Fiber Positioner development for survey instruments

Marco Azzaro, SIDE group

London, March 23rd, 2010

SIDE (Super Ifu Deployable Experiment)

- SIDE is an instrumentation group targeted to instrumentation for survey spectroscopy.
- SIDE has a valuable experience about precision fiber positioning mechanisms and is currently testing a Fiber Positioner prototype built for the GTC in collaboration with the University of Barcelona. This project involves the mechanics, electronics and control software for the prototype.
- A patent is in progress for the prototype design concept.
- SIDE participated to the ESO-ELT OPTIMOS-EVE Phase A work and has been invited to participate to the BigBOSS project.

SIDE Group Members:

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S. Becerril (Mechanical & System engineer , IAA-CSIC),
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I. Morales (Software engineer , IAA-CSIC),
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Collaborators:

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The Ground-Based Stage IV BAO Experiment

BigBOSS

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BigBOSS: The Ground-Based Stage IV BAO Experiment

The BigBOSS experiment is a proposed DOE-NSF Stage IV ground-based dark energy experiment to study baryon acoustic oscillations (BAO) and the growth of structure with an allsky galaxy redshift survey. The project is designed to unlock the mystery of dark energy using existing ground-based facilities operated by National Optical Astronomy Observatory (NOAO) *. A new 5000-fiber R=5000 spectrograph covering a 3-degree diameter field will measure BAO and redshift space distortions in the distribution of galaxies and hydrogen gas spanning redshifts from $0.2 < z < 3.5$. The Dark Energy Task Force figure of merit (DETF FoM) for this experiment is expected to be equal to that of a JDEM mission for BAO with the lower risk and cost typical of a ground-based experiment. This project will enable an unprecedented multi-object spectroscopic capability for the U.S. community through an existing NOAO facility.

BigBOSS white paper

NOAO ReSTAR program

Team-Wiki (Private)

Team-Wiki (Public)

* NOAO is the US national center for ground-based nighttime astronomy and is operated by the Association of Universities for Research in Astronomy under cooperative agreement with the National Science Foundation.

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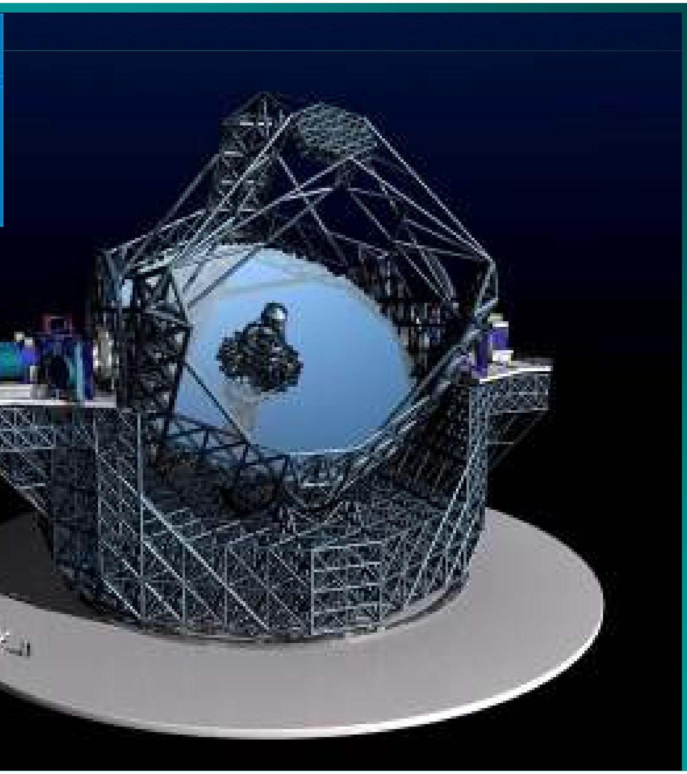
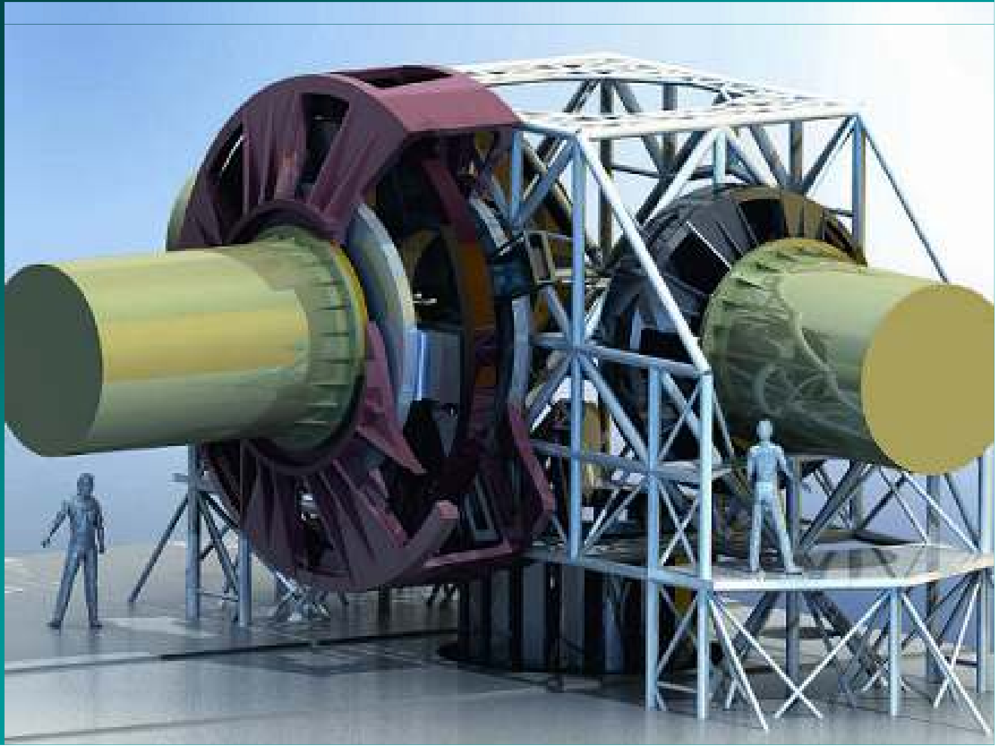
Call for Proposals ref. CFP/ESO/08/20579/LCO for the
Advanced Study of a new Instrument Concept for the European Extremely Large Telescope (E-ELT) at a firm fixed price of € 100.000

Recommendation:

OPTIMOS-EVE

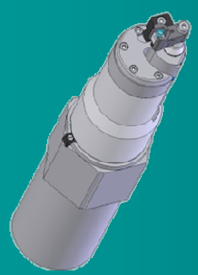
The SWG emphasizes the very strong science case for an instrument which provides multi-object spectroscopy from the r band to the h band, with a multiplex of at least 100. It is not required to give spatially resolved information. The field of view is of order 10arcmin. The spectral resolution would be 3000, or more, subject to a trade-off. A goal would be to extend the spectral range further into the blue, and the red. Another goal would be to include R=5000-10000. The SWG would strongly encourage that an instrument like this is studied, for example as one of the studies for new instrument concepts.

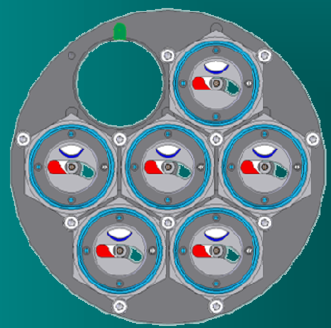


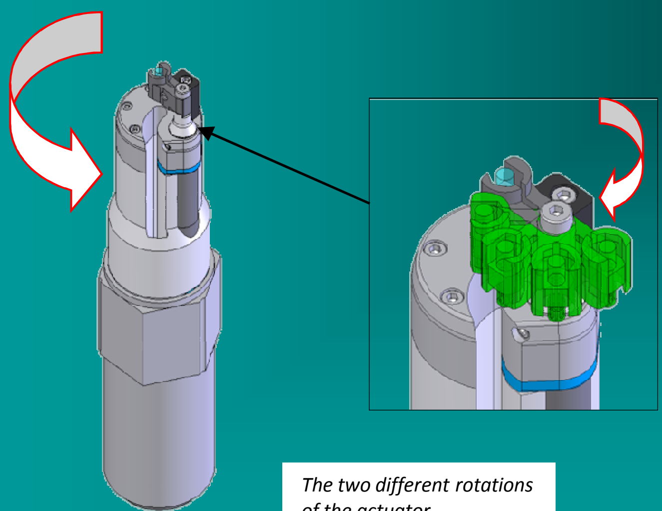


SIDE experience

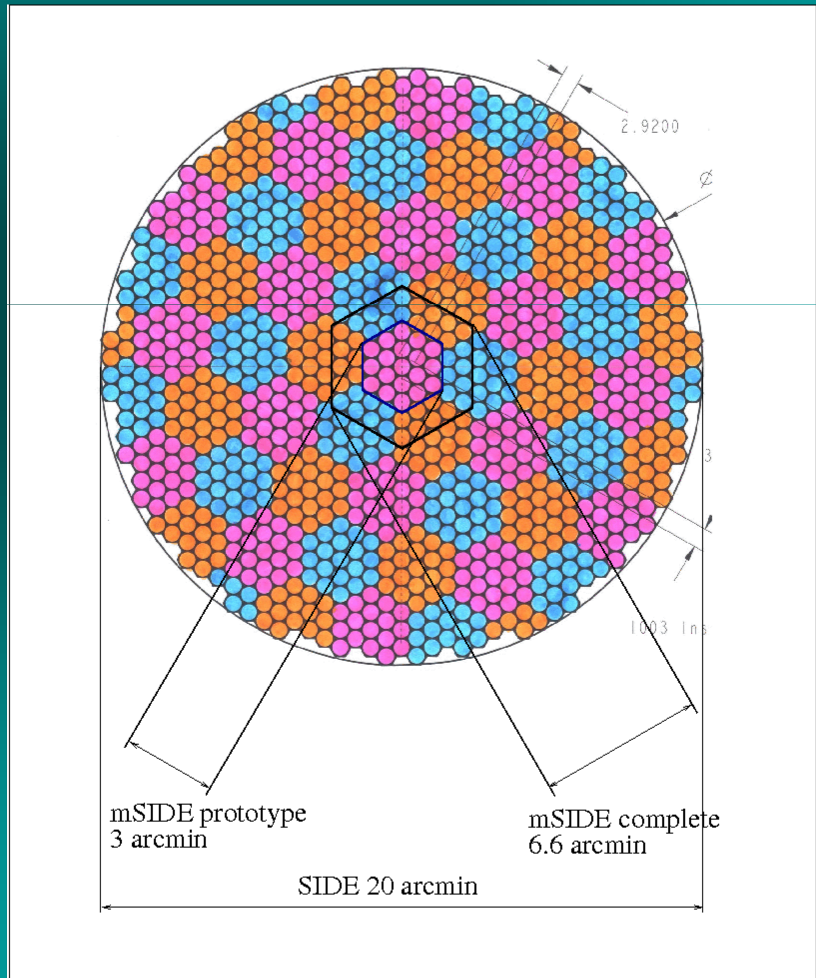
SIDE has developed a prototype of Fiber Positioner sized for GTC Nasmith focus. The 99 cm Ø focal plane is divided into cells, each with one actuator moving one fiber. Actuator's centre-to-centre is 29.2 mm, the patrol disc is 33.72 mm diam. No blind spots are left. The picture shows the GTC Nas focal plane with 1003 actuators for 20 arcmin Ø field . Basic requirements are: repeatability ±40μ, abs. positioning ±200μ.



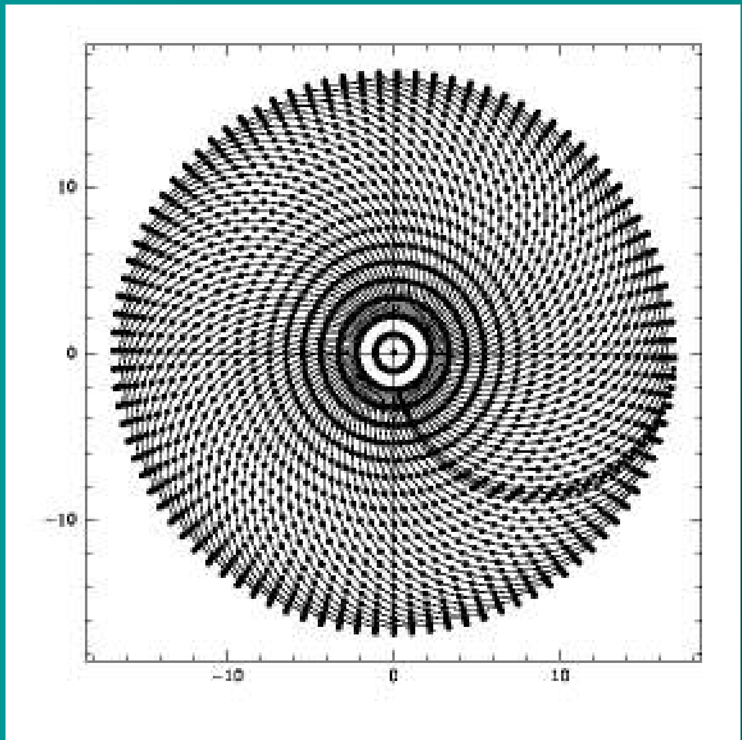




The two different rotations of the actuator

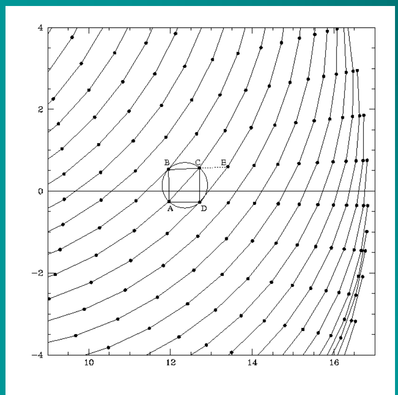


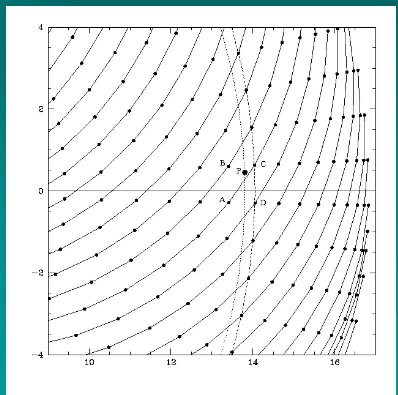
Prototype geometry

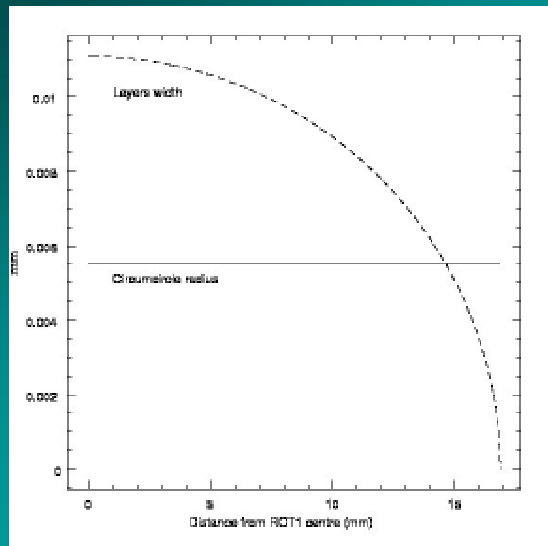


Due to the combination of two stepper motors, the fiber can be positioned on a discrete grid with more than 23 million points, of which a reduced example is given in the picture (top left).

We determined that the theoretical spatial resolution of the device is never worse than 5.5 μ, and the resolution is constant across the patrol circle.

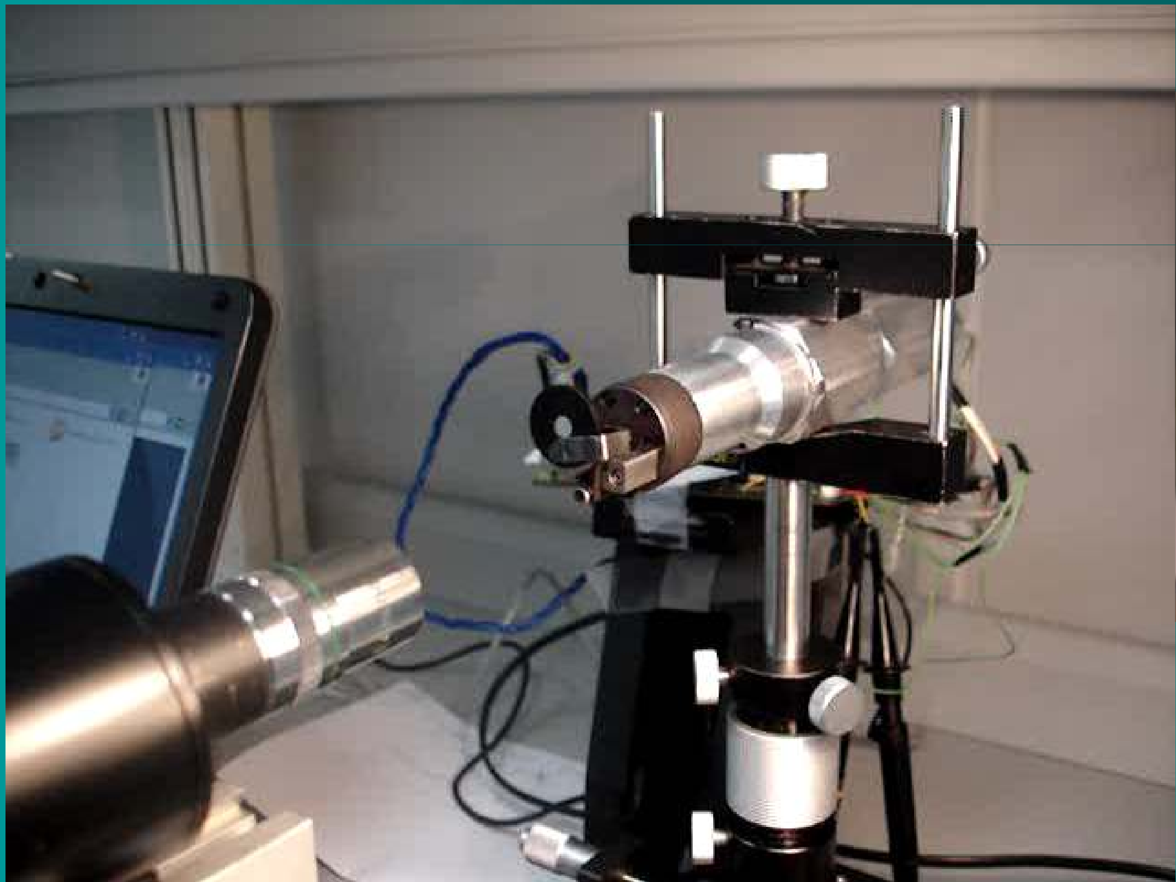


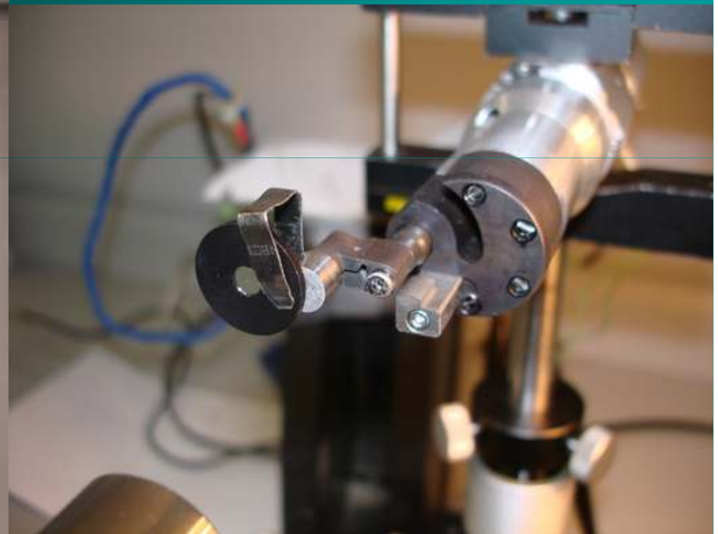




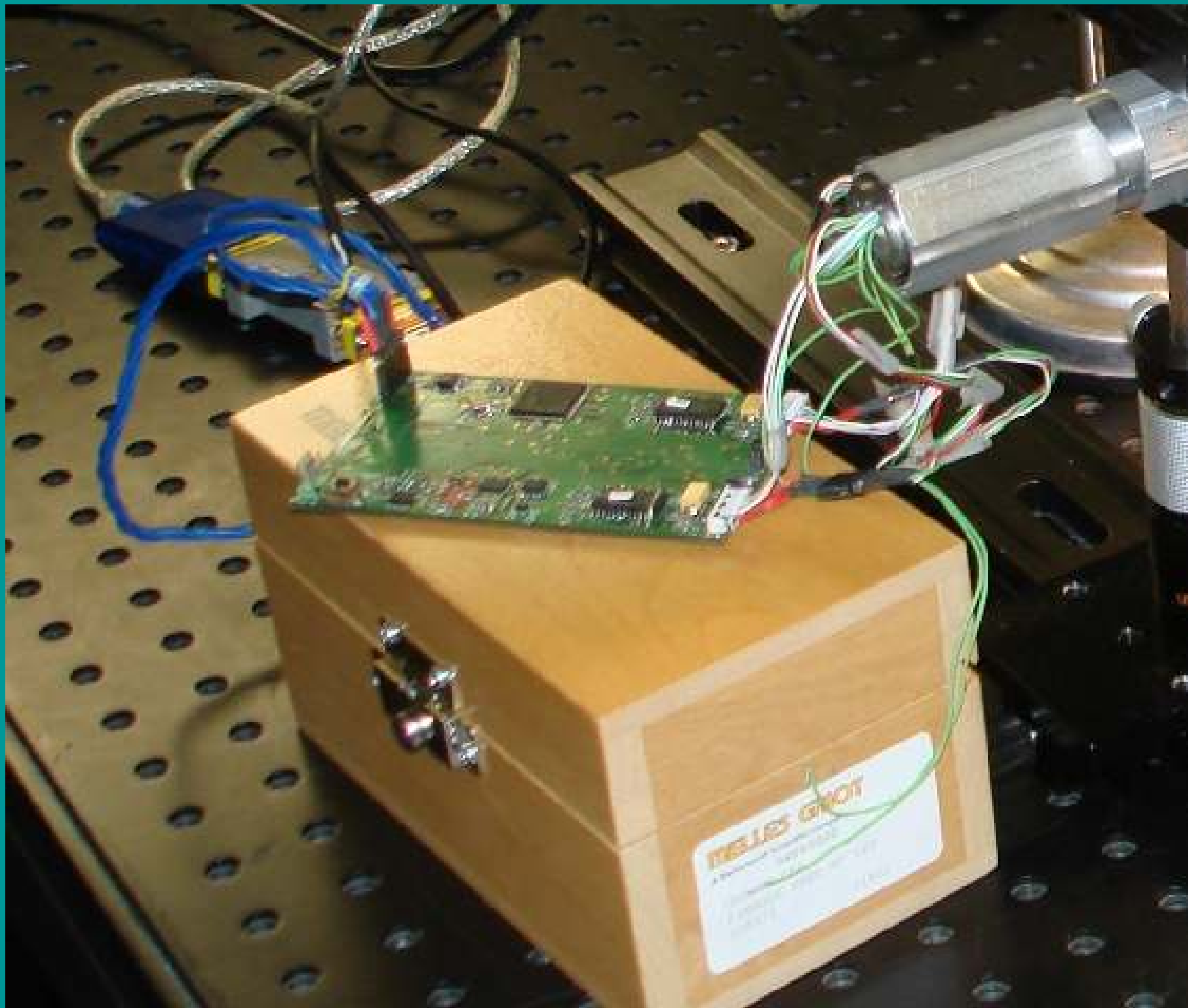
Prototype movements

This movie shows a few example movements of the actuator. On top of the fiber button (right) you can see a black washer clamped to the dummy button (the fiber was removed for the tests). This has a 2µ pinhole which was used as target for the microscope measurements.





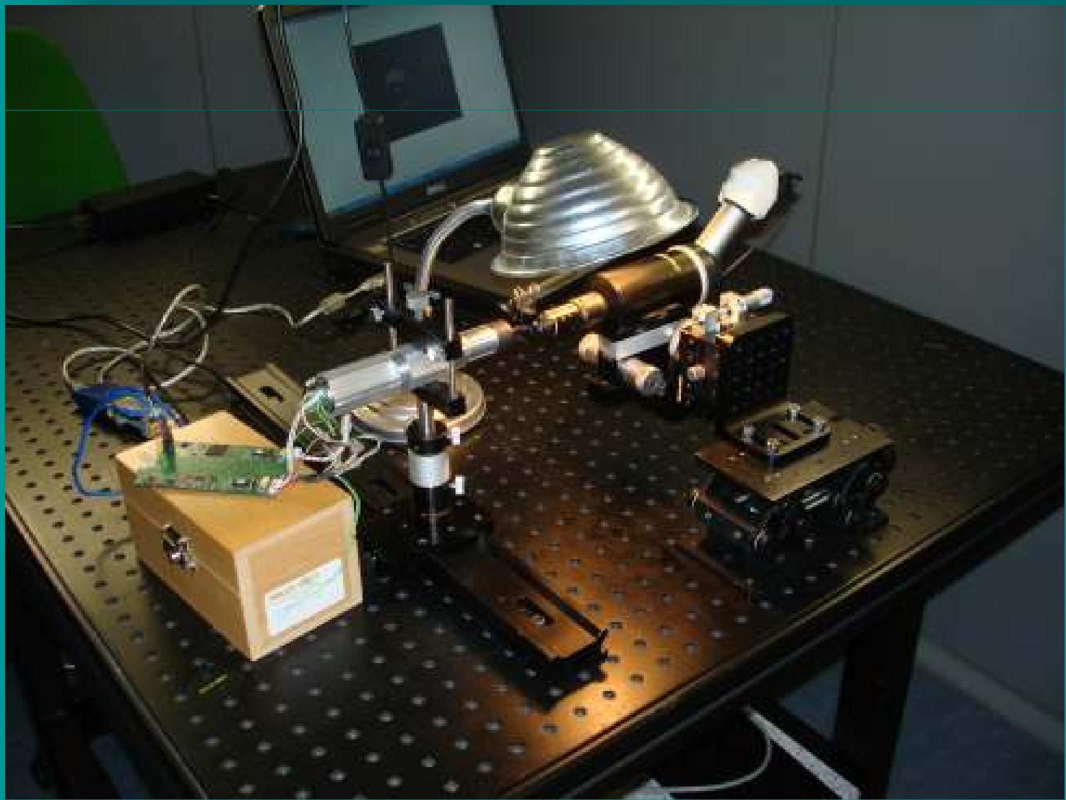
Electronics board by IAA-UB



The electronics for controlling the prototype was designed and built in collaboration with the University of Barcelona. A functional breadboard is currently used for the tests, and a sized board is being designed for being fitted to the prototype (whose envelope would fit within the hexagonal frame of the prototype). The control software for this PCB was developed at IAA.

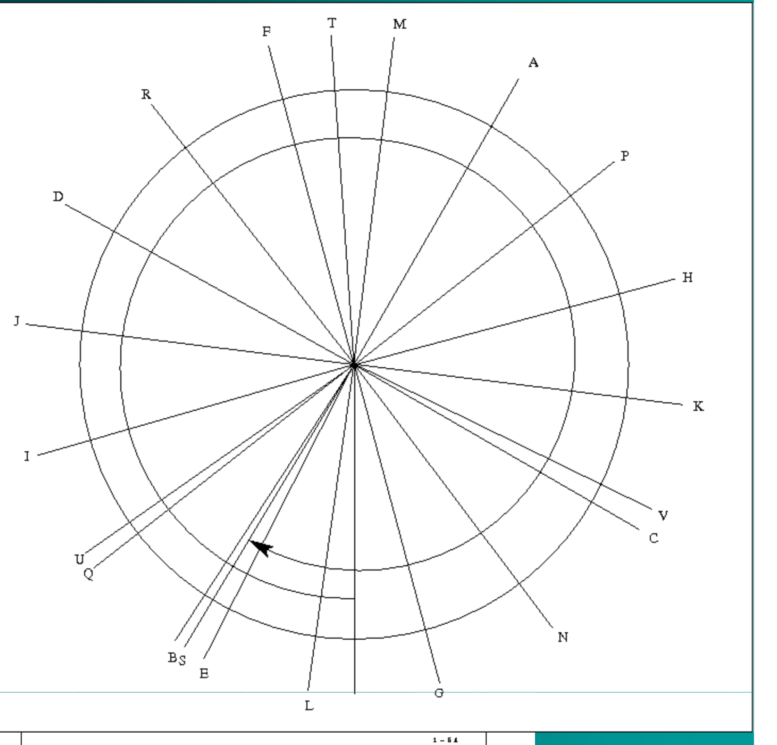
Repeatability tests

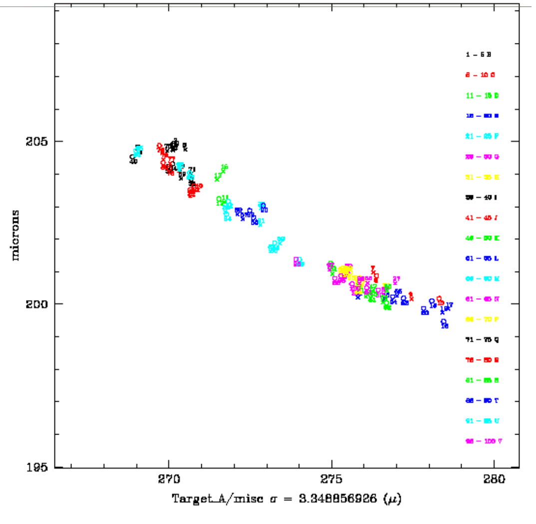
The use of this setup with a microscope and a 2μ pinhole (see picture) allowed us to test the prototype repeatibility with an accuracy of about 1μ. The result are still being analyzed, but it can be said that, given a pair of points, the repeatibility of going from one to the other is outstanding (we can hardly measure any difference), specially in ROT2, which has the arm directly driven by the motor. In particular, the tests performed concern (in both axes separately) : 1) Backlash 2) Stepping stability 3) Best approach mode 4) Repeatability of sample points.

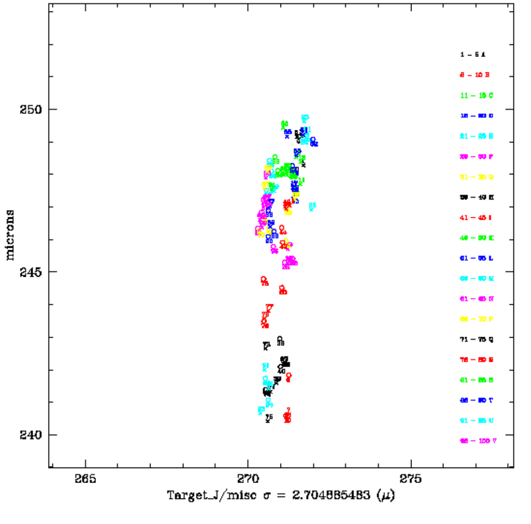


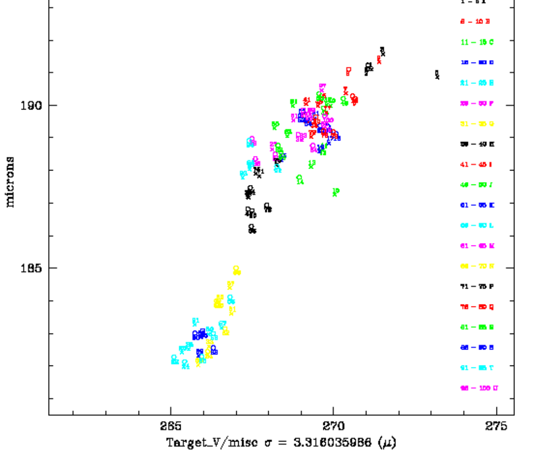
Repeatability tests results

Some of the results of the Repeatability of ROT1 show that, usually, the total radial dispersion of a position is below ±1μ and the total tangential dispersion is below ±5μ.

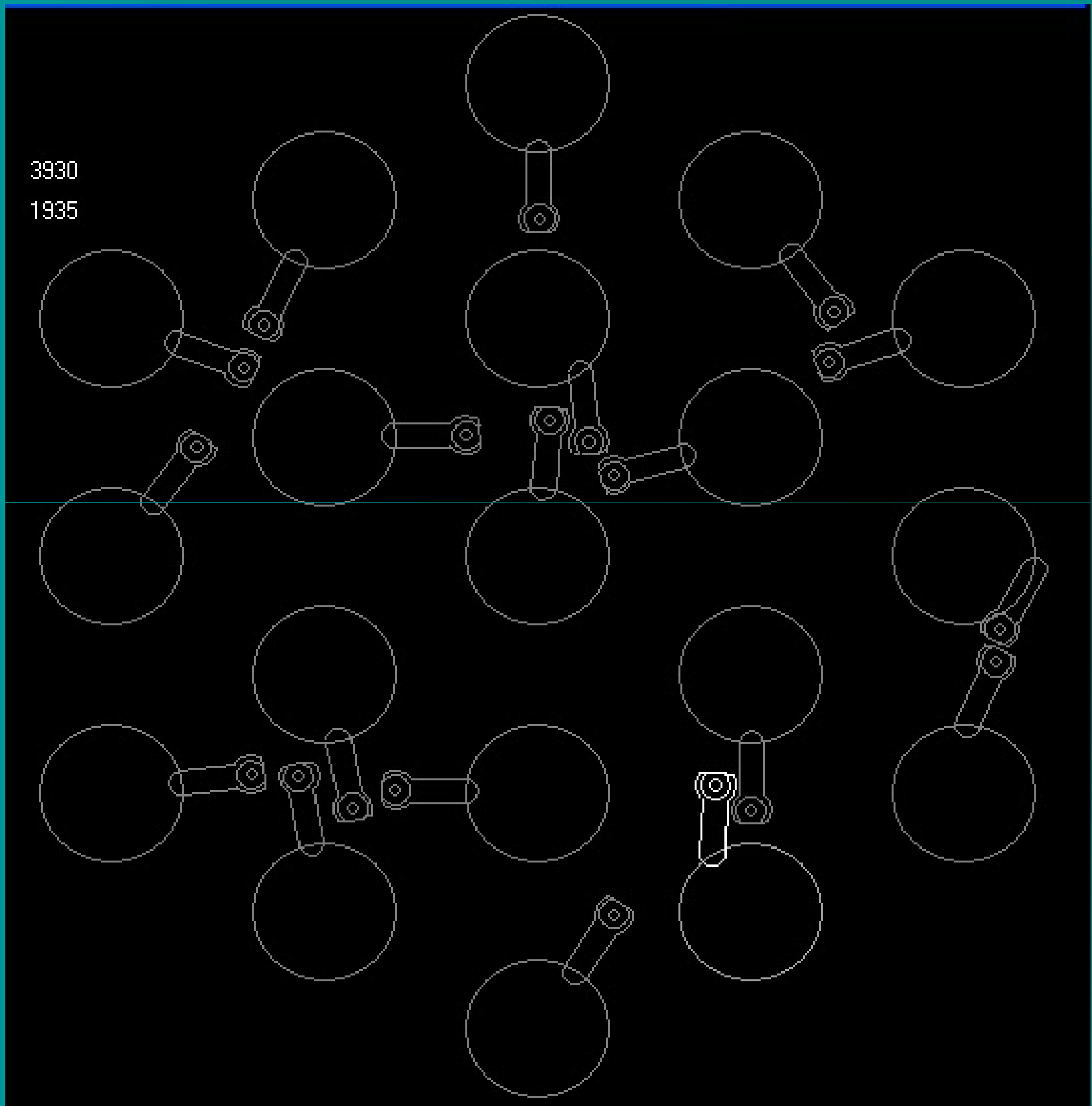








Positioning software



The High-Level control software for a set of actuators is under development at IAA. The anti-collision algorithm is simulated here for a typical conflicting situation with 19 units: several fibers cannot be moved because they are too close one to another. The algorithm finds the necessary movements to disentangle the paths: 1) the free actuators go to their safety zones 2) the colliding actuators are freed and 3) all the actuators can reach safely their respective security zone.

The algorithm which efficiently assigns actuators to objects is under development.

Other projects where we can help

- MEGARA @ GTC
- Future Wide-field spectrograph @ WHT

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PHYSICS DIVISION

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January 25, 2010

Instituto de Astrofisica de Andalucía (IAA)
Camino Bajo de Huetor, 50
Granada, Spain

Attention: Dr. Francisco Prada

Dear Sir or Madam,

This letter is to invite Dr. Prada and the Instituto de Astrofisica de Andalucía (IAA) to participate in the BigBOSS survey.

BigBOSS is designed to map the expansion history of the Universe and the effects of dark energy from $z=2$ to $z=0$. The challenges to efficiently measure the redshifts of 50 million galaxies in a 10-year survey utilizing the Kitt Peak 4-m and Cerro Tololo 4-mtelescopes. The instrument design allows a scientific reach exceeding that of the proposed JDEM (U.S.) or EUCLID (European) dark energy satellites.

The Lawrence Berkeley National Laboratory (LBNL) is strongly committed to the research and development needed to move forward with the BigBOSS project. The LBNL Director has provided funds for Laboratory Directed Research and Development to address some of the long-term issues related to the project. Looking forward, we expect that the United States Department of Energy will support the instrument construction. A review by the DOE Particle Astrophysics Scientific Assessment Group states: "Substantial immediate support is recommended for BigBOSS R&D so that ground Baryon Acoustic Oscillation (BAO) possibilities are known for timely planning of a coherent ground-space dark energy effort."

Participation by the IAA would address the largest technical risk in the BigBOSS project: the fiber positioners. The BigBOSS focal plane requires positioners that can reconfigure 5000 fibers in less than one minute with 15-micron accuracy. We have reviewed the available technologies, including a formal review of the IAA/AVS fiber positioners by the LBNL Engineering Division. We are extremely impressed with the IAA/AVS designs, and hope to build upon their experience for the smaller and more-challenging BigBOSS design.

Our expectation is that IAA would be a partner in the design of BigBOSS, the construction, and the scientific program beginning in 2016. This builds upon a successful scientific collaboration with IAA in the past with the Sloan Digital Sky Survey.

The scientific reach of the BigBOSS program is proving to be very substantial, and we look forward to a rewarding U.S.-Spain partnership to best advance our understanding of dark energy, dark matter, and perhaps even the signatures of inflation.

Sincerely,

James Siegrist

James Siegrist
Associate Laboratory Director, General Sciences
Director, Physics Division
Professor, University of California, Berkeley

Copy: David Schlegel (LBNL) djschlegel@lbl.gov
P.I. BigBOSS