LSST Camera Calibration Program

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SLAC

Camera Face-to-Face
BNL
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Camera Test and Calibration Goals

Data and procedures:

- To support a broad program of science.
- To support operations and on-line analysis and verification of data quality.
- To verify performance during construction (and maintenance).

Context of the Calibration Program

Nature's calibration.

Sky Targets and Standards

Atmosphere (including Dome) "Sky Background"
Transmission, Scattering, Distortion, Scintillation

Sets baseline; how and where?
⟶ Still need data and simulation.

Telescope
Beam (AΩ), Distortion (Z_n, WFS), Tracking
Transmission, Scattering, Vignette

Camera (including Optics and Filters)
Photons - Band-pass and QE
- Ghosts and Fringes

Electronics (including Sensor Circuits)
- Cross-talk, CTE, full-well, retention, dark current
- Gain, bias, read-noise

Metrology

⟶ A lot depends on the Camera!

Operations and Data Analysis
Calibration Images

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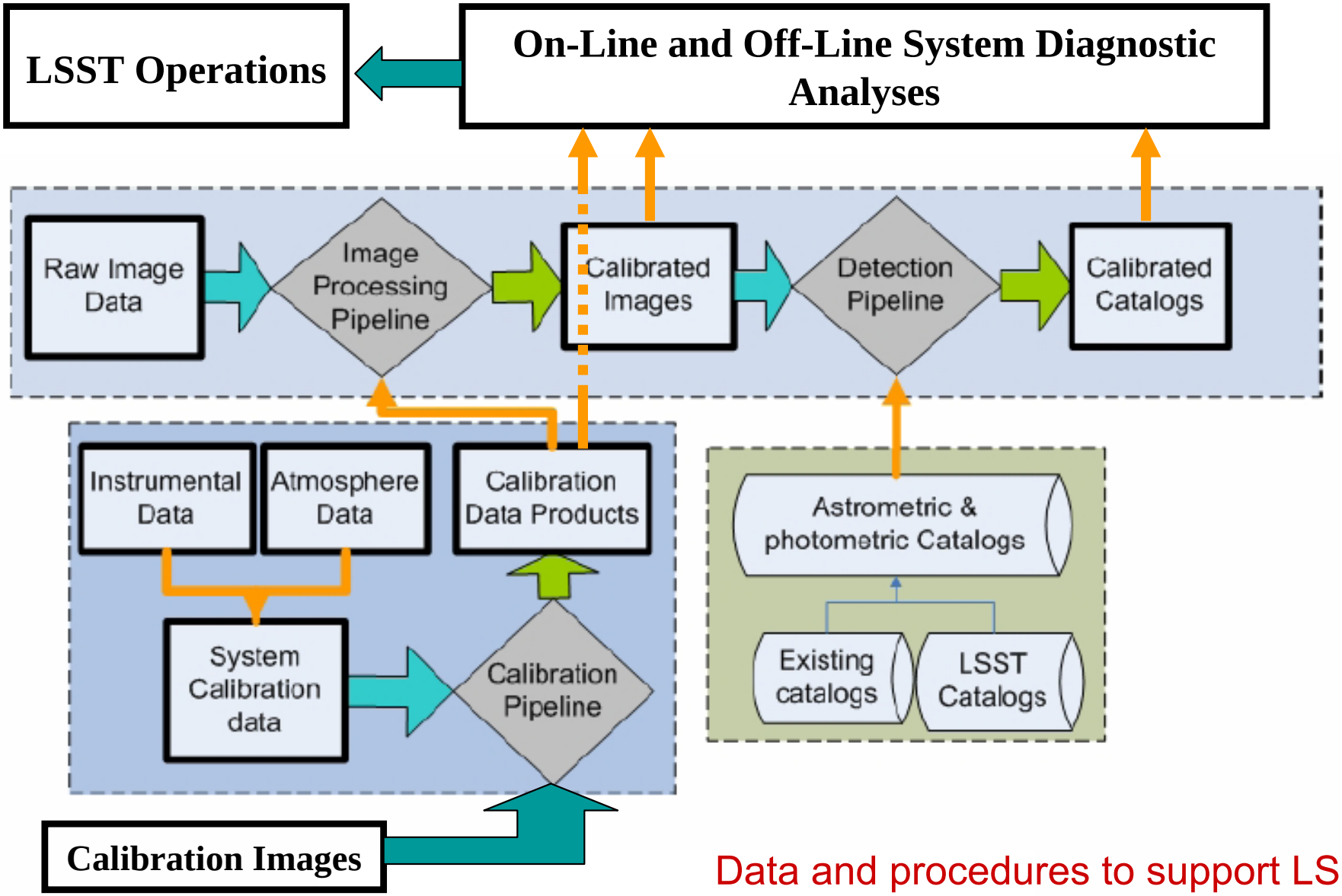
Data Pipelines and LSST Operations



Data and procedures to support LSST operations and science.

Scope of Camera Calibration Program

- Capture data taken during production and assembly.
- Design and carry-out tests and calibrations of integrated systems, including the final verification of performance of the Camera before it is shipped to the mountain.
- Work with Telescope and DM Teams to design and carry out tests and calibrations of fully integrated LSST hardware and operations.

Production and Assembly

What to Capture During Production and Assembly … a partial list …

- Photometric
  - Optical coefficients, band-pass and reflectivity of optics and filters.
  - Sensor quantum (photon) parameters.
  - Sensor/FEE electronic circuit parameters.
  - Raft and FPA metrology; thermal (and gravitational?) parameters.
- Operational
  - Shutter speed and dwell time.
  - Camera actuator and read-back calibrations.
  - Thermal coefficients and response times; vacuum profiles.
  - Vibration and settle times.
  - WFS and guider calibrations --- who does this?

Need to …

Finalize this list.

Define process and data management.

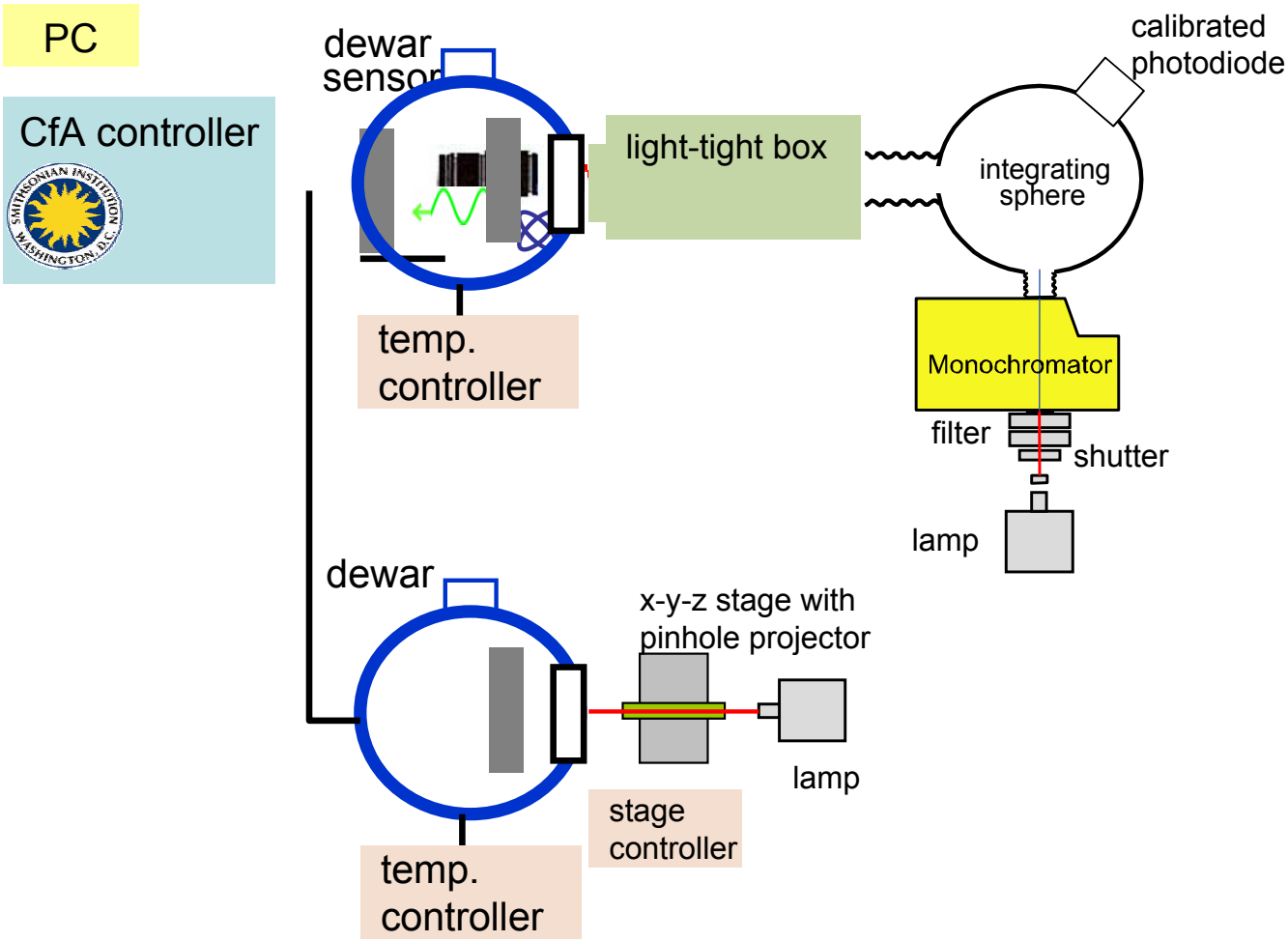
E.g. Production units fully or partially sampled?

Example from June Camera Face to Face

→

Sensor test facilities
(prototype evaluation phase)

P. O'Connor
June Camera F2F



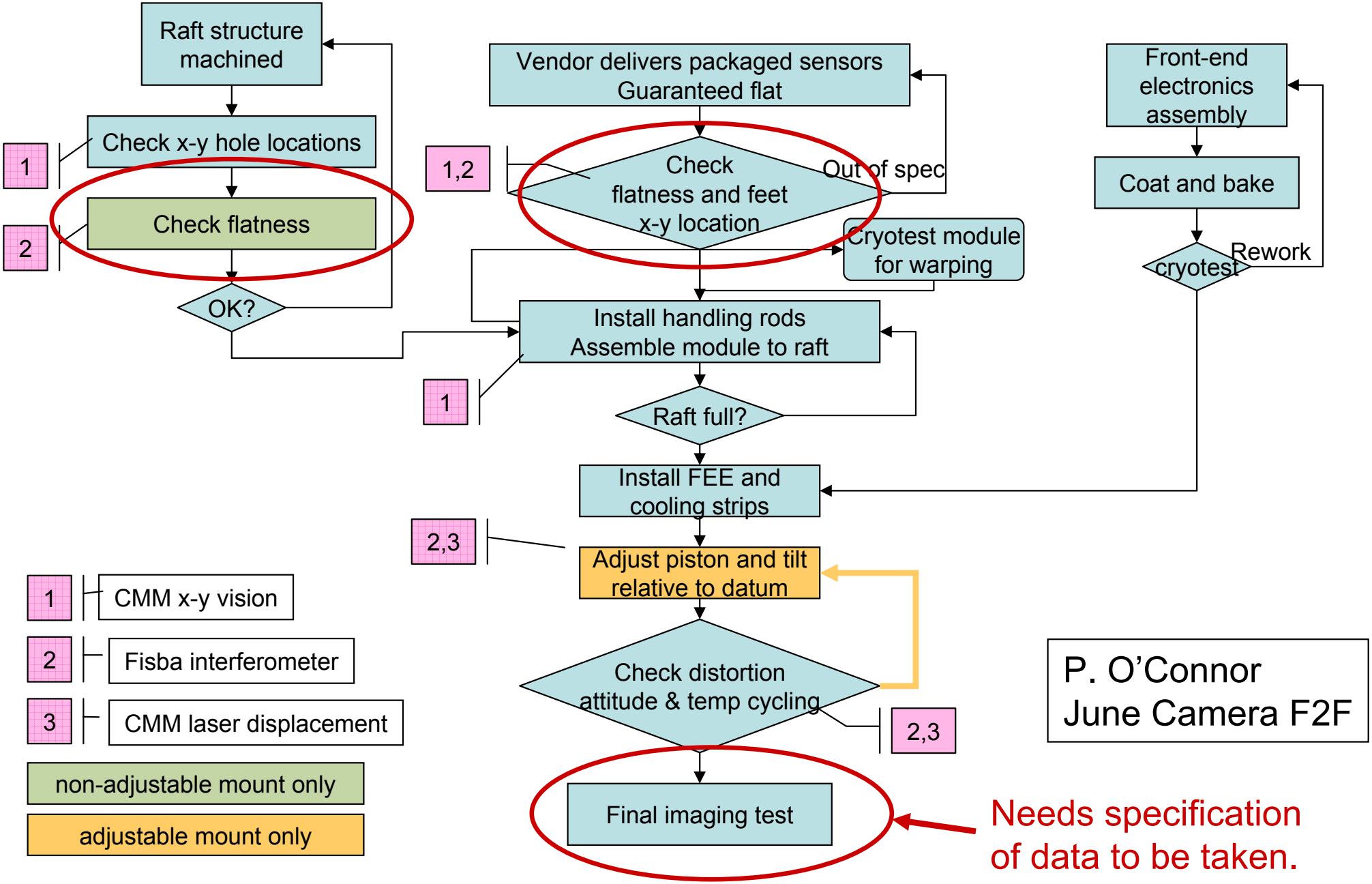
defects
crosstalk
imaging

dark current
CTE
full well
noise, gain
persistent image

QE

PSF

Raft Assembly Flowchart



Integrated Camera Tests and Calibration

When …

Camera is completed and sitting in SLAC assembly room.
Electronics and DAQ working.
Peripherals (shutter, filters, etc) in place and working.

Goal

Verify we are ready to ship the Camera to the mountain.

Method

Run the camera as if it were taking data on the telescope!

Images to Record and Analyze

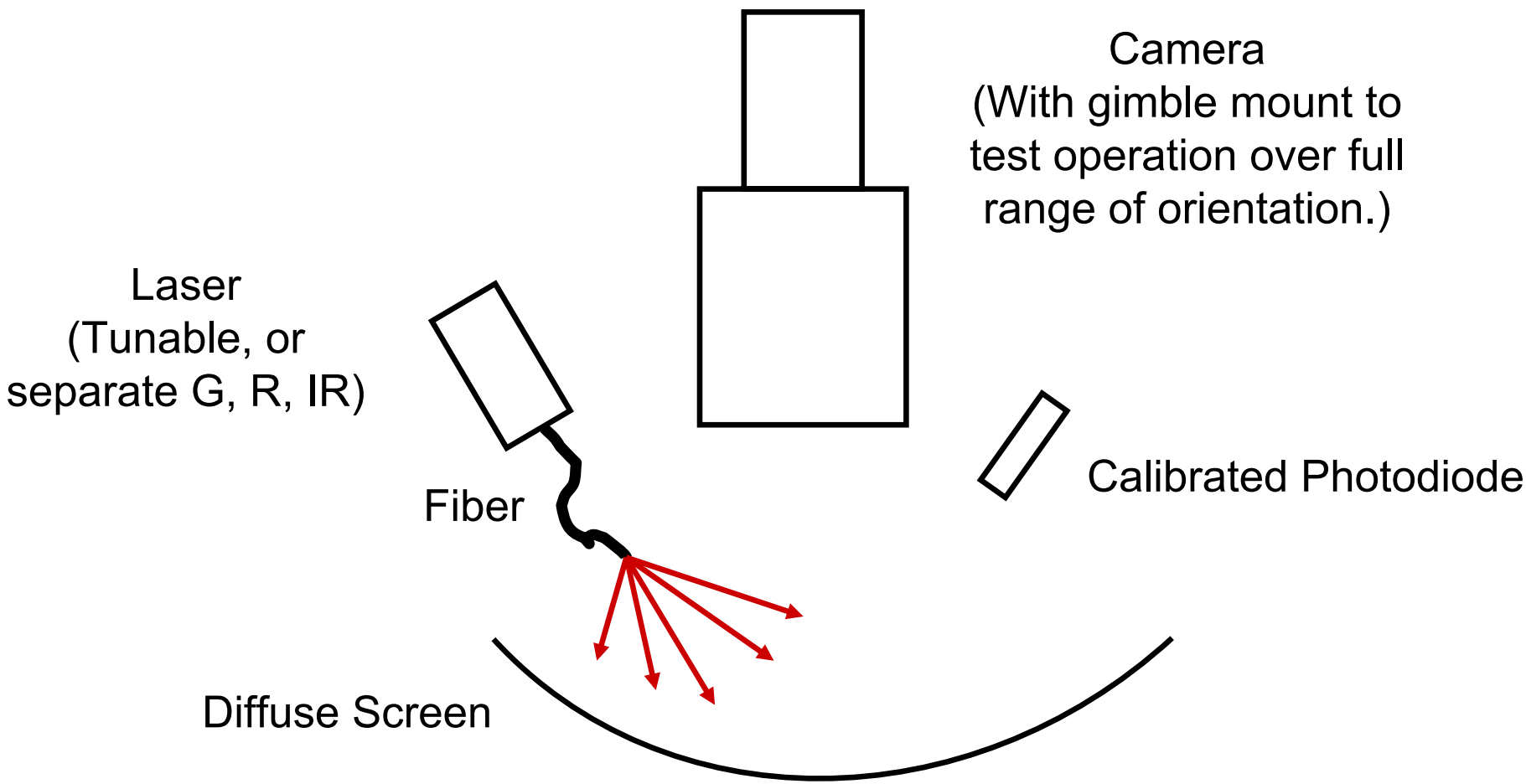
Bias frames – zero exposure time.
Darks (long and short) – shutter closed.
Flats – illuminated screen monitored with photodiode.
Laser “stars”.

Flat Field and Integrated Response

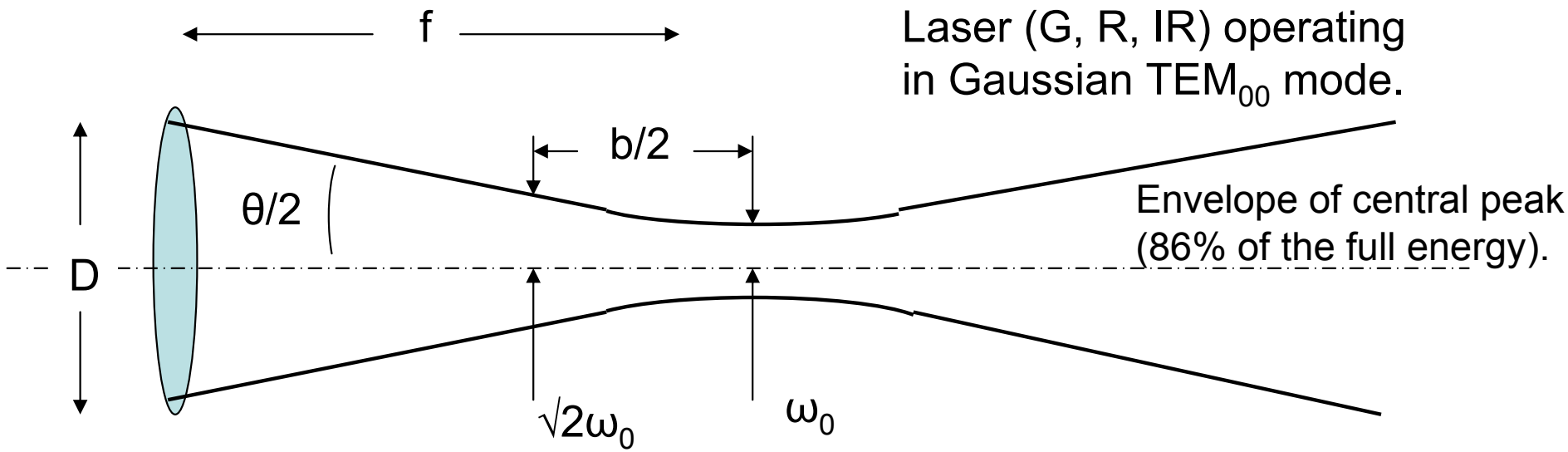
(e.g. Fringing Tests)

Coordinate with Telescope Team

Match as closely as possible the dome-flat calibration technique and parameters that will be used on the mountain (e.g. Stubbs):



Focusing a Laser Beam



Laser (G, R, IR) operating in Gaussian TEM_{00} mode.

Envelope of central peak (86% of the full energy).

Formulae:

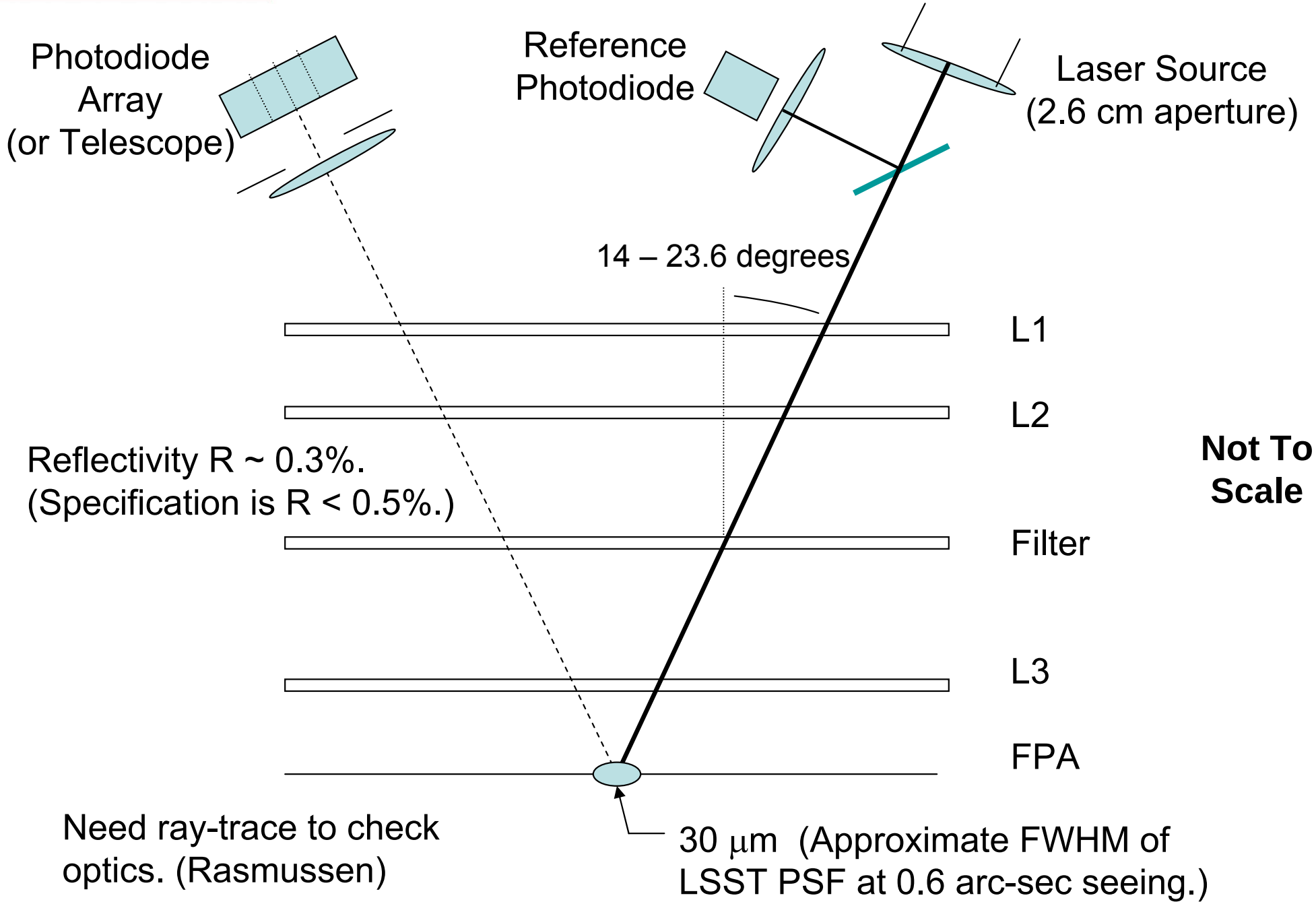
$\theta = 1.27\ \lambda/2\omega_0$

$b = 2\pi\ \omega_0^2 / \lambda$

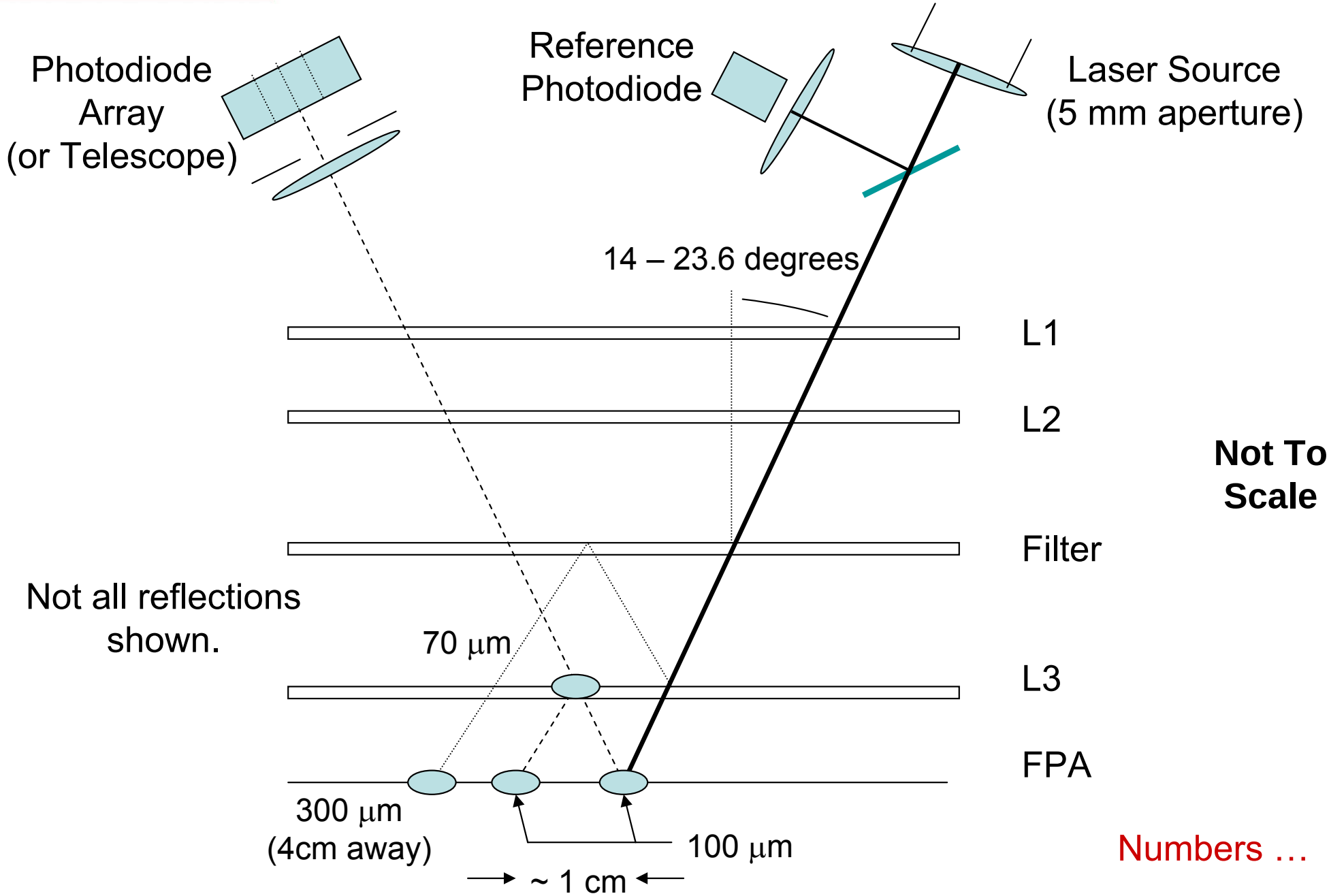
Numbers:
(f = 1.2 meters; λ = 0.5 μm)

$2\omega_0$ (μm)	b (cm)	D (cm)
30	0.3	2.6
60	1.1	1.3
140	6.2	0.5

Laser "Star" Schematic



Ghosting Test Schematic



Numbers …

Some Numbers and a Possible "Run Plan"

Input Specifications

R < 0.5% Take 0.3%, for example → intensity after two reflections is reduced by factor of 10^{-5}.

CCD Full Well > $0.7 \bullet 10^5$ electrons.

Read Noise ≈ 5 electrons.

So if we just saturate a pixel at the primary spot, then get ~ 1 electron at corresponding pixel a centimeter or so away.

Will want to run with primary spot saturated (maybe a sequence something like: unsaturated pulse, saturated pulse, dark frame).

Use LSST cadence of two 15 second exposures every 32 seconds.

Stack images – an LSST field stack of ≈ 240 images every hour – a data analysis challenge!

Summary

Lot of work to be done!