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In-Situ Laser Polarimetry for Cloud Microphysics: The Hyper-Angular Cloud Polarimeter (HACP)

HACP Series

The Hyper-Angular Cloud Polarimeter (HACP) is an advanced laser-based polarimeter developed for high-resolution particle light scattering analysis. It facilitates non-invasive, in-situ characterization of particle ensembles by capturing the full polarization phase matrix at high angular resolution.

Cloud microphysical parameters such as effective radius and liquid water content are globally retrieved from satellite remote sensing by using modern polarimetric detectors.

The HACP applies the same polarimetric measurement principles, but performs them in-situ. This provides unique benchmark data for validating existing satellite retrieval algorithms and enhancing our understanding of liquid and mixed-phase cloud microphysics.

Applications and Advantages

Versatile Deployment: Adaptable to various platforms, including aircraft, mountain top stations, and cloud and aerosol chambers.

Non-Intrusive Measurements: The instrument eliminates the need for traditional sampling, ensuring observations free from sampling artefacts.

Cloud Droplet Size Distribution: Obtain real-time cloud droplet size distribution parameters from the polarization ratio ($-S_{12}/S_{11}$) in the cloud bow region.

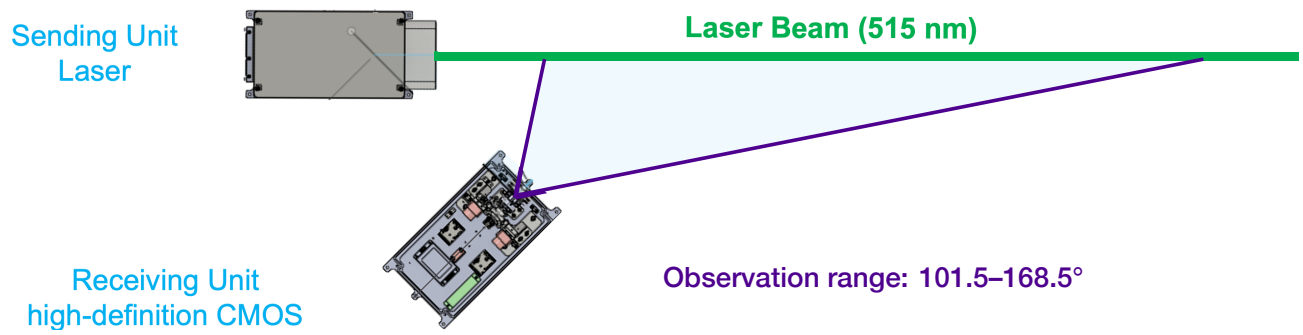
Real-time Cloud Phase Information: Receive real-time information on cloud phase (liquid, mixed, ice) through quasi-simultaneous measurements of the linear and circular depolarization ratios S_{22}/S_{11} and S_{44}/S_{11}.

Validation of Optical Models for Non-Spherical Particles: Full phase matrix measurement constrains the optical model used for parameterizations of the particle optics in radiative transfer algorithms.

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Measurement concept

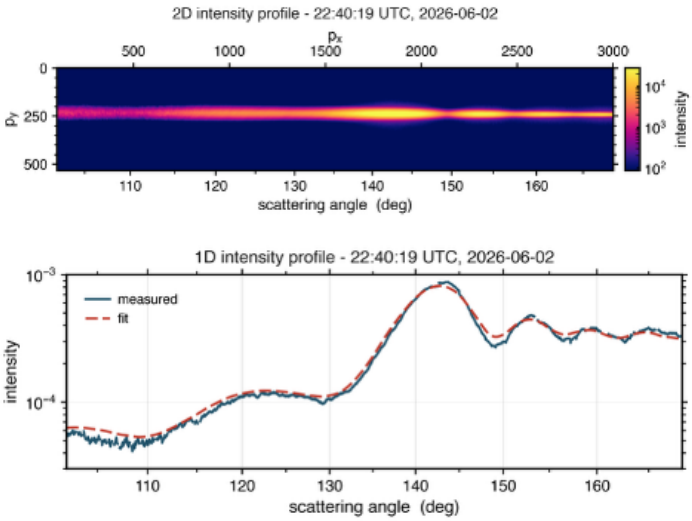


Example geometry with the receiving unit at 45° to the sending unit.

Operation

The sending unit illuminates cloud particle ensembles with a laser beam of adjustable polarization. A wide-angle receiving unit images the scattered light onto a high-definition CMOS sensor, mapping each pixel to a scattering angle.

Adjustable polarization optics enable full scattering phase-matrix measurements across 100–170°, with angular resolution better than 0.1°. These measurements characterize cloud particle scattering and support cloud microphysics research and optical model validation.



Example cloud data: CMOS intensity (top) and extracted angular scattering profile (bottom).

Instrument setup

Sending unit

Laser	25–150 mW; 515 nm; cw; TEM_{00}
Beam	12 mm ($1/e^2$) diameter; adjustable polarization
Safety	Diverging lens for on-site beam-divergence adjustment; accessible interlock and lid switch; shutter and independent power measurement

Receiving unit

Optics	83.9° wide-angle lens; 8 mm focal length
Sensor	1.1-inch monochrome CMOS; 4112 × 3008 pixels; 12-bit depth
Polarization	Thin film linear polarizer and $\lambda/4$ retarder; stepper-motor orientation control
Geometry	Scheimpflug tilted image plane, adjustable to the observation setting
Volume	Approx. 200 cm^3, depending on installation settings

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HACP Specifications

Concept	The HACP is a cutting-edge laser-based optical instrument designed for precise, non-contact measurement of cloud particle scattering properties to advance atmospheric research and climate modeling.
Angular Resolution	<0.1°
Observation Range	100–170°
Observation Volume	Approximately 200 cm^3 (depending on the actual installation settings)
Laser	25–150 mW, 515 nm, cw, TEM_{00} profile.
Sensor Specification	1.1-inch CMOS monochrome sensor, 4112 × 3008 pixel resolution, 12-bit depth
Temperature	–40 °C to +40 °C (heating system in operation)
Humidity	20–100 % relative humidity (r.h.)
Altitude	<3500 m asl
IP Protection Rating	IP66: dust-tight and protected against strong water jets
Installation Place	Outside or indoor installation; installation base plates, allowing for flexible adaptation to on-site conditions.



HACP measurement setup during the Pallas Cloud Experiment (PACE) in 2026.

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Discover Next-Generation Cloud Analysis

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