Piezo actuators for telescope active optics

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Innovation in Mechatronics

INTRODUCTION

Piezo actuators are commonly used within Fast Steering Mirrors (FSM) for active stabilization, pointing and tracking functions. Such compact mechanisms are requested for Free-Space Optics and Deep Space Optical Communication since they are embedded and offer fast (up to 1kHz) and precise (µRad) tip tilt motion (up to +/-2°) [(1)]. The use of large amplified actuator within mirror telescope [(2)] is new and become relevant since it displays enough power, reliability and do not fall apart when a failure occurs: steady state design with high stiffness 64N/µm. The purpose of this poster is to present the development and the qualification of **the world largest Amplified Piezo Actuator ever integrated in a telescope** tip-tilt mirror of more than 2 meters diameter.

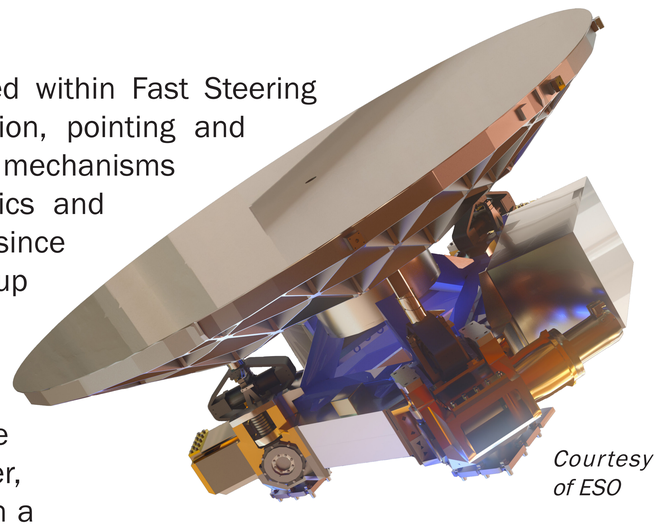

Fig.1 : M5 Units using APA500XXL

ACTUATOR DESIGN

The high preload applied to the piezo-electric material ensures a good behavior in dynamic mode, while preventing micro-slippage of the preload line.

The actuator combines a very high blocked force in compact dimensions, while its high stiffness also allows dynamic applications.

For optical purposes, **the thermal expansion and dissipation is needed to be as low as possible**. The system only dissipates 0.7W during actuation at 0.1Hz. This leads to less than 1K elevation in steady state at the actuator interface.

A detailed analysis has been performed to ensure a lifetime **higher than 30 years**, on both aspect : first ensuring an encapsulation to protect the piezo-electric material from humidity, second ensuring significant margins of flexible part for fatigue.

A stress and thermal analysis has been performed to guarantee a proper behavior from -5°C to +45°C in operational mode and from -15°C to +60°C non-operational. The thermal expansion has been compensated with thermal washer in order to reach 6µm/K from design.

ACTUATOR MANUFACTURING

The actuator is assembled with **several position and force sensors**, to verify the preload and dimensions. The coordinate measurement verifies ~10µm tolerances in flatness and ~20µm in parallelism between top and bottom interfaced.

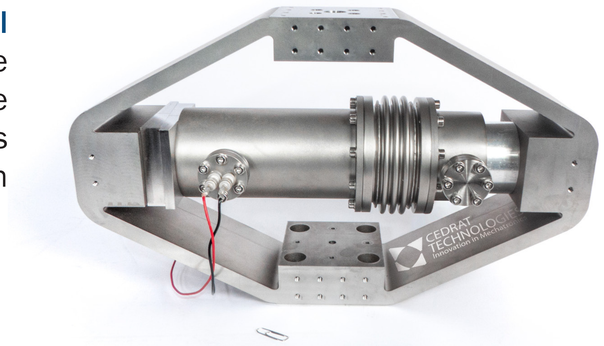

Fig.2 : The world largest Amplified Piezo Actuators: APA500XXL

QUALIFICATION & TESTS

An intensive qualification test campaign has been performed.

In **static**, the stiffness has been measured in small displacement and large displacement with up to 10kN.

The **dynamic** of the actuator has also been studied, in free-free conditions, block free conditions, but also with 200kg attached on both side.

Thermal cycling has been performed for verifying the stroke in operational temperature range. The self-heating of the actuator has been measured to 1K in continuous use at 0.1Hz.

Operational	
Stroke	670 µm
Stiffness	70 N/µm
Preload	22 kN
Actuator Mass	19 kg
Actuator Height	215 mm

Thermal	
Operation temperature range	-5 to 45°C
Thermal expansion	6 µm/K
Surface temperature	<1°K @ 0.1Hz

Dynamics resonance frequency	
Unloaded (blocked-free)	300 Hz
Unloaded (free-free)	1.1 kHz
Loaded (free-free 2x 200 kg)	110 Hz

The most demanding test has been the **accelerated lifetime** study, for which the actuator was realizing its operational stroke 550µm in free-free conditions with two masses of 200kg. Helium tests and full stroke health tests were realized periodically to up to 22 million cycles.

Lifetime	
Hermetic sealing (He test)	<10-9 Pa.m3/s
Fatigue cycling	22 Mcycles
Micro-slippage after lifetime	<1 µm

CONCLUSIONS

1. **The largest tip tilt in the world uses CEDRAT TECHNOLOGIES APA® piezo actuators**
2. **The Actuator is designed, built and qualified for +30 years life-time**

The APA500XXL is about to become COTS product solution [(3)]

REFERENCES

(1) F. Claeyssen, et al, CEDRAT TECHNOLOGIES, Large-Stroke Fast Steering Mirror for Space Free-Space Optical communication, Conference OPTRO 2020 , Paris France, 28-30 january 2020

(2) E. Vernet, ESO ELT M5 unit: design and manufacturing status, Proc. SPIE. 11445, SPIE Astronomical Telescopes + Instrumentation, 2020,

(3) Web CEDRAT TECHNOLOGIES, www.cedrat-technologies.com/fileadmin/datasheets/APA500XXL.pdf