Advanced Precision Engineering in Cryogenic Environment

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Abstract

A configurable slit mask for worlds' largest optical telescope, the GTC located on La Palma (Canary Islands, Spain), is being developed by Janssen Precision Engineering. The instrument will be used for observing in the NIR wavelength range (1-12 mm), which forces the nominal working temperature to be at cryogenic temperature (77 K). The system contains 110 bars which can be positioned in the instruments' field of view to create optical slits, where each specific bar can be independently positioned under closed loop control. New technologies are successfully realised and tested in subsequent testing campaigns that have been launched to show the feasibility of the chosen concepts. Besides actuation and position control of the bars, also optical and thermal behaviour of the so called configurable slit unit (CSU) concept and more generic design principles have been successfully demonstrated within these campaigns. The design and realisation of the final instrument is currently ongoing. This paper gives an insight in the conceptual and practical challenges that are overcome in order to realize an instrument that will fulfil the demanding requirements.

1 Introduction

The current development of the EMIR (Espectrógrafo Multiobjeto Infrarrojo) instrument for the GTC (Gran Telescopio de Canarias) will create pioneering opportunities for astrophysical research. Not only the extremely large field of view, but also the fully cryogenic layout and the in-situ reconfigurable slit pattern will put the EMIR ahead of present instruments and create an enormous observation efficiency increase.

Being one of the key functionalities of EMIR, the development of the CSU is of major importance. In order to phase the development of the complex and pioneering development, two demonstrators (a 1 and a 6 bar) have initially been build and evaluated. The results revealed the potential of chosen concepts on one hand, and on the other hand set focus to critical issues. This has lead to, and set the baseline for, the currently ongoing development of the final unit.

2 CSU requirements

The Configurable Slit Unit is located at the entrance field of view of the EMIR instrument. The field of view has a size of 340 x 340 mm. The CSU shall enable the possibility to generate a multi-slit configuration, a long slit, or an imaging aperture. This shall be realised by positioning bars close to eachother from opposite sides within the 340x340mm wide aperture of the instrument. This leads to the global concept layout as depicted in figure 1.

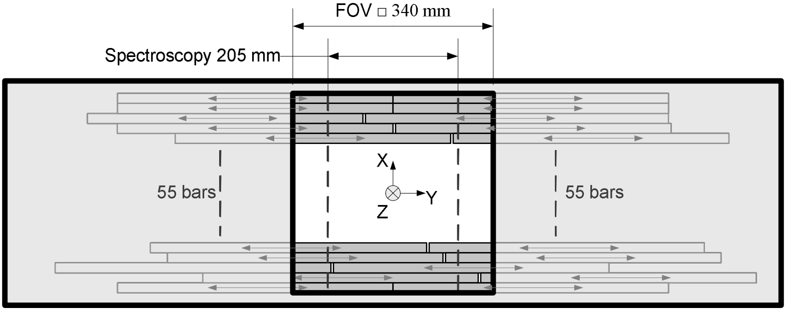

Figure 1: Concept layout of the configurable slit unit

The following key specifications are applicable for the CSU:

- number of bars	110 (2 x 55)
- mechanical stroke for each bar	275 mm
- position accuracy for each bar	< ± 6 micrometer
- reconfiguration time of the mechanism	< 300 seconds
- operational conditions	77 K, 10e-6 mbar
- allowed power dissipation during standstill	no, 0 Watt

3 CSU Mechanism

This chapter will illustrate the design details of the main building blocks of the CSU mechanism.

3.1 Actuator Mechanism

Based on the given constraints that come with the environment (vacuum and cryogenic temperature) in combination with the very narrow design envelope, a dedicated piezo actuator is developed. The actuator is based on the inertial piezo drive concept, where nett movement is created by using different accelleration levels for extending and retracting movenents of the piezo. At slow acceleration the movement is transferred by friction to the bar, whereas at high acceleration the movement is not transferred by friction such that the actuator can reset to its original position without movement of the bar.

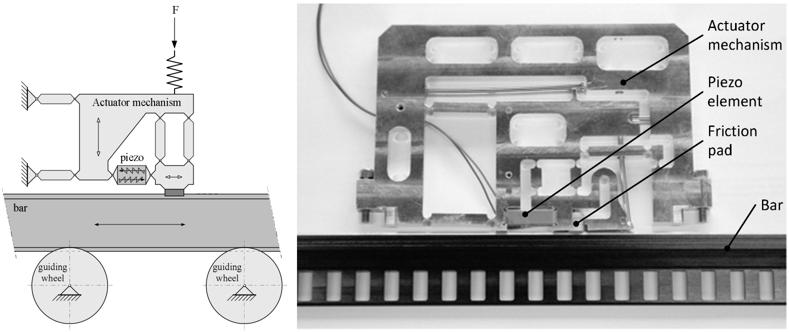

Figure 2: Concept and realisation of CSU piezo actuator

The actual piezo displacement per cycle is very small (≈ 18 μm ambient at ΔV = 120V) and is even less at cryogenic temperatures. Therefore the actuator mechanism is constructed from a monolithic piece aluminum to maximize drive stiffness and to avoid any kind of play, both in order to make most efficient use of the piezo steps. A special alloy has been chosen to eliminate the risk of fatigue as a result of large numbers of stepping cycles.

3.2 Bars

The bars are the main functional elements in the system. The bars should block all the incident light from entering the optical system, and create a knife edge slit where two opposing bars are positioned in front of eachother. To fullfill this function the bars are designed with a labyrinth crossection, an a sharp tip in the front like depicted in figure 3.

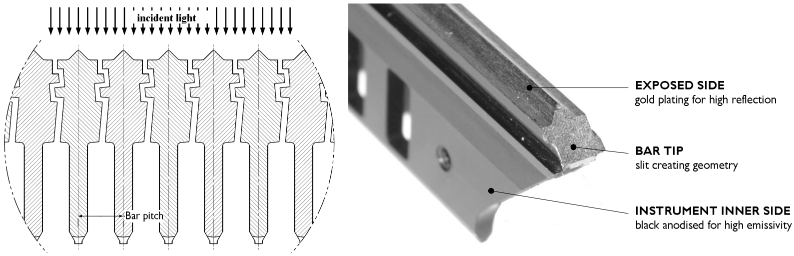

Figure 3: Concept and realisation of CSU bar

Furthermore the bars are designed with dedicated geometry features for guiding and actuator interfacing. Also a slot pattern is integrated for position sensing. The slender, strip-like geometry of the bar in combination with the high level geometric tolerances (applicable @ cryogenic temperature) make this an extreme complex machining part. But the most pioneering development for this part is the partial surface treatment which is required for optical reasons, where the top surface is hard-gold treated and the rest of the part is black anodised.

3.3 Position sensing

Each bar has an individual position sensor to enable closed loop control. Given the boundary conditions for the design envelope and environmental conditions, a dedicated sensor has been developped based on a capacity sensing principle.

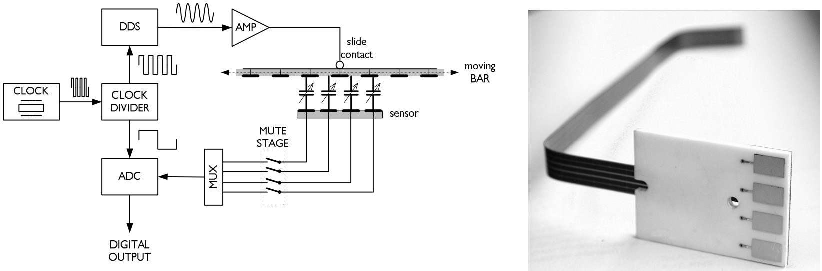

Figure 3: CSU measrement scheme and sensor

In the mechanics, special care has been taken to enable a stable mounting and a design that is robust against the large temperature differences between ambient and working temperature. From the electroncis side, special care has been taken to guard the capacative signals which are very sensitive to external disturbances.

4 Conclusion

The technology development for the required functionality of the CSU has been carried out and succesfully demonstrated by means of prototypes.

An actuation and measurement system have been developed for use in a vacuum and cryogenic environment with virtually endless stroke and accuracy in the sub-micrometer range.

5 References

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