

The Visible–Light Magnetograph at the Big Bear Solar Observatory: Hardware and Software

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Abstract. In this paper we report about the current status of the control and acquisition software package developed to control the visible-light imaging magnetograph (VIM) system at the Big Bear Solar Observatory (BBSO). The instrument is designed to perform high-spatial and high-temporal observations of the solar photosphere and chromosphere utilizing the remodeled Coudé-feed of the 65 cm vacuum telescope.

1. Introduction

The visible-light magnetograph (VIM) is a Fabry-Pérot based filtergraph instrument in a telecentric configuration, it will expand the capabilities for measuring solar magnetic fields at BBSO (Denker et al. 2002, Shumko et al. 2002). VIM is designed to work with a combination of a narrow-band prefilter and a single Fabry-Pérot interferometer (FPI). Standard observations will be performed in the Zeeman sensitive neutral Iron lines at 630.10 nm and 630.25 nm respectively. Modifications of the optical setup will also allow for observations in other spectral lines in order to probe the solar atmosphere from the photosphere to the chromosphere. The two-dimensional filtergraph will replace the Digital Vector Magnetograph (Spirock et al. 2001), attached to the 25 cm telescope, after the New Solar Telescope is operational. VIM is currently operating in a spectrometer mode. The integration of an adequate polarization optics (calibration unit, modulation package, analyzer) and the development of the corresponding control mechanisms is a future task.

2. Hardware

The key parts of the instrument are formed by (a) the SIFAM (formerly Queensgate) servo-stabilized FPI system and (b) a high-speed DALSA CCD camera used for image acquisition. Both parts, the FPI system and the camera are controlled and synchronized via a single processor PC (2.8 GHz INTEL CPU) operated under Windows XP. The user operates the whole system via a graphical user interface (GUI). Three serial ports (RS-232) are used to control the external hardware. Two parallel ports, currently not in use, are available for additional hardware. Figure 1 visualizes schematically the VIM remote control system.

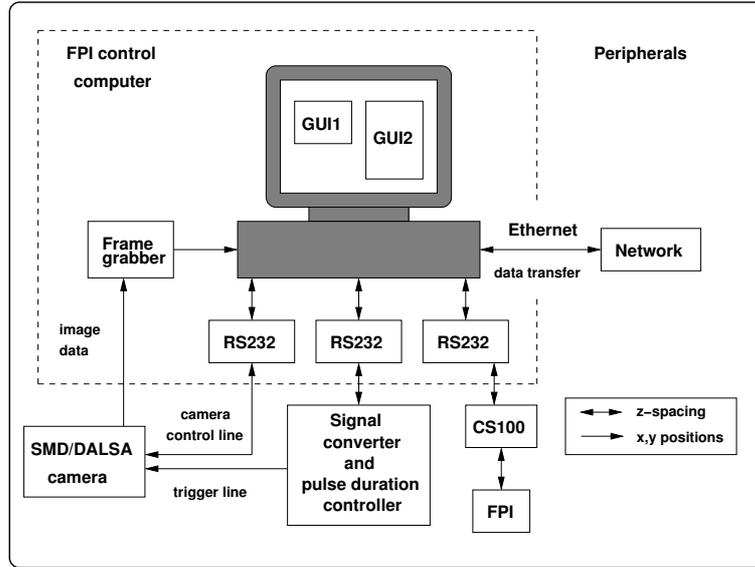


Figure 1. Schematic control and acquisition structure of the instrument.

The detector is a 1024×1024 pixel high-speed DALSA camera with a 12 bit digitization. The pixel size is $14 \times 14 \mu\text{m}$. In the full resolution mode ($1\text{k} \times 1\text{k}$) the maximum frame rate is 60 fps or 110 fps in the 2×2 binning mode. Images are acquired via an IC-PCI frame grabber manufactured by Coreco Imaging. Due to limitations of the frame grabber 12 bit are not supported in the full resolution mode. Instead, the 2×2 binning mode is used to obtain 12 bit images. Camera parameters, such as binning, gain, exposure time (four factory preset values), frame rate (five factory preset values), and the synchronization mode are set through a serial port. The camera features also a TTL *trigger-in* synchronization input which is used to control the exposure time and to synchronize the camera with the etalon.

Due to an inability of the camera to set a custom exposure time and the instability of the computer produced pulses, which can be up to 5 ms off we had to develop an external controller, the *signal converter*. The signal converter communicates with the computer via a serial port. The control computer can set exposure times between 3 ms and 850 ms with a step increase of approximately 3 ms and a precision in the range of $1 \mu\text{s}$. After the exposure time is set, the computer starts the integration by sending a signal to the signal converter which sets a TTL signal for the camera. When the preset exposure time is ended, the converter drops the TTL signal to the camera to finish the exposure and sends a signal back to the computer. If the exposure time exceeds 850 ms, the computer is used to produce an exposure pulse and the signal converter just converts the pulse, i.e. the converter does not change duration of the pulse, into a TTL pulse and resends it to the camera.

The SIFAM (former Queensgate) FPI system comprises an ET-series II fused silica, ambient temperature etalon and the CS100 control unit. The CS100 controller operates the FPI, stabilizes the etalon spacing and parallelism and

serves as the interface to the control software. The CS100 is a three channel controller using capacitance micrometers and Piezo actuators (incorporated into the etalon) to monitor and correct plate spacing and parallelism. The controller has both manual and remote controls via the RS-232 serial port. The remote control has some limitations, e.g. only the z -spacing value, i.e., the plate separation, can be read back. The plate parallelism (x - and y -channel) can be set remotely, but the current values cannot be obtained. At the moment, we only set the z -spacing remotely.

3. The Software

The control software has to perform and synchronize different tasks: the communication with the Telescope Control Computer (TCC), the acquisition and storage of data, setting the cavity spacing of the Fabry-Pérot etalon and controlling the polarization optics. All tasks can be performed in a stand-alone mode (one task at a time) or in three different observing modes: a 2D-spectrometer mode (only Stokes I), a longitudinal mode (only Stokes I and V), and a full 2D-spectropolarimetric mode (Stokes I, Q, U , and V). With regard to these rather event-oriented requirements the GUI and the program modules are written in Microsoft Visual C++ and compiled with Microsoft Visual C++ version 6. To control the frame grabber the program uses the Coreco C routines library ITEX. The images are stored taking advantage of the public-domain CFITSIO library provided by NASA.

The code consists of a couple a dozen C++ classes which can be separated in three groups: the GUI group, the hardware control group and the acquisition classes. A separate class enables communication with the TCC via the TCP/IP protocol and sockets. Currently this class only retrieves the telescope pointing information and active region numbers. The GUI classes provide an user interface that allows the observer to set numerous camera and FPI parameters.

The hardware control classes control various parts of the instrument. For each part of VIM (with exception of the signal converter) there is one class which provides the methods to control it. The acquisition classes group consists of three classes: one class controls various aspects of the acquisition process and synchronizes the tasks; another one keeps track of the settings and is also responsible for their saving and retrieval. The third class, `CImage`, provides methods to acquire images from the camera.

3.1. The `CImage` class

The implementation of the `CImage` class and its corresponding hardware control class `CCameraControl` is an example of our idea to hide hardware details from a high-level programmer. With this approach it is easy to replace the current camera (and/or frame grabber) with a different one. We only need to rewrite methods of the underlying hardware class `CCameraControl`, keeping names of those methods and their parameters intact. All the other parts of the code will remain unchanged.

To perform image acquisition tasks, all that the programmer needs is to create an object of the `CImage` class and then use one of the *Acquire* set of functions to get an image from the camera. Then, with the image data already

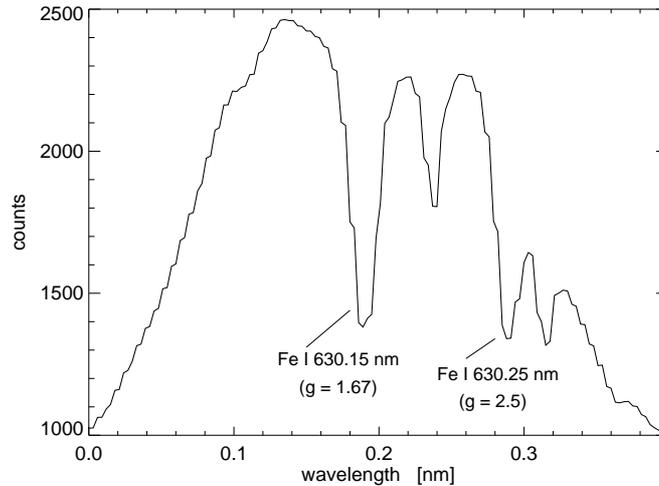


Figure 2. The spectrum of the pre-filter range.

in the computer memory, the programmer can display the image with the help of the *Display* function and save it as a FITS file using the *Save* function.

4. First-light measurements

First sun-light observations with VIM were taken on February 6, 2004. The data set covers a full scan (801 narrow-band filtergrams) of quiet solar granulation using the entire FPI scanning range of about 1.2 nm. A 0.3 nm wide (FWHM) interference filter was used to preselect the wavelength band around the Zeeman sensitive Fe I 630.25 nm ($g = 2.5$) spectral line. With a step size of 3 pm the whole scan consists of 801 narrow-band filtergrams. The exposure time was set to 360 ms for each individual filtergram, which resulted in total scan time of 4.8 min. Figure 2 displays the spatially averaged (over the VIM field of view) spectrum of the pre-filter range, corresponding to 133 wavelength points.

5. Conclusion

We continue to work on both hardware and software improvements. The GUI will be replaced with an upgraded and more userfriendly version. We want to point out that the object-oriented approach has proven to be useful during the GUI alterations. Furthermore, we plan to add another CCD detector to the project to allow for simultaneous broad-band observations.

References

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