Beam Combiner studies for MROI

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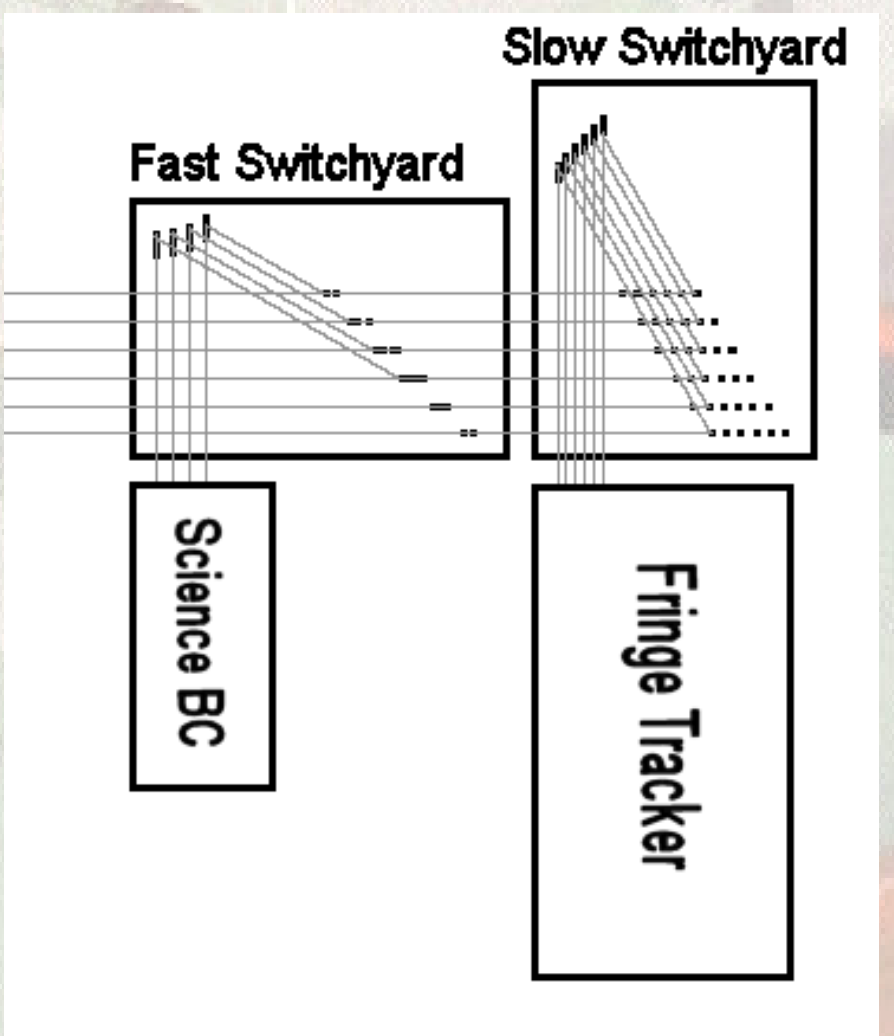
Aims & Background

- **Want beam combiners that will meet MROI top-level science goals**
- **First priority is near-infrared combiners (J,H,K bands)**
  - *Visible-wavelength combiners will be part of a later phase*
- **Cambridge currently performing studies of candidate concepts**
  - Will be finished in a few months
  - COAST experience & VLTI concept study feed into this

MROI combiner requirements

- **Top-level Requirements**
  - Separate science and fringe tracking combiners
  - Combiners operate simultaneously
    - Need to match paths (inter-band dispersion, internal drifts)
  - Science at J or H or K, choice of $\lambda/\Delta\lambda$
  - Handle 6 telescopes
  - Upgrade path for 10 telescopes

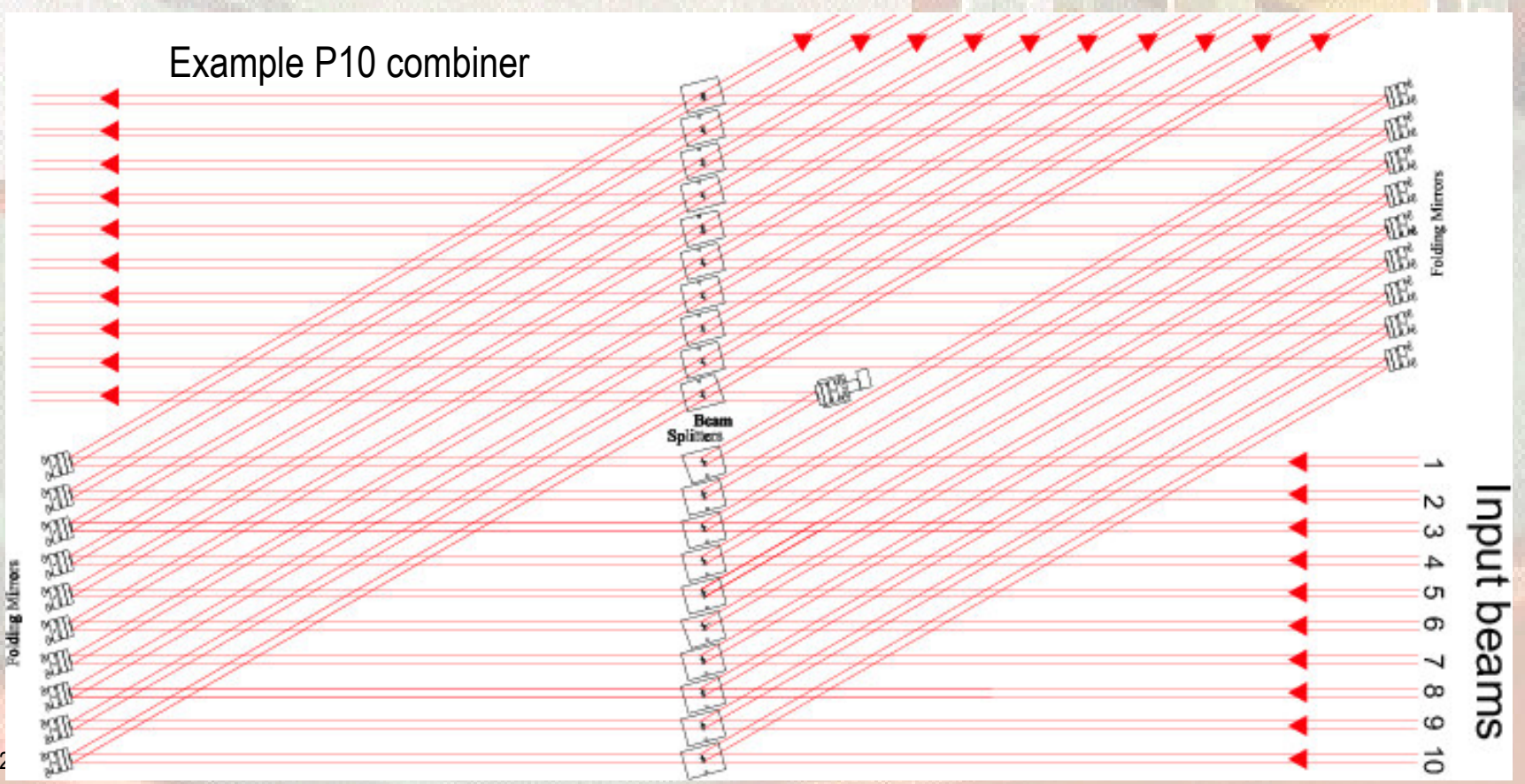


Requirements - Individual Combiners

- **Requirements for Fringe Tracking Combiner:**
  - Support hardware coherencing and software co-phasing
  - Limiting sensitivity H=14 for AGN science mission
  - Switchable between operation at H (1.5-1.8μm) & K (2.2-2.5μm)
    - Best sensitivity will be at H
  - Track on all nearest-neighbour baselines simultaneously
- **Top-level requirements for IR Science Combiner:**
  - Science at J (1.2-1.35μm) or H or K, choice of $\lambda/\Delta\lambda$ ~ 30, 300 (switchable)
    - Possibly a case for high-res. mode ($\lambda/\Delta\lambda$ > 1000)
  - S/N>2 in 100sec for K~13 at low spectral resolution
    - For AGN science mission
  - Access to all baselines and independent closure triangles, within ~few minutes
  - Calibration of V^2 to 2% rms, closure phase to 0.8° rms (bright targets)

Candidate Fringe Tracking Combiners

- **Pupil-plane pairwise nearest neighbour (PNN)**
- **Image-plane pairwise nearest neighbour (INN)**
- **Image-plane all-on-one 6-way (I6)**

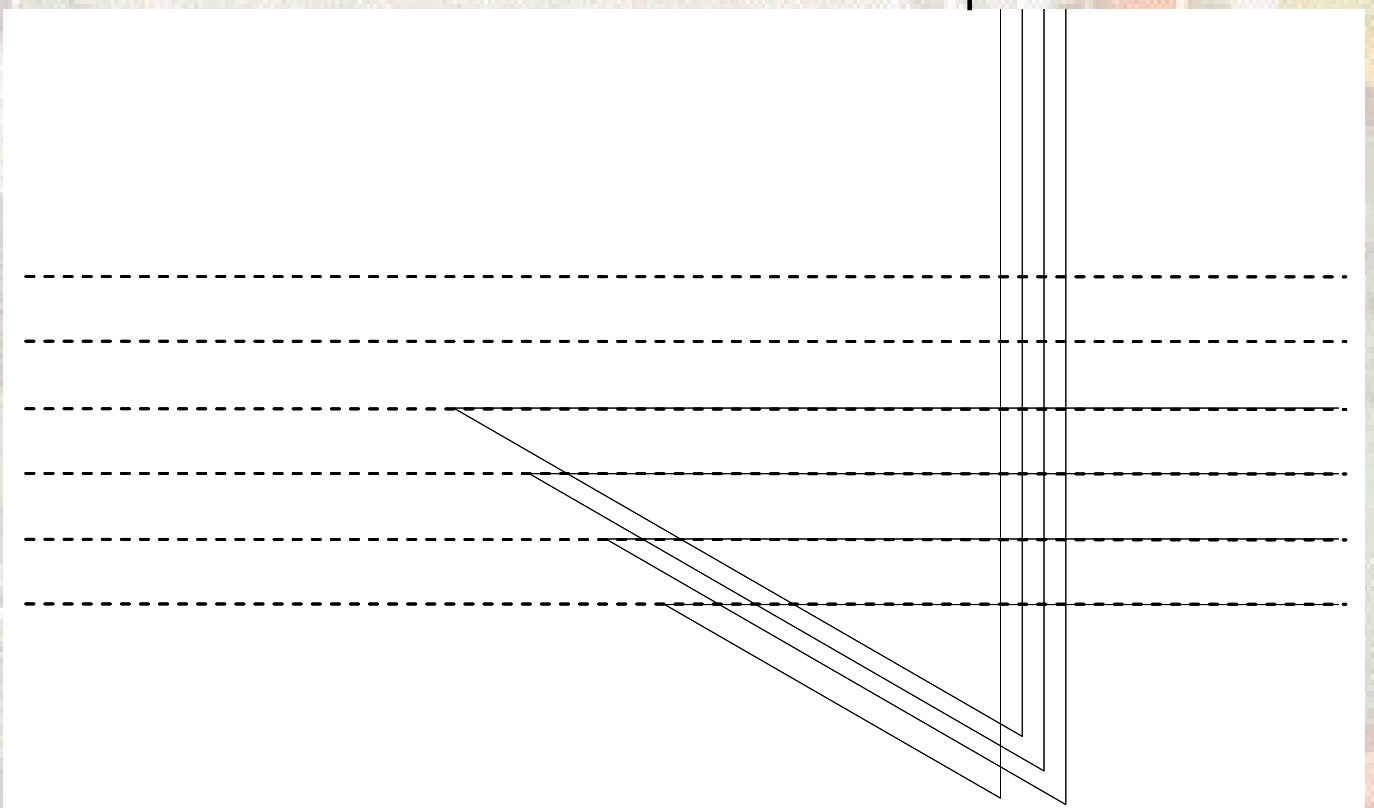


Candidate Science Combiners

- **Contacted 4-way pupil plane fed by fast switchyard** (P4S)
  - 4 of 6 beams selected by fast switchyard
  - Contacted optics combine 4 beams
    - Path modulators encode fringes in time domain
    - 4 combiner outputs, each contains all baselines
- **Contacted 8-way (6 inputs used) pupil plane** (P8)
  - Always feed in 6 beams
  - 2-position internal switchyard selects baselines/triangles measured
- **4-way image plane fed by fast switchyard** (I4S)
  - 4 of 6 beams selected by fast switchyard
  - Combine 4 beams in focal plane on single detector – spatial fringes
- **6-way image plane** (I6)

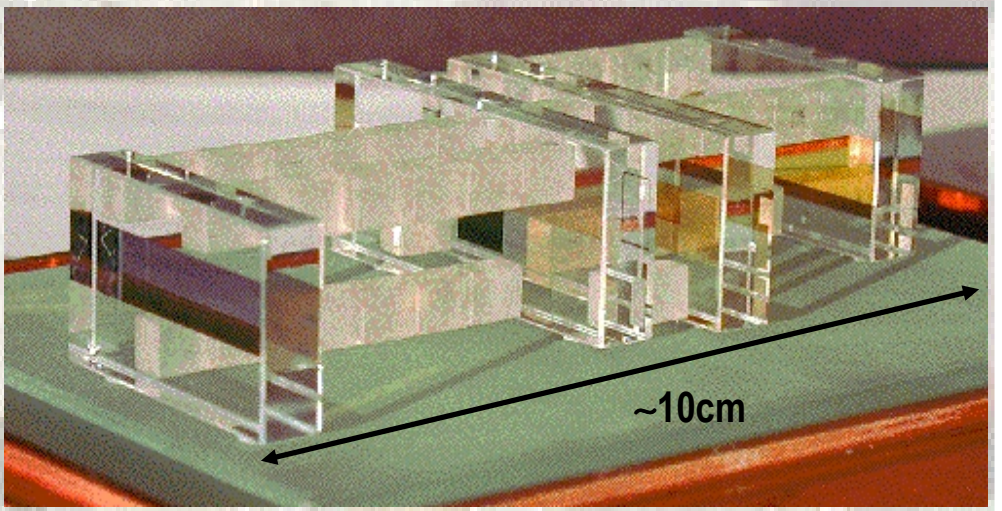
Fast Switchyard for P4S/I4S

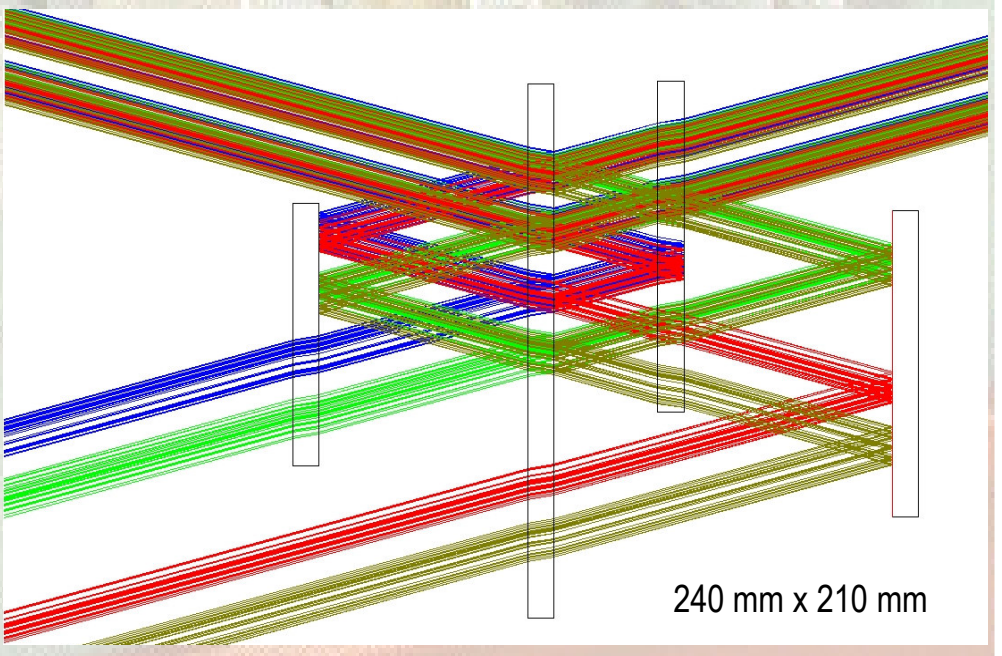
- **Needed when > 4 telescopes**
- **Select any 4 from 6 beams, preserve relative paths**



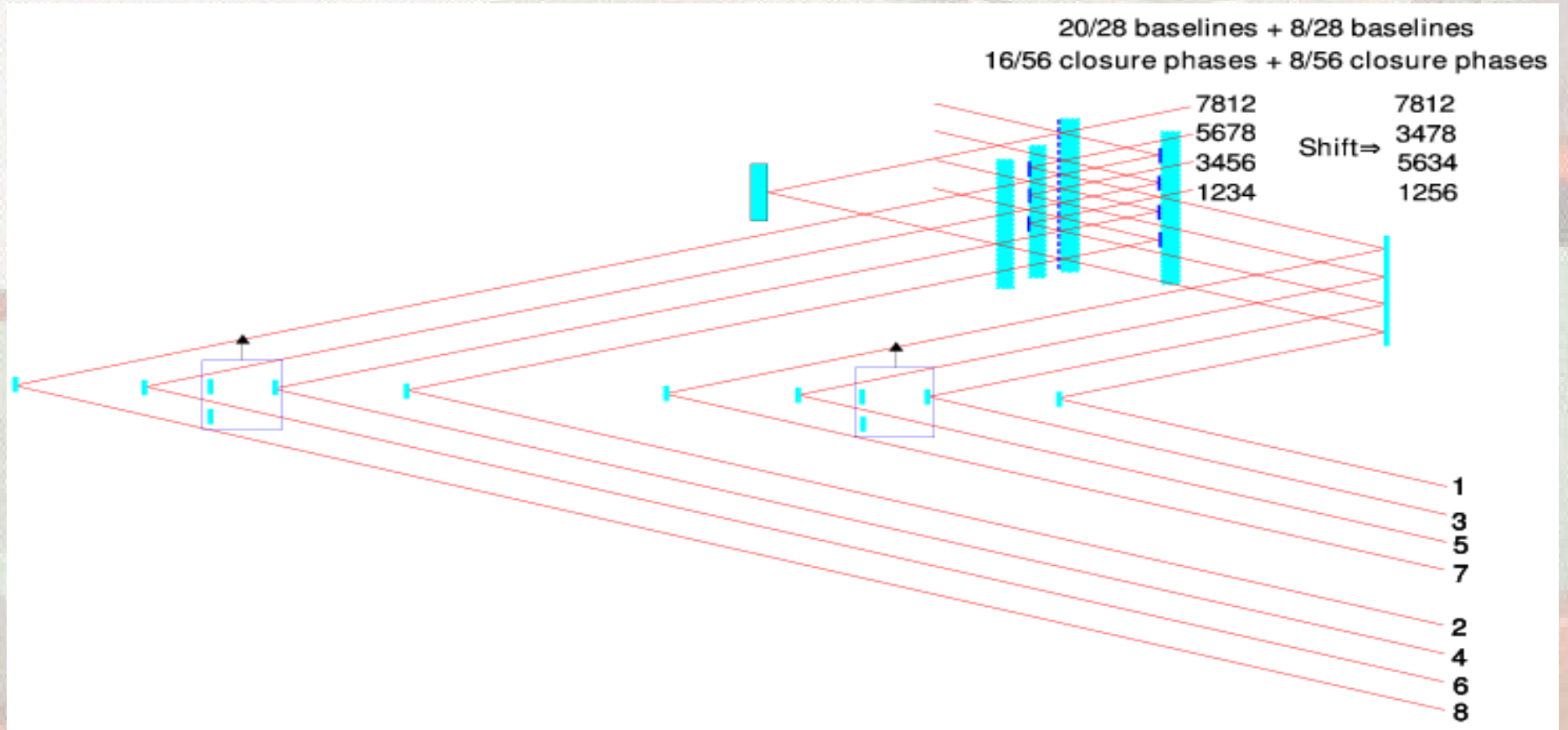
P4(S) Combiner

- **Similar to existing contacted 4-way 1-2.5μm combiner made by Cambridge**
- **Existing combiner features:**
  - Performance verified in lab
  - But designed for 5mm beams
- **Advantages of contacted optics**
  - Stability
  - Ease of alignment
- **Disadvantages**
  - >4 beams unproven until now
  - Need thin or matched coatings





P8 Switchyard and Combiner



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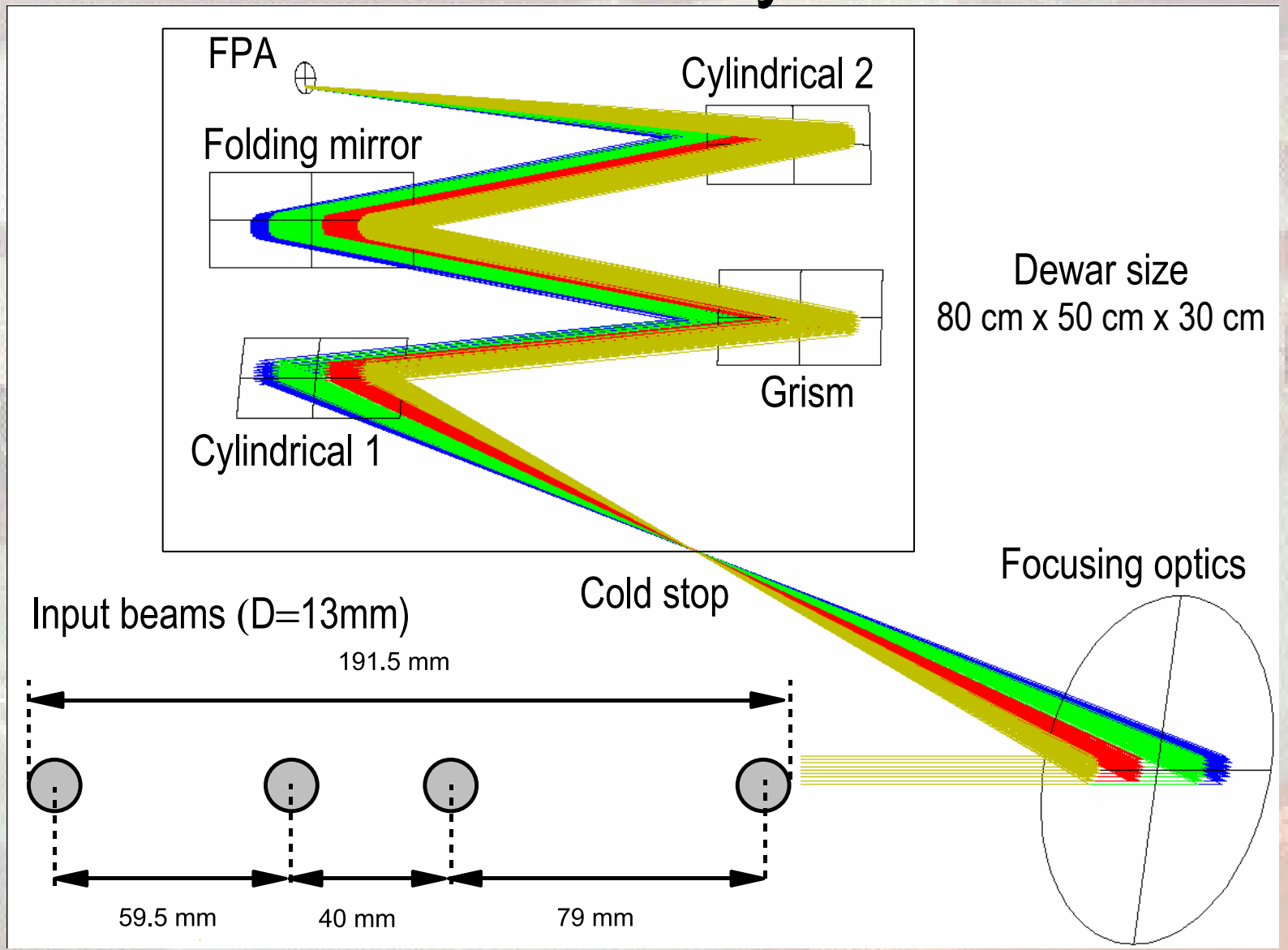
I4S beam combiner layout



Spectrographs

- **Spectrograph for pupil plane combiner is simple**
  - Focus single combined beam onto cold stop
  - Inside Dewar : collimate, disperse, and focus spectrum onto FPA
  - Multiplexing possible
- **Spectrograph for image plane is more complex**
  - Same principle but very large anamorphosis factors (>100)
  - Dewar size must be kept reasonable…
- **Reconfigurations**
  - Want to switch:
    - Low <=> Medium dispersion (Science Combiners only)
    - Operating waveband
      - May need change of dispersing element even if not changing spectral resolution
  - OK to switch a few times a night, or even between nights
  - Typically need to adjust last mirror and FPA

Ongoing work

- **Science combiner spectrographs (I... & P...)**
  - Simultaneous optimization for 6 configurations (3 bands $\times$ 2 res.)
- **Pupil plane (P...) combiners**
  - How many combiner outputs can be multiplexed onto each detector ?
  - Contacted combiners – glass procurement
- **Image plane (I...) combiners**
  - Optimization to reduce Dewar sizes
- **Fast switchyards (...S)**
  - Alignment procedure (if needed) after reconfiguration
  - See if repeatable enough to use look-up table

Evaluation of designs

- ***Realistic* signal-to-noise**
  - FT combiner S/N, sets magnitude limit for operating array
- **Imaging speed, depends on:**
  - Science combiner instantaneous S/N
  - No. of switchyard reconfigurations required (if any)
  - Reconfiguration & calibration overheads
- **Cost : Optics, Mechanics, Detectors**
- **Technical risk**
- **Schedule risk**
- **Calibration and stability issues**

Conclusion

- **Demanding MROI requirements for infrared instruments**
- **Several optical combiners have been designed :**
  - FT : pupil or image plane pairwise, or all-in-one I6 combiner
  - SC : contacted 4/6 beams, or image plane 4/6, switchyards if necessary
- **Most optimizations are finished and final evaluation is ongoing**
- **Milestones:**
  - Evaluation finished in July 06
  - First closure phase in August 08
  - Six telescopes on site in late 2009