XMM Optical Monitor

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DICHROIC MECHANISM DESIGN

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A TECHNICAL DESCRIPTION OF THE DICHROIC MECHANISM (XMM-OM)
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Introduction

The dichroic behaves as a beam steering mirror for the blue beam, directing it to one of the two blue detectors, while transmitting red light along the main optical axis (with a small refractive shift) to the red detector system. The two blue axes are at right angles to the main optical axis, and are diametrically opposite one another. Various mechanical configurations have been considered, but optical requirements have led to a design in which the axis of rotation of the mechanism is coincident with the main optical axis. The mechanism therefore has to rotate through 180° from one blue system to the other, and the front dichroic surface is set at 45° to the axis of rotation. An extra optical element, which belongs to the red focal reducer system, has been added to the rear surface of the rotating dichroic assembly.

Note : At a late stage, the red detector system was dropped from the design along with the extra optical element and the dichroic was changed to a beam steering mirror.

The device should therefore now be considered to be a beam steering mechanism, and all references to dichroic should be understood to mean beam steering mirror.

Specification

a) After movement, the mechanism will locate the beam to an accuracy of 500 μm on the blue detector.

b) The mechanism must not cause the beam to wander by more than 1μm on the blue detector.

c) The mechanism is part of a redundant blue system and is intended to operate only once in space, to change from the primary blue detector to the redundant one. It will be designed and tested assuming two hundred complete cycles in air, two hundred in vacuum on the ground and ten cycles in space.

d) The mechanism *could* be used only once and that could be towards the end of its ten years in space.

General description

The dichroic element is mounted at 45° on one end of a tubular “shaft” as shown in figure 1. The red optical element is mounted in the other end of the shaft (no longer part of the design). This assembly is suspended in a pair of large diameter, thin section bearings, and is driven through an integral gear ring by a pinion mounted on a layshaft extension of a size 11, 4 phase, 90° stepping motor.

Because of the steadiness required for the rotor position, it was considered that positive stops were the only possible positioning device. This meant that the rotor would have to turn through 180° in both directions. Extra magnetic detents are provided on the rotor to pull it firmly on to the stops.

No position monitor is used.

Rotor

The rotor is tubular and made from aluminium alloy 6082. The dichroic is mounted, without provision for adjustment, on its angled face. The six degrees of freedom of the dichroic are removed by six carefully placed pads, and it is held in place by three spring loaded clamps. The mirror is located with only a very small clearance by adjustable stops. During vibration the mirror is allowed to rattle within the small clearance. In space some light springs in the clamps return the mirror to its required position, without causing undue distortion.

The optical element belonging to the red focal reducer (no longer part of the design) is mounted in its own cell, which is then attached to the end of the rotor.

Bearings

The bearings used are purpose built by SNFA for the volume available and for space use. They are based on standard thin section deep groove bearings, but have raceway depths as thick as the structure will allow. This maximises the resistance of the raceways to distortion by the aluminium alloy housings. Covers are fitted to both sides of the races.

The bearings have duroid cages which snap in and are therefore similar in their lubrication characteristics to Bartemp bearings. SNFA are familiar with the space bearing requirements and practices of ESTL Risley, and ESTL was consulted by MSSL about the bearing design and characteristics.

All of the raceways apart from the outer one at the rear end are axially clamped. An axial spring load of 50 N is applied to the remaining one to take up the small internal clearance of the bearings. This load was determined by ESTL to be suitable for the dry lubricated regime.

During vibration the radial inertial loads of the rotor are shared between the two bearings, but the axial load is carried by the front bearing alone. With such large bearings however the inertial loads, even at 100g, are less than a fifteenth of their static capacity.

There is a problem with providing for differential thermal expansion over the full temperature range, and for reasonable manufacturing tolerances in the bearing housings. Either the bearings must be radially strained in some circumstances, or clearances (leading to optical errors) must be accepted. It has been decided to dimension the bearing housings to minimise clearances and accept some radial strain, using a limited design temperature range of 10°C to 30°C. The radial strain envisaged is a small part of the radial clearance of the bearings.

It is for the above reasons that maximum bending and compression stiffness has been incorporated into the raceways.

Gears

The rotor gear is cut from aluminium alloy 6082, and it is surface hardened by anodising. The drive pinion is made of stainless steel to BS970 321 S31. The gear ratio is 14.5 :1.

The pinion is on the end of a layshaft supported in a pair of small Bartemp bearings. The layshaft is connected to the motor shaft by a splined sleeve. This arrangement is used because it was found to be impossible to place the motor closer to the rotor gear.

All gear teeth are sputter coated with molybdenum disulphide (MoS_2)

Motor

The drive motor is a size 11, four phase, 90° stepping motor made by

Norcroft Dynamics Ltd. Redundant windings are included.

An upper value for the mean friction torque of the bearings with the previously specified preload is estimated to be 1.7 mNm at the wheel. The holding torque of the motor is 6 mNm (87 mNm at the wheel).

Because the motor is used infrequently, it will be driven slowly enough for inertial effects to be negligible. A drive frequency of 2Hz is specified.

Position determination

The system is traversed from one position to the other in open loop, by pulse counting. The final step overdrives the rotor to its stop and it is lightly held there by the force from a magnet built into an adjustable stop-like feature adjacent to the hard stop. The magnetic detent force (about 300 mN, giving a detent torque of about 12 mNm at the wheel) will be set by adjusting the air gap between the magnetic elements. There is no harm in overdriving the system against the stop, but the final step must be applied in the appropriate phase.

Positional adjustment

The mechanical stops are screws in locking helicoil inserts in the fixed housing, which limit the movement of a protuberance on the rotor. The stops can be simply adjusted to give the appropriate blue beam alignments and then left. After any adjustment of a mechanical stop, the air gap in the adjacent magnetic detent must also be adjusted.

Electrical

A connector for the motor supplies is provided on a bracket on the motor mounting plate. The motor is to be wired in with the common connections to the negative of the power source.