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In astronomical instrumentation, the trend is currently to build up large telescopes. Such structures enable to gather more light and hence, to see our universe brighter. Numerous projects like VLT, ELT, TMT ... are well known cases showing the tendency.

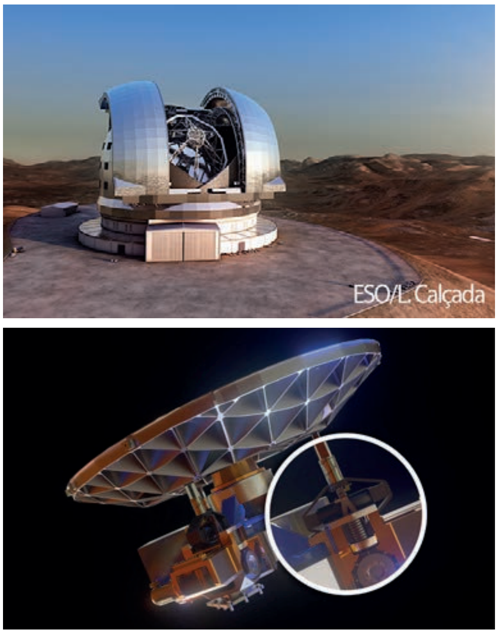

Fig. 1: Extremely Large Telescope (Top)
M5 mirror & APA actuators (Bottom)

OBJECTIVE

The full-size telescopes are sensitive to their environment. The challenge is to eliminate the external disturbances which lower the image quality. The disturbances can be environmental factors like gravity, wind, telescope axis deformation... or less intuitive factors like wave front distortion by the atmosphere. Telescopes are hence equipped with real-time monitoring systems controlling and adapting the position and shape of the mirrors by piston, tilt and steering operations.

CEDRAT TECHNOLOGIES ACTUATORS

CEDRAT TECHNOLOGIES (CTEC) designs actuators and mechanisms to answer to the compact, dynamic and precise motion requirement from the astronomical instrumentation designer and manufacturer. Here below we show some applications in the field of astronomy.

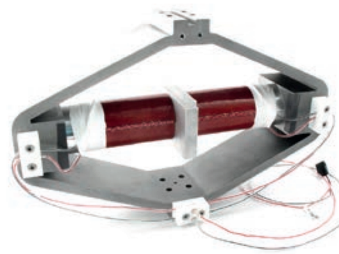

Fig. 2: Actuator APA500XXL for M5 field stabilization

EXTREMELY LARGE TELESCOPE (ELT) - ESO

CTEC has been involved in the development & delivery of several piezo actuators and mechanisms for critical subsystem parts of the ELT (fig.1) stucture and instrumentation like M5 filed stabilization unit and MICADO instrumentation detailed in the paragraphs below.

> ELT - M5 FIELD STABILIZATION UNIT - ESO

The aim is to generate a dynamic tip-tilt motion with stabilized piston motion on the M5 tip-tilt elliptical mirror of 2.7 m x 2.2 m and 430 kg mass in the Extremely Large Telescope (ELT). The actuation is made by three heavy duty APA500XXL (Fig.2) piezo actuators with 500 µm stroke and 30 kN blocked force under 1 kV voltage. This high force and stiffness make this APA500XXL a certified robust actuator to earthquakes. The first prototypes delivered to SENER with CSEM collaboration fulfilled ESO specifications (Fig.3). To reach the specified 30 years minimum of operations, CTEC decided to encapsulate the piezo stack into a bellows assembly (Fig.4&5) to protect the piezo ceramic against humidity and then increase significantly the Mean Time To Failure (MTTF) of the APA500XXL.

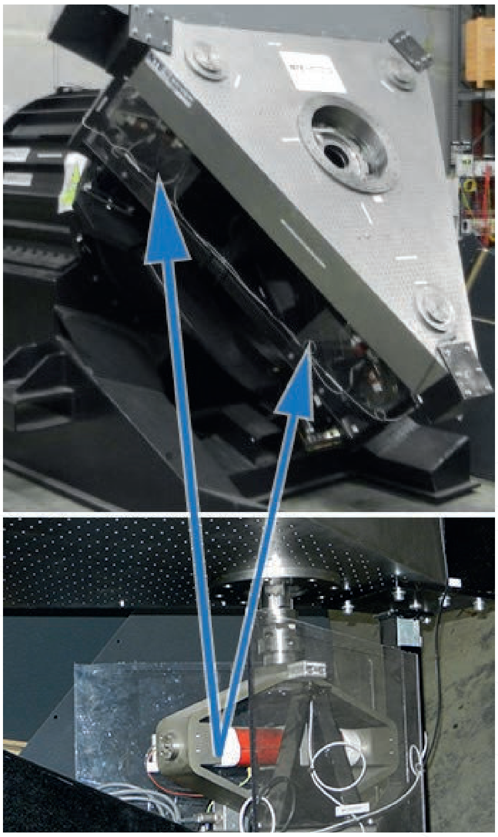

Fig. 3: APA500XXL integrated in the Tip Tilt platform of the M5 field Stabilization unit

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Thanks to its high resolution, the APA500XXL, coupled with an optimized close-loop control, allows to compensate perturbations caused by the telescope mechanisms and wind vibrations, with an accuracy of few micro-radians and 10 Hz bandwidth and alignment system in three degrees of freedom (Z, Rx, Ry) for the fifth mirror positioning. Although the M5 mirror will be the smallest mirror on the ELT, it will be the largest tip-tilt stabilized mirror in the world that will compensate perturbations caused by the telescope mechanisms, wind vibrations, and atmospheric turbulence.

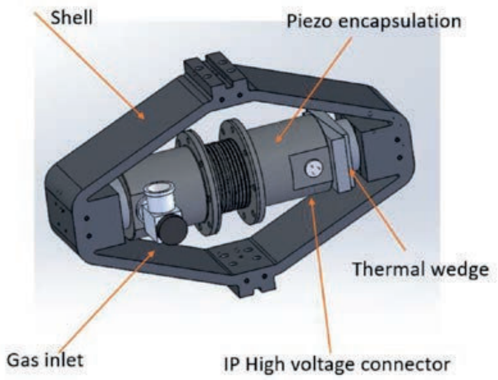

Fig. 4: APA500XXL preliminary design with encapsulation of piezo ceramic

ELT - MICADO - BEAM STEERING MIRROR FOR SIGNAL MODULATION

MICADO, a large multi-purpose infra-red camera, is one of the first light instrument to be installed at the Extremely Large Telescope (ESO telescope) and an Adaptive Optics system to correct atmosphere defect will be realized at LESIA (Paris Observatory / CNRS). This AO system is based on a pyramid Wave Front Sensor to measure the wave front aberration with a very high accuracy. To linearize the signal and adapt the sensitivity of the sensor the focused image has to be modulated around the top of the pyramid optical component using a Fast Steering Mirror based on a piezo tip-tilt mechanism DTT40SM-SG. This FSM consists of a 50 mm diameter and 8 mm thickness glass mirror located in a pupil plane (Fig.6). To measure and correct fast change in the turbulent atmosphere, the system may run up to 500 Hz with a stroke up to 2 mrad in closed loop. In addition, CTEC has taken care to add a cover to ensure protection against excessive humidity in the environment, as well as a bracket to fix the modulation system with the mirror in a vertical position. Also, the FSM is equipped with strain gauges to measure the position of the angular deflection.

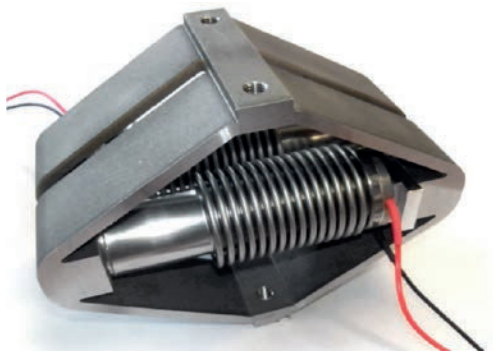
Fig. 5: Example of piezo ceramic encapsulated with bellows assembly

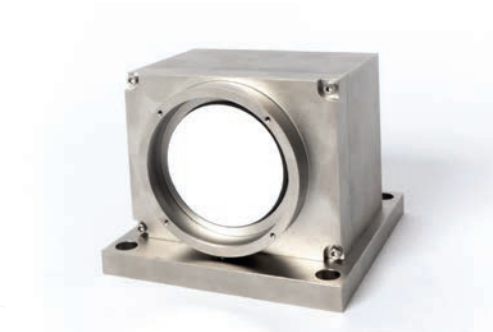
Fig. 6: Customised DTT40SM-SG for LESIA

OTHER INSTRUMENTATIONS

FAST STEERING MIRROR FOR ATMOSPHERIC DISTURBANCE COMPENSATION

CTEC has developed the DTT300ML-SG-SV which is a piezo tip-tilt platform welcoming large SiC mirror (Fig.7) to be used as Fast Steering Mirror (FSM) system. The DTT300ML-SG-SV is driven in closed-loop by a controller rack mounted. This FSM consists of a 200x140 mm elliptical SiC mirror with a total angular travel of 5 mrad on each axis and a control bandwidth greater than 100 Hz. The application could be about high power laser or even line of sight stabilization for atmospheric disturbance compensation.


Fig. 7: FSM with non-coated SiC mirror with its customised controller

BEAM STEERING MIRROR (CELTIC PROJECT) - LAM

The astronomical laboratory of Marseille (LAM) has developed a beam steering mirror (BSM) using actuators APA230L (Fig.8) and power electronics from CTEC. The BSM has been designed according to the specifications required on an ELT instrument and can perform translation, tip-tilt and deformation. The active surface deformation is meant to compensate for astigmatism introduced by spherical pickoff mirrors. A prototype has shown that this design allows to generate pure astigmatism and focus. Perceived as a good compromise between stroke (Up to 230 µm) and dynamic force (Up to 675 N), 4 APA230L are integrated in the device to generate the deformation.

A FAST AMPLIFIED FRINGE MODULATOR - UNIVERSITY OF CAMBRIDGE

For temporally modulated fringe patterns, stellar interferometric fringe acquisition rates must generally exceed 1 kHz to avoid significant atmospheric related loss of contrast and crosstalk between fringe components. Furthermore, sufficient travel and high waveform stability in the temporal phase modulation are essential to clean fringe visibility extraction. The system uses a piezoelectric actuator APA40SM (Fig.9) that takes advantage of a resonating stage to achieve an accurate and stable high amplitude motion. Nanometer accuracy in waveform optimization and in continuous waveform stability is demonstrated.

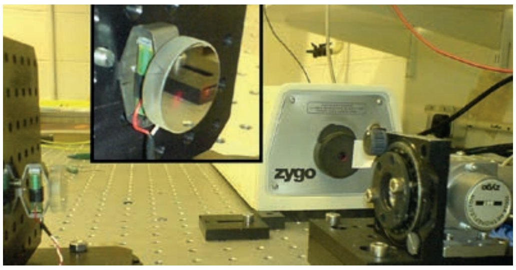

Fig. 8: Interferometric fringe modulator with APA40SM

KEY WORDS

Astronomical instrumentation; interferometer; tip-tilt stage; adaptive optics; active optics; piezo actuators; fringe modulator; ESO; ELT M5; Extremely Large Telescope; LAM; BSM; CELTIC; Fast Steering Mirrors