Emerging New Technologies for Ocean Color Research

SCATTERING SENSORS

DEVELOPMENT OF A HYPERSPECTRAL BACKSCATTERING SENSOR

LISST-VSF OVERVIEW

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Today's Breakout:

Radiometry

Platforms

IOPs (scattering)

Two Sensors

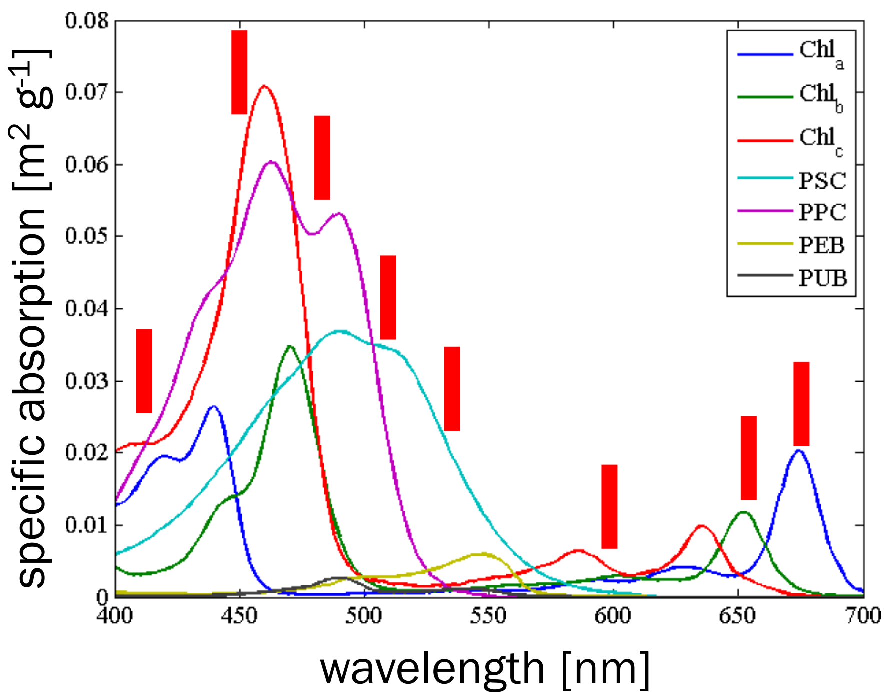
HyperBb

LISST-VSF

Discussion

Ultimate goals of IOP sensing:
model closure/validation, biogeochemistry/proxies

$$R(\lambda) \sim \frac{b_b(\lambda)}{a(\lambda)}$$



Bricaud et al. 2004

Availability of hyperspectral absorption, scattering, radiometry, current tech is ~9 wavelengths of bb on a platform.

Two issues:

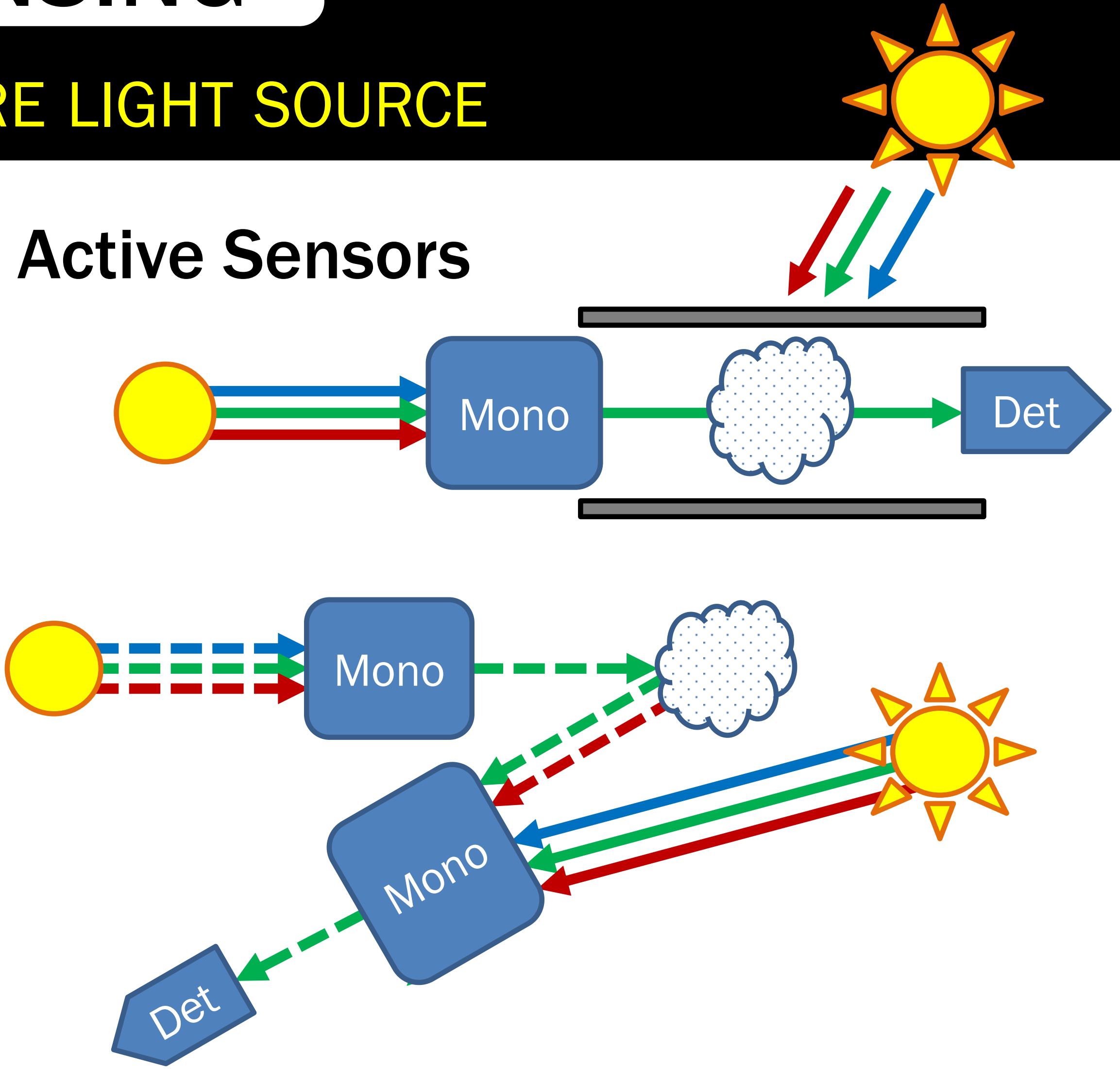
(1) Currently hyperspectral closure requires assumption of bb spectral models. Move beyond power-law…

(2) Low res bb data in spectral regions where we expect pigment absorption to affect bb → PFTs and biogeochemistry from space.

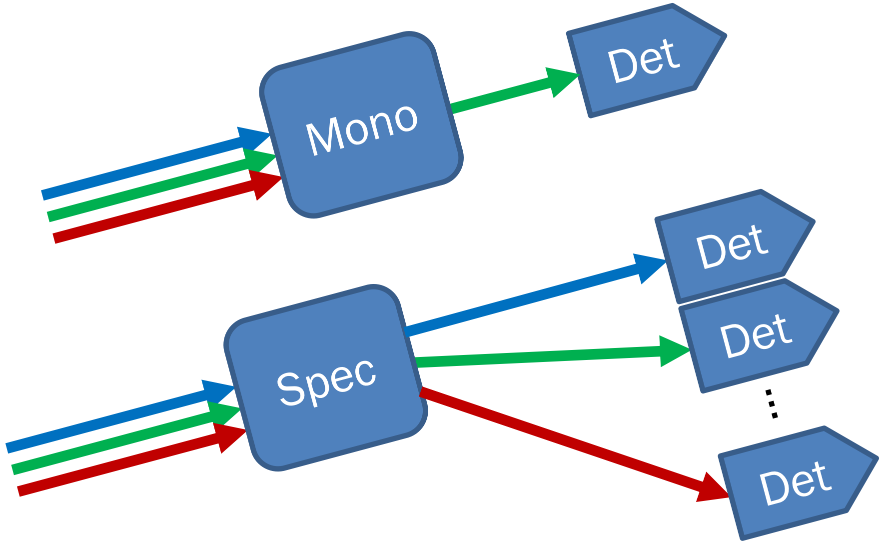
Active vs. Passive Sensing

IOP sensors are active–require light source

Active Sensors



Passive Sensors (Radiometry)



No modulation allows long and dynamic integration time

Source modulation needed for separation of ambient light, limiting detector integration time

HyperBb: Hyperspectral Single Angle Bb

Similar concept as other COTS single angle backscattering sensors (HOBI Labs HydroScat, WET Labs ECO-BB). Previous systems are multi-spectral using parallel channels.

HyperBb uses broadband source, monochromators on transmit and receive optics. Design backscattering centroid angle ~135° in water.

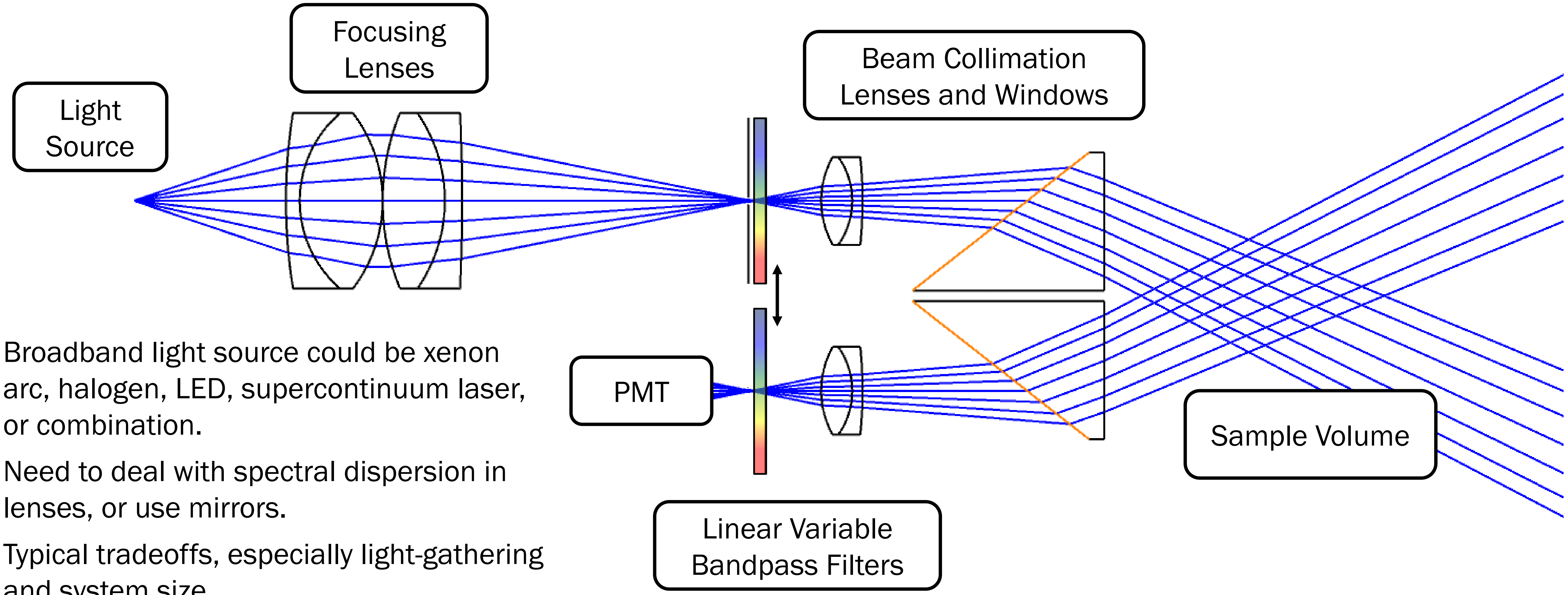
Original design employed halogen lamp with chopping wheel, now using neutral white LED with digital modulation. 420-700 nm.

Analog front end for demodulating received scattering signal. ~2kHz modulation. Photomultiplier tube for high performance and variable gain. LED power also variable.

Monochromators are linear variable bandpass filters. 8-18nm FWHM, arb. channels. Requires focusing and collimating optics in both transmit and receive sections.

HyperBb: Design Concept

Overview of “reference” design



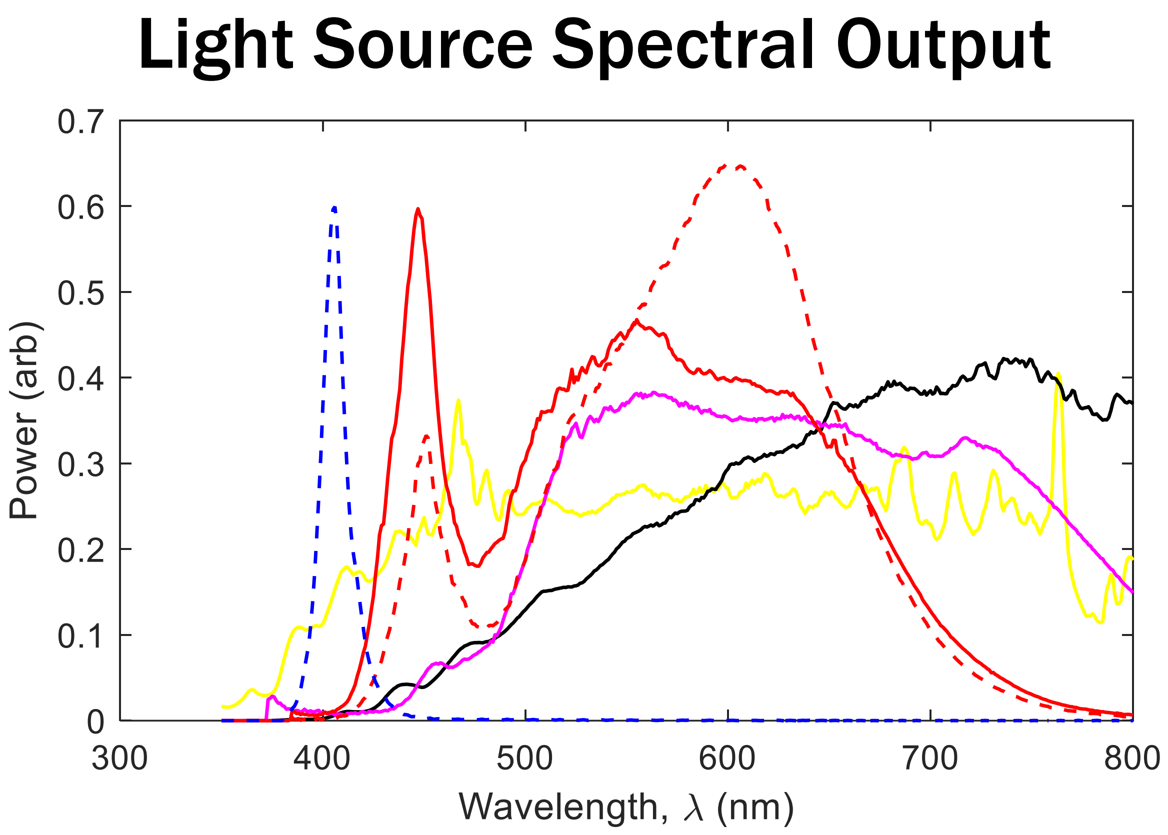
Broadband light source could be xenon arc, halogen, LED, supercontinuum laser, or combination.

Need to deal with spectral dispersion in lenses, or use mirrors.

Typical tradeoffs, especially light-gathering and system size.

Apertures to limit spot size on LVBP.
Receive and Transmit LVBPs translate together.
Translation driven by stepper motor, spectral channels are configurable.

Light sources are a major limitation for wider band sensors



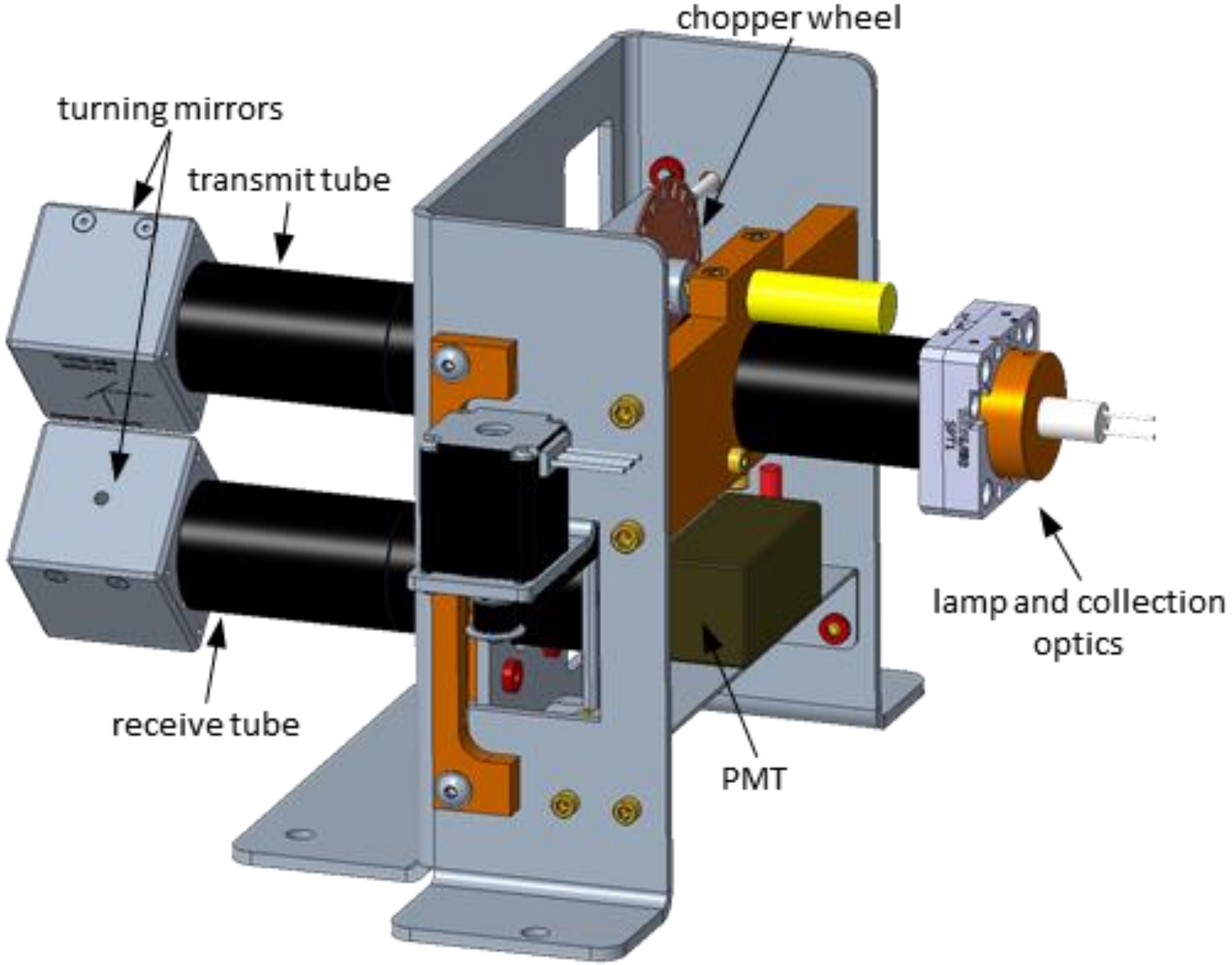
Halogen with cold mirror	Hot, inefficient, large source
Xenon arc	Difficult drive, stability issues
Neutral (warm) white LEDs	Long life, modulation, high power
Broadband white LED	Slow response, lower power
Blue 405nm LED	Combine with white for low blue?

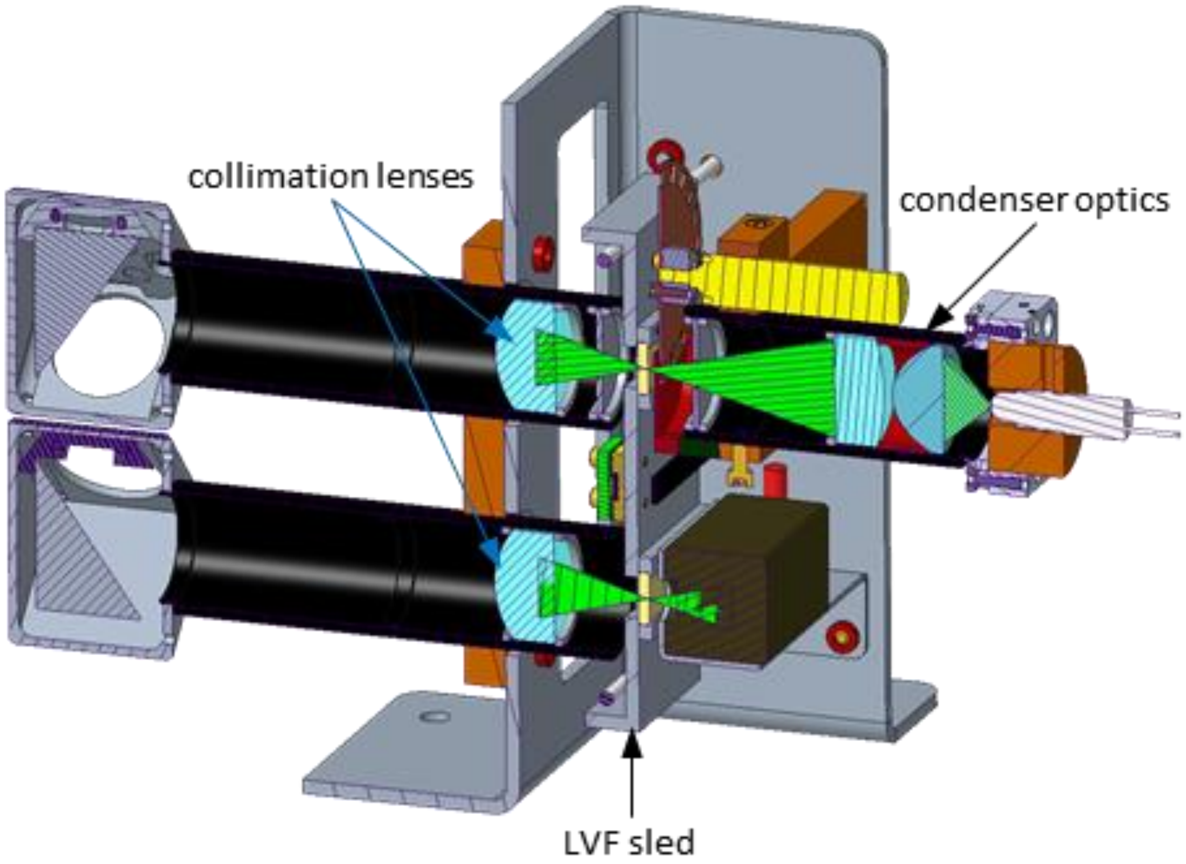
What is typically most limiting to design is spectral characteristic of light source.

Most sources weak in blue to UV. Can use more complicated optics with dichroic elements to combine sources.

Halogen, arc, and supercontinuum sources usually emit strongly into NIR and IR as well, wasting energy and adding heat.

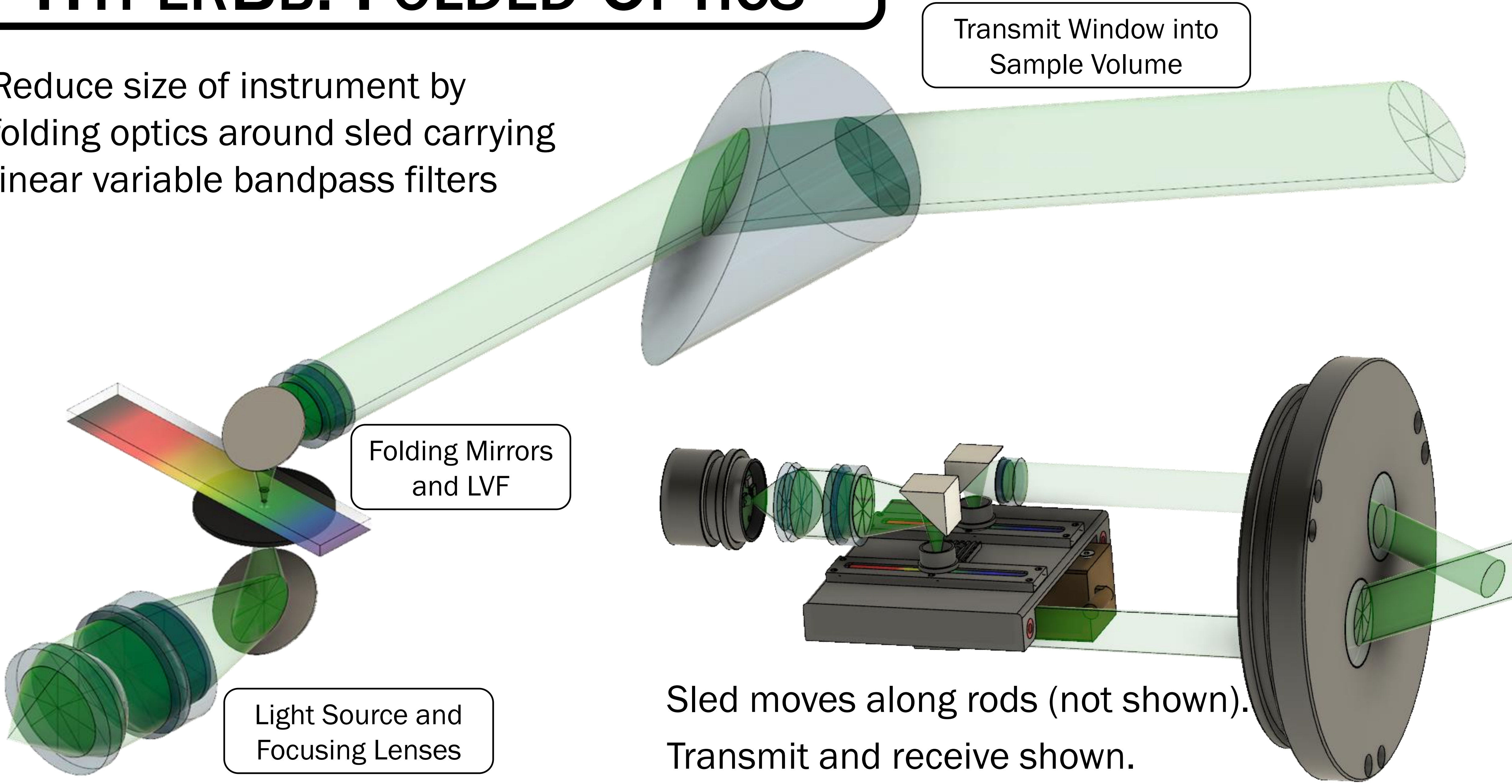
HyperBb: Benchtest Optics





HyperBb: Folded Optics

Reduce size of instrument by folding optics around sled carrying linear variable bandpass filters



Sled moves along rods (not shown).

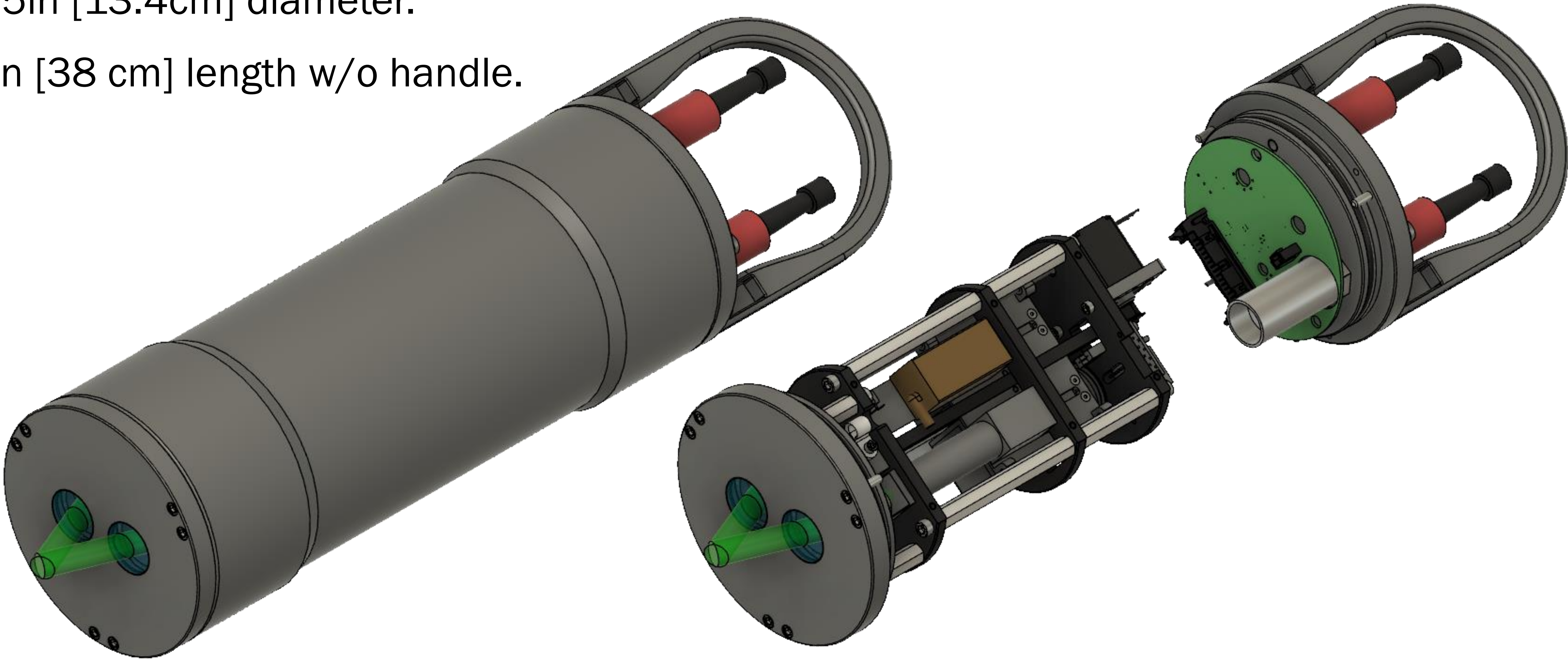
Transmit and receive shown.

HyperBb: Folded Optics

Self-contained instrument, externally powered.

~5.25in [13.4cm] diameter.

~15in [38 cm] length w/o handle.



HyperBb: Ongoing & Future Work

Finishing build of new folded optics prototype.
Lab characterization mid-April 2019, in-water testing starting end of April.

Characterization and calibration is ongoing, including reflective plaque and validation on bead suspension.

Additional work on auto-gain and sampling routines for faster sampling.
Spectral channels will be configurable (i.e., higher resolution in blue where higher variability is expected).

Prototype unit to NASA summer 2019.
Seeking additional collaboration for field testing (contact me).

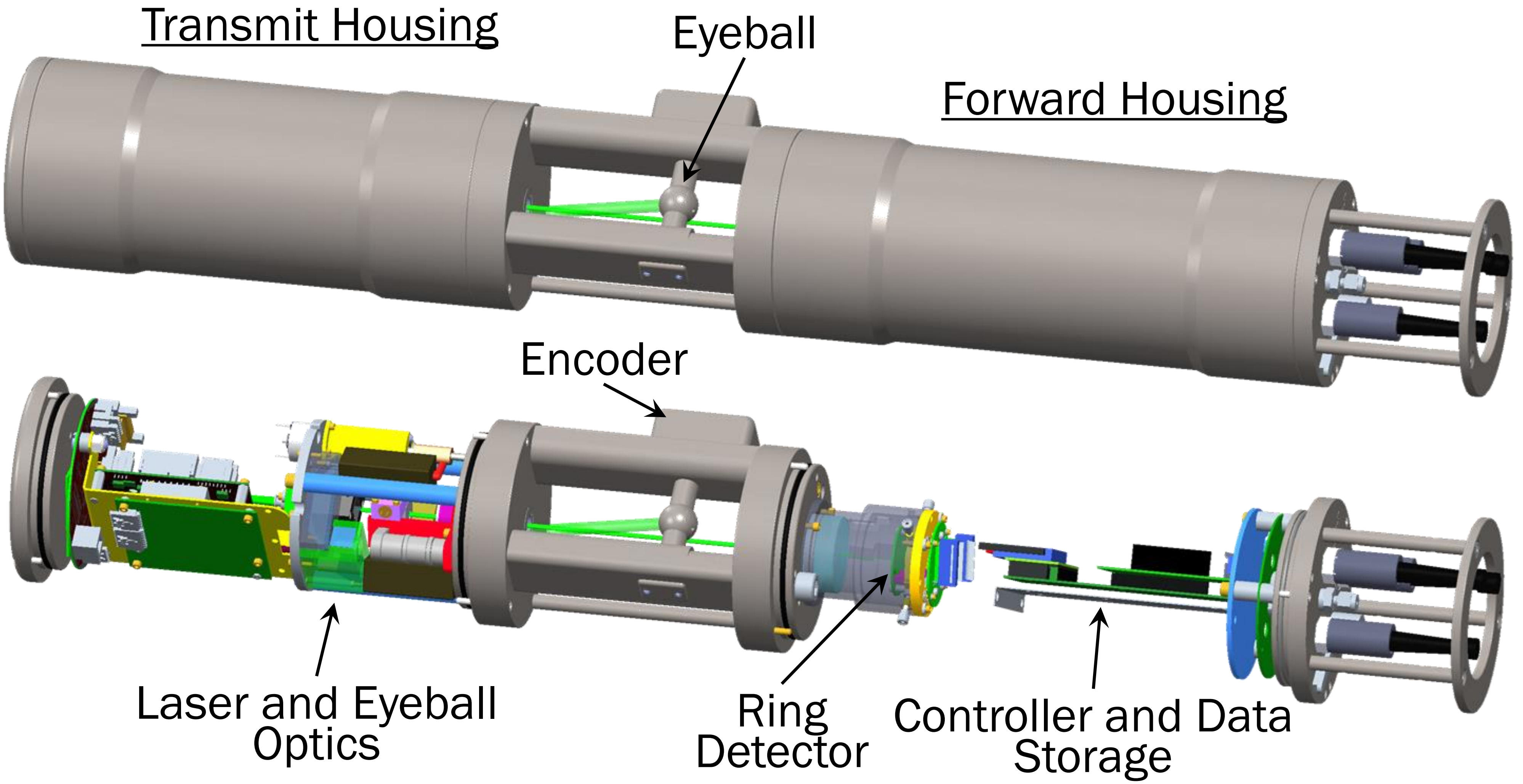
Expected commercial availability ~Q4 2019. Extending to lower blue?

LISST-VSF Overview

In situ instrument for measuring the volume scattering function and degree of linear polarization

- First commercially available, ~2011
- Agrawal NASA SBIR

LISST-VSF Instrument



LISST-VSF Instrument Optics

520nm diode laser, modulated

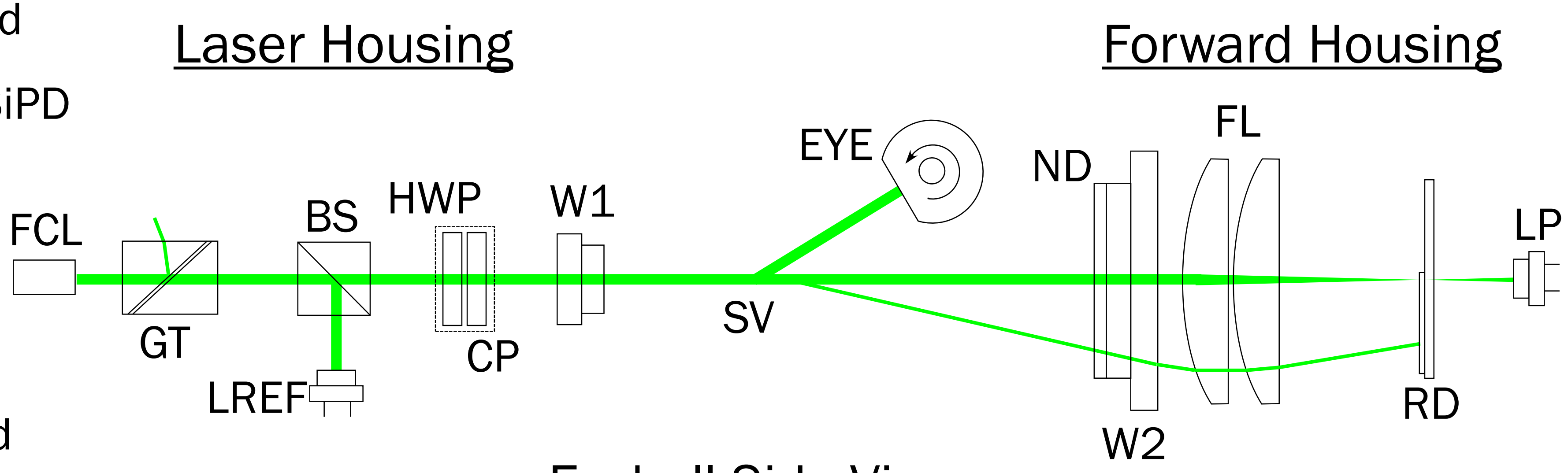
Beam-splitter and reference SiPD

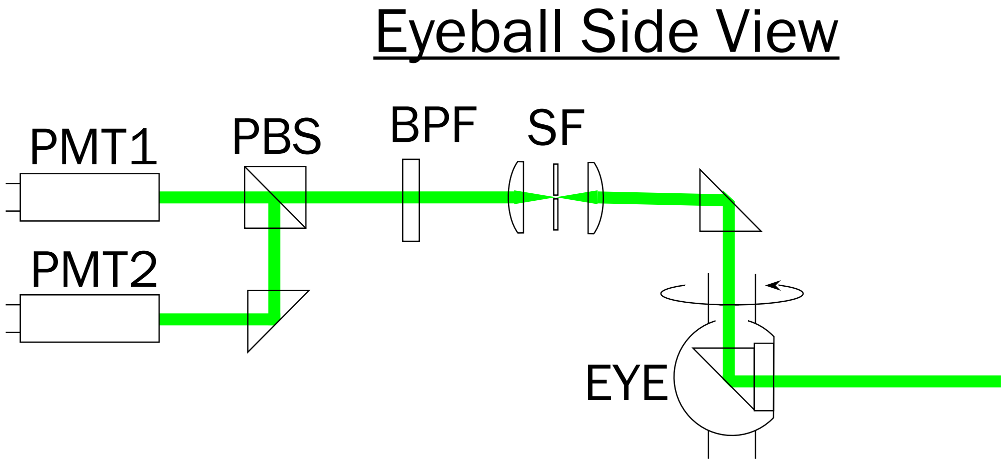
Half-wave plate for rotating polarization

Scattering in sample volume measured with LISST near-fwd optics and “eyeball”

Eyeball measurements are separated into linear pol components and measured with PMTs

Spatial-filter type optics used to limit eyeball FOV





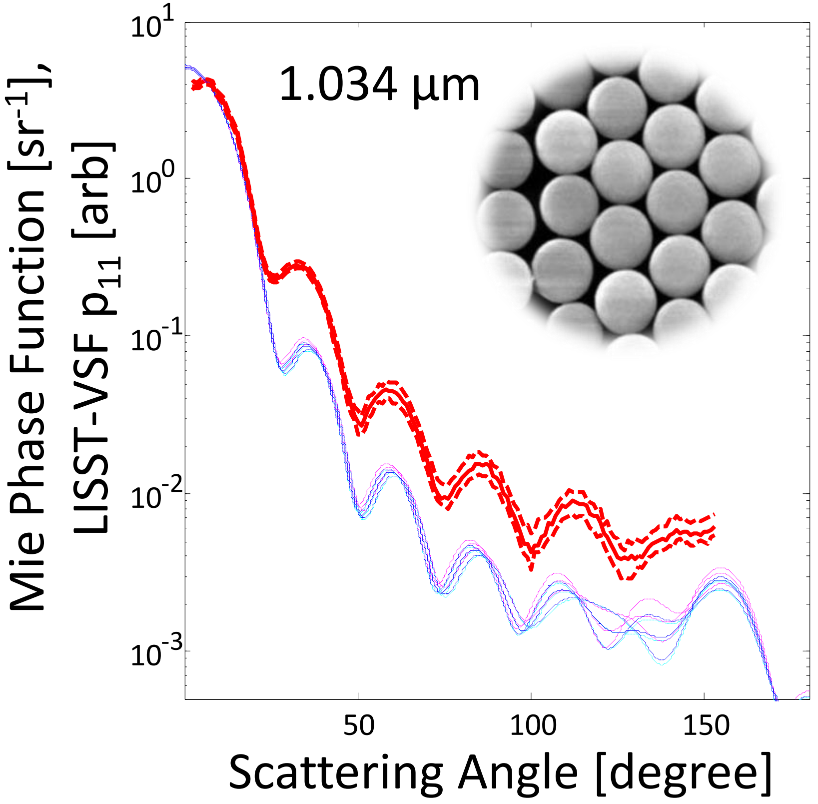
LISST-VSF Basic Operation

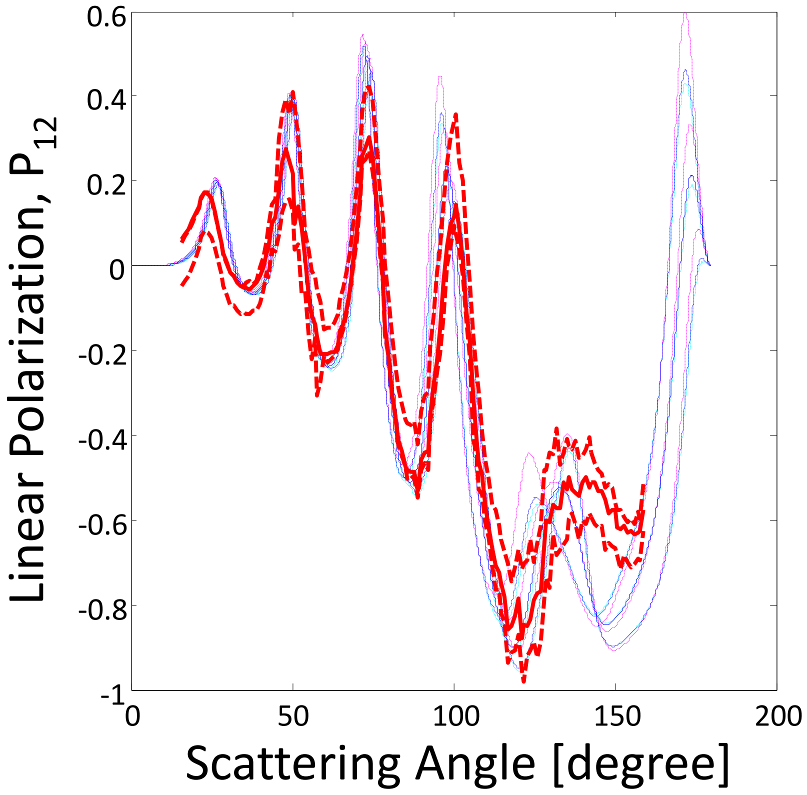
Eyeball scans VSF from approx. 10 to 160°, ring detectors measure VSF from approx. 0.1 to 15°, and the two are merged during processing

Eyeball rotates at ~1.5 sec/rot, two rotations are needed to get both incident polarizations → "set" of measurements

Rings and transmission are read while the eyeball is looking outside of the sample volume

LISST-VSF Measurements: Polystyrene Microspheres





Instruments in the wild...

See more recent data by LISST-VSF customers:

Koestner et al 2018 (UCSB/Stramski)

X. Zhang's lab (USM) in prep (lab+EXPORTS)

(both including field data)

Thoughts for IOP Discussion

How important is bb (and other IOP) in the UV? Going below 400 nm is a challenge.

Chi-factor variability. Issue with all single-angle sensors.
Still a major need for basic research to model & measure chi.

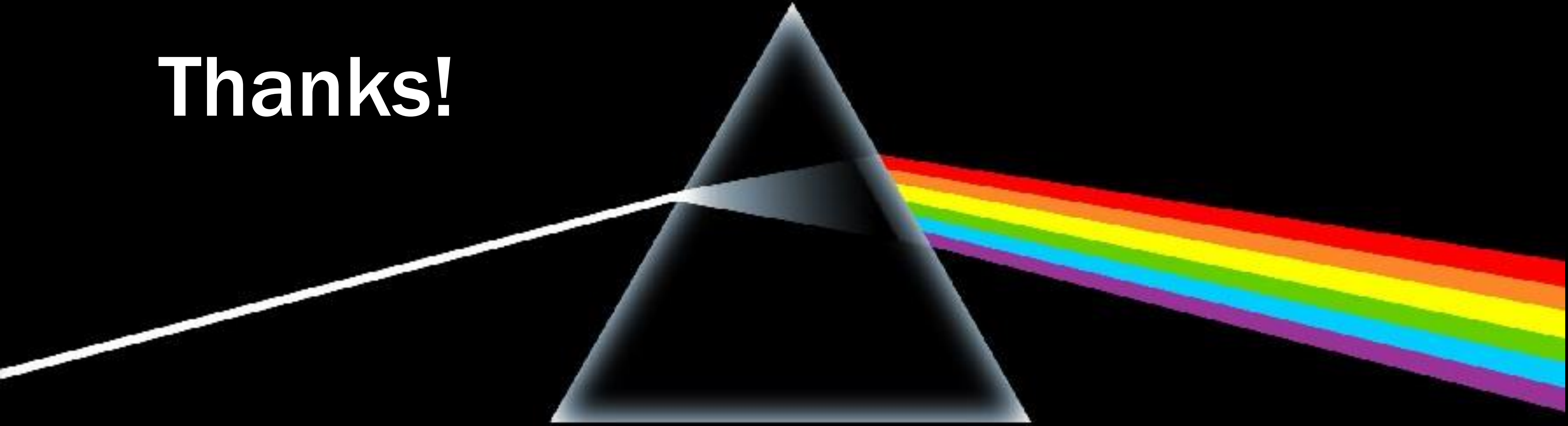
What we want is Hyper-Polarized-VSF that is cheap, doesn't disturb particle field. What is good enough?

What about instrumentation for validating lidar systems and polarimeters?

Instrumentation for UV-vis absorption that doesn't require scattering correction.

Added complexity in wide-band instruments → higher cost and limited market in ocean color. This is a difficult prospect for small companies.

Thanks!



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