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


*Departamento de Astronomia, IAG, Universidade de São Paulo, Cidade Universitária, 05508-900, São Paulo, Brazil;  †Department of Physics and Astronomy, Texas A&M University, 4242 TAMU, College Station, TX, 77843-4242 USA;  ‡Prime Optics, Australia;  ††Instruments4, CA 91011, USA;  †Department of Astronomy, C1400, †University of Texas at Austin, Austin, TX 78712;  †School of Space Research, Kyung Hee University, Yongin-si, Gyeonggi-do 17104, Republic of Korea

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.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Requirement</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field of View</td>
<td>30 arcmin sq.</td>
<td>50 arcmin sq.</td>
</tr>
<tr>
<td>Wavelength Coverage</td>
<td>350-950nm</td>
<td>320-1000nm</td>
</tr>
<tr>
<td>Spectral Resolution</td>
<td>Blue and red: 1000-6000nm</td>
<td>Blue and red: 1000-6000nm</td>
</tr>
<tr>
<td>Image Quality</td>
<td>80% EE at 0.3 arcsec</td>
<td>80% EE at 0.15 arcsec</td>
</tr>
<tr>
<td>Spectral Stability</td>
<td>0.3 spectral res. elements/hour</td>
<td>0.1 spectral res. elements/hour</td>
</tr>
<tr>
<td>Number of gratings</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Slit Mask Exchange</td>
<td>12</td>
<td>200</td>
</tr>
</tbody>
</table>

Table 1. GMACS principal functional 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. 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].

Optical Design

The current GMACS optical system is based on a totally reflective 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 reflective 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 (BFSF) less then 150µm across the entire diameter, located in the element closest to the collimator exit pupil.

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.

Blue Camera

The blue camera, f/2.2, 592mm focal length, is comprised of only FS and CaF2 glasses for high throughput <350nm, two aspherical surfaces on both first CaF2 lens (BFSF < 1mm) and < 240µm for all diameter), Fig.4.

Red Camera

The red camera, f/2.2, 592mm focal length, is comprised of CaF2, PBL6Y and BSM51Y glasses for good spherocromatic correction, two aspherical surfaces on both first CaF2 lens (BFSF < 350µm). Fig.5.

Integrated Spectrograph – Blue arm

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

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


Acknowledgment

Texas A&M University thanks Charles R. ‘62 and Judith G. Munnerlyn, George P. ’40 and Cynthia Woods Mitchell, and their families for support of astronomical instrumentation activities in the Department of Physics and Astronomy.