2.5 THZ AIRBORNE HETERODYNE SYSTEM FOR MEASUREMENT OF STRATOSPHERIC OH

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Abstract
A 2.5 THz heterodyne system originally designed for astronomical purposes [1] was modified and further developped for atmospheric measurements. In several flights it was successfully used aboard the research aircraft FALCON at flight altitudes between 11km and 12 km and with pointing angles between 5° and 20° versus horizon. The thermal emission of the hydroxyl radical OH at 2.514 THz was received. The lastest results show a sufficient signal-to-noise ratio that OH concentration profile can be retrieved.

Introduction
The hydroxyl radical OH is involved in all main catalytic ozone destruction cycles. For remote observation of OH the most sensitive spectral range is the far infrared (FIR). The lowest rotational transitions of this short life molecule are in the THz range, where the triplet at 2514.3 GHz is best suited for remote sensing with a heterodyne system [2]: it is strong, interference with lines of other atmospheric species is weak and the frequency is accessible with state-of the art heterodyne technique.

Airborne Heterodyne System
The scheme and the specifications of the airborne heterodyne system are given in Fig. 1 and Tab. 1. The essential parts are the optically pumped far infrared laser used as local oscillator (LO), the GaAs Schottky barrier mixer diode and the acousto-optical spectrometer (AOS).
The FIR laser is designed as a ring resonator, pumped by 20 W of the discharge CO2 laser. With methanol as laser gas it emitts around 10mW FIR output power at 2.522 THz, enough to drive the GaAs Schottky diode mixer in an open structure mount. The atmospheric signal and the FIR laser are spatially overlapped with a double sideband diplexer (Martin-Puplett type). The diode, the diplexer and the other optical components including the pointing mirror are fixed to the optical plate which is mounted at the level of the aircraft window. The position of the pointing mirror determines the angle at which the atmospheric signal is received, furthermore the mirror can be switched to a hot and a cold calibration load. An off-axis parabolic mirror focuses the radiation into the main beam of the 4λ whisker antenna (10dB beam width: 26°). The Schottky diodes of type 1I12 and 1T15 were used, designed and fabricated by the University of Virginia [3]. The intermediate frequency at 8.5 GHz is first amplified with a 33dB low noise HEMT amplifier at liquid nitrogen temperature. In a second mixer stage the signal is downconverted a second time to adopt it to the center frequency of the acousto-optical spectrometer (AOS). In the first flight campaigns the AOS of the University of Bremen was used with 0.995 GHz center frequency, 840 MHz bandwidth and a resolution of 1.5 MHz, for the last flight an AOS of MAN Technology (center frequency: 2.1 GHz, bandwidth: 1400 MHz, resolution: around 1 MHz) was used.

Results
The system has been successfully operated from aboard the DLR jet aircraft FALCON at flight altitudes between 11km and 12km over Germany [4].
The first measurement was performed in June 1994 at a flight altitude of 11.3km, observation angle 20° and a system noise temperature of 68000K (diode: 1I12). Temperature recording outside the aircraft indicated that we were above the tropopause. In Fig. 2a the spectrum is shown which results out of 245sec OH net observation time. During the second flight in September 1994 the flight altitude of 11.9km was still in the tropopause. The observation angle was 22°. The net observation time for OH was 314 sec. The system noise temperature was improved to 18000K (diode: 1T15), which yields a less noisy baseline comparing (a) and (b) in Fig. 2. In Fig. 2a and b calculated spectra are given

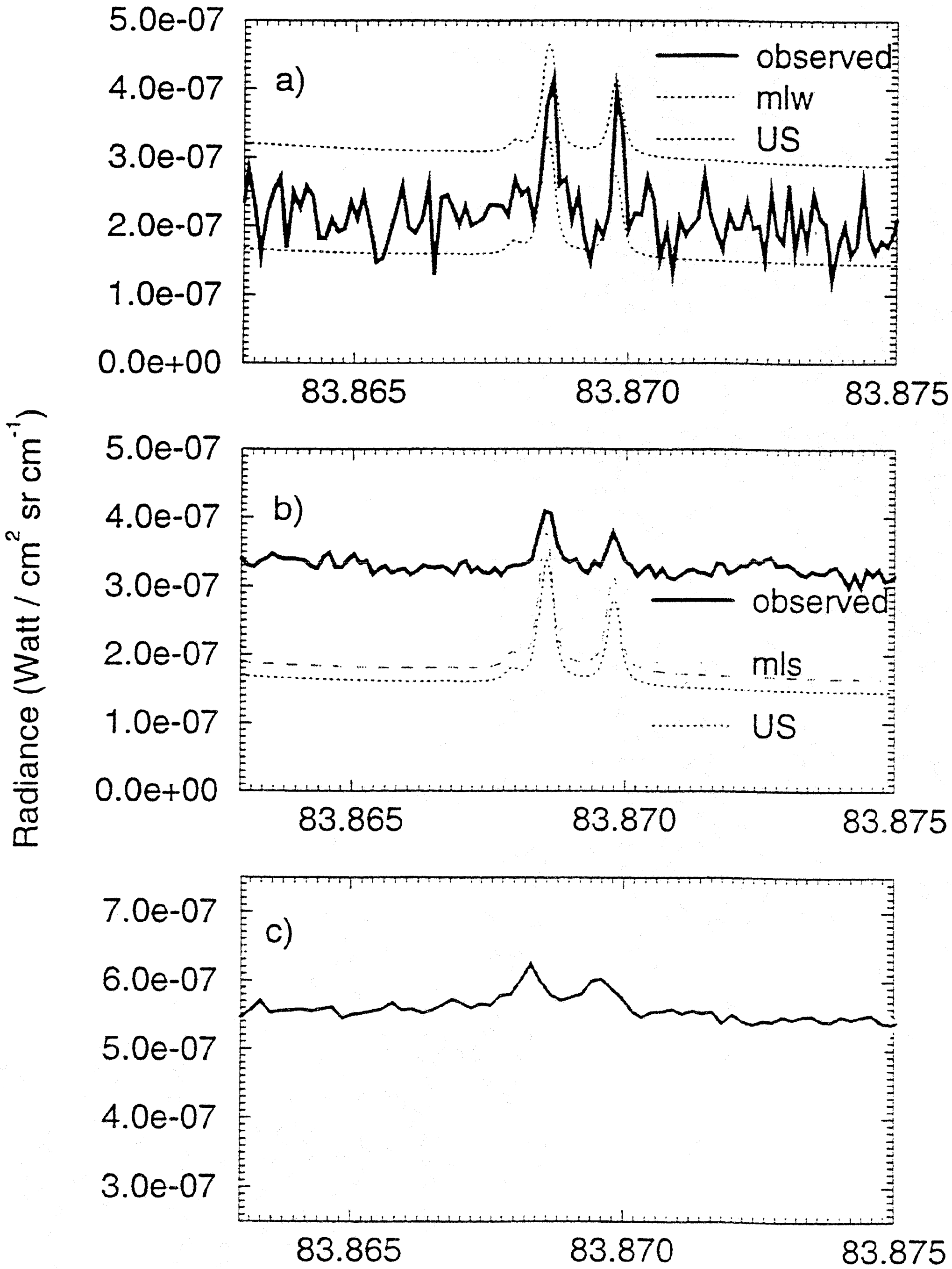


Fig. 3: Spectra of stratospheric OH measured aboard the FALCON aircraft

a) June 1994, observation angle: 20°, Tsys= 68000 K, altiude: 11.3 km, above tropopause, OH observation time: 254 sec.

b) September 1994, angle: 22°, Tsys= 18000 K, altitude: 11.9 km, in the tropopause, OH observation time: 314 sec.

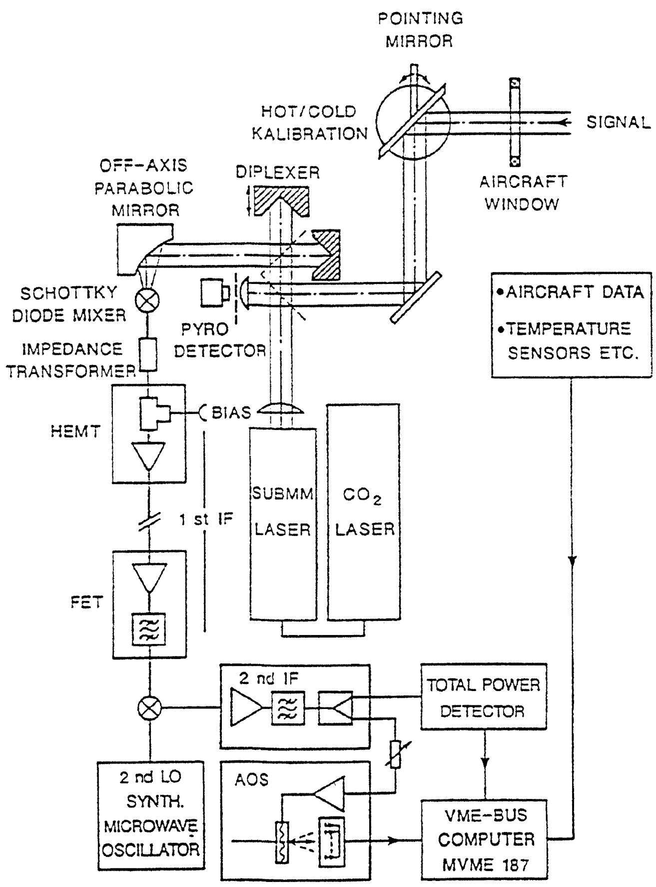
c) March 1995, angle: 10°, Tsys:18000 K, altitude: 10.7 km, in the tropopause, OH observation time: 831 sec.

with respect to the flight conditions and different atmospheric models. For the June measurements the model of midlatitude winter (mlw) seems to fit best, for September the midlatitude summer (mls) model was closest to the measurements, in both figures the forward calculation with the US standard atmosphere is also given.
In February/March 1995 we participated in the Second European Stratospheric Arctic and Mid-latitude Experiment (SESAME). In Fig. 2c a spectrum is shown which was obtained at 10.7 km with an observation angle of 10° during a flight from Stockholm to Munich. The system noise temperature with a 1T15 diode was around 18000K. Because of a further improved system, especially with respect to the optically pumped laser, the time for measuring the atmospheric signal could be increased to 831 sec during one flight hour.

Conclusion
A heterodyne system at 2.5THz has been used to measure the thermal emission of upper stratospheric OH in several flights. The system was improved steadily, the latest results yield spectra which can be inverted in order to obtain OH concentration profiles. This seems to be a promising step towards the space qualification of a THz heterodyne system.

References:

[1] S. Miller, M. Birk, F. Schreier, D. Hausamann, Int J Infrared and Millim Waves **13**, 1241-1268 (1992)
[2] H.P. Röser, J. Schmid-Burgk, G. W. Schwaab, R. U. Titz, Proc. 29th Int Astrophysical Coll , Liège, Belgium, 3-5 July 1990, ESA SP-314 (1990)
[3] T.W. Crowe, R. J. Mattauch, H.P. Röser, W.L. Bishop, W.C:B: Peatman, X. Liu, Proc. IEEE, **80**, 11 (1991)
[4] R. Titz, M. Birk, D. Hausamann, R. Nitsche, F. Schreier, J. Urban, H. Küllmann, H.P. Röser, Infrared Phys (accepted for publication 1995)



Mixer	GaAs Schottky Diode in a open structure mount Type: 1I12 and 1T15
Local Oscillator	Optically pumped gas laser at 2522 GHz with 10mW output power
1st IF	8.46 GHz
2nd LO	Synthesizer: 7.475 GHz /6.55 GHz
AOS center frequency resolution bandwidth	2048 channels 0.995 GHz / 2.1 GHZ 1.5 MHz / 1MHz ±420 MHz / ±700 MHz
Sensitivity (1T15)	Tsys (DSB)= 18000 K

Tab. 1: Specifications of the heterodyne system. First value for the measurements with the AOSof University of Bremen, second one with the MAN Technology AOS.

Fig. 1: Airborne heterodyne sytem