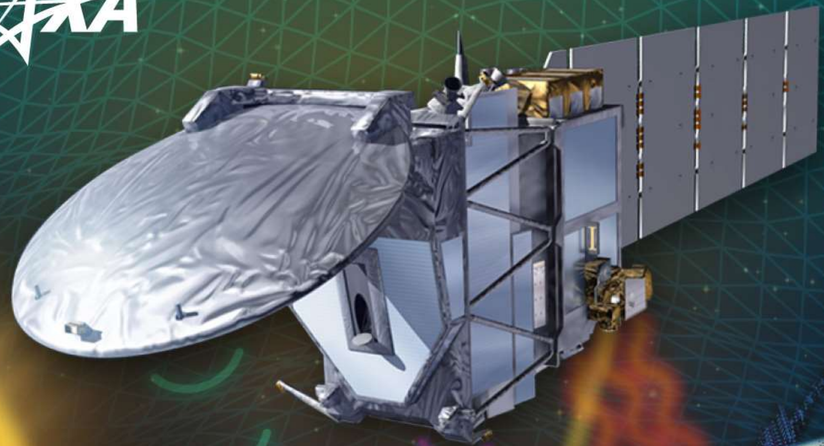


JAXA

esa

ESA-JAXA Pre-Launch EarthCARE Science and Validation Workshop

13 – 17 November 2023 | ESA-ESRIN, Frascati (Rome), Italy

EVID 12: LITES

optical, microphysical and chemical characterization of aerosols with lidar

Detlef Müller / University of Hertfordshire and Wuhan University

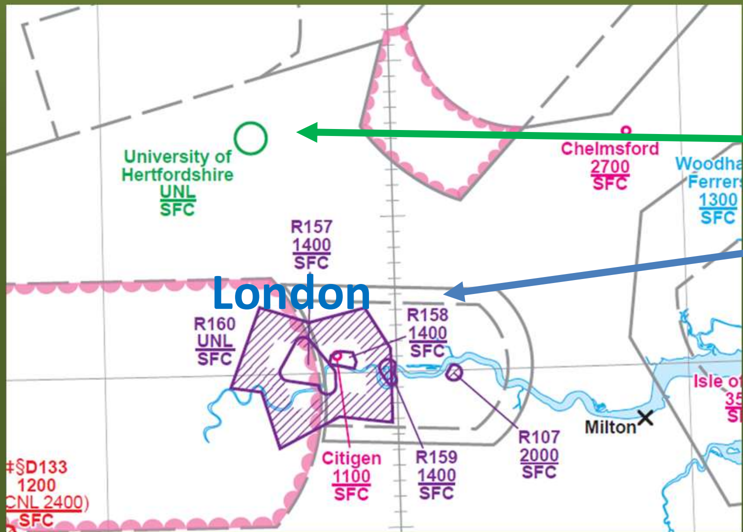
and

Boyan Tatarov / University of Hertfordshire

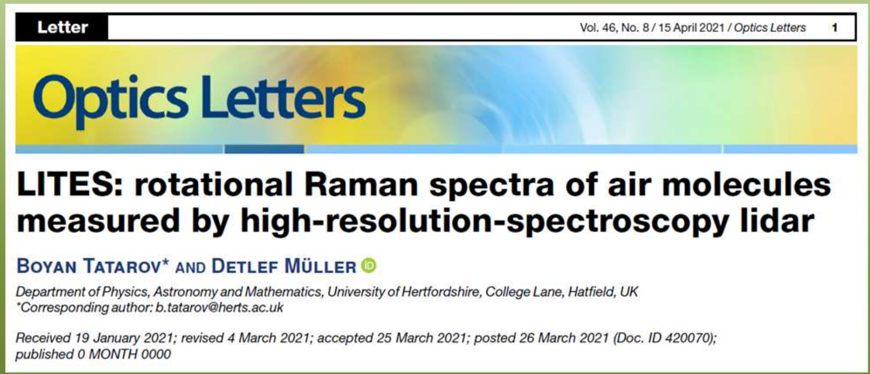
University of Hertfordshire - in the south-east of the United Kingdom, approximately 40 km to the north of London

Location of LITES allows for observations of

- smoke (NA, SW Europe)
- dust from NW Africa
- "London plume"



Multi-channel Lidar Spectrometer as part of LITES
→ Lidar Innovations for Technologies and Environmental Sciences (LITES)
design, construction, operational: 2012 - 2022


Letter Vol. 46, No. 8 / 15 April 2021 / *Optics Letters* 1

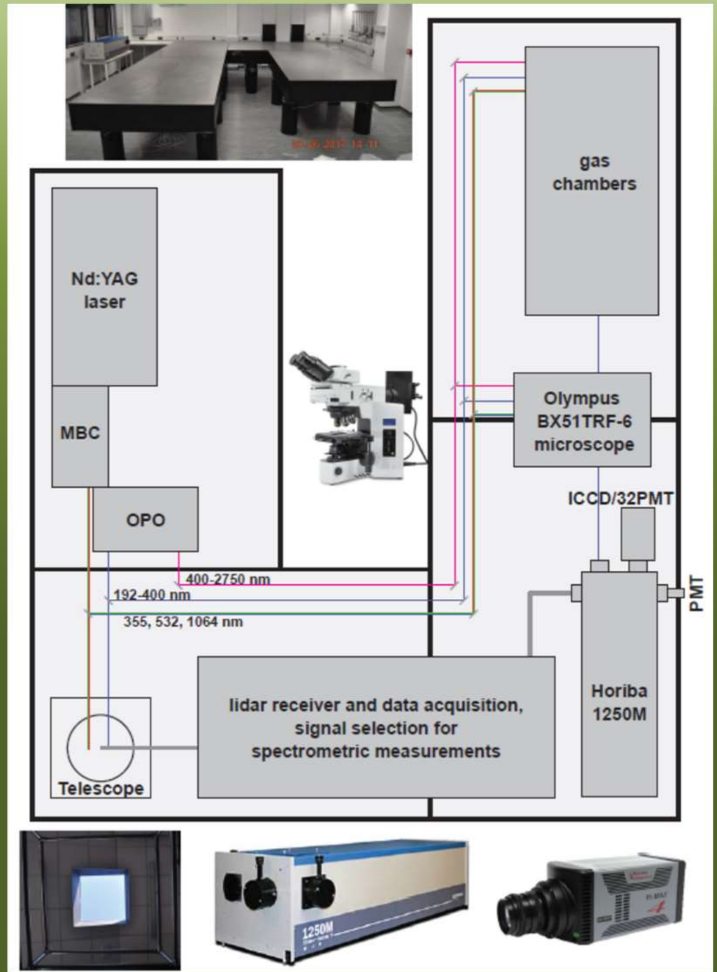
Optics Letters

LITES: rotational Raman spectra of air molecules measured by high-resolution-spectroscopy lidar

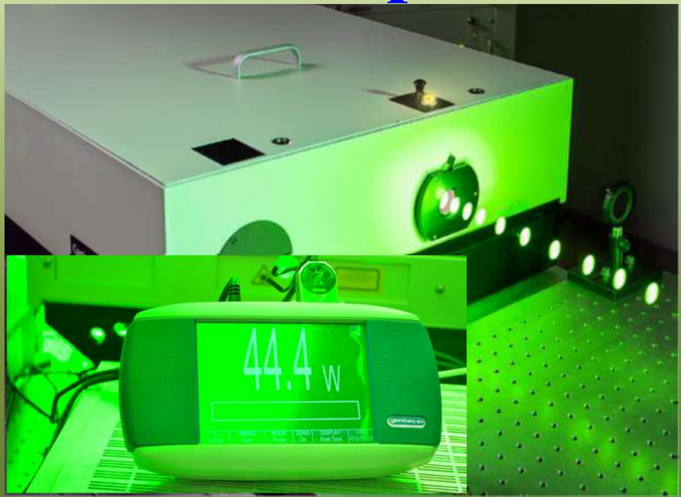
BOYAN TATAROV* AND DETLEF MÜLLER

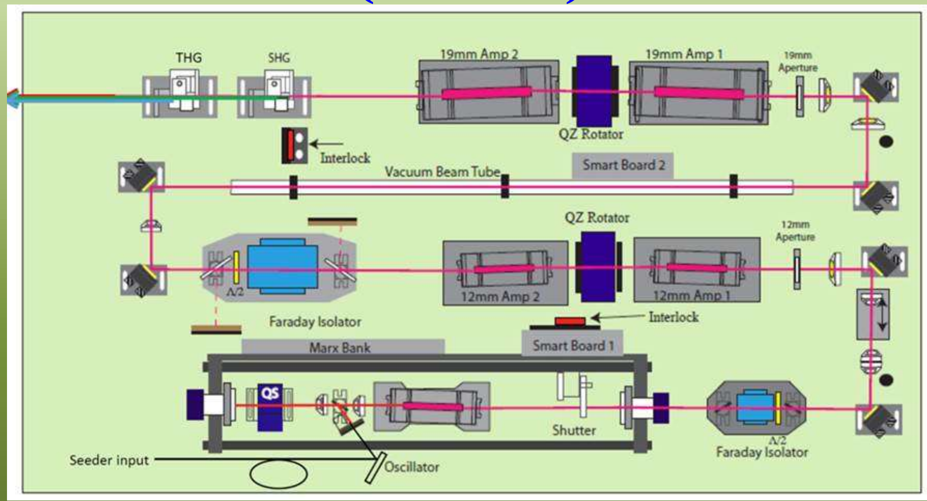
Department of Physics, Astronomy and Mathematics, University of Hertfordshire, College Lane, Hatfield, UK
**Corresponding author: b.tatarov@herts.ac.uk*

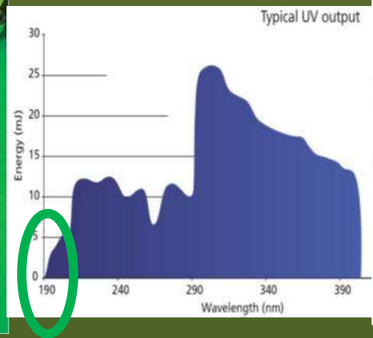
Received 19 January 2021; revised 4 March 2021; accepted 25 March 2021; posted 26 March 2021 (Doc. ID 420070); published 0 MONTH 0000

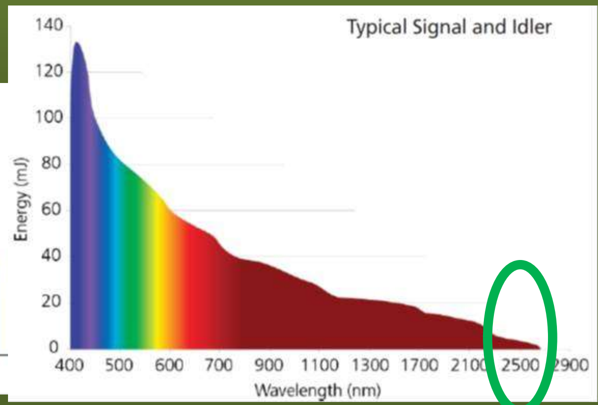


Main Laser System: Nd:YAG + OPO
up to 7 J at 1064 nm (10 Hz)



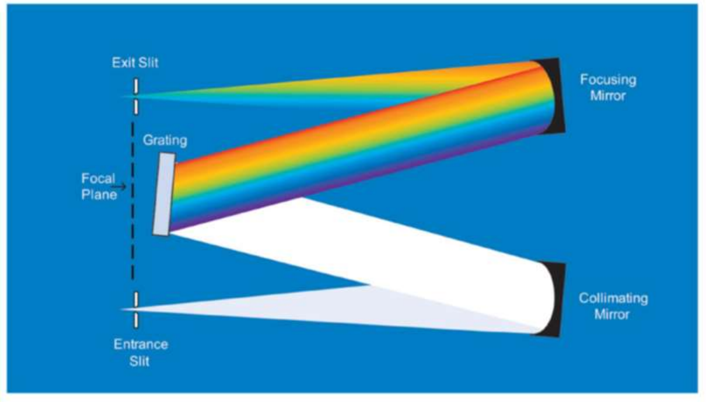






Main Spectrometer

Horiba 1250M-SII Specifications.



1250M		
Focal Length (m)		1.25
Aperture		f/9
Spectral Range		0 - 1500 nm
Grating Size		110 mm x 110 mm
Number of Gratings on Turret		1
Resolution at Exit Slit with PMT		.006 nm
Wavelength Accuracy		±0.15
Repeatability		±0.005
Spectral Dispersion (@ 500 nm)		0.65 nm/mm
Magnification		1
Scan Speed		4000 steps/nm
Step Size		0.00025
Computer Interface		USB 2.0
Dimensions	Length	134.6 cm (53 in)
	Width	45 cm (17.75 in)
	Height	36.8 cm (14.5 in)
Weight		72.7 kg (160 lb)

Combine 3 Steps in Particle Characterization

1. **Optical properties – use LIDAR (as part of LITES) for exploratory studies**
   - Aerosol types over UK – for extending existing knowledge
   - Depolarization ratio - could be used for tests of new particle light-scattering models
2. **Microphysical Properties – use TiARA (Tikhonov Advanced Regularization Algorithm)**
   - Test new TiARA versions for improved particle characterization
   - Use TiARA for quality assurance
3. **Chemical Properties – use LITES (lidar, aerosol chambers, single-particle analysis)**
   - Can we identify chemical components from Raman lidar observations?
   - Can we add this knowledge to improved microphysical retrievals?
   - Can we improve aerosol typing (e.g. aerosol components)?

LITES
Lidar Innovations for Technologies and Environmental Sciences

University of Hertfordshire

Lidar observations of linear depolarization ratio by lidar with circular polarized laser transmitter at Hatfield, United Kingdom

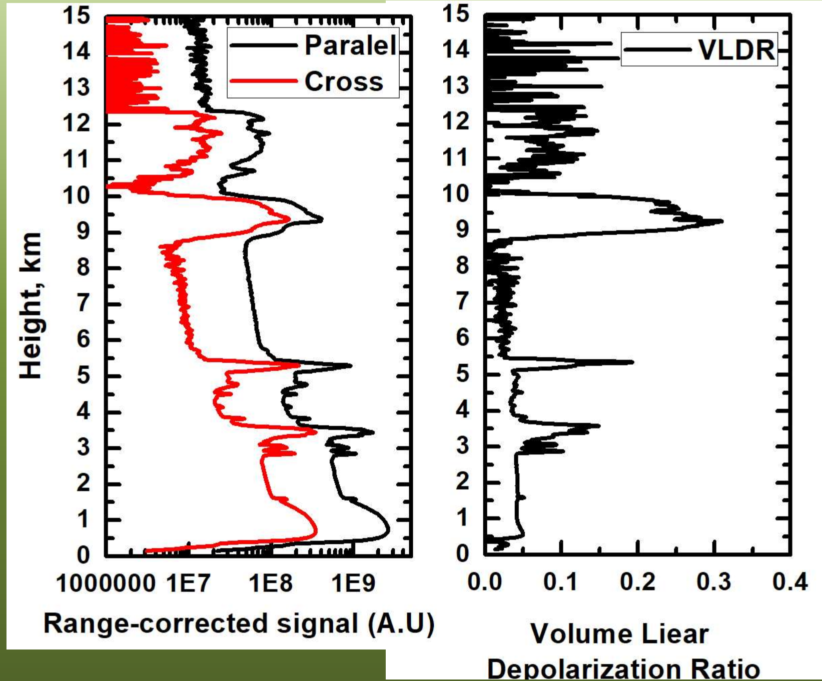
Boyan Tatarov and Detlef Müller

13 September 2023

European Lidar Conference, Cluj/Romania 2023

Examples of linear and circular depolarization measurements

10 September 2023, averaged over 18600 laser shots (31 min)

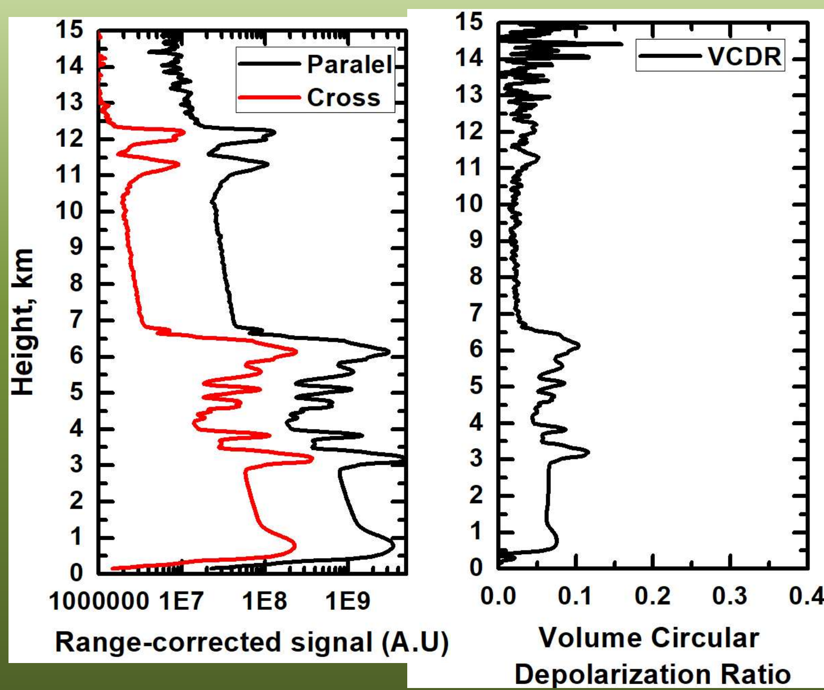


Linear VDR

Work carried out in context of Aeolus cal/val

Circular VDR

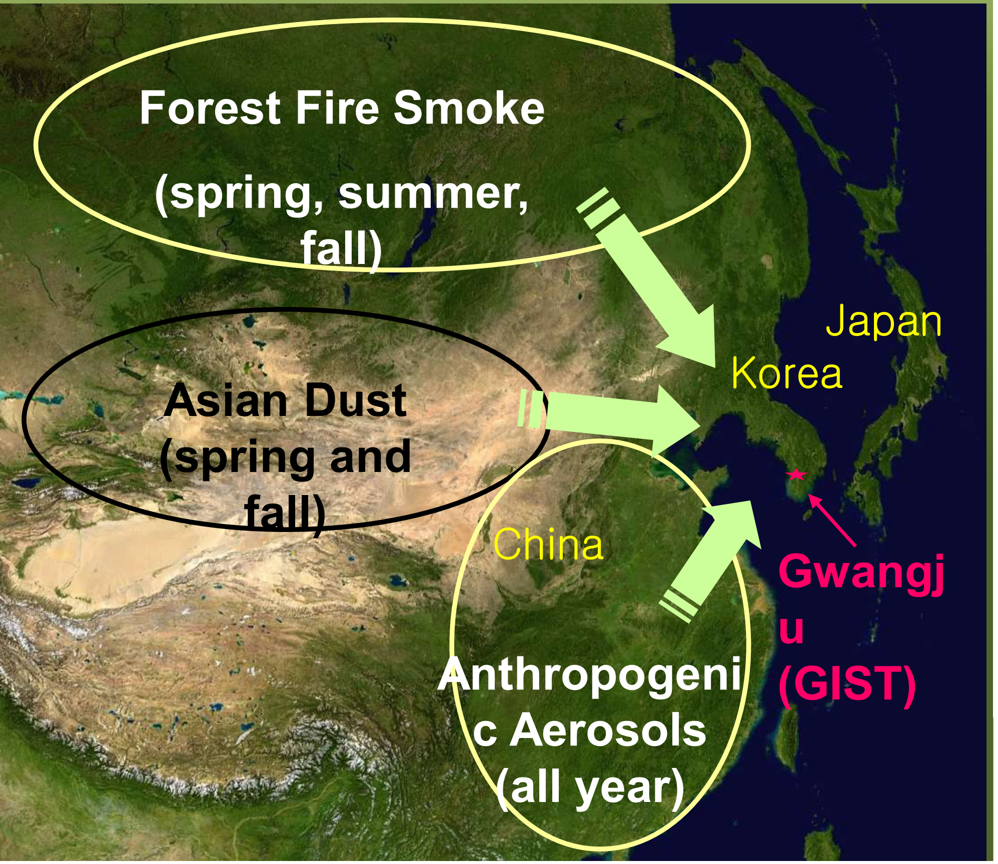
10 September 2023, Averaged over 39600 laser shots (66 min)

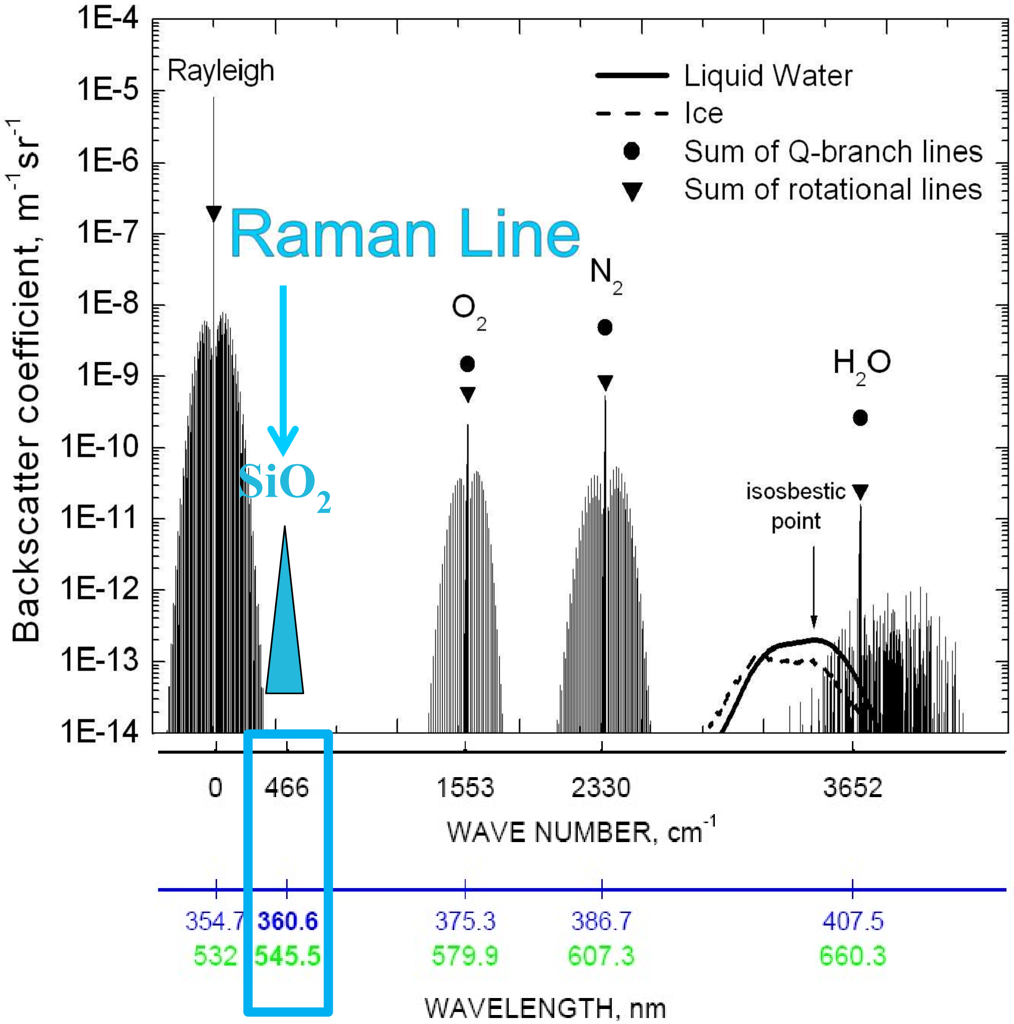


- use data for testing new particle light-scattering models
- at present microphysical data inversion
  - rests on the use of data for which particle depolarization ratio is 0
  - thus no analysis of observations of e.g. mineral dust, volcanic ash, ...

Identification of "Chemical Signatures" of Particles

South Korea, 2008 to 2016
mixed pollution plumes - separating mineral quartz from other aerosol types
(Müller, Tatarov, Noh. et al)





Methodology

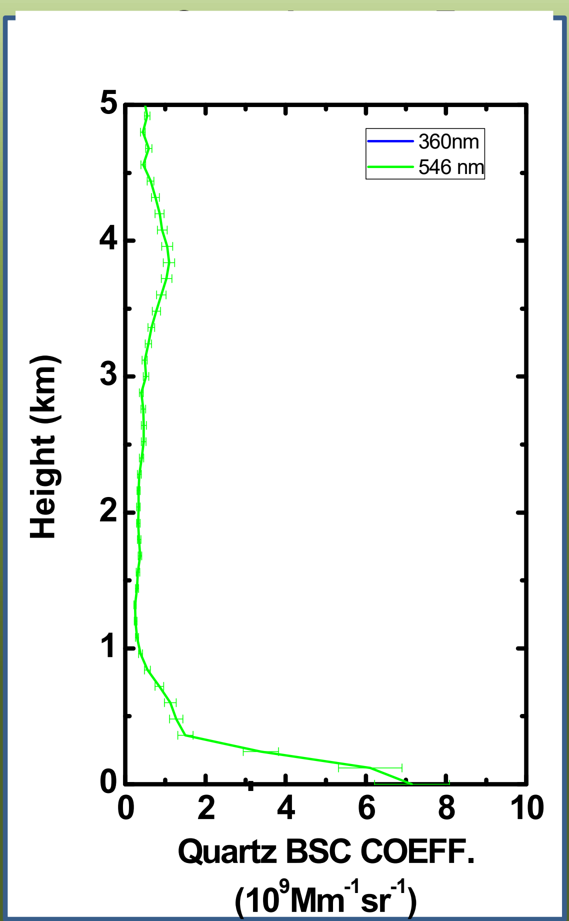
We use the relation of the Raman backscatter coefficient to the **Raman backscatter differential cross section** $d\sigma(\lambda_L, \lambda_R, \pi)/d\Omega$ and the number density of quartz molecules N_q.

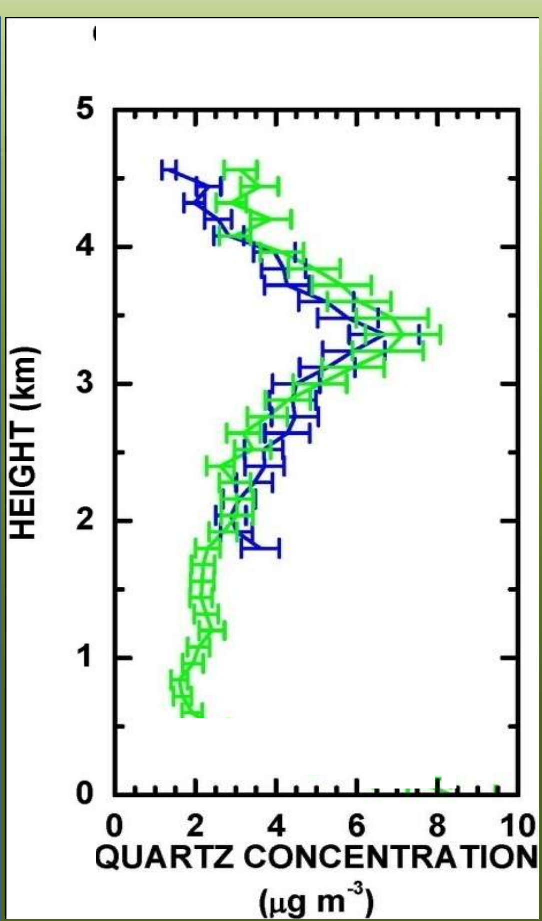
$$\rightarrow \quad \beta_R(r, \lambda_L, \lambda_R) = N_q(r) \frac{d\sigma(\lambda_L, \lambda_R, \pi)}{d\Omega}$$

we assume:
power-4 dependence between
546 (emission at 532 nm) and 360 (355 nm)

- significantly dependent on the structure of the crystal and the crystallization process
- we need more studies for quartz in mineral dust particles.

Example of the first measurement with optimized instrument Quartz concentration profile: „super dust outbreak“ Korea 2010





Müller et al., Geophy. Res. Let., 2010
first results

Mineral quartz concentration measurements of mixed mineral dust/urban haze pollution plumes over Korea with multiwavelength aerosol Raman-quartz lidar

D. Müller,[1] I. Mattis,[2] B. Tatarov,[3] Y. M. Noh,[1] D. H. Shin,[1] S. K. Shin,[1] K. H. Lee,[1] Y. J. Kim,[1] and N. Sugimoto[3]

Tatarov et al., Opt. Exp., 2011
instrument

Lidar measurements of Raman scattering at ultraviolet wavelength from mineral dust over East Asia

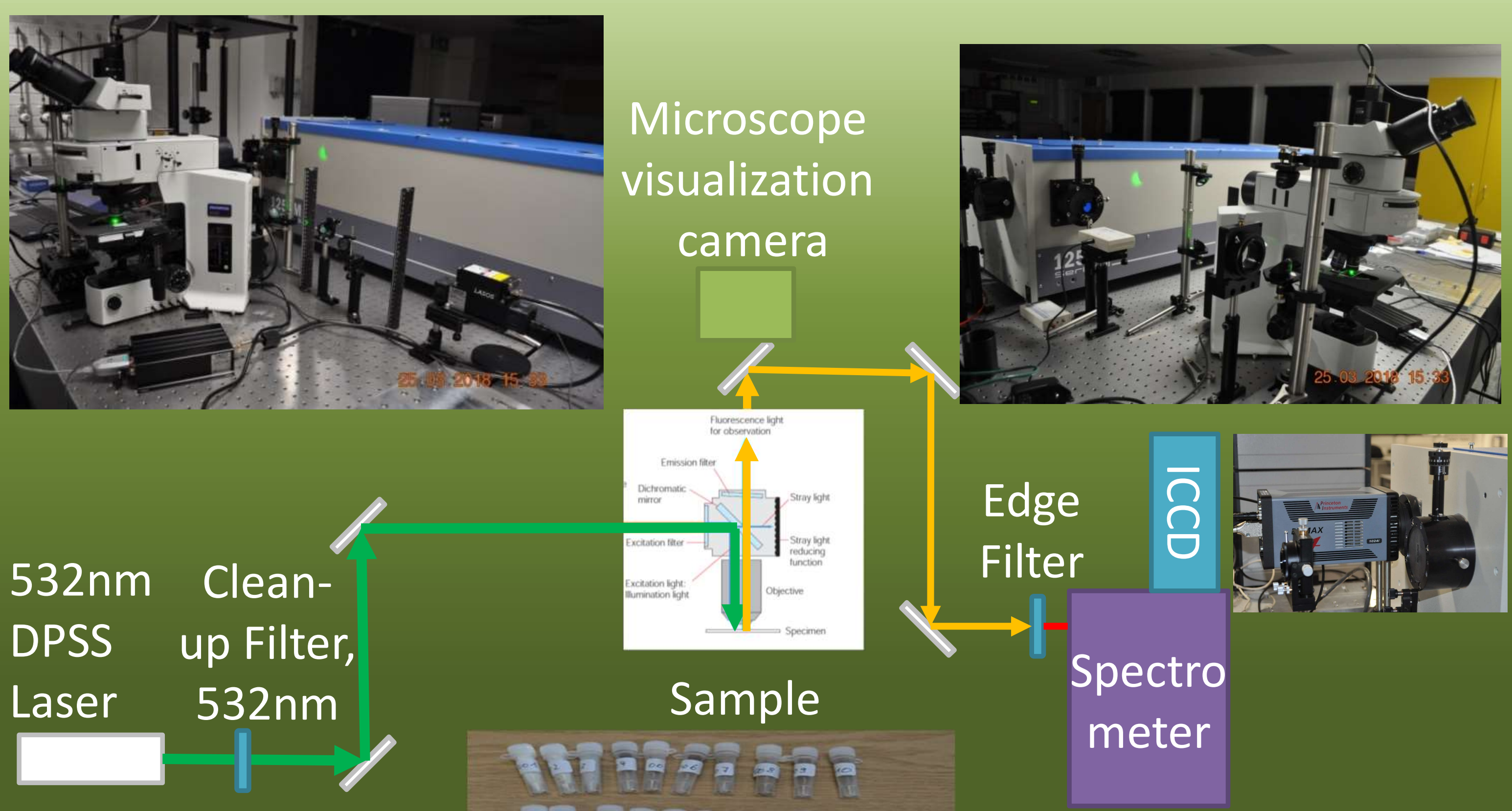
Boyan Tatarov,[1,*] Detlef Müller,[2] Dong Ho Shin,[2] Sung Kyun Shin,[2] Ina Mattis,[3] Patric Seifert,[3] Young Min Noh,[2] Y. J. Kim,[2] and Nobuo Sugimoto[1]

Noh et al., Chemosphere, 2016
overview

Vertically-resolved profiles of mass concentrations and particle backscatter coefficients of Asian dust plumes derived from lidar observations of silicon dioxide

Youngmin Noh[a], Detlef Müller[b,*], Sung-kyun Shin[c], Dongho Shin[d], Young J. Kim[c]

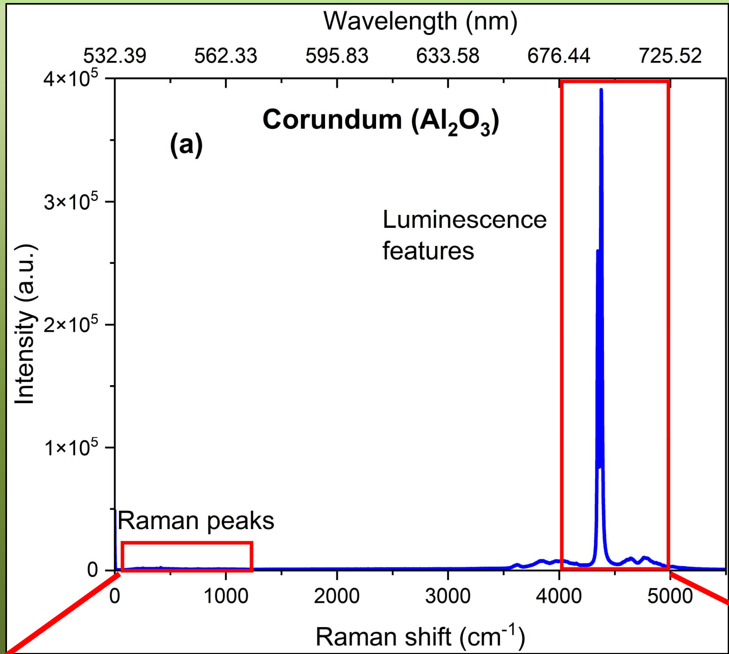
Transfer Experience From These Studies to LITES: Laboratory Experiments with Raman/Fluorescence Microscope



40 different dust samples from desert regions

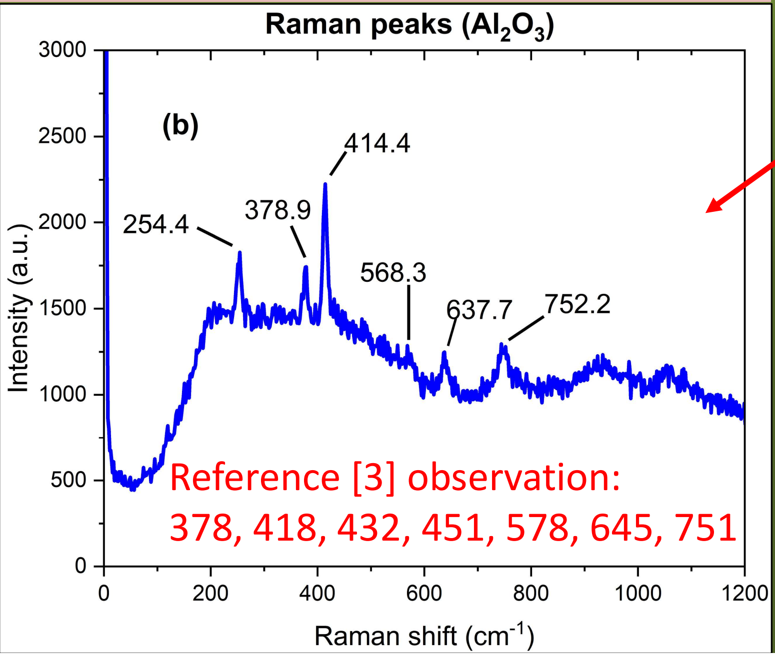
Aluminum oxide, Quartz, Kaolinite, Dolomite, Goethite, Calcite, …

Results: Corundum (AL_2O_3)

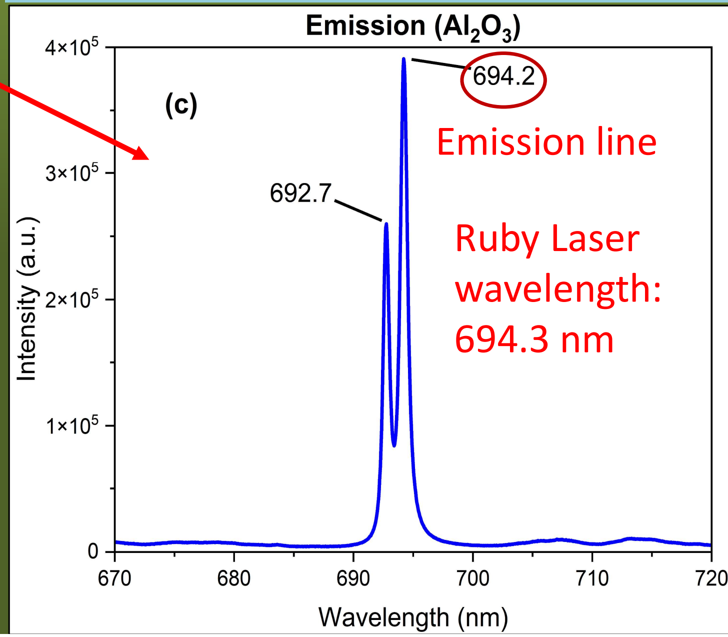


Raman spectrum of corundum

Raman lines of corundum



Position of luminescence features



Signal strength of emission line of corundum shows that atmospheric Al_2O_3 molecules can be detected with lidar.


EC - Marie Skłodowska Curie Programme (2017)
European Commission
LIDAR Project CAPABLE
Chemical composition characterization
of Air Pollution (Aerosols and gases) on
the Basis of nonlinear multi-channel
Lidar Experiments

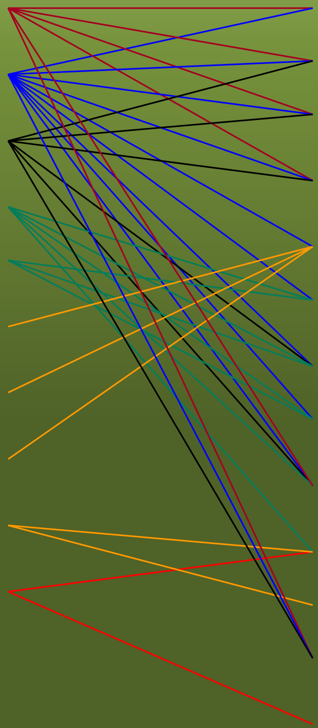
Future Work with LITES: „Chemical Fingerprint“

aerosol types versus aerosol components

OPAC (Database on Optical Properties of Aerosols and Clouds, Hess et al. 1998)

Aerosol components
microphysics, chemistry, morphology

- Insoluble
- Water-soluble
- Soot
- Sea-salt: accumulation mode
  - coarse mode
- Mineral: nucleation mode
  - accumulation mode
  - coarse mode
  - transported
- Sulfate droplets



Aerosol types
optics

- Continental: clean
  - average
  - polluted
- Urban
- Desert
- Maritime: clean
  - polluted
  - tropical
- Arctic
- Antarctic
- Mineral transported
- Free troposphere
- Stratosphere