BATMAN: MOS spectroscopy on demand

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Abstract. Multi-Object Spectrographs (MOS) are the major instruments for studying primary galaxies and remote and faint objects. Current object selection systems are limited and/or difficult to implement in next generation MOS for space and ground-based telescopes. A promising solution is the use of MOEMS devices such as micromirror arrays which allow the remote control of the multi-slit configuration in real time. TNG is hosting a novelty project for a real-time, on-demand MOS masks based on MOEMS programmable slits. We are developing a 2048 x 1080 Digital-Micromirror-Device-based (DMD) MOS instrument to be mounted on the Galileo telescope and called BATMAN. It is a two-arm instrument designed for providing in parallel imaging and spectroscopic capabilities. With a field of view of 6.8 arcmin x 3.6 arcmin and a plate scale of 0.2 arcsec per micromirror, this astronomical setup can be used to investigate the formation and evolution of galaxies. The wavelength range is in the visible and the spectral resolution is R=560 for 1 arcsec object and the two arms will have 2k x 4k CCD detectors. ROBIN, a BATMAN demonstrator, has been designed, realized and integrated. We plan to have BATMAN first light by mid-2016.

1. Introduction

Next generation Multi-Object Spectrographs (MOS) for space like the Near Infrared Multi-Object Spectrograph (NIRSpec) for the James Webb Space Telescope (JWST) require a programmable multi-slit mask. MOEMS programmable slit masks could be next-generation devices for selecting objects in real time. MOEMS devices such as micromirror arrays (MMA) (Burg et al. 1998; Zamkotsian et al. 1999) or micro-shutter arrays (MSA) (Li et al. 2010) are promising solutions. MMAs are designed for generating reflecting slits, while MSAs generate transmissive slits. At LAM an effort is currently under way to develop micromirror arrays for infrared multi-object spectroscopy (Canonica et al. 2013). By placing the programmable slit mask in the focal plane of the telescope, the light from selected objects is directed toward the spectrograph, while the light from other objects and from the sky background is blocked. To get more than 2 millions independent micromirrors, the only available component is a Digital Micromirror Device (DMD) chip from Texas Instruments (TI) that features 2048 x 1080 mirrors and a 13.68μm pixel pitch. DMDs have been tested in space environment (-40°C, vacuum, radiations) by LAM and no showstopper has been revealed (Zamkotsian et al. 2011).

We are presenting in this paper a DMD-based spectrograph called BATMAN, including two arms, one spectroscopic channel and one imaging channel. BATMAN will be placed on the Nasmyth focus of Telescopio Nazionale Galileo (TNG) during 2016. ROBIN, a BATMAN demonstrator, has been designed, realized and integrated.

2. BATMAN CONCEPT AND OPTO-MECHANICAL DESIGN

BATMAN is a compact spectro-imager with two arms in parallel: a spectroscopic channel and an imaging channel. Both arms are fed by using the two DMD mirrors stable positions (Fig. 1) (Zamkotsian et al. 2012, 2014). Our goal is to make a robust and

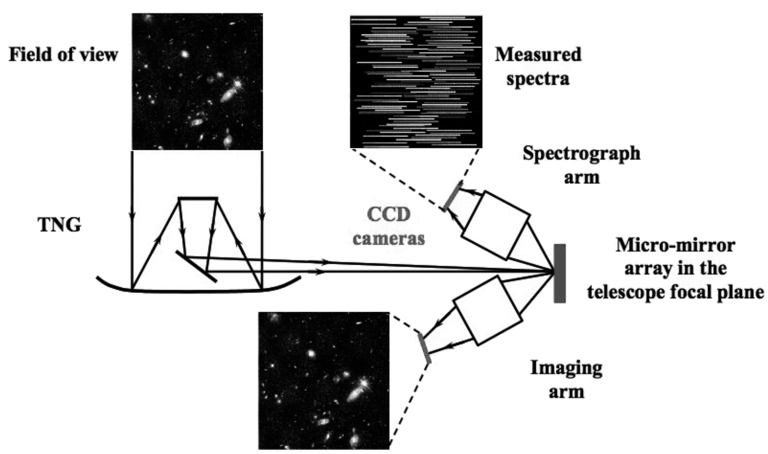

Figure 1. Principle of BATMAN spectro-imager

efficient instrument for a space mission, focussing on large areas and fixing some constraints:
(a) focal ratios feeding DMD should be close to F/4, thus allowing relatively easy decoupling from the incoming an outcoming beams on the DMD surface;
(b) incoming beam must hit DMD surface at normal incidence, everywhere on the DMD chip, a simpler relay system not introducing tilted image planes and being telecentric;
(c) both spectroscopy and imaging modes could be available;
(d) all optical components should lie in plane, for easy integration and alignment;
(e) use as much as possible plane and spherical optics, to reduce cost and delivery time.
BATMAN baseline is resumed in Table 1.

Digital Micromirror Devices (DMD) from Texas Instruments could act as objects selection reconfigurable mask. The largest DMD chip developed by TI features 2048

Table 1. Table 1: Baseline of BATMAN

Primary mirror diameter	3.6 m
Field of view	6.8 arcmin x 3.6 arcmin
Focal ratio	F/4 on DMD (with 2048 - 1080 micro-mirrors)
Plate scale = 0.2 arcsec per micromirror	
Beams on DMD	incoming light at normal incidence ; out-coming light at 24° ; DMD orientation at 45°
Wavelength range	400 - 800 nm
Spectral resolution	R=560 for 1arcsec object (typical slit size)
Two arms instrument	one spectroscopic channel and one imaging channel
Detectors	Two 2k x 4k CCDs

x 1080 mirrors on a 13.68μm pitch, where each mirror can be independently switched between an ON (+12°) position and an OFF (-12°) position. Specialized driving electronics and a cold temperature test set-up have been developed and tested in different environmental conditions. **These results do not reveal any concerns regarding the ability of the DMD to meet environmental space requirements** (Zamkotsian et al. 2011).
In Europe an effort is currently under way to develop single-crystalline silicon micromirror arrays for future generation infrared multi-object spectroscopy (collaboration LAM / EPFL-CSEM). First arrays with 2048 micro-mirrors have been successfully designed, realized and tested at 160K (Canonica et al. 2013). On a longer time scale, these arrays could be used in BATMAN concept.

Fig. 2 shows the optical layout. The entrance beam is adapted in F-number by the fore optics and is split by the DMD into 2 arms, a spectrograph arm and an imaging arm. BATMAN is based on a double Offner relay system with a 1:1 magnification between the DMD and the detector pixels.

The general mechanical design of BATMAN consists of a main optical bench supporting all optical elements except the detectors mounted on a second bench over the first one and attached to the main bench (Fig. 2). The main bench supports 2 arms: the entrance beam is adapted by the fore optics and is split by the DMD into 2 arms, a spectrograph arm and an imaging arm.

3. ROBIN: A BATMAN DEMOSTRATOR

Before developing BATMAN, we have built a demonstrator named ROBIN. The design of the demonstrator is identical to the instrument design for being fully representative, with a global reduced size, on mirrors as well as on the grating. The general mechanical design of ROBIN consists of a main optical bench supporting 2 arms: a spectrograph arm and an imaging arm. The detectors are located on both sides of the bench. ROBIN picture is shown in Fig. 3.

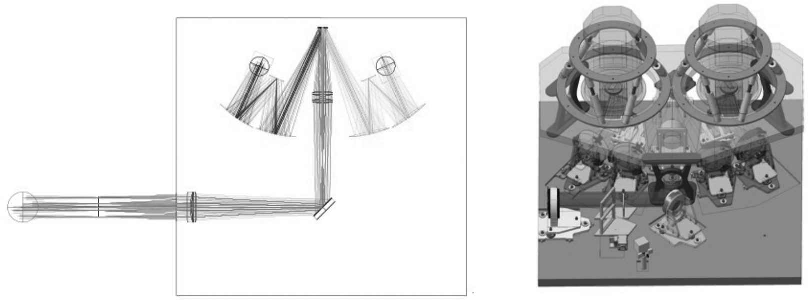

Figure 2. Optical layout of BATMAN. Light coming from the telescope is split by the DMD into 2 arms, a spectrograph arm and an imaging arm (both are Offner relays); BATMAN opto-mechanical design: overall view

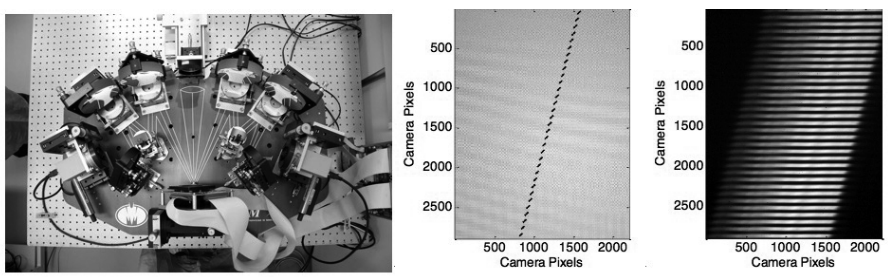

Figure 3. Integrated ROBIN picture; Image of the slit mask in the imaging channel and the corresponding spectra in the spectral channel

First images and first spectra have been recorded (Fig. 3). A serial of slits, 5 micromirrors wide and 15 micromirrors long are set on the DMD: in the imaging arm, they appear in black as the light located on these slits is sent towards the spectrograph; in the spectroscopic arm, the slits generate spectra for each of them, and all spectra are aligned on the detector, due to the dispersion orientation of the grating.

4. CONCLUSION

BATMAN is a 2048x1080 Digital-Micromirror-Device-based (DMD) MOS instrument to be mounted on the 3.6m Galileo telescope. A two-arm instrument has been designed for providing in parallel imaging and spectroscopic capabilities. The field of view (FOV) is 6.8 arcmin x 3.6 arcmin with a plate scale of 0.2 arcsec per micromirror. The wavelength range is in the visible and the spectral resolution is R=560 for 1 arcsec object (typical slit size). The two arms will have 2k x 4k CCD detectors.

ROBIN, a BATMAN demonstrator, has been designed, realized and integrated. This instrument will be placed on the Telescopio Nazionale Galileo mid-2016.

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