A small satellite with a dual-frequency heterodyne spectrometer for the detection of atomic oxygen in the atmosphere of Earth

H. Richter[1], J. Hildebrandt[2], T. Roth[2], M. Lengowski[2], C. Philpot[3], A. Braukhane[3], T. Delovski[3],
M. Wienold[1], S. Klinkner[2], H.-W. Hübers[1,4]

Atomic oxygen (OI) is the main component of the mesosphere and lower thermosphere (MLT, altitude approx. 80-300 km) of the Earth. It is generated through photolysis of molecular oxygen or ozone by ultraviolet radiation from the Sun. The photochemistry and the energy balance of the MLT are governed by OI. In addition, it is a tracer for dynamical motions in the MLT. OI is extremely difficult to measure with remote sensing techniques, since it has not many optically active transitions. We have measured the fine-structure transition of OI at 4.7448 THz using the GREAT heterodyne spectrometer on board of SOFIA, the Stratospheric Observatory for Infrared Astronomy. This is the first measurement of the OI emission line shape at 4.7448 THz. This method enables the direct measurement of OI without involving photochemical models and agrees within 10% with recent atmospheric models. In contrast, OI concentrations derived from satellite instruments are not derived from direct observations of OI and involve complex photochemical models. This is where a small satellite mission could be beneficial. The derived concentrations are up to 100% larger than predicted by atmospheric models. Therefore, we propose to measure the fine structure transitions of OI at 2.06 and 4.7 THz with a dual-frequency heterodyne spectrometer on a small satellite. This satellite mission, called OSAS (Oxygen Spectrometer for Atmospheric Science) will yield more accurate results than previous missions, global coverage and annual variations of OI.

As a first step towards realization of OSAS, a small satellite study has been performed based on Concurrent Engineering methods. The proposed science payload is a dual frequency heterodyne spectrometer (Fig 1). The low-frequency channel is centered at the 2.06 THz fine-structure transition of OI and the high-frequency channel is centered at its 4.7-THz fine-structure transition. The low-frequency channel has a Schottky diode mixer with a multiplied microwave oscillator as local oscillator (LO). The high-frequency channel is based on a Schottky diode mixer and a quantum-cascade laser (QCL) as LO. The backend is a digital fast Fourier spectrometer. To provide complete OI mapping of the Earth plus characterization of particular areas of interest, the spacecraft design options allow the observation of the MLT at different local times during the time of the mission. Therefore, a high inclination low earth orbit, preferably a sun synchronous orbit (SSO), is intended as initial orbit. In case of a SSO a propulsion system adapts the orbit to observe the MLT at different local times. A total mission duration of 24 months is planned. Five solar array panels will provide up to 260 W electrical power required by the entire spacecraft for this challenging mission. The total mass of the spacecraft (Fig. 2) has been estimated at approx. 240 kg with the 50 kg OSAS payload.

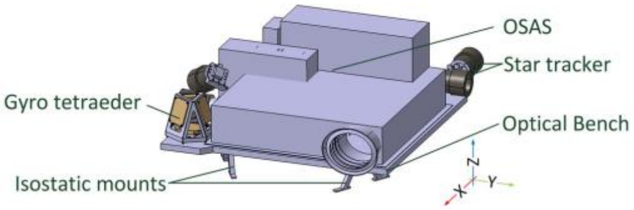

Fig. 1: Scheme of the optical bench with OSAS payload.

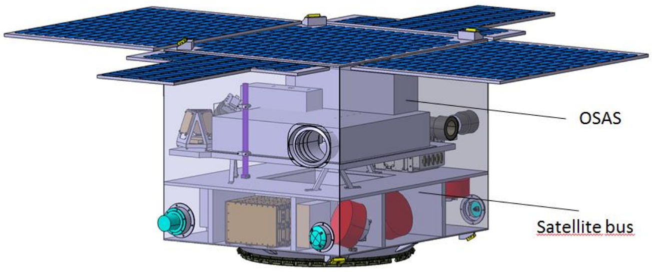

Fig. 2: Scheme of the satellite (deployed).

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[1] German Aerospace Center (DLR), Institute of Optical Sensor Systems, Rutherfordstr. 2, 12489 Berlin, Germany

[2] University of Stuttgart, Institute of Space Systems, Pfaffenwaldring 29, 70569 Stuttgart, Germany

[3] German Aerospace Center (DLR), Institute of Space Systems, Robert-Hooke-Str. 7, 28359 Bremen, Germany

[4] Humboldt-Universität zu Berlin, Department of Physics,
Newtonstr. 15, 12489 Berlin, Germany

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