Airyx GmbH
https://airyx.de

Designed and manufactured in Germany.
A Spin-off from the University of Heidelberg/Germany.

SkySpec-1D-200

(200 series)

Instrument Description

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Scientific measurement system to observe atmospheric gas concentrations by recording high resolution UV-VIS sky spectra (scattered solar light) with a 1-D scanning telescope. It can be applied e.g. for atmospheric gas measurements by the Multi Axis Differential Optical Absorption Spectroscopy (MAX-DOAS) method (according to VDI standard 4212)

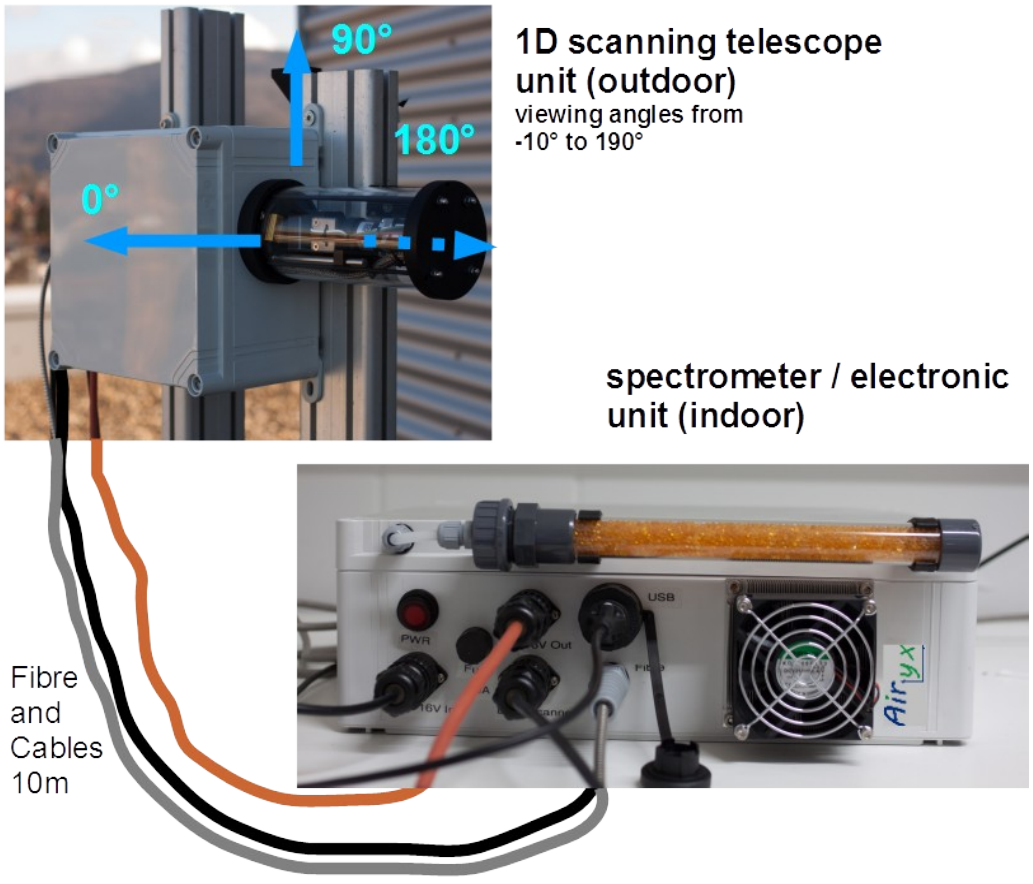

Figure 1: Picture of the Airyx SkySpec-1D 100 System with external telescope.

Airyx offers a variety of custom made spectroscopic instruments for measurements of atmospheric trace gases using e.g. the DOAS technique. Models range from instruments designed for permanent installation and long term measurements to mobile field instruments. Since required measurement sensitivities depend on the application we offer instruments with standard detectors as well as high grade detectors using a back-thinned sensor.

In the SkySpec systems the direct or scattered sunlight is collected by an optical system with a telescope and guided with fibres to one or two spectrometers. The telescope can be moved to different viewing elevation angles. Data acquisition and instrument control are performed with either an internal or external PC.

Our systems are optimized in terms of high measurement accuracy with small measurement setups. Compact spectrometers with good cost-benefit allow smaller and easily mobile systems.

In order to achieve high measurement accuracies, our systems are optimized for:

- high light throughput
- high spectral resolution with constant resolution over the measurement range (typ. 0.6nm or 0.45nm according to configuration)
- coverage of a large spectral range (typ. 300 - 550nm)
- use of high quantum efficiency detectors
- high spectrometer stability due to precise temperature control (better 0.04°C)
- low spectrometer stray light
- small telescope opening angle (typ. 0.4° vertical)
- precise elevation position of telescope (scanner) with automatic elevation angle correction (no need to manually adjust the telescope)
- automatic telescope heating below 5°C
- low electronic noise
- low power consumption with the use of a high efficiency temperature controller
- full automatic long term operation

The measurement systems are operated by MSDOAS (free for scientific use) and a preconfigured measurement script for each instrument. Optional spectral data analysis packages based on the DOAS technique and adapted to each instrument can be offered. For scientific applications we recommend the DOASIS software. We currently do not provide a software to retrieve vertical aerosol and trace gas profiles.

The new 200 Series

The 200 Series provides an update from the previous version for the main electronic and the telescope optical setup.

The new electronic provide more reliable and robust instrument operation with more features to change and adapt the instrument parameters to personal needs. The improved electronic design should further reduce electronic malfunctions and can easier be upgraded with additional features.

The new optical telescope design improves the reliability of the optics also unter hard conditions, to avoid moving and deajustment of optical parts. Also malfunction of motor controlled optomechanical parts is further reduced.

Basic System Setup:

The system consists of two components: indoor module with temperature stabilized spectrometer(s) and electronics and outdoor optical system (telescope) for light collection (see Figure 2). Both components are connected with an optical fibre (typical 10m and up to 20m), power and controlling cables. This system is recommended for long term or permanent installations or measurements at very cold or warm environments as the sensitive spectrometers and electronics can be set-up indoors in a dry and relatively temperature stabilized environment. Thus, longer lifetimes and better measurement accuracies can be achieved.

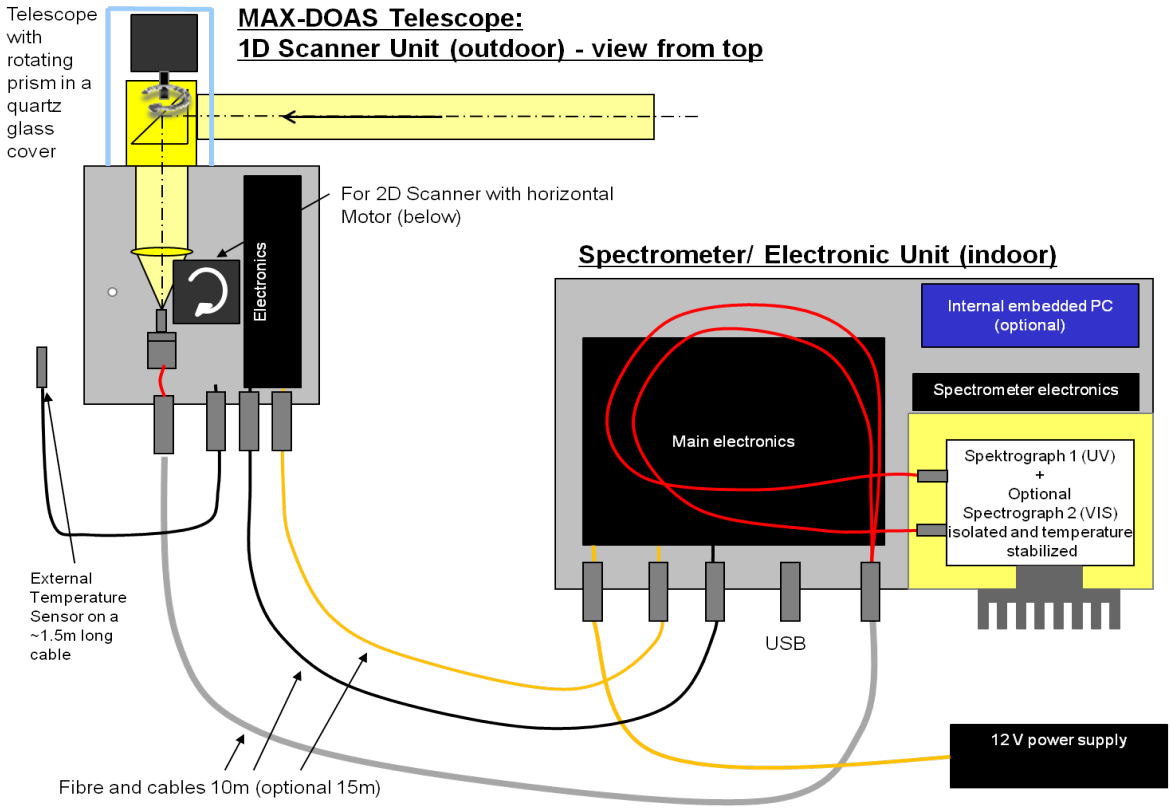

Figure 2: Sketch of the SkySpec-1D with Separate Spectrometer Scanner System. The spectrometers and all main electronics are located indoor. The telescope unit with the scanner is located outdoor. (side view).

Spectrometer unit

The spectrometer system includes the spectrometer(s), controlling electronic and spectrometer temperature control. We offer systems with one spectrometer (Spec1) and with two spectrometers (Spec2). Two spectrometers allow coverage of a larger spectral range. We apply custom made high quality spectrometers from Avantes. For many applications with lower required sensitivity, regular CCD detectors can be applied. For high sensitivity measurements, particularly in the UV spectral range (below 400nm), the high grade detector with back-thinned CCD sensor is highly recommended. The quantum efficiency of this sensor is between 60 and 80% compared to 10 to 40% of the regular CCD sensor. The largest differences arise for measurements of the UV spectral range below 400nm. Additionally the back-thinned sensor size (in height) is almost a factor of four larger. Thus, with the optimised fibre bundle, more light can be collected. Both effects lead to an improves signal to noise. For applications that require high accuracy measurements we strongly recommend spectrometers with high grade detectors. Additionally Airyx arranged custom-made adjustment and optimisation of Avantes spectrometers for best performance in DOAS instruments. Thus we can provide much better spectral properties than available for standard Avantes spectrometers. For more general details on spectrometer properties please consult www.avantes.com.

The spectrometer system includes an air drying unit with desiccant that must be replaced regularly (depending on surrounding humidity typical replacement every 6 to 12 months, colour change indicate the requirement to change desiccant).

Spectrometer(s)	Avantes AvaBench-75
Spectrometer focal length	75mm
Spectrometer spectral range	UV: 300 – 460nm or 300 - 405nm* VIS: 407 – 560nm or 430 – 574nm or 407 to 500nm* (custom configurations are possible)
Spectrometer spectral resolution	~0.6nm and 0.45nm* (for standard configuration)
Spectrometer stray light	Ultra low stray light configuration (ULS), typical total stray light ratio <0.04%
Spectrometer detector options	High Grade: back-thinned Hamamatsu detector with 2048 pixels (14µm) and 895µm sensor height, high UV sensitivity with quantum efficiency of ~ 60%, high light throughput due to high sensor height Regular: Front illuminated Sony detector with 2048 pixels (14µm) and 200µm sensor height, additional UV/VIS collimator lens for better sensitivity with high entrance slits Regular - DUV: Front illuminated Sony detector with 2048 pixels (14µm) and 200µm sensor height, Deep UV lumogen coating for sensitivity below 350nm down to 200nm (~10-20% quantum efficiency), additional UV/VIS collimator lens for better sensitivity with high entrance slits
Spectrometer RMS	RMS noise of ~10^{-4} with 1000 scans
Integration time	2.5ms – 60s typical integration time for SZA < 45° is below 100ms/ scan typical more than 500 scans / spectrum or elevation angle within 60s
Optical filters	Band pass filters are applied in the spectrometers to further reduce perturbing spectrometer internal stray light UV spectrometer: UV bandpass filters (e.g. BG 3) VIS spectrometer: band pass filter (e.g. BG40, BG39)
Spectrometer interface	USB 2.0 (1 outside connector, internal USB hub)
Spectrometer power supply	via USB hub
Spectrometer temperature control	Fast response with efficiency of typical >90% with PWM control[1)] and smoothed power output for low electronic noise
Spectrometer temperature control range[2)]	0°C to 40°C, steps of 0.1°C, system can heat and cool
Spectrometer temperature control accuracy	<0.05°C (with optimized parameters according to the environment), typical better than 0.02°C
Spectrometer temperature control interface	USB 2.0, with data logging

Telescope unit (1D)

The light collection is performed by a telescope that consists of a rotating quartz glass prism in a quartz glass tubing and a quartz glass lens to focus the light on the optical fibre. Only quartz glass optical components are used for optimal UV light transmission. No moving or rotating components are outside and thus corrosion and degradation of mechanical components due to rain water is avoided. A stepper motor rotates the prism to achieve different elevation angles. For precise movement to the chosen elevation angles, the prism is equipped with a tilt sensor and the internal electronic automatically measures and corrects the elevation angle. This makes the system easy to install and reliable as no manual precise adjustment of the telescope position is required.

Telescope viewing direction	About -10° to 190° in respect to the horizon
Telescope elevation angle steps	0.1° or smaller
Telescope elevation angle correction	Better than 0.2°

Telescope opening angle (vertical)	typ 0.4°
Optical fibre configuration	Multimode quartz glass fibre bundle 7 x 100µm fibres from telescope split to 6 x 100µm fibers arranged in slit for UV-spectrometer 1 x 100µm fibre for VIS–spectrometer This configuration is chosen, as typically much more light is available in the visible spectral range. (different configurations are possible) all connectors are FSMA
Optical fibre length	10m or 15m with stainless steel metallic jacket (other fibre length are available, please consider light loss with long fibres)
Operating temperature	-30° to +60°C (with telescope heating) +3° to + 60°C (without telescope heating)
Low temperature configuration	To operate the telescope between -30°C and 0°C an additional heater for the optics is installed, which switches on at temperatures below 5°C to avoid condensation and snow and ice building up on the optics. Additionally cold temperature resistant cables and sealing are applied
Dimensions 1D Telescope (housing with scanner head, mounted on the side e.g. wall)	36 x 13 x 20 cm^3 (width x depth x height)
Weight 1D Scanner with cable	~ 6kg

Power

Voltage	9-15V
Maximum power consumption (without PC)	120W
Typical power consumption (without PC)	20 - 30W

The instrument power consumption strongly depends on the set temperature of the spectrometers in relation to the surrounding temperature of the spectrometer housing. If an appropriate temperature is chosen, the system requires only few Watts (excl. PC). The instruments are delivered with the according 12V power supply.

Measurement Software

On license MSDOAS from the Institute of Environmental Physics, University of Heidelberg. A preconfigured, adapted and tested measurement script will be provided. Recorded data are in *.mfc format for subsequent data processing and analysis with the software DOASIS (University of Heidelberg, Germany) and WinDOAS (BIRA-IASB, Belgium).
MSDOAS allows flexible selection of a number of added spectra and/ or integration time, choice of elevation angle(s), recording geographic location, calculation of solar zenith angle, and ability to collect automated measurements over several days, automated measurements of offset and dark current at night, and records each spectrum with its own running file number.

Optional Components

Integrated HG wavelength calibration lamp (PenRay)	The telescope will feature an integrated HG (mercury) lamp (Pen Ray low pressure lamp) for wavelength calibration. The HG light will be redirected by a diffuser plate to the fibre (blocking the sunlight). Automatic HG lamp spectra will be supported by the hard- and software. This setup includes the telescope shutter. (other calibration gases on request)
Telescope shutter	A shutter to block the sunlight entering the fibre. This allows automatic recording of offset, dark current and calibration spectra during daylight. The shutter can be controlled by the software.
Hand held HG calibration lamp	A hand held HG (mercury) lamp with fibre connector for manual wavelength calibration measurements (4x1.5V batteries).
Embedded PC	Low power embedded PC for measurements,~8W power consumption, 1.6GHz processor, 4GB memory, SSD hard drive as data storage and Windows 10 system, LAN / W-LAN communication for operation and data transfer via remote desktop.
GPS	USB GPS system on separate USB cable