Instrument Development

Keith Taylor (USP)

BTFI CoDR

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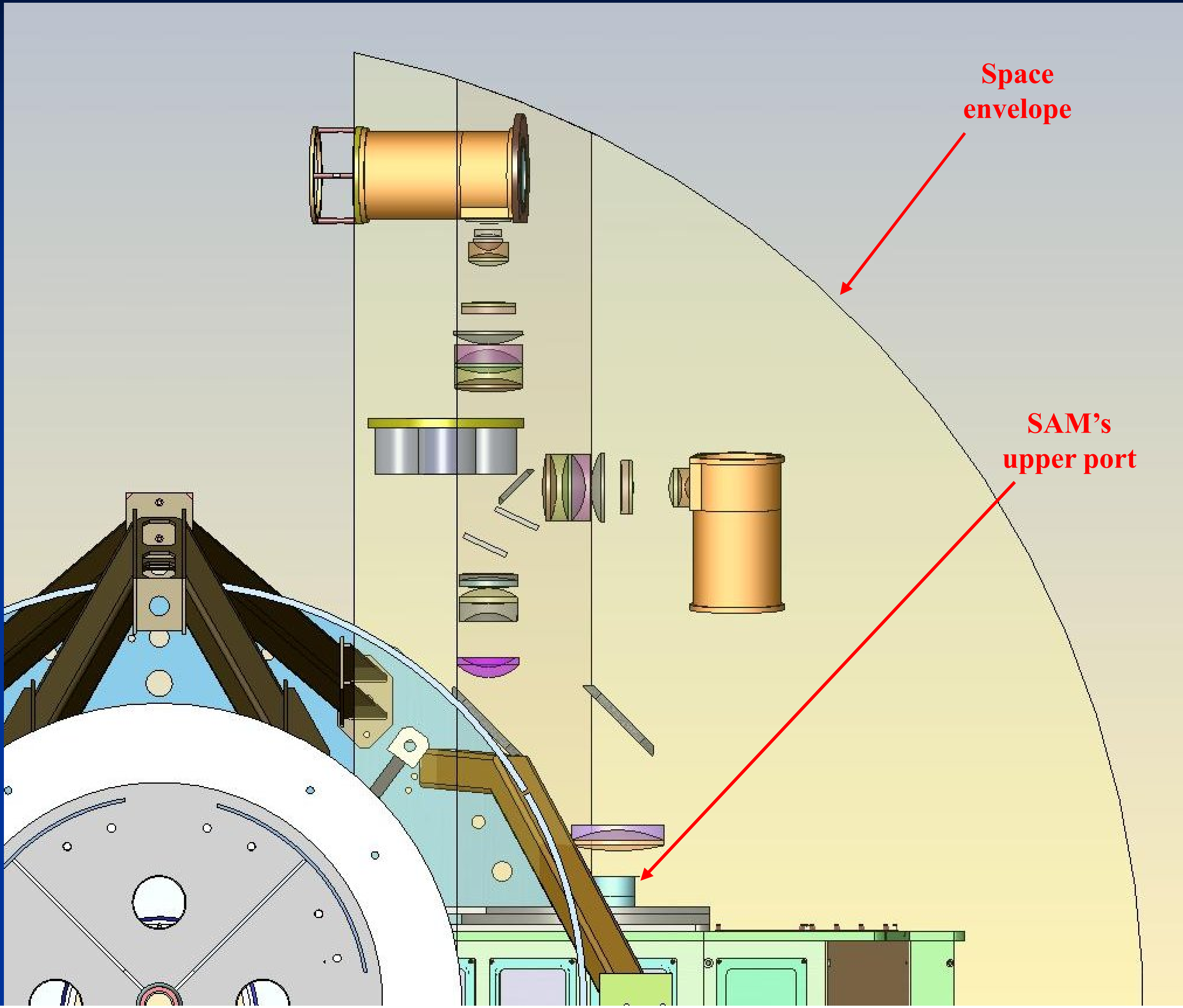
Change in Base-line

- **Pre-Sept'07 advantages:**
  - Large seeing-limited FoV (~6*6 arcmin)
  - Single FP (Φ ~70mm) – cost issue?
  - Simultaneous iBTF mode always available

- **Post-Sept'07 advantages:**
  - 2 cameras (2*f/6.7) instead of 4 (2*f/3.3 & 2*f/6.7):
    - No f/3.3 cameras required - complex/expensive
    - No need for camera exchange mechanism
  - Smaller iBTF gratings:
    - ~70mm instead of ~100mm
  - Dual FP operation:
    - FP^1 in pupil (Φ ~70mm) + FP^2 in image plane (Φ ~100mm)
      - Higher Rs (>25,000) available
      - Better continuum/sky/star suppression
      - Significantly fewer IFs required for high-R work – cost savings
      - FP^2 can be regarded as an upgrade path (or borrowed from 3DNTT?)
  - Use of IR-direct port for SL work is a back-up when GLAO is non-operational

BTFI on SOAR/SAM visitor port



Observatory Interfaces

- Will BTFI be competitive in non-GLAO mode? – Yes, but …
  - Loss of uniqueness space (cf: 3DNTT etc.)
    - ➪ iBTF capabilities (R <250) needs to be **emphasized**
- How will we share SAM with SIFS?
  - SIFS pick-off mirror within BTFI? – are we too late?
    - SIFS fibre bundle could, in principle, be mounted in FP[1] carriage for simultaneous TF + IFU spectroscopy
  - Should IR-direct port be an option for seeing-limited operation? - Yes
    - Important back-up facility - Confirm availability & space envelope
- Is Acquisition & Guiding adequate? - Yes
  - No requirement for OIWFS for SAM operation.
  - We can use 2nd channel (lowest-R) for guiding, if necessary.
    - Requires internal flexure FEA
- Weight limit for SAM's VI-port (currently ~100kg – unrealistic)
  - No good numbers – need FEA for SAM + BTFI
  - BTFI weight budget ~200kg (not including electronics or contingency)

Optical Design Development

- New optical design specification required:
  - Collimator FoV ~4.25' dia. (reduced from ~8.5')
    - Simplify design : Reduce cost : Avoid fold mirrors (?)
    - Ease iBTF crowding & tuning angle constraints
  - Collimator pupil relief <150mm (as before)
  - Camera f-ratio ~f/6.7
    - Reduced from f/8 to accommodate EMCCD
      - 1600^2, 16μm pixel, format
    - No requirement for ~f/3.3 large field camera
    - Pupil relief: ~100 – 170mm range
      - Dependent on iBTF angle (in Rx & Tx)

FP Procurement

- 2 SESO etalons (same/different? ; cost?)
  - KT & Rene to visit in Nov'07
- Do we have space for FP[1] at f/16.5 input focal surface? - Yes
  - Φ ~100mm ~3.5-by-3.5 arcmin
  - Optical depth of FP[1] requires either:
    - Re-focusing collimator
    - Placing dummy etalon in "Clear" etalon slide position
      - Preferred, but extra weight
- FP[2] in 50mm pupil space
  - Φ <~70mm clear dia.
    - Is a smaller SESO etalon significantly cheaper? – SESO visit
    - Do we need to plan for FP[1] in pupil? - Yes

Alignment of FP[1]
(Low-R in Image Plane)

- By eye:
  - Only for etalon gaps, ℓ >10μ (ie: R >1,000)
    - No visible rings (angles too large for eye)
  - FP[1] retracted out of image space:
    - Na line source (eg)
    - Viewing window
    - Head room required
- Need automated procedure
  - Can be done with FP[1] in-situ (but with FP[2] retracted)
  - In-beam calibration line source
    - from SAM/SOAR system?
  - 4-hole mask in image plane
  - Rapid data-cube acquisition
  - On-line analysis software and feed-back to plate parallelism adjustment
    - Algorithm has to converge robustly

Alignment of FP^2
(High-R in Pupil Plane)

- By eye:
  - FP^2 rings visible for all gaps
  - FP^1 retracted out of image plane:
    - Na line source (eg)
    - Viewing window
    - Head room
- Automated procedure preferred:
  - Can be done with FP^2 (and FP^1) in-situ
  - 4-hole hartmann mask required (in filter wheel?)
    - Remotely operable (4-pos^n)
  - Data cube acquisition synch^d with Hartmann mask pos^n
  - Algorithm different from FP^1 alignment
    - Also has to converge robustly

iBTF issues

- iBTF exchange and control:
  - How many VPHG pairs are required? – 4, initially
  - Ergonomics of the *manual* exchange process
  - Do we need to exchange them during the night? - Rarely
  - Do they need to be aligned on installation? – Yes
    - Pitch / Roll / Yaw
      - Need to define alignment procedure (in each case)
  - VPHG[1] – Pitch only ; VPHG[2] – Pitch & Translation
    - Opto-mechanical tolerances – see “Critical Alignment” slide
    - Maximum speed – ~<1Hz per z-step
    - Tilt angle range? – 25^{o} to 45^{o}
      - Accessible ranges of R – see later slide
      - Avoid 0th order vignetting/contamination

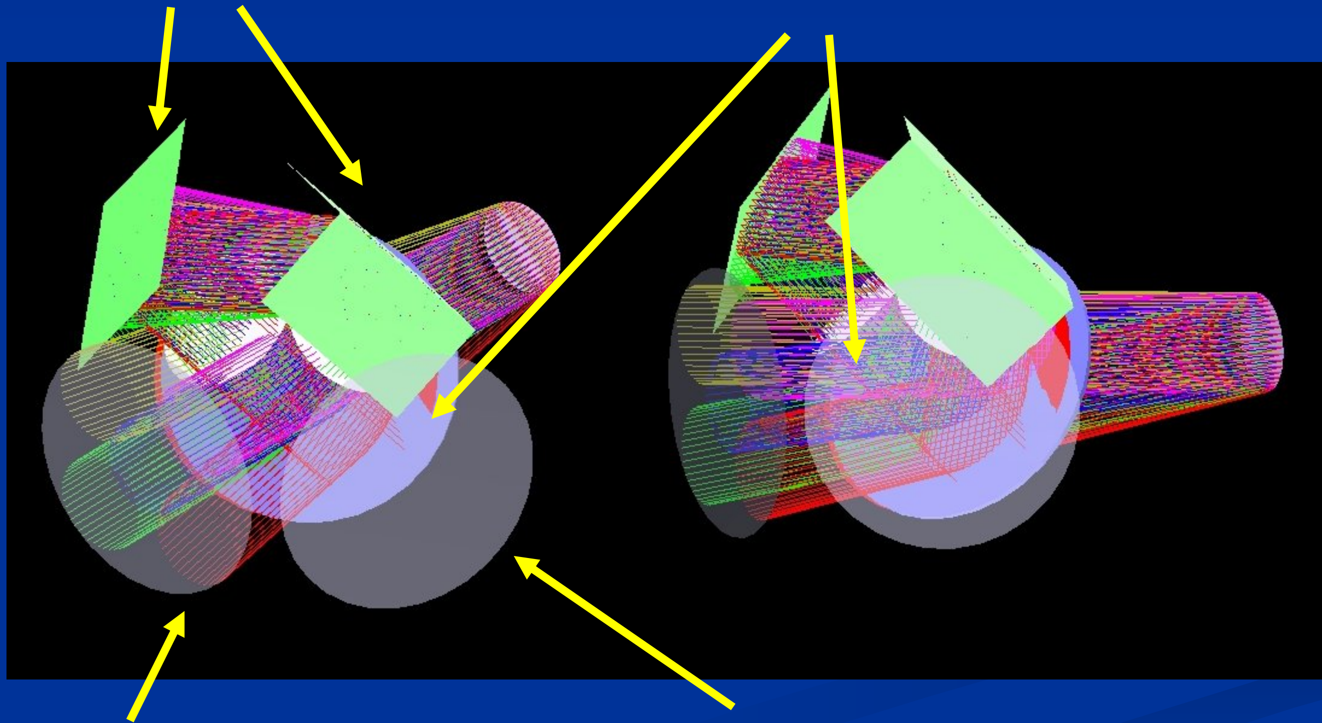
iBTF issues, continued

- iBTF configuration:
  - Have we abandoned pupil-relays? - Yes
    - Gratings are now small enough
  - What about SBO's single VPHG option?
    - Single VPHG ✓
    - Large VPHG (by ~50%) 👎
    - 3 extra reflections 👎
    - Simpler tilt mechanism ✓
      - No translation
      - Tilt angle range?
    - Collimator/Camera angle = 90º
  - VPHG doped-glass mosaics?
    - Smallest configuration requires 2-by-2 (40mm square)
    - Internal alignment/mounting? – see "Critical Alignment" slide

Crossed retroreflector

Hard to visualize and complex to design.

It works but complex and grating size ~>100mm



Detectors Issues

- EMCCD as base-line {*vs. classical slow-read CCD or GaAs PCs*} – what are the arguments?
  - Data cube acquisition (*naïve calculations*)
    - Assume data-cube is ~100 [20] λ-samples deep
    - Assume read-noise ~3e^{-} (rms)
    - If T_{Cube} ~4 [8] hrs ⇨ T_{λ} <140s [1500s]:
      - ⇨ Detector noise limited for R >125 [800] (Nyquist λ-sampling)
      - ⇨ High-QE photon counting ideal for all R >125 [800]
    - If: $T_{\lambda} < \boldsymbol{T_{Variability}} < T_{Cube}$
      (*for seeing & transparency: this is always the case* – [1/f noise])
      - ⇨ Rapid λ-scanning highly desirable
      - ⇨ $T_{read\text{-}out}$ >1s (limit set by maximum pixel read-rate ~3MHz)
        - ⇨ $T_{\lambda} \sim 10{*}T_{Read\text{-}out}$ to minimize duty-cycle losses
      - ⇨ Photon counting for ~ALL data-cube acquisition

Detectors Issues, cont. #2

- 3 readout modes
  - Classical, slow reads (200kHz)
    - ~3e^{-} (rms)
  - Amplification mode
    - Analogue, non-photon counting: DQE = QE/2 (Gain-noise)
    - CIC (*important but poorly quantified*) + dark noise
  - Photon counting mode
    - DQE = QE
    - Flux rate <10*Frame-rate (typically <0.1Hz/pixel)
      - ⇨ Small dynamic range (non-linearity can be ~corrected, but SNR hit)
    - Trade between CIC + dark noise
- Smaller format EMCCDs had frame-store but ***NOT*** the 1600^2 version:
  - What effect on CIC noise? – seems OK
  - Any other issues? – seems OK (tbc)

Detectors Issues, cont. #3

- Requirements:
  - Supports all 3 modes
    - Classical reads give ~3e^-/s – for ultra-faint, low-R work
    - Amplification mode – for ultra-low flux @ high-R
    - Photon counting – for most 3D obs. - med/high-R
  - Controller has to be supported by SOAR staff
    - Does not exclude Daigle controller
    - Visitor instrument status for 1st year (tbc)
  - Can be run under ArcView
- Questions:
  - Daigle -vs- modified-Leach:
    - Performance; Robustness ; Supportability
  - Expected value for CIC noise – assume 0.024/pixel (tbc)
    - How will this evolve over time?
    - BTFI detector lab characterization will tell

Electro-Mechanical Issues

- Mechanisms (Manual or Remote?):
  - Aperture exchange (3-pos$^{n.}$ slide) – mask/filter/clear
  - FP$^{1\&2}$ retraction (2-pos$^{n.}$ slide) *2 - viewing port
  - FP$^{1\&2}$ control (SESO controller)
  - VPHG$^{1\&2}$ exchange
  - VPHG^{1} pitch
  - VPHG^{2} pitch & translation
  - Filter slide (6-pos^{n}) 5 filters + clear
    - Tilt mechanism – 0º to 15º
  - CCD shutters (activated by CCD)
    - Fast (<0.1s) for photon counting
  - EMCCD$^{1\&2}$ controller (Leach or Daigle?)

NB: Dry air/N_2 flushing (of complete instrument) for etalon stability

Software Issues

- Mechanism control
  - iBTF actuation
  - Filter slide
- Etalon (FP) controller *2 (SESO/LAM)
  - GUI development
    - z-scanning
    - Parallelism & λ-calibration
- EMCCD controller *2
  - GUI development (ArcView)
    - 3-modes
- Data Reduction
  - FP & iBTF calibration
  - Quick look
  - Pipeline

Critical Alignments

- Collimator/Camera (need tolerance analysis for all components/groups)
  - Internal
    - Critical – but built as units
  - External
    - Tilt/Axial – relaxed
  - Focus – relaxed
    - Cameras – no adjustment
    - Collimator – no adjustments
- Fold mirrors – adjustment & stability/z-frame ~3" (~2µ across ~100mm)
- VPHGs – adjustment & stability/z-frame
  - Rx – Pitch/Roll as per Fold Mirrors ; Yaw ~1' (or 30µ across ~100mm)
  - Tx – Pitch ~40" ; Roll ~1º ; Yaw ~1' (or 30µ across ~100mm)
- FPs
  - Internal alignment (parallelism) – critical (~2nm; with Capacitance Micrometry)
  - External alignment- tilt/translation/axial – v. relaxed
  - External stability - translation/axial – v. relaxed ; FP^2 **tilt/data-cube** ~3"
- IFs – Tilt mechanism - relaxed

Daytime Calibrations

- FP[1&2]
  - Visual inspection
    - Plate parallelism (coarse)
  - In-beam (automated)
    - Plate parallelism (fine)
    - ℓ determination
    - λ calibration
    - White-light 3D flat-field
    - Emission-line 3D data cube
- iBTF
  - Tilt alignment (coarse)
  - Rotational alignment (fine)
  - λ calibration
  - White-light 3D flat-field
  - Emission-line 3D data cube

Nighttime Calibration

- FP[1&2]
  - In-beam (automated) – every 3-4 hours
    - Plate parallelism (fine)
    - λ calibration (cube or ring)
- iBTF
  - λ calibration – every 3-4 hours
- EMCCD
  - EM Gain calibration – every 2-3 hours? tbc
  - Dark
  - Bias
  - CIC noise measures? tbc
- Photometric
  - Absolute
  - Differential

Calibration requirements

- $FP^{1\&2}$
  - FP slides for installation & visual inspection
    - Hand-held FP (x,y,z) controller
    - Line source and diffuser for illumination
    - Viewing port
  - Line and continuum sources - from ISB
  - Image plane mask – needs 3-pos^n slide (manual)
    - Matrix pin-hole – for spatial mapping (astrometry)
    - 4-hole mask (cardinal pos^n) for FP^{Image} parallelism & λ-calibration
  - Automatic parallelism procedure (software control loops)
    - FP^1 (λ-calibration lamp + 4-hole mask):
      - λ-scan ⇨ 4*1D λ-profiles ⇨ (x,y,z) adjustment ⇫ iteration
    - FP^2
      - 4-pos^n pupil mask (in Filter wheel) – remotely operated
      - Pos^n #n (n=1:4): λ-scan (1D) ⇨ Gaussian fits
      - Repeat for all 4 pos^n ⇨ (x,y,z) adjustment ⇫ iteration