2014 Sep 08 光赤外天連シンポ @ 国立天文台三鷹

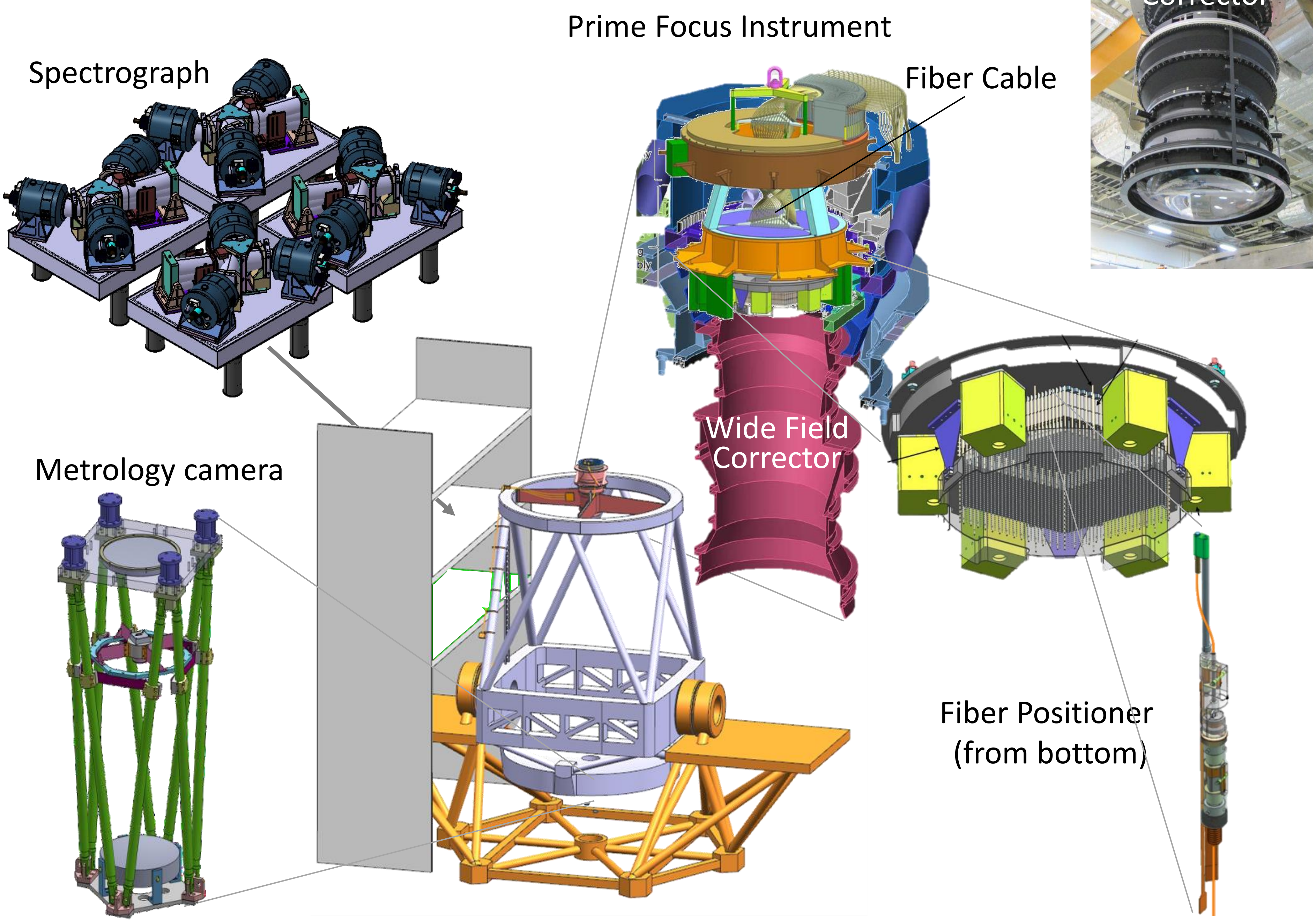
Progress with the Prime Focus Spectrograph for the Subaru Telescope: a massively multiplexed optical and near-infrared fiber spectrograph

Hajime Sugai (PFS Project Manager; Kavli IPMU (WPI)), PFS Collaboration

2014年12月に台湾(ASIAA)で
第6回コラボレーションミーティングが
行われます。

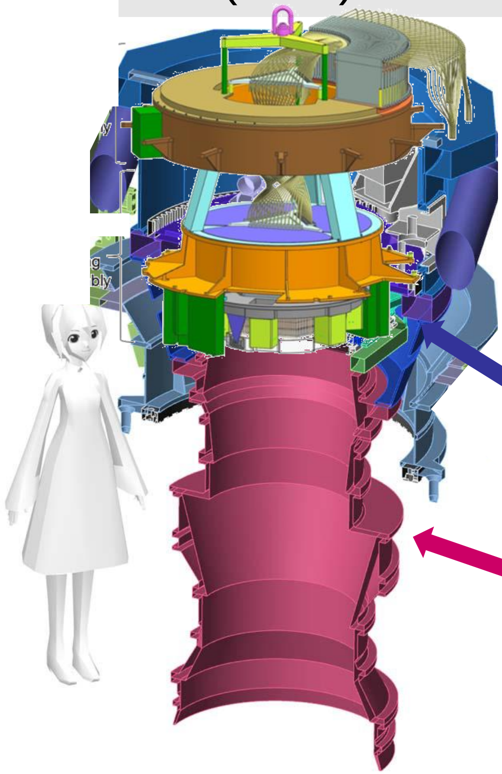

LAM
LABORATOIRE D'ASTROPHYSIQUE DE MARSEILLE
KAVLI IPMU
INSTITUTE FOR THE PHYSICS AND MATHEMATICS OF THE UNIVERSE
Caltech
PRINCETON UNIVERSITY
Max-Planck-Institut für Astrophysik
中央研究院
ACADEMIA SINICA
1928
NASA
Jet Propulsion Laboratory
California Institute of Technology
JOHNS HOPKINS UNIVERSITY
NAOJ
OBSERVATÓRIO DE SÃO PAULO
SANCTI PAVLI CÆLVM AGER MEVS
LNA LABORATÓRIO NACIONAL DE ASTROFÍSICA

PFI部分に一部HSC team作成の図が使われています（WFC,POpt2部分。次ページ参照）



Sharing WFC & POpt2 with HSC

Prime Focus Spectr.
(PFS)
(HSC)



PFS case:

Optical interface with Wide Field Corrector

Field element

= 54-mm thickness flat plate

substitutes for filter + dewar window

Prime Focus Unit POpt2

Wide Field Corrector (WFC)

HSC from http://www.eso.org/sci/facilities/eelt/fp7-elt-pub/wfi_workshop/pdffile/SMiyazaki.pdf

Science targets

9.3 h^{-3} Gpc^3 in $0.8<z<2.4$

1400 deg^2 — HSC Wide field

Dark Energy

Test General Relativity

HSC Deep field

$1<z<2$ 16 deg^2 to J_{AB}~23.4

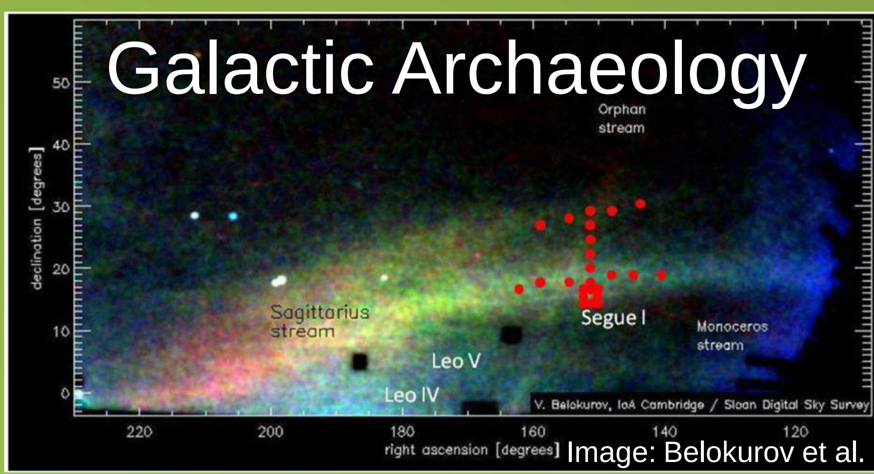
Chemical Evolution

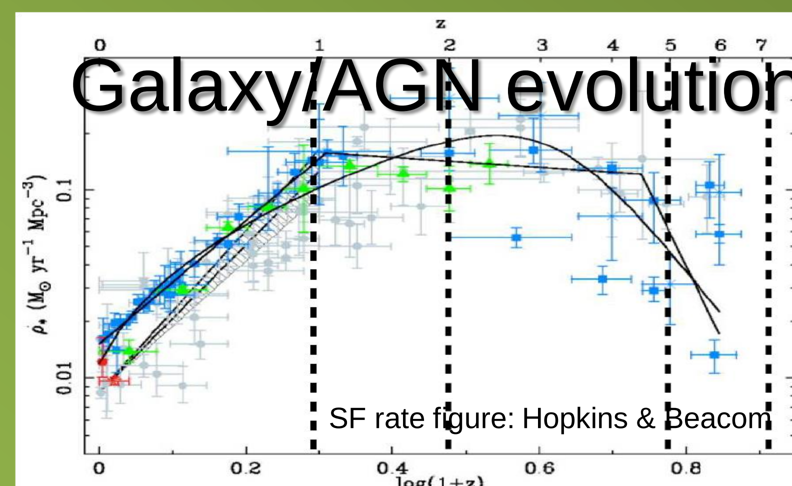
Star Formation

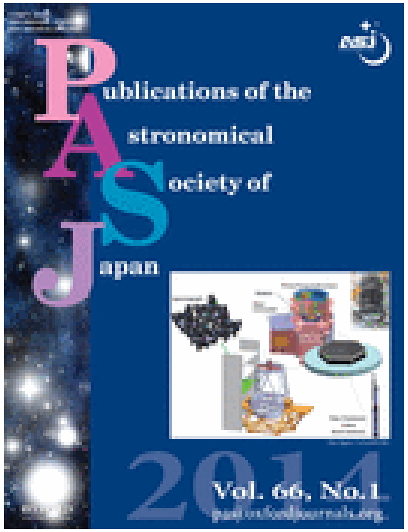
Milky Way $17<V<21.5$ 390 deg^2

M31halo $21.5<V<22.5$ 65 deg^2 — HSC sample

Dark Matter







“Extragalactic science, cosmology, and Galactic archaeology with the Subaru Prime Focus Spectrograph”,
Takada et al., 2014, PASP, 66, R1

2014 Jun SPIE papers from PFS

Instrument overview

Progress with the Prime Focus Spectrograph for the Subaru Telescope:
a massively multiplexed optical and near-infrared fiber spectrograph (Sugai et al.)

Microlens

Design and performance of a F/#-conversion microlens for Prime Focus Spectrograph at Subaru Telescope (Takato et al.)

Fiber system

Fiber Optical Cable and Connector System (FOCCoS) for PFS/ Subaru (Cesar Oliveira et al.)
Studying focal ratio degradation of optical fibers with a core size of 128 microns for FOCCoS/ PFS/ Subaru (dos Santos et al.)
Slit device for FOCCoS – PFS – Subaru (Cesar Oliveira et al.)
Polish device for FOCCoS/PFS slit system (Cesar Oliveira et al.)
Multi-fibers connectors systems for FOCCoS-PFS-Subaru (Cesar Oliveira et al.)

Fiber positioner

Developing Engineering Model Cobra fiber positioners for the Subaru Telescope’s Prime Focus Spectrometer (Fisher et al.)

PFI, Metrology camera

Prime Focus Instrument of Prime Focus Spectrograph for Subaru Telescope (Wang et al.)
Metrology camera system of Prime Focus Spectrograph for Subaru telescope (Wang et al.)

Spectrograph

Current status of the Spectrograph System for the SuMIRe/PFS (Vivès et al.)
Optical design of the SuMiRe/PFS Spectrograph (Pascal et al.)
Integration and test activities for the SUMIRE Prime Focus Spectrograph at LAM : first results (Madec et al.)

Dewar & Detector

Focal Plane Alignment and Detector Characterization for the Subaru Prime Focus Spectrograph (Barkhouser et al.)
CCD readout electronics for the Subaru Prime Focus Spectrograph (Hope et al.)
(Cryocooler vibration damping for the Subaru Prime Focus Spectrograph (Hope et al.))
VPH gratings for the Subaru PFS: performance measurements of the prototype grating set (Barkhouser et al.)
The near infrared camera for the Subaru Prime Focus Spectrograph (Gunn et al.)

Updates on income

Presently drastic phase: 2014 March - end of FIRST fund

- updates after 2013 Dec negotiation with NAOJ

(1) Further contribution from IPMU determined

(2) Borrowed money from University of Tokyo

(3) Contribution from NAOJ in addition to Subaru modification

(4) MPA as new partner

(5) Negotiating with new partner candidates

(6) Negotiating with smaller partner candidates

(7) Budget request of PFS submitted from University of Tokyo

現在、contingencyを含めないと、必要なトータル額に対して4%不足。
Contingencyも含めると8%不足。もちろん、cost reductionも実行中。

PFS Basic Characteristics

Optical + NIR Multi-object fiber spectrograph

- Number of science fibers (Polymicro, Fujikura): 2394

  600 or 597 per module X 4 Spectrograph modules

- Fiber core diameter 127,128,129μm

  Microlens (PID Nitto) attached to fiber input edge

  fiber input F/2.2 -> F/2.8 (1".1 diameter per fiber)

- Field of view: 1.3 deg diameter
- Wavelength: 0.38 - 1.26 μm

PFS Basic Characteristics

- Each spectrograph module: 3-color-arm design

Arm	Coverage[nm]	Resolution[$\lambda/\delta\lambda$] (Kaiser VPHG)
Blue	380 - 650	2500
Red	630 - 970	3200
NIR	940-1260	4500

(**Medium res. 710-885nm, R=5000**
Ohara prisms glued)

Spectrograph collimator F/2.5, camera F/1.1
Detector pixel 15μm

(2Kx4K x 2 Hamamatsu FDCCDs for each Blue/Red arm,
4Kx4K Teledyne HgCdTe(1.7μm cutoff) for NIR arm)

Major milestones (events)

Endorsement by Japanese community	2011 Jan
MOU between NAOJ and IPMU	2011 Dec
Project CoDR (Conceptual Design)	2012 Mar
Project RR (Requirement)	2012 Oct
Project PDR (Preliminary Design)	2013 Feb
Subsystem CDRs (Critical Design)	**various**
First Light (Engineering)	S17B
Subaru Strategic Program	S19A-S23B

Challenge with Microlens on fast telesope F-ratio.

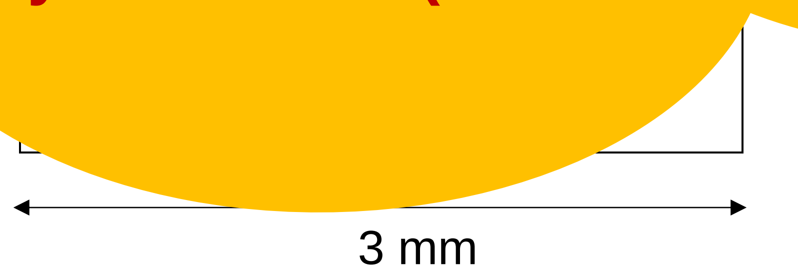
After successful productions of Mechanical & Optical samples,
Mass production of 3500 microlenses completed.

PID Nitto:

K-VC82 (n_d=1.75), 4.8643-mm curvature-radius concave

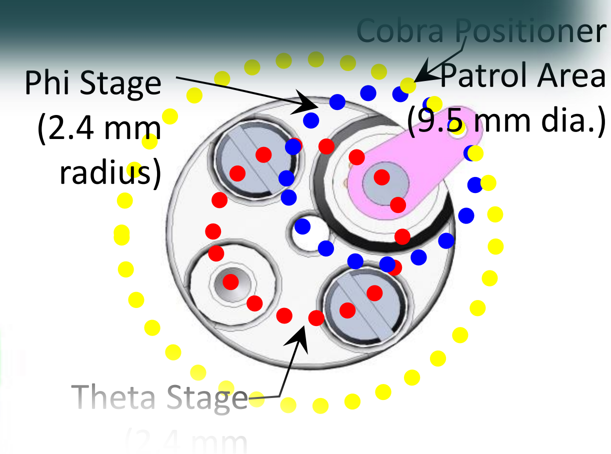
outer diameter = 1.486 mm +/- 1.2 μm (1σ)
(specification 1.482-1.490 mm).
thickness 3mm within +/- 10μm (as specified).

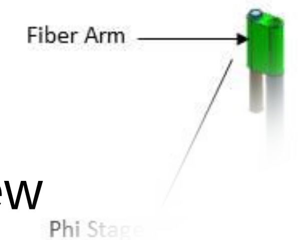
Superbroad AR coating by NAOJ ATC (Waseda et al.)



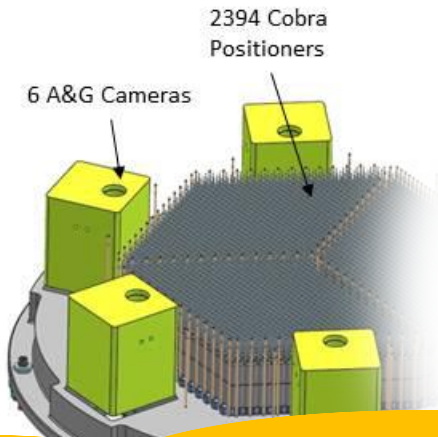
Fiber positioner

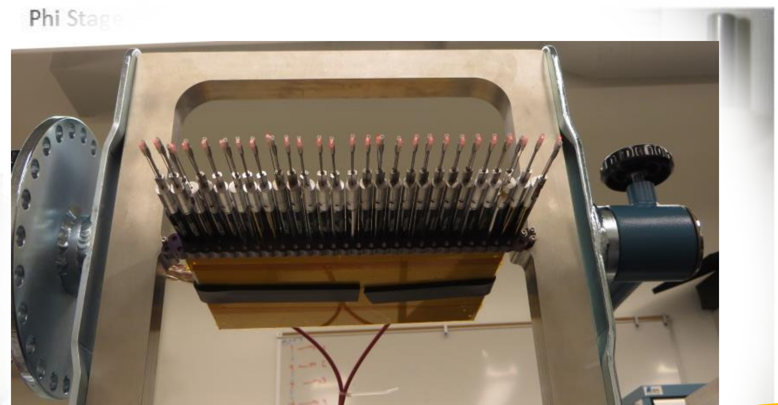
movie1 movie2 movieold





1.3° Field of View

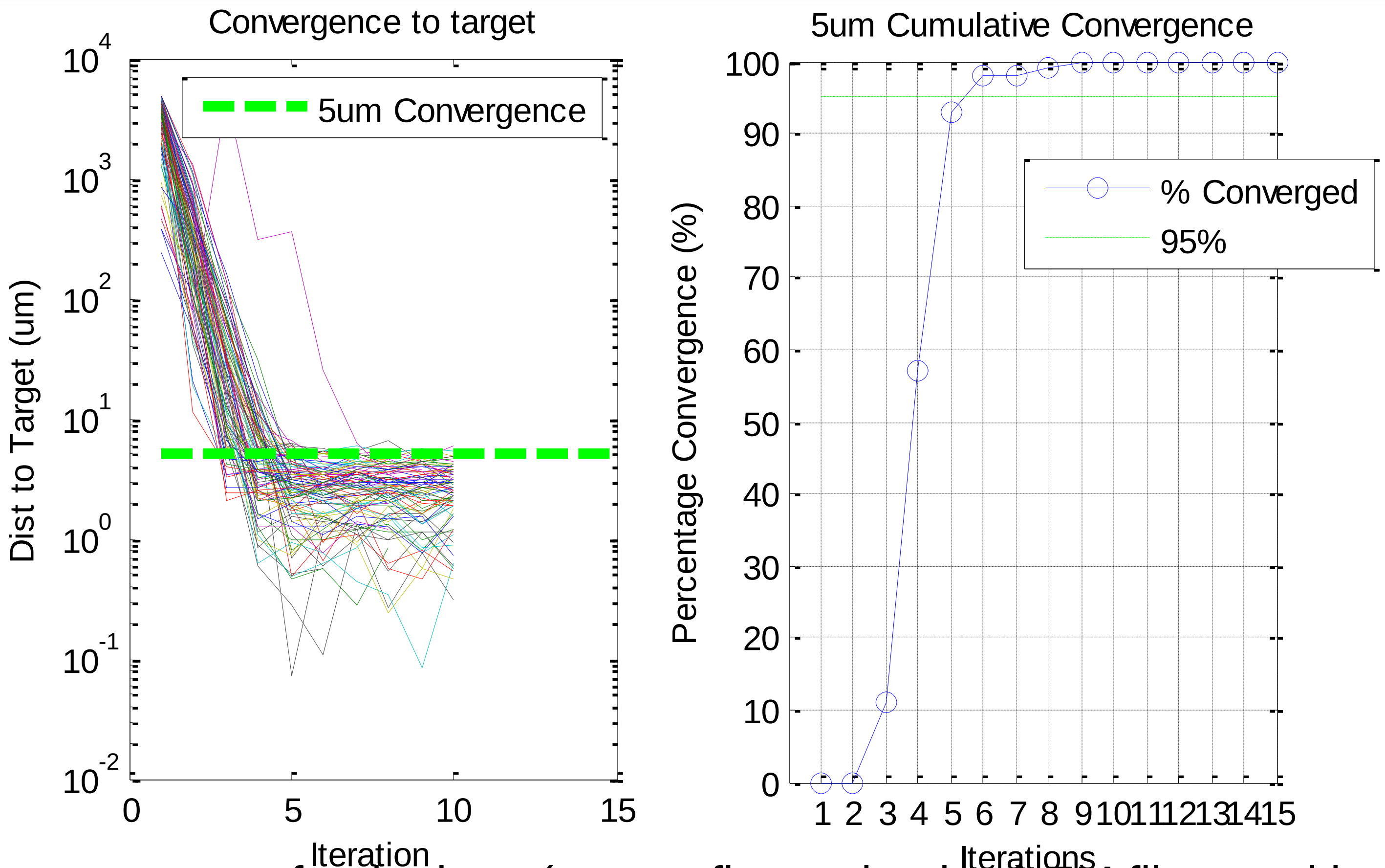




After Generation 3,

Engineering Model (EM: one module with a half of 57 fiber positioners) **tested.**

Fiber positioner



Convergence to target for the best (among five at the time) EM fiber positioner.
For randomly selected 100 target points within 9.5 mm diameter patrol area.

Left) Fiber position is converged with iteration. For each of 100 target positions (cases).
Right) Fraction of cases where the fiber positions are converged within 5 μm.

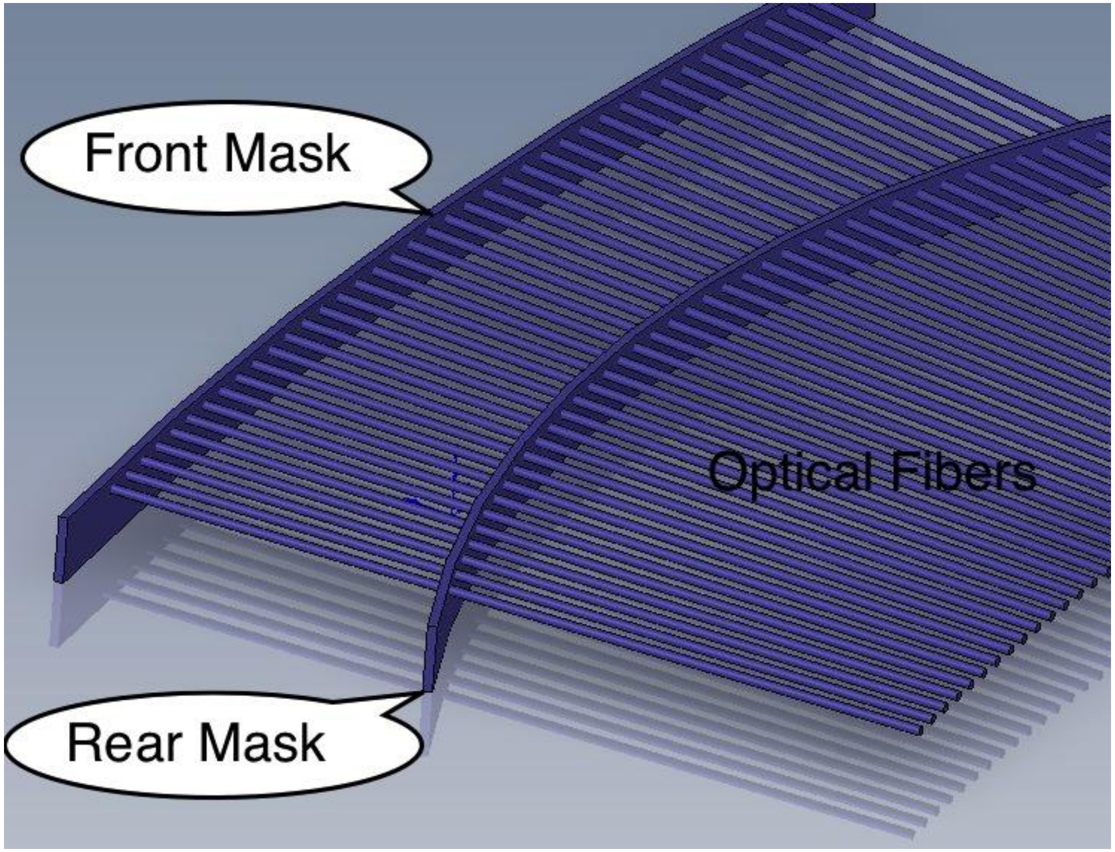
Fiber Positioner (Cobra) Contract

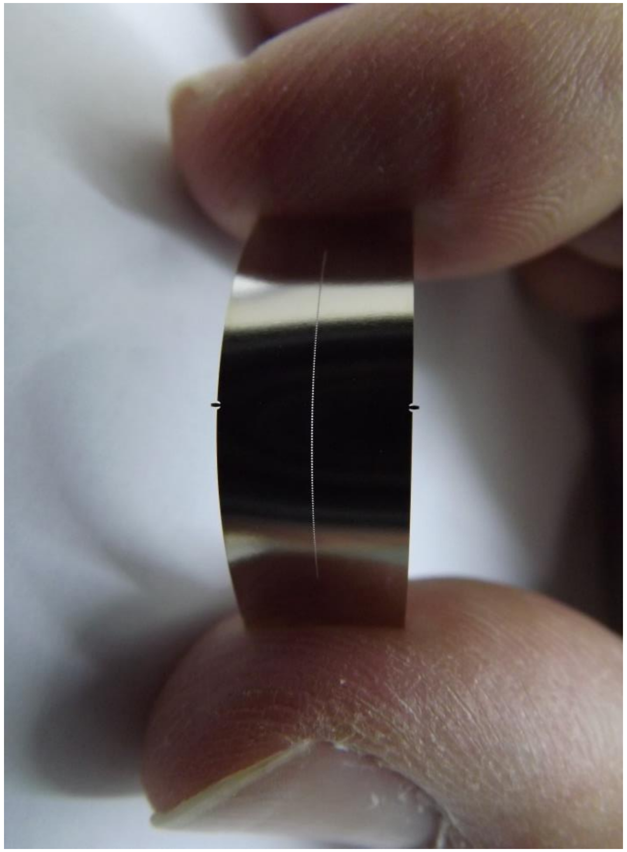
EM試験を通した改良・価格削減をもとにfixed price contract

Sep 03 – **starting contract with NewScale**
with a half of Non Recurring Cost (NRC)
Nov 01 – another half of NRC

NRCにより量産体制 **200 cobras per month**
→ 体制整うと~2400 cobrasを１年間で。

Basic Concept of the Slit Device





Fiber-slit Prototype

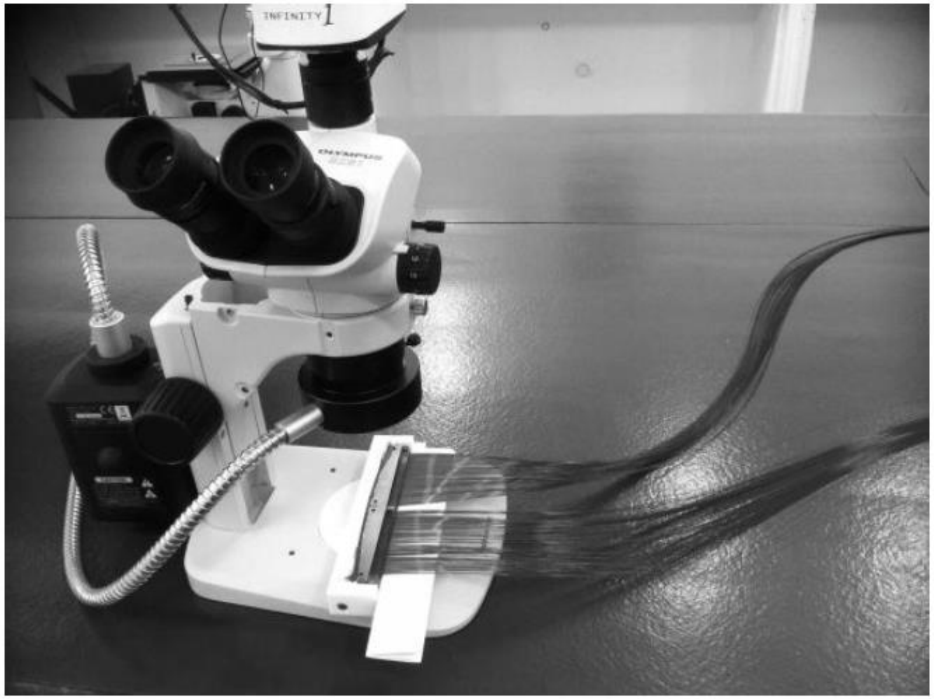


Figure 8 – Prototype during steps number 1 and number 2 under the microscope.

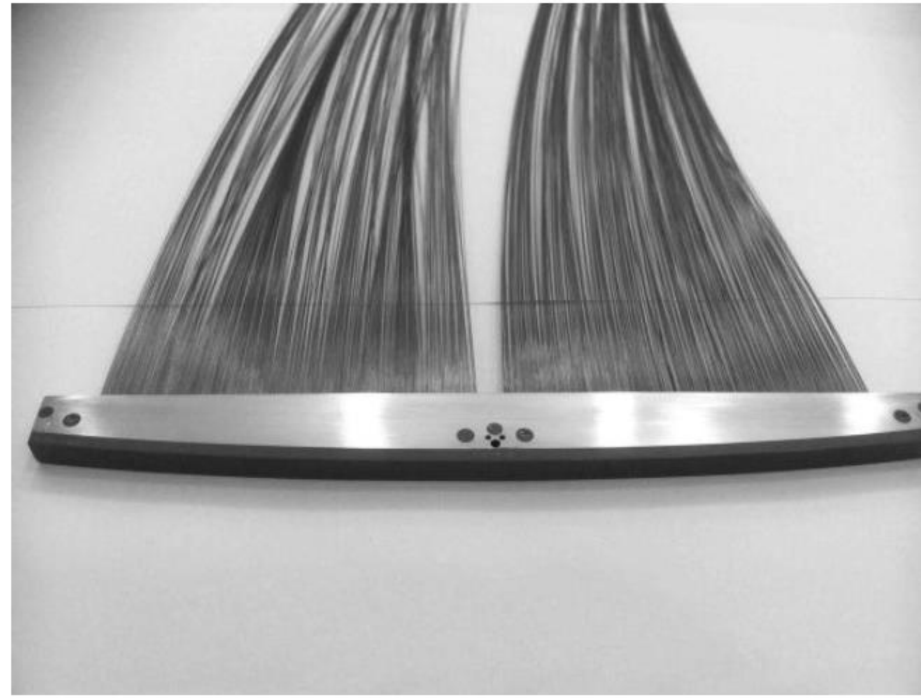


Figure 9 – Prototype ready to be polished

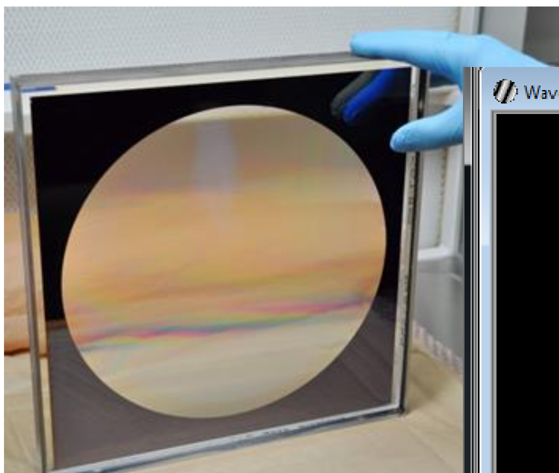
実際に使用するスリットも製作開始。

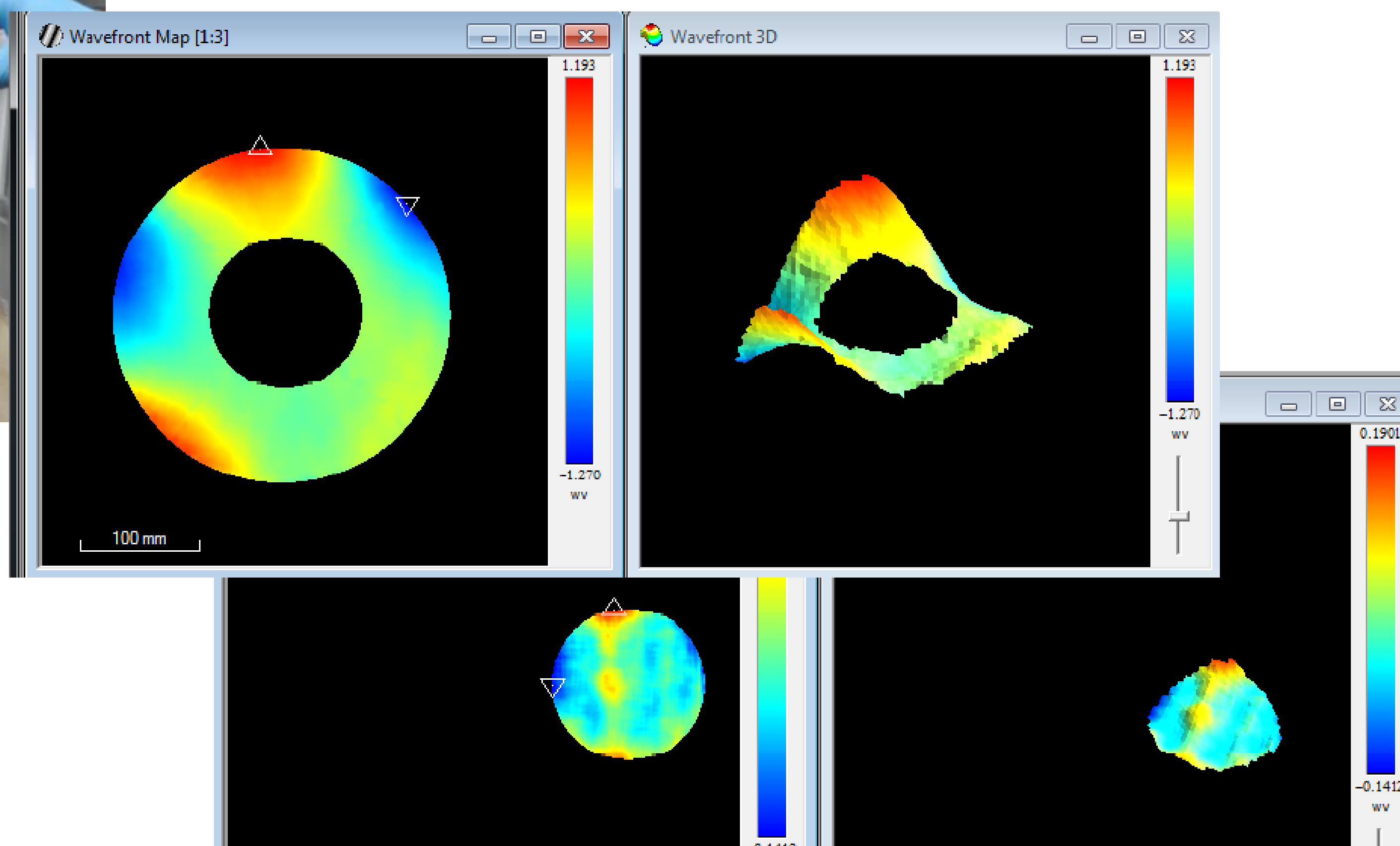
PRINCETON UNIVERSITY JOHNS HOPKINS UNIVERSITY

Spectrograph modules

Measurements on “prototype” VPHGs

Wavefront error measurements: e.g., 0.4 waves RMS for 280mm clear aperture for blue VPHG prototype





Volume Phase Holographic Grating Wave front error 改善策

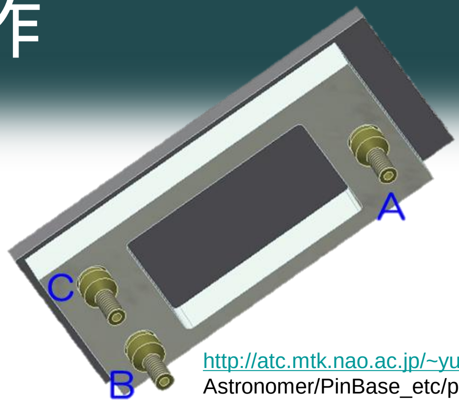
改善案1：
原因究明し製作工程を治す。
難しいが、できれば、きれいはVPHができてベスト。

改善案2：
カバープレートを研磨する。VPHによるWFEをキャンセルするように。
研磨代・時間がかかる。エレガントでない。

→

実際とったのは、**改善案1**
JHU,PUががんばって、カイザーにも行って**原因究明**。
ホログラフィック作成光学系のアラインメント改善。
実際使用するVPHGを製作開始するところ。

CCD Pin bases製作



http://atc.mtk.nao.ac.jp/~yukiko/FDCCD_Manual/Astronomer/PinBase_etc/pinbase.png

NAOJ ATC Nishino et al.

AlN pin bases

placing Ti pins with positional accuracy σ=1.4μm in each of x,y.

pin-diameter accuracy of 0.4μm.

→ Accurate alignment of a pair CCDs

ACKNOWLEDGEMENTS in Sugai et al. 2014, SPIE

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location for setting four spectrograph modules

- now fourth floor of the infrared instrument side (IR4), following decisions by SAC based on Subaru UM 2014 Jan discussion.

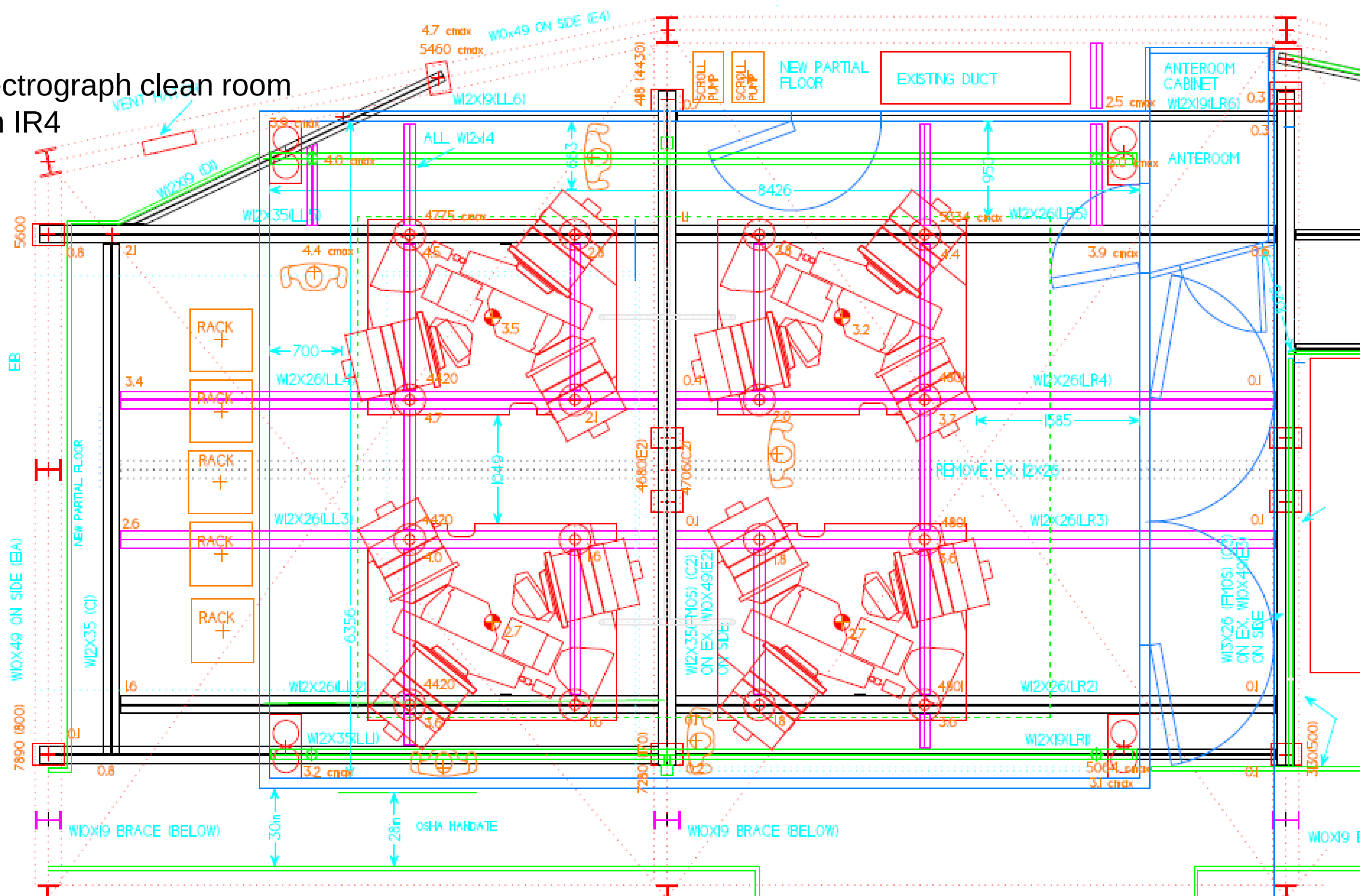
(1) much less work/cost of reinforcement for IR4, compared with IR3;

(2) less effects on operations of Nasmyth-floor instruments since IR4 floor is farther;

(3) more space available on IR4 floor compared with IR3 floor with an elevator etc.

disadvantage on IR4: slightly longer Cable B fibers are necessary (connecting through the second floor, close to tel. elevation axis).

Floor / spectrograph clean room designs on IR4



prototypes / mockups