Detailed Characterization of Aerosol Scattering Properties

(Polarimeter Capabilities Theory and Instruments)

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2- NASA GSFC

Holistic Aerosol Characterization Approach

- Laboratory generation and characterization
  - Natural
  - Artificial particles
- In situ measurements
  - Ground Based
  - Aircraft

Produce a database of aerosol particle scattering (and spectral absorption) properties with different particle size, shape, composition

- Remote Sensing
  - Aircraft
  - Satellite

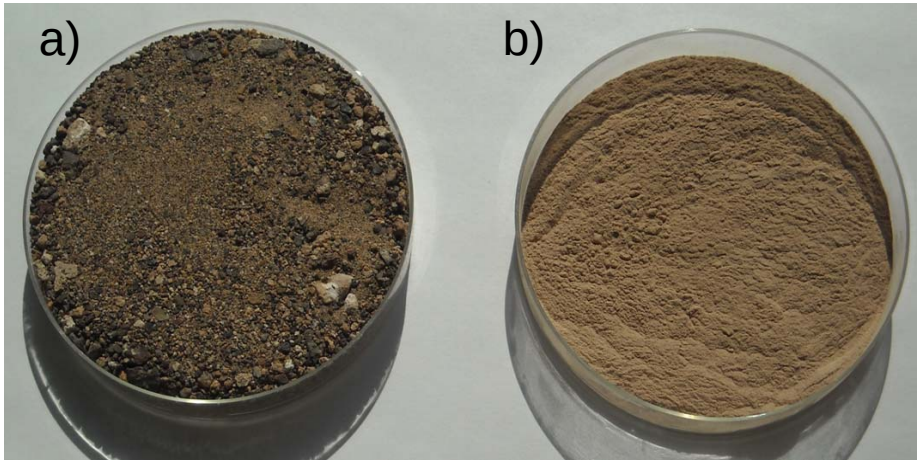
Develop instrumentation and Methods for the polarized hyper-angular measurement of aerosol and cloud particles.

Dry Aerosol Generation:

LACO
Laboratory for Aerosol, Clouds and Optics

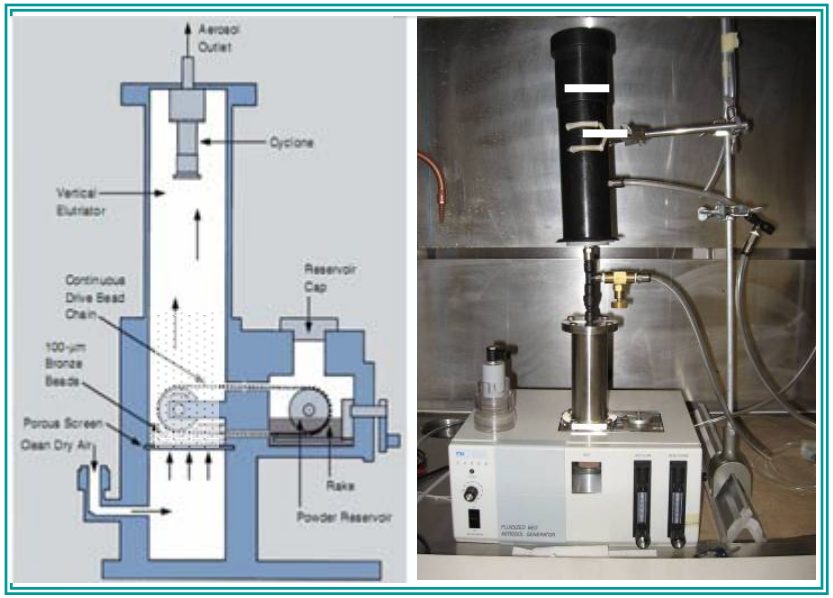
UMBC
AN HONORS UNIVERSITY IN MARYLAND

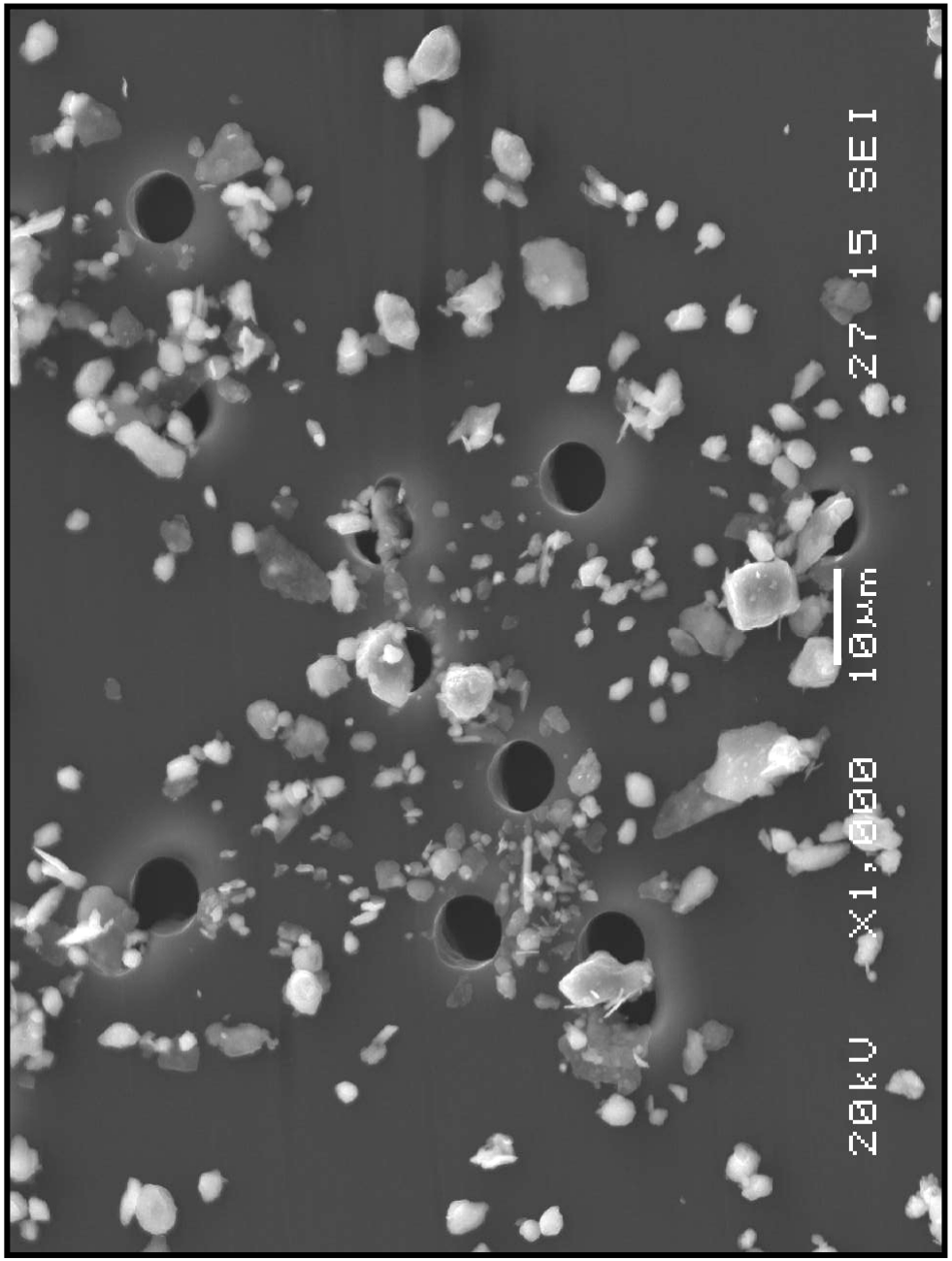
Dust – Collected at UMBC.



Before a) and after b) sieving: particles < 43mm.

FBAG – Fluidized Bed Aerosol Generator

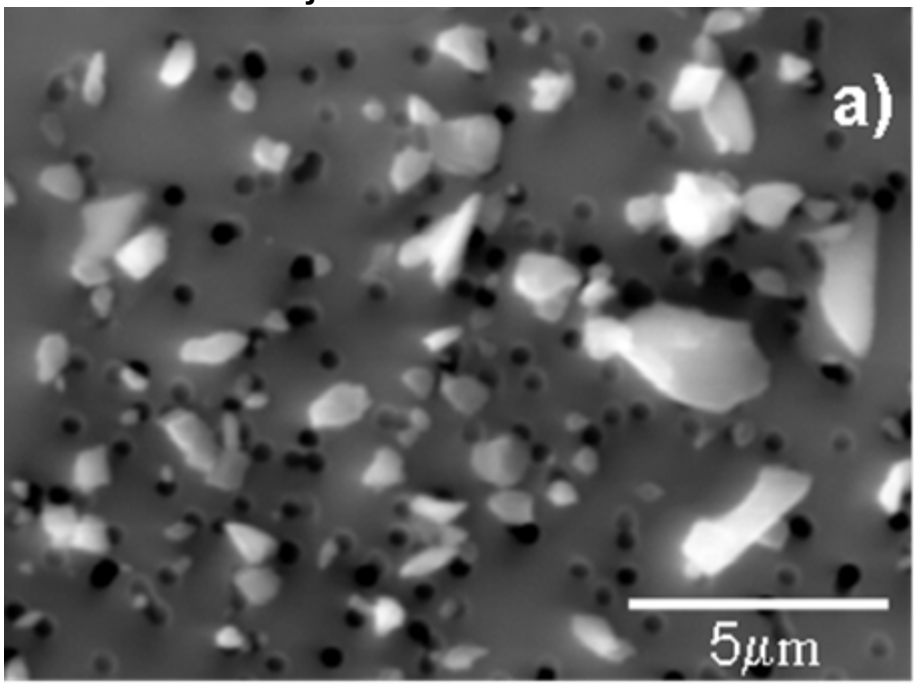




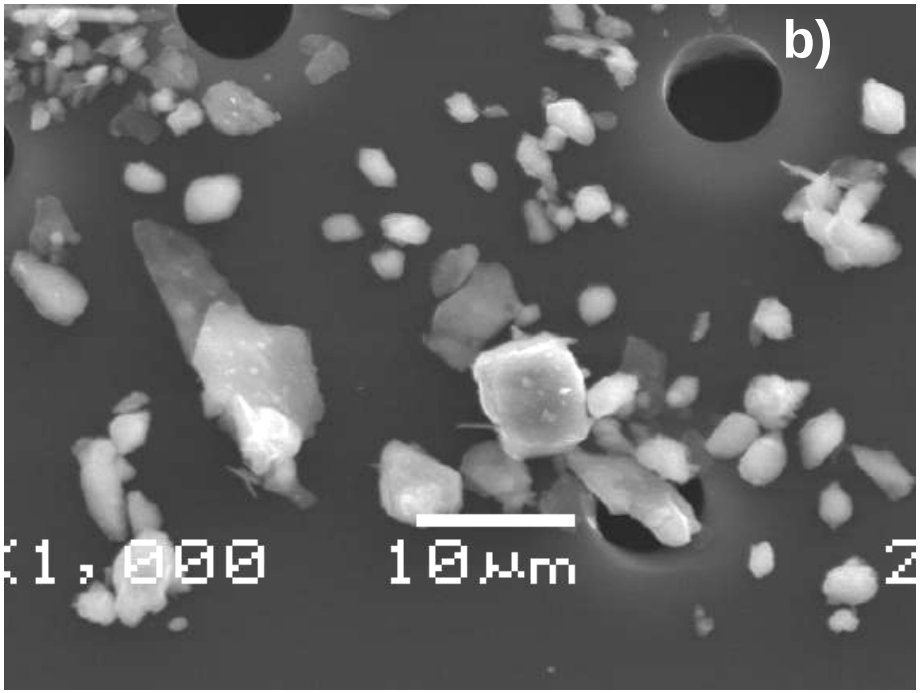
Dry Aerosol Generation

Solid Material » De-agglomeration/Re-suspension » Dry/Humidified aerosols:

Volcano Eija 2010



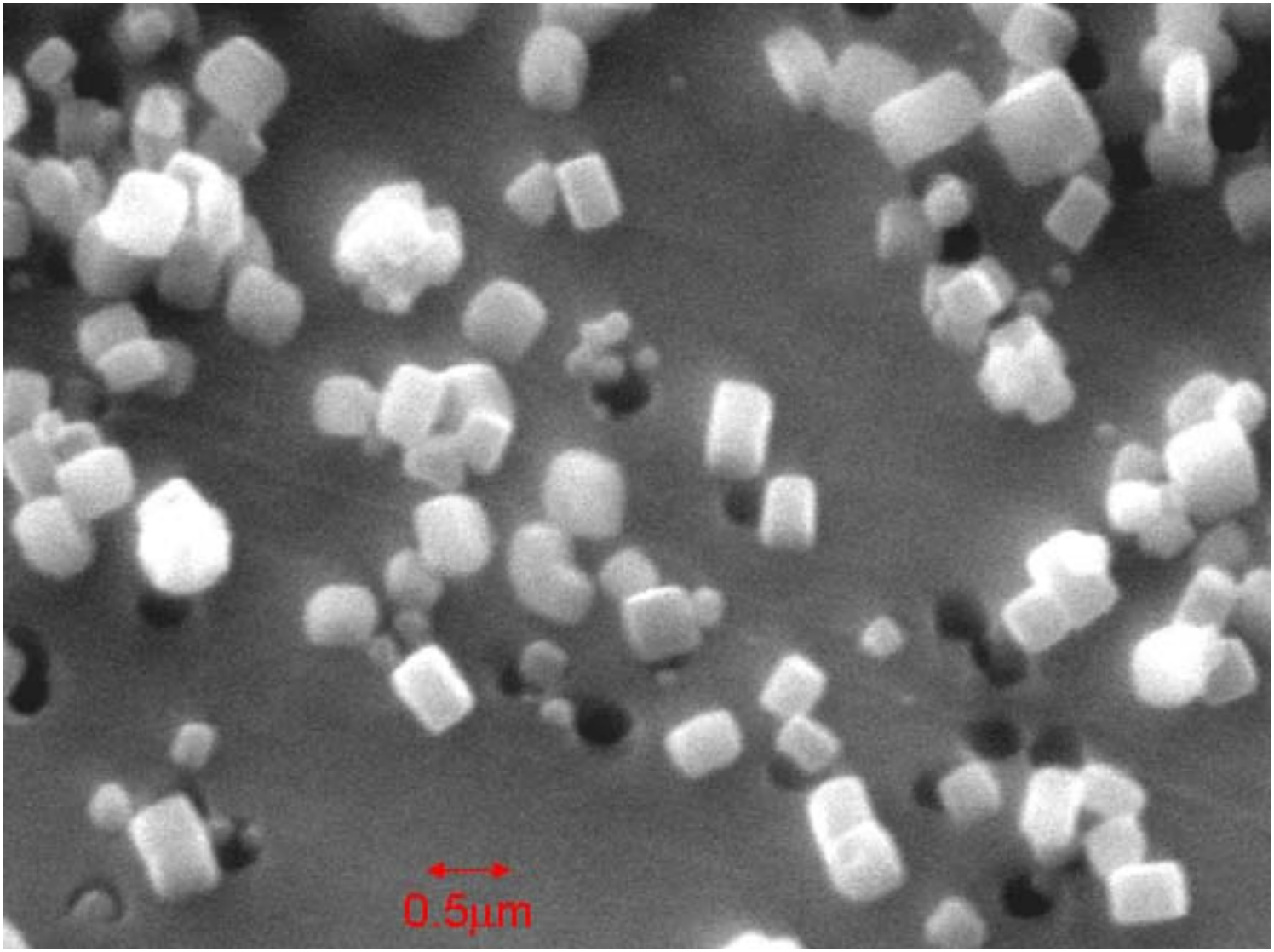
UMBC Dust



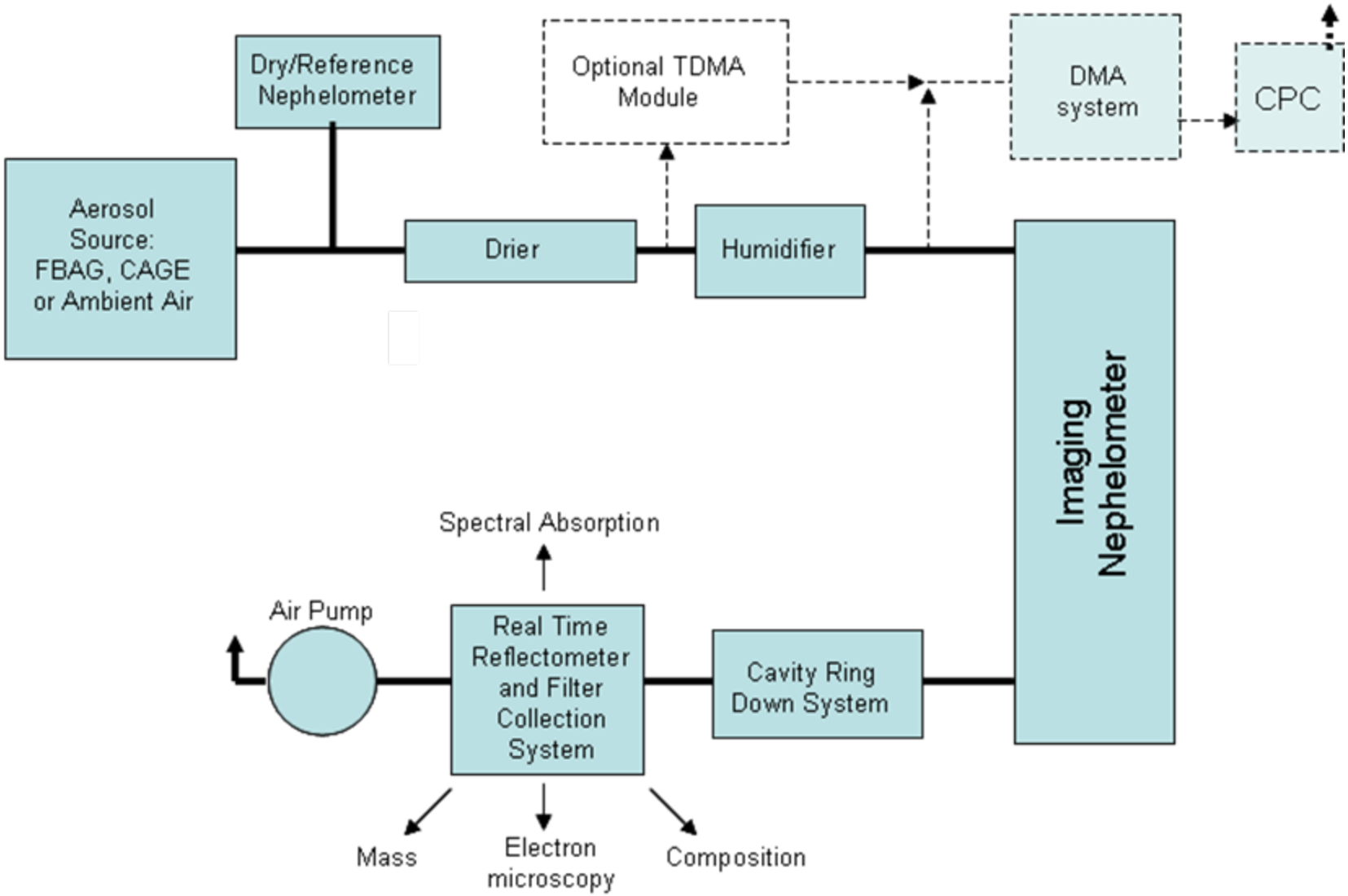
Wet and Dry Aerosol Generation

Chemical solutions » Water Droplets » dry/humidified aerosols

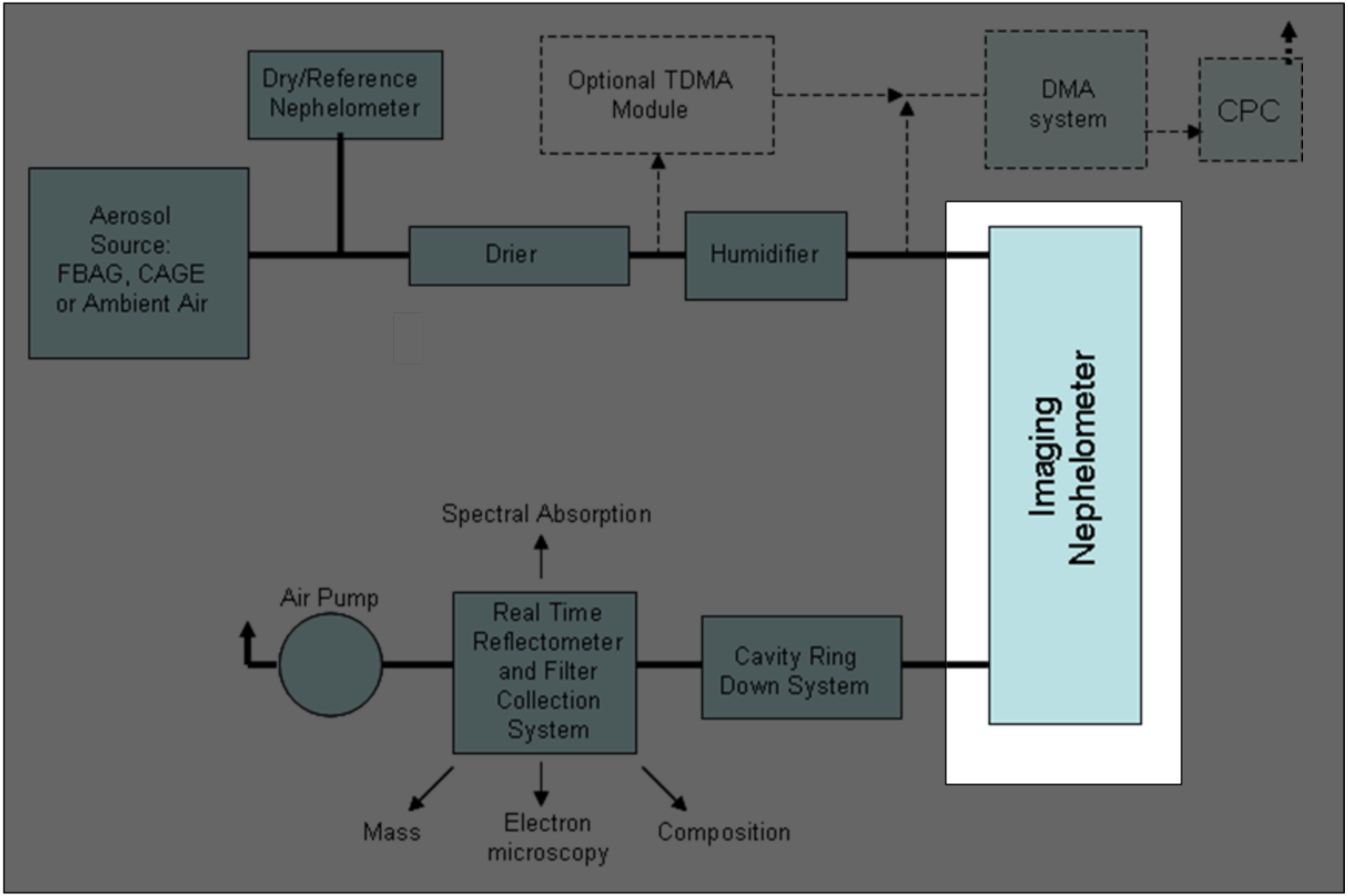
Cubic NaCl Particles



Detailed Aerosol Scattering Properties:



Detailed Aerosol Scattering Properties:

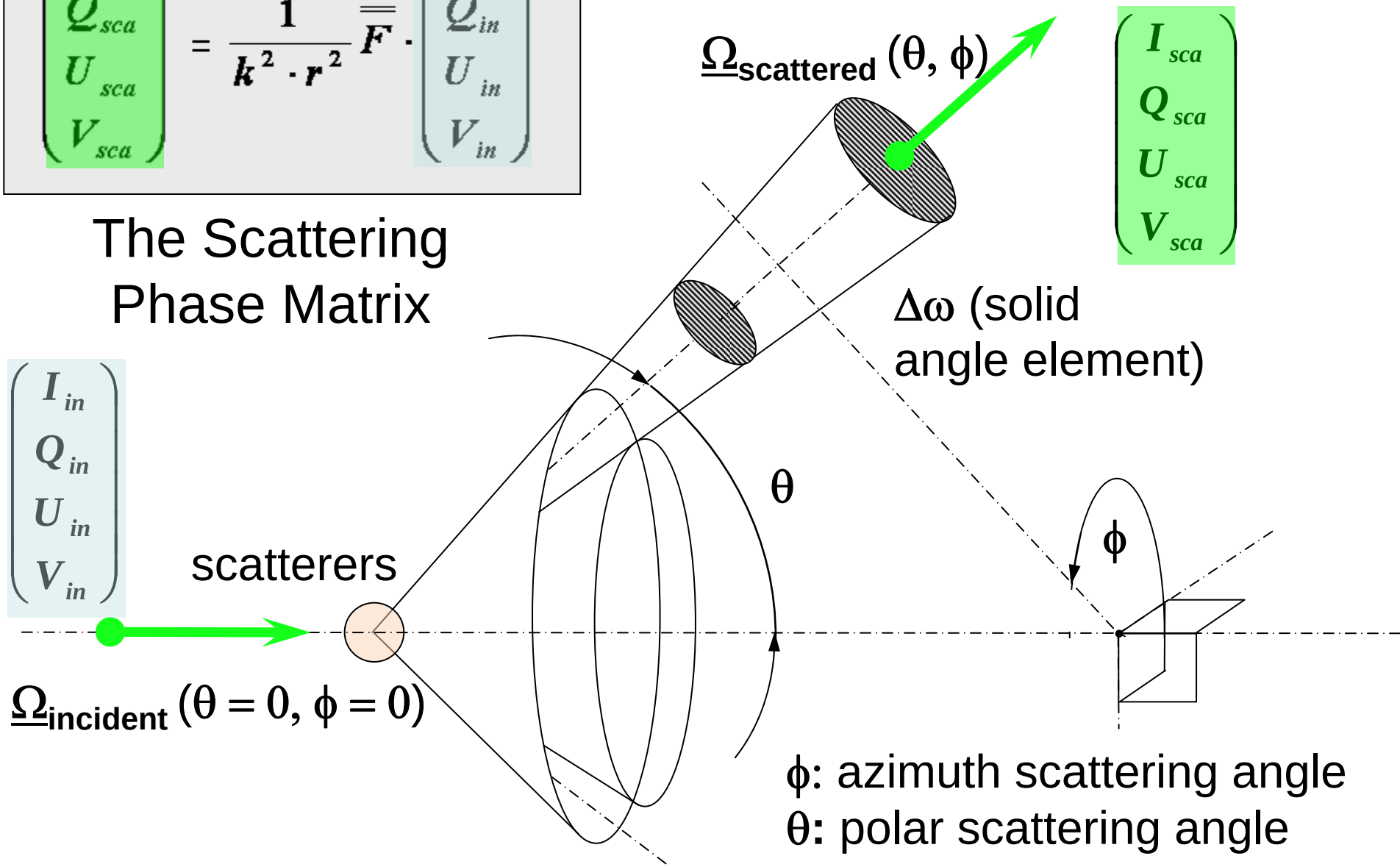


Polarized Imaging Nephelometer

- Funded as part of the Langley DEVOTE project
  - Develop a Polarized Imaging (Polar) Nephelometer system to characterize the angular distribution of light scattering by aerosol particles
  - Demonstrate these measurements inside the Langley B-200 aircraft
- As part of the Glory project we plan to Extend the PI-Neph application by characterizing laboratory and in-situ particles on the ground and aircraft

$$\begin{pmatrix} I_{sca} \\ Q_{sca} \\ U_{sca} \\ V_{sca} \end{pmatrix} = \frac{1}{k^2 \cdot r^2} \overline{\overline{F}} \cdot \begin{pmatrix} I_{in} \\ Q_{in} \\ U_{in} \\ V_{in} \end{pmatrix}$$

The Scattering Phase Matrix



ϕ: azimuth scattering angle
θ: polar scattering angle

Polarized Imaging Nephelometer

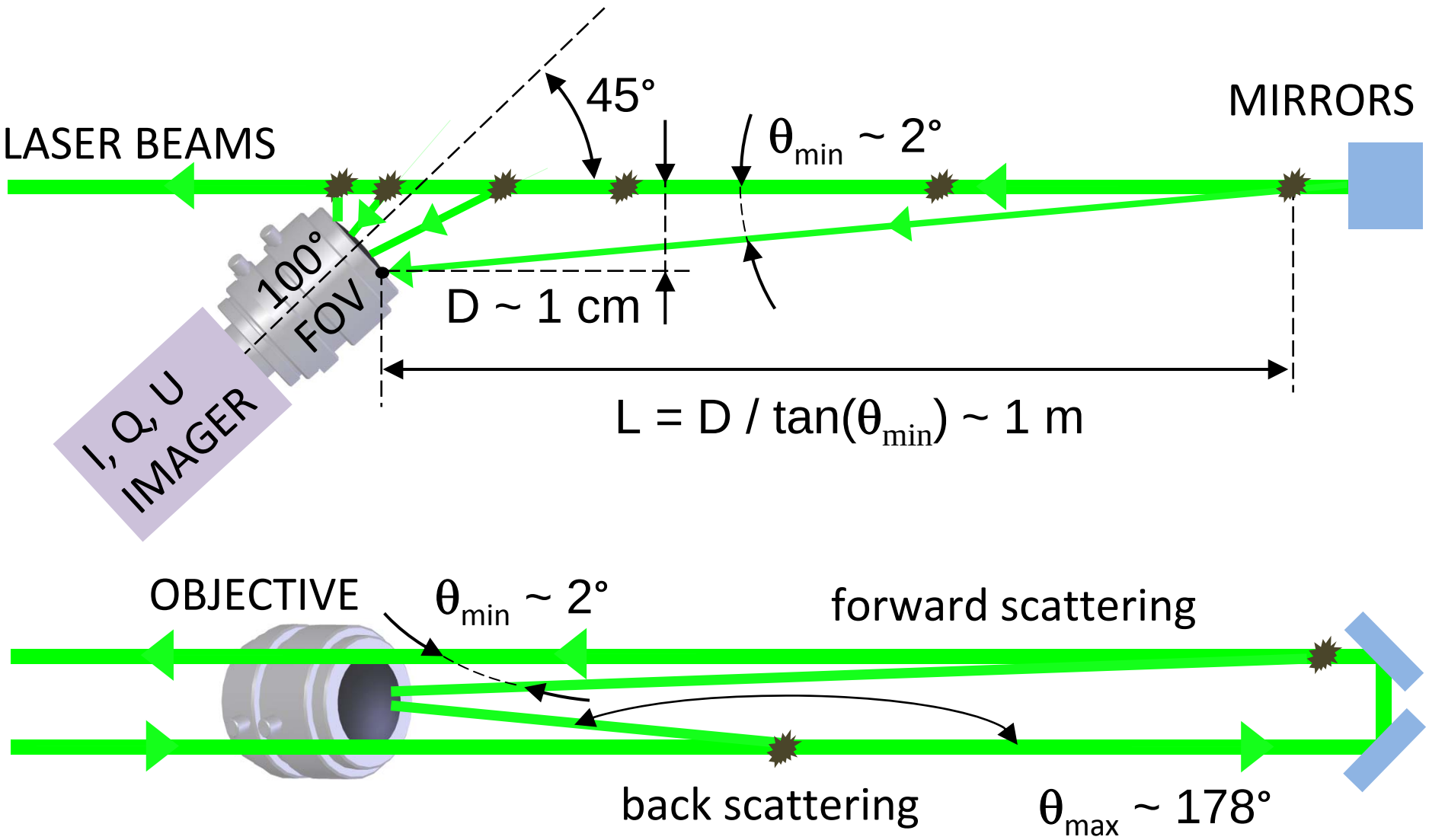
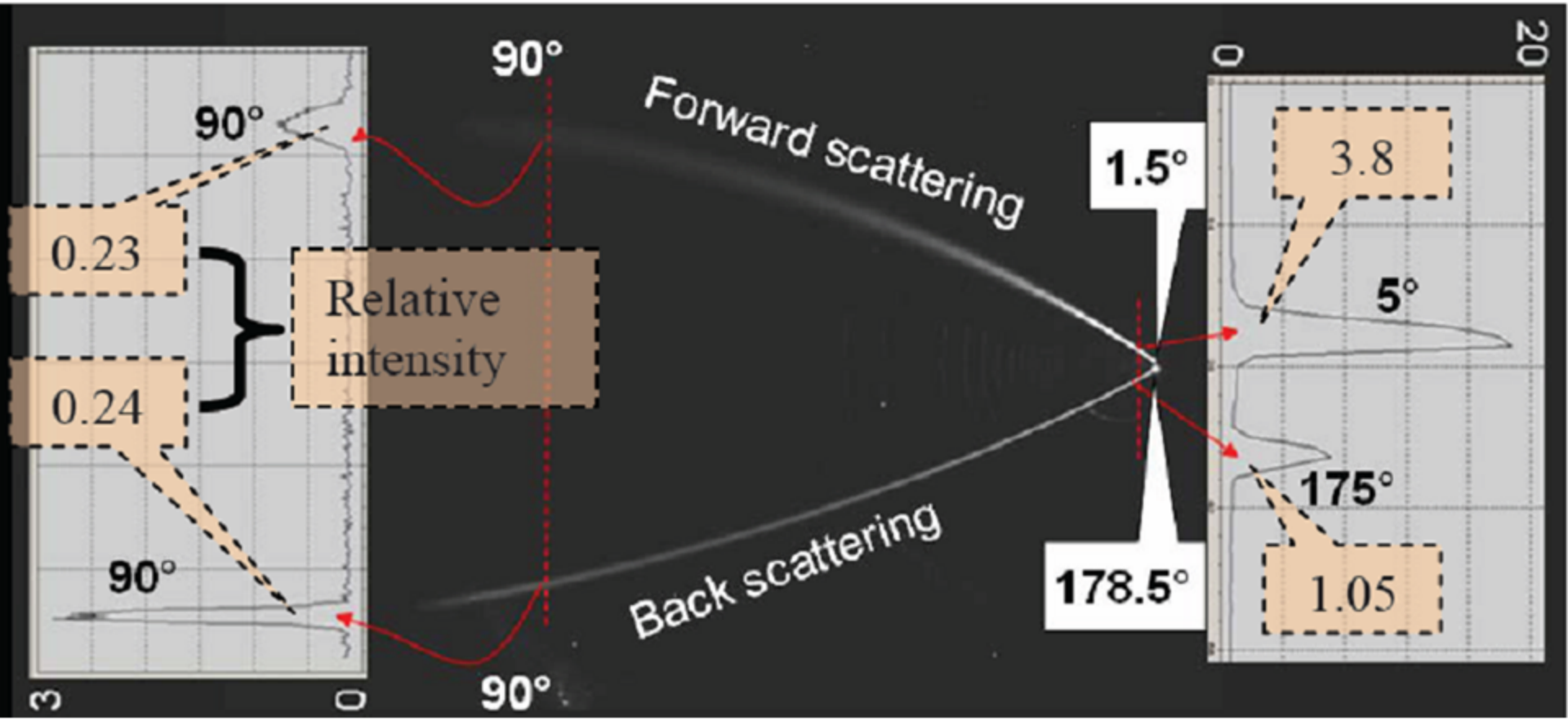
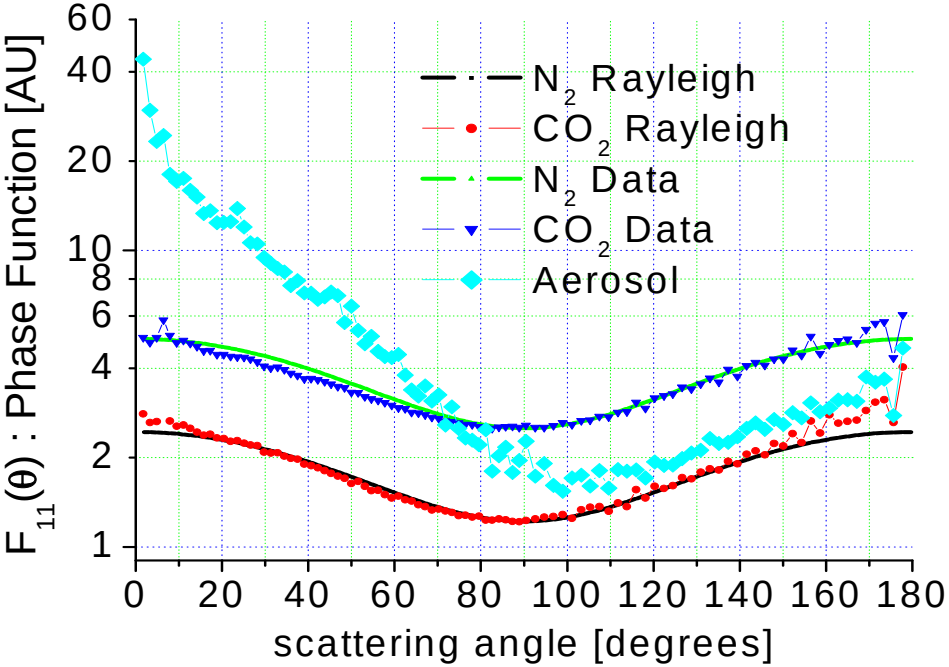


Image Data Reduction

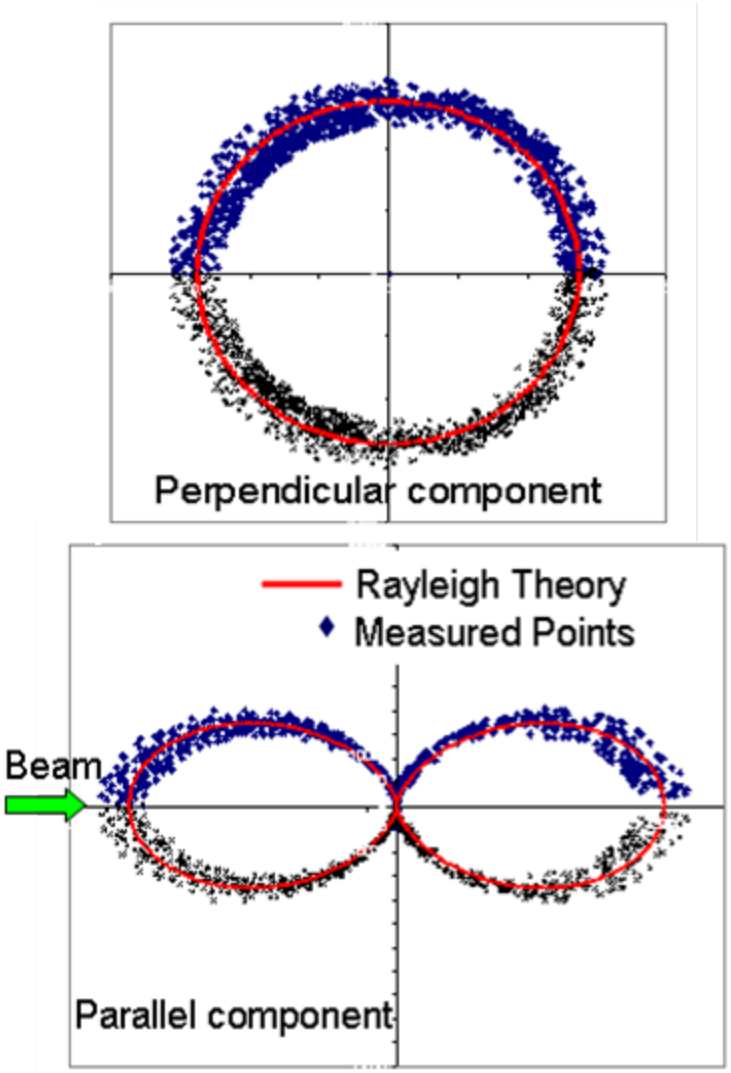


LACO PI-Neph Prototype

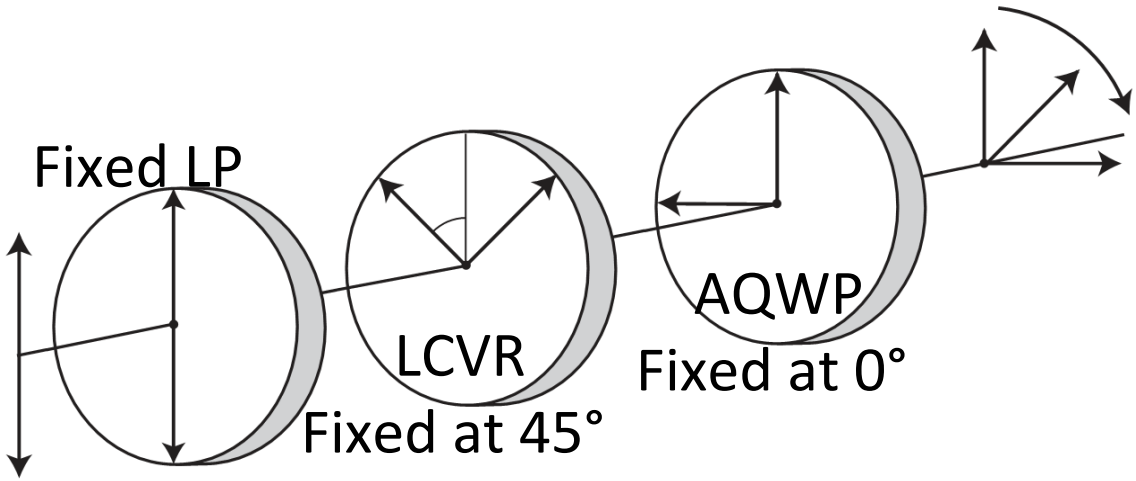
F11 Raw Data:



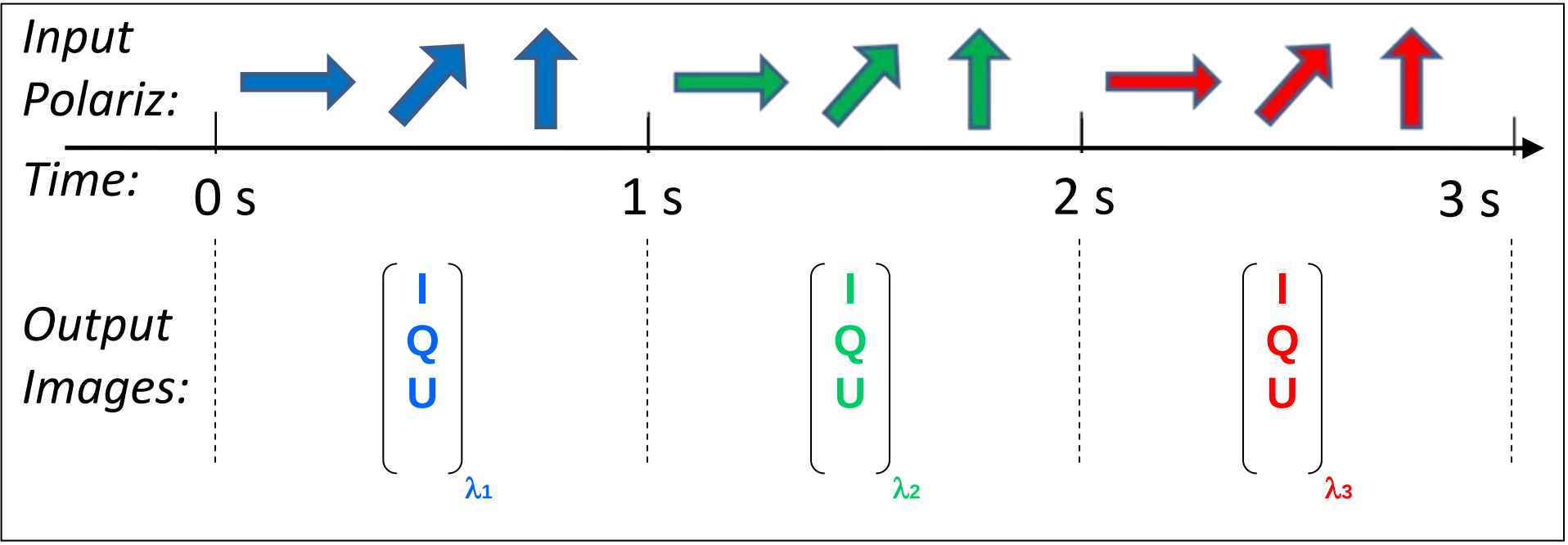
Polarized Phase Function:



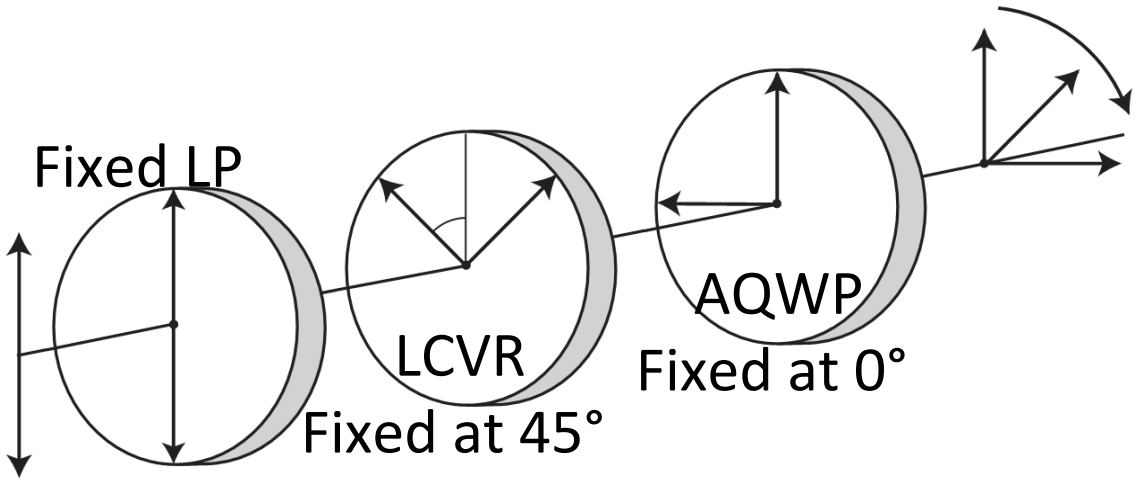
Setup 1: Polarized beam + 1 Unpolarized Camera: Rotate & measure scattering at each wavelength



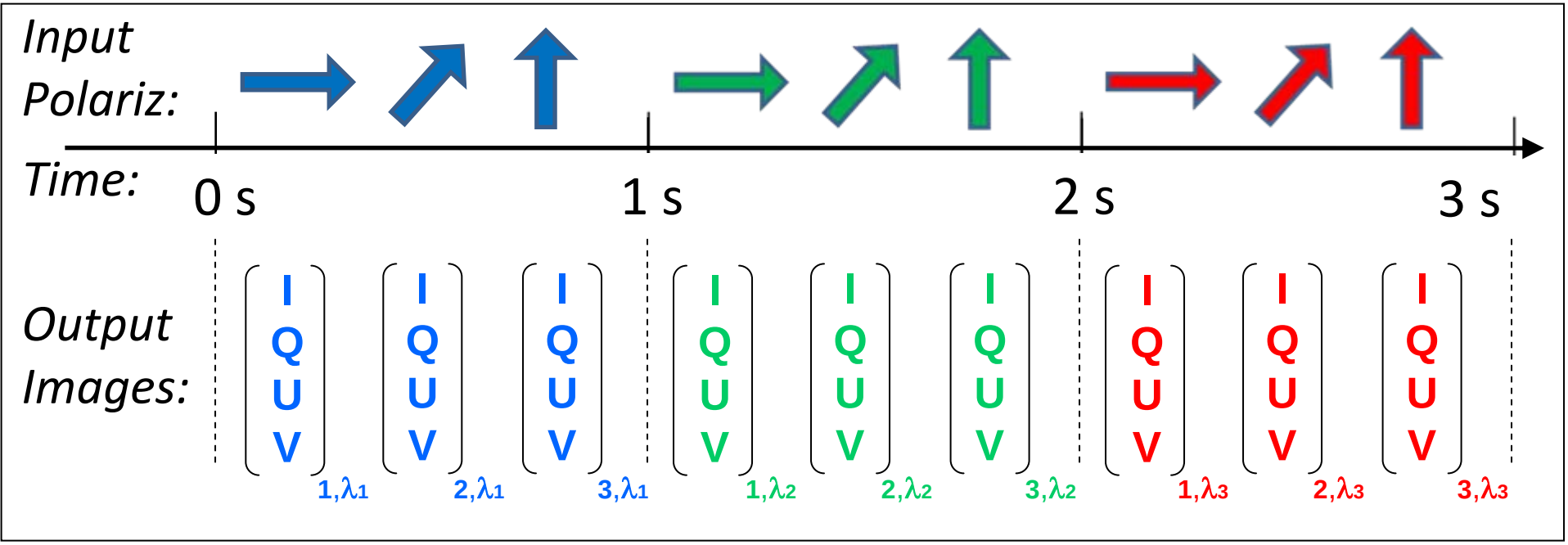
$$\begin{pmatrix} I_{in}(\Psi_i) \\ Q_{in}(\Psi_i) \\ U_{in}(\Psi_i) \\ V_{in}(\Psi_i) \end{pmatrix} = \overline{S_{in}^{i}}$$

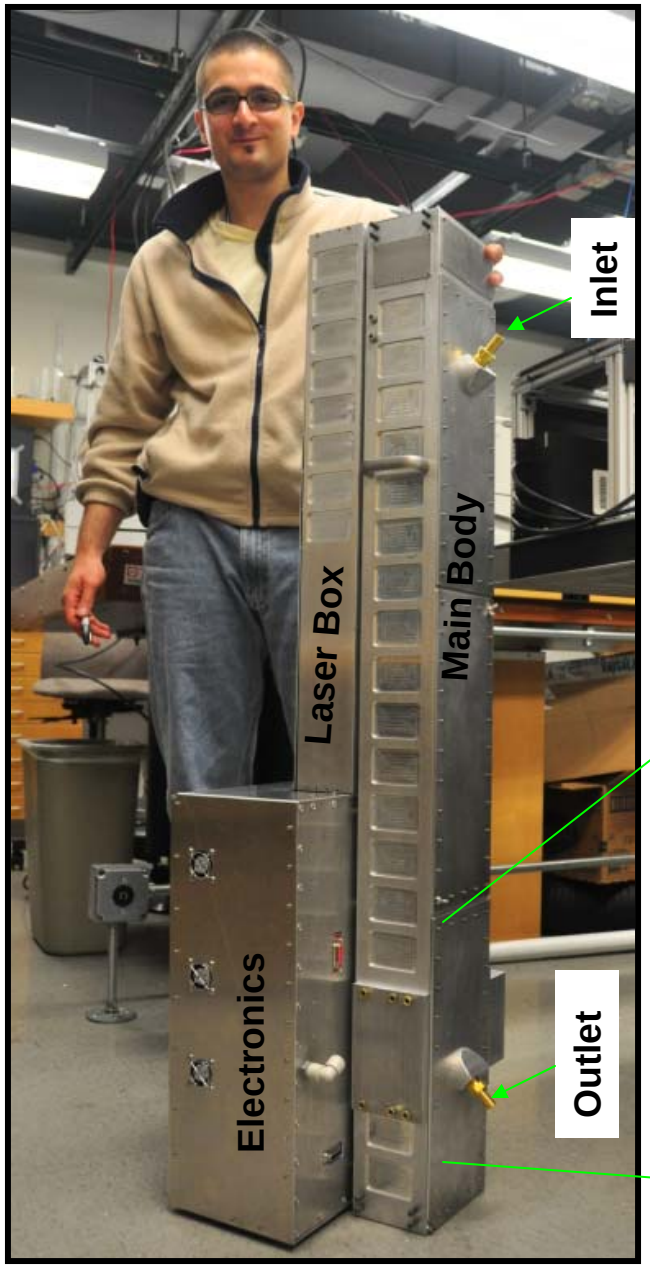


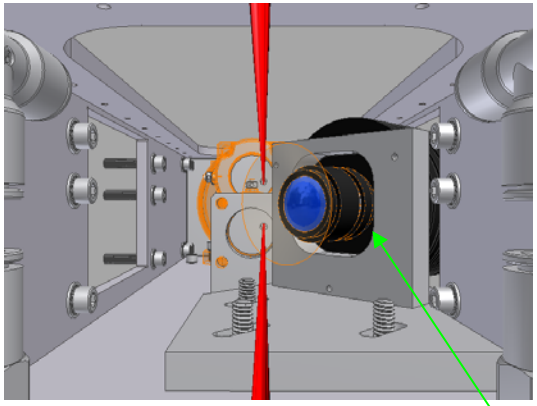
Setup 2: Polarized beam + 4 Polarized Cameras: Rotate & measure scattering at each wavelength

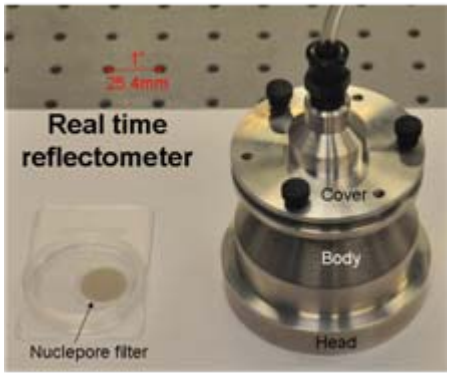


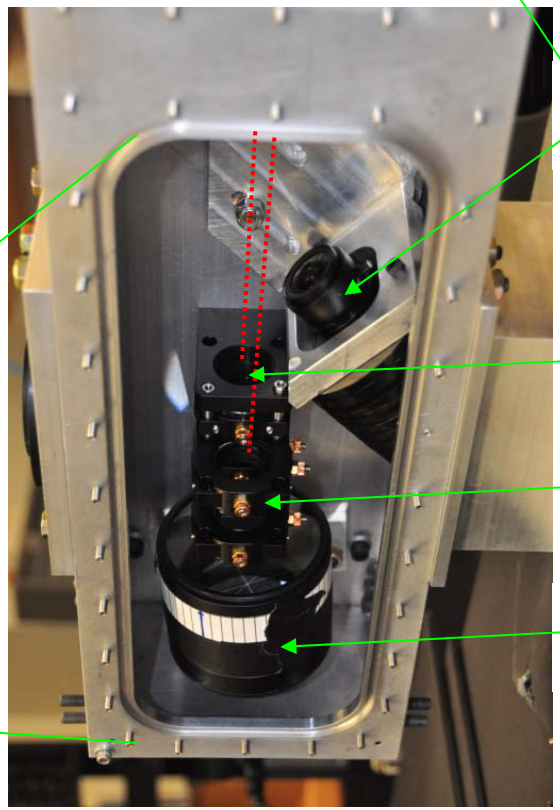
$$\begin{pmatrix} I_{in}(\Psi_i) \\ Q_{in}(\Psi_i) \\ U_{in}(\Psi_i) \\ V_{in}(\Psi_i) \end{pmatrix} = \overline{S_{in}^{i}}$$











Scattering Camera

Laser beams

colimators

Retro-reflector

Currently testing in the Lab – plan to integrate to NASA Langley Aircraft Sept/11

Alternatives for Polarized Remote Sensing Measurements

HARP (or PACS) – Hyper-angular Rainbow Polarimeter

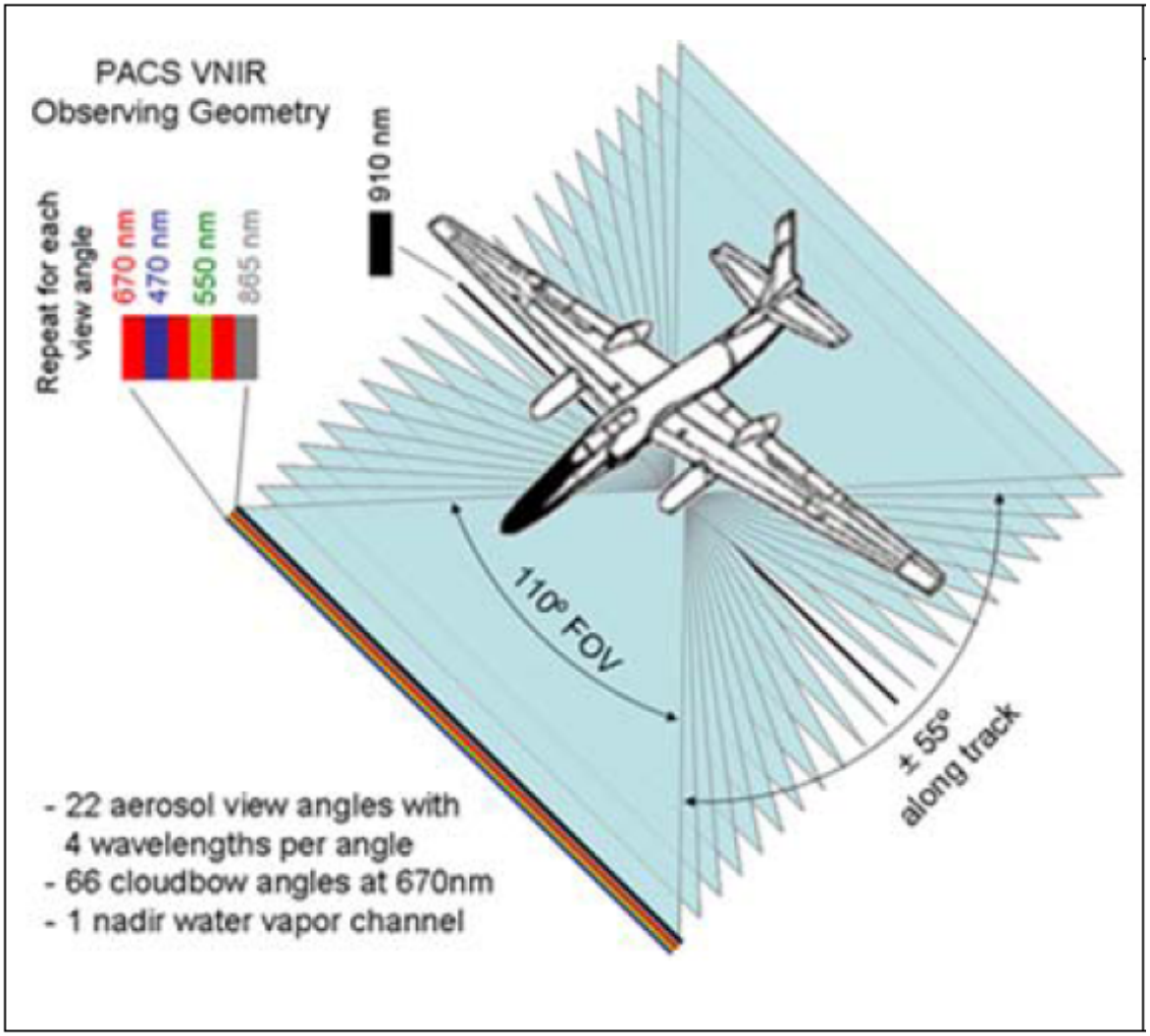
PACS/HARP Imaging Polarimeter

PACS ER-2 Facts:

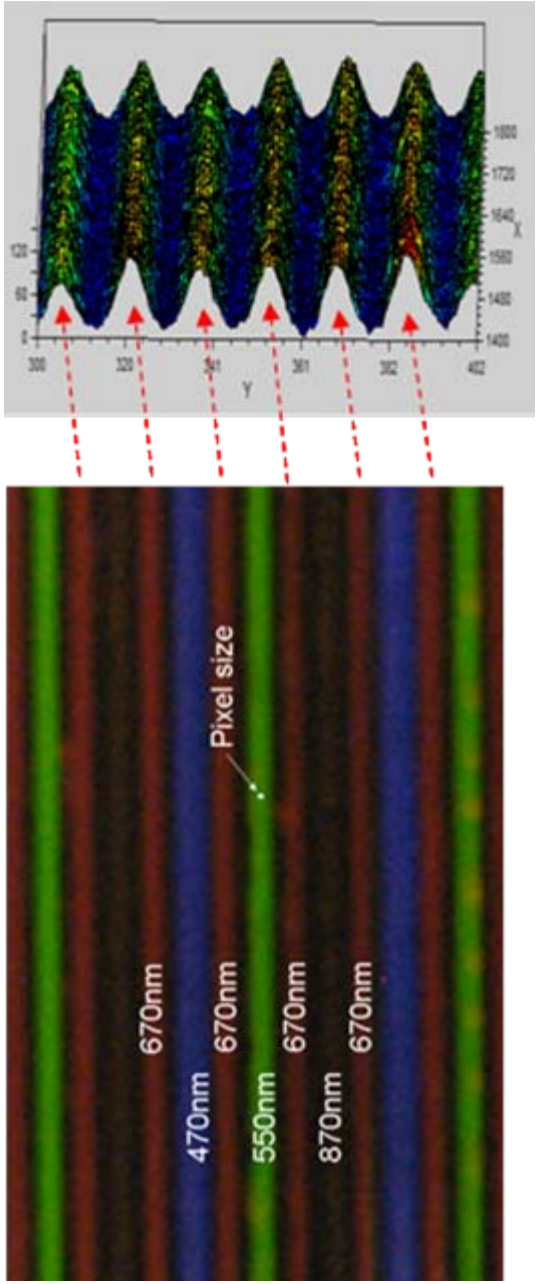
- Ground Resolution = 37m
- Swath = 37Km
- 470, 550, 670, 865, 910 nm
- 1K pixels x-track
- 22 aerosol angles
- 66 cloudbow angles at 670nm
- 110º FOV x-track
- +/-55º along-track

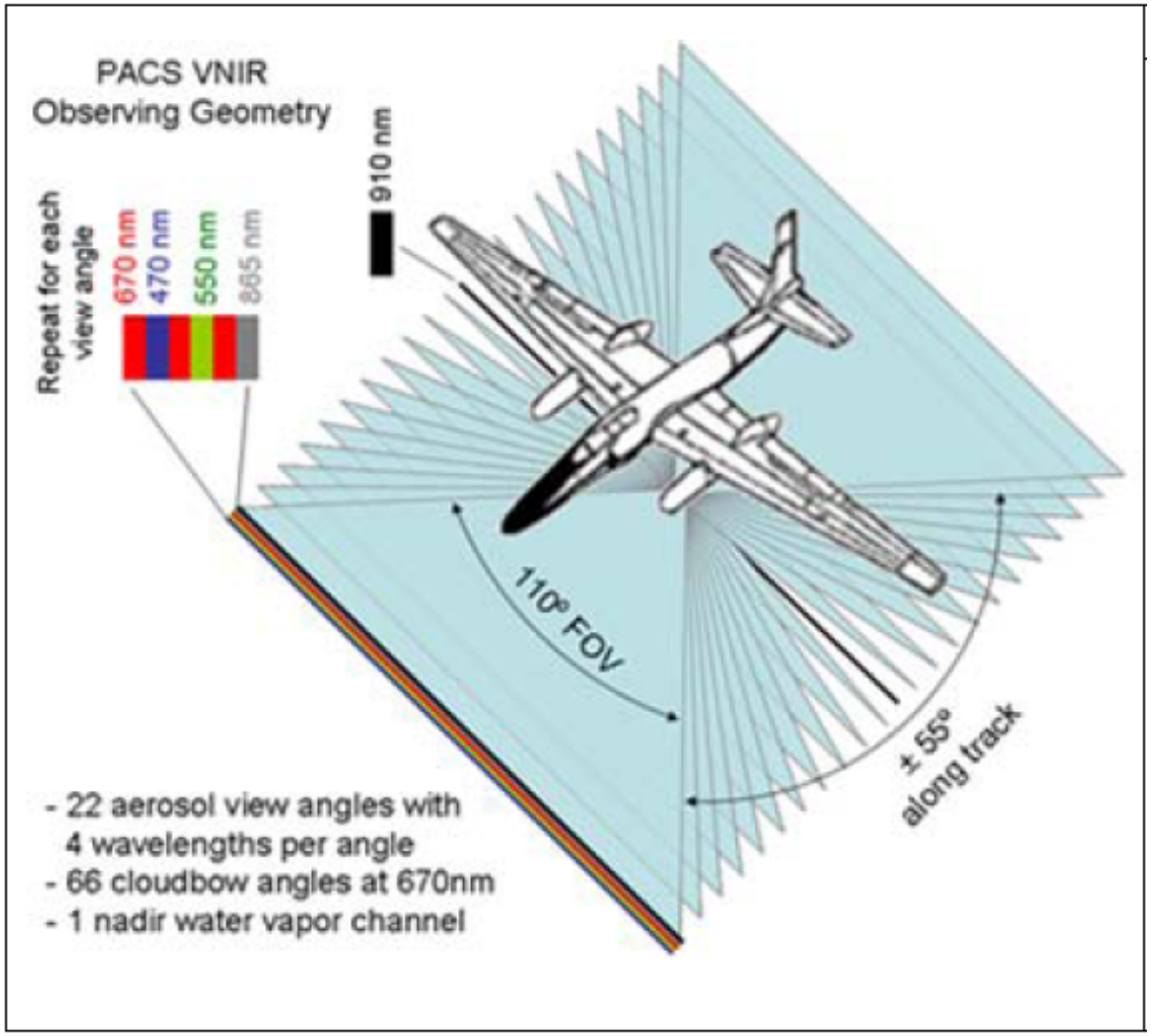
Goal:

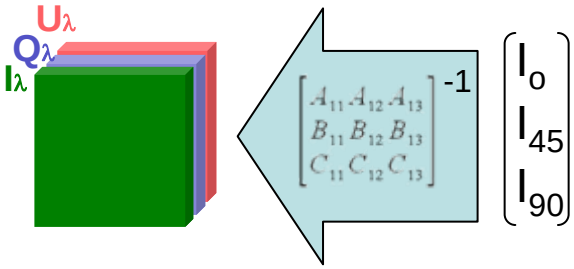
- SWIR Imager at 1650, 2130, 2250nm; 320x256 pixels, adjustable FOV
- System designed for the wing Super-Pod fore body. Other options are available requiring some modification



PACS/HARP Imaging Polarimeter

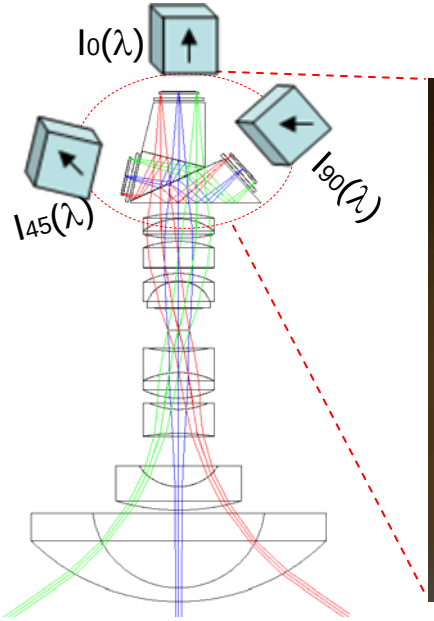


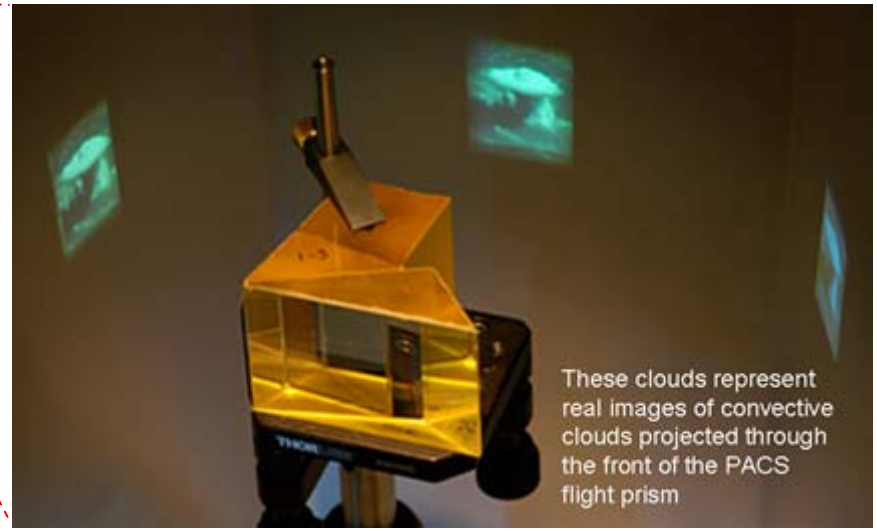


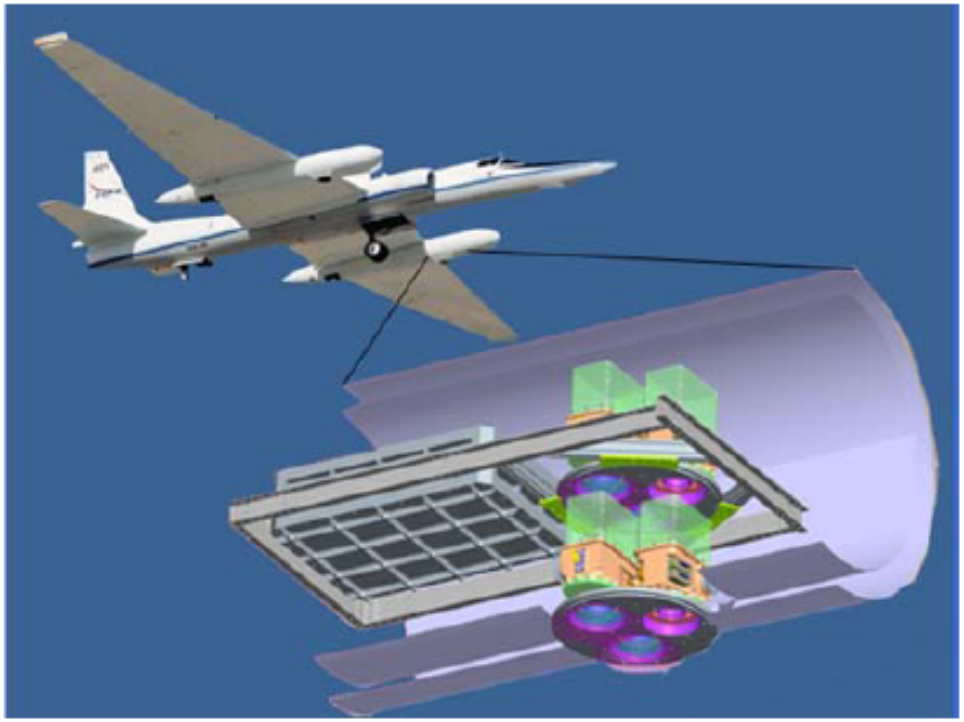


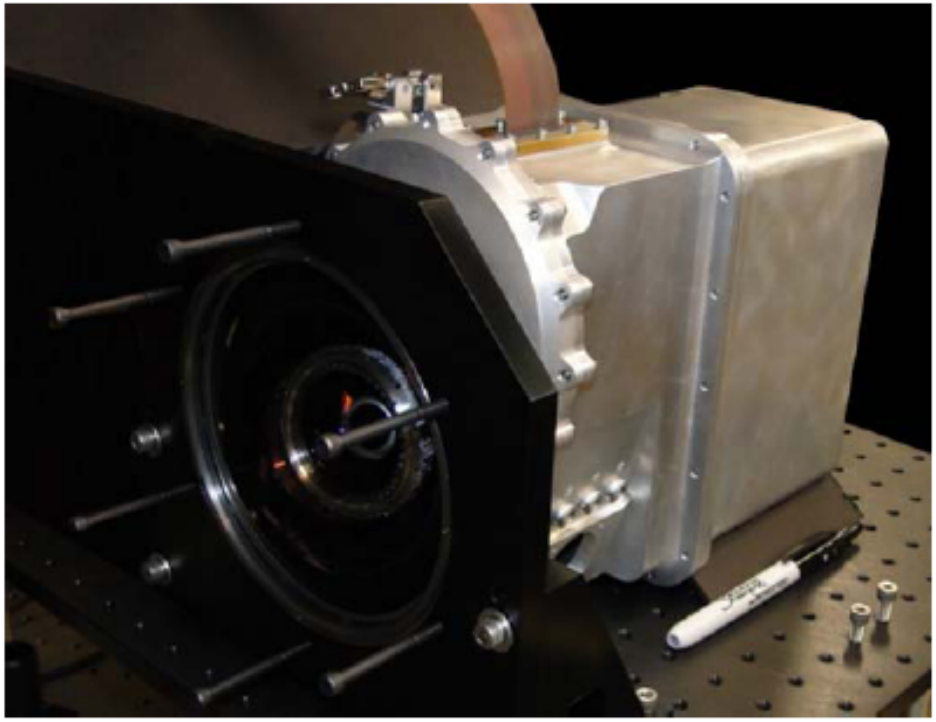
PACS/HARP:

Compact hyper-angular, Multi-Spectral Imaging Polarimeter with no operational moving parts





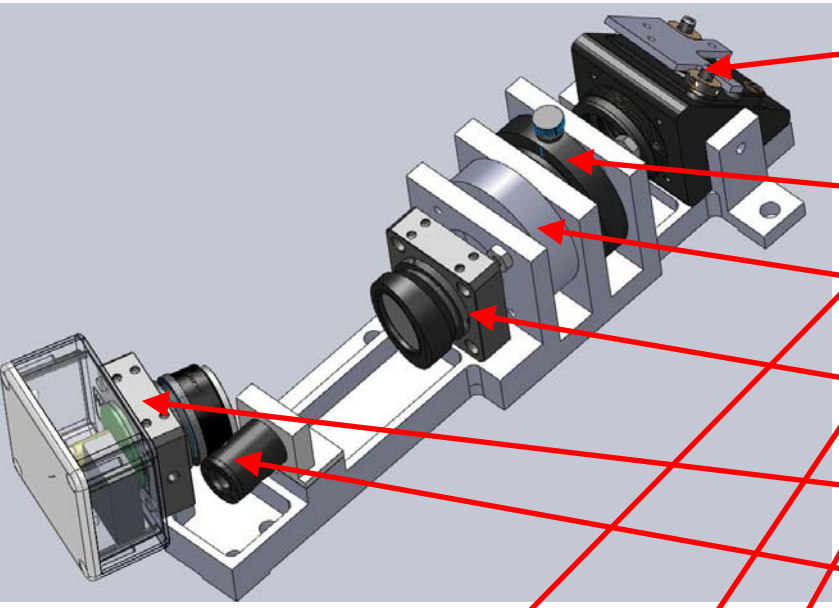




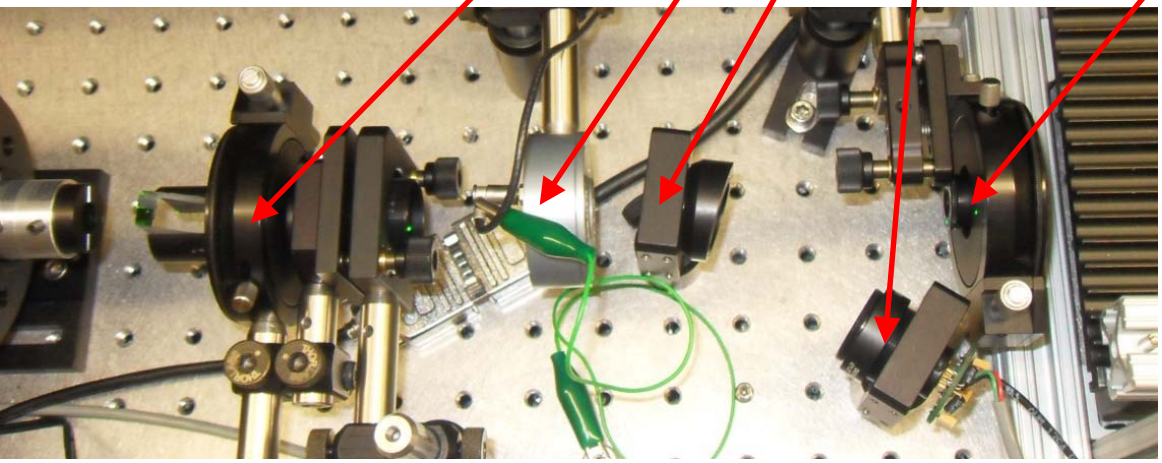
VNIR component to fly in 2011

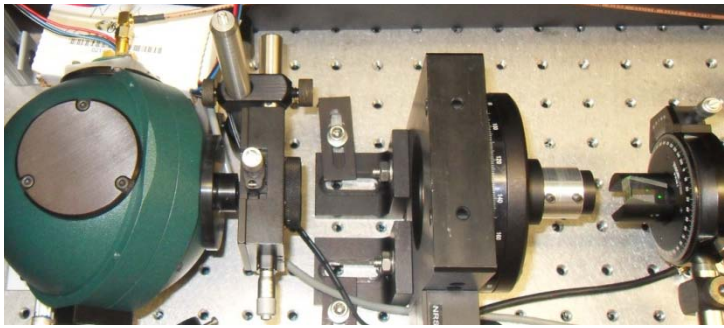
Backup Materials

Design and Lab Tests



- 45° Alignment Mirror Mount
- Achromatic Quarter Wave plate
- Liquid Crystal Variable Retarder
- Beam Splitter
- Reference detector
- **Linear polarizer**





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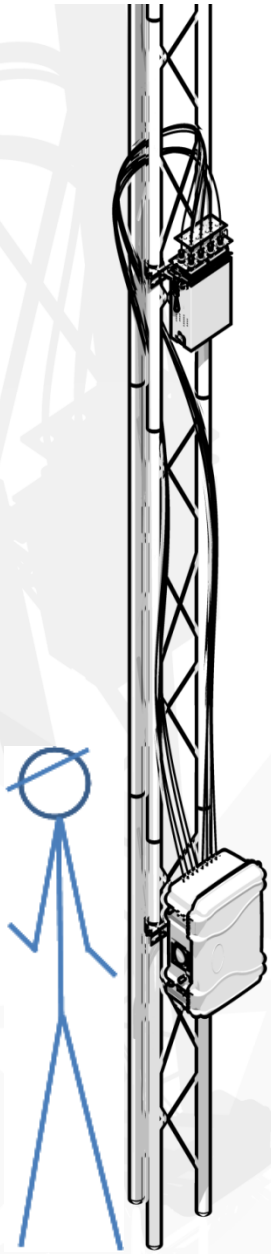
Automatic Aerosol Sampling Station for Fennec Experiment in the Sahara June 2011.

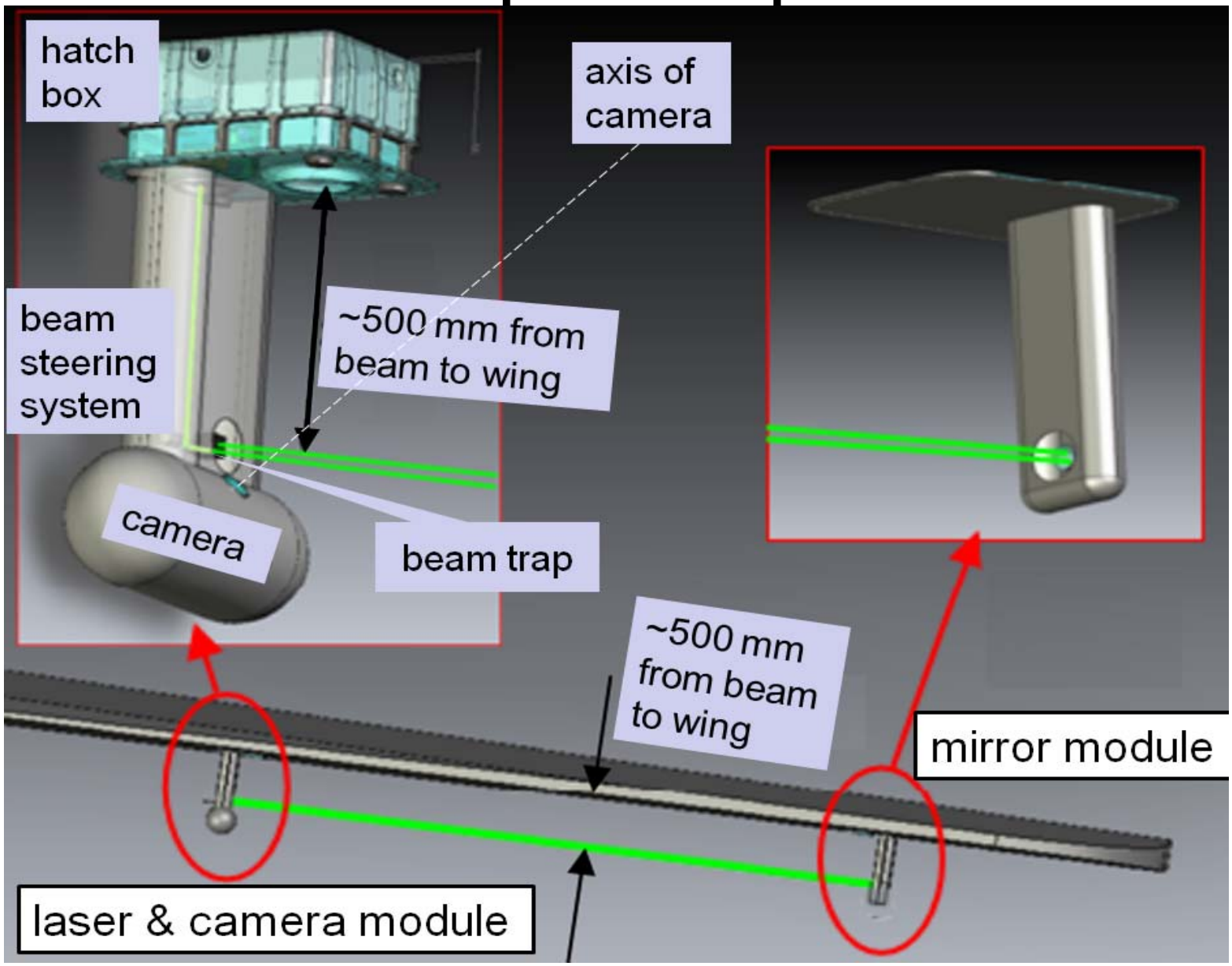
- Aerosol filter collection
- Spectral Absorption
- Scattering Coefficient



Multi-filter Inlet

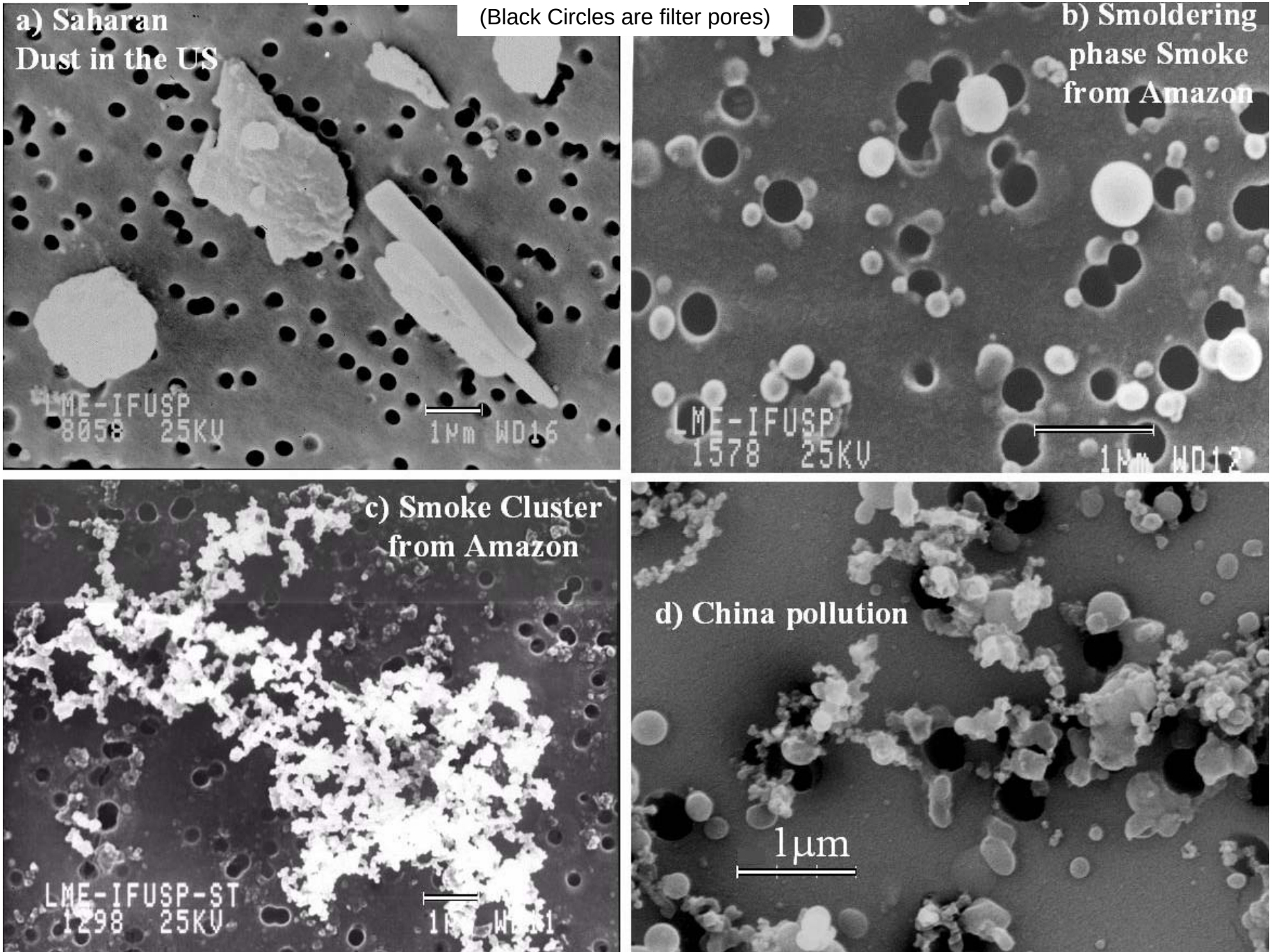
Automatic Controller

Airborne Open Nephelometer

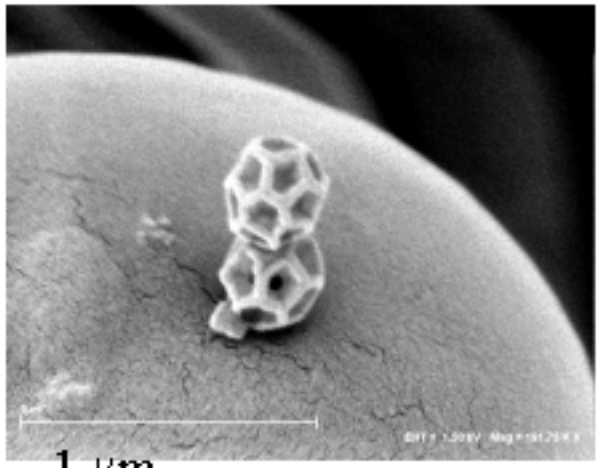


Scanning Electron Microscopy of Aerosols:

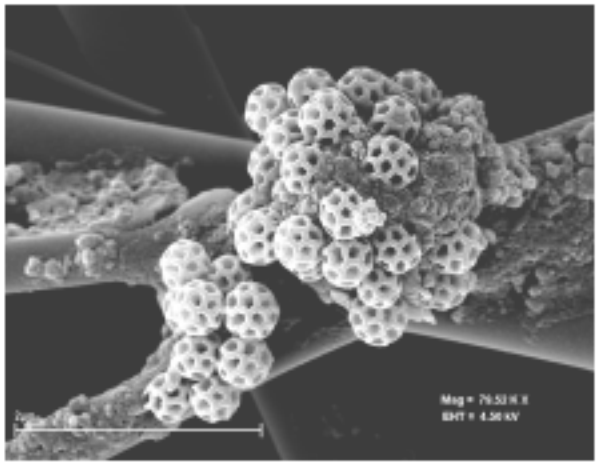
(Black Circles are filter pores)



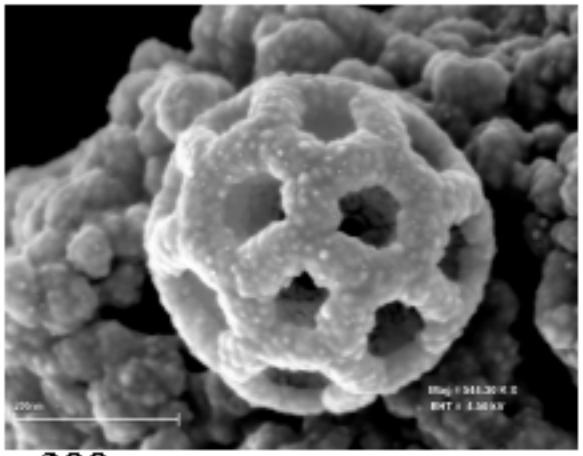
Natural biogenic aerosol particles



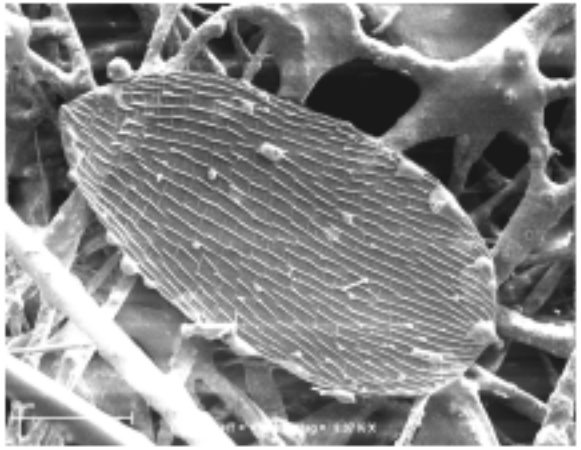
1 μm



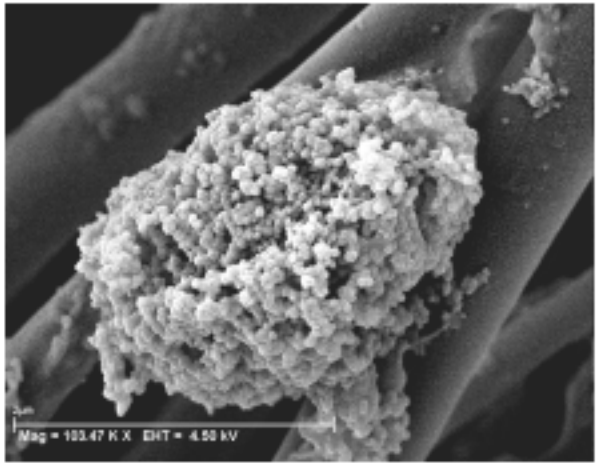
2 μm



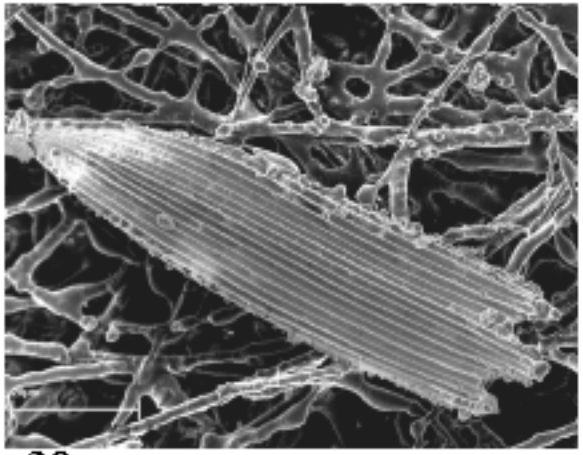
200 nm



10 μm



2 μm

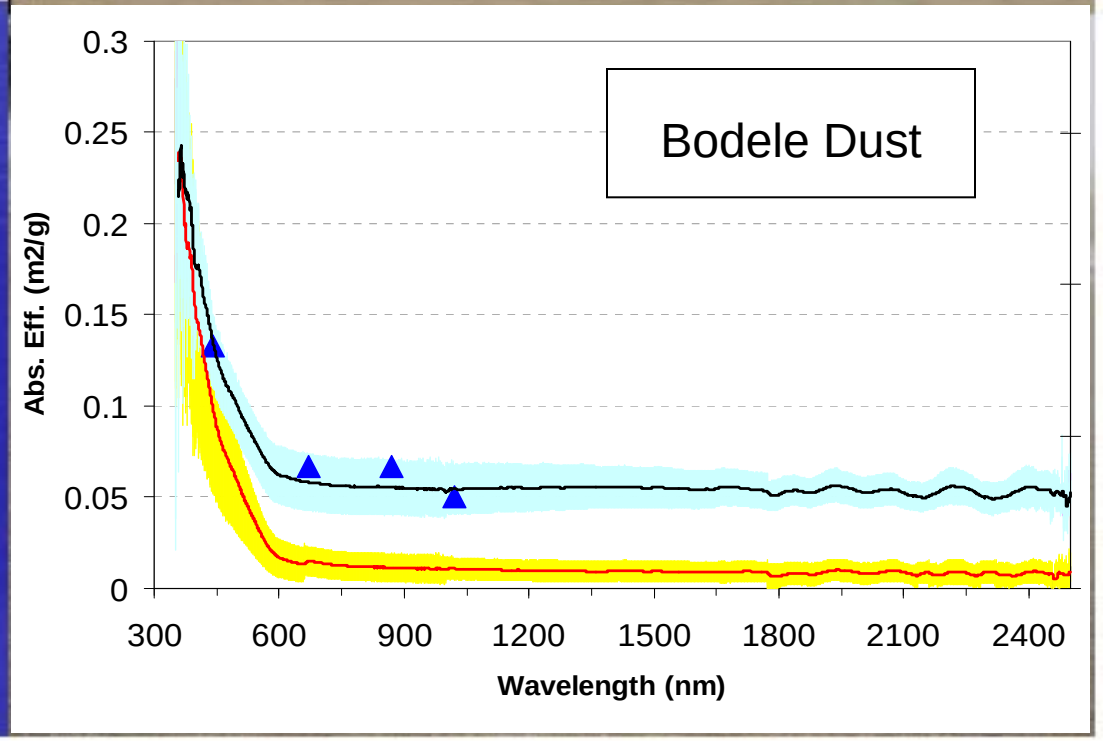


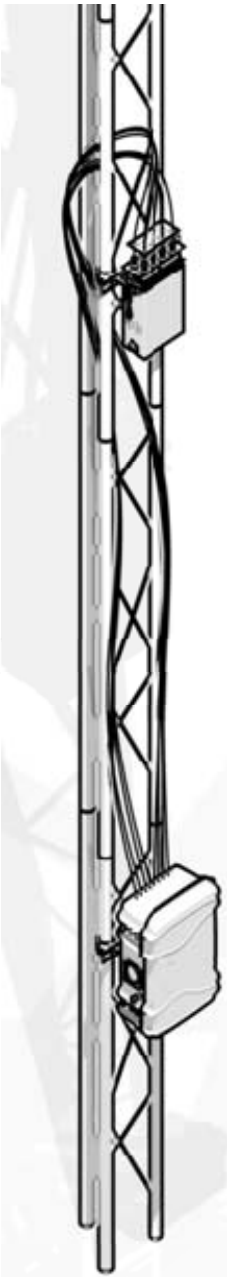
20 μm

EPMA photos from Gunther Helas, MPIC

Pictures from the Bodele Dust Experiment (BoDEx) 2005

by: Martin Todd, Gill Lizcano (UCL)





Multi-filter Inlet

Automatic **Controller**

Things to add

- New data figure from Gergely
- New pictures from Gergely FER presentation
- Picture of PACS aircraft setup
- PACS Calibration data