VIENTOS: a feasibility study of innovative pupil systems for the new generation of instruments in the large telescopes

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Abstract

The goal of VIENTOS project is to analyze pupil innovative systems that could be used in the new generation of instruments for the large telescopes. This study tries to identify the current scientific needs, to understand why some of them have not been fulfilled yet (due to pre-conceived technical ideas or to managerial reasons) and to propose opto-mechanical solutions for these pupil elements that could produce a qualitative leap in the performance of the instruments to operate in the large telescopes.

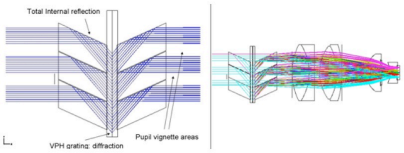
VIENTOS is currently on-going as a collaborative project between FRACTAL and the University Complutense of Madrid (UCM) and is being partially funded by a CDTI grant under the program Industry for Science. CDTI is the Development and Industrial Transfer Center from the Minister of Science and Innovation (Spain).

Among the different innovative systems that we have carried out, our team has explored potential solutions for narrow band Imaging with tunable filters in the near-IR and a novel pupil system called sliced-pupil grating, a device designed for increasing the spectral resolution in astronomical spectrographs, without changing the geometry of the main optics. Nanotechnology customized filters to be applicable to astronomical systems are under study.

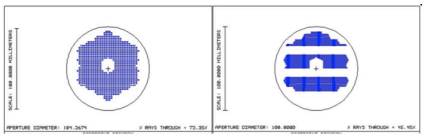
SLICED-PUPIL GRATING DESIGN AND PROTOTYPE OUTCOMES

The aim of the sliced-pupil grating is to increase the resolution of the instrument by a factor of 3 or 4 times without changing the instrument geometry. A prototype to prove the feasibility of this concept was designed and manufactured for ELMER (a spectrograph-imager for the GTC 10-m telescope). This unit is composed of six prisms (three on each side) and the grating, consisting on a VPH hologram sandwiched between two flat windows. The VPH has 3400 lines/mm (providing R=10,000 at first order).

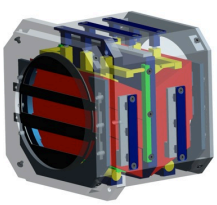
Optical and Opto-mechanical design



The unit is placed at the pupil (89mm Ø size) with a clear aperture of 105mm that allows covering all unvignetted field at the edges. Nevertheless, as the pupil is sliced in three pieces to minimize assembly difficulties, some parts of the pupil's flux are lost (producing vignetting). In fact only 62% of the incoming pupil beam passes through the system .

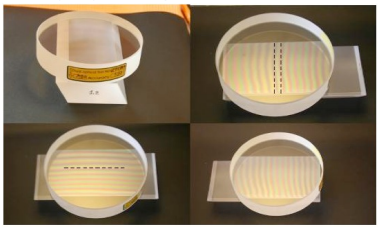


The mount allows placing the different optical elements in its exact position relative to each other as well as locating the whole grating with precision onto the optical path. The mount has been designed to absorb the differential thermal dilatations of the optics with respect to the aluminum mount, maintaining its performance, and preventing surface stresses that may affect the transmission.



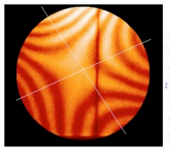
Prism tests

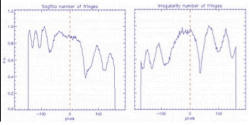
The prisms used in the prototype were manufactured by SESO. We measured the parallelism of the surfaces, the surface quality, the angles between the prism surfaces and the equality of the angles



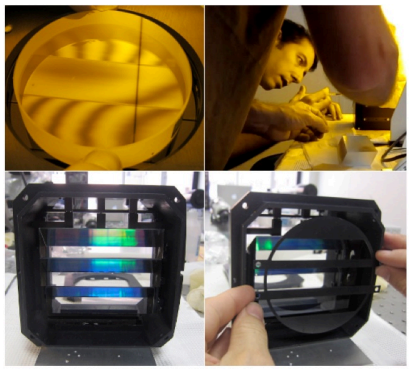
VPHs tests

The VPHs were manufactured by Wasatch Photonics, who sent us several gratings fulfilling the same specifications. We performed the measurements to verify the specification fulfilment and to assess which VPH provides the best quality and use this unit for the assembly.





Mounting process



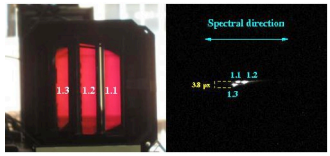
Assembled unit tests

Test rigs consists of two 900mm of focal refractive telescopes facing each other and previously collimated, one of them used as a collimator and the other one as a camera, with the disperser placed in between.

Prototype conclusions

The prototype was able to increase the resolution of the instrument in more than 3 times (from R = 2,500 to ≈ 8,000).

The experience gained with this prototype shall allow us to improve the mounting process that should be done for further units registering the stacking while gluing the prism to verify that the three beams are going into a common point at the focal plane.



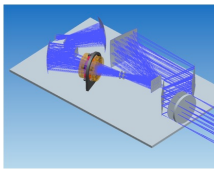
TUNABLE FILTER FEASIBILITY STUDY

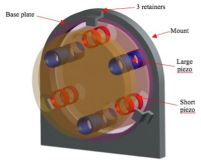
The feasibility of using a tunable filter (FISIR) for CIRCE was analyzed. CIRCE is an instrument proposed by the University of Florida as visitor instrument for the GTC 10-m telescope. FISIR is an initiative of the UCM and the University of Florida.

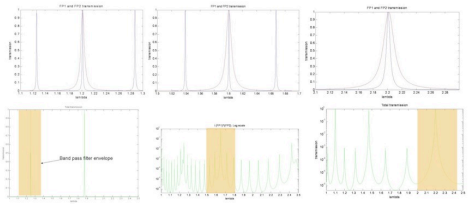
The FISIR requirements are that it shall be capable of scanning any wavelength in the near-IR range (from 1.0µm to 2.5µm) with a spectral resolution of R ~ 750.

We propose the use of a Fabry-Perot concept in etalon configuration. Two instruments positions were analyzed: at the pupil and near the entrance focal plane.

The figure below shows CIRCE optical train with FISIR at pupil (left) and the filter opto-mechanical design (right)







LICA UCM SET-UP ACTIVITIES

VIENTOS tests have been performed at the optical laboratory Laboratorio de Instrumentación Científica Avanzada (LICA) of the Astrophysics department of the Universidad Complutense de Madrid (UCM).

LICA capabilities have been improved to be ready for carrying out the characterization of VPH gratings and prisms, the assemblies of gratings with prisms to produce dispersive pupil elements based on VPH technology and to verify the sliced pupil grating prototype.

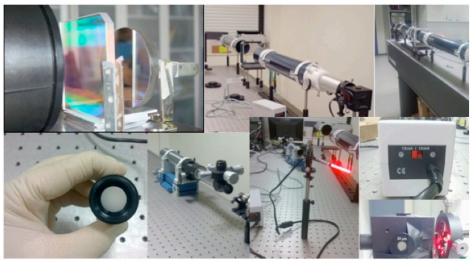
In order to follow the study and application of VPHs for infrared we plan to extend this set-up to be able to perform the pupil elements tests at cryogenic temperatures.

LICA has also a CCD Test Bench and an optical fibers characterization system is being prepared.

VPH GRATING FOR NEAR-INFRARED INSTRUMENTS

Although VPHs are currently only used in optical instruments, the goal is to use them in NIR spectrographs if the VPHs performance at low temperatures and resistance to cryogenic cycles can be verified. We performed a study to analyze the use of VPHs in IR ranges, the feasibility of reaching Infrared wavelength range > 1.0µm and the feasibility of VPHs with temperatures below 200 K.

The conclusions reached in the experiments that we found about this matter is there is not significant change in the VPH diffraction efficiency in a range of temperature between 200K and 100K and up to 2.2µm. Most of those tests have used for their VPHs BK7 glass and dichromatic gelatin. The transmission of these glasses is over 90% in range below 2.0µm, but there exist other possibilities as the ZnSe crystal for wavelengths well beyond the 2.0µm that could be used to perform further tests beyond this limit.



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VIENTOS project is being co-funded by CDTI, FRACTAL and UCM. This work has been done also in the framework of the Moncloa Campus of International Excellence initiative (UCM-UPM)