.0 -167.0 -167.0 -169.0 -169.0 -170.0 -171.0 -172.0 -172.0 -173.0 -174.0 -175.0 -176.0 -177.0 100 100 0.93 0.92 80 80 Contrast pixels pixels 0.91 60 60 0.90 0.89 4040 0.86 20 20 0.87 -178.00 -179.00 0.86 20 60 80 20 60 80 0 40 100 120 Ð 40 100 120 pizels pixels



Wavelength and Spatial Dependence (III)



Light Source:

dye Laser +stimulus telescope +circular target ($\emptyset = sun$) in the focal plan of the stimulus telescope +diffuser

-Objective:

to obtain phase and contrast maps for the non-tunable elements

•Procedure:

in Calmode, we first take a detune sequence and then we take a series of 10-position cotune sequences at different laser wavelengths (27), we fit for: phases and contrasts (E2, E3, E4, E5), and laser relative intensity. The images are corrected for variations in the laser intensity. Idem in Obsmode

Assumptions:

we use measured values of FSRs we use an averaged front window+blocker filter transmission profile laser wavelengths known, laser intensities known laser line assumed to be a Delta function with linewidth < 1mA



What has already been done:

In Feb.: data available but due mainly to instability in laser wavelength and to wavemeter off, no useful results In June: in process

 Problems encountered difficulties to remove the dark frame wavemeter off (main problem) laser wavelength unstable (main problem) laser intensity unstable



Wavelength and Spatial Dependence (IV)



-Light Source:

lamp +stimulus telescope +field stop (ø=sun) at focal plan of stimulus telescope

·Objective:

to obtain phases and amplitudes or Fourier coefficients of the fringes produced by front window +blocker filter

in Calmode, we take a detune sequence and fit for the 14 Fourier coefficients (7 cos, 7 sin) and the lamp relative intensity idem in Obsmode: front window not in focus anymore

Assumptions:

we use phase and contrast maps of the tunable elements we use an averaged front window+blocker filter transmission profile lamp power spectrum assumed to be flat, and intensity constant we use measured FSRs



-What has already been done:

In Feb., 3 detune sequences in Calmode analyzed: 2 with field stop, including 1 for radiation test front window and 1 for flight front window

In June, several detune sequences taken. None analyzed

Problems encountered

a lot of parameters to fit for: lack of accuracy !









D.0

0.0

D.D

9.0

ę

é

텯

ę





묾

Angular Dependence

Light Source:
dye Laser +stimulus telescope +diffuser
Obsmode: circular target (ø=sun) at the focal plan of the stimulus telescope +PCU with hole-plate (as an aperture stop)
Calmode: field stop (small ø) at the focal plan of the stimulus telescope

·Objective:

to obtain wavelength drifts as a function of incidence angle for the tunable and non-tunable elements

•Procedure:

in Obsmode: we use the PCU with a 25 mm ø hole in between stimulus telescope and HMI. Radial distance of the hole center determines incidence angle. Diameter of the hole determines angle range. There is no (or reduced) cone averaging, and the ray paths inside the filter vary with angle. We need to disentangle spatial and angular dependences, either using phase maps of the individual elements, or by comparing overlapping areas with the case "normal incidence".

In Obsmode



PCU with hole



Angular Dependence



hole location known by taking Obsmode image. We tested 2+2 angles (horizontal+vertical) +0°, more needed to cover the entire phase map. We need to take detune (or co-tune) sequences at different laser wavelengths to characterize the non-tunable elements.

in Calmode: using only the laser +field stop +stimulus telescope, and selecting different incidence angles by moving the instrument legs. Small spatial dependence corrected by comparing with individual phase maps or comparing overlapping areas with the case "normal incidence"

-Assumptions:

we use an averaged front window+blocker filter transmission profile laser wavelengths assumed to be known (will be monitored) laser intensity assumed to be known (will be monitored) we use the measured FSRs



Angular Dependence



-What has already been done:

In Feb.: only Obsmode. We have at least 4 detune sequences taken different days analysis done for tunable elements but results useless because phase maps too different from individual phase maps In June: in process

 Problems encountered not enough angles wavemeter off laser wavelength unstable laser intensity unstable individual phase maps different from phase maps obtained with this procedure: impossible to disentangle angular from spatial effects



Throughput



Light Source:Sun through heliostat

Objective:to determine the exposure time

•Procedure:

in Obsmode, we take a series of 27-position detune sequences at different times during the same day, we fit for: solar continuum intensity *Ic*, solar line wavelength, linedepth, and linewidth. Using average value of *Ic*, we determine the atmospheric absorption coefficient by plotting Ic=f(airmass). The ratio outside intensity/ inside intensity is measured before each detune. Nothing done in Calmode

-Assumptions:

value of CCD reverse gain = 19 we derive a theoretical value for the average HMI filter equivalent width, based on averaged front window and blocker filter transmission profiles, and phases=0 and contrasts= 0.98



Throughput



we use a theoretical value (blackbody radiation; from Jesper) for the number of photons per pixel per second in the passband outside the instrument

Solar line approximated by a Gaussian profile

Phases for the tunable elements are obtained from previous tests

What has already been done:

In Feb.: we have at least 4 detune sequences taken the same day at a different time In June: 1 cotune and 1 detune analyzed

-What we need

more detune sequences around noon (local time) to access the lowest airmass possible

Problem encountered

ratio intensity inside/intensity outside inconsistent for one detune sequence











listSun080222°002209



listSun060222°174615



Temperature Dependence



Light Source:

Sun through heliostat (we need a very stable light source, solar line wavelength drifts by --at most-- 0.35 mA in 10 minutes) lamp+ stimulus telescope

-Objective:

to determine the wavelength drift, and the fringe pattern variations, with the temperature

•Procedure:

in Vacuum, and Calmode only (for stability), we perform detune sequences at different temperatures that span the range of the oven (e.g. 28°, 30° and 35°). In sunlight: we will fit for the solar continuum relative intensity, solar linewidth and linedepth, and phases of E1, NB and WB. Solar line central wavelength corrected for Earth orbital and rotational motions.

With lamp: we fit for the Fourier coefficients of the fringe pattern.



Temperature Dependence



Assumptions:

solar line approximated by Gaussian profile measured FSRs lamp power spectrum flat and lamp intensity constant averaged blocker+front window transmission profile

What has already been done: nothing