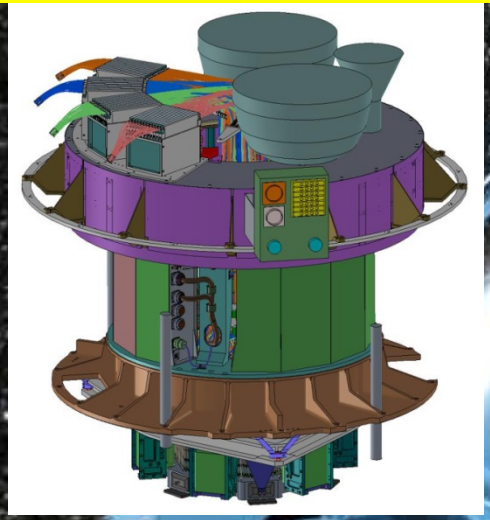
SUBARU PRIME FOCUS SPECTROGRAPH

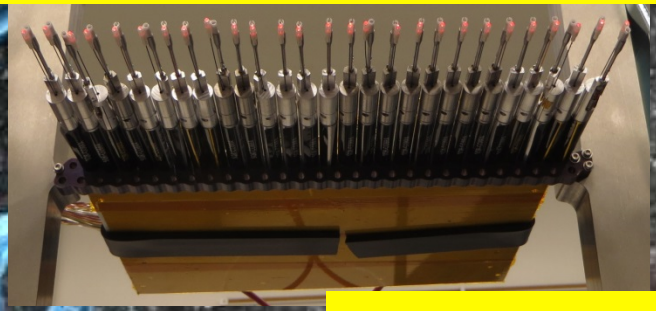
Naoyuki Tamura
(Kavli IPMU, U. Tokyo)

On behalf of
PFS collaboration

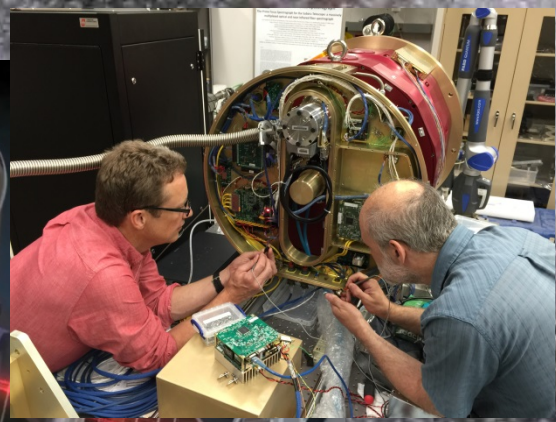
Prime Focus Instrument "PFI"



"Cobra" engineering model module



Camera cryostat



Spectrograph system

Fiber connectors

装置ワークショップ@東北大学, 12/7 (Mon), 2015 JST

先日世話人の某A氏から・・・

- 今回はプロジェクト全体の話はほどほどにして、普段話せないことや、困っていることがたくさんあるでしょうからそういう話を・・・

- 困っていること・・・
  - お金、人手不足、タイトなスケジュール、コミュニケーションの難しさ、色々なしがらみや文化の違いの中でどう折り合いをつけつつ進めていくか・・・。
    (延々愚痴りそうなので止めます。)
  - 今日は装置「技術」ワークショップですね！
  - PFS 技術部門を統括する立場にもあるのでした！！

技術的なこと？

- Kavli IPMU + NAOJ で構成されるプロジェクトオフィスの主たる役割は全体の統括、システム統合、コミッショニング。

- 大世帯がゆえに・・・
  - 作っては試験・確認して受け渡しの積み重ね
  - Formality

PFS Collaboration

(There are a few potential new partners.)

国立天文台 NAOJ

KAVLI IPMU INSTITUTE FOR THE PHYSICS AND MATHEMATICS OF THE UNIVERSE

SSP is open to all "Japanese" researchers. Please join & commit !!

中央研究院 ACADEMIA SINICA 1928

CALIFORNIA INSTITUTE OF TECHNOLOGY 1891 Caltech

PRINCETON UNIVERSITY

NASA JPL

JOHNS HOPKINS UNIVERSITY

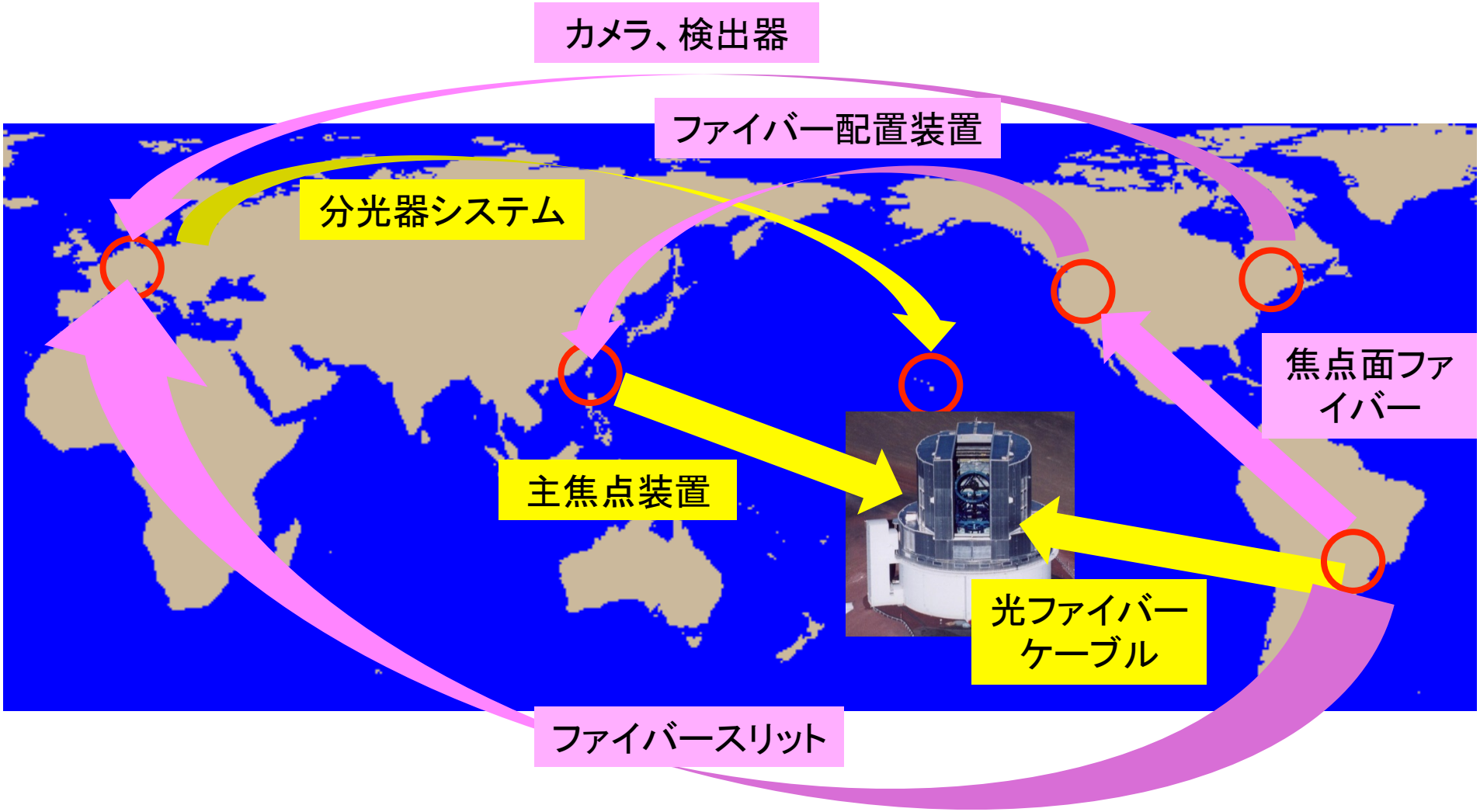
OBSERVATORIO DE SÃO PAULO SANCTI PAVLI CÆLVM AGER MEVS

LAM LABORATOIRE D'ASTROPHYSIQUE DE MARSEILLE

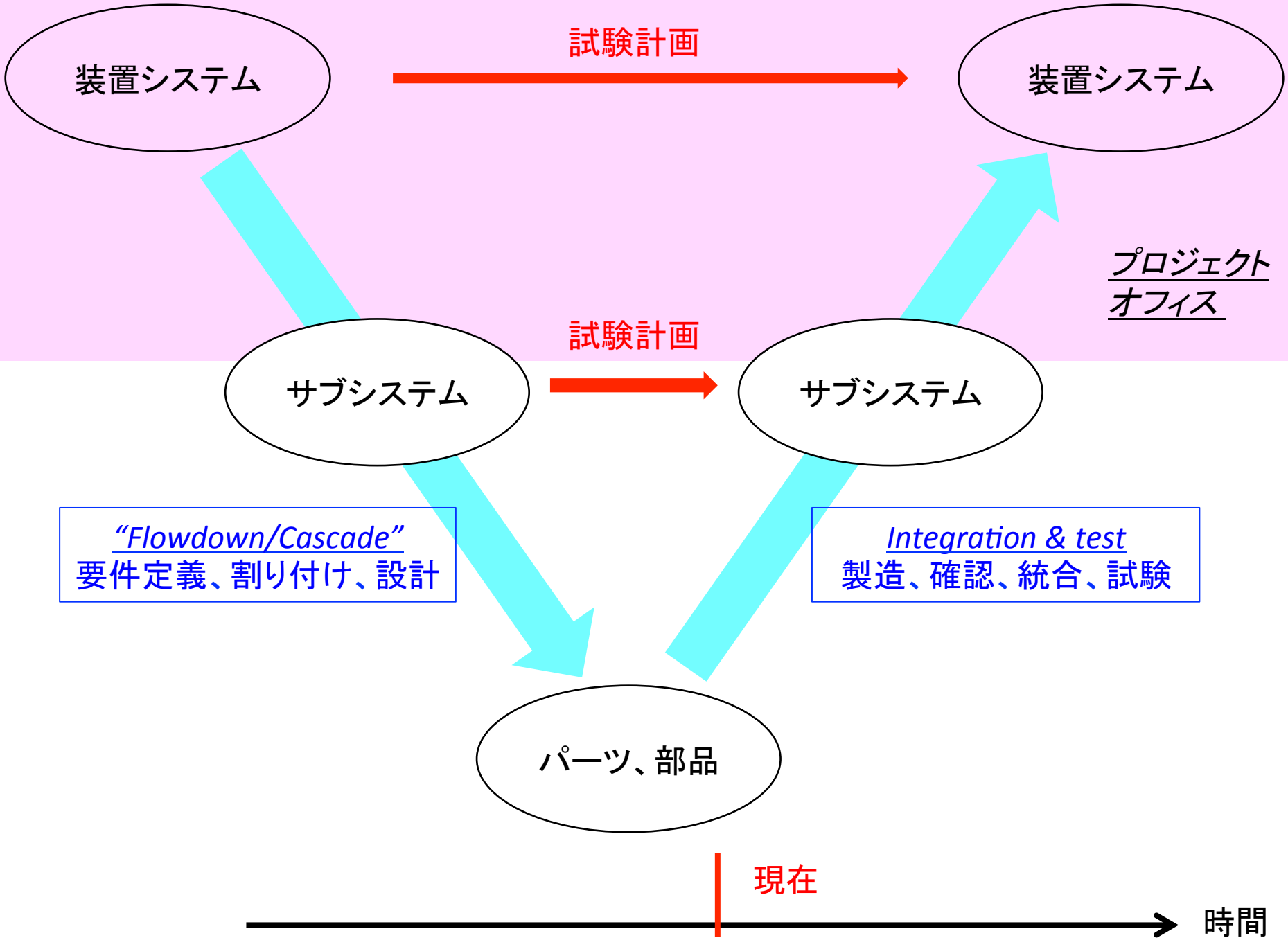
LNA LABORATÓRIO NACIONAL DE ASTROFÍSICA

Max-Planck-Institut für Astrophysik

各機関が分担して開発製作した要素を一つのシステムに組み上げ、望遠鏡＋観測装置として性能を出す



インターフェース管理、品質管理、文書管理、物流、・・・


装置システム
試験計画
装置システム
プロジェクト
オフィス
サブシステム
試験計画
サブシステム
“Flowdown/Cascade”
要件定義、割り付け、設計
Integration & test
製造、確認、統合、試験
パーツ、部品
現在
時間

技術的なこと？

- Kavli IPMU + NAOJ で構成されるプロジェクトオフィスの主たる役割は全体の統括、システム統合。

- 大世帯がゆえに・・・
  - 試験・確認しては受け渡しの積み重ね
  - Formality

- 光ファイバー＋α (その他最近の進捗を少し)

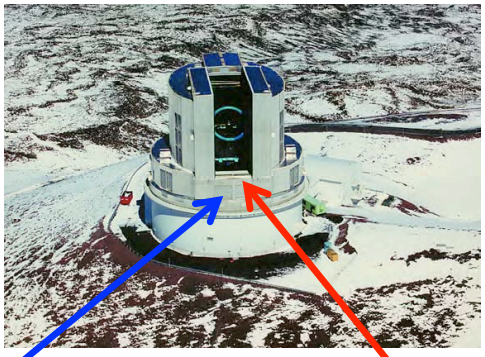
講演概要

- イントロ(済)
- ・・・とはいえごく簡単にプロジェクト・装置概要
- 光ファイバーの光学試験
- ファイバー分光とスカイ引き
- その他最近の進捗を少し
- まとめ

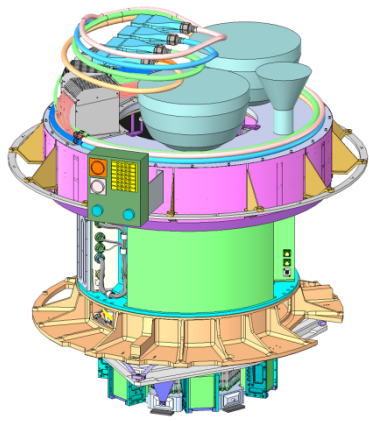
The "SuMIRe" project

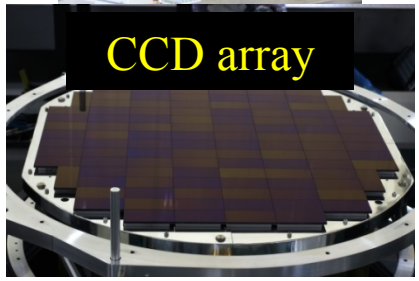
Subaru Measurement of Images and Redshifts

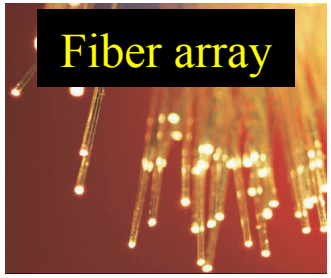
HSC + PFS

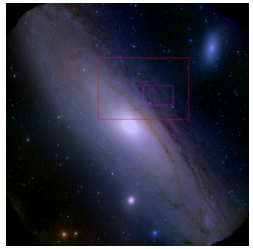


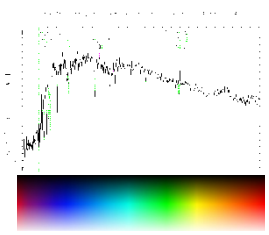
- Exploiting the *~1.5 deg* field of view on the prime focus of the *8.2m* Subaru Telescope.
- Wide-field imager *"Hyper-Suprime Cam (HSC)"*
  - ✓ ~0.9 billion pixels
  - ✓ 300 nights in 2014--2018
  - ✓ 1400 sq. degrees, ~1B galaxies
- Wide-field multi-object spectrometer *"Prime Focus Spectrograph (PFS)"*
  - ✓ 2400 optical fibers
  - ✓ 300? nights from 2019?
  - ✓ ~4M galaxy redshifts
  - ✓ ~1M stars in MW, M31, dSphs.
- SDSS-like survey at z>1 & Galactic Archaeology to address cosmic evolution & dark sector.
- **Enables Subaru to be a world-leading facility out to the next decade making effective synergy with *TMT, LSST, JWST, Euclid, WFIRST,* etc.**











"PFS" – Fast facts

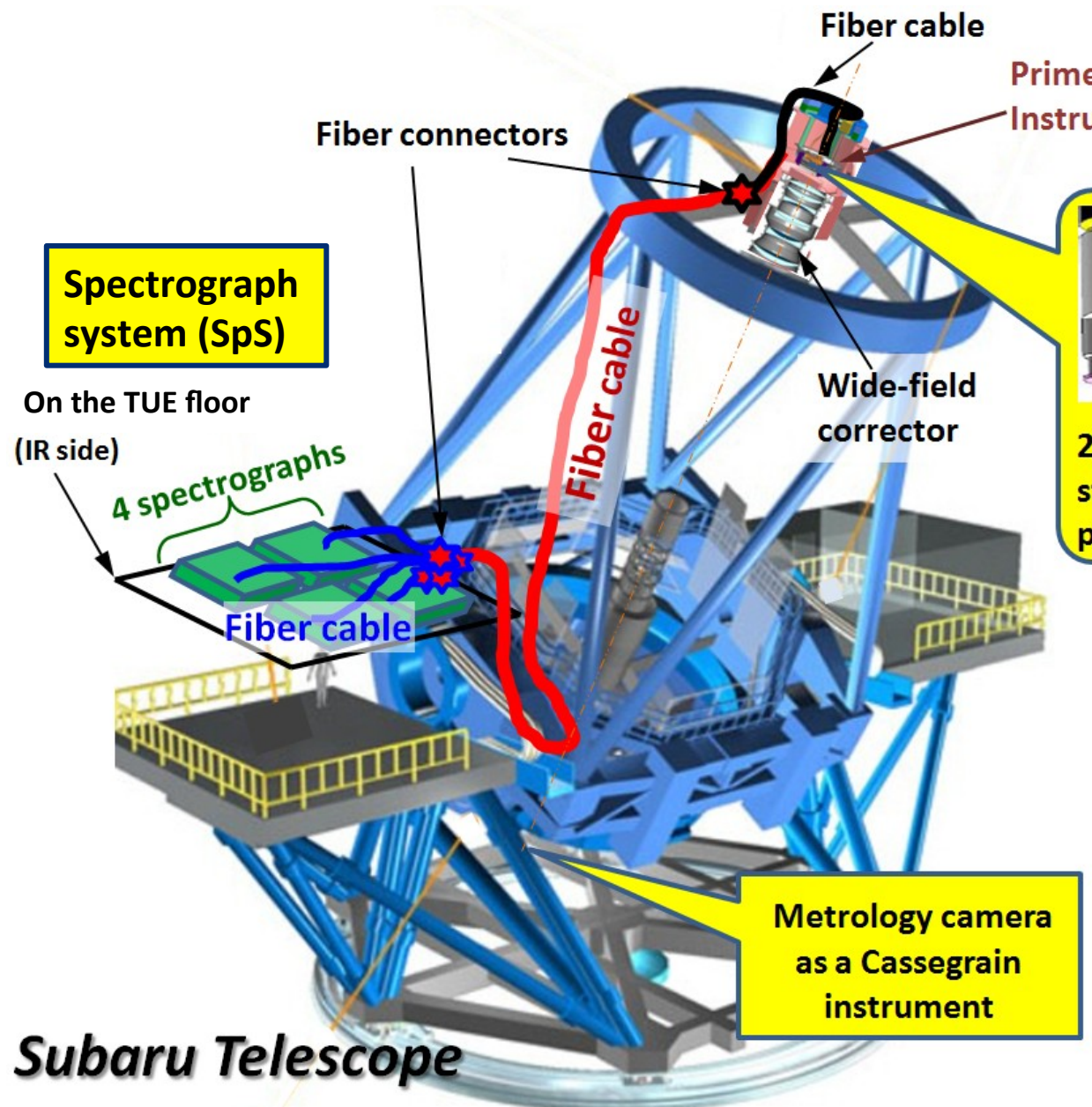
- Subaru *Prime Focus Spectrograph*
  - Wide field: *~1.3 deg* diameter
  - Highly multiplexed: *2400 fibers*
  - Quick fiber reconfiguration: *~60-100 sec* (TBC)
  - Optical-NIR coverage: *380-1260nm simultaneously*
- Developed by *international* collaboration, under the initiative of *Kavli IPMU*
- ***Cosmology, Galaxy/AGN evolution, Galactic Archaeology*** as the key science areas in the PFS collaboration
- Aiming to start science operation from *2019*, as a *facility instrument* on Subaru.

Project timeline

- Apr 2011: Project Office was established. Design study activities were formalized.
- Mar 2012: Conceptual Design Review (CoDR: 概念設計会議) @ Hilo
- Feb 2013: Preliminary Design Review (PDR: 基本設計会議) @ Hilo
- Mar 2013 – Present: A hybrid of critical/final design phase & production phase
  - Critical Design Review (CDR: 詳細設計会議) is held at subsystem level (instead of no project CDR).
    - Mar 2014: Cable A & Spectrograph System (SpS) CDR – ***Done!***
    - Mar 2015: PFI, fiber positioner system (delta on Jun 22), Cable C CDR – ***Done!***
    - Sep 2015: Metrology camera CDR (delta on Dec 3) – ***Done!***
    - Early 2016: Cable B (TBC)
- 2017-2018 : Subsystem delivery to Subaru and system integration
- Early? 2018: Engineering First Light
- Mid-late 2019: Start open use & SSP

Subject to updates

PFS subsystems distribution



… in Prime focus unit "POpt2" with Wide Field Corrector "WFC".

POpt2 & WFC will be shared with Hyper Suprime Cam (HSC).

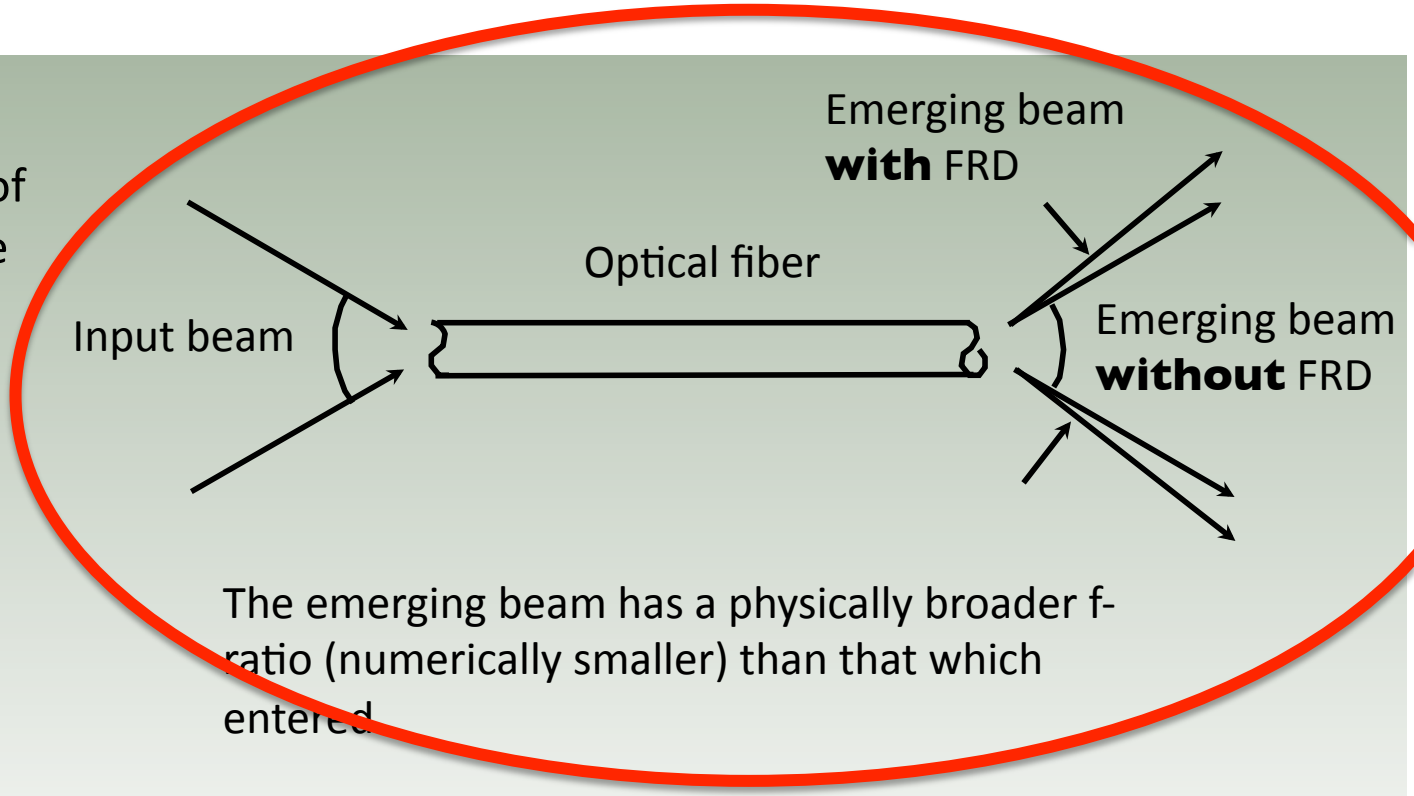
Software system

(Calibration system)

Subaru Telescope

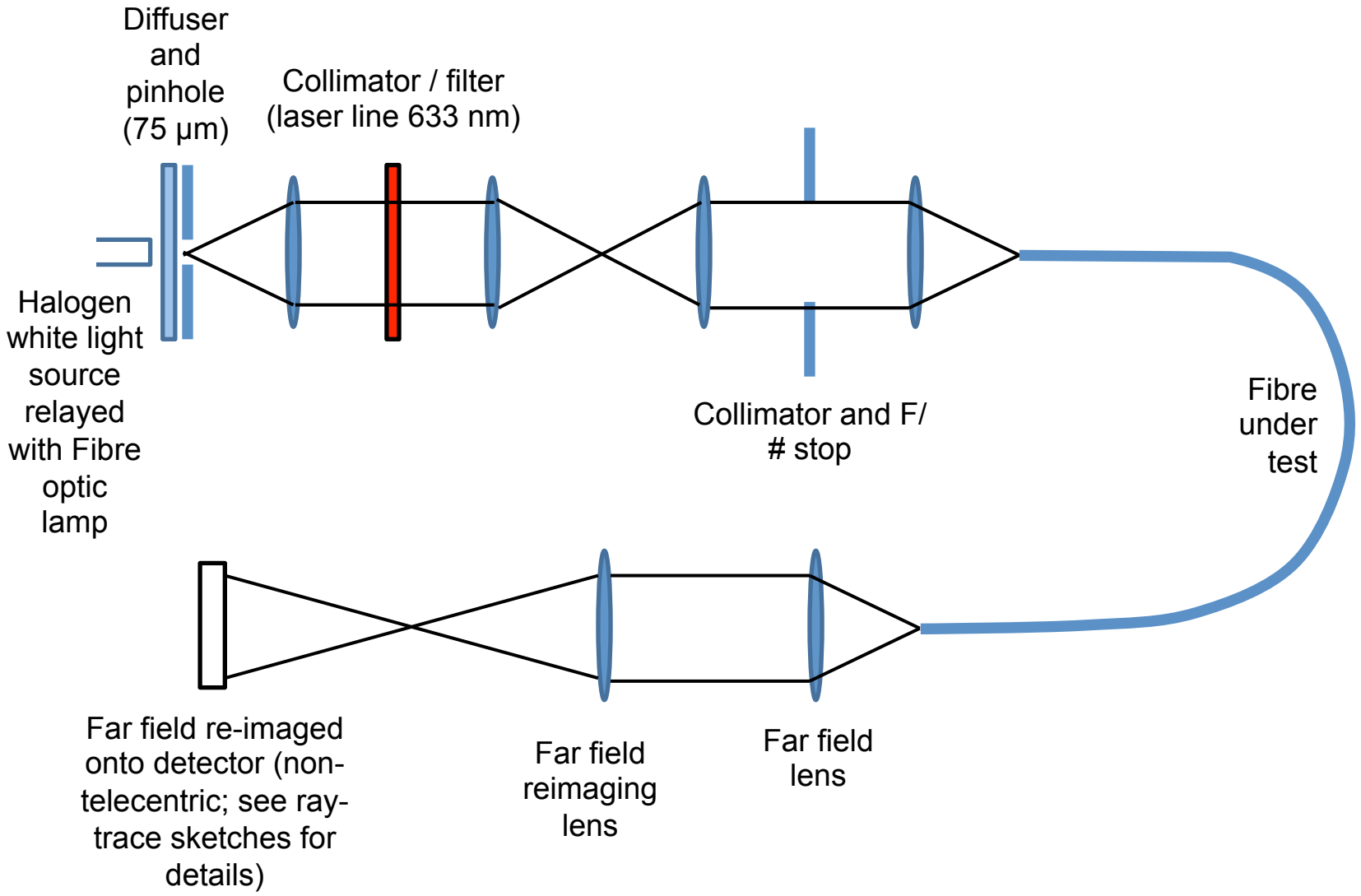
Focal Ratio Degradation (FRD)

We are not yet certain of the severity, and degree of variability/ repeatability (due to cobra rotation) of FRD effects

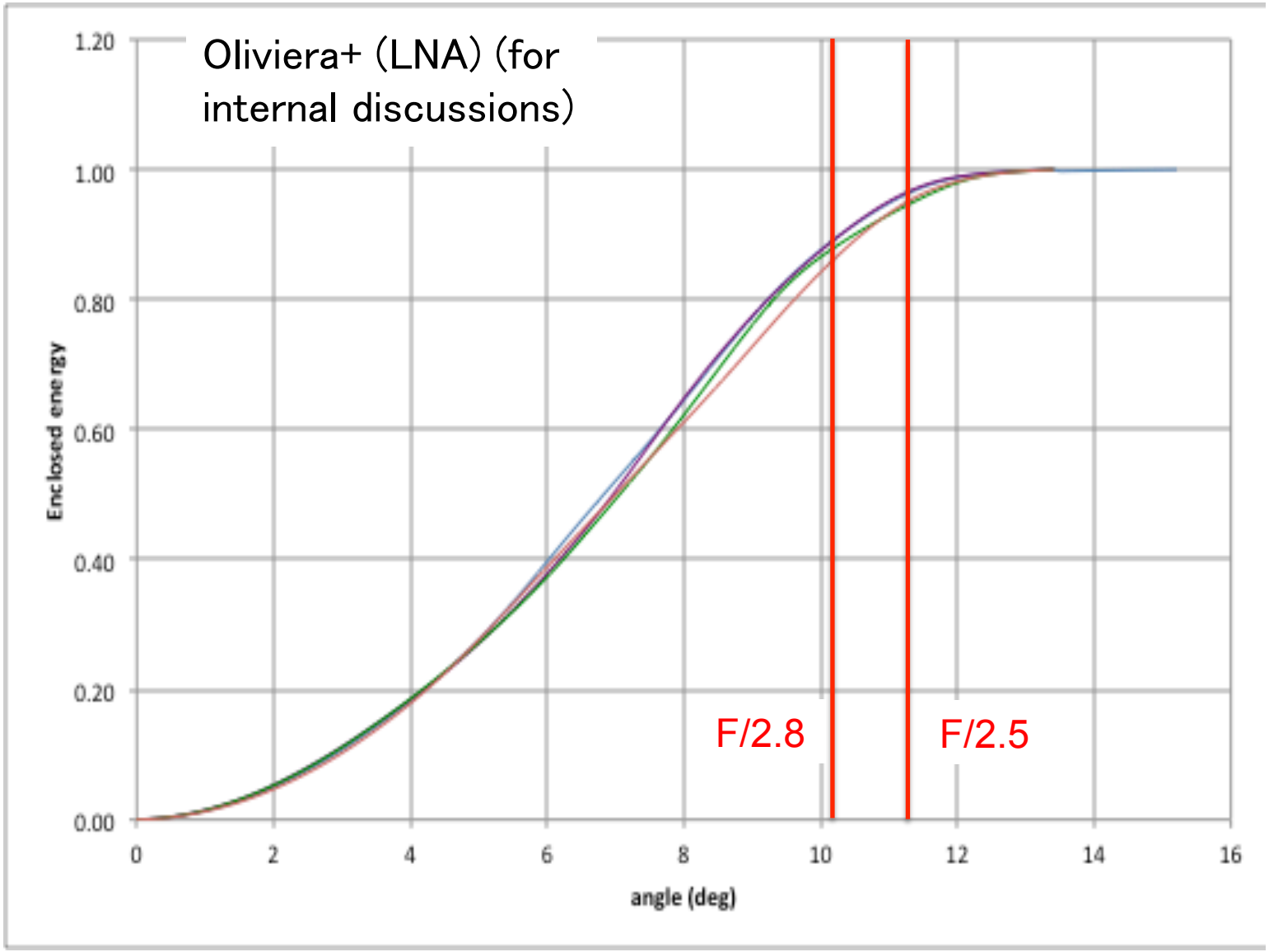


The PSF will be specific to each fiber and wavelength, and a 2D model across the chip is not likely to be successful.

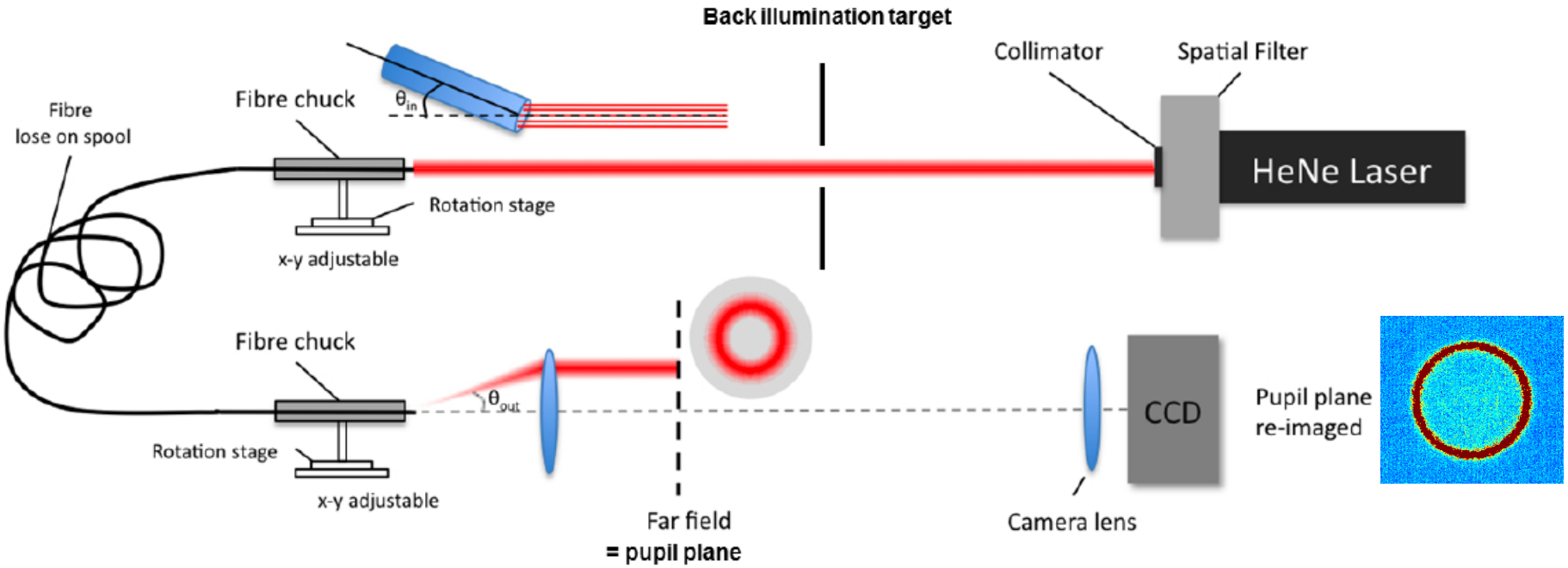
FRD “cone” measurement



Encircled energy from the far-field image

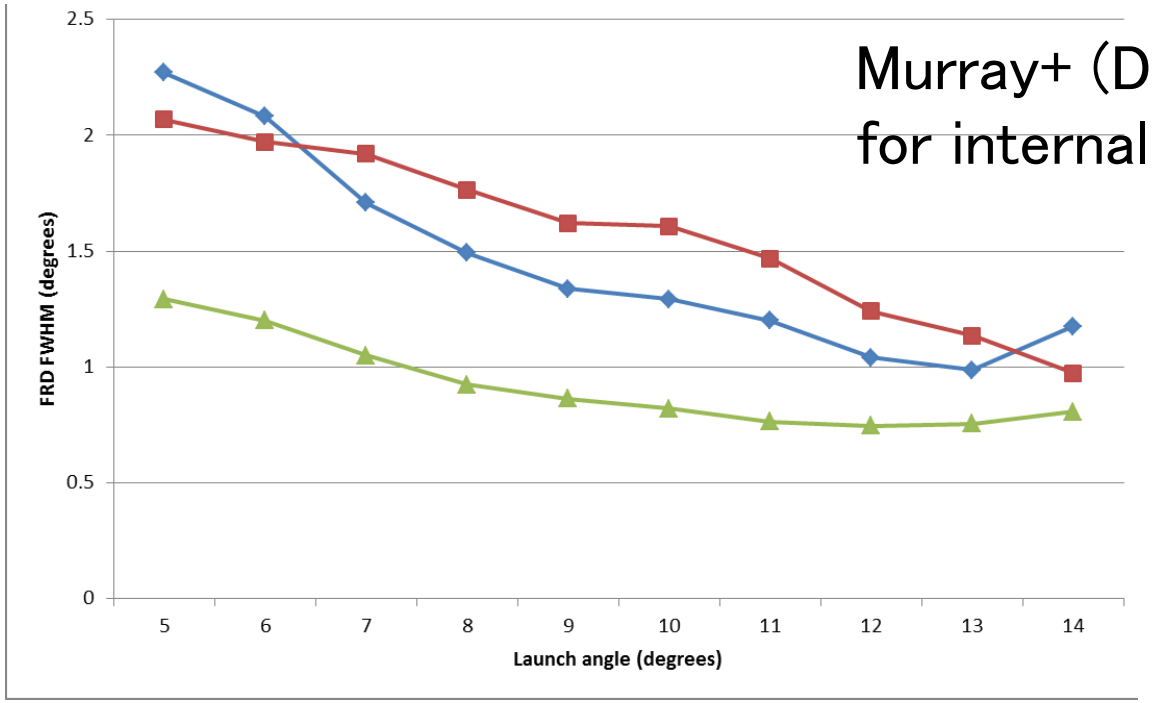


Collimated beam FRD measurement (FRD “ring” test)



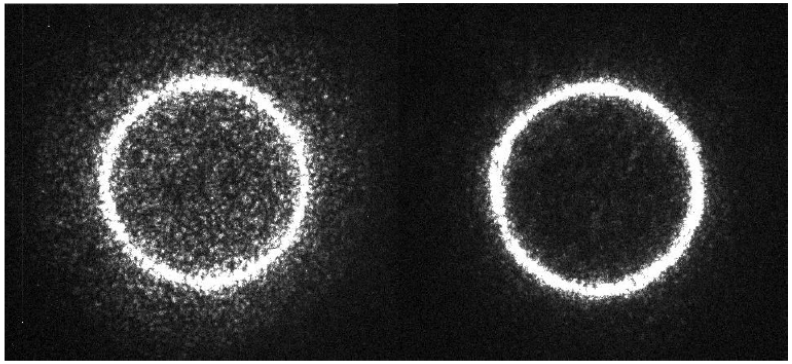
Collimated light at the input, mounted on rotation stage allows scanning through different angles.
(Pre-alignment is achieved using *back-illumination* to identify the 0˚ launch angle)
The output in the far-field is an annulus. This is re-imaged directly onto the CCD (no screen is used).

出射リング
の太さ



入射角

Haynes+ (2008, 2011)



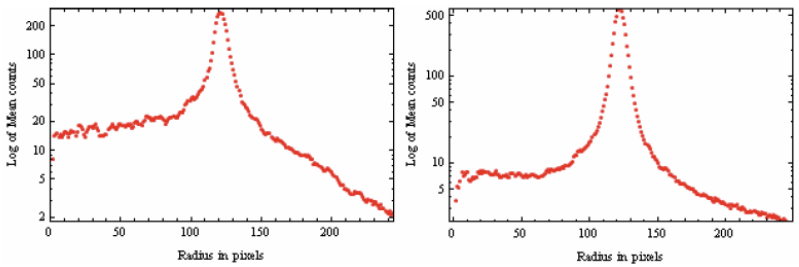


Figure 5 FRD radial profile plots for δ_i = 245nm rms (left) and δ_i = 8nm rms (right). θ_i = 8°, δ_o = 25nm rms , λ= 633nm.

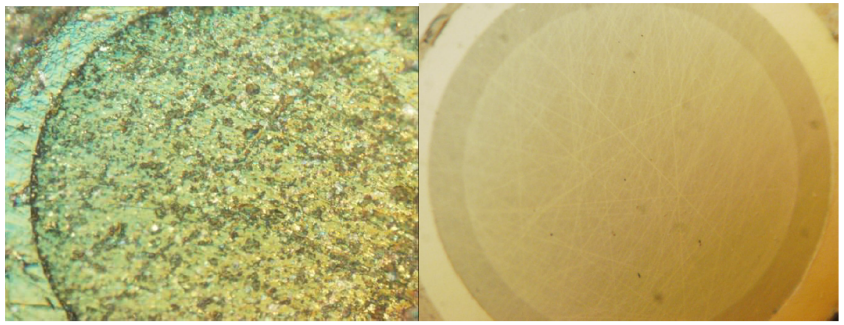


Figure 2 Fiber end-face optical microscope images, (left) δ_i = 270nm rms, (right) δ_i = 8nm rms, taken with Olympus microscope in phase contrast mode and x100 objective.

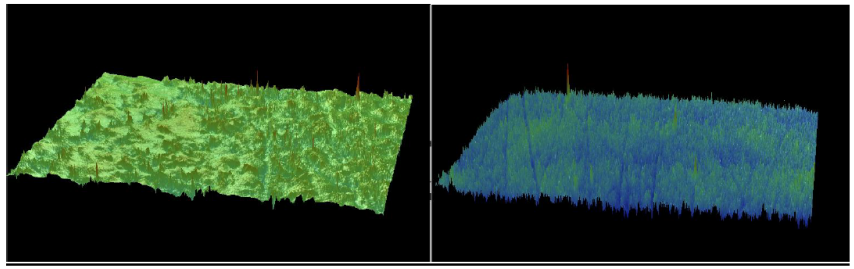


Figure 3 Fiber end-face 3D Optical Profilometer images, (left) δ_i = 270nm rms section area 33 x 40 µm, (right) δ_i = 8nm rms section area 88 x 114 µm, taken with WYKO NT3300 in VSI mode.

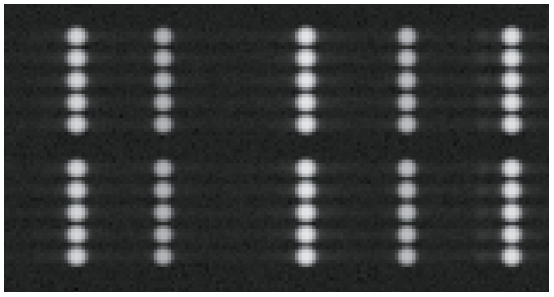
ファイバー分光とスカイ引き

- スカイ引きがうまくいかないと観測・積分時間とともに期待通り S/N が上がっていかない。
  - 「ファイバー」ごとの個性(焦点面、検出器などの特性も含め)をいかに消せるか。
  - 空の観測データと整合性のあるキャリブレーションデータが撮れるか。
  - … etc

- *FRD 等の変化を含む*装置の安定性・再現性。
- キャリブレーションデータ取得時、主鏡・焦点面・装置へ “realistic” に光を入れる。
- ファイバー像の pixel sampling

→ PSFの特徴づけ

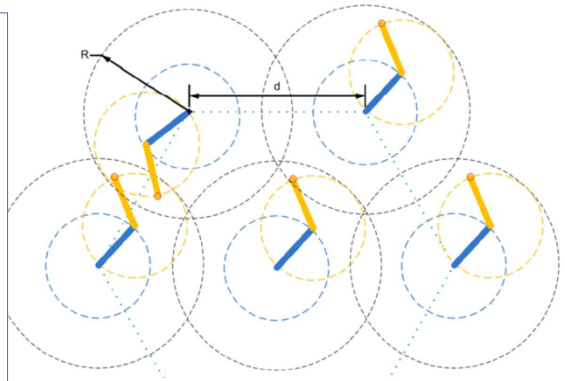
FRD ←→ PSF(λ, fiber)

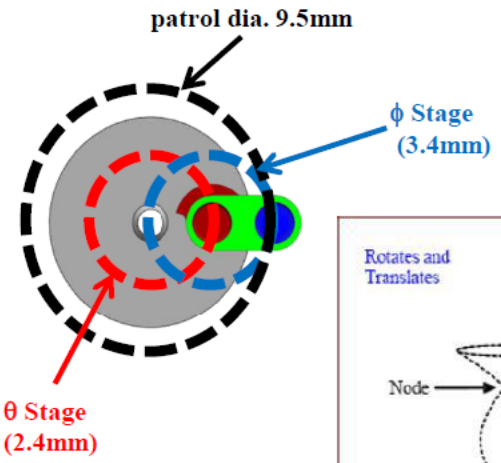


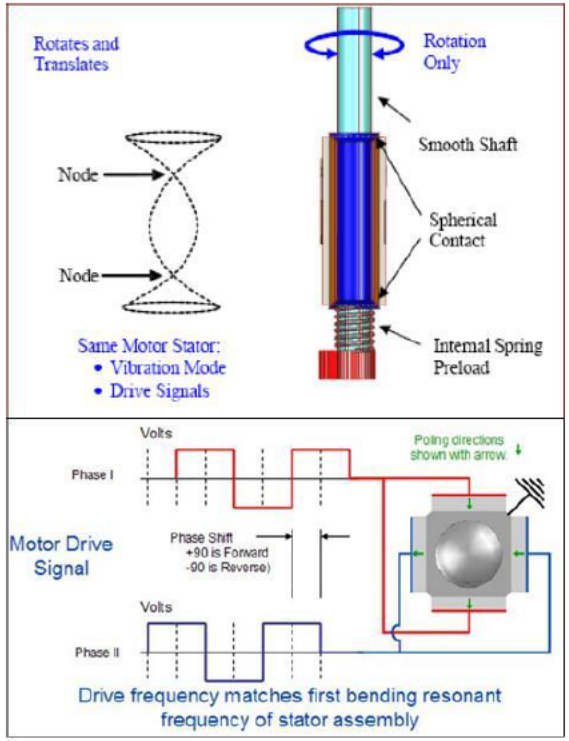
Cf. 空のスペクトルでキャリブレーション？→ OH輝線の分布・強度
Cf. (クロス)ビームスイッチ観測？ → 観測効率(天体積分時間、ファイバー配置)

Focal plane: Fiber positioner "Cobra"

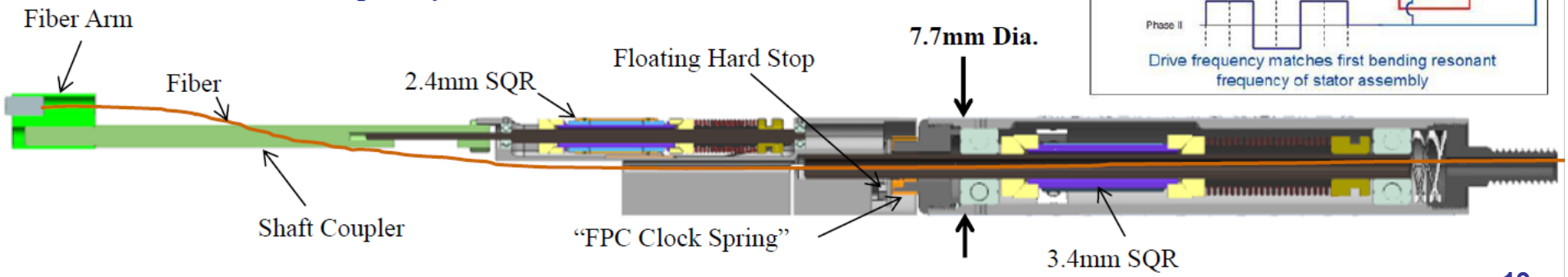
Positioners with a 8mm pitch.
→ Patrol areas have some overlaps.

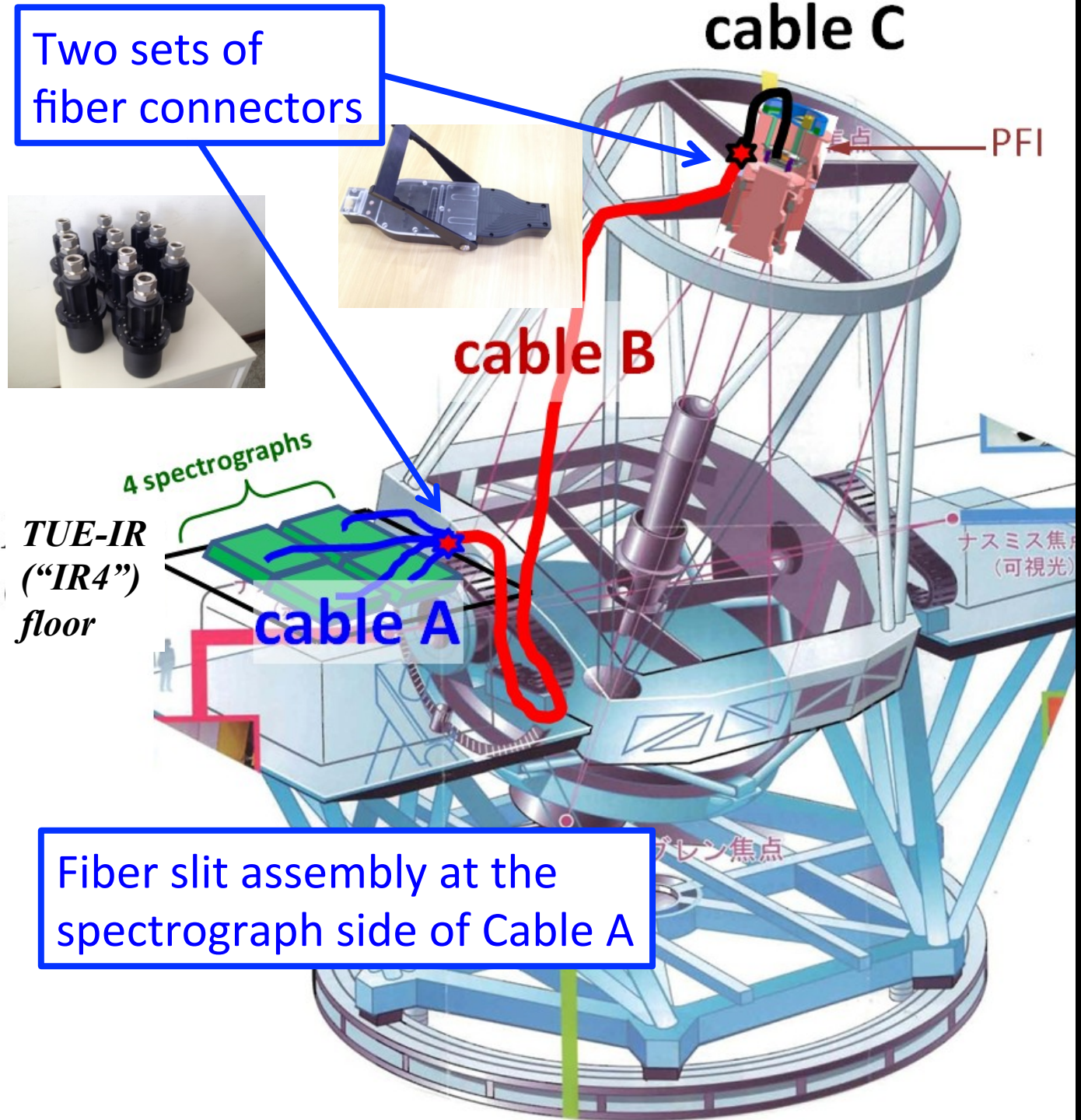






- Fiber is routed from the arm on the phi-stage through the center of the Cobra
  - Stages utilize hard stops to allow for full range of motion, yet prevent over twisting of the optic fiber
  - Protects fiber during handling and operation
- Piezo motors use phase shifted signals to excite the motor body at the first bending resonant frequency



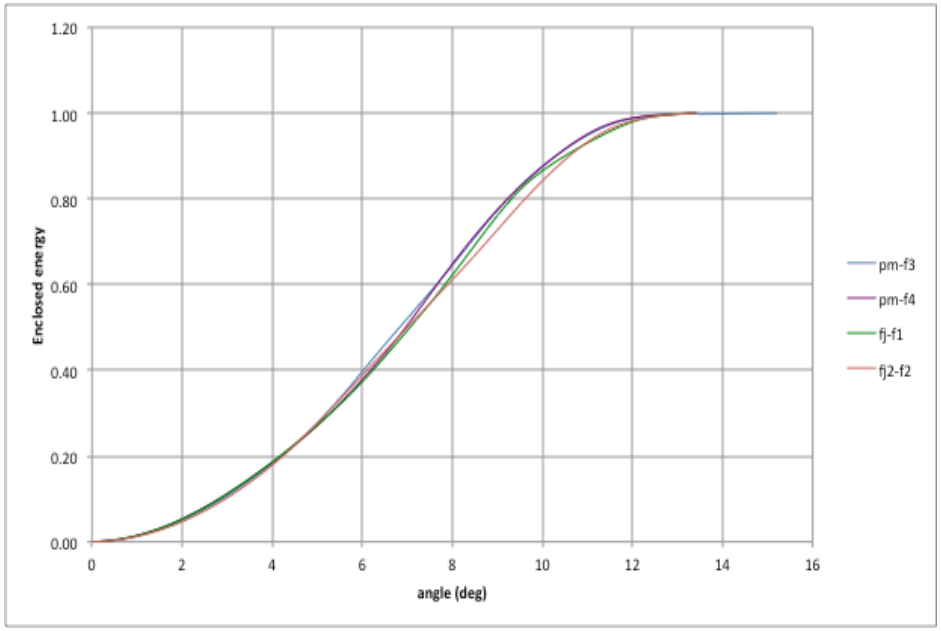


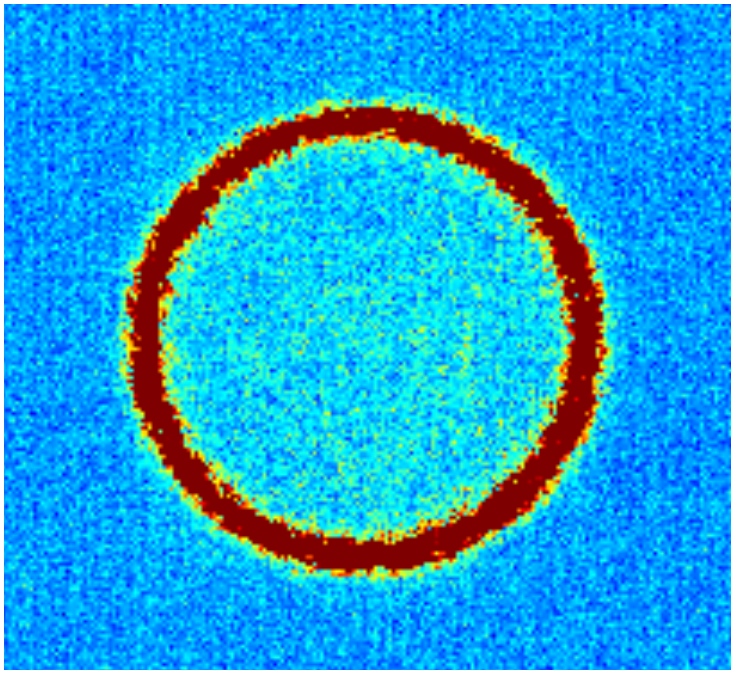
- 試験用ケーブルを1往復分(e.g. Ns → PF → Ns)這わせ、入射と出射を同じ場所でケアしつつ昼間に測定できるようなシステムを検討中(高遠さん＋PFS チーム)

フラットスクリーンがなくても昼間ならPFSがついた状態でキャリブレーションデータが取れるような別光源？

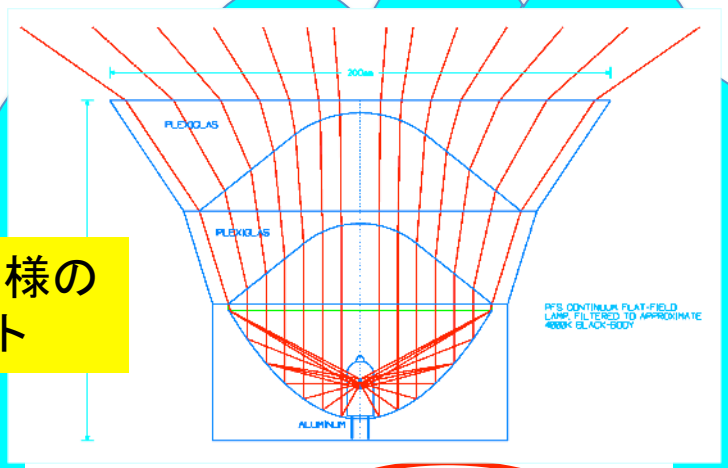
FRD change to be characterized

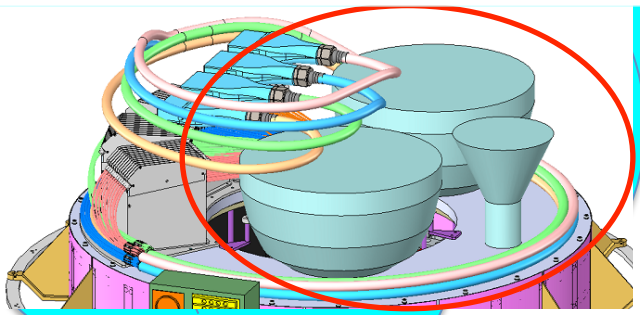
Cone or Ring ??

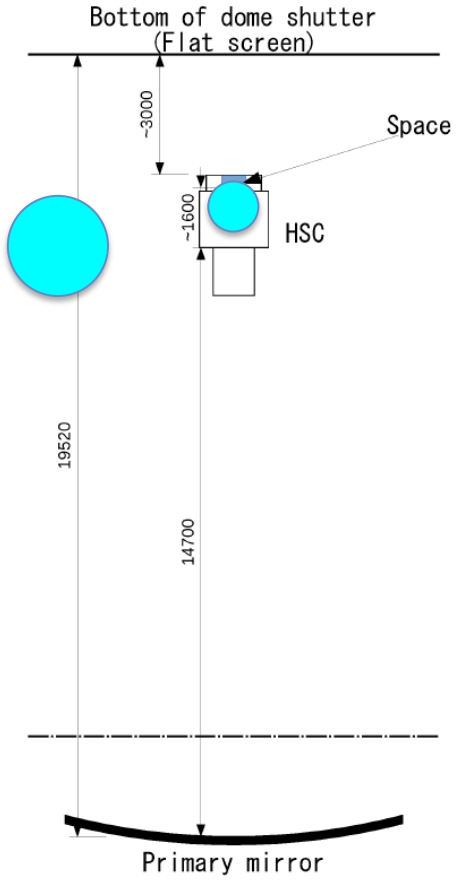




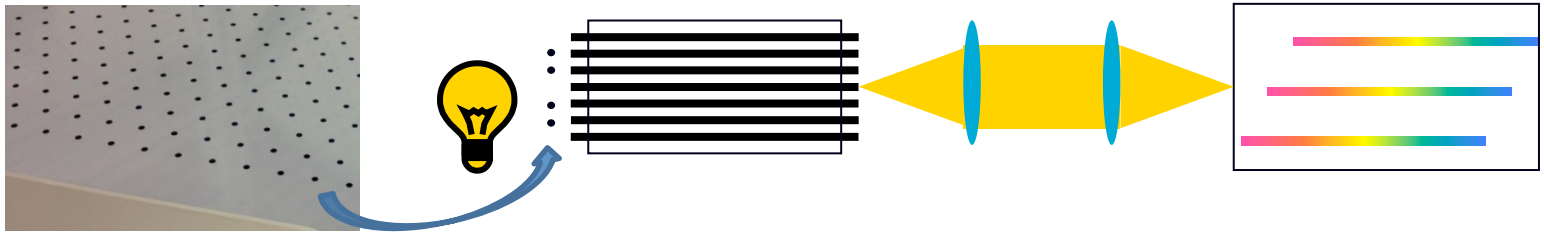
HSC と同様のコンセプト



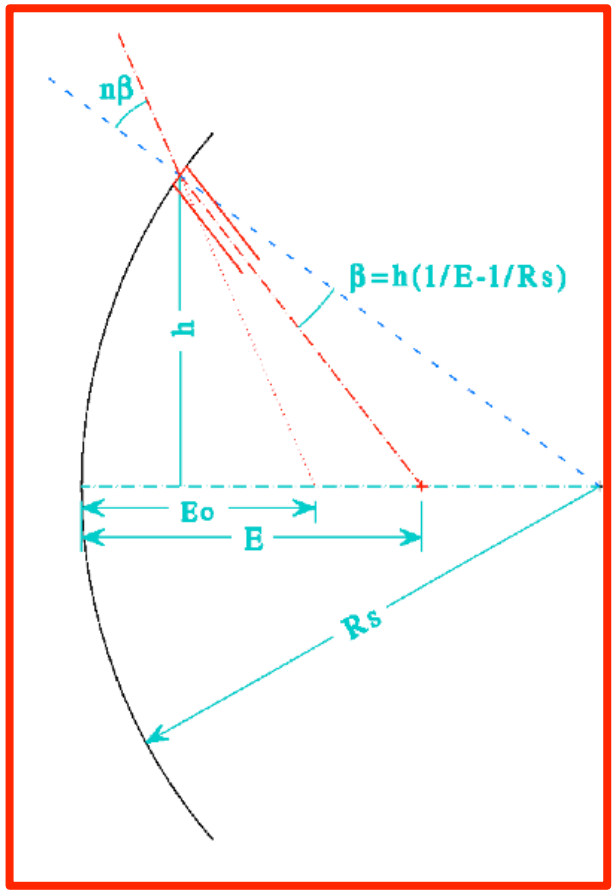


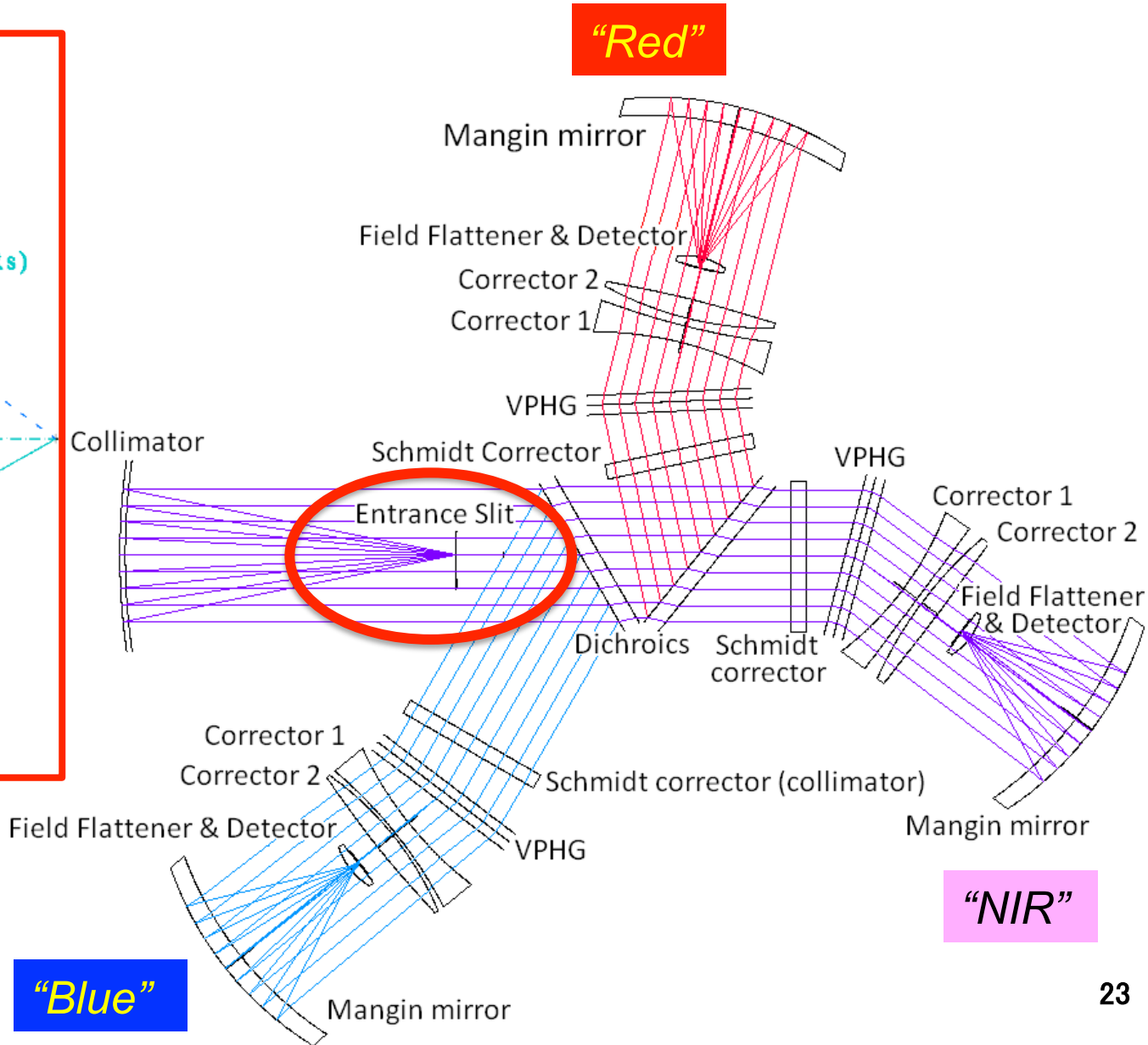


一部のファイバーのみ照射 → PSF の裾野までよく調べる



Spectrograph System (SpS)





Fiber aiming test

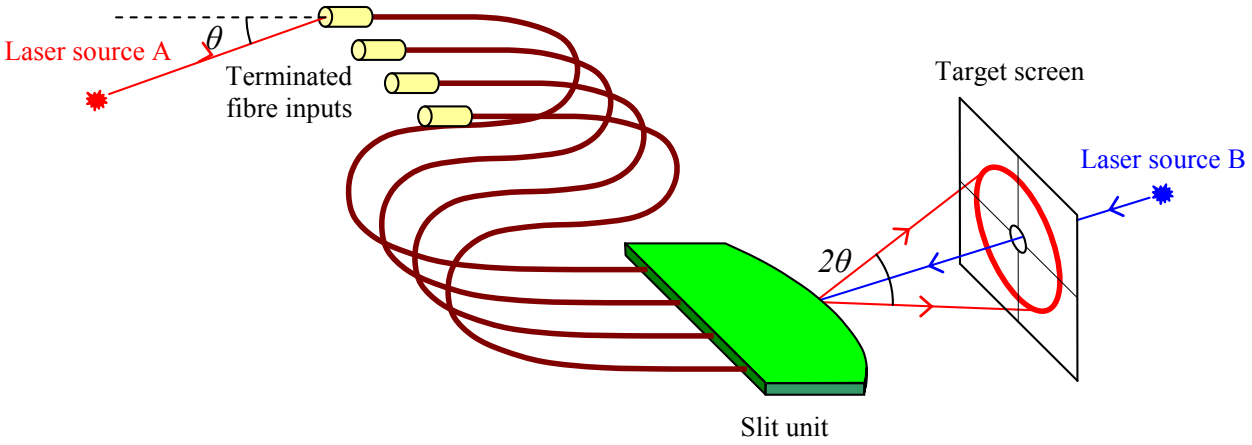
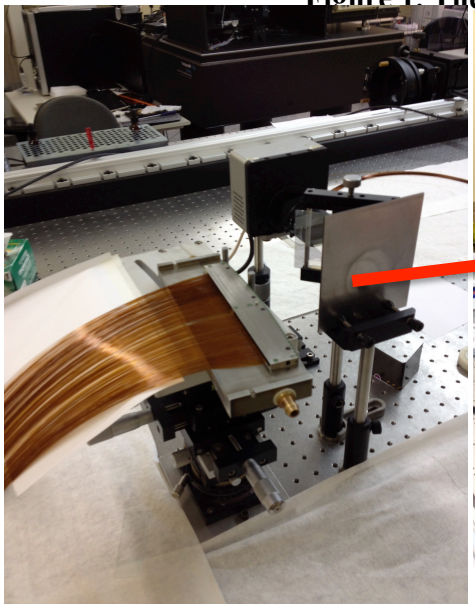
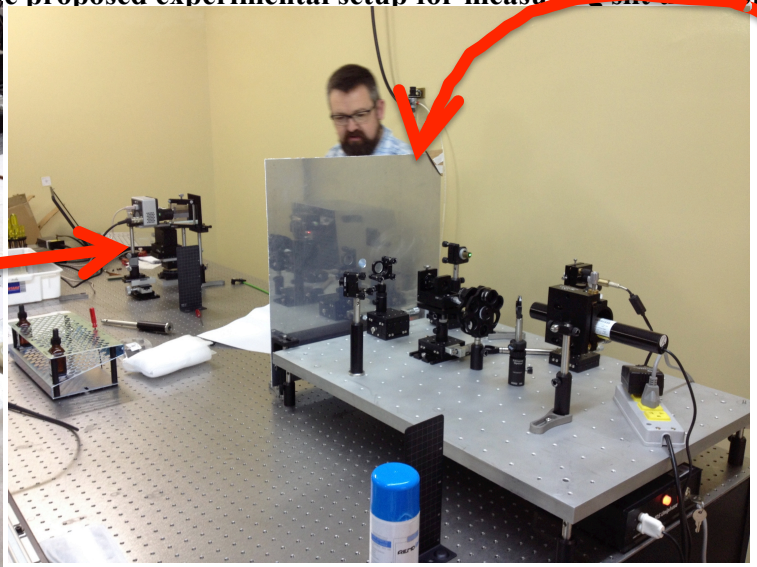
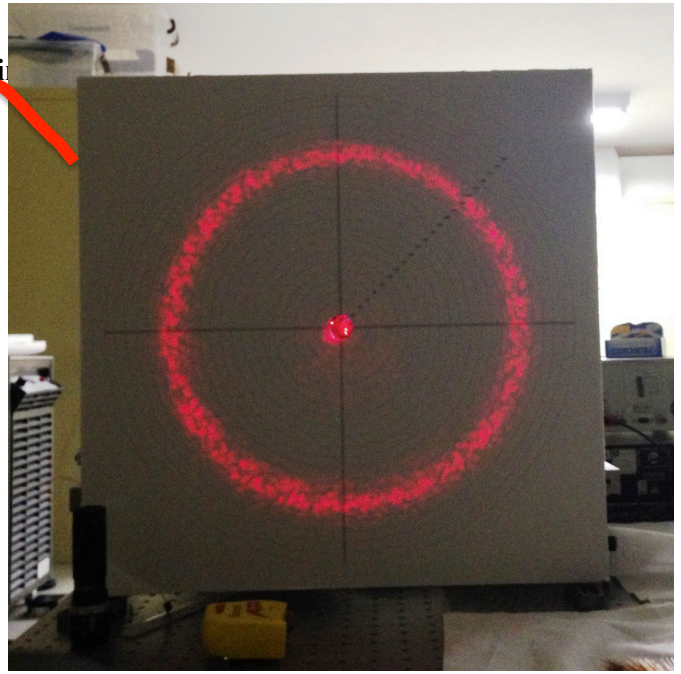


Figure 1. The proposed experimental setup for measuring slit unit poi



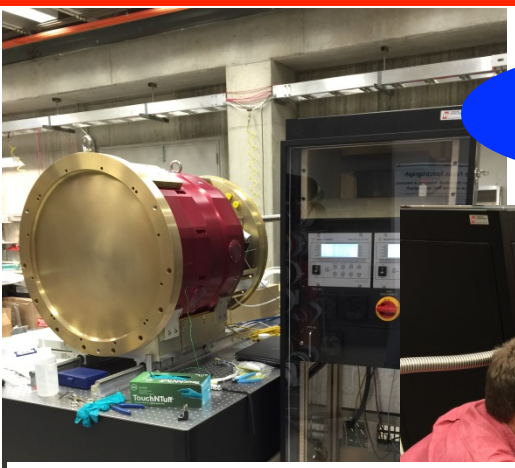


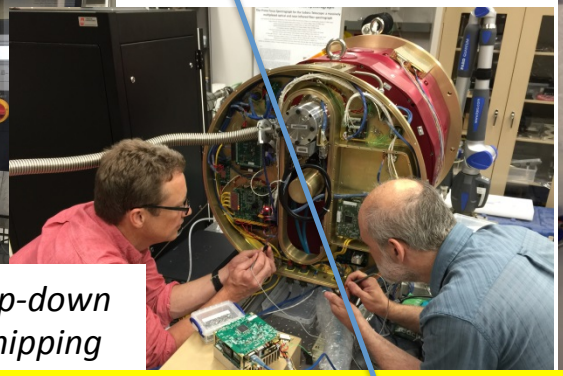


ファイバーポジショナー “Cobra”

- 今年上旬に大量生産前の最終デザイン「調整」と試験で耐久性の問題が発覚。
  - >100k cycles の耐久性が必要なところ、<50k で止まってしまうという問題があった。
- 原因調査とデザイン改良を経て１２本の新たなプロトタイプの耐久試験を実施中。経過順調(~200-400k cycles)。500k までは継続。
- 今週中にレポートがある予定(審査し、大量生産開始予定)。

SpS – What's happening now

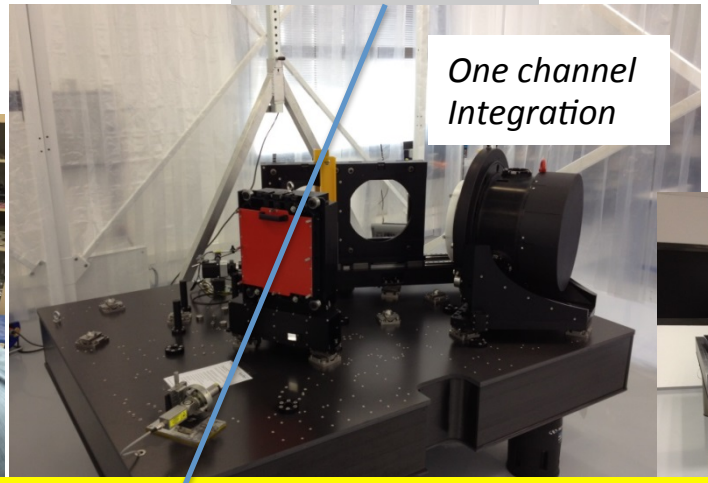




Cryostat assembly, pump-down and cool-down before shipping

JHU

Winlight

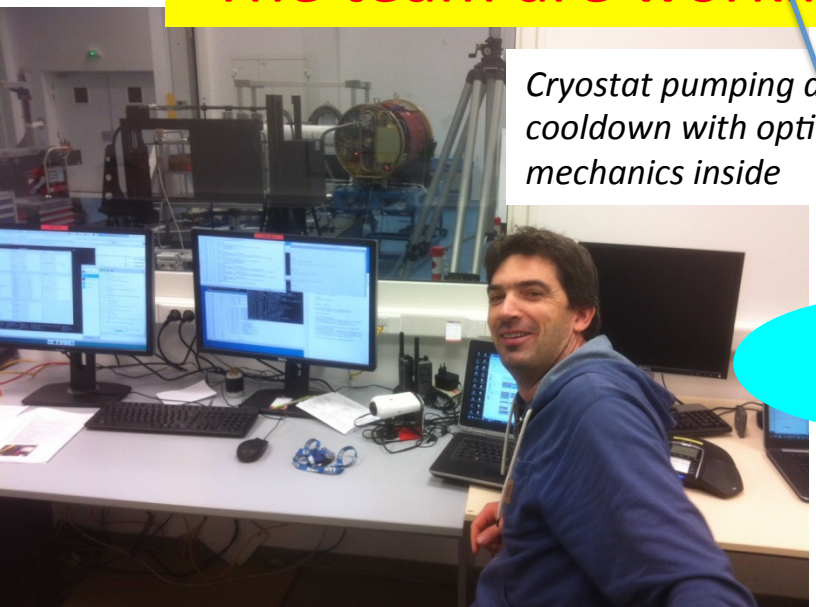


One channel Integration

Mangin

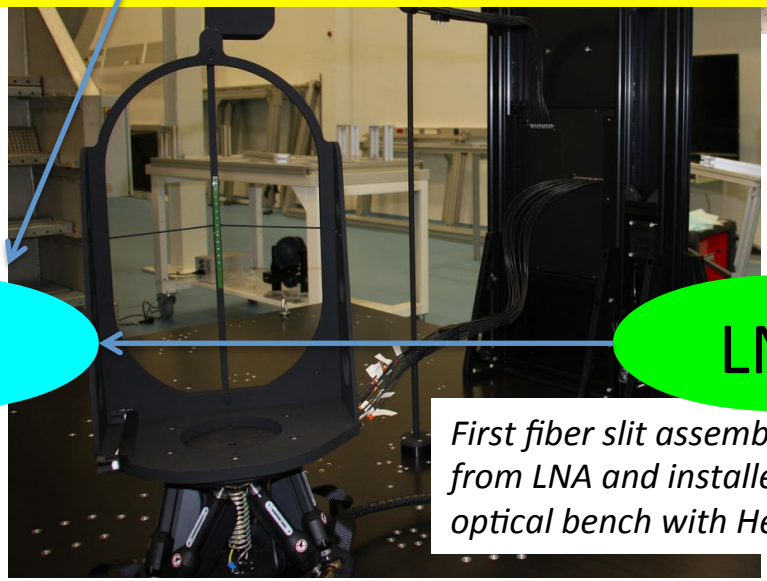
Collimator

The team are working hard to get first lab spectra.



Cryostat pumping and cooldown with optics & mechanics inside

LAM

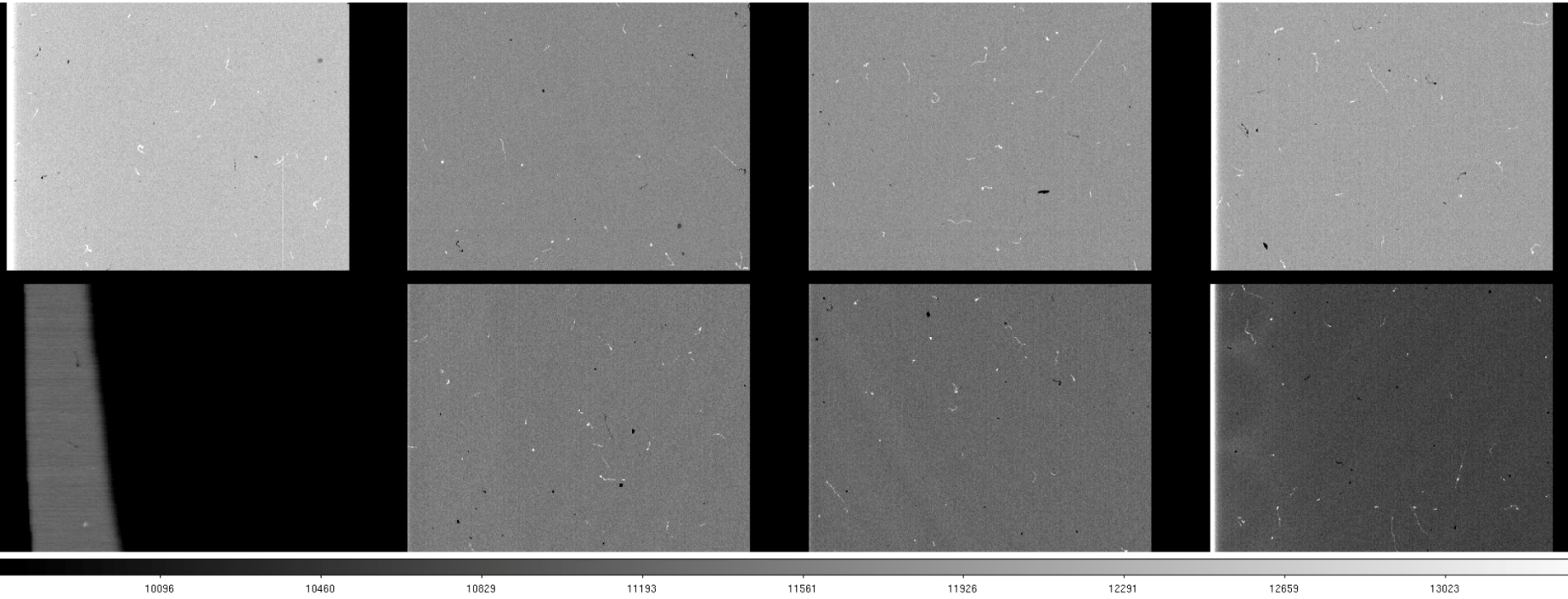


LNA

First fiber slit assembly arrival from LNA and installed on the optical bench with Hexapod.

SpS – What's happening now

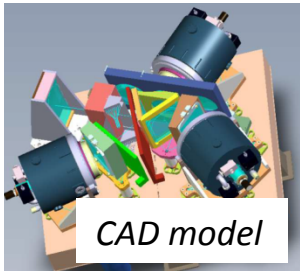
First images with the engineering CCDs reported on Oct 31
(2 chips, 4 channels per each)

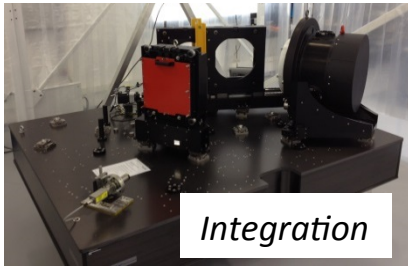


The first science-grade H4RG array will be delivered this month.
(The other three will be coming next year)

Summary about PFS

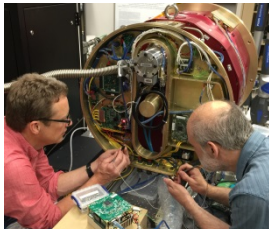
- The project passed Conceptual Design Review in 2012 and Preliminary Design Review in 2013.
- The Spectrograph System (SpS) & the Prime Focus Instrument (PFI) also passed the subsystem Critical Design Review in 2014 & 2015, respectively.
- Now finalizing the design studies and proceeding with production, integration & test.


CAD model


Integration


Optics

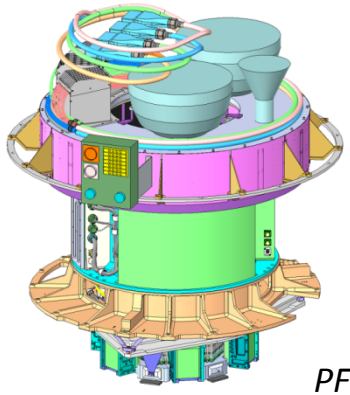
Cryostat

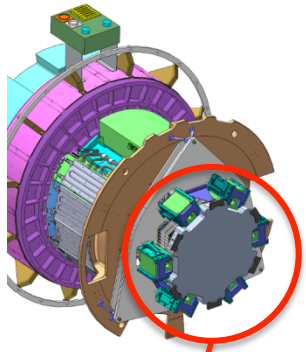


- Aiming at engineering observation from early 2018 & science operation from mid-late 2019.
- ***Unique capability of Subaru for unique science via synergy with TMT, LSST, JWST, Euclid, WFIRST.***

Refer to PFS web & blog for more detailed information and updates.

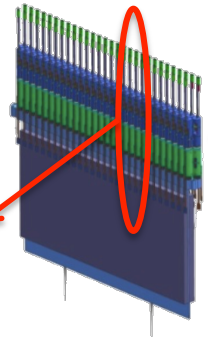
PFI CAD model

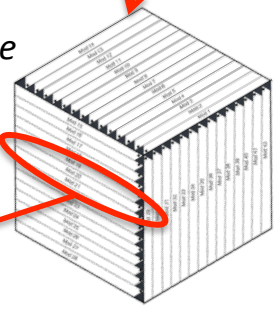




PFI focal plane

"Cobra" positioner module





"Cobra" engineering model module

Individual "Cobra" positioners