The Opto-Mechanical Design of the GMT-Consortium Large Earth Finder (G-CLEF)

Poster Number: 9908-374

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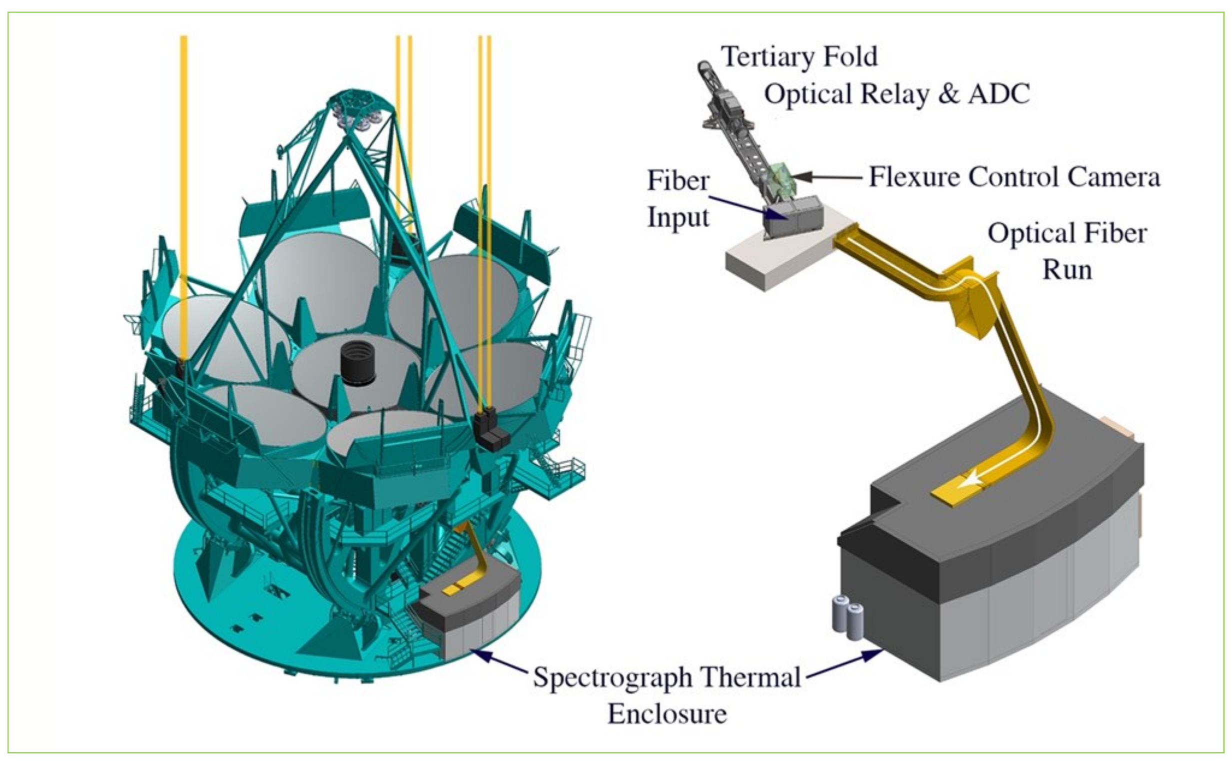
OVERVIEW

- The GMT-Consortium Large Earth Finder (G-CLEF) is a fiber fed, optical echelle spectrograph that has been selected as a first light instrument for the Giant Magellan Telescope (GMT) currently under construction at the Las Campanas Observatory in Chile's Atacama desert region. We designed G-CLEF as a general-purpose echelle spectrograph with precision radial velocity (PRV) capability used for exoplanet detection. The radial velocity (RV) precision goal of G-CLEF is 10 cm/sec, necessary for detection of Earth-sized planets orbiting stars like our Sun in the habitable zone.
- Stability in instruments of this type is typically affected by changes in temperature, orientation, and air pressure as well as vibrations caused by telescope tracking. For these reasons, we have chosen to enclose G-CLEF's spectrograph in a thermally insulated, vibration isolated vacuum chamber and place it at a gravity invariant location on GMT's azimuth platform.

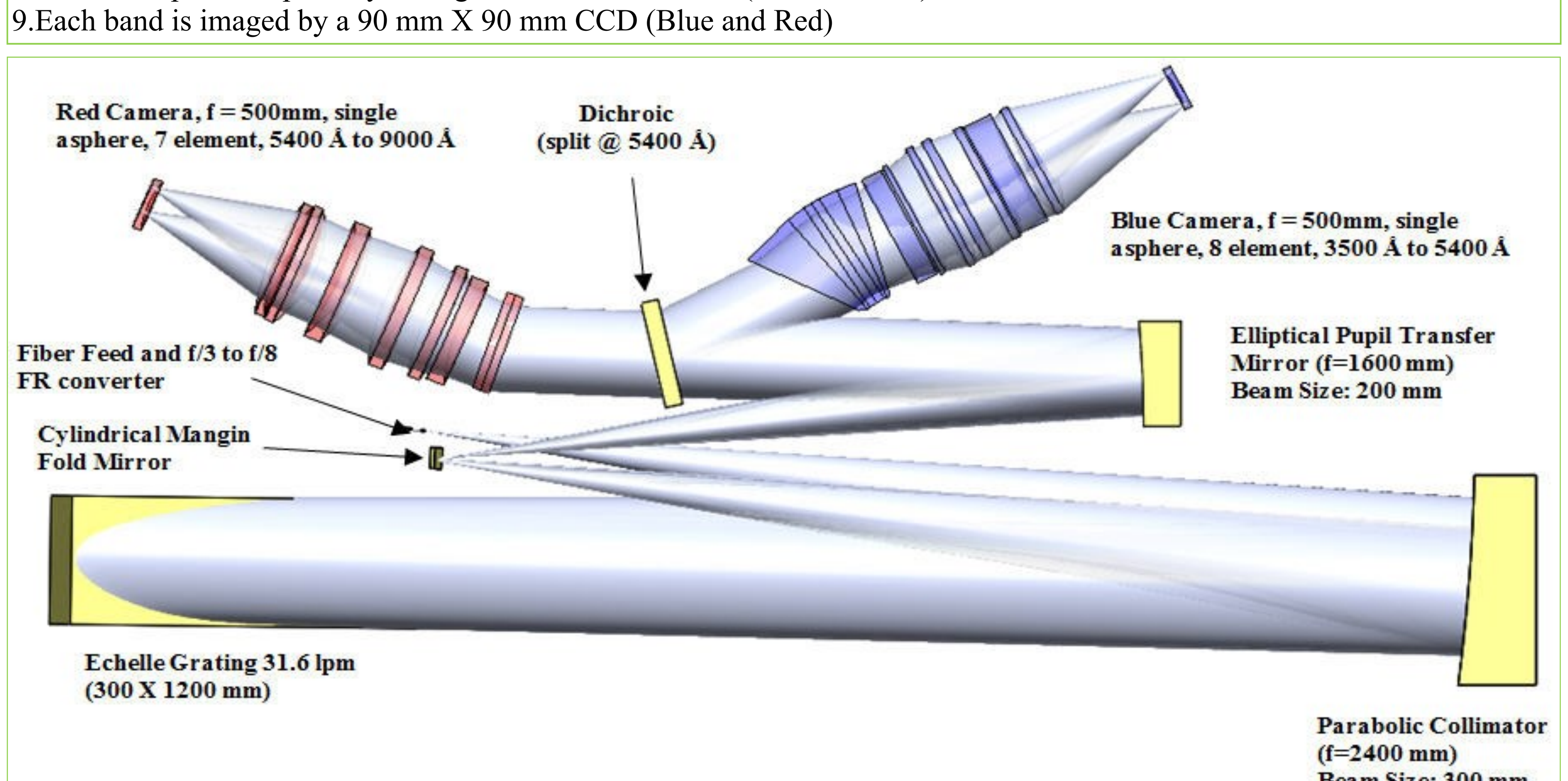
G-CLEF on GMT's Azimuth Platform



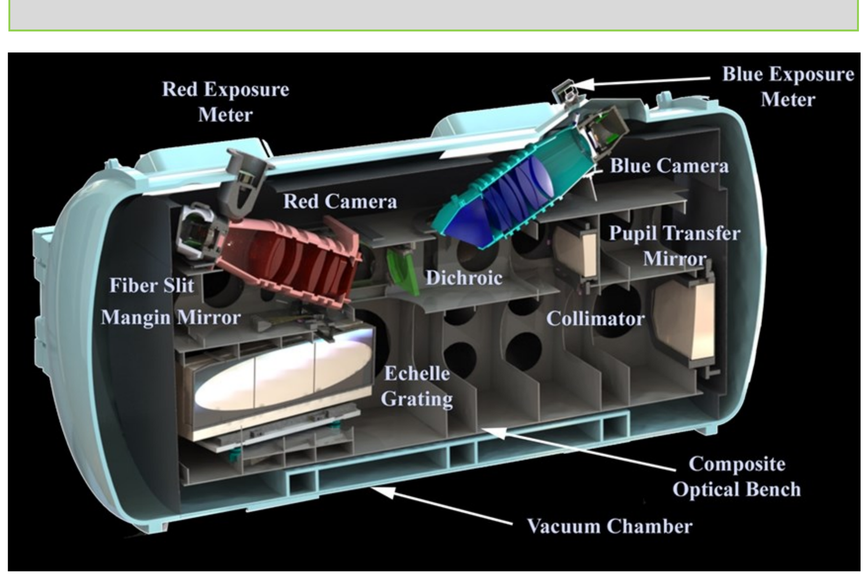
G-CLEF SPECTROGRAPH OPTICAL DESIGN

Emerging from the fiber feed and passing through a focal ratio converter, an f/8 beam follows the following optical path:

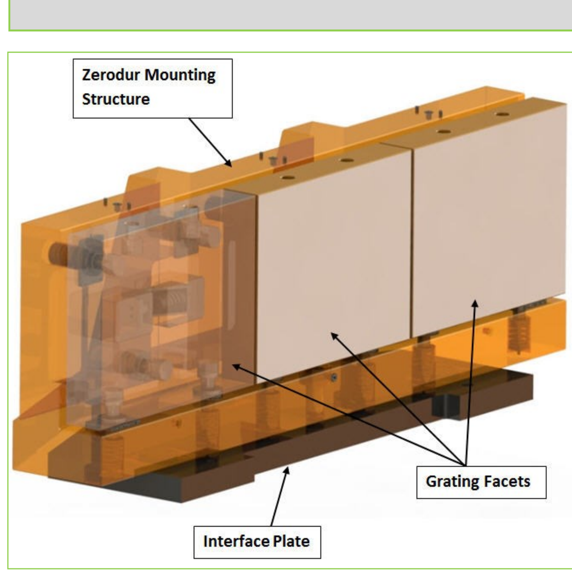
1. Reflected off an off-axis parabolic collimator
2. Reflected and dispersed from the Echelle grating
3. Reflected (2nd pass) off the off-axis parabolic collimator and focused
4. Reflected off a cylindrical Mangin fold mirror
5. Reflected and collimated off an elliptical transfer mirror (M2)
6. Red wavelengths are transmitted, Blue reflected by a dichroic into separate Blue and Red camera systems
7. Each band passes through separate Blue or Red cross-dispersers
8. Each band passes separately through a multi-lens camera (Blue and Red)
9. Each band is imaged by a 90 mm X 90 mm CCD (Blue and Red)

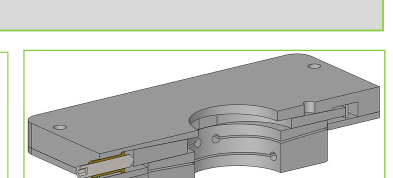


SPECTROGRAPH IN VACUUM CHAMBER



GRATING MOSAIC MOUNT





Adjustable Shim Design

KEY DESIGN REQUIREMENTS

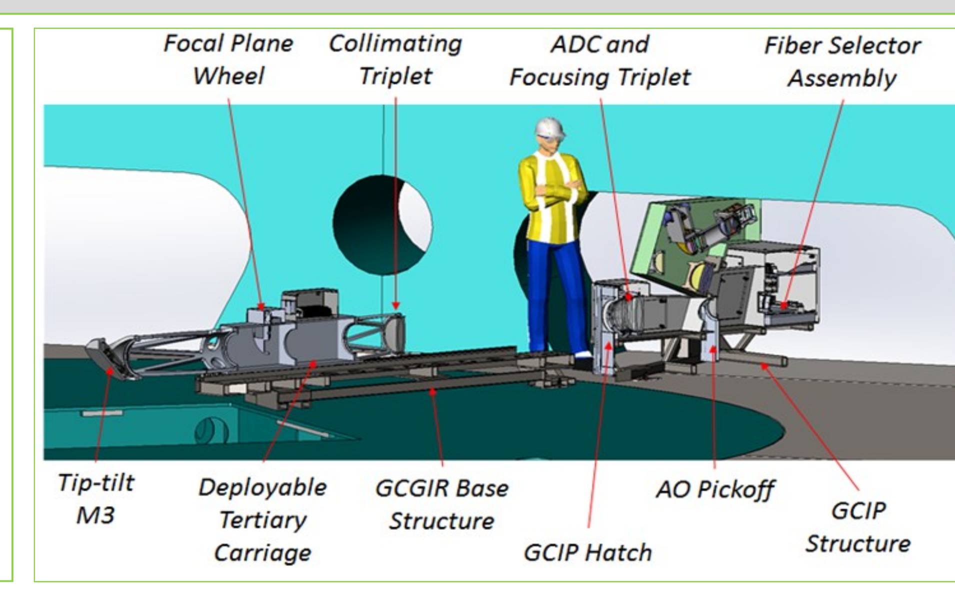
Requirement Title	Requirement Statement
Seeing Conditions	Meet requirements at GMT 75th percentile seeing, with a full width half maximum (FWHM) of 0.79 arc seconds
Optical Feed	Provide an Optical Feed which deploys into the telescope beam and relays light into the G-CLEF Fiber Feed System
Flexure and Defocus Detection	Provide an instrument flexure and defocus sensing system which measures flexure-induced telescope to instrument guide and focus offsets. Send these offsets to the GMT telescope Control System for correction
Instrument Passband	3500Å to 9000 Å simultaneous wavelength coverage
Measurement Modes and Spectral Resolution	Optically Scrambled Precision Radial Velocity mode (PRV) with Spectral Resolution = 108,000 (Pupil Sliced) High Throughput, non-scrambled PRV Mode (PRV-NS) with Spectral Resolution = 108,000 (Pupil Sliced) High Throughput (HT) Mode with Spectral Resolution = 19,000 Medium Throughput (MT) Mode with Spectral Resolution = 35,000
Estimated Instrument Throughput (Includes all pre-optics and fiber run, excludes the telescope. Assumes 75% seeing or 0.79" and a Gaussian PSF)	See table below
Brightness Limit	Function with target brightness of M_R = 6 (or fainter)
Atmospheric Dispersion Compensation	Provide on-instrument atmospheric dispersion compensation
Operating Air Mass	Operate in all modes with air mass ≤ 2
PRV Measurement Precision	Capable of making single PRV measurements with a radial velocity single measurement precision of 40 – 50 cm/second with a goal of 10 cm/second.

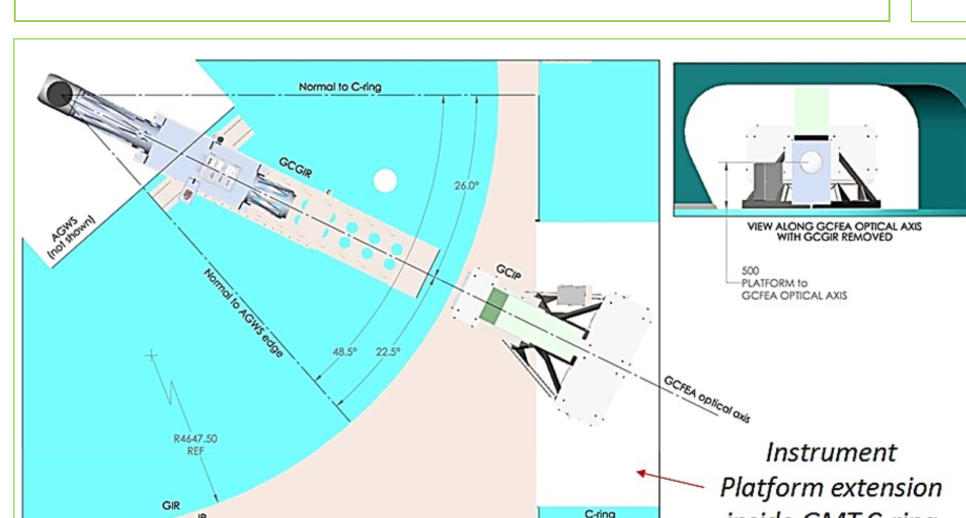
Wavelength(nm)	HT	MT	PRV	PRV-NS
350	7.7%	4.9%	3.8%	4.7%
500	16.2%	10.3%	8.1%	10.1%
650	15.0%	9.6%	7.6%	9.4%
800	14.2%	9.0%	7.1%	8.8%
900	8.5%	5.4%	4.3%	5.3%

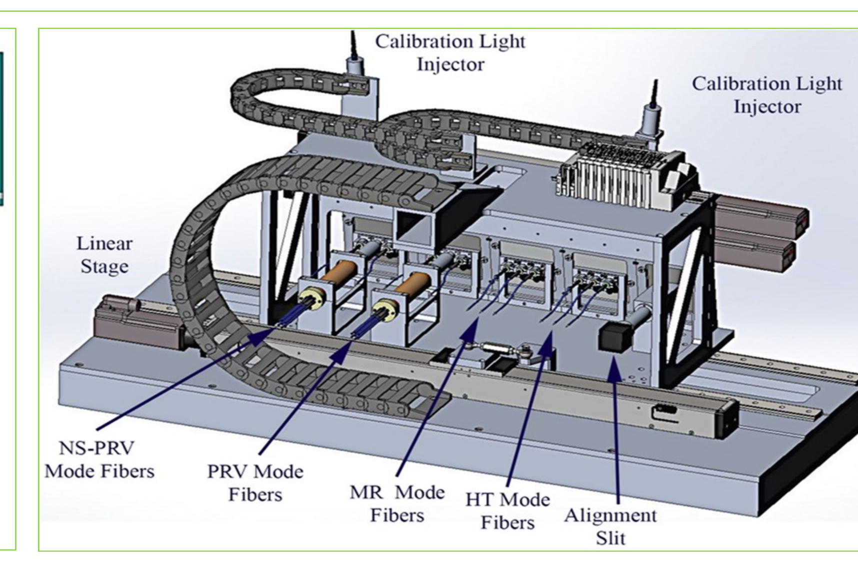
FRONT END SUB-SYSTEM ON GMT's GIR ASSEMBLY

The Front End contains the following components:

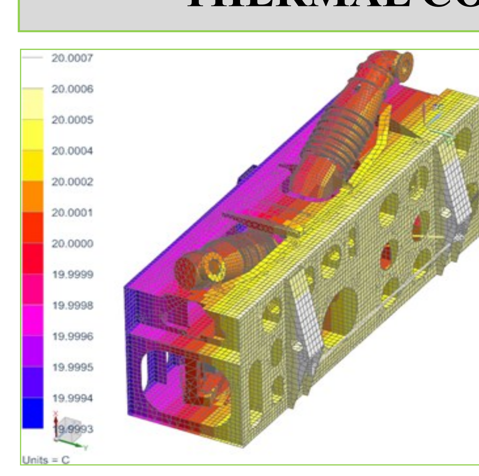
- Pick-off tertiary mirror with tip-tilt capability for flexure compensation
- Relay optics (Collimating and Focusing Triplets)
- Atmospheric Dispersion Compensation (ADC) Prism Assemblies
- Calibration system input fiber mechanism
- Slit plane and fiber/operational mode selector
- Guide camera
- Focus sensor







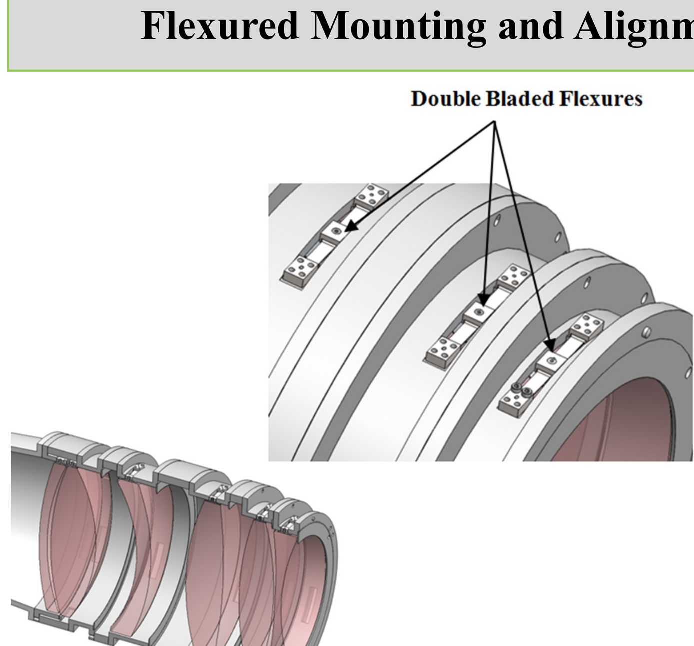
THERMAL CONTROL OF ABSOLUTE TEMPERATURE AND GRADIENTS

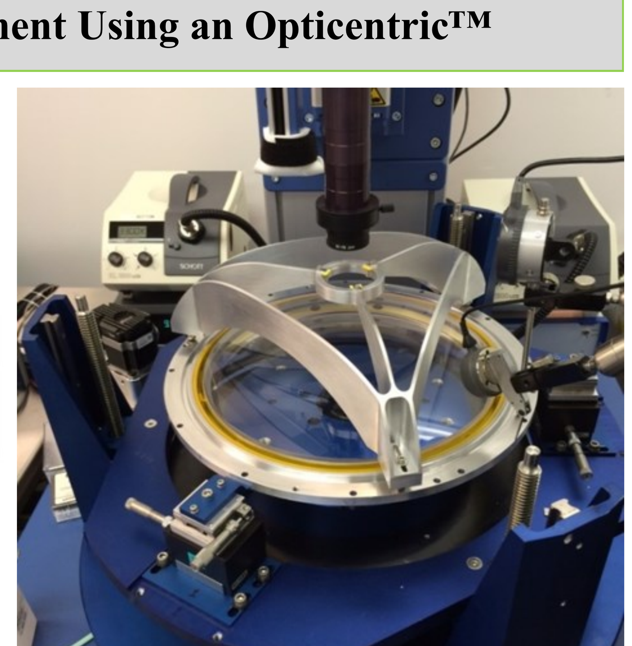


Load Case	Image Motion at Detector (IMAD) in Dispersion, Angstroms		
	Red IMAD	Blue IMAD	SE Budget
Thermal Soak +0.001 °C	3.33	1.18	5.4
Vertical Gradient	0.22	1.47	3.2
Lateral Gradient	5.41	4.16	7.8
Lengthwise Gradient	0.93	0.24	---

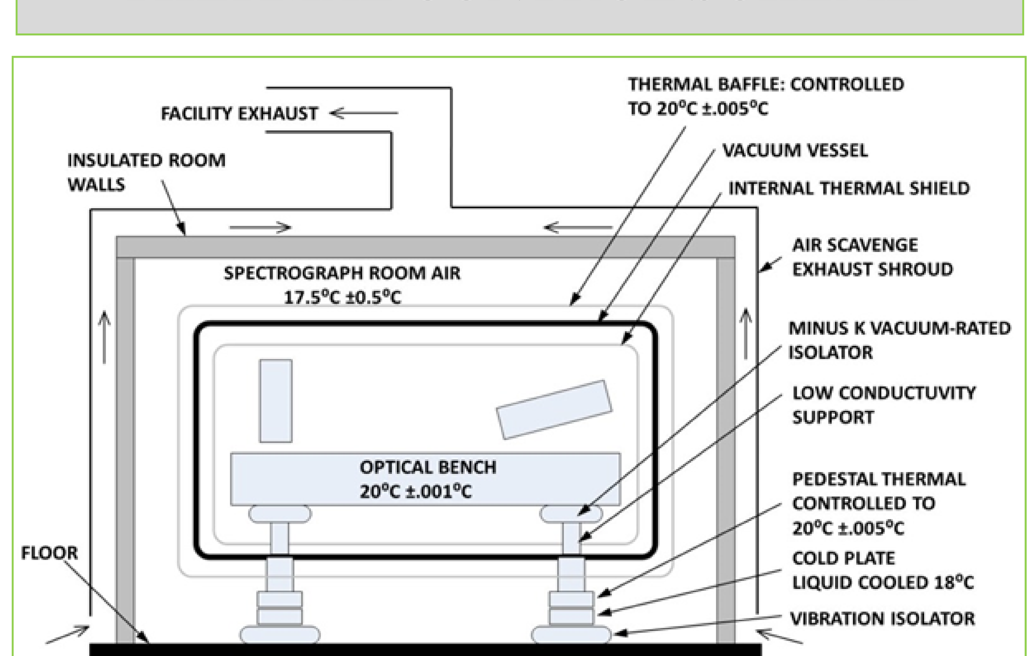
CAMERA OPTICS

Flexured Mounting and Alignment Using an Opticentric™





THERMAL CONTROL SCHEME



REFERENCES

[1] Szentgyorgyi, A., et al., "The GMT-Consortium Large Earth Finder (G-CLEF): An Optical Echelle Spectrograph for the Giant Magellan Telescope (GMT), Proc. SPIE, 9908-76, (2016).
[2] Jacoby, G., Bernstein, R., Bouchez, A., Colless, M., DePoy, D., Espeland, B., Jaffe, D., Lawrence, J., Marshall, J., McGregor, P. Sharp, R., Szentgyorgyi, A. and Walls, B., "Instrumentation Progress at the Giant Magellan Telescope project," Proc. SPIE, 9908-68, (2016).
[3] Fűrész, G. et al., "The G-CLEF Spectrograph Optical Design: An Update to the White Pupil Echelle Configuration", Proc. SPIE, 9147, (2014).
[4] Johns, M., McCarthy, et al., "Overview and status of the Giant Magellan Telescope Project", Proc. SPIE, 9906-37, (2016)
[5] Podgorski, W. A., et al., "A Novel Systems Engineering Approach to the Design of a Precision Radial Velocity Spectrograph - the GMT-Consortium Large Earth Finder (G-CLEF)", Proc. SPIE, 9147-333, (2014)
[6] Cohen, L. M., "Effects of Temporal Dimensional Instability on the Advanced X-ray Astrophysics Facility (AXAF-I) High Resolution Mirror Assembly (HRMA)"
[7] Opticentric™ is a product of Trioptics USA, 2223 West San Bernardino Road, West Covina, CA 91790 USA
[8] Isotech North America is located at 158 Brentwood Drive, Unit 4 Colchester, VT 05446
[9] SuperTran™ is a product of Janis Research Company, 225 Wildwood Avenue, Woburn, MA 01801-2025 USA
[10] Menlo Systems Inc. is located at 56 Sparta Avenue, Newton, NJ 07860