Optical design for the Giant Magellan Telescope Multi-object Astronomical and Cosmological Spectrograph (GMACS)

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Abstract

We describe the optical design of GMACS, a wide field, multi-object, optical spectrograph currently being developed for the Giant Magellan Telescope (GMT). We outline the details of the optical design subsystems, their individual and combined optical performance and the expected throughput. The predicted alignment tolerances, detector specifications, field acquisition/alignment optics, and optical considerations for the active flexure control system are discussed in the paper.

Requirements

Table 1 gives the GMACS principal functional requirements. Additional performance goals and constraints, such as throughput, glass blank availability, and detector dimensions will also guide the design process.

Parameter	Requirement	Goal
Field of View	30 arcmin sq.	50 arcmin sq.
Wavelength Coverage	350-950nm	320-1000nm
Spectral Resolution	Blue and red: 1000-6000	Blue and red: 1000-6000
Image Quality	80% EE at 0.30 arcsec	80% EE at 0.15 arcsec
Spectral Stability	0.3 spectral res. elements/hour	0.1 spectral res. elements/hour
Number of Gratings	2	≥2
Slit Mask Exchange	12	≥20

Table 1. GMACS principal functions parameters

GMACS mounting location

GMACS will be mounted in the GMT Direct Gregorian (DG) focus location, which consists of four bays within the Gregorian Instrument Rotator (GIR) structure each accommodate instruments up to 5.5 m in height and 2.78 m square, Fig.1. DG instruments are mounted on slides to move them from the bays into the center of the GIR and place them at the focus [1].

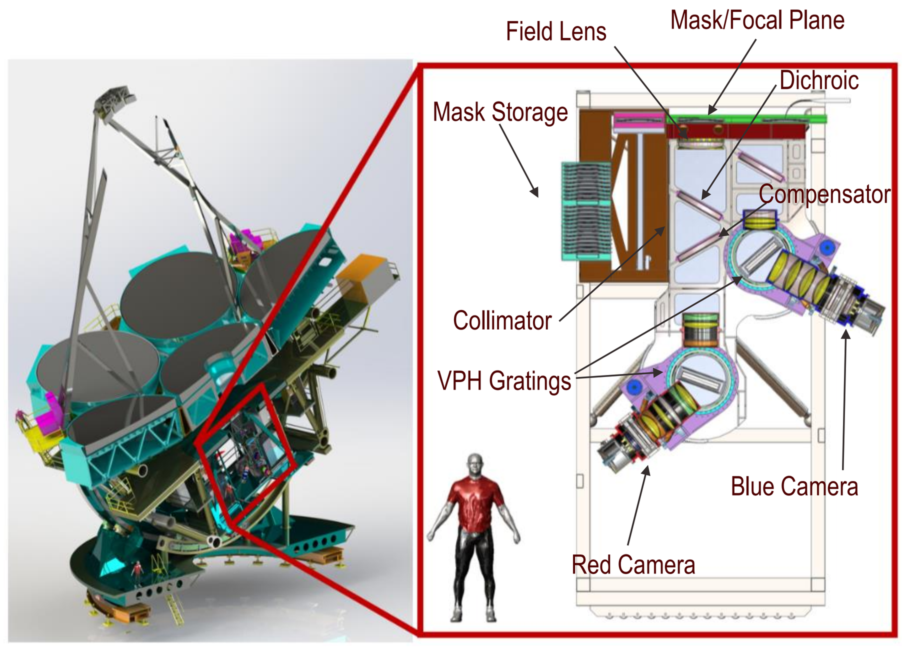

Figure 1. The new opto-mechanical design concept [2] for GMACS. The slit mask exchangers can be seen on either side at the top of the image. GMT focal plane and mask are located in the thin green box directly above the large field lens.

Optical Design

The current GMACS optical system is based on a totally refractive split collimator architecture. It uses a dual-beam Volume Phase Holographic Grating (VPHG) with a CCD mosaic as its detector. The collimator images the GMT entrance pupil onto the grating planes while splitting the incoming light into two spectral bands corresponding to blue (320nm to 600nm) and red (500nm to 1000nm) as separated by a tilted dichroic. The dispersed beams are imaged by two independent articulated f/2.2 refractive cameras operating in transmission Littrow. All the GMACS optical groups comprise singlets or air-doublets to avoid the use of cemented or coupled optics.

Collimator

The collimator is f/8.2, with 2,200mm effective focal length, the Field of View (FoV) is 7.4 arcmin diameter, Fig.2. The fused silica field lens (FL) is shared by both collimator arms. The wedge dichroic (≈15 arcmin) splits the beams feeding the two collimator arms. For the blue arm, a plane mirror is used to comply with space constraints. The red arm has a wedge compensator to minimize the aberrations caused by the dichroic located in a converging beam. Both collimator groups have one aspherical surface with best fit spherical deviation (BFSD) less then 150μm across the entire diameter, located in the element closest to the collimator exit pupil.

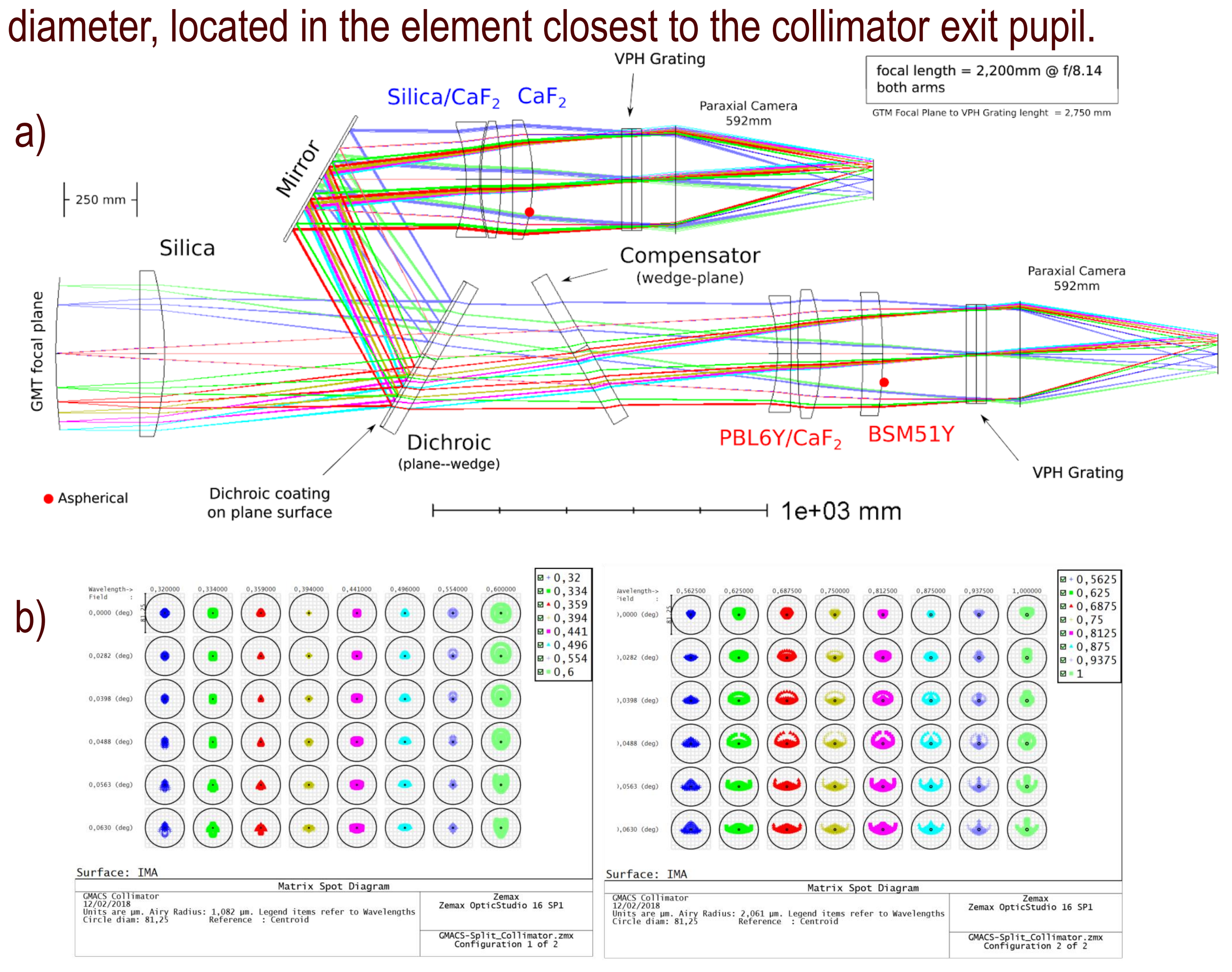

Figure 2. a) Optical layout of the GMACS split collimator and b) the spot diagram with a 592mm paraxial camera. Circle diameter is 0.3 arcsec.

Focal Plane

The focal plane is made of a two by three array of 4096 × 4096, 15 μm pixel CCD's for a total of 8k (spatial) by 12k (spectral) pixels, Fig 3.

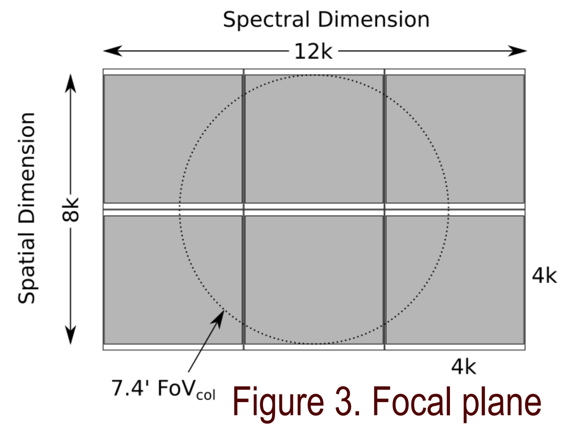

Figure 3. Focal plane

Blue Camera

The blue camera, f/2.2, 592mm focal length, is comprised of only FS and CaF_2 glasses for high throughput <350nm, two aspherical surfaces on both first CaF_2 lens (BFSD < 1mm and < 240μm for all diameter), Fig.4.

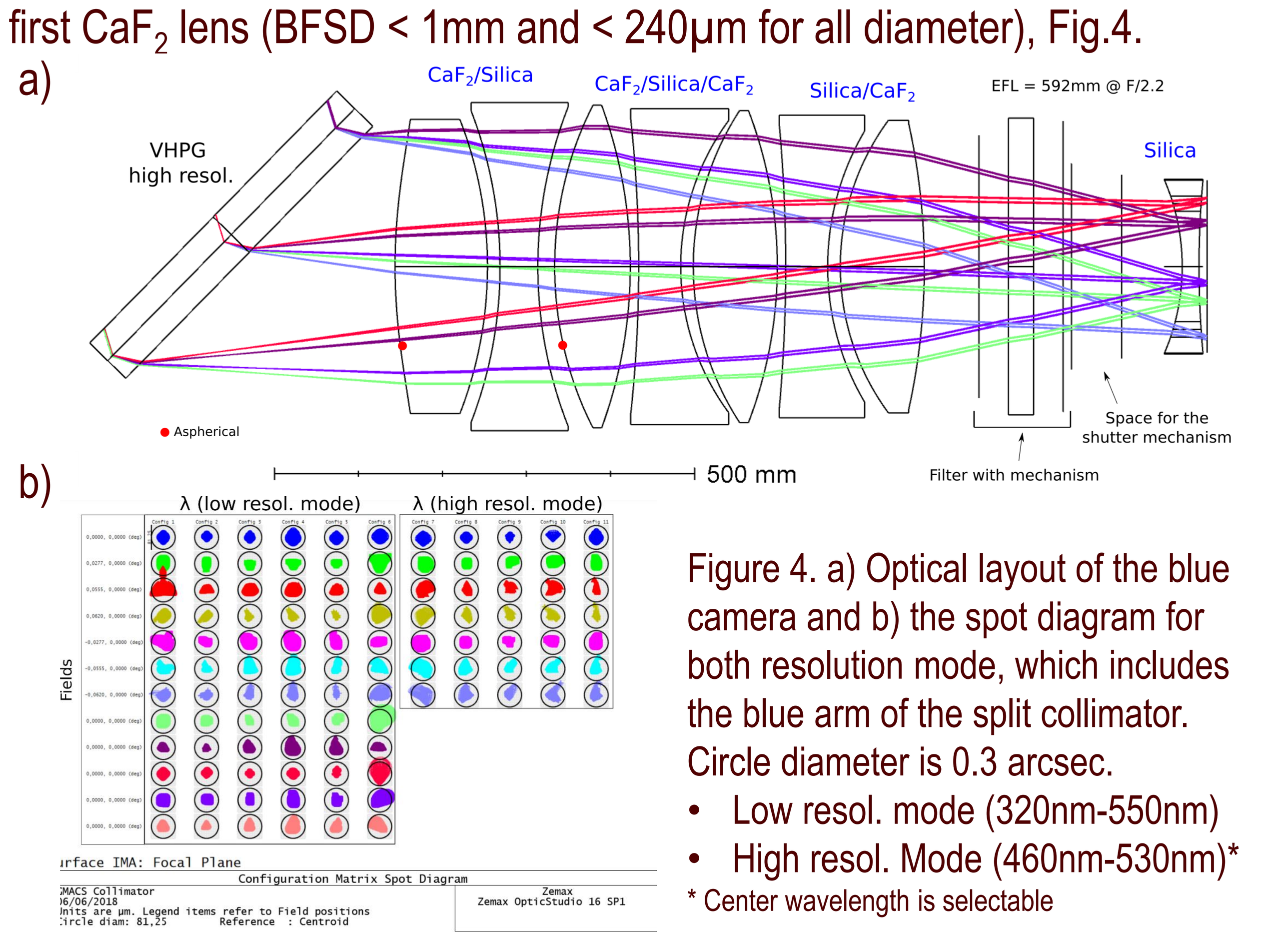

Figure 4. a) Optical layout of the blue camera and b) the spot diagram for both resolution mode, which includes the blue arm of the split collimator. Circle diameter is 0.3 arcsec.

- Low resol. mode (320nm-550nm)
- High resol. Mode (460nm-530nm)*

* Center wavelength is selectable

Red Camera

The red camera, f/2.2, 592mm focal length, is comprised of CaF_2, PBL6Y and BSM51Y glasses for good spherochromatism correction, two aspherical surfaces on both first CaF_2 lens (BFSD < 350μm, both), Fig.5.

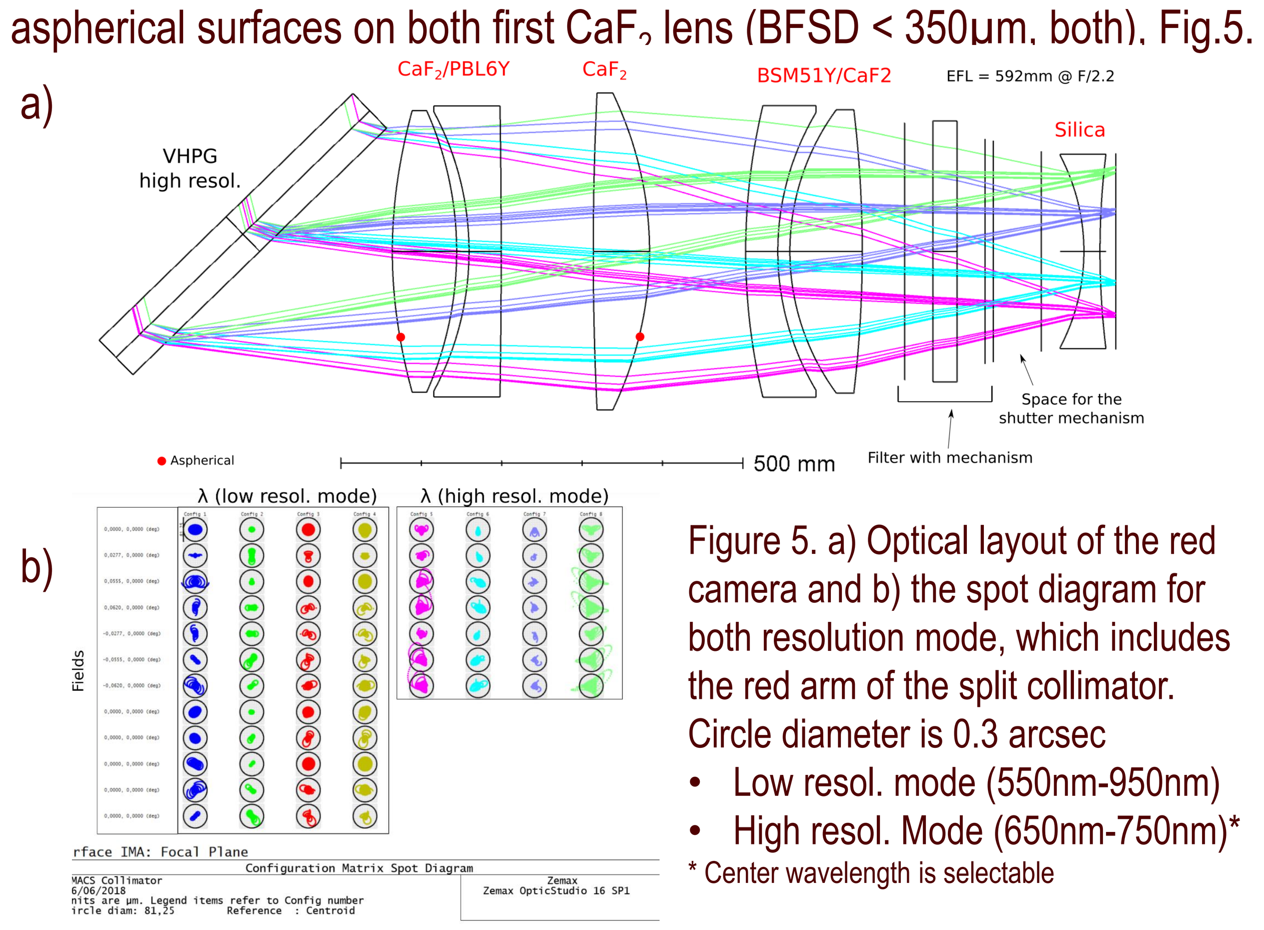

Figure 5. a) Optical layout of the red camera and b) the spot diagram for both resolution mode, which includes the red arm of the split collimator. Circle diameter is 0.3 arcsec

- Low resol. mode (550nm-950nm)
- High resol. Mode (650nm-750nm)*

* Center wavelength is selectable

Integrated Spectrograph – Blue arm

Fig.6. shows the superposition layout of both spectrograph modes for the complete blue arm of the GMACS optical system.

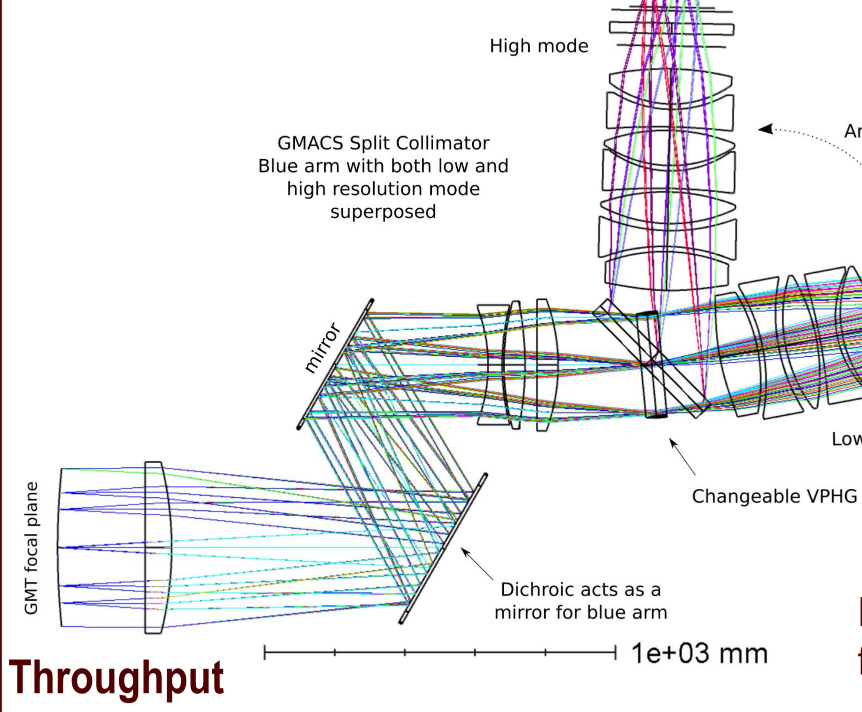

Figure 6. GMACS Blue arm for both resolution modes

Throughput

The throughput for over all the GMACS spectral range is 55% for both arms, considering both the split collimator and the cameras elements (for this simulation, all the optical interfaces have AR coating 99%, the folded mirror has 95% reflectance and internal absorbance of the glasses are considered. GMT mirrors, slit losses, spectral filters, dichroic and grating performance are not included).

Auxiliary Systems

We are working with the MANIFEST team to develop the interface between GMACS and MANIFEST (the GMT fiber positioner), which will allow GMACS to carry out multiplexed observations over the entire 20 arcmin GMT FoV,.

Future Work

GMACS is currently in conceptual design and will undergo a midpoint conceptual design review in July of 2018. After this meeting, we will model the consequences of the flexure due to gravity on the spectral stability and a perform a trade-off for the flexure metrology and compensator approach.

References

[1] GMTO: GMT System Level Preliminary Design Review - Section 6: Telescope (2013).
[2] Prochaska et al. "The optomechanical design of the Giant Magellan Telescope Multi-object Astronomical and Cosmological Spectrograph (GMACS)" Proc. SPIE 10702, Instrumentation for the ELTs III, 10702-364 (June, 2018).

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GMT

HETDEX Hobby-Eberly Telescope Dark Energy Experiment

LSST Large Synoptic Survey Telescope

DARK ENERGY SURVEY

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