The Brazilian Tunable Filter Imager

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Summary

The Brazilian Tunable Filter Imager (BTFI) project aims to equip the SOAR telescope with a state-of-the-art optical scanning tunable filter imager for high spatial resolution observations over a field of view of 3 arcminutes. Spectral resolutions stretching from R~10 to R~40,000 will be accessible. Dual cameras will allow for atmospheric and adaptive optics monitoring during rapid-scanned data cube acquisition.

Instrument Overview

The BTFI is designed to be a highly versatile, new technology, optical tunable filter imager for the SOAR telescope which is to be used both for seeing-limited and ground-layer adaptive optics (GLAO) seeing-enhanced observations. Such an instrument is dedicated to the acquisition of spatio-spectral data-cubes (with 2-spatial and 1-spectral dimension) and opens up important new science capabilities for the Brazilian astronomical community from studies of nearby galaxies and the interstellar medium to statistical cosmological investigations.

The BTFI instrument is being designed to accommodate both seeing-limited (SL) and GLAO-fed operation over a field of view of ~3arcmin. and is planned to be deployed at SOAR's IR-direct port (for SL) and the SAM Visitor Instrument port (for GLAO) where it will take maximal advantage of SOAR's unique GLAO facility using the SOAR Adaptive Optics Module (SAM).

The instrument concept takes advantage of two new technologies that have been successfully demonstrated in the laboratory environment but have yet to be deployed in astronomical instrumentation. The imaging Bragg Tunable Filter (iBTF) concept utilizes a crossed pair of Volume Phase Holographic (or Bragg Diffraction) Gratings (VPHGs) while a new Fabry-Perot concept involves the use of commercially available technology allowing a single etalon to act over a very large range of interference orders. The combination of both technologies allows for a highly versatile instrument with spectral resolving powers spanning anywhere in the range between R ~10 and R ~40,000. The BTFI will also pioneer Electron Multiplying Charge Coupled Device (EMCCD) detector technology to enhance the detection of ultra faint signals in the predominantly detector noise limited conditions characteristic of high spatio-spectral resolution data-cube acquisition.

While the full cost of such an instrument, including hardware and manpower, is estimated to be in the region of ~US$3M, we are planning to employ Universidade de São Paulo (USP), Instituto Nacional de Pesquisas Espacaias (INPE) and the Laboratório Nacional de Astrofísica (LNA) manpower for much of the design work. The project is estimated to be complete within a 30 month time-frame thus delivering the instrument in late 2009.

The possibility of having the instrument fed by SAM, with superb spatial resolution over a relatively large GLAO-corrected field of view, will produce a powerful tool, allowing the SOAR community to conduct high impact scientific programs. Of specific interest will be the study of the centers of nearby active galaxies and the study of the kinematics of galaxies in groups and clusters at redshifts 0.1-0.3 (a distance at which a number of galaxies can be observed in only one shot). There is currently no Fabry-Perot/Tunable Filter instrument on any 4-10m class telescope which works with adaptive optics.

The BTFI project is a multi-national collaborative project led by Claudia Mendes de Oliveira (USP) - the list of people presently involved with this project can be found at http://www.astro.iag.usp.br/~btfi. While the BTFI project will be mainly using Brazilian resources (at USP, INPE and LNA) and will be involving Brazilian industry and students as much as possible, the project also involves collaborations with the Universidade de Estadual de Santa Cruz (Brazil), the Laboratoire d'Astrophysique de Marseille (France), the University of Montreal (Canada) and the private company, Photonetc (http:/www.photonetc.com).

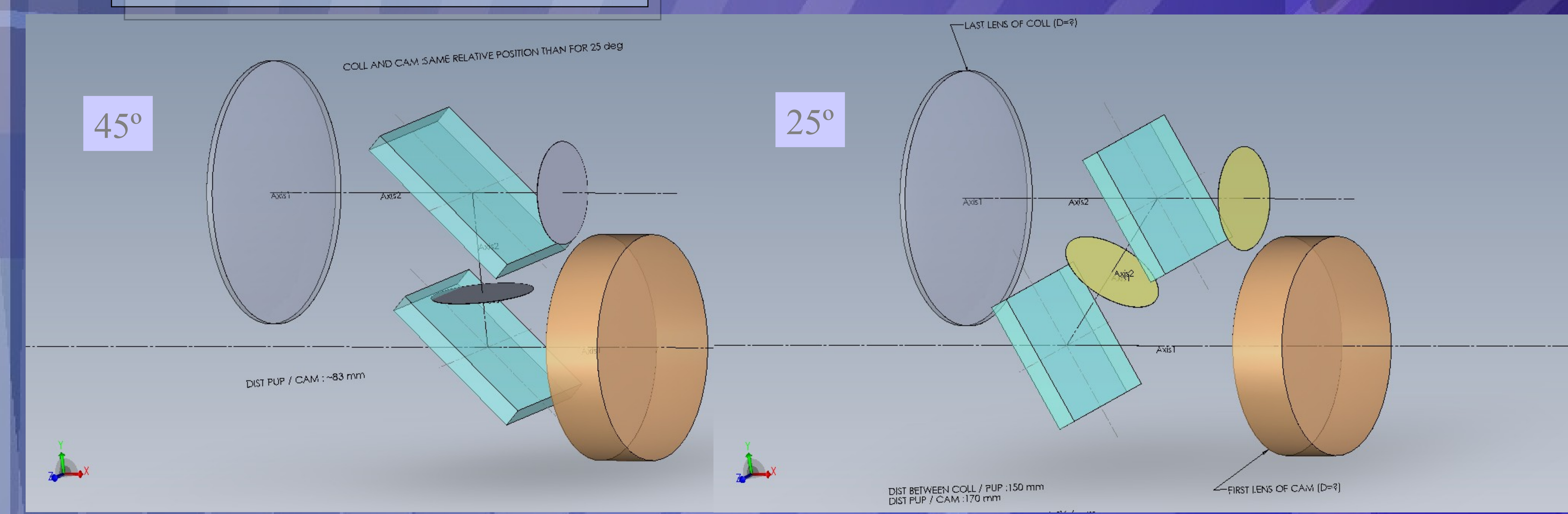
Operation Modes

BTFI modes: Two channels can be used together either as a single science channel with a complementary output which can be used to monitor atmospheric instabilities (eg: PSF and/or transparency) or as two independent science channels to do high and low spectral resolution data-cubes simultaneously.

Image Plane	Pupil Plane 1st channel	Pupil Plane 2nd channel	Configuration 1st channel	Configuration 2nd channel
BBF	iBTF (Tx or Rx)	Clear	iBTF (Scanned)	Complementary
Clear (or BBF)	iBTF (stationary)	FP (+ IF)	Complementary	FP (hi-R; scanned)
Clear (or BBF)	iBTF (Tx or Rx)	FP (+ IF)	iBTF (Scanned)	FP (hi-R; scanned)
FP	iBTF (stationary)	BBF	Complementary	FP (lo-R; scanned)
FP + BBF	iBTF (stationary)	FP	Complementary	FP (hi-R; scanned)

BTFI multiple configurations:
- BBF = Broad-band Filter
- IF = Interference Filter
- FP = Fabry-Perot
- iBTF = Image Bragg Tunable Filter

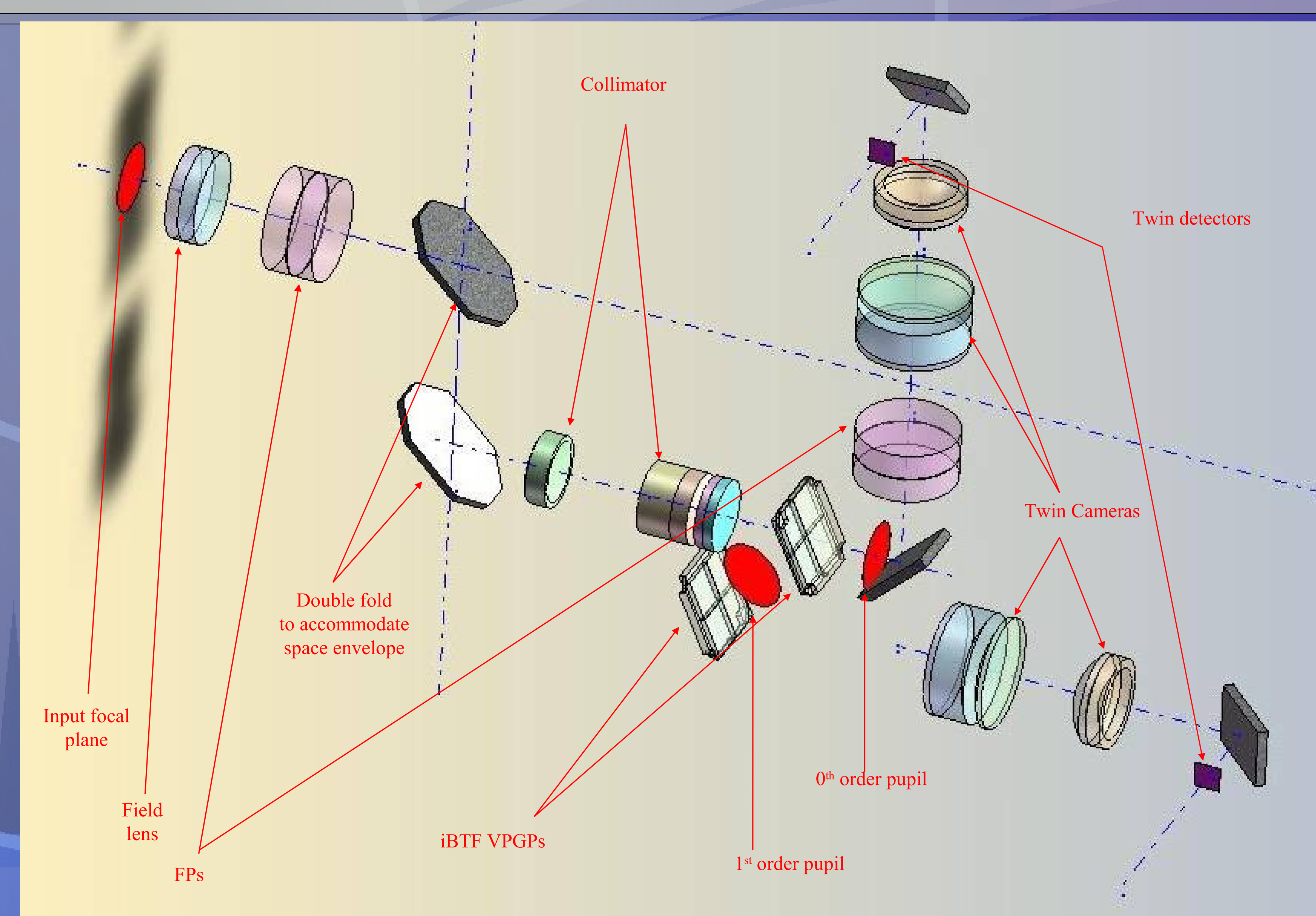
iBTF schematic



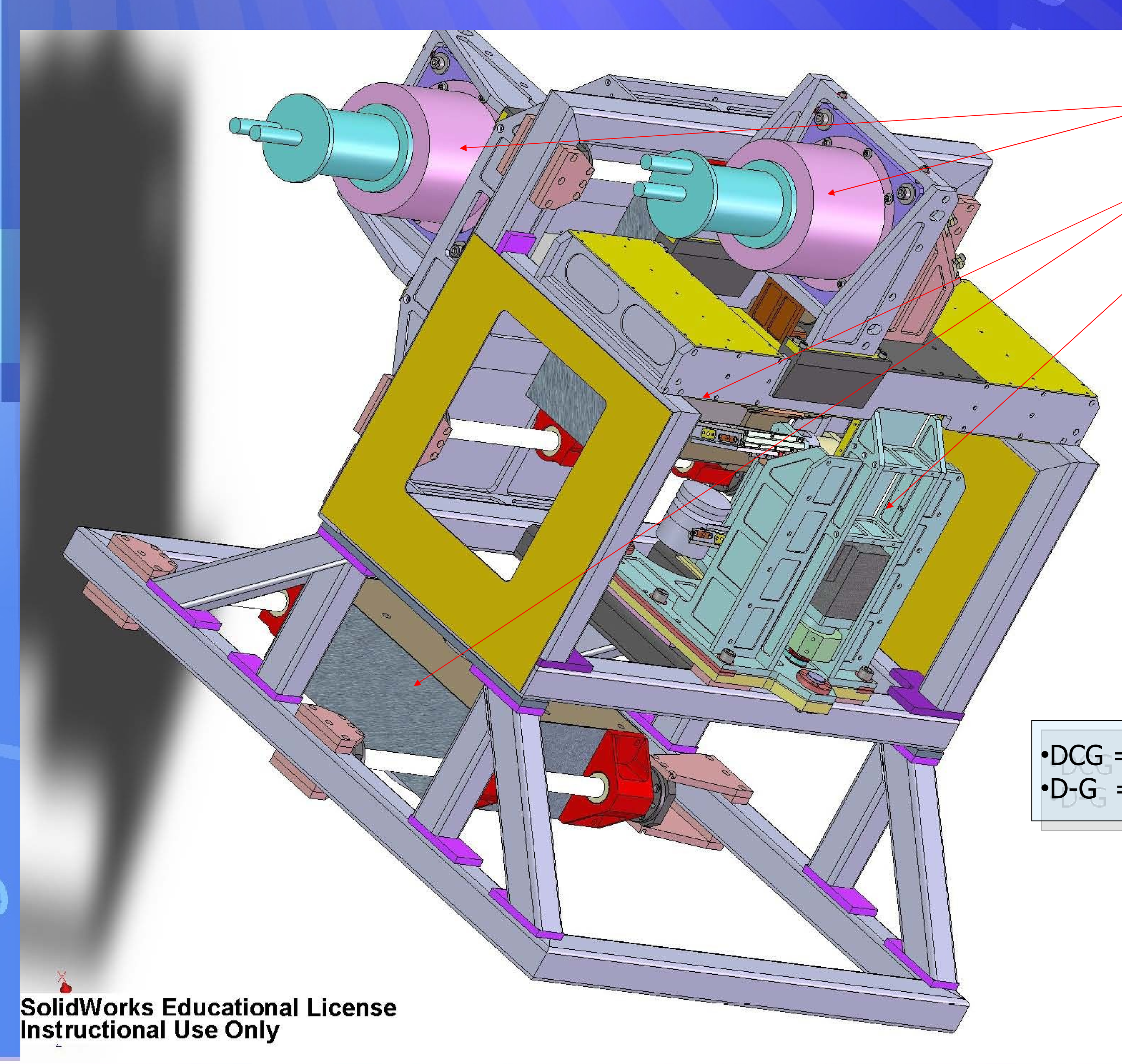
The twin identical VPHGs (blue) following the collimator (grey) such produce dispersion cancellation permitting only the blaze profile to be passed to the camera (gold). The blaze profile is tuned by varying the angle between 45° and 25°. The dispersed and 0th order (undeviated) and pupils are shown.

Optical Design

BTFI optical design (courtesy Damien Jones, Prime Optics, Qld) showing the twin f/7 cameras used simultaneously for imaging the 0th order (undeviated) and iBTF filtered light (here shown as twin VPHGs working in reflection). The f/16.5 collimator takes the light from either the native Nasmyth focus or the output from SAM's GLAO feed. The fold mirrors are simply to allow the optics to stay within the space envelope. FPs are shown in both the image and collimated sections and can be used separately or in series with the first being used as a pre-filter for the second (as in the 3DNTT instrument).



The "real" instrument



Detectors

FPs

iBTF module

Performance:

- Pixels = 0.12arcsec.
- FoV = 3.0 arcmin.
- Single FP
  - 250<R<25,000
- Dual FP
  - 16,000<R<40,000
- iBTF
  - DCG: 5<R<200
  - D-G: 200<R<5,500

•DCG = Dichromated Gelatin
•D-G = Doped Glass