Mimir Operations Notes

Mimir Unit	Version	Date	Author	Notes
Filter Wheels	1.0	5/24/2004	D. Clemens	Initial Writeup
	1.1	5/26/2004	D. Clemens	Fixed FW rotation directions
	1.2	6/11/2004	D. Clemens	Updated True Filter Complement

1. Overall Operation Description

The filter wheel units consist of four filter wheels and the half-wave-plate rotator. Three of the filter wheels are identical, ten-position wheels, designated FW1, FW2, and FW3 (in increasing distance from the instrument entrance window). The fourth wheel has six positions, each of which may contain a rotating filter, for example a half-wave-plate. This wheel is designated as the POL wheel. As the POL wheel is rotated, a POL filter moving into the optical beam engages a gear drive that enables spinning the filter about the optical axis. This gear drive is designated the HWP unit, as it normally controls the rotational orientation and motion of any half-wave plate in this wheel. All of these units are driven by individual stepper motors. FW1-3 and POL also have spring loaded detents to lock their positions with one filter in the optical path. These detents are encoded with magnets and reed switches to signal when the detent is engaged and holding its particular wheel. The HWP unit also uses the detent signal, but as a zero-phase sensor for each rotating filter. The magnets in this case are embedded in the POL filter cells and trip the zero-phase sensor only when they are in the optical path and rotated to the proper spin angle. FW1-3 filter positions are uniquely encoded using a 4-bit code. The POL wheel filter positions are encoded with a 3-bit code.

Because these units all wheel-based, there are no software or hardware limits or sensors. Instead, the four bits reserved for soft and hard limits are used to pass the (up to) 4-bit absolute encoding information. The 5th bit is the detent signal, used for FW1-3 and POL to indicate a bona-fide detent and by HWP to signal detection of zero-phase of the filter orientation.

Movement consists of designating the correct wheel unit and issuing the right number of steps to change to the desired filter. Provisions for automatically finding the home (first) filter position and for reading the current position are in place. The stepper motors are normally operated in the SO (stepper powered down after use) mode and there are no brakes other than the mechanical detents.

In the following, details of the design and operations are explained so that robust and repeatable operation can be achieved.

1.1. Stepper motor details

A single AMS stepper motor (with nominal 200 steps per revolution) is operated in a half-step mode by the STP100 stepper motor boards to achieve 400 steps per motor revolution. For FW1-3 and POL, the gearing consists of a 24 tooth gear on each stepper motor shaft, engaging a 128 tooth gear on the coaxial filter wheel shaft. The gear ratio is 3:16, leading to 2,133.33 steps per revolution, or 213.33 steps between filter positions for FW1-3 and 355.555 steps per filter position for the POL wheel. The gear ratio for the HWP is 3:4, so it takes 533.33 stepper motor steps to rotate the HWP one revolution. *[How in the world did we end up with all these non-integer values???]* Equivalently, one motor step accounts for 0.675 degrees of phase angle, so the 0.3333 step offset from one HWP rotation to the next should cause no more than 0.25 degrees of phase wobble.

1.2. Home Positions

Home positions are encoded in the POL and FW1-3 wheels as a special position code (1001 = position 1), which when detected asserts the "Panic/Home" signal line in the I/O board, detected on the "Bit 8" input of the STP board. Thus a wheel may be homed by the following sequence of STP100 commands:

TC8 (set up watch on bit 8)
II30000 (a large value – bit 8 will go low when HOME is detected, Causing the motor to halt stepping).

1.3. Filter Positions and Step Numbers

The POL and FW1-3 wheels are normally operated in a relative step mode, followed by a query to the detent and position encoders to ascertain that the wheel has reached the correct position. The following table reviews the number of steps between wheel positions.

Wheel	Home Position Code	Stepper Motor Steps between filter positions	Notes
HWP	**Zero-Phase**	**33.333 / 22.5 deg**	Continuous Rotation
POL	**1001**	**+356**	SR
FW1	**1001**	**+214**	Wide-field camera
FW2	**1001**	**+214**	Narrow-field camera
FW3	**1001**	**+214**	LED Illuminator

The table below summarizes the position codes and nominal filter selections returned by each wheel:

Pos'n	**POL**		**FW1**		**FW2**		**FW3**	
Home (1)	**1001**	**Dark**	**1001**	**Dark**	**1001**	**Dark**	**1001**	**Dark**
2	**1010**	**f/5 baf.**	**0010**	**J**	**0010**	Tight	**0010**	**JHK Grism**
3	**1011**	**f/17 baf.**	**0011**	**H**	**0011**	**1.17LP**	**0011**	**…**
4	**1100**	**H-HWP**	**0100**	**Ks**	**0100**	**1.8 LP**	**0100**	**…**
5	**1101**	**…**	**0101**	**L'**	**0101**	**…**	**0101**	**SED Grism**
6	**1110**	**Open**	**0110**	**M'**	**0110**	**2.8 LP**	**0110**	**WireGrid**
7	**X**	**X**	**0111**	**PK50-2**	**0111**	**PK50-1**	**0111**	**…**
8	**X**	**X**	**1010**	**H2-On**	**1010**	Tight	**1010**	**LM Grism**
9	**X**	**X**	**1100**	**H2-Off**	**1100**	**Open**	**1100**	**…**
10	**X**	**X**	**1110**	**Open**	**1110**	**J-Corr**	**1110**	**Open**

1.4. Motor Commands

1.4.1. Initialization

Initialization consists of the I/O boards recognizing their wheel unit, autoconfiguring the I/O board, and issuing a set of commands to the I/O board to cause the wheel unit to find the home position signal.

Unlike the case of the camera or decker units, the wheels have no limit sensing or limit actions. There is a detent sensor that echoes whether the detent arm is fully engaged and the wheel is locked.

Operation of the stepper motors should be in the "SO" or unpowered mode, which will allow the detent springs to pull the wheels properly into detent. Use of the "SP" or stepper always powered mode should be avoided.

1.4.2. I/O Board Assignments and Configuration

The wheel units are currently assigned to I/O boards 2-5 (BD2-5). When in raw RS232 communication with the STP100 chain of boards, one needs to issue the following commands to access these boards:

BD3 (selects board 3, the FW1 unit)

When powered up, the I/O boards should test for the voltage divider encoder resistor and return the encoded voltage to the I/O board front panel in the 7-segment LED numeral. The wheel units should return values in the range 1-5 (see table). If this is not true, press the black buttons on the front of the I/O boards to force a retest of the resistors. If this fails, stop and get help.

The following table lists the mapping of BD to wheel units:

Wheel Unit	I/O Board Assigned	I/O Board ID Echoed	Description
HWP	**BD1**	**1**	**Half-wave plate rotation**
POL	**BD2**	**2**	**HWP or baffle selection wheel**
FW1	**BD3**	**3**	**First Filter Wheel**
FW2	**BD4**	**4**	**Second Filter Wheel**
FW3	**BD5**	**5**	**Third Filter Wheel**

When in idle, the I/O boards should show both "Bit 5" and "Bit 6" lit on the 10-LED bar on the I/O board. Bit 5 is the fourth LED from the top and should be yellow when lit. Bit 6 is the red LED just above it. If both are lit, the I/O board is in the "READ A" mode (a safe way to start since the brake is set in both READ modes).

To move a wheel unit, issue a PS6 (“Pin Set 6”) command to the I/O board’s STP100. This causes the I/O board to change from READ-A to MOVE mode. This is necessary, because although the motor can be moved outside of MOVE mode, the home position detection will not work properly

Once in MOVE mode, the home position and detent signals are continuously monitored.

After the move has been completed, issue a PC6 (“Pin Clear 6”) command to return the I/O board to READ A mode. The position encoding is read using the READ A and READ B modes, each of which move two of the four encoding bits from the STP100 lines out through the RS232 serial system to the host computer. This is accomplished as follows:

BD2	(Select FW1)
PC6	
PC5	(force READ A mode)
RP3	(get Bit 0)
RP8	(get Bit 1)
PS6	(force READ B mode)
RP3	(get Bit 2)
RP8	(get Bit 3)
PC6	(return to READ A mode)

The bit values are returned to the host computer in the text return string from the STP100 as ASCII “0” or “1.”

1.4.3. Moves

There are several ways of moving the stepper motor with the STP100 commands. These include immediate moves (II-type), absolute moves (MI-type), and others. Wheel moves generally use II-type moves to find the home sensor and to move between filter locations.

For example, after homing FW3, I wish to move the wheel to filter position 7. To do so, I issue a:

II1280

command to move the wheel 1,280 steps, or 6 filter positions.

1.4.4. Detent Sensing

Another wheel move method is to go from detent fall to detent fall, using the detent sensor to identify a filter position. This will be used only if absolute encoding has failed, but either auto homing or manual homing work.

To find a detent position, set the STP100 in MOVE mode and test for a clear (signal asserted) on the detent signal line ("Pin 3"), as listed below.

PC6	(to go to MOVE mode in the I/O board)
TC3	(test for "clear" on "Pin 3" – the zero-phase sensor)
II2000	(an arbitrarily large move guaranteed to find a "clear")

1.4.5. HWP Zero-phase sensing

The HWP unit is somewhat different from the filter wheels in that it has no mechanical detent and no set position. Each filter in the POL wheel has a magnet embedded in it that will trip the zero-phase sensor in the HWP unit each revolution. In general, then, one should operate the HWP drive in a sort of "open loop" mode of positioning the filter rotation on the zero-phase sensor and then offsetting fixed numbers of steps to the proper phase angle. This will work, but is made a bit more complicated because the magnets cause not one, but generally two, closures of the zero-phase sensor per revolution. Thus it is crucial to operate the HWP drive unit in the same direction to prevent introducing substantial hysteresis.

At present, the only half-wave-plate in Mimir is the H-band one, which we would like to operate in steps of 22.5 degrees of HWP phase. Because this corresponds to a non-integer number of stepper motor steps, it may be wiser to move by the nearest integer, 33 steps, corresponding to 22.275 degrees. Of the two baffles in the POL wheel, the f/17 one is round, so needs no phase correction. The f/5 one is square, so must be correctly oriented to not produce vignetting.

The empirical phase offsets of the H-band HWP and the f/5 baffle will need to be determined at the telescope. The table below is a placeholder for those vales:

POL Filter	Offset from Zero-Phase	Notes
H-Band HWP	…	To nominal "0 deg"
f/5 baffle	…	To proper orientation

1.4.6. Motor Speed Settings

The wheel unit I/O boards have been set to some default motor speed settings. The settings consist of:

Motor Speed Parameter	STP100 Command	Default Value	Current Value	Low Limit	High Limit
Step Type	**SH**	**Half**		**SF (Full)**	
Step Delay	**SD, RSD**	**1600**		**450**	**2000**
Step Acceleration	**SA, RSA**	**6**		**0**	**100**
Step Min Delay	**SM, RSM**	**1000**		**0**	**2000**

The units of the step delay are 1.6 microseconds. Limits should be redone with the wheels have filters and are cold. Current value column left blank for future tuning.

These are changed by issuing an STP command, for example:

SD550 (sets step delay to 550)
RSA (returns current step acceleration value)
WSS (saves the current settings in EEPROM)