IMACS: The multi-object spectrograph and imager for the Magellan I telescope

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ABSTRACT

The Inamori Magellan Areal Camera and Spectrograph (IMACS) will be one of three first-generation instruments for the Magellan 6.5m telescopes. It will be installed at the f/11 (Gregorian) Nasmyth focus. This instrument drove the specification and design of the f/11 configuration, which it uses to feed an all-spherical, wide-field collimator. The combination of the Gregorian secondary and refracting collimator lead to 0.2 arc-sec images over a 17 arc-min field with an f/2.66 camera, and 0.4 arc-sec images over a 27 arc-min field with an f/1.49 camera. This paper describes the preliminary specifications for the multiple spectrographic and imaging modes, the optical layout of the instrument and Epps cameras, and strategies for the design and fabrication of the instrument.

1. INTRODUCTION

On behalf of the Magellan Telescope Consortium, The Observatories of the Carnegie Institution of Washington (OCIW) are currently building two 6.5m telescopes, located at the Las Campanas Observatory in Chile. Concurrently, the Observatories are in the early stages of the development of the first generation of optical and infrared instrumentation for the telescopes. See Johns[1] for a report on telescope construction progress.

The IMACS multi-object spectrograph and imager mounts at the Nasmyth focus of the Magellan I telescope. Fed by the f/11 Gregorian configuration, with an integral ADC and field corrector mounted at the tertiary mirror, the transmitting, all-spherical collimator produces a well corrected, unvignetted field of 24 arc-min in diameter, and a full field of 30 arc-min with slight vignetting.

Two cameras are used to re-image the 150mm diameter collimator exit pupil at 0.111 and 0.201 arc-sec/pixel. The all-spherical, f/2.66 Epps long camera can directly image a 21.4 arc-min diameter FOV, or spectroscopically image a 17 arc-min long slit with a variety of standard 150 x 200 mm diffraction gratings. The aspheric, f/1.49 short Epps camera can directly image a 38.8 arc-min diameter FOV (with slight vignetting by the collimator), or spectroscopically image a 27 arc-min long slit with a variety of standard 150mm aperture grisms. Both cameras feed a 8192 x 8192 CCD array. A general summary of the instrument specifications is shown in Table 1.

Fields of view	15 x 15 arc-min^2 (long camera) 27 x 27 arc-min^2 (short camera)
Spectral resolution	$\lambda/\Delta\lambda \leq$ 10,000 (1 arc-sec slit, grating mode) $\lambda/\Delta\lambda \leq$ 1800 (1 arc-sec slit, grism mode)
Wavelength ranges	0.365-1.00 microns (long camera) 0.390-1.05 microns (short camera)
Image scales	0.111 arc-sec/pixel (long camera) 0.201 arc-sec/pixel (short camera)
Detector array	8192 x 8192 x 15 micron pixels (4 x 2 array of 2048 x 4096 CCDs)
Telescope configuration	f/11 Gregorian field corrector and ADC at tertiary mirror field de-rotation at Nasmyth instr. mount
Operating modes	grating dispersed single and multi-object spectroscopy grism dispersed single and multi-object spectroscopy 21 arc-min dia. FOV direct imaging 36 arc-min dia. FOV direct imaging

Table 1: Instrument Specifications

2. INSTRUMENT OPTICAL DESIGN

The optical design of the first Magellan telescope is described in a paper by Shectman[2]. The f/11 Gregorian configuration of the telescope and the design of the all-spherical, refracting collimator were matched to provide a 30 arc-min, highly corrected field for both direct imaging and multi-object spectrography. Figure 1 shows how the IMACS fields of view compare with several existing and planned multi-object spectrographs.

2.1 Collimator

The current design of the collimator, a collaborative effort by Epps and Shectman, is shown in Figure 2, and it consists of two fused silica singlets and a calcium fluoride / Ohara BAL35Y doublet. The current design is slightly oversized (for a unvignetted, rather than slightly vignetted 30 arc-min dia. FOV), and awaits a final iteration. In combination with a fused silica field lens immediately behind the telescope Nasmyth focal surface, the collimator produces a 150mm diameter exit pupil approximately 275mm beyond the last lens vertex. At the exit pupil, gratings, grisms, and a mirror can be positioned to feed either of the cameras in the imaging or spectrographic modes.

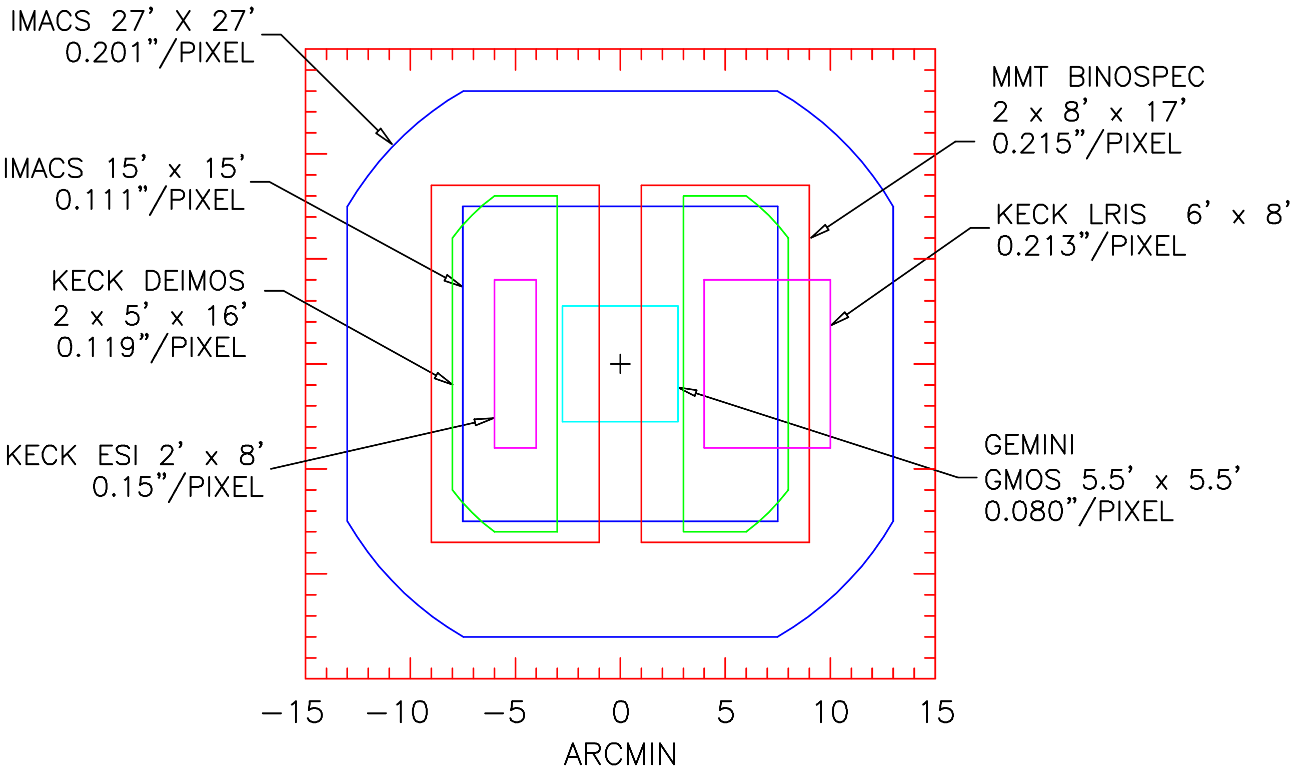

Figure 1: Current multi-object spectrograph fields of view

2.2 Long Camera

A full description of the design of the all-spherical, f/2.66 long camera can be found in a paper by Epps[3], and it is shown schematically in Figure 3. The camera re-images a 166 x 208mm elliptical entrance pupil in spectrographic mode, or a 150mm circular pupil in the imaging mode. This camera produces 0.10 - 0.15 arc-sec diameter (RMS) images across the 0.365 - 0.8 micron passband, and 0.15 - 0.2 arc-sec diameter (RMS) images in the 0.8 to 1.0 micron passband, across all field positions. As all the lens elements are spherical, fabrication by commercial optical processes will be straightforward.

2.3 Short Camera

A full description of the design of the aspheric, f/1.49 short camera can be found in Epps[3]. In this case, the camera re-images a 161 x 194mm elliptical entrance pupil in the spectrographic mode, or a 150mm circular pupil in the imaging mode. This camera produces 0.2 - 0.3 arc-sec diameter (RMS) images across the full 0.39 - 1.05 micron passband and over all field positions. The design includes three aspheric surfaces, which in the worst case requires a 1.0mm aspheric departure from the nearest sphere. These aspheres pose a considerable fabrication challenge, and various sources for the figuring are being considered.

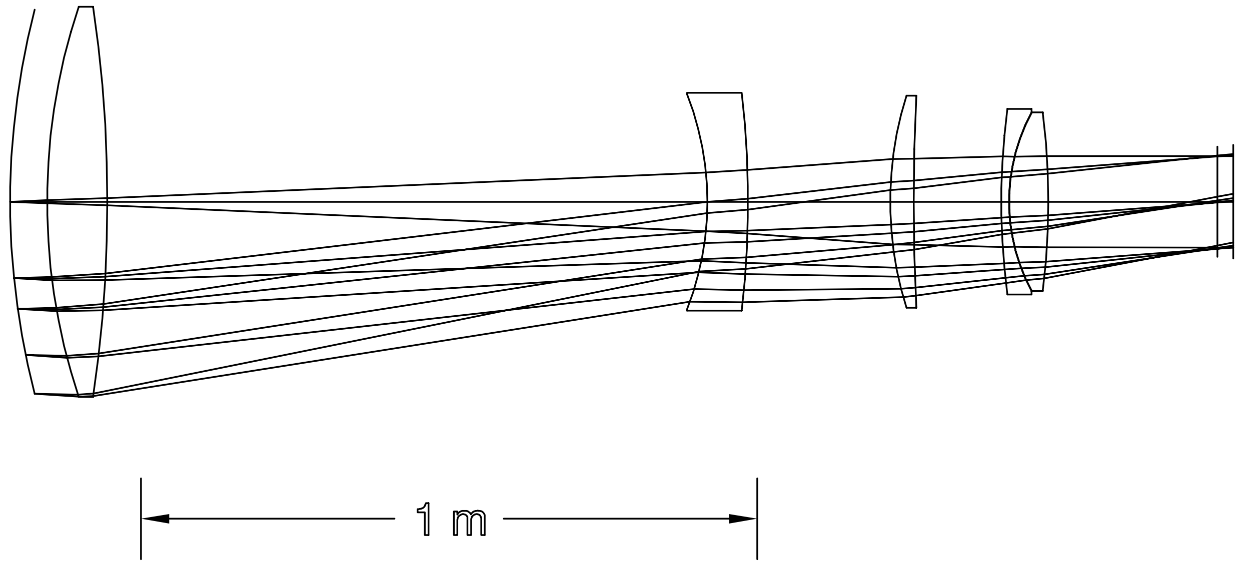

Figure 2: IMACS field lens and collimator optics.

3. MECHANICAL DESIGN

3.1 Instrument Structures

Flexure is the well recognized enemy of most spectrographs, and IMACS will be no exception. The instrument structures will be designed to minimize flexure, and to ensure that the unavoidable residual flexures result in simple translations, as opposed to rotations, of the critical optical elements. The residual image motions due to flexure can then be corrected by translation of the CCD detector array.

Structures based on determinate space frames[4] could be used exclusively, or in conjunction with welded plate structures. A preliminary concept for the instrument mechanical system can be seen in Figure 4, and consists of a single-bay hexapod connecting the instrument mounting flange at one end, to an optical support structure (OSS) at the other. Additional trusses attach the collimator, long camera, and short camera to the OSS. Although the geometry of the mainframe could be such that cantilever loads lead to parallel deflections and no rotations, the loads transmitted to the Nasmyth rotator bearing would be excessive. Consequently, the OSS disc will most likely be independently supported.

3.2 Slit-mask Handler

The wide-field Gregorian focal surface, with a image scale of 346.77 microns/arc-sec, leads to a focal surface 620mm in diameter for the full 30 arc-min field of view. The instrument specifications call for a set of up to six slit masks to be remotely selectable during a night's observing run. A motion stage will place one of the masks in the insertion position, where it can then be translated to the focal surface. Kinematic attachment features on the mask frames will locate the masks repeatably at the focal position. The masks themselves will be formed into spherical shells which approximately match the radius of curvature of the focal surface. Individual slits will be machined by a numerically controlled mill with a high-speed air-bearing spindle.

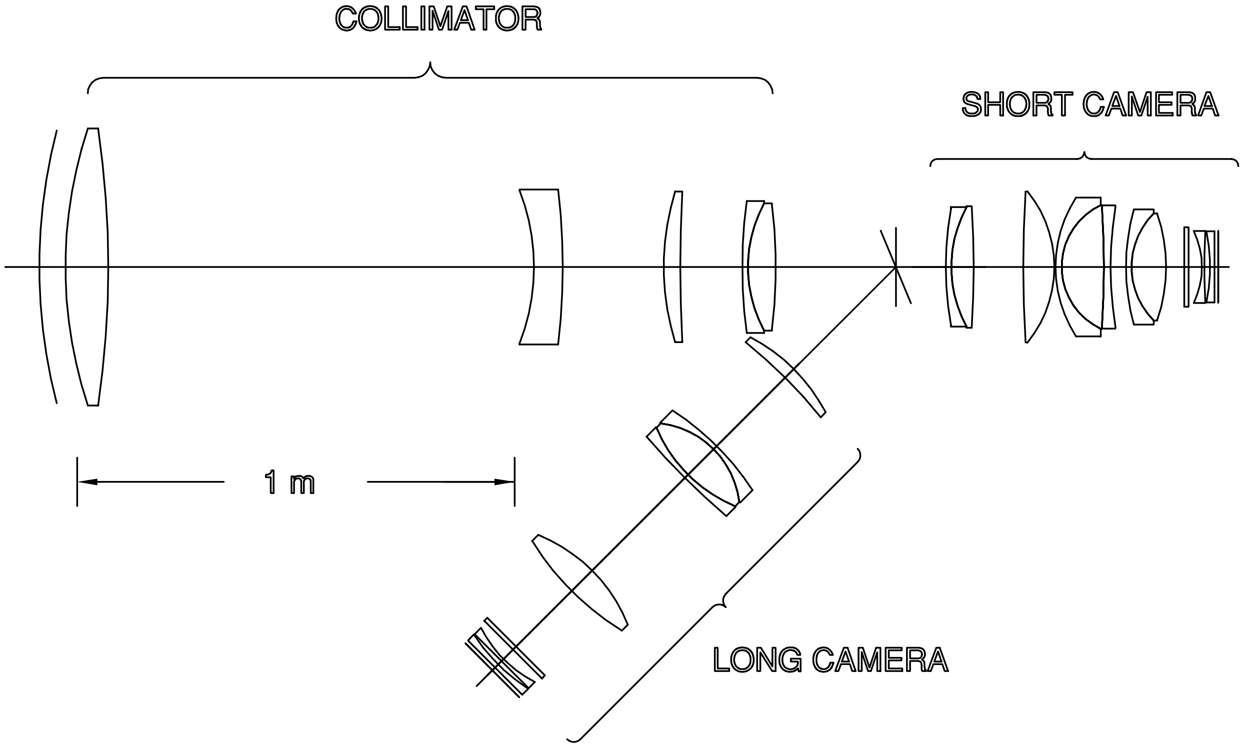

Figure 3: IMACS optical system layout.

3.3 Disperser Selector

Final specifications for disperser options (gratings and grisms) are being developed, but the initial complement is expected to include three 150 x 200mm diffraction gratings, three 150mm dia. grisms, and a single folding-flat for the long camera imaging mode. Grating rotation, if provided, will be implemented with commercial goniometers, or custom tilt mechanisms. The grisms and imaging mirror are not adjustable. Mode changes between imaging and spectrography are intended to be repeatable such that flat-fields and wavelength calibrations are stable over the course of a night's observing. Kinematic location of the dispersers relative to the cameras and collimator may be required to reach this goal. A disperser server, consisting of a rotating or translating motion stage, will position the required optic at the location of the collimator exit pupil.

3.4 Filter Changers

The smallest beam diameters in each arm of the spectrograph occur within the camera barrels. Both camera designs include space for shutters and filters. However, even at the minimum beam diameter, the filters are still nearly 200mm in diameter. A set of up to 8 filters per camera are remotely selectable during observations. A shuttle mechanism similar in concept to the slit mask handler will serve filters to the cameras, and a single filter set and selecting mechanism is expected to interchange (with the CCD array) between the two cameras.

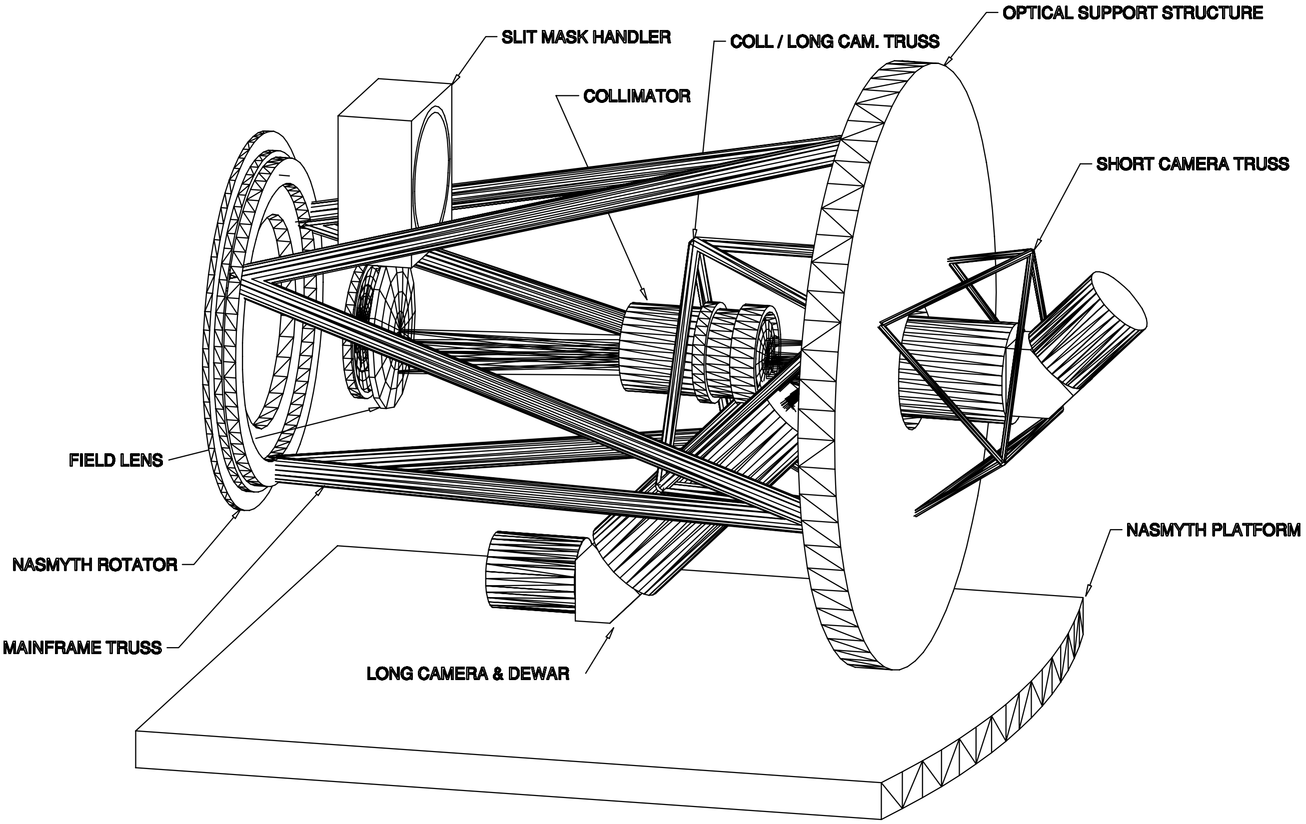

Figure 4: IMACS preliminary mechanical layout.

3.5 Flexure Control and Dewar Interchange

A single 8K x 8K array composed of eight 2048 x 4096 x 15 micron pixel SITe CCD's will interchange between the long and short cameras. Kinematic mounting features will allow repeatable positioning of the CCD array and dewar relative to the two cameras. Although the location of the instrument at the Nasmyth focus and the structural design are intended to minimize image motions due to varying gravity loads, some residual image motion is inevitable. A cryogenic translation stage (for both X and Y axes), modeled on a design for the Gemini Multi-Object Spectrograph (GMOS)[5], could be used to translate the detector, under open- or closed-loop control, to remove residual image motion down to the 0.1 pixel level.

4. CONCLUSIONS

The preliminary performance specifications for the IMACS multi-object spectrograph have been presented. The optical design of the instrument is nearly complete, and options for fabrication of the large aspheric lenses are being examined. The SITe CCDs for the detector array have been ordered, and approximately half have been received and found to meet specifications. The mechanical design of the instrument is still in the conceptual stage, but mechanical concepts for most of the instrument mechanisms have been produced, and strategies for minimizing and correcting flexure have been described. IMACS is currently budgeted at approximately $3.5 million, and is scheduled for delivery at the Magellan I telescope in the second half of the year 2000.

5. ACKNOWLEDGMENTS

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6. REFERENCES

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