PFIS – Slitmask Mechanism

SPECIFICATION
SALT-3130AE-0002

DRAFT
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1. Scope

1.1 Identification

This document covers the design of the Slitmask Mechanism for PFIS. In it are detailed the specifications, operating criteria and details of the design.

1.2 System Overview

The Slitmask Mechanism is the mechanism that selects one of 30 multislits or one of 10 longslits from slitmask magazine and positions it in the slitmask holder in the beam at the focus of the telescope.

1.3 Document Overview

This document first details the functional (science) requirements, then the technical (physical) requirements and then details the design of the mechanism and sub mechanisms.

2. Referenced Documents

SALT-1000AS0007 SALT System Specification
SALT-1000AA0030 SALT Safety Analysis
SALT-3150AA0003 Slitmask Requirements and Fabrication Document

* Needed – Instrument Power Document
             Instrument Logic Document
             Instrument Pneumatics Document
             Lubrication Document
3. Science Requirements

3.1 Schematic Diagram

3.2 Geometry

3.2.1 Multi Slits

Maximum mask clear aperture: 107mm (8 arcmin at 4.46 arcsec/mm FP plate scale)
Thickness: 100µm
Number of multi slits: 30

3.2.2 Reflective Long Slits:

Dimensions:

Slit widths range from 0.5—3.0 arcsec: 0.11—0.67mm
Slit lengths: Most will be full field (i.e. 107mm), but need:
- ½ length clear for Frame Transfer mode
- ½ length clear (centered) for Spectropolarimetry

Total number of long slits: 10
3.3 Speed into Position and Duty Cycle

Time to change slit masks: <1 min
No. of changes per evening: 8-12 (i.e. probably not more than 1 slit per track/target) + 8-12 daytime calibrations.

3.4 Positional Repeatability and Alignment

Tolerance specs (long slits and multi-slits):

The Slitmask must be positioned on the focal plate of the telescope.

Rotations: X,Y: 4 arcmin (140 micron end-to-end) absolute (primarily for multi-slits, long slits can be weaker)
Z: 1 arcmin (35 micron end-to-end) absolute ≥ actually need only be as good as CCD chip alignment

Translations: X,Y: 30 micron repeatable, machine tolerance absolute
Z(sag): 65 micron absolute (can probably loosen up here to ~200 micron, need to check w/ZEMAX)

Note: Once a multi-slit mask has been removed from its frame, we can not expect that it can be reinserted into a frame with the same absolute position. Any mask inserted into a frame will be considered a new mask, and should be treated as such.

3.5 Operational Modes

The mechanism must be able to select any one of 30 multi slits or 10 long slits and position it in the Slitmask holder. Each mask will be placed in the beam at least twice, the first for daytime calibrations and then secondly for the nighttime observation.

4. Technical Requirements

4.1 Interfaces

The focus sub-assembly will connect to the holder of the first collimator element and will provide high positional accuracy to the position of the collimator optics and the guider.

The elevator and magazine sub-assemblies will be attached to the PFIS structure to a less stringent positional accuracy.

4.2 Physical Characteristics

4.2.1 Mass Estimate
The Mechanism has a budget mass of 19Kg (including masks). The current estimate is given in the part list Appendix 1

4.2.2 Materials used and Properties

The baseline choice of material will be aluminium but invar will be considered for high position tolerance areas due to its low CTE.

4.3 Geometric Requirements

4.3.1 Position of Mechanism and Envelope

The slits must slide in parallel to the x-axis of the instrument. The final position of the mask is to be center at the focus of the telescope. The magazine and carrier need to fit into an envelope, within the structure, defined by the following coordinates: x: 160, 430. y: -100, 100. z: -10, 500. This envelope is defined by the wave plate mechanism and camera tube in -x, the hexagon of the structure in the +x, y and -y, other structural members in +z, and 10mm below the focal plane in -z.

The focus pusher actuator is stationary in z and has thus been allowed to fit below this envelope.
4.3.2 Dimensions of Slitmask

The multi slits (in holder) should be less than 6mm thick and the long slits less than 12mm thick. This to ensure all the slits stowed in the magazine fit within the space constraint.

4.4 Positional Tolerances

The positional tolerance of the optical elements is detailed in section 3. The other sub-systems will be positioned and aligned so as to allow smooth and unobstructed sliding of the mask holders between them. Typically the mechanism will be aligned to within 100µm of each other. The magazine holder and the linear stage will have adjustable mounts to ensure alignment.

4.5 Drive Requirements

4.5.1 Maximum Heat and Power Output
The Power and temperature requirements of the SALT Telescope as set out in SALT System Specification Section, 5.3.2.5 shall be adhered to.

4.5.2 Encoding
All motor driven stages will have absolute encoding while pneumatic actuators will only have position sensors at their end positions. The motor drive stage will have encoding and soft limits used for positioning while hard limit switches will stop the stage from going outside of its operating range.

4.6 Safety
All mechanisms shall be designed such that electrical or software malfunctions cannot damage any hardware. Pneumatics should hold their position during a power failure and solenoids should fail in a clamped position.
5. Description of Design

5.1 Layout

Above are shown the four main subassemblies of the Slitmask mechanism.

5.1.1 Mask and Holder

Multi Slit:

The fibre-composite multi slit mask (which has been precut in a laser cutting mill) is held in the slitmask holder. The mask is indexed to the holder by two holes, one round and one elongated (which are cut at the same time as the slits) and held in position by magnetic strips (TBD). The aluminium holder has 3 grooves cut in it: The ball detent groove is for a ball detent to hold the mask while stowed in the magazine. The carrier pusher cutout is
for the actuator that pushes the mask from the magazine to the carrier, and back, to engage with. The focus pusher cutout is for the actuator that pushes the mask from the carrier into focus position, and back, to engage with.

Long Slit:

The details of the long slit design have not yet been finalized, however the rail and outer structure (with grooves) will be the same as the multi slit to facilitate using the same rails and push-pull mechanisms.

5.1.2 Focus Subassembly

A tapered chute guides the mask into 6 ball bearing rollers (with 4mm grooves) that slide and position (in y and z) the masks in the focus area. An adjustable hard stop (not shown) positions the mask to the required accuracy and repeatability in x.
5.1.3 Elevator

The elevator is made up of an off the shelf liner stage and a standard nema 23 stepper motor. A lower efficiency high gear ratio threaded shaft is specified to eliminate the need for braking (16 threads per inch acme screw). The motion is encoded loosely using a position transducer and exact ‘floor’ indicators are given by a photomicrosensor. The latch pusher attached to the bottom of the stage pushes on the carrier latch to release the mask when on the focus plane and ready for insertion into the beam.
5.1.4 Carrier Subassembly

The mask is driven into the elevator from the magazine by a rodless pneumatic actuator. A latch, mounted to the actuator engages the mask in the magazine as the elevator moved up and down. Powering the actuator pushes the mask out and holds it in the carrier. As the carrier approaches the bottom of its travel (at the focus plane) a pusher pushes the latch out of the mask so that it is free to move through the carrier when acted upon by the focus actuator. Care is taken to ensure that the engaging tooth on the focus actuator is properly engaged before the latch is released.
5.1.5 Magazine

The Magazine is designed to be removable and to hold 30 multi slits and 10 long slits. The Magazine mount is attached to the PFIS structure and the magazine is clamped into the mount using releasable clamps (not shown). Ball detents engage in a groove in the mask holder to ensure the masks are firmly held in the magazine until the actuator pulls them out. The pneumatic actuator, which drives the mask into the focus position, is attached to the bottom of the magazine mount.
5.2 Speed of Motion
The pneumatic actuators will undergo their full range of motion in less than 4 seconds.

The linear stage has a lead screw with 16 threads per inch. The maximum speed of the motor (directly coupled) is 2000 rev/min (which would provide 5 oz-in of torque which would lift 5 kg on the carrier). Twice the full travel of the linear stage – 300mm, would require 200 revolutions which would take 6 seconds, running the motor at 75% of top speed would still enable full motion in 9 sec.

Stacked together the motions would take a maximum of 43 seconds the encoding time must thus be of the order of 10 seconds to ensure a mask changeover in less than 60 seconds.

<table>
<thead>
<tr>
<th>Remove mask from focus (4s)</th>
<th>Return mask to magazine (4s)</th>
<th>Remove mask from magazine (4s)</th>
<th>Insert mask into focus (4s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevator to mask storage position (9s)</td>
<td>Elevator select new mask (9s)</td>
<td>Elevator to focus position (9s)</td>
<td></td>
</tr>
</tbody>
</table>

5.3 Motion Control

5.3.1 Slide Mask between Magazine and Elevator

Motion
A pneumatic actuator (FESTO DGP-8-135-P-A-B) slides the mask frames along the rails from the magazine onto the elevator carrier (and back). The actuator is controlled by a micro-pneumatic valve (FESTO MZH-5/3-M3-L).

Encoding
There are proximity sensors (FESTO SME-8-K-24) at the home and extended position of the actuator.

5.3.2 Elevator Up and Down

Motion
The elevator motion is by means of a Stepper Motor (Oriental Motors PK266-03) driving a worm screw on a linear stage.

Encoding
There is a Linear Cable Transducer (UniMeasure LX-PA-10k) which gives full range absolute encoding.
On the elevator are limit switches (My-Com E100/80) at the top and bottom of travel and at the bottom of travel in the magazine. These give top and bottom limit stops. There is
also a proximity switches (My-Com E100/80) at the bottom elevator position to indicate
the in focus position and it is also used to index the absolute encoder.
A reflective photomicrosensor (OMRON EE-SY191) runs along a printed reflective tape
on the side of the magazine and registers mask positions to ensure that the elevator stops
at a mask position and not in between two masks.

5.3.3 Slide Mask between Magazine and Focus

Motion
Motion in and out of Focus position from the elevator carrier is by means of a pneumatic
actuator (FESTO DSNU-20-250-PPV-A). The actuator is controlled by a micro-
 pneumatic valve (FESTO MZH-5/3-M3-L).

Encoding
There are proximity sensors (SMEO-4-K-24-B) at the home and extended position of the
actuator.

5.4 Control Interlocks

For the normal modes of operation to be executed, the following conditions must be met:

5.4.1 Remove Mask from Magazine
For A1 to remove mask from the magazine the following conditions must be met:
A1 = home
A2 = home
Position Transducer must give correct magazine position
Reflective photomicrosensor must register in a mask position
   OK when A1=extend

5.4.2 Return Mask to Magazine
For A1 to return a mask to the magazine:
A1 = extend
A2 = home
Position Transducer must give correct magazine position
Reflective photomicrosensor must register in a mask position
   OK when A1=home

5.4.3 To Select a Mask in the Magazine
For E1 to move up and down in magazine select mode:
   A1=home
   A2=home
Use position transducer to encode to the mask to be selected.
Use the reflective photomicrosensor to accurately find mask position (ie slow down 1mm early and hunt for marked line).
   OK  when position transducer at correct value (to 0.5mm approx.)
   reflective photomicrosensor within n steps of a line

5.4.4 Elevator Moves Full Carrier to Bottom (Focal Plane) Position
For E1 to move down to Focus position:
   A1=extend
   A2=home
Use position transducer to encode motion down to bottom
   Slow down 1mm early and find elevator bottom proximity switch
   OK When E1=bottom

5.4.5 Elevator Moves Full Carrier to an Empty Magazine Position
For E1 to return mask to it’s magazine position:
   A1=extend
   A2=home
Use position transducer to encode to the correct magazine position of the mask in the carrier.
Use sliding proximity switch to accurately find mask position (ie slow down 1mm early and hunt for detent).
   OK  when position transducer at correct value (to 0.5mm approx.)
   reflective photomicrosensor within n steps of a line

5.4.6 Mask Inserted into Focus
For A2 to insert the Mask:
   A1=extend
   A2=home
   E1=bottom
   OK when A2=extend

5.4.7 Mask Retracted onto Elevator
For A2 to retract the Mask:
   A1=extend
   A2=extend
   E1=bottom
   OK when A2=home
6. System Air, Power & Signal Requirements

6.1 Air
2 l/min at 6bar.
This will be the maximum usage and is expected during and insertion or the mask from
the carrier into to focus position.

6.2 Electrical Power

<table>
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<tr>
<th>Item</th>
<th>Quantity</th>
<th>Power</th>
<th>Voltage</th>
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<td>24</td>
<td>24/day, 8/hour</td>
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<tr>
<td>Solenoid Valve for Pneu</td>
<td>2</td>
<td>.55W</td>
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6.3 Logic

<table>
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<tr>
<th>Item</th>
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<td>Proximity Sensor–Reed switch, magnetically actuated</td>
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<tr>
<td>Photomicrosensor</td>
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<td>Bar Code Reader</td>
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## Slitmask Mechanism Parts List

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<th>Sub-Assembly</th>
<th>Part Name</th>
<th>Part Number/Drawing Number</th>
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**Total:** 16.552
Slitmask Mechanism Specification

M - Manufactured
O - Optic
C - Commercial off the Shelf
C* - Commercial off the Shelf with Modifications