The Subaru Prime Focus Spectrograph (PFS)

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on behalf of the

PFS Collaboration



DESpec KICP, U. Chicago May 31 2012

2nd Collaboration Meeting 2012 Jan 8-9 in Tokyo

1st Collaborati

Conceptual Design Reivew, 2012 March 17-18, Hilo

PFS Collaboration

PI: Hitoshi Murayama (Kavli IPMU)

Survey Committee Co-Chairs: Richard Ellis (Caltech), Masahiro Takada (IPMU) Science Working Group Co-Chairs:

Cosmology:

Masahiro Takada (IPMU), Chris Hirata (Caltech), Jean-Paul Kneib (LAM) Galactic Archeology:

Masashi Chiba (Tohoku U.), Judy Cohen (Caltech)

Galaxy:

J. Greene (Princeton), K. Bundy (IPMU), J. Silverman (IPMU), M. Ouchi (U. Tokyo) AGN/QSO:

Tohru Nagao (Kyoto), Michael Strauss (Princeton)

Steering Committee: H. Aihara (U. Tokyo,IPMU), N. Arimoto (NAOJ), R. Ellis (Caltech), T. Heckman (JHU), P. Ho (ASIAA). O. LeFevre (LAM), H. Murayama (IPMU), L. Sodre Jr. (Sao Paulo), M. Seiffert (JPL), D. Spergel (Princeton), Y. Suto (U. Tokyo), H. Takami (NAOJ) Project Office: H. Karoji (IPMU), H.-H. Ling (ASIAA), Y. Ohyama (ASIAA), H. Sugai (IPMU), A. Shimono (IPMU), N. Takato (IPMU), A. Ueda (NAOJ)



PFS Status and Milestones

1	WFMOS Team B (Caltech/JPL led) proposal selected Gemini Funding for WFMOS cancelled	March 2009 May 2009
1	Kavli – IPMU proposal to Japanese Government (based on WFMOS B design)	September 2009
✓	Kavli IPMU proposal accepted	early 2010
✓	PFS endorsement by the Subaru Users Meeting as next generation instrument for Subaru telescope	January 2011
✓	Established PFS project office	early 2011
✓	NOAJ endorses Subaru Strategic Program for up to 300 nights for the PFS team in collaboration with Japanese community.	Dec 2011
✓	Successful Conceptual Design Review (CoDR) (Preliminary Survey, instrument conceptual design, management, and cost)	March 2012
	=> Decision to proceed with construction. > 2/3	3 of \$\$ in place.

Cosmology Survey Goals

- 1. Better than 3% measurement of $D_A(z)$ and H(z) via BAO in each 6 redshift bins 0.8 < z < 2.4
- 2. Better than 7% measurement of $\Omega_{de}(z)$ via BAO in each of 6 redshift bins
- 3. Measure Ω_{κ} to better than 0.3% via BAO
- 4. Better than 6% measurement of the growth rate of structure via RSD in 6 redshift bins

Observations:

100 nights

[OII] emission line survey, two 15 minute observations per field

1400 deg² survey area

Targets selected from HSC wide survey

Galactic Archaeology Survey

Measure radial velocities and metallicities for a large sample of stars in synergy with HSC and GAIA

Milky Way Survey:

17 < V < 21.5

390 deg²

S/N > 30 per resolution element

75 nights (2 hours exposures)

Grey time okay for V < 20 !

M31 Survey:

21.5 < *V* < 22.5

65 Deg²

S/N > 20 per resolution element

30 nights (5 hour exposures)

Galaxy Evolution Survey

Follow the growth of the full panoply of the galaxy population from Cosmic Dawn to the present:

Explore the redshift range when star formation rate density and black hole growth were at their peak

Use Ly $\boldsymbol{\alpha}$ to trace galaxies and black holes back to the epoch of reionization

- => 100 nights, 16 deg²
 - 1. Color-selected survey of 5 x 10⁵ galaxies with 1 < z < 2 to $J_{AB} = 23.4$ and a z < 1 component limited to $J_{AB} = 21$.
 - Survey of 30,000 bright dropout galaxies and Ly α emitters over 2 < z < 7
 - 3. Color-selected survey of quasars from 3 < z < 7

PFS System Overview



Wide Field Corrector

Wide Field Corrector: 7-element with ADC, completed March 29, 2011 Built for the 1.6 degree HyperSuprimeCam (HSC) imager Will be shared with the 1.3 degree Prime Focus Spectrograph. (PFS)



POpt2 – Housing, Hexapod, Rotator shared with HSC

The PFS prime focus hardware will replace the HSC detector dewar, but share much of the mechanical infrastructure.





Prime Focus Layout



Rotating part of Prime Focus Hardware



Positioner Module

- A module is a subassembly of actuators and drive electronics boards
- 57 positioners with drive electronics and 2 rows of fibers with connectors
- Modularity enables:
 - Staggered production
 - Parallel module integration
 - Early mechanical and electrical functional testing
 - Parallel fiber integration to reduce schedule
 - Serviceability





Module Layout



Positioner Prototype – Developed for WFMOS (2009)



- Ceramic friction drive
- Lubrication free, zero backlash
- Journal bearing limits motor side loads
- Hardstops to limit fiber twisting
- Speed: Motor movement < 1 sec per iteration
- Accuracy: 5 um precision of fiber positioning. This translates to of order 0.05 arc sec, but is only part of the alignment budget

Movement is converted from desired angular movement to open-loop run time for each motor. Metrology camera views back illuminated fibers to measure position and positioners are iterated.



Positioner Prototype Iteration and Development for PFS

Previously demonstrated:

Speed and accuracy of single element (< 1 sec iterations, < 7 iterations) Operation at required temperature Operation at required pressure Simulated lifetime testing

Successfully incorporated improvements: Hardstop design Rotor to stator interface Flex cable routing

=> Preliminary indication is improved performance: 3-4 iterations will suffice

Still to come:

Upgrade control algorithm Demonstrate speed, convergence, collision avoidance Retire any remaining risks



Fiber Coupling



Conclusion: Field is non-telecentric, but does not lead to much additional loss over the unavoidable vignetting from the corrector

Fiber Coupling with Microlens

Input from WFC: angular size 1.1" diameter, f/2.2, 100 μm diameter For high coupling efficiency, convert to f/2.8, 128 μm diameter Better match to fiber NA Better match to spectrograph (i.e. output F/# is ~2.5 with FRD considered)

Investigating several designs for the microlens – considerations are fabrication, handling, alignment, and assembly. Prototyping later this summer.



Spectrograph Design



Spectrograph Mechanical Layout

Each spectrograph carries 3 vacuum Schmidt cameras, f/1.10, with a 275mm beam.

Modular design of cryostats

CCDs cooled to 163 K IR arrays cooled to 110K

Footprint 5 x 5 m Height 1.8 m

Minimize alignment activities at summit



Instrument Properties

Number of Fibers	2400			
Field of View	1.098 deg ² (hexagonal – 1.3 deg inscribed circle)			
Fiber Diameter	1.13" field center,	1.03" field edge		
Fiber reconfiguration time	< 3 min			
	<u>Blue arm</u>	<u>Red arm</u>	<u>IR arm</u>	
Wavelength Range	380-670	650-1000	970-1300	
Spectral Resolution	1900	2400	3500	
Pixel Scale	0.71	0.85	0.81	
Detector Format	CCD pair of 2k x 4k	CCD pair of 2k x 4k	HgCdTe 4k x 4k	
Spectrograph Image Quality (um rms/axis)	14	14	14	

22%

Average Throughput

(excluding atmosphere, central obscuration, vignetting, and fiber aperture effect)

24%

22%

Conclusion

Project website: <u>http://sumire.ipmu.jp/en/2652</u>

Science white paper coming soon to astro-ph:

"Extragalactic Science and Cosmology with the Subaru Prime Focus Spectrgraph (PFS)"

More detailed instrument information, Proc. SPIE (2012)

"Prime focus spectrograph: Subaru's future"

"Detectors and cryostat design for the SuMIRe Prime Focus Spectrograph (PFS)"

"A spectrograph instrument concept for the prime focus spectrograph on Subaru Telescope" "FOCCoS for Subaru PFS"

"The Metrology Camera for Subaru PFS and FMOS"

"Developments in high density Cobra fiber positioners for the Subaru Telescope's Prime Focus Spectrometer"

"The system software development for prime focus spectrograph on Subaru Telescope"

Now working towards a Preliminary Design Review (PDR) scheduled for early 2013.

First light anticipated 2017