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ARIEL Fine Guidance System Design

Miroslaw Rataj (1), Piotr Wawer (1), Mateusz Sobiecki (1), Konrad Skup (1), Roland Ottensamer (2), Paul Eccleston (3)

(1) Space Research Centre of the Polish Academy of Science, Poland, (rataj@cbk.waw.pl)

(2) University of Vienna, Austria, (3) RAL Space, STFC, UK

Abstract

The Fine Guidance System (FGS) of the ESA M4 mission ARIEL is provided by the payload consortium and is designed as a science instrument with payload in the loop functionality. Its main task is to ensure the centering, focusing and guiding of the satellite, but it will also provide high precision astrometry and photometry of the target star for complementary science. In particular, the data from the FGS will be used for de-trending and data analysis on ground.

1. Mission and Instrumentation

ARIEL (Atmospheric Remote-sensing Exoplanet Large-survey) will observe known exo-planets with a metre-class telescope and gather spectroscopic and photometric data to study the planets' atmospheres [1]. Its instrumentation consists of a photometer for the 0.50-0.55 µm range (VIS-Phot), two FGS channels covering the 0.8-1.0 µm and 1.0-1.2 µm ranges, as well as NIR-Spec, an infrared spectrometer covering two medium-resolution channels (1.95-3.9 µm and 3.9-7.8µm) and one low-resolution channel (1.25-1.95 µm). All of the instruments operate simultaneously. They share the same input beam, which is divided by three dichroic beam-splitters and one band-pass filter. The spectrometer beam also contains a prism. This concept of the dichroic system with prism is shown in Figure 1.

1.1 FGS

While the VIS-Phot and the NIR-Spec instruments are controlled by the instrument control unit (ICU) [2], the FGS channels have their own independent electronics. Each FGS channel is able to provide guiding information to the spacecraft at a rate of 10 Hz with 0.01 arcsec precision. Each FGS also collects the image data of the target star, compresses and sends them to ground along with metrology and housekeepings.

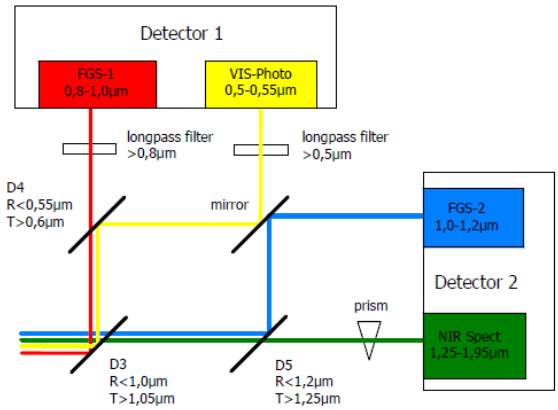

Figure 1: Scheme of the dichroics system. "Detector 1" denotes the visual channels and "Detector 2" denotes the NIR channel of the FGS and the spectrometer.

2. FGS Design

The FGS is composed of the optics box and the electronics box. The optics box is situated at the instrument optical bench (IOB) containing cryogenic optics with two detector modules at 50 K and the cold front-end electronics (CFEE).

The electronics part – FGS Control electronics Unit (FCU) is accommodated in the spacecraft service module at a temperature of 270-300 K. The FCU modules control and read the detectors and carry out the data processing for centroid calculation and image processing. The FGS systems are independent from the spectrometer instrument, thus have their own power and data interfaces with the spacecraft. The FGS is also involved in the focusing of the main telescope. This will be done using images from the

two detector arrays, which have different focus offset. The procedure will be controlled interactively from ground.

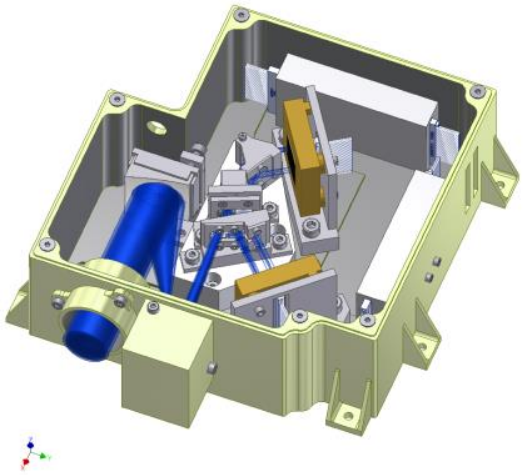

Figure 2: FGS module for optics and detectors.

2.1 Optical Design

The optical module has been designed with the following basic assumptions:

- FoV – max usable on sky FGS FoV is 25.2", corresponds with ±0.19 deg (FGS internal)
- Spectral bandwidth: 0.5-1.95 µm is split into four bands
- MCT detector FPA with minimum array and pixel size (18 µm for MCT) and ~1024x1024
- Low distortion (< 1% level over FoV)
- Minimum bin/star image spread FWHM: 6x6 pixels
- Able to achieve centroiding to 1/10th of a pixel level
- WFE: 250 nm rms = telescope diffraction limit @ 3 µm + allocation for dichroics

The FGS uses an off–axis Gregorian mirror telescope internally. It has a focal length of 500 mm and an F-number of 25. Inside the optics box are the detectors and the cold read-out electronics. The baseline for the detectors is to use H1RG TELEDYNE devices with with its SIDECAR read-out electronics, a European detector option with a pixel size of 15 µm is optional and subject to the outcome of an on-going development study.

2.2 Electronics Design

The FGS has its own control electronics in the service module of the spacecraft to carry out all necessary communication, control and data processing tasks.

The FGS control electronics are housed in a typical warm electronics box, with a total mass estimation of 5.5 kg. They consist of power supply and digital electronics – the Data Processing Unit (DPU) – in a redundant configuration. The DPU design is base on the Aeroflex GR712RC processor and uses SpaceWire interfaces for communication.

2.3 Flight Software Design

The FGS application software will control and read the FGS detector electronics, establish a control loop with the spacecraft and deliver scientific data products. The telemetry contribution of the FGS is below 4 kbit/s if no images are sent and below 79 kbit/s for measurement mode. The FGS application software will offer its functionality in the form of ECSS service commands and reports. The software includes fault detection, isolation and recovery (FDIR) functionality and offers several modes of operation to support maintenance and calibration activities.

3. Conclusion

The FGS for ARIEL will be developed by CBK-PAS, the University of Vienna and RAL. It will ensure the high-precision guiding of the telescope and provide complementary science data.

References

[1] Tinetti, G., et al.: The science of ARIEL, EPSC 2017-713, September 2017

[2] Focardi, M., et al.: The ARIEL Instrument Control Unit design, Experimental Astronomy, November 2017.