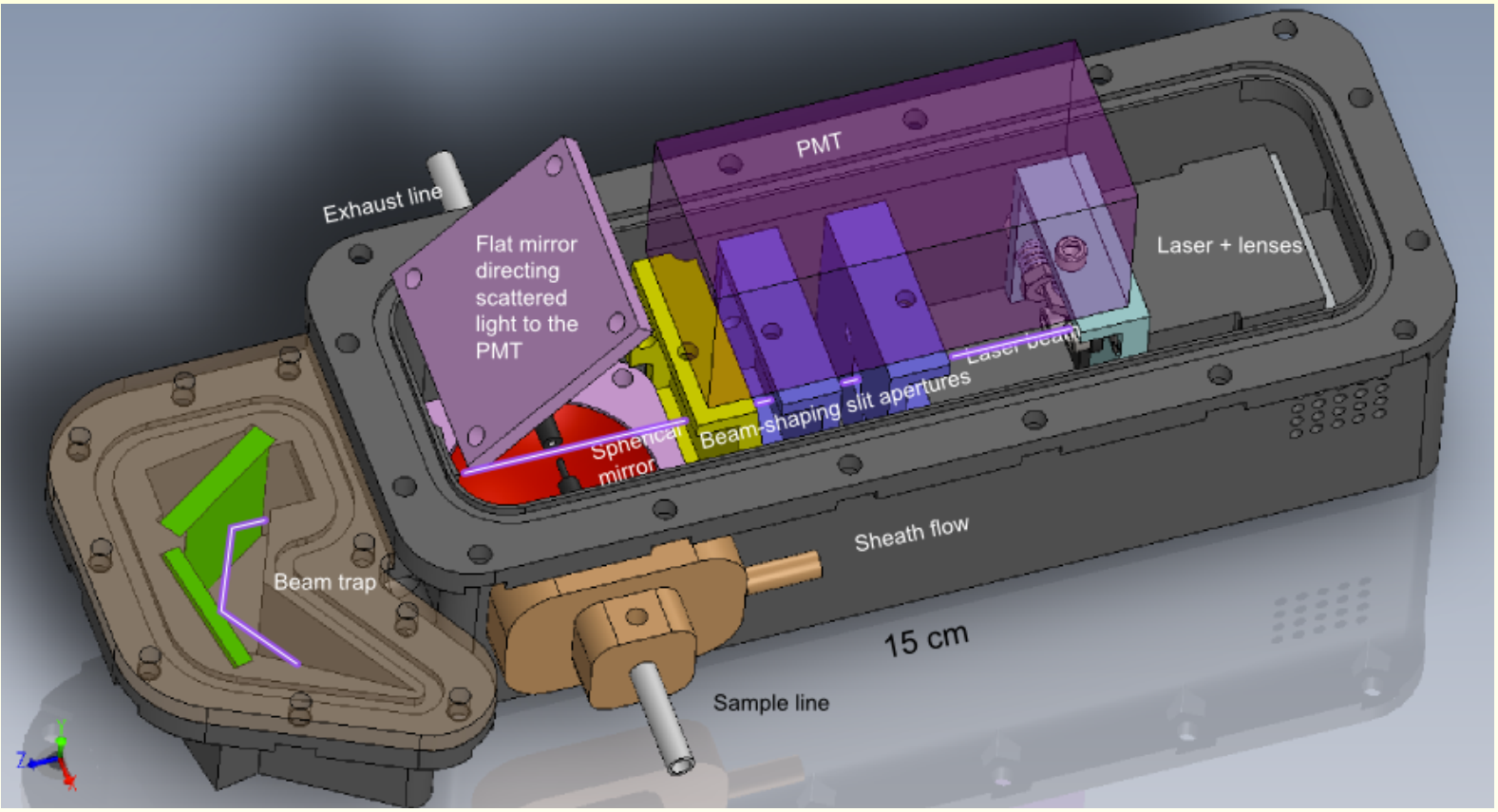
Printed **O**ptical **P**article **S**pectrometer

A small, sensitive, light-weight, and disposable aerosol spectrometer for balloon and UAV applications

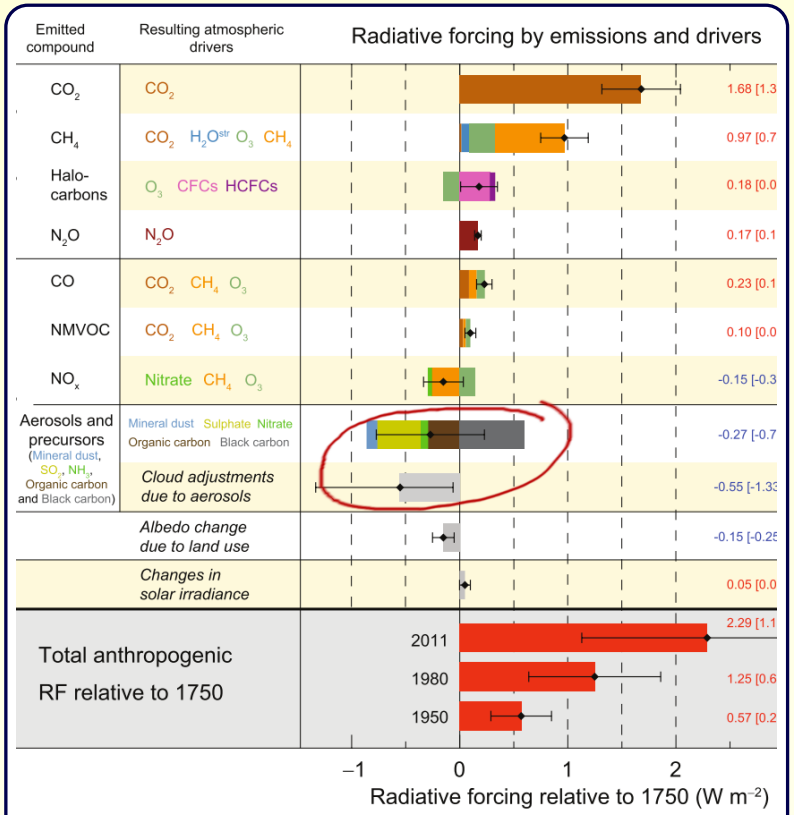


Hagen Telg

Cooperative Institute for Research in Environmental Sciences
NOAA Earth System Research Laboratory

May 20, 2014

Motivation



IPCC: Summary for Policymakers. In: Climate Change **2013**:The Physical Science Basis

Why aerosols

⇒ large uncertainty about effect on radiative forcing

Scientific questions that are difficult to address with existing tools

- Aerosol profiles inside the Asian Monsoon → no aircraft excess
- Fire plume sampling → no aircraft excess
- Volcanic aerosol and ash quantification → no aircraft excess, monitoring needed
- Geo-engineering → monitoring needed

⇒ A small, light-weight, low cost, low power optical particle counter will help greatly

Motivation

Why aerosols

⇒ large uncertainty about effect on radiative forcing

Scientific questions that are difficult to address with existing tools

- Aerosol profiles inside the Asian Monsoon → no aircraft excess
- Fire plume sampling → no aircraft excess
- Volcanic aerosol and ash quantification → no aircraft excess, monitoring needed
- Geo-engineering → monitoring needed

⇒ A small, light-weight, low cost, low power optical particle counter will help greatly

Motivation

UAV

weather balloon

Why aerosols

$\Rightarrow$ large uncertainty about effect on radiative forcing

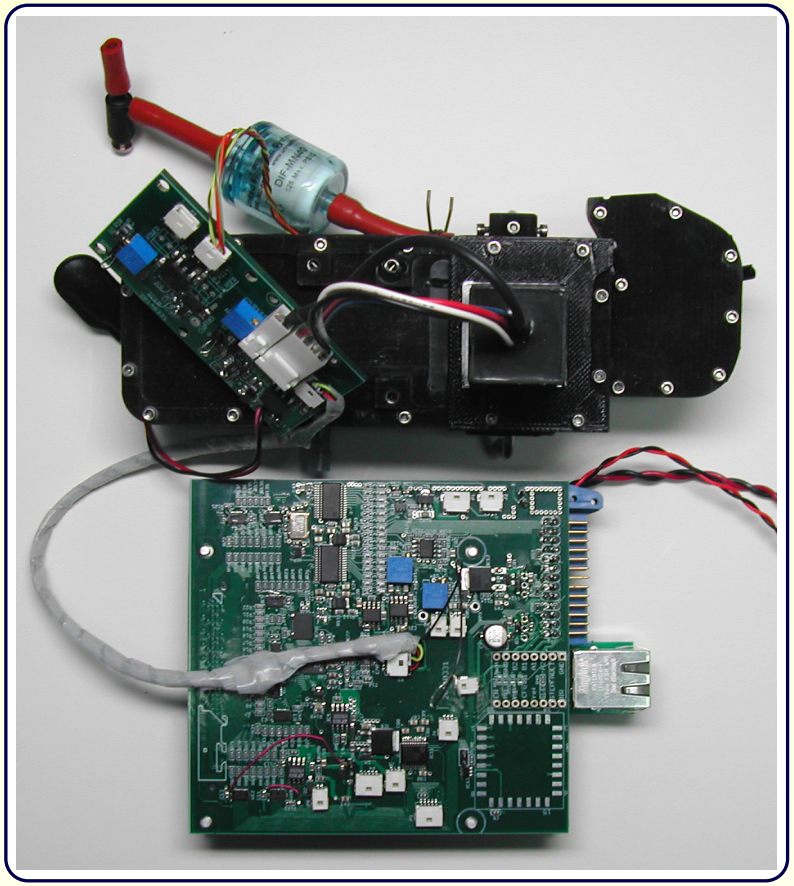
Scientific questions that are difficult to address with existing tools

- Aerosol profiles inside the Asian Monsoon $\rightarrow$ no aircraft excess
- Fire plume sampling $\rightarrow$ no aircraft excess
- Volcanic aerosol and ash quantification $\rightarrow$ no aircraft excess, monitoring needed
- Geo-engineering $\rightarrow$ monitoring needed

$\Rightarrow$ A small, light-weight, low cost, low power optical particle counter will help greatly

NOAA CIRES

Motivation



Why aerosols

⇒ large uncertainty about effect on radiative forcing

Scientific questions that are difficult to address with existing tools

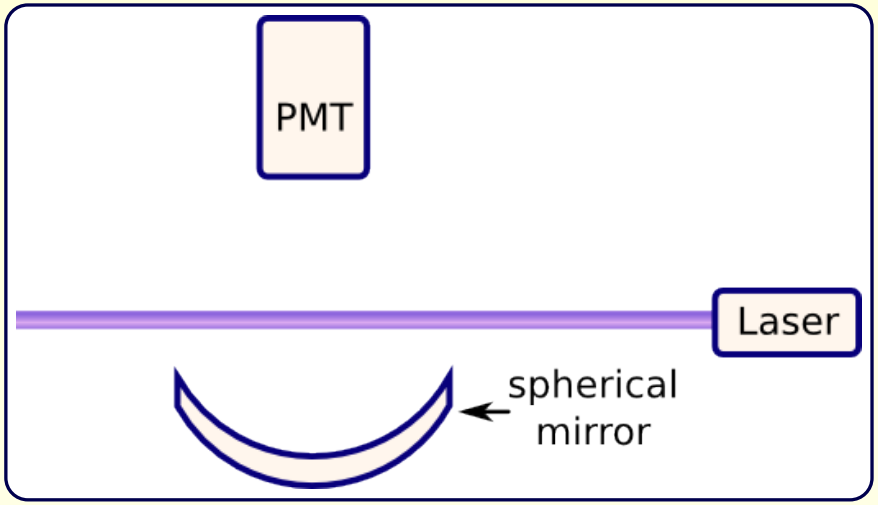
- Aerosol profiles inside the Asian Monsoon → no aircraft excess
- Fire plume sampling → no aircraft excess
- Volcanic aerosol and ash quantification → no aircraft excess, monitoring needed
- Geo-engineering → monitoring needed

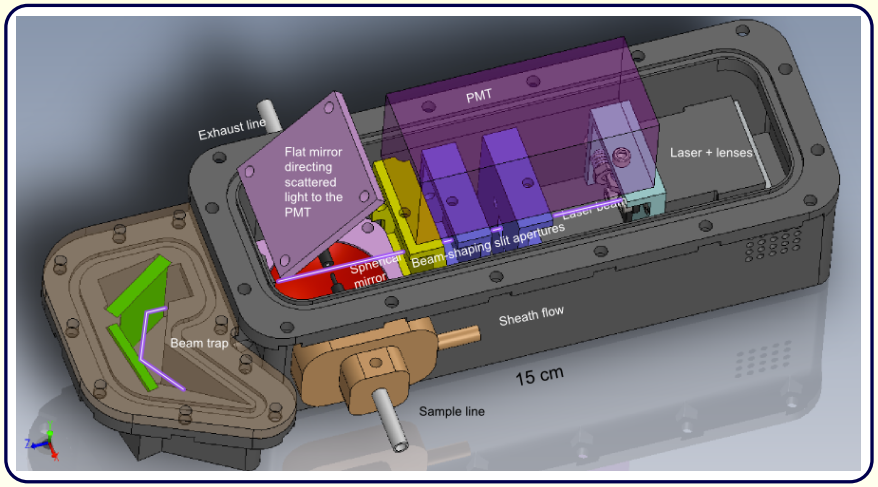
⇒ A small, light-weight, low cost, low power optical particle counter will help greatly

⇒ **P**rinted **O**ptical **P**article **S**pectrometer

CIRES

How POPS works

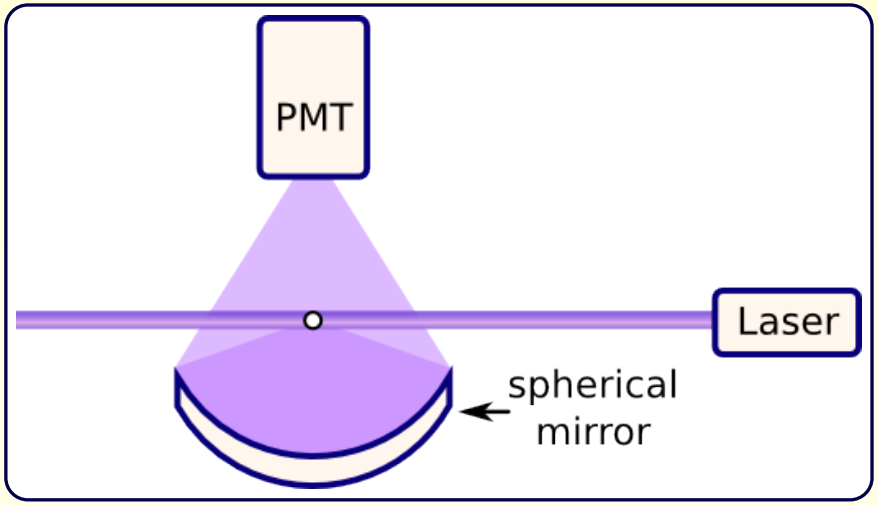


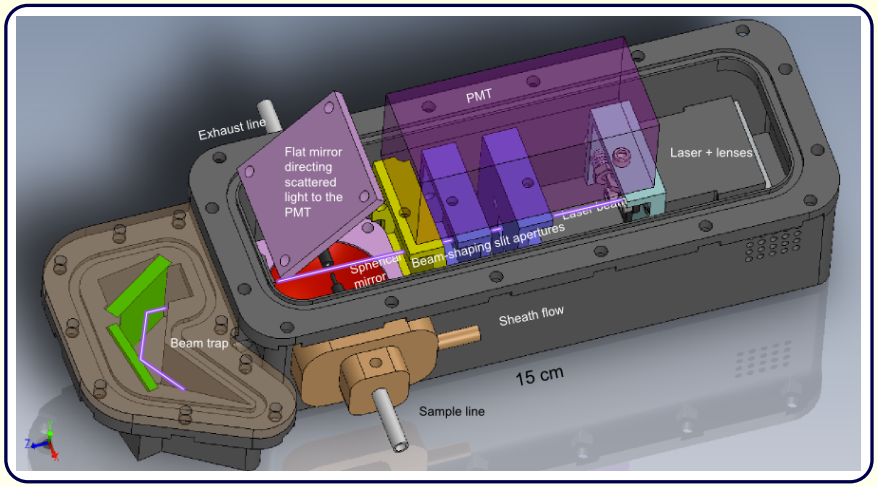


light-source	405 nm laser diode
beam shaping	aspherical, and cylindrical lenses shape laser to line
light collection	spherical mirror image scattered light on **P**hoto**m**ultiplier **T**ube
stray light	multiple slits suppress stray light
signal processing	PMT output current converted to voltage → amplified → digitized (4 MHz; 16 bit) → analyzed on single-board computer → communicate via serial port
sizing	intensity of scattered light depends on particle size

R. S. Gao *et al.*, *Aerosol Sci. Technol.* **2013**, 47, 137

How POPS works

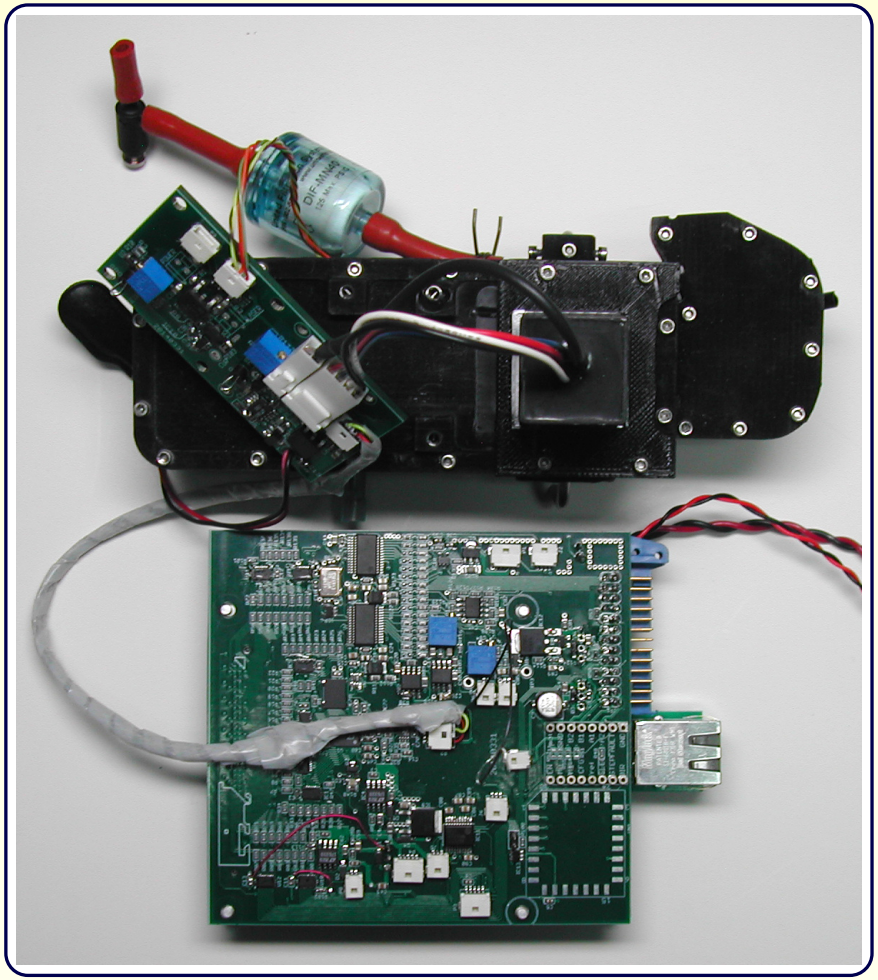




light-source	405 nm laser diode
beam shaping	aspherical, and cylindrical lenses shape laser to line
light collection	spherical mirror image scattered light on **P**hoto**m**ultiplier **T**ube
stray light	multiple slits suppress stray light
signal processing	PMT output current converted to voltage → amplified → digitized (4 MHz; 16 bit) → analyzed on single-board computer → communicate via serial port
sizing	intensity of scattered light depends on particle size

R. S. Gao *et al.*, *Aerosol Sci. Technol.* **2013**, 47, 137

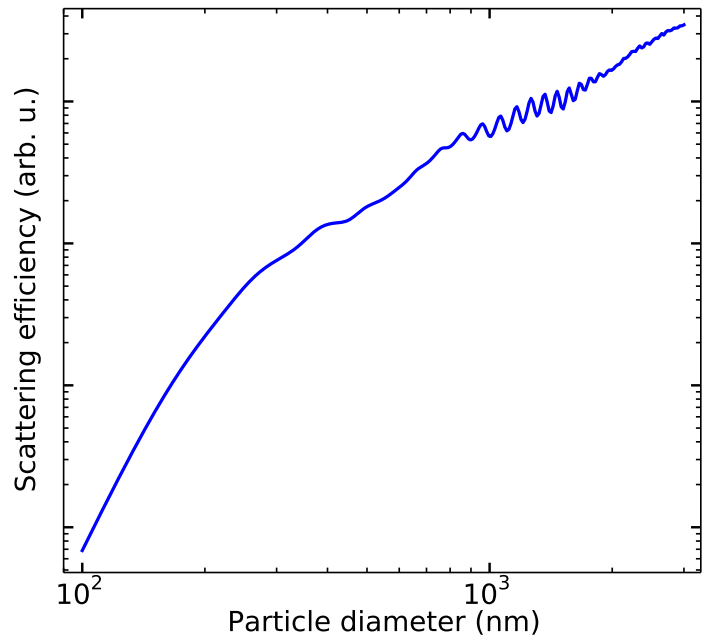
How POPS works



light-source	405 nm laser diode
beam shaping	aspherical, and cylindrical lenses shape laser to line
light collection	spherical mirror image scattered light on **P**hoto**m**ultiplier **T**ube
stray light	multiple slits suppress stray light
signal processing	PMT output current converted to voltage → amplified → digitized (4 MHz; 16 bit) → analyzed on single-board computer → communicate via serial port
sizing	intensity of scattered light depends on particle size

How POPS works

Mie scattering simulation

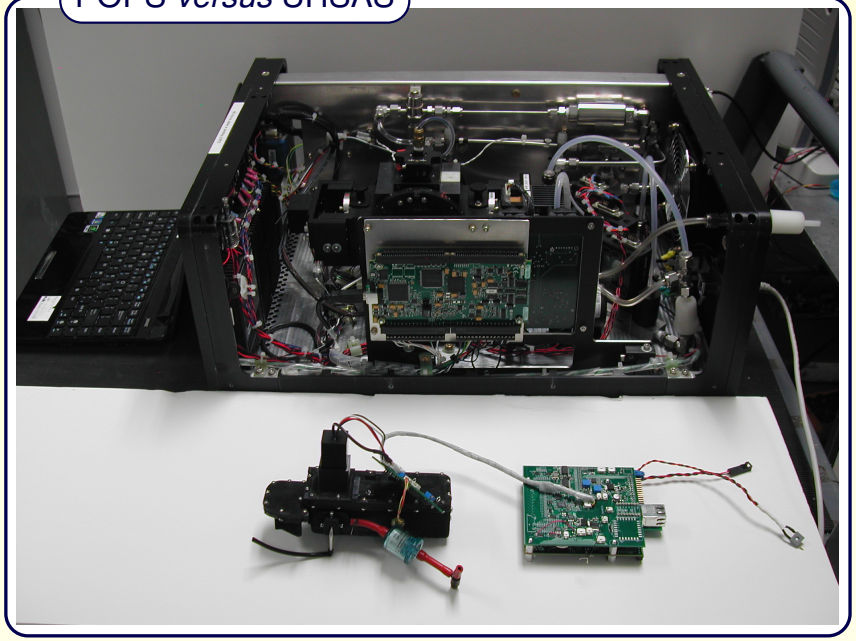


light-source	405 nm laser diode
beam shaping	aspherical, and cylindrical lenses shape laser to line
light collection	spherical mirror image scattered light on **P**hoto**m**ultiplier **T**ube
stray light	multiple slits suppress stray light
signal processing	PMT output current converted to voltage → amplified → digitized (4 MHz; 16 bit) → analyzed on single-board computer → communicate via serial port
sizing	intensity of scattered light depends on particle size

R. S. Gao *et al.*, *Aerosol Sci. Technol.* **2013**, 47, 137

How POPS works

POPS *versus* UHSAS



dimensions	15x6x6 cm
weight	< 1 kg
cost*	∼2500 $
power	3 W

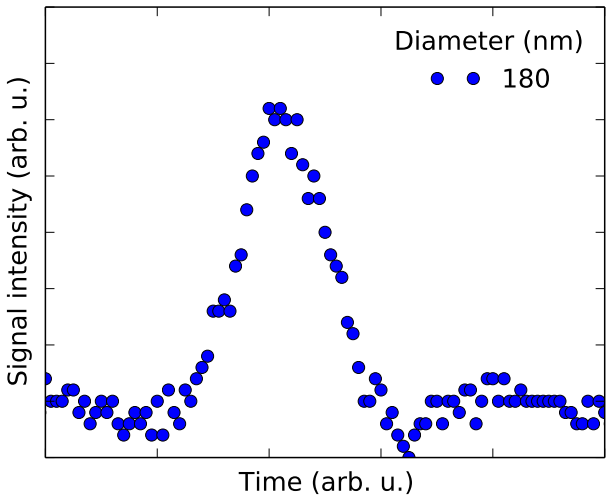
* labor excluded

light-source	405 nm laser diode
beam shaping	aspherical, and cylindrical lenses shape laser to line
light collection	spherical mirror image scattered light on **P**hoto**m**ultiplier **T**ube
stray light	multiple slits suppress stray light
signal processing	PMT output current converted to voltage → amplified → digitized (4 MHz; 16 bit) → analyzed on single-board computer → communicate via serial port
sizing	intensity of scattered light depends on particle size

R. S. Gao *et al.*, *Aerosol Sci. Technol.* **2013**, 47, 137

how POPS performs

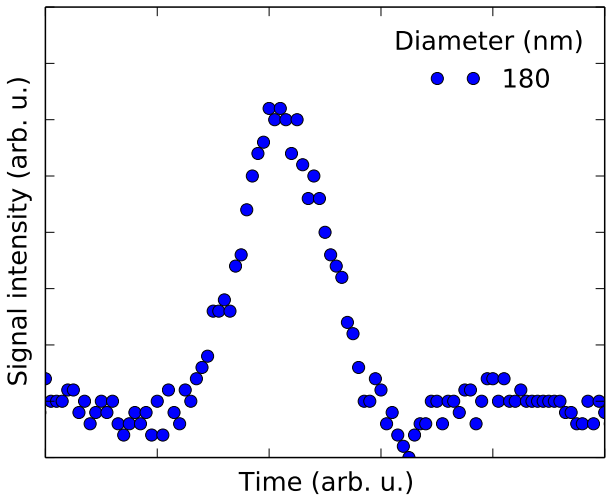
raw data



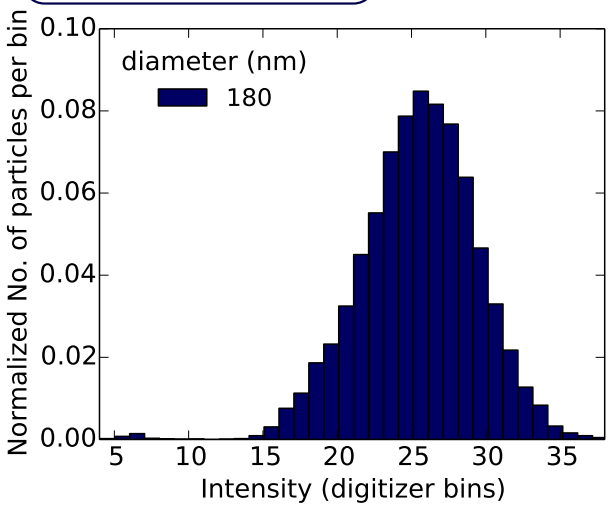
- single particles are resolved
- good diameter resolution $\Delta d/d \approx 15\ \%$
- minimum measurable diameter <150 nm
- agreement with theory
- comparison to UHSAS shows good agreement in absolute counts (down to 190 nm)

how POPS performs

raw data



peak height histogram

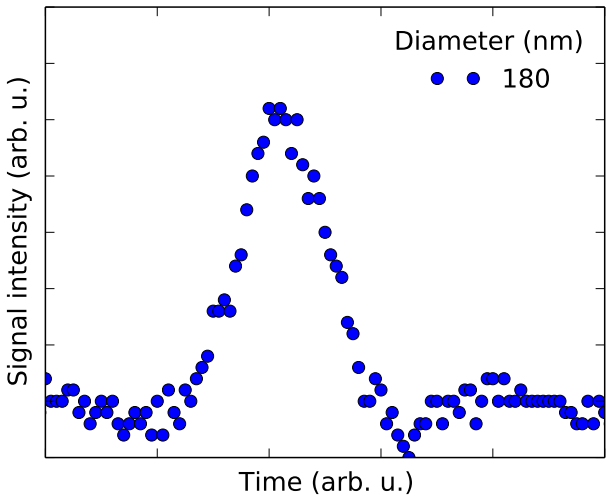


- single particles are resolved
- good diameter resolution $\Delta d/d \approx 15\ \%$
- minimum measurable diameter <150 nm
- agreement with theory
- comparison to UHSAS shows good agreement in absolute counts (down to 190 nm)

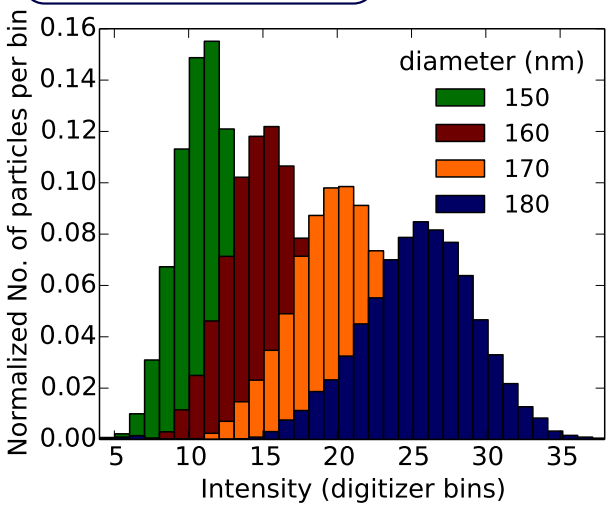
NOAA CIRES

how POPS performs

raw data



peak height histogram

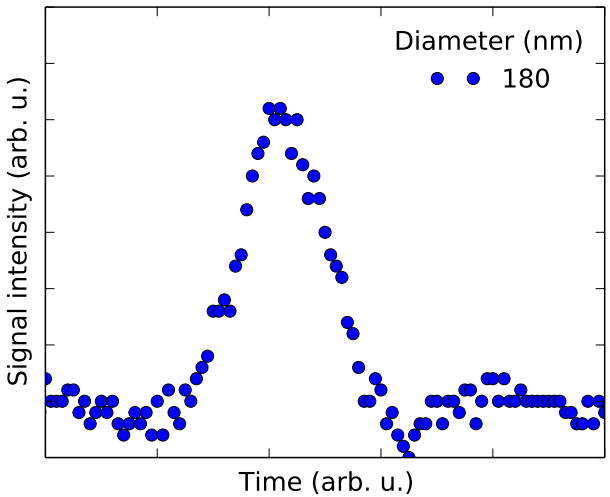


- single particles are resolved
- good diameter resolution $\Delta d/d \approx 15\ \%$
- minimum measurable diameter $<$150 nm
- agreement with theory
- comparison to UHSAS shows good agreement in absolute counts (down to 190 nm)

CIRES

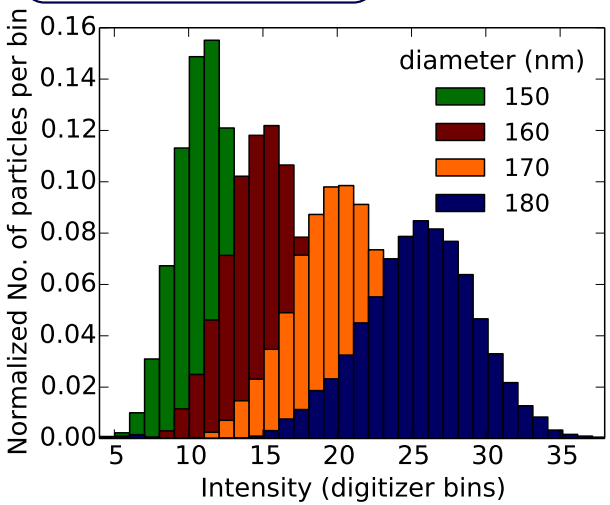
how POPS performs

raw data

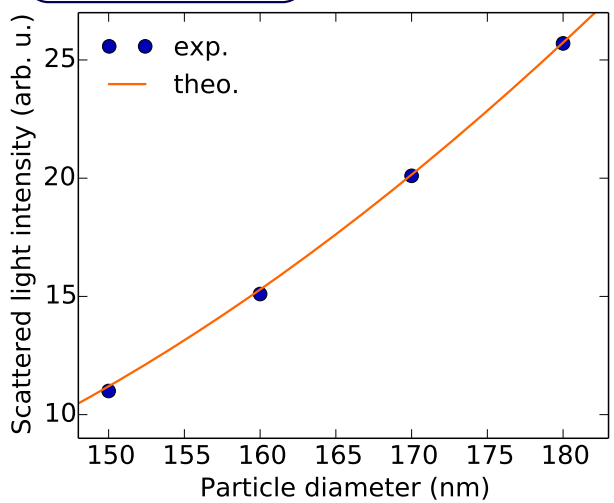


- single particles are resolved
- good diameter resolution $\Delta d/d \approx 15\ \%$
- minimum measurable diameter <150 nm
- agreement with theory
- comparison to UHSAS shows good agreement in absolute counts (down to 190 nm)

peak height histogram

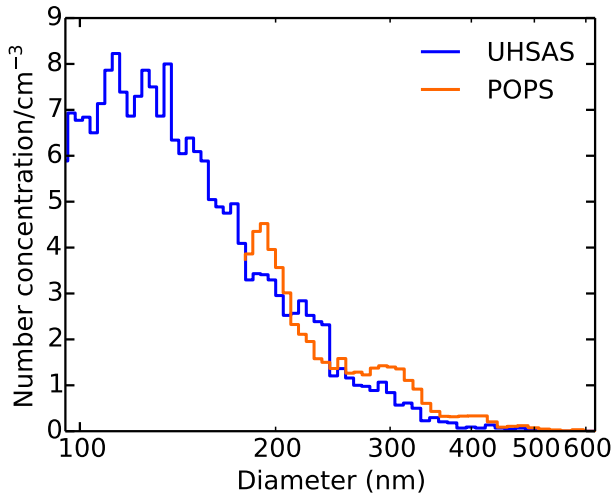


exp. *versus* theo.

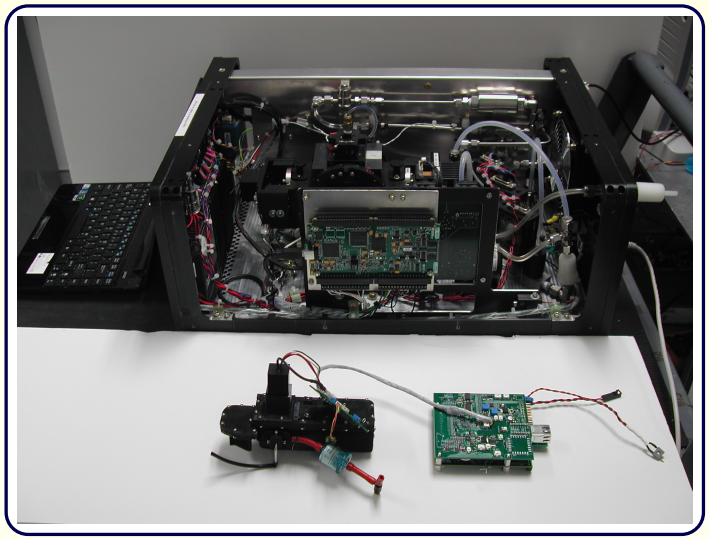


how POPS performs

POPS *versus* UHSAS @ room air



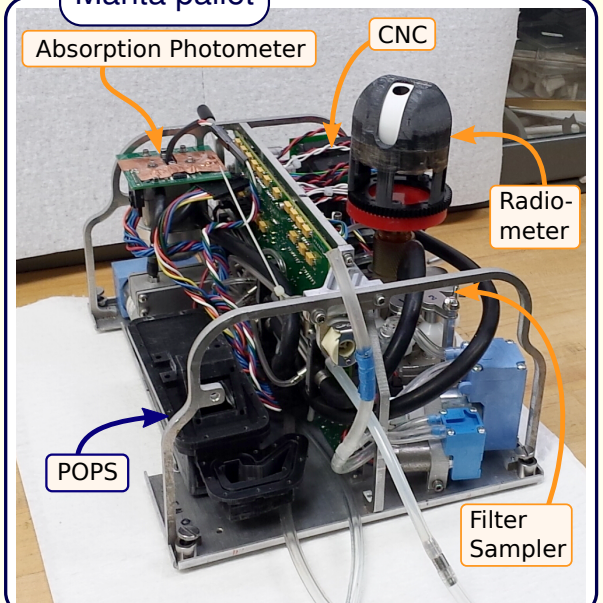
- single particles are resolved
- good diameter resolution $\Delta d/d \approx 15\ \%$
- minimum measurable diameter $<$150 nm
- agreement with theory
- comparison to UHSAS shows good agreement in absolute counts (down to 190 nm)



field test on Manta UAV

Manta & launcher

Manta pallet



package

- POPS
- **C**ondensation **N**uclei **C**ounter
- 3 wavelengths aerosol absorption ahotometer → like CLAP
- aerosol filter sampler → 6 filters
- Radiometer

outcome

- POPS functional

but interference with UAV communication and other instruments → bursts of noise

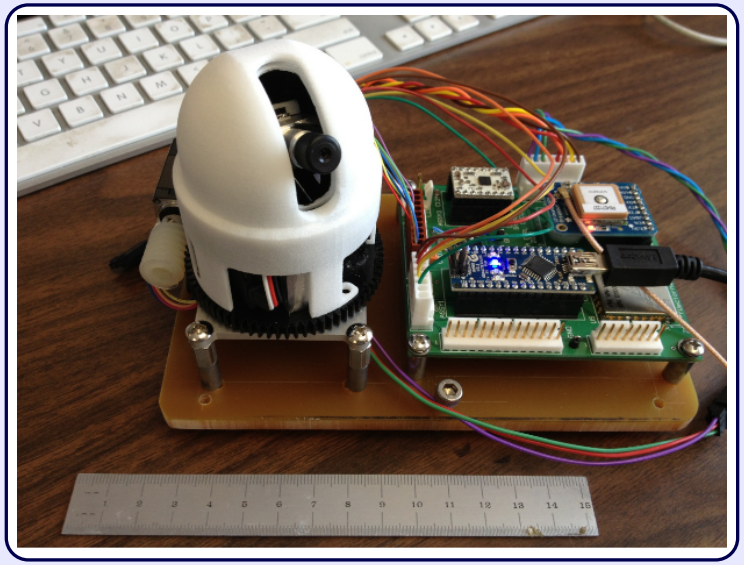
⇒ improve shielding

NOAA CIRES

field test on Manta UAV

Manta & launcher

poster by D. Murphy
presented by R.S. Gao



package

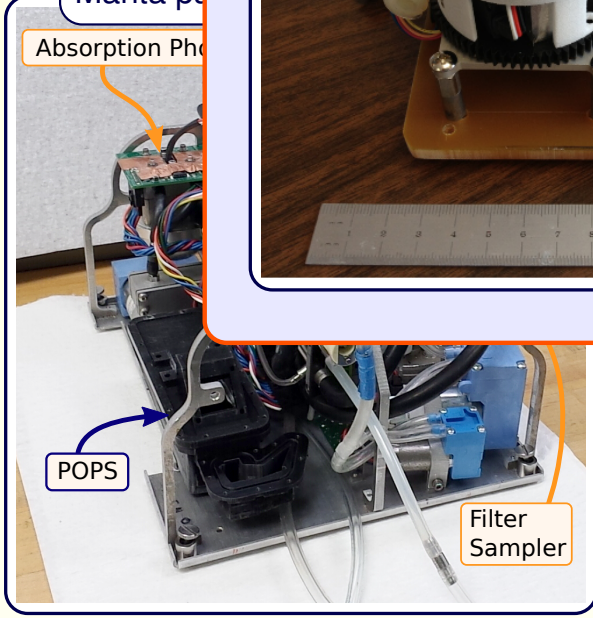
sation **N**uclei **C**ounter

engths aerosol absorption
eter → like CLAP

filter sampler → 6 filters

eter

Manta pa



unctional

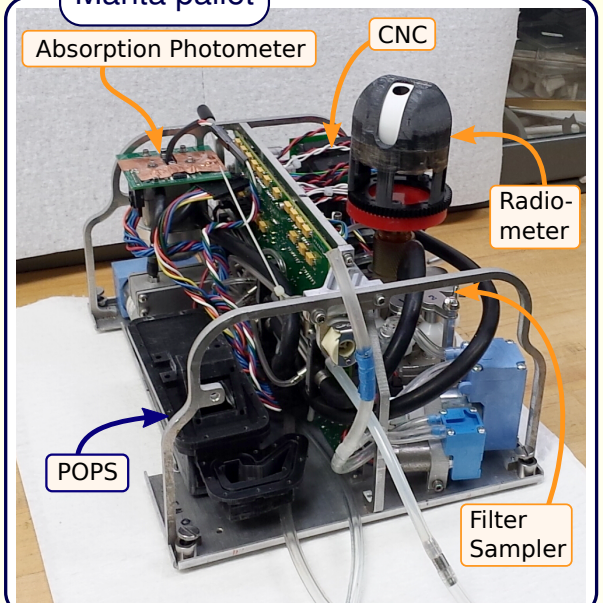
nce with UAV communication
r instruments → bursts of

⇒ improve shielding

field test on Manta UAV

Manta & launcher

Manta pallet



package

- POPS
- **C**ondensation **N**uclei **C**ounter
- 3 wavelengths aerosol absorption ahotometer → like CLAP
- aerosol filter sampler → 6 filters
- Radiometer

outcome

- POPS functional

but interference with UAV communication and other instruments → bursts of noise

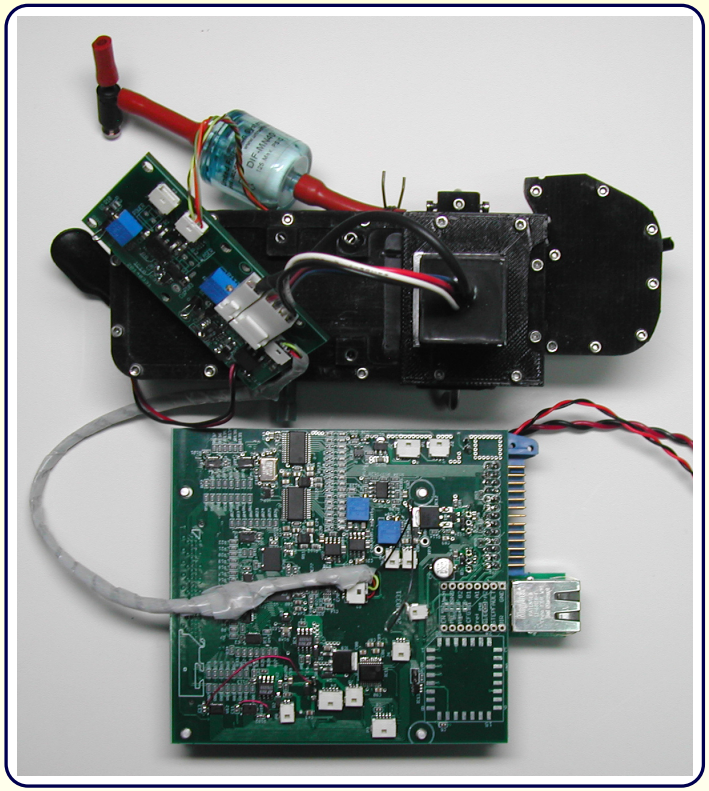
⇒ improve shielding

summary

Printed Optical Particle Spectrometer

light weight	< 1 kg $\Rightarrow$ light enough for small weather balloon or UAV
low cost	$\sim$2500 \$ $\Rightarrow$ disposable
diameter range	150 - 2500 nm
tested	Manta UAV

POPS will be fully functional in a couple of months!



acknowledgment

- Ru-Shan Gao
- Laurel Watts
- Steven Ciciora
- Richard McLaughlin
- Matt Richardson
- Joshua Schwarz
- Anne Perring
- Charles Brock
- Nick Wagner

- Tim Bates
- James Johnson