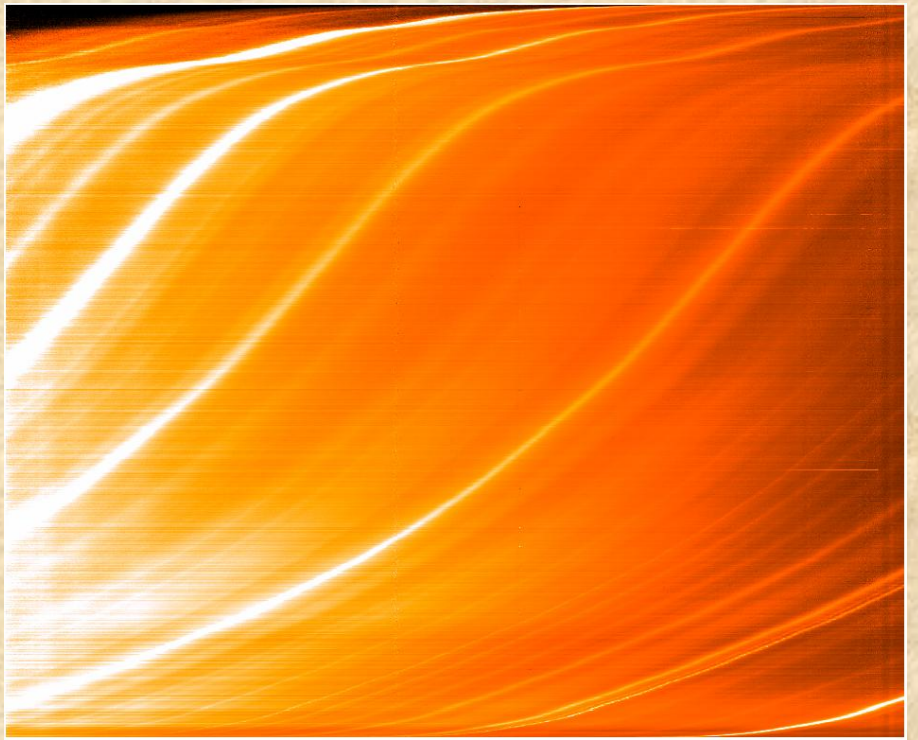
The Subaru Prime Focus Spectrograph

Michael Strauss (*with help from Hajime Sugai, Masahiro Takada, Naoyuki Tamura, Hitoshi Murayama, Jim Gunn, Richard Ellis, Jenny Greene…*)

すみれ SuMIRe
Subaru Measurements of Images and Redshifts

The Combination of Imaging and Spectroscopy

SDSS has demonstrated the scientific power of a coupled photometric and spectroscopic survey.



SDSS quasar spectra, ordered by redshift. Slide by Xiaohui Fan

With Spectra, We Can:

- Unambiguously determine the identity of objects
- Measure real redshifts of galaxies/AGN
- Measure emission line strengths and widths
- Measure stellar populations
- Measure absorption lines in the interstellar medium
- Etc., etc.

- The Japanese community has long been interested in wide-field multi-object spectroscopy, via the WFMOS concept from Gemini.
- Although WFMOS failed, Hitoshi Murayama was able to raise ~$30M for the SuMIRe concept, including a substantial component of the cost of a major spectrograph.

PFS: A World-Wide Collaboration

Characteristics of the Prime Focus Spectrograph

- 2394 fibers deployable over a 1.1 deg^2 field of view. Entrance aperture 1.13".
- Wavelength coverage 380-1260 nm:
  - "Blue" (380-640 nm): *R*=2300
  - "Red" (640-955 nm): *R*=3000

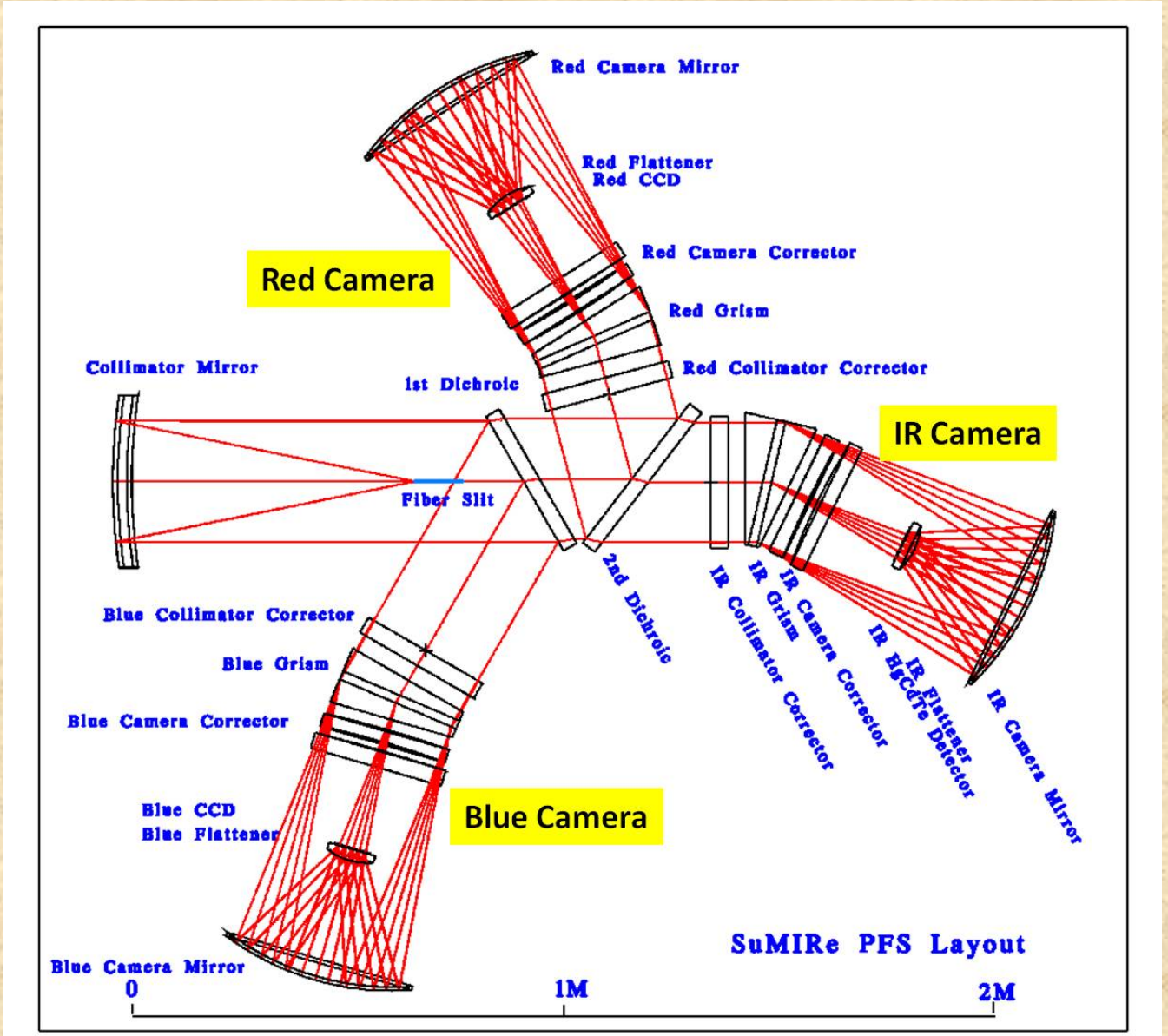
    (also a medium-resolution mode with R=5000 for stellar work?)
  - "NIR" (955-1260nm): *R*=4400

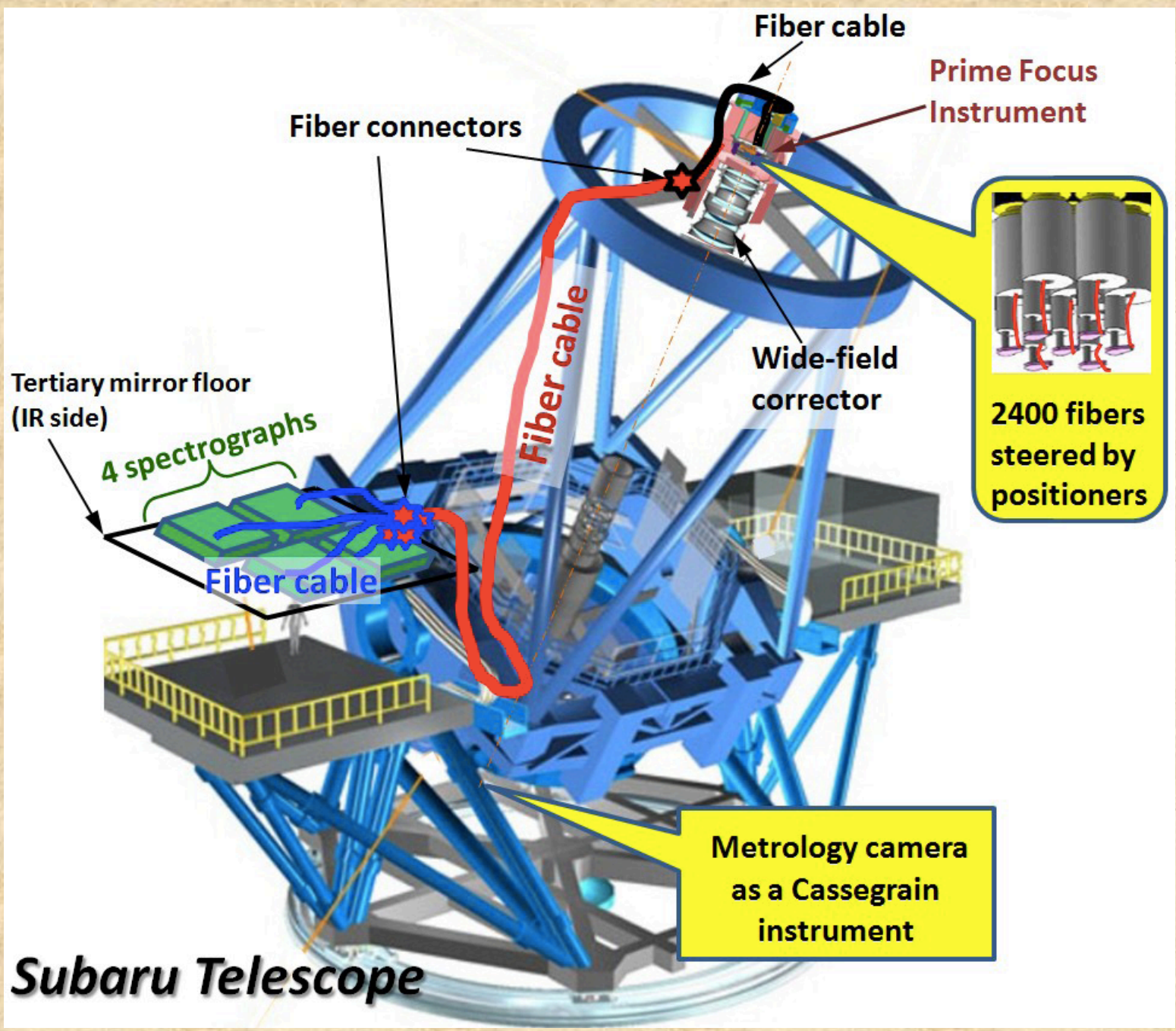
  This is almost constant 3Å resolution at all wavelengths
- End-to-end throughput of 20%

No Redshift Desert

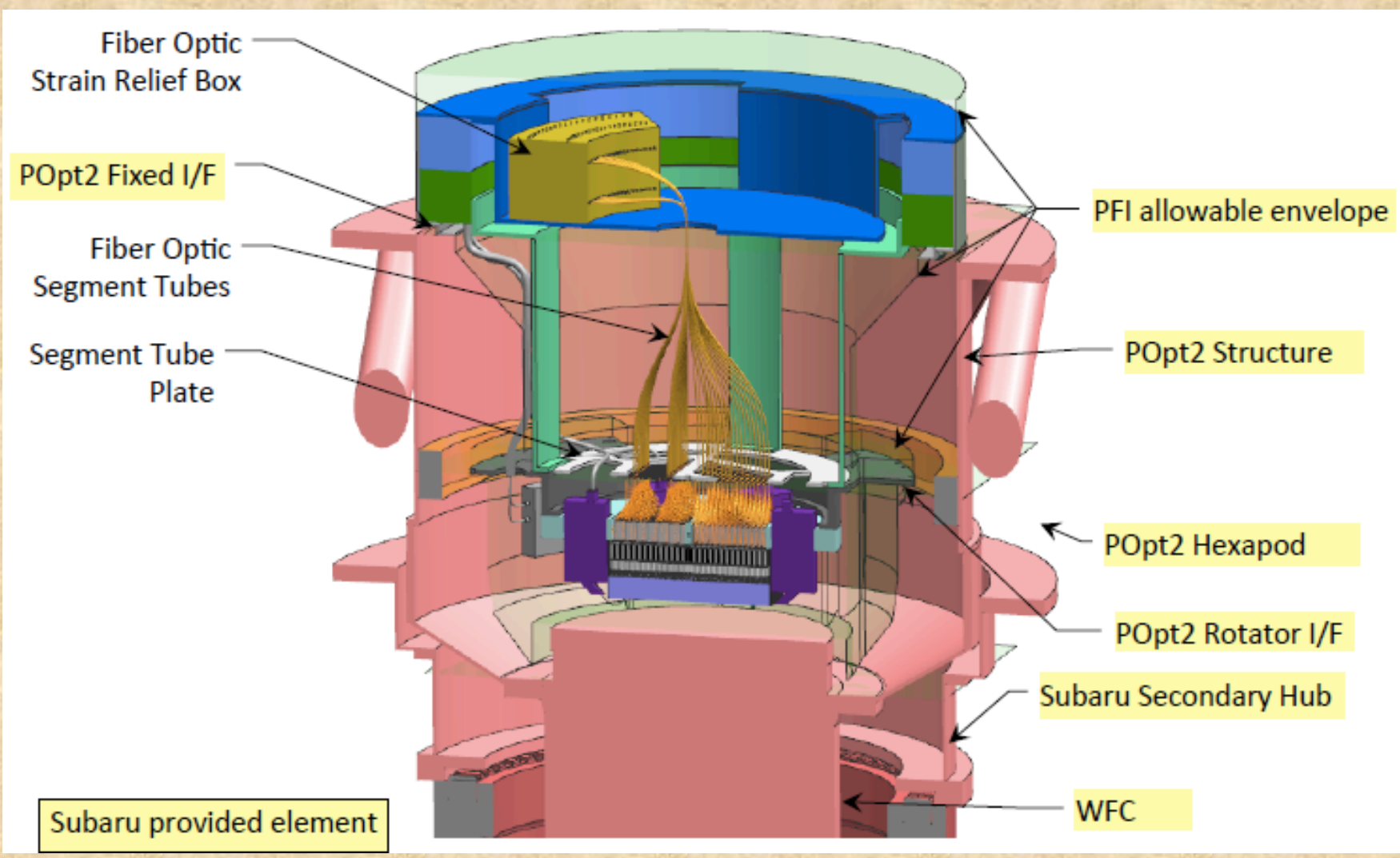
- This wavelength coverage means that one of the strong spectral features (Balmer lines, 4000Å break, [OIII], [OII], MgII, CIV, Lyα) is visible at all redshifts to z~9.
- Hα to z=0.9, [OIII] to z=1.5, MgII from z=0.35 to z=3.5, CIV from z=1.45 to z=7.
- This will be the most powerful redshift machine in the world. No other planned MOS has such spectral coverage.

Four identical spectrographs, each taking 600 fibers

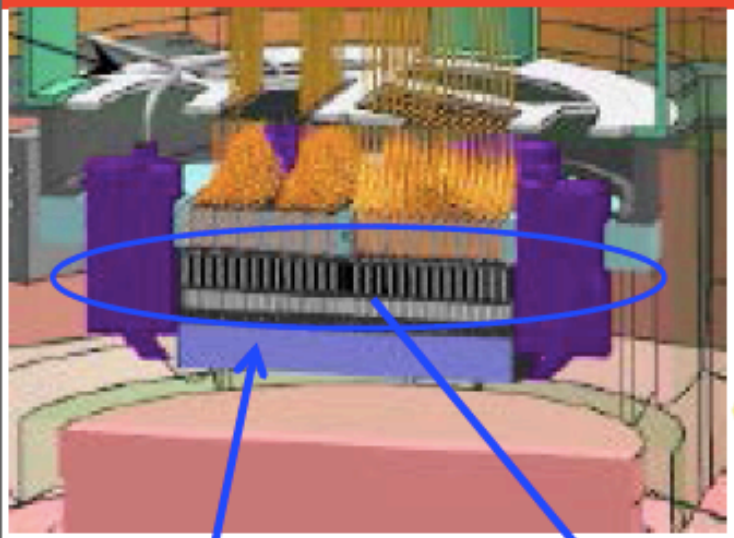



Fiber cable
Prime Focus Instrument
Fiber connectors
Fiber cable
Wide-field corrector
2400 fibers steered by positioners
Tertiary mirror floor (IR side)
4 spectrographs
Fiber cable
Metrology camera as a Cassegrain instrument
Subaru Telescope

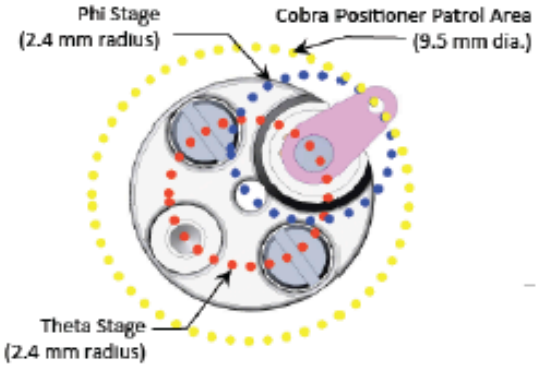
Prime Focus Instrument (PFI)



Focal plane configuration

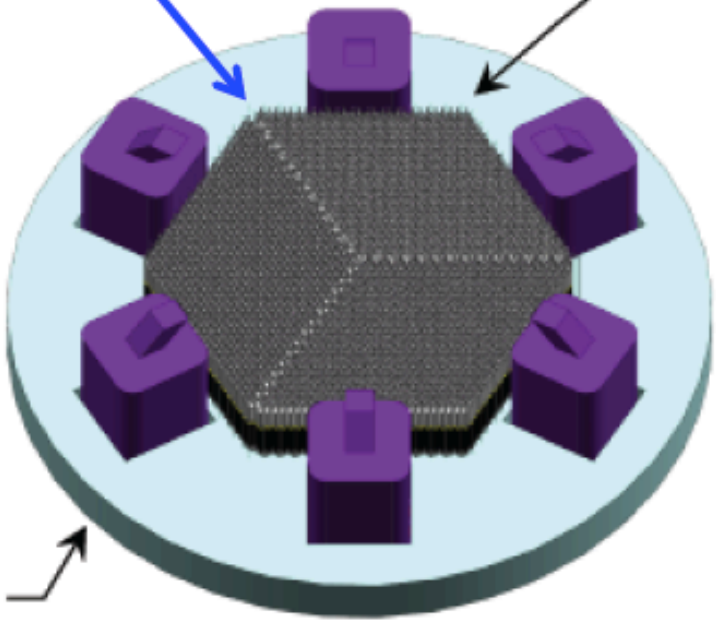


Acquisition & Guide (A&G) camera

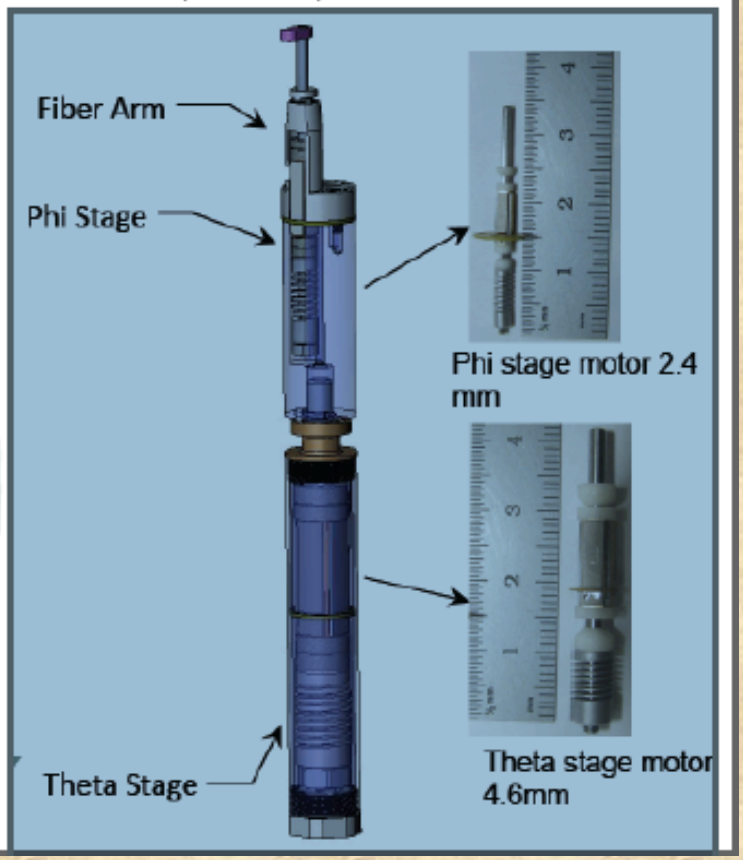


2400 Cobra Positioners

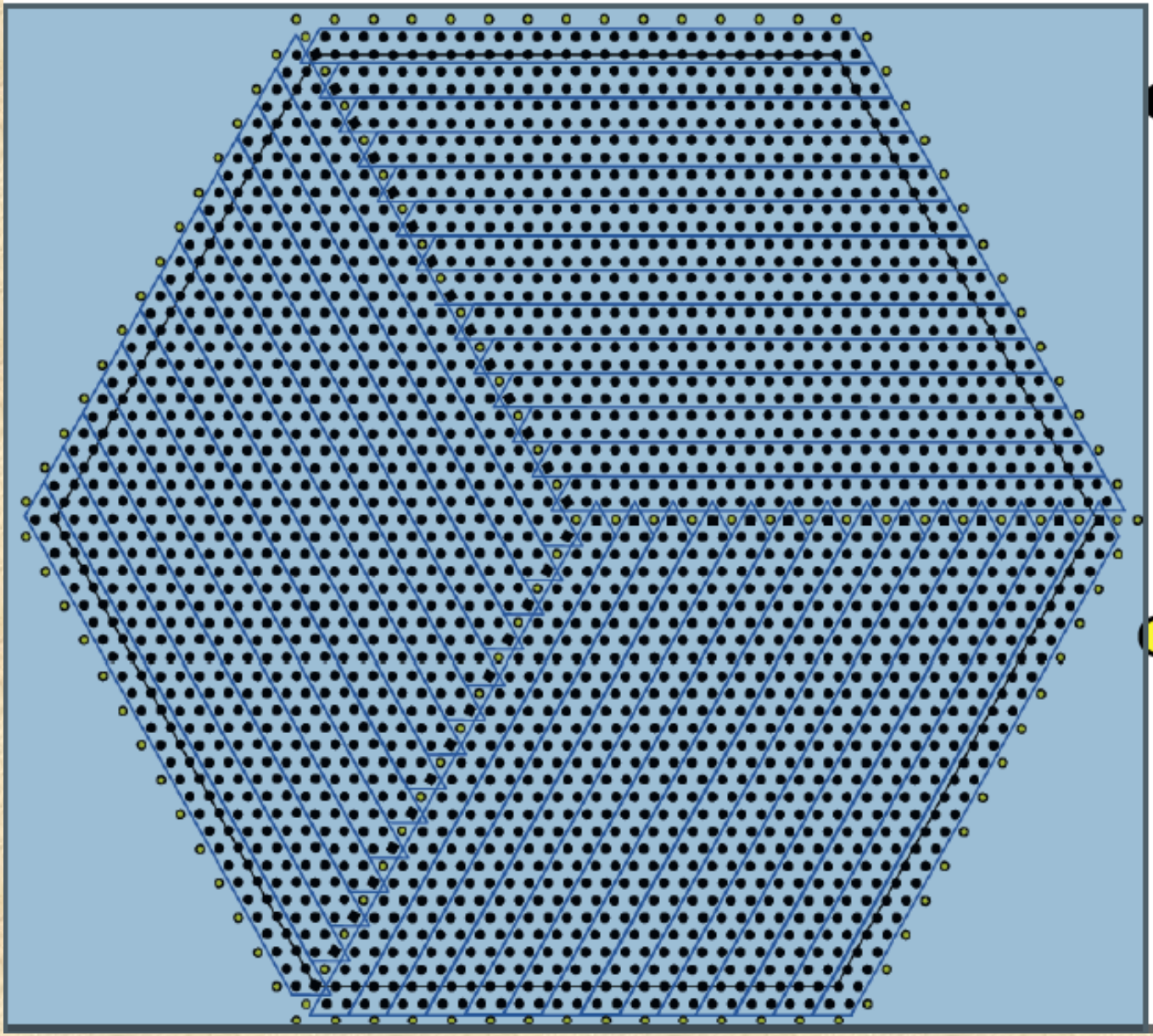
Field element



Cobra Optic Bench

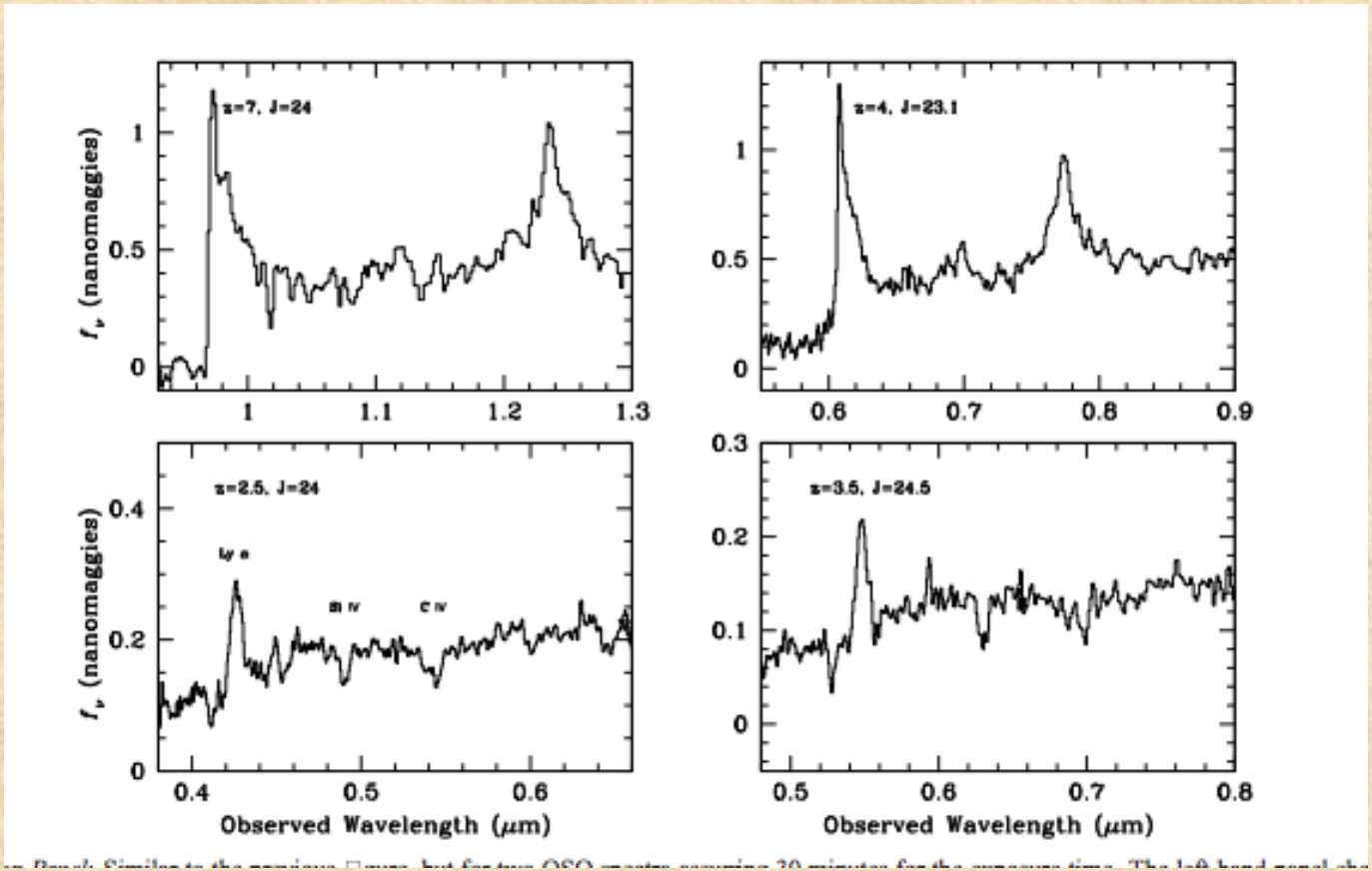


Fiber distribution on the focal plane



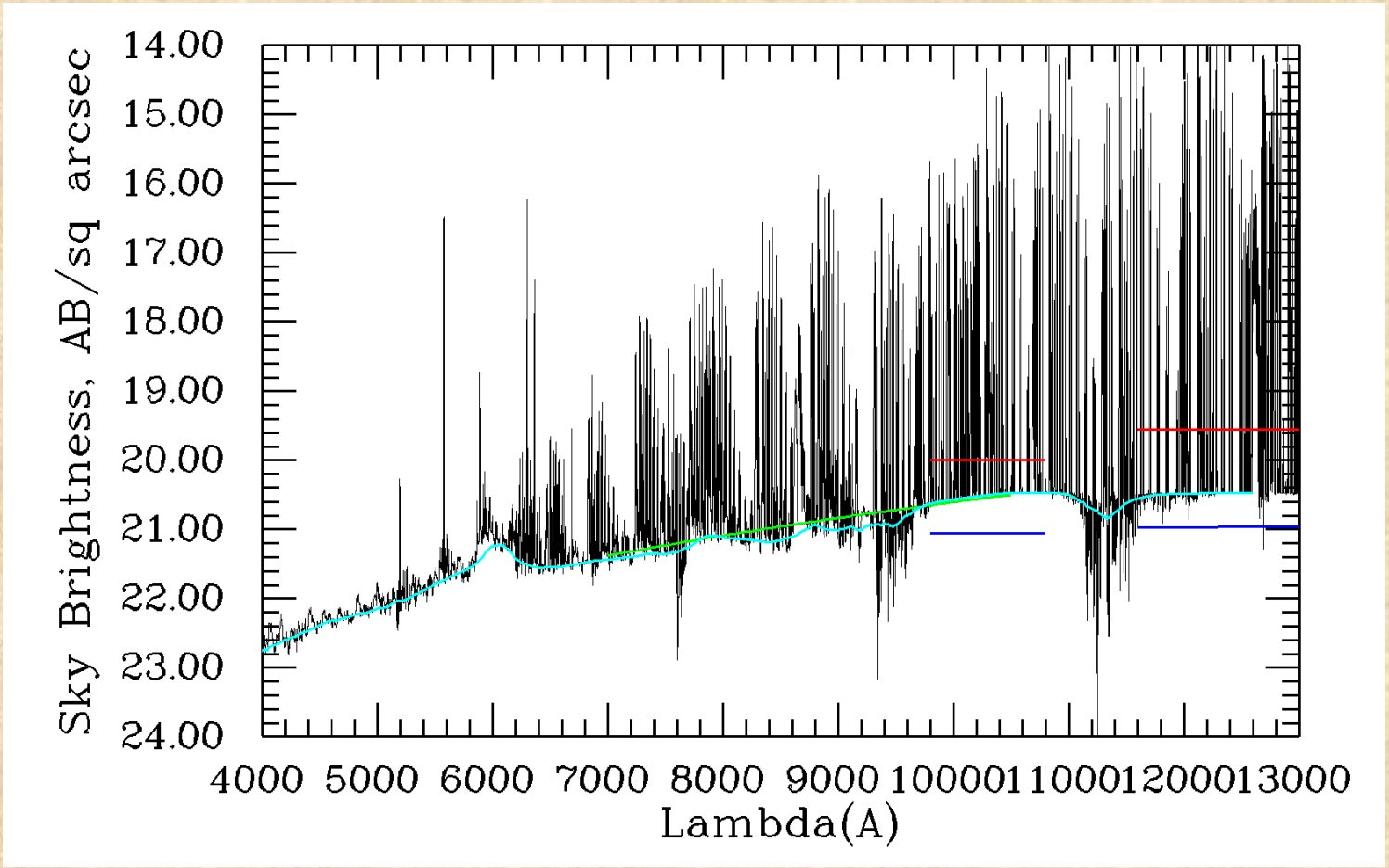
- Science fibers: Configurable and back-illuminated from *science fiber back illuminator* in the spectrograph system.
- Fiducial fibers: Static as physical references on the focal plane. Back-illuminated from *fiducial fiber illuminator* in PFI.

Simulations of Spectral Quality



Simulations of smoothed 30-minute exposures of quasars and high-z star-forming galaxies. Note that the listed magnitudes are too faint by about 1 magnitude.

- Work is on-going to characterize the expected sky background and the signal-to-noise ratio. Systematics in sky subtraction will be crucial in the NIR.



EXTRAGALACTIC SCIENCE AND COSMOLOGY WITH THE SUBARU PRIME FOCUS SPECTROGRAPH (PFS)

RICHARD ELLIS[1], MASAHIRO TAKADA[2], HIROAKI AIHARA[2,3], NOBUO ARIMOTO[4], KEVIN BUNDY[2], MASASHI CHIBA[5], JUDITH COHEN[1], OLIVIER DORE[6,1], JENNY E. GREENE[7], JAMES GUNN[7], TIMOTHY HECKMAN[8], CHRIS HIRATA[1], PAUL HO[9], JEAN-PAUL KNEIB[10], OLIVIER LE FEVRE[10], HITOSHI MURAYAMA[2,11], TOHRU NAGAO[12], MASAMI OUCHI[13], MICHAEL SEIFFERT[4,1], JOHN SILVERMAN[2], LAERTE SODRÉ JR[14], DAVID N. SPERGEL[7], MICHAEL A. STRAUSS[7], HAJIME SUGAI[2], YASUSHI SUTO[3], HIDEKI TAKAMI[4], ROSEMARY WYSE[8], & THE PFS TEAM

Draft version June 21, 2012

ABSTRACT

The Subaru Prime Focus Spectrograph (PFS) is a massively-multiplexed □ber-fed optical and near-infrared spectrograph ($N_{\rm fiber}$=2400, 380$\leq \lambda \leq$ 1300nm), offering unique opportunities in survey astronomy. Following a successful external design review the instrument is now under construction with □rst light predicted in late 2017. Here we summarize the science case for this unique instrument in terms of provisional plans for a Subaru Strategic Program of ≃300 nights. We describe plans to constrain the nature of dark energy via a survey of emission line galaxies spanning a comoving volume of $9.3h^{-3}$Gpc^3 in the redshift range $0.8 < z < 2.4$. In each of 6 independent redshift bins, the cosmological distances will be measured to 3% precision via the baryonic acoustic oscillation scale and redshift-space distortion measures will be used to constrain structure growth to 6% precision. As the near-□eld *cosmology* program, radial velocities and chemical abundances of stars in the Milky Way and M31 will be used to infer the past assembly histories of both spiral galaxies as well as the structure of their dark matter halos. Complementing the goals of the Gaia mission ($V < 17$), radial velocities and metallicities will be secured for 10^6 Galactic stars to $17< V < 20$. Data for fainter stars to $V \simeq 21$ will be secured in areas containing Galactic tidal streams. The M31 campaign will target red giant branch stars with $21< V <22.5$ over an unprecedented area of 65 deg^2. For the extragalactic program, our simulations suggest the wide wavelength range of PFS will be particularly powerful in probing the galaxy population and its clustering over a wide redshift range and we propose to conduct a color-selected survey of $1 < z < 2$ galaxies and AGN over 16 deg^2 to $J \simeq 23.4$, yielding a fair sample of galaxies with stellar masses above $\sim 10^{10} M_\odot$ at $z \simeq 2$. A two-tiered survey of higher redshift Lyman break galaxies and Lyman alpha emitters will quantify the properties of early systems close to the reionization epoch. PFS will also provide unique spectroscopic opportunities beyond these currently-envisaged surveys, particularly in the era of Euclid, LSST and TMT.

Ellis, Takada et al, http://arxiv.org/abs/1206.0737, submitted to PASJ

Timeline

Endorsement by Japanese community	2011 Jan
MOU between NAOJ and Kavli IPMU	2011 Dec
Project CoDR (Conceptual Design)	2012 Mar
Project PDR (Preliminary Design)	2013 Feb
Project CDR (Critical Design)	2013 Dec
SIR/TRR (System Integration /Test Readiness)	2016 Feb
ORR (Operational Readiness)	2016 Nov
First Light (Engineering)	2017 Jan

Total budget: $62.4M (not including contingency!), most of this money is currently in hand.

Thinking about a Strategic Survey Proposal

- Current suggestion (subject to change!):
  - 100 nights for cosmology/BAO survey (15 min exposures for redshifts over 1400 deg^2),
  - 100 nights for stars in MW, M31 halo
  - 100 nights for galaxies in 16 deg^2, $1 < z < 7$
  - Target quasars over 1400 deg^2 and other AGN selected in X-ray, IR, and variability over smaller areas.

We will present a "proof of concept" survey plan at PDR

- 500,000 color-selected galaxies to J_{AB}=23.4 over 16 deg^2, designed mostly for $1 < z < 2$. 3 hour exposures. S/N = 10 per R=300 resolution element.
- J_{AB}=21 with no color selection (20 min exposures) for z<1 studies.
- Two pointings to J_{AB}= 23.4, without color cuts, to understand selection effects.

- 60,000 LBGs with $2 < z < 7$ selected from the Deep, UD Fields. Target to i=24 to z=4 (3 hours exposure), and i=25 at higher redshift (6 hour exposure). S/N~3 for R=400 resolution element.
- LAEs from NB imaging over 16 deg^2 to 25th mag. 5 hour exposures.
- LBGs to i=26 in UD fields, 16-hour integrations.
- 50,000 high-z quasar candidates selected from the Wide layer (1/2 hour exposures).
- 1600 fainter quasar candidates in deep layer. 1 hour exposures.

Discussion Topics

- Target selection for AGN
- Understanding the quality of the data. How good will sky subtraction be?
- Strategies for SSP
- Working with international collaboration: people are interested in AGN in Brazil, France, Johns Hopkins, Caltech….
- Where will our subject be in 2018? Are we looking enough to the future?