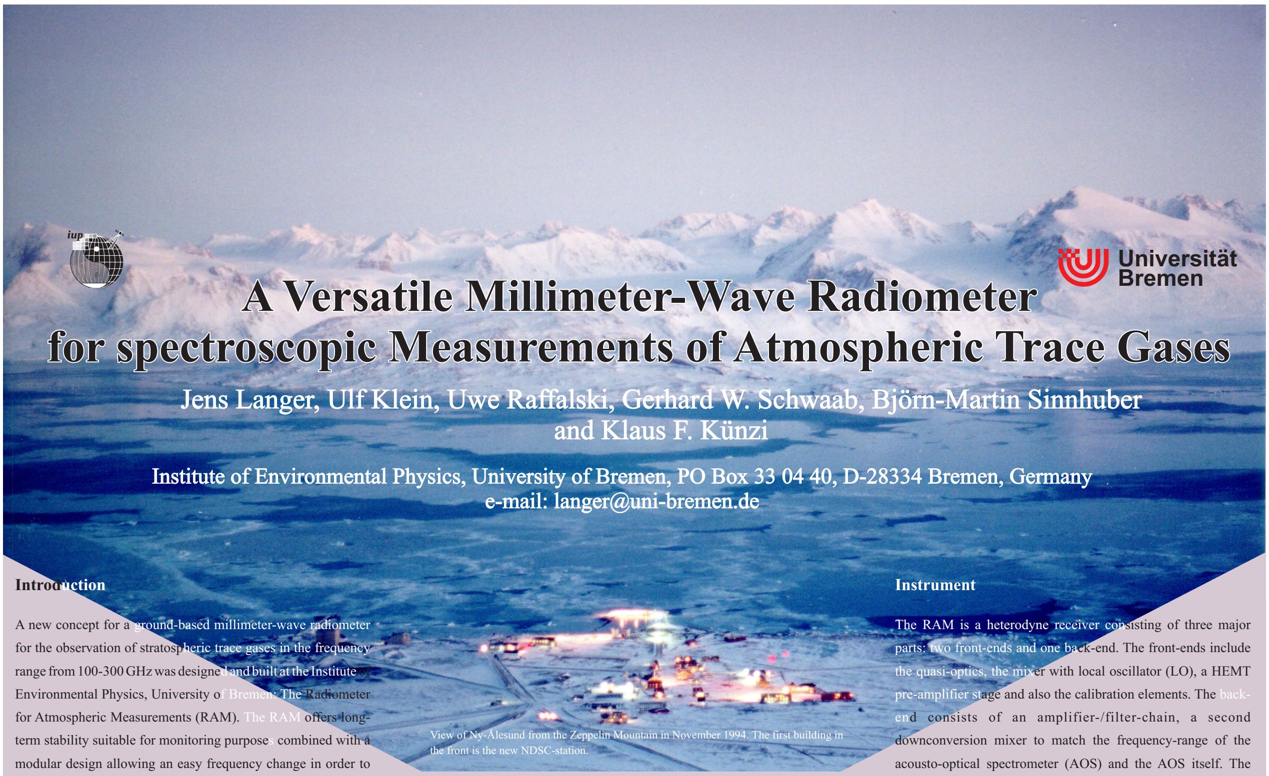

# A Versatile Millimeter-Wave Radiometer for spectroscopic Measurements of Atmospheric Trace Gases

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View of Ny-Ålesund from the Zeppelin Mountain in November 1994. The first building in the front is the new NDSC-station.

## Introduction

A new concept for a ground-based millimeter-wave radiometer for the observation of stratospheric trace gases in the frequency range from 100-300 GHz was designed and built at the Institute of Environmental Physics, University of Bremen. The Radiometer for Atmospheric Measurements (RAM). The RAM offers long-term stability suitable for monitoring purpose, combined with a modular design allowing an easy frequency change in order to observe different trace species.

The RAM was built in 1992 and tested in two winter campaigns. In November 1994 it was permanently installed in the new station at Ny-Ålesund, Spitsbergen, of the Network for the Detection of Stratospheric Change (NDSC). The RAM is now operated continuously and provides data throughout the year.

In the present configuration it measures an ozone line at 142.175 GHz and a set of chlorine monoxide (ClO) lines around 204.352 GHz with a bandwidth of about 1 GHz. From these spectra we can retrieve volume-mixing ratio profiles of ozone and ClO extending from 15 to 55 km.

## Instrument

The RAM is a heterodyne receiver consisting of three major parts: two front-ends and one back-end. The front-ends include the quasi-optics, the mixer with local oscillator (LO), a HEMT pre-amplifier stage and also the calibration elements. The back-end consists of an amplifier-/filter-chain, a second downconversion mixer to match the frequency-range of the acousto-optical spectrometer (AOS) and the AOS itself. The firstly built front-end measures a strong ozone line at 142.175 GHz and the second front-end a set of weak chlorine moxide (ClO) lines at 204.352 GHz. Because of the short integration time required for the ozone detection, both front-ends use the same back-end in a time-sharing mode. The observing time is divided into 80% for ClO and 20% for ozone measurements providing at least one ozone profile per hour.

## Quasi-optics and mixer

The basic design of the two front-ends is quite similar. All quasi-optical components are made from polished aluminum. Wire grids are used as polarisation selective elements. The alignment of the quasioptical elements is done with a laser and a system of apertures. The design goal of the quasi-optics was the frequency independence realized by a modular design restricting the frequency depending elements to the mixer and the LO.

The 142 GHz-mixer is a coolable high performance mixer especially developed for the RAM. It uses a finline structure with an antiparallel mounted pair of Schottky-barrier beam-lead diodes. The mixer is driven by a 67.0875 GHz phase locked gunn diode with a cascaded doubler. It is operated in the upper sideband mode to detect the ozone line at 142.175 GHz.

The 204 GHz mixer consists of a coolable whisker contacted diode which is driven by a phase locked gunn diode at 98.176 GHz with a cascaded doubler. The mixer is used in the upper sideband mode with a center-frequency of 204.352 GHz.

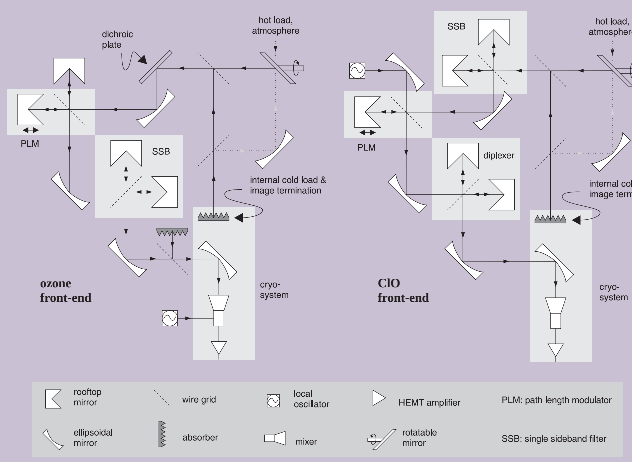


**Figure 1.** The quasi-optics of the two front-ends. On the left is the ozone front-end, on the right is the ClO front-end.

## Instrument performance

| | |
|---|---|
| **quasi-optics** | |
| sideband suppression | > 15 dB |
| Fabry-Perot effect suppression | > 15 dB |
| total loss | 0.13 dB |
| **HEMT** | |
| noise at 12 K | 13 K |
| **back-end** | |
| IF-frequency-range [GHz] | 7.5 – 8.5 |
| total amplification | 100 dB |
| **AOS** | |
| center frequency | 2.1 GHz |
| bandwidth | 955 MHz |
| effective resolution (center channels) | 1.3 MHz |
| **System performance 142 GHz** | |
| SSB system noise temperature (12K) | 620 K |
| SSB system noise temperature (295 K) | 2610 K |
| **System performance 204 GHz** | |
| SSB system noise temperature (12 K) | 1150 K |

## Spectral baseline

The systematical errors superimposed on an emission line are called baseline. Such effects can not be distinguished from the line and therefore directly influence the retrieved profiles. The baseline contributions to the spectra are:

– An offset
– A scaling of the line
– A frequency depending structure

We found two instrumental reasons for the baseline effects in our ozone front-end:

– The mixer is sensitive to higher harmonics of the LO-frequency.
– The mixer is sensitive in the undesired crosspolarisation and also shows a substantial sensitivity at the higher harmonics in the cross-polarisation.

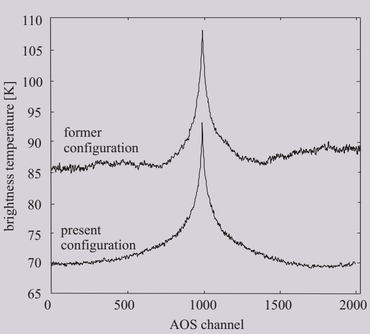


**Figure 2.** Two ozone lines under similar troposheric conditions. The upper line has been measured without the modifications in the quasi-optics to minimize baseline effects, the lower line is a typical ozone line measured with the present configuration and an integration time of 160 seconds for the atmospheric signal (corresponding to 600 seconds total operation time). A profile of high quality can be retrieved from the spectrum without further data preparation.

We successfully cured these problems by mounting two additional elements in the quasi-optical path:

– Cross-polarisation sensitivity: The cross-polarisation was blocked out by an appropriate wire grid polarizer.
– Sensitivity at higher harmonics of the LO: The higher frequencies are successfully suppressed by a dichroic plate acting as an quasi-optical low pass filter.

In Figure 2 two ozone lines are shown measured under similar troposheric conditions without and with the polarizer and dichroic plate. The upper spectrum without the modifications is clearly disturbed by a strong baseline. The lower line is measured with the actual configuration and is nearly undisturbed by baseline effects.

**Figure 3.** Picture of the RAM inside the NDSC-building. On the left side is the rack with the 142 GHz front-end including the electronics and the back-end. On the right side is the rack with the 204 GHz front-end and the required electronics for this front-end. Behind the racks one can see the styroform windows which are transparent in the measured frequency-range. The two front-ends are quite similar and consist of the quasi-optics and the cryo system (the boxes on the right side with the green cooling unit below it). The IF-chain (not visible) is mounted under the quasi-optics of the left rack and the AOS is the box in the lower left corner in this rack.