SOLAR-C B案
Solar UV-Vis-NIR Telescope
焦点面観測装置の概念検討

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基本仕様

- Telescope aperture
  - 1.5mϕ
- Telescope length
  - Fit within the H-IIA nose fairing
- Spatial resolution
  - 0.1" in UV
  - 0.16" in Vis/NIR (Diffraction limit of 1.5mϕ at 1μm)
- FOV
  - ~200" x 200" to cover a medium size AR
- Wavelength coverage
  - Shortest ~250 nm to observe Mg II h/k.
  - Longest ~1100 nm to observe He I 10830.
- I/F between the telescope and the focal-plane instrument
  - Collimated beam with 60mmϕ to relax the tolerance of alignment.

２次元分光の必要性

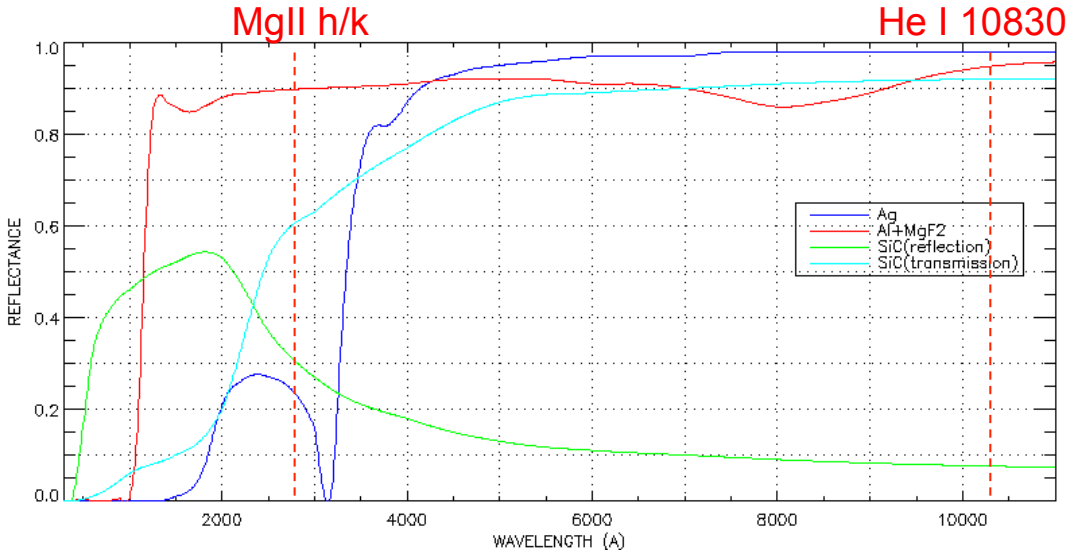
- 彩層における時間変化の速い現象があらゆる場所で観測される
  - V> 50km/s (sometimes 100km/s). 音速(~10km/s)よりもはるかに高速.
- 変化の速い現象を観測するためには、1スリット分光はもはや不十分
  - 100 km/s (velocity) x 300 sec (duration) ~ 30,000 km (~40”)
  - スリットスキャンに要する時間は約2000 sec。現象の持続じかんよりはるかに遅い。

    40" (FOV) / 0.18" (slit step) x 10 sec (integration at each step) ~ 2200sec

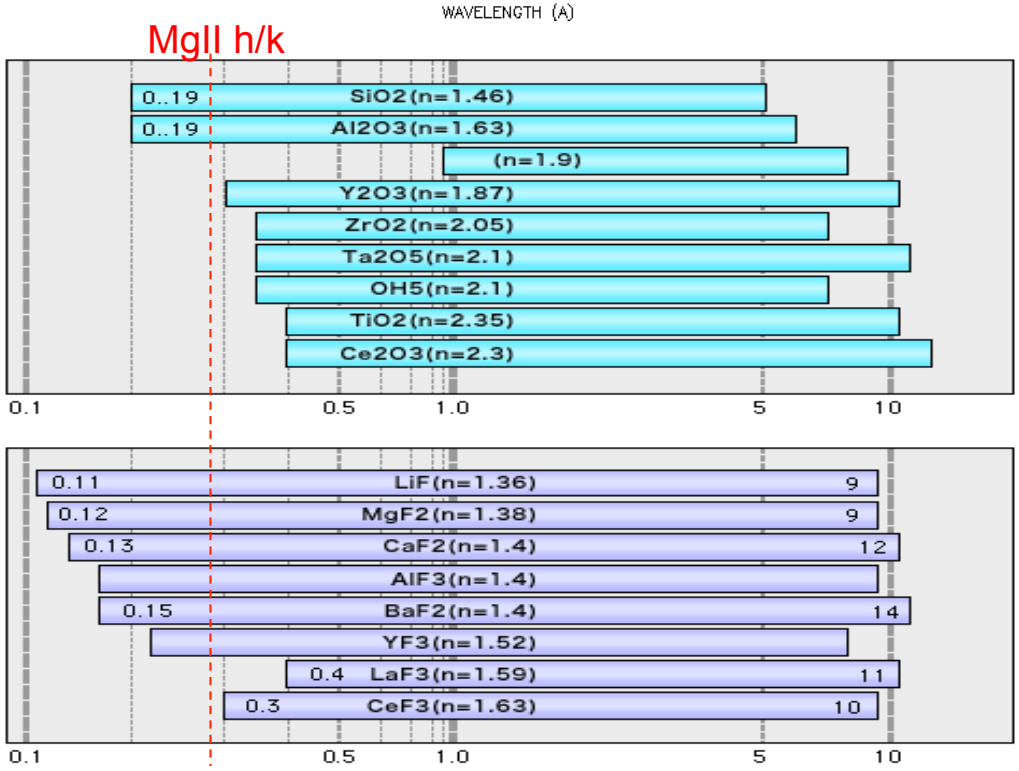
- SOLAR-Cでは2次元的な分光の実現が望まれる。いくつかのオプションについて検討
  - Multi-slit
  - Double pass spectrograph
    - Slot spectroscopy with medium wavelength dispersion
  - Integral field spectroscopy
    - Fiber-optics bundle or image slicer
  - Tunable filter-type instruments with rapid wavelength tuning
    - Fabry-Perot or Lyot

Limitation in the wavelength coverage

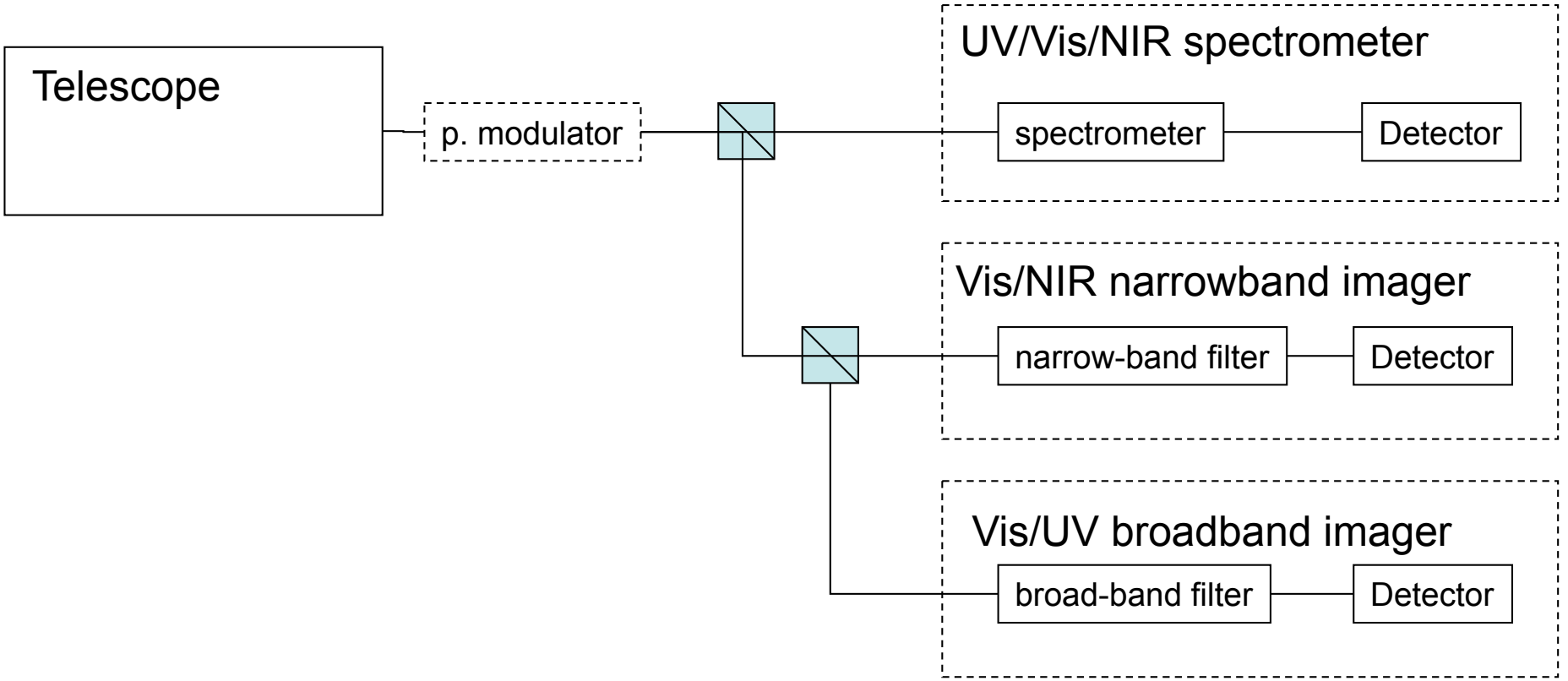
- Mirror reflectivity
  - Al coating is required to reach the wavelength shorter than 300nm.
  - Al+MgF2 coating can reach 110nm.



- Optical materials (for lenses and coatings)
  - There are few glass materials available under 200nm.

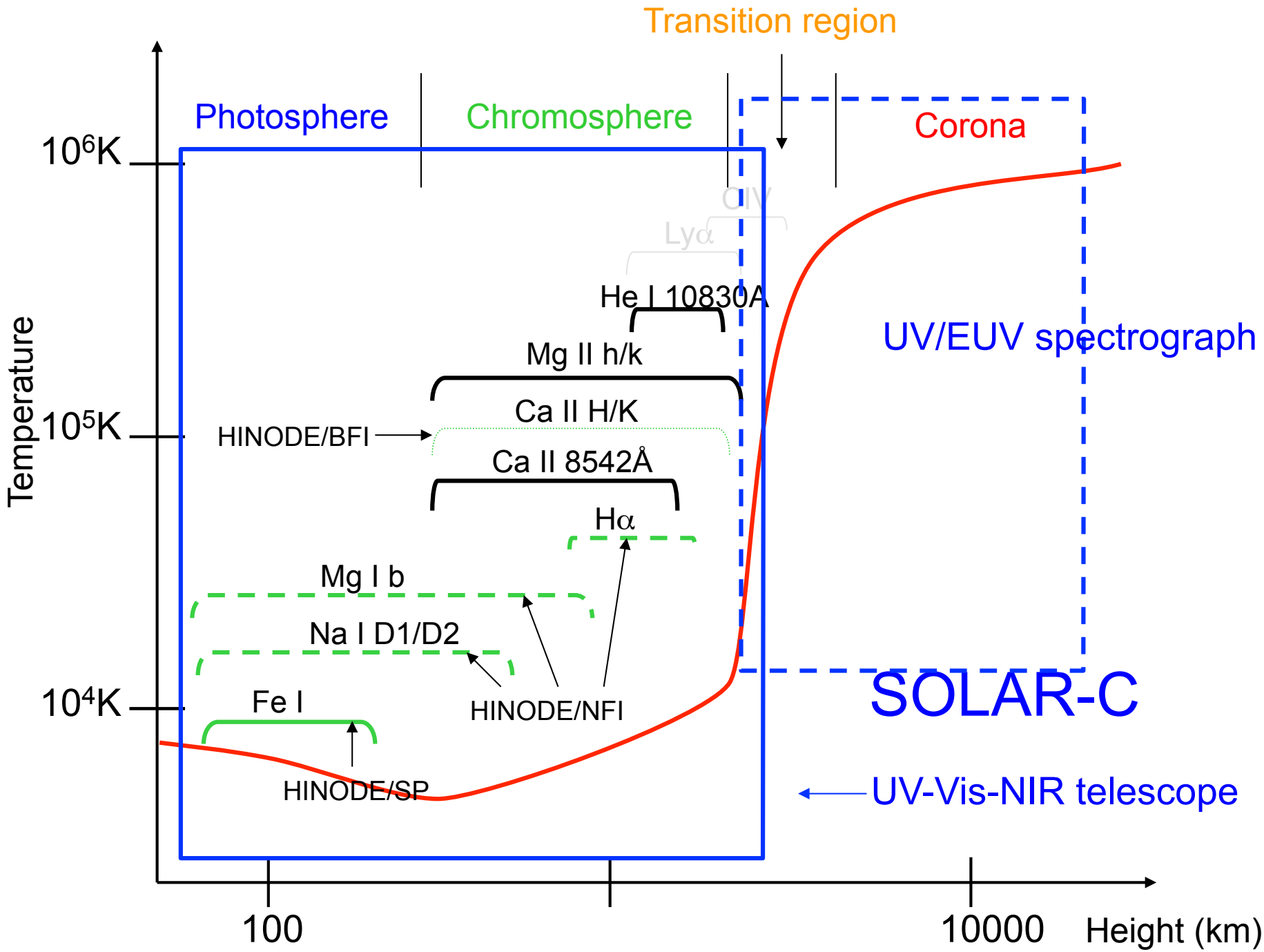


Block diagram of the optical configuration



Pixel size and FOV of the mission instruments

			FOV	Pixel size	Exposure	Note.
UV-Vis-NIR telescope		Broadband	164" x 164"	0.04"	< 1sec	• 2.5 pix sampling of **0.1"** res. • 4Kx4K detector
		Narrowband	246" x 246"	0.06"	< 1sec	• 2.5 pix sampling of **0.16"** res. • 4Kx4K detector
		Spectrometer	246" x 246"	0.06"	1sec (S/N~1600)	• 2.5 pix sampling of **0.16"** res. • 4K pix along slit
				0.12"	10sec (S/N~10^4)	
UV/EUV imaging spectrometer		Spectrometer	1024"x 1024"	0.5"	0.5sec (AR) 5sec(QS)	• **0.5"**pixel size • 2Kx2K MCP+CMOS detector
X-ray telescope	NI	Imaging	410"x410"	0.1"	1sec (AR) 10sec (QS)	• High res imaging with NI telescope • 4Kx4K detector
	GI	Imaging	1024"x1024"	0.5"	1sec	• Imaging spectroscopy with GI • 2Kx2K CMOS detector
		Photon count	1024"x1024"	2.0"	60sec	

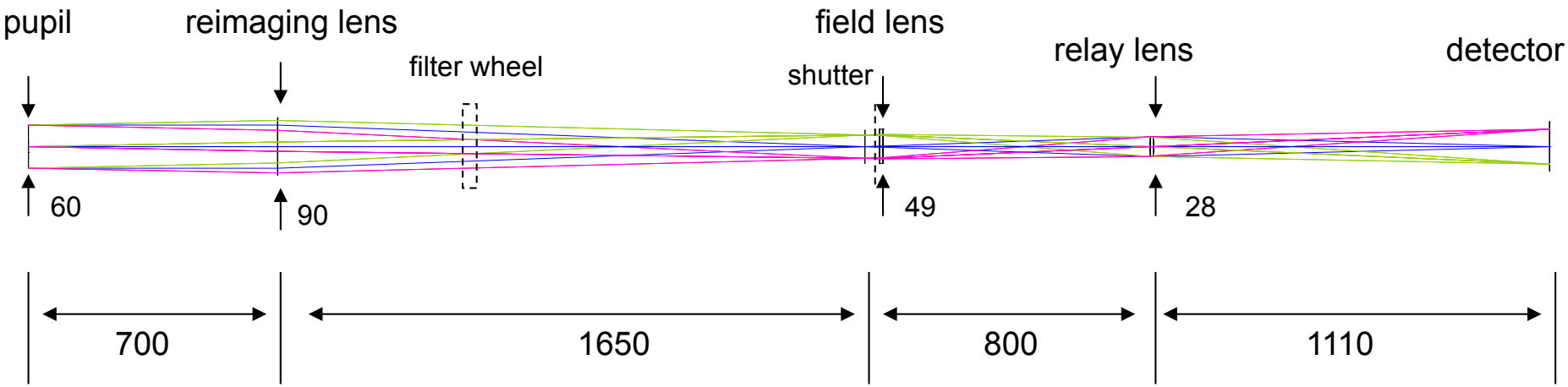

Transition region
Photosphere
Chromosphere
Corona
10^6K
10^5K
10^4K
Temperature
CIV
Lyα
He I 10830A
Mg II h/k
Ca II H/K
HINODE/BFI
Ca II 8542Å
Hα
Mg I b
Na I D1/D2
Fe I
HINODE/NFI
HINODE/SP
UV/EUV spectrograph
SOLAR-C
UV-Vis-NIR telescope
100
10000
Height (km)

Preliminary choices of spectrum lines (deluxe configuration)

Instrument	Spectrum line	wavelength	Purpose
Vis/UV broadband imager	UV continuum	~250nm	High res. Img of photospehre
	Mg II h/k	280nm	High res img of chromosphere
	CN band	388nm	Granules and magnetic elements
	G-band	*430nm*	*Granules and magnetic elements*
Vis/NIR narrowband imager	Mg Ib2	512nm	Low chromosphere V and B
	Fe I	525 or 630nm	Photosphere B
	Na ID1/D2	589nm	Low chromosphere V and B High photosphere
	Hα	656nm	High chromosphere V
	Ca II IRT	854nm	High chromosphere T, V and B
UV/Vis/NIR spectrometer	Mg II h/k	280nm	High chromosphere T and V
	Ca II IRT	854nm	High chromosphere T, V and B
	He I	1083nm	High chromosphere V and B

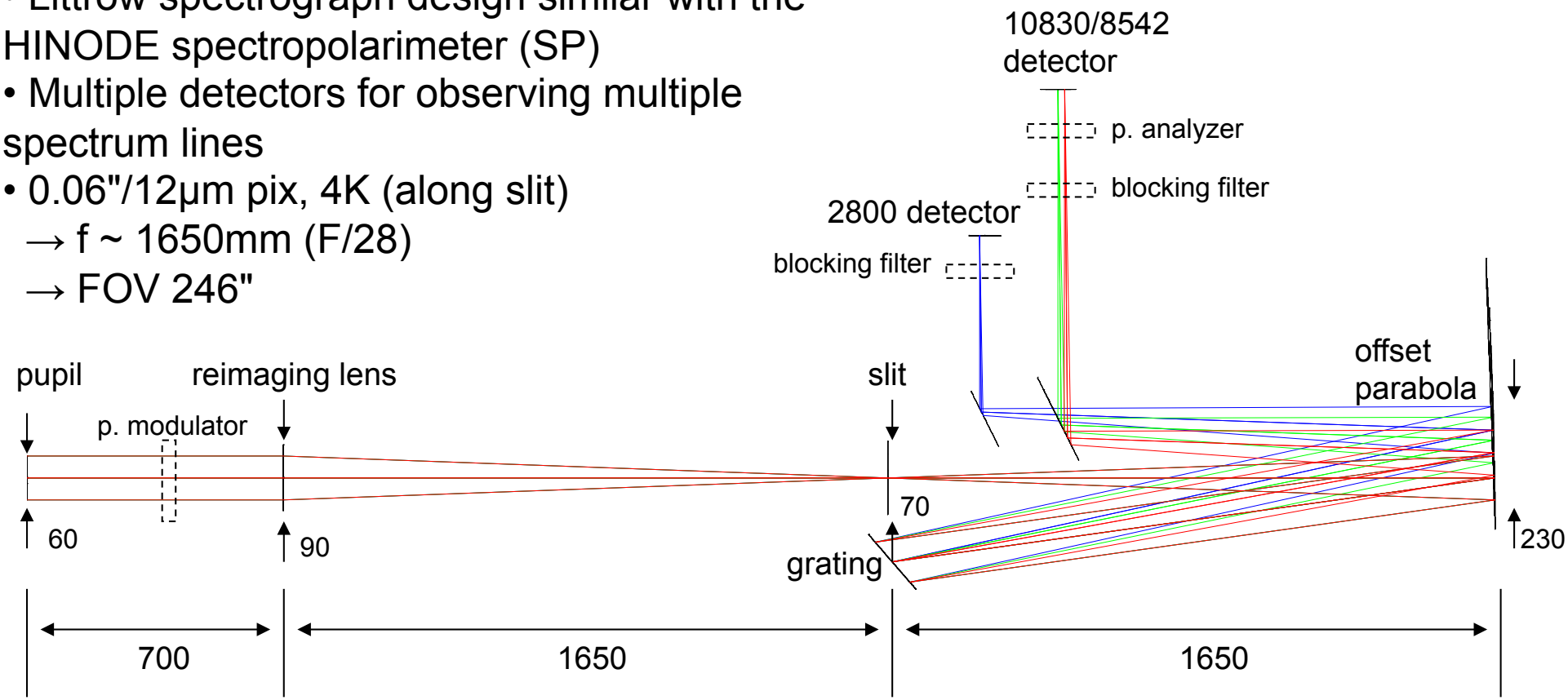
Broadband imager layout

- Similar design with the HINODE broadband filter imager (BFI).
- The rotating shutter is located near the focal plane
- 0.04"/12μm pix, 4Kx4K
  → f ~ 2470mm (F/41)
  → FOV 164"



Spectrograph layout

- Littrow spectrograph design similar with the HINODE spectropolarimeter (SP)
- Multiple detectors for observing multiple spectrum lines
- 0.06"/12μm pix, 4K (along slit)
  → f ~ 1650mm (F/28)
  → FOV 246"

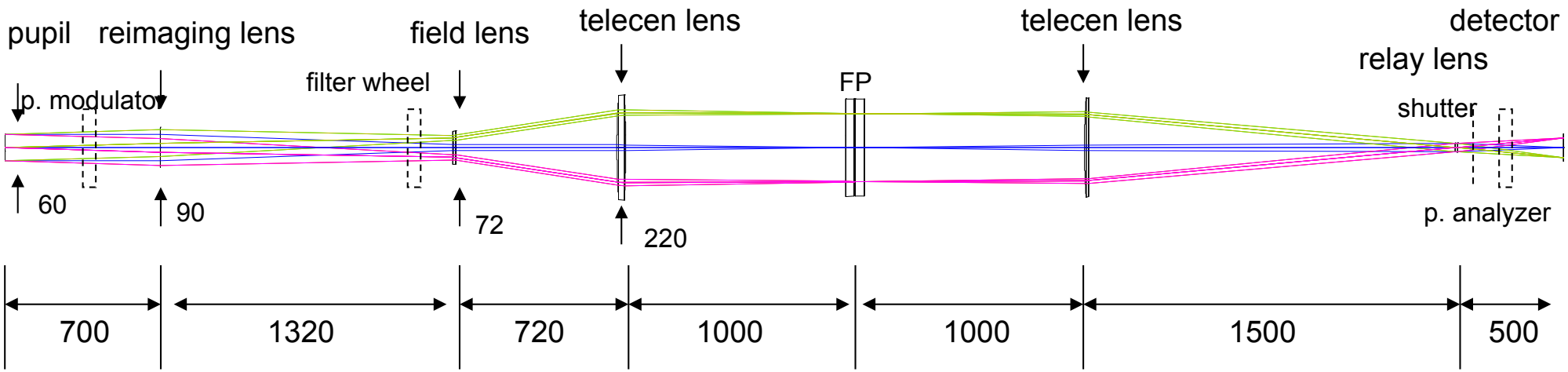


blaze angle	56°
groove	80lines/mm

λ	Order	dispersion
2800A	73	7.0mÅ/12μm
8542A	24	21mÅ/12μm
10830	19	27mÅ/12μm

Narrowband imager layout

- Telecentric configuration to have uniform wavelength over FOV.
- Large F (F>150) at the Fabry-Perot etalon.
- The shutter is located near the exiting-pupil.
- 0.06"/12μm pix, 4Kx4K
  → f ~1650mm (F/28)
  → FOV 246"

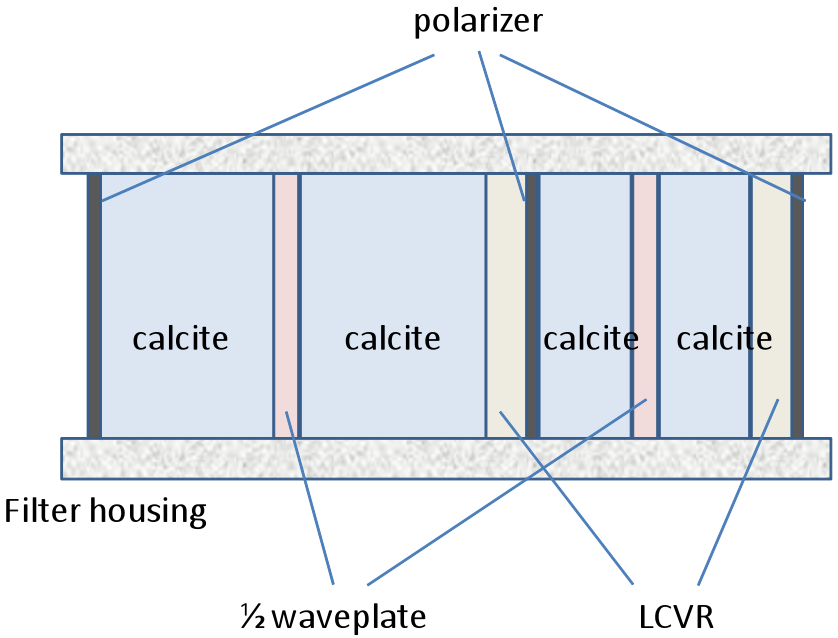


Tentative requirements on TF

- Wavelength range	TBD (a possibility 5000 – 8700A)
- band width (FWHM)	~100mA (50~70mA)
- Strehl	>0.9
- FOV	~200 arcsec w/ϕ1.5m (TBR)
- free spectral range	>5A
- tuning range	+/- 5A
- tuning speed	<50ms
- tuning resolution	<5mA
- repeatability	<2mA
- uniformity	
wavelength	5mA (TBD)
transmission	5%
- stability	
wavelength	5mA /day
transmission (flat)	1% /day
- Parastic light	<2%
- Ghost	<1%

Choice of tunable filter

Lyot filter vs. Fabry Perot



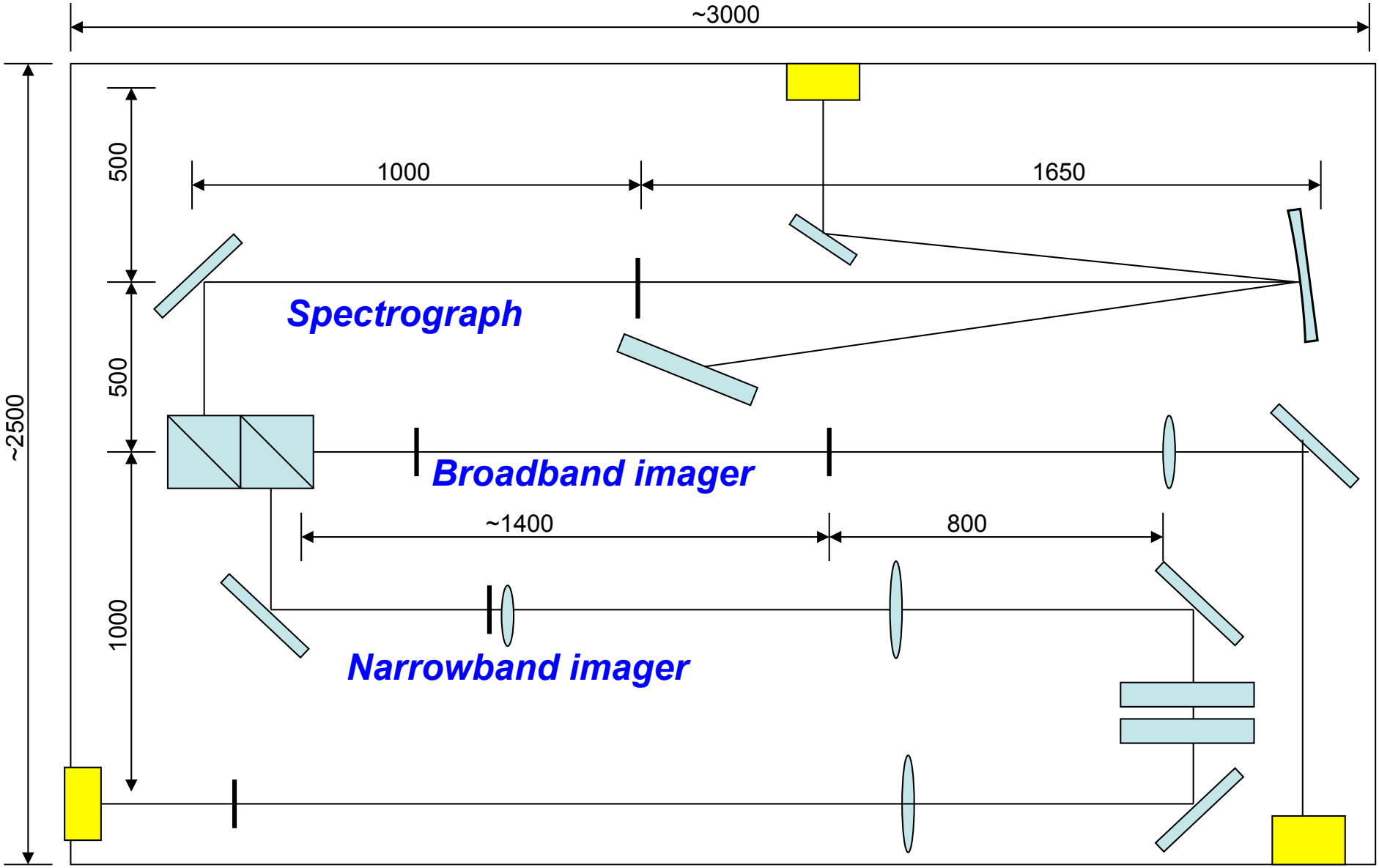
SOUP
Hinode SOT

地上望遠鏡による高解像度撮像分光観測において近年大きな成果をあげてきた

	Lyot filter	Fabry Perot
Speed of incident beam	F~ 40	F ~ 200 (air space)
Necessary diameter of filter (D=1m, FOV=3')	~40mm	~180mm
Transmission	~ 5%	~ 70%
Simultaneous 2-polarization	impossible	possible
Simultaneous multi wavelen	(in principle possible)	impossible
Structure	Complex	High accuracy
Oil	Necessary	Free
Control device	Rot. waveplate or liquid crystal	Piezo or LiNb
Past experience	SOT/Hinode	LASCO C1/SoHO
Concern	- Contact of opt. elem.s (avoiding bubble) - Mounting calcites - Outgas - Calcite availability -	- Mount and control for high accuracy surfaces (thermal/mech. stress) - Endurance of coating - Stability of inhomogeneity -

Filter diameter, L_{min} = image size = $F*D*(W/60/180*\pi) = 0.0003*F*D*W$ (cm, Telecentric)
D: aperture, cm、 W: FOV, arcmin、 F: F-ratio

Rough layout in the focal-plane package



まとめ

- 科学的要求に基づく観測すべき彩層ラインの優先度決定はサブWGにて完了している。

- 1.5mΦ口径の望遠鏡性能を最大限引き出すためには、焦点面装置の大型化は避けられない。
  (ひので SOT/FPPの約2倍の大きさ)

- 要素技術の実現性の見通しを立てること
  - Large format Fabry-Perot, Lyot filter
  - 2D spectroscopy for space instruments