NIRCam Filter Wheels

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ABSTRACT

The NIRCam instrument will provide near-infrared imaging capabilities for the James Webb Space Telescope. In addition, this instrument contains the wavefront-sensing elements necessary for optimizing the performance of the primary mirror. Several of these wavefront-sensing elements will reside in the NIRCam Filter Wheel Assembly. The instrument and its complement of mechanisms and optics will operate at a cryogenic temperature of 35K. This paper describes the design of the NIRCam Filter Wheel Assembly.

Keywords: Cryogenic mechanisms, filter wheel assembly, NIRCam

1. INTRODUCTION

The NIRCam instrument has two optical benches. Each optical bench has a long wavelength Filter Wheel Assembly and a short wavelength Filter Wheel Assembly. The Filter Wheel Assembly is comprised of two independently rotating wheels (a pupil wheel and a filter wheel). Each 290mm diameter wheel is driven by a redundantly wound DC motor. The pupil wheel and the filter wheel actuators are capable of positioning twelve 48 mm diameter optical elements centered on a 225mm diameter circle. The design solution is a balance of lifetime and power at cryogenic temperature.

2. FILTER WHEEL DESIGN

2.1. Overview

The Filter Wheel Assembly (FWA) (Fig. 1) contains two independently rotating wheels. The Pupil Wheel receives light first. This wheel contains a complement of light projectors, wave-front-sensing elements, filters, and weak lenses. The precision and control of the assembly is largely driven by the requirements of the optics in the pupil wheel. The final optical surface of the Filter Wheel Assembly is placed 25 mm from the first surface of the Pupil Wheel. The Filter Wheel optics are tilted 4 degrees to the plane of the optical bench. All elements in the Filter Wheel are 5 mm thick.

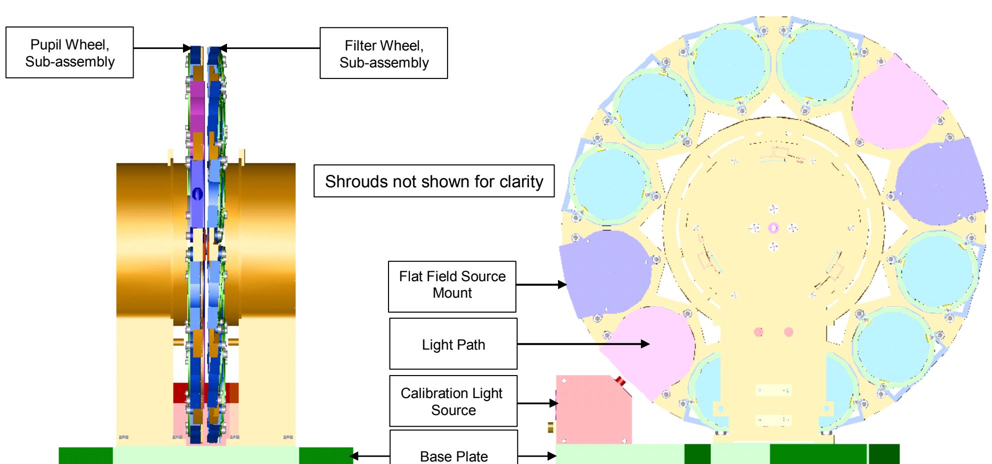

Figure 1: FWA Layout

A flex-plate (Fig. 2) will be used to mount the Filter Wheel Assembly to the bench. This plate will provide adjustability and alignment capabilities as well as accommodating the difference in CTE between the titanium Filter Wheel Assembly and the beryllium bench.

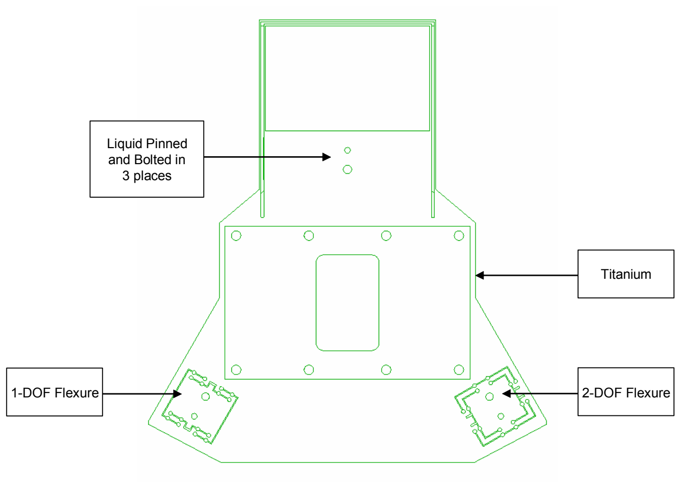

Figure 2: Flex Plate

2.2. The Wheels

The center of each optical element is placed at a diameter of 225mm (see Fig. 3). The wheels can accommodate 48 mm diameter optical elements. The pupil wheel can accommodate elements that are 10 mm thick. Each element in the filter wheel is tilted 4 degrees about an angle parallel to the optical bench.

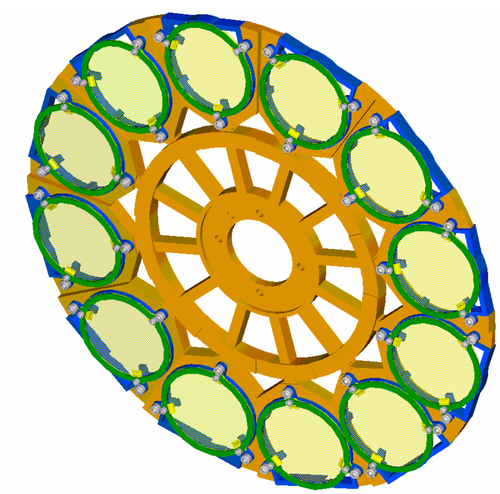

Figure 3: The NIRCam Filter Wheel accepts 12 optical elements

2.3. The Optical Mount

Each optical element is spring mounted inside a titanium chassis (see Fig. 4). A simple two-point constraint is proposed. This simple arrangement provides a cost effective solution to the various thermal properties of the material being mounted.

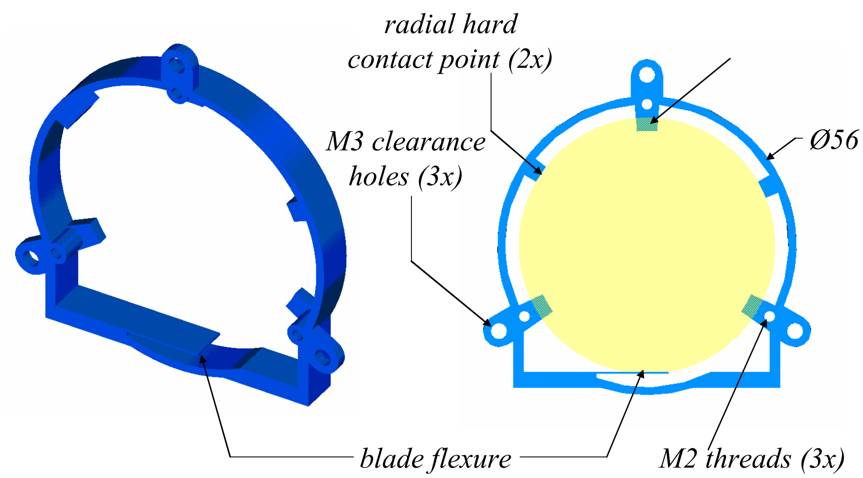

Figure 4: Optical Mounts

2.4. The Motor

Each wheel is mounted directly to the custom rotor of a 3.6 inch diameter 3-phase, brushless DC motor (Fig. 5). The cogless design allows for increased precision in positioning. A high torque constant requires only 130 mA of operating current to drive the motor (with margin).

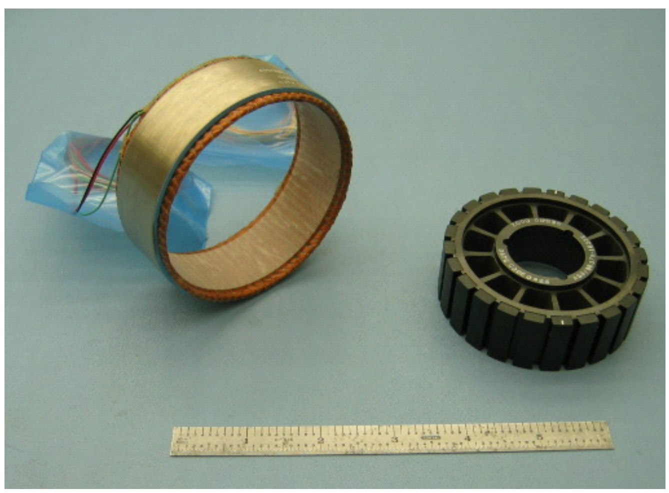

Figure 5:   Filter Wheel Drive Motor

2.5. The Bearings

A duplex bearing pair (Fig. 6) mounted back to back provides the necessary rotational degree of freedom. A standard 35mm OD and 17 mm ID bearing is used. A dry-film lubricated cage provides lubrication that is compatible with the 35K environment.

Figure 6: Duplex Bearings

2.6. The Sensors

The NIRCam Filter Wheel Assembly uses a set of inductive sensors (Fig. 7) to provide position feedback. A sensor "track" composed of a series of 15-degree ramps converts linear inductive sensing into rotation knowledge.

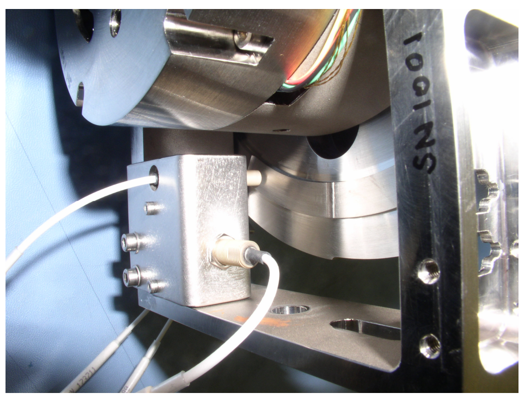

Figure 7: Sensors

2.7. The Control Modes

The Filter Wheel Assembly will have the ability to be driven in both open and closed loop modes. The primary move between filters will be accomplished open loop in a micro-stepped mode of operation. Three sinusoidal current waveforms composed of 4095 "steps" each will be used to vector the motor motion. One electrical cycle will complete the 30-degree move between filters. Once the coarse filter position has been achieved, the closed loop control will be used to provide a precise final position based on position feedback of the inductive sensors.

2.8. The Prototype

The Filter Wheel Assembly Prototype (Fig. 8) has provided information on a variety of flight concepts. The prototype has survived multiple thermal cycles to cryogenic temperatures, and it was operated for 2400 revolutions at 20K. The three-phase DC motor stator was flex-mounted into a titanium housing. The bearing cage material, size, and preload are identical to those of the proposed flight bearings. Inductive sensors were successfully used to provide position feedback.

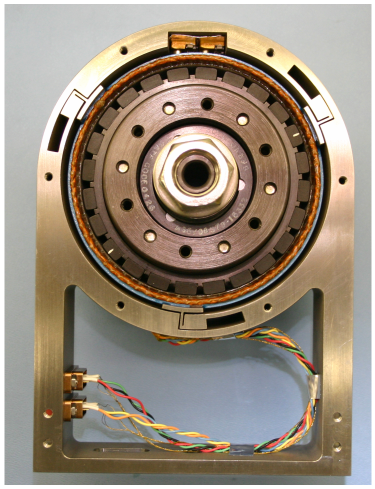

Figure 8: Filter Wheel Assembly Prototype

3. SUMMARY

The Critical Design Review for the Filter Wheel Assembly is scheduled to occur in July of 2005. The motor, bearing, and position sensor procurement contracts have been initiated. Prototype testing has successfully retired significant risks associated with operating margins at cryogenic temperatures. The Engineering Test Unit (ETU) NIRCam Filter Wheel Assembly is scheduled to complete its component level testing in early 2006. The qualification assembly will be built and tested in parallel.

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