Next Generation Space Telescope

Integrated Science Instrument Module

Technology Development Requirements for the Near Infrared Multi-Object Spectrometer Micro-Electromechanical System

DRAFT RELEASE 3a

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1.0 INTRODUCTION

The Integrated Science Instrument Module (ISIM) is the payload of the Next Generation Space Telescope (NGST).

The ISIM includes the following:

- Facility sensor
    - Fine Guidance Sensor (FGS)
- Science Instruments (SI)
    - Near Infrared Camera (NIRCam)
    - Near Infrared Spectrometer (NIRSpec)
    - Mid Infrared Instrument (MIRI)
- Associated/shared subsystems
    - Structure
    - Thermal Control
    - Command and Data Handling (C&DH) hardware and software
    - Front-end electronics (Analog/Digital [A/D] conversion)
    - Focal plane (detector) control electronics

1.1 SCOPE

The NIRSpec design studies are considering/investigating a multi-object spectrometer (MOS) implementation. This implementation requires the development of a micro-electromechanical system (MEMS).

This document establishes the requirements for the MEMS technology development for the NIRSpec MOS.

2.0 APPLICABLE DOCUMENTS

The following documents provide information applicable to the contents of the document as well as basic information used in its generation. These documents are subject to periodic revision, the user, therefore, should refer to the latest available version. In the event of a conflict between documents referenced herein and the requirements of this document, the requirements of this document shall take precedence.

2.1 DOCUMENTS

2.1.1 GSFC Documents

Document Number	Document Title
NGST-REQT-000633	NGST Level 1 Requirements
NGST-REQT-000634	NGST Level 2 Requirements
www.ngst.nasa.gov/science/drm.html	NGST Design Reference Mission
NGST-IRD-00729	Near Infrared Spectrometer Interface Requirements Document

2.1.2 Non-GSFC Documents

Document Number	Document Title

2.2 DRAWINGS

2.2.1 GSFC Drawings

Drawing Number	Drawing Title

2.2.2 Non-GSFC Drawings

Drawing Number	Drawing Title

3.0 MEMS DESIGN REQUIREMENTS

3.1 MICRO-MIRROR REQUIREMENTS

3.1.1 Dimensional Requirements

Parameter		Requirement	Goal
A1	Pitch Size	50 µm ≤ X ≤ 100 µm X ≤ Y ≤ 3X	X = 50 µm
A2	Array Dimensions	$N_X \geq 1800$ $N_Y \geq X/Y\ 1800$	$N_X = 3000$
A3	Pixel Size Uniformity	<1 %	
A4	Large Scale Array Flatness (Entire Array)	Chip displacement from reference plane (piston):< ± 200 µm	
A4	Small Scale Array Flatness (~10x10 mirrors)	Implicit in Optical Requirement #1 (Note 1)	
A5	Fill Factor	Implicit in Optical Requirement #1	
A6	Facet Surface Roughness	Implicit in Optical Requirement #1	
A7	Facet Flatness	Implicit in Optical Requirement #1	
A8	Facet Alignment	Implicit in Optical Requirement #1 (Note 2)	

3.1.2 Switching Requirements:

Parameter		Requirement	Goal
B1	ON-OFF Tilt Stroke	ON position: 0˚± 0.025˚ (Note 3) OFF Position: ≥10˚± 0.5˚	
B2	Reconfiguration Speed (complete array)	<1000 s	<100 s
B3	Static Pixel Failures (BOL)	ON pixels in <1 % of Y-rows <1 % OFF pixels in entire array	0 % 0 %
B4	Static Pixel Failures (EOL)	ON pixels in <20 % of Y-rows <20 % OFF pixels in entire array	<10 % <10 %
B5	Command Failure Rate (single pixel)	erroneous ON: $<1.0\ 10^{-5}$ erroneous OFF: $<1.0\ 10^{-3}$	$<1.0\ 10^{-8}$ $<1.0\ 10^{-6}$

3.1.3 Optical Requirements:

Parameter		Requirement	Goal
C1	MEMS Efficiency (1-5µm) Variation with position	%>70 % (Note 4) <10 % (Note 5)	>85 <1%
C2	ON-OFF Contrast	≥2000	$>10^4$

3.2 MICRO-SUTTER REQUIREMENTS

3.2.1 Dimensional Requirements

Parameter		Requirement	Goal
A1	Pitch Size	50 µm ≤ X ≤ 100 µm X ≤ Y ≤ 3X	X = 50 µm
A2	Array Dimensions	$N_X \geq 1800$ $N_Y \geq$ X/Y 1800	$N_X = 3000$
A3	Pixel Size Uniformity	<1 %	
A4	Array Flatness	Shutter displacement from reference plane (piston): 400 m	
A5	Fill Factor	Implicit in C1	
A6	Facet Surface Roughness	Not Applicable	
A7	Facet Flatness	Not Applicable	
A8	Facet Alignment	Not Applicable	

3.2.2 Switching Requirements:

Parameter		Requirement	Goal
B1	ON-OFF Tilt Stroke	Not Applicable	
B2	Reconfiguration Speed (complete array)	<1000 s	<100 s
B3	Static Pixel Failures (BOL)	ON pixels in <1 % of Y-rows <1 % OFF pixels in entire array	0 % 0 %
B4	Static Pixel Failures (EOL)	ON pixels in <20 % of Y-rows <20 % OFF pixels in entire array	<10 % <10 %
B5	Command Failure Rate (single pixel)	erroneous ON: $<1.0\ 10^{-5}$ erroneous OFF: $<1.0\ 10^{-3}$	$<1.0\ 10^{-8}$ $<1.0\ 10^{-6}$

3.2.3 Optical Requirements:

Parameter		Requirement	Goal
C1	MEMS Efficiency (1-5µm) Variation with position	>70 % (Note 4) <10 % (Note 5)	>85 <1%
C2	ON-OFF Contrast	≥2000	$>10^4$

3.3 REQUIREMENTS NOTES

1) According to calculations done within the ESA studies, this requirement corresponds to a facet-to-facet piston error over an area 1 mm^2 of order ±0.1 µm.

2) According to calculations done within the ESA studies, this requirement corresponds to an absolute facet misalignment with respect to the nominal ON position of 0˚ of order ±1 mrad.

3) The specified tolerance is in accord with the requirement C1 and consistent with the facet alignment inferred for A8 in note 1).

4) This requirement is intended to control the overall magnitude of the diffraction effects occurring at the MEMS array. The MEMS efficiency is defined as the ratio of the energy contained in the out-going and in-coming beams. The required efficiency is to be achieved at all wavelengths 1-5 µm with all MEMS pixels ON and a representative coherent point source illumination having an input beam of F-number F_{IN} and a 20% oversized output beam (spectrograph angular acceptance cone) of F-number F_{OUT}, where:

$$F_{IN} = X/(q_{PIX} D) \quad \text{and} \quad F_{OUT} = F_{IN}/1.2 = X/(1.2\, q_{PIX} D)$$

with:

X = physical dimension of MEMS facet in dispersion direction

q_{PIX} = angle sampled per MEMS facet

D = Diameter of NGST primary

Examples: With a D = 6 m telescope and X = 100 µm MEMS facet, F_{IN} = 34.4 and F_{OUT} = 28.6 for q_{PIX} = 100 mas sampling, and F_{IN} = 22.9 and F_{OUT} = 19.1 for q_{PIX} = 150 mas sampling.

5) This requirement is primarily intended to control any rapid variation in the MEMS efficiency due to changes in the out-going diffraction pattern as the incoming PSF is moved across the MEMS array on the sub-facet to several-facet scale. The required small-scale uniformity in efficiency is to be achieved at all wavelengths 1-5 µm in order to constrain the corresponding rapid modulation in the spectral response with wavelength as a function of exact PSF position on the MEMS array.

4.0 MEMS ENVIRONMENTS

The MEMS device will be housed within the NIRSpec Optics Assembly and will be subject to the environments there-of. The MEMS developers are referred to the NIRSpec Interface Requirements Document (NGST-IRD-000729). The MEMS device shall meet the environmental requirements as contained in the NIRSpec IRD.

5.0 INSTRUMENT INTERFACES

The MEMS device will be housed within the NIRSpec Optics Assembly. Section 5 of the NIRSpec Interface Requirements Document (NGST-IRD-000729) provides details of the MEMS interfaces with the instrument. The MEMS device shall meet the interface requirements as contained in the NIRSpec IRD.