DESIGNING A MULTIPASS ABSORPTION CELL
FOR A HIGH RESOLUTION FTIR SPECTROMETER

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Abstract

A laser controlled White-type cell has been constructed for high-resolution infrared Fourier spectroscopic research of gas molecules. The cell has been optically optimized for a Bruker IFS 120 high resolution spectrometer. The cell optics has been constructed so that astigmatism caused by off-axis imaging processes at spherical surfaces has been minimized. The basement and the cell itself is transportable. It has been tested many high resolution measurement in the infrared laboratory of Oulu as well as in the Max-laboratory in Lund in Southern Sweden. The construction and properties of this cell are described. The results of the final tests will also be presented.

Introduction

The Fourier spectrometer in the infrared laboratory of Oulu was furnished 1995 with a large (300 l) long path cell giving an absorption path length up to 200 m [1]. Soon after that the cell equipment was completed by building a new multi-pass unit by optimizing the volume and the path length. The newest cell has been published only in several scientific conferences. Because there has been interest in the cell, we decided to publish it in electronic form. The cell has been designed exactly for the optics of the Bruker IFS 120 high resolution FTIR spectrometer. Imaging errors have also been minimized in the optical design of the cell. The model proposed by W.H. Kohn [2] has been applied to minimize astigmatism caused by the off-axis imaging processes at spherical surfaces. With this optimization the cell could be realized for using the absorption path length from 3.2 up to 41.6 meters. The volume is as low as about 20 litres. The cell is transportable and the construction is such that it can be connected to a similar Bruker instrument which is utilizing a synchrotron radiation source at MAX laboratory in Lund.

The cell has been successfully tested in the 10 μm region by measuring the very weak $3\nu_2$ band of $^{13}CS_2$ and the laser bands of CO_2 [1]. With the longest absorption path length of 41.6 m for 100% peaks $S/N_{pp} > 200$ was achieved in 112 hours. In the lower region at 400 cm^{-1} the ν_2 bands of $^{12}CS_2$ and $^{13}CS_2$ have been measured with spectrometer in the IR-laboratory of Oulu (Fig. 10.). In these newest measurement we attained the resolution of 0.0009 cm^{-1} and the signal-to-noise ratio of about 90 with a total recording time of 44 hours and an absorption path length of 16 m. The cell has also been tested in Lund by measuring the $\nu_1 - \nu_2$ band of $^{13}CS_2$ at 274 cm^{-1}. In this test with synchrotron radiation, practically the same resolution was attained with a path length of 9.6 m. For the first time a high resolution spectrum of the very weak torsional ν_6 band of CH_3SiD_3 could also be measured with this cell by using synchrotron radiation [3].

Specifications of the cell

Absorption path length: 3.2 - 41.6 m

Volume: 20 litres

Cell body: Acid-resistant steel

Mirrors: F= 800 mm, spherical, gold coated, dia = 80 mm

Optimized to be used with Bruker IFS 120 Fourier spectrometer.

Transportable.

Absorption path length is controlled by a HeNe-laser.

Micrometer alignments.

Easy changeable window frames

Provided with KBr, KRS-5 and White polyethylene windows.

Window diameter 38 mm.

KF16 flanges for sample inlet and pressure gauges.

Air leakage < 10-3 Torr l/day

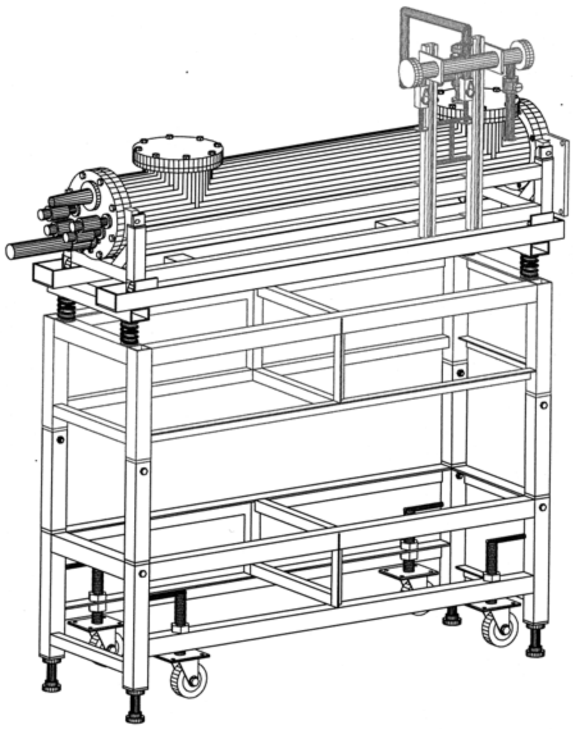

Fig 1. Construction of the cell basement.

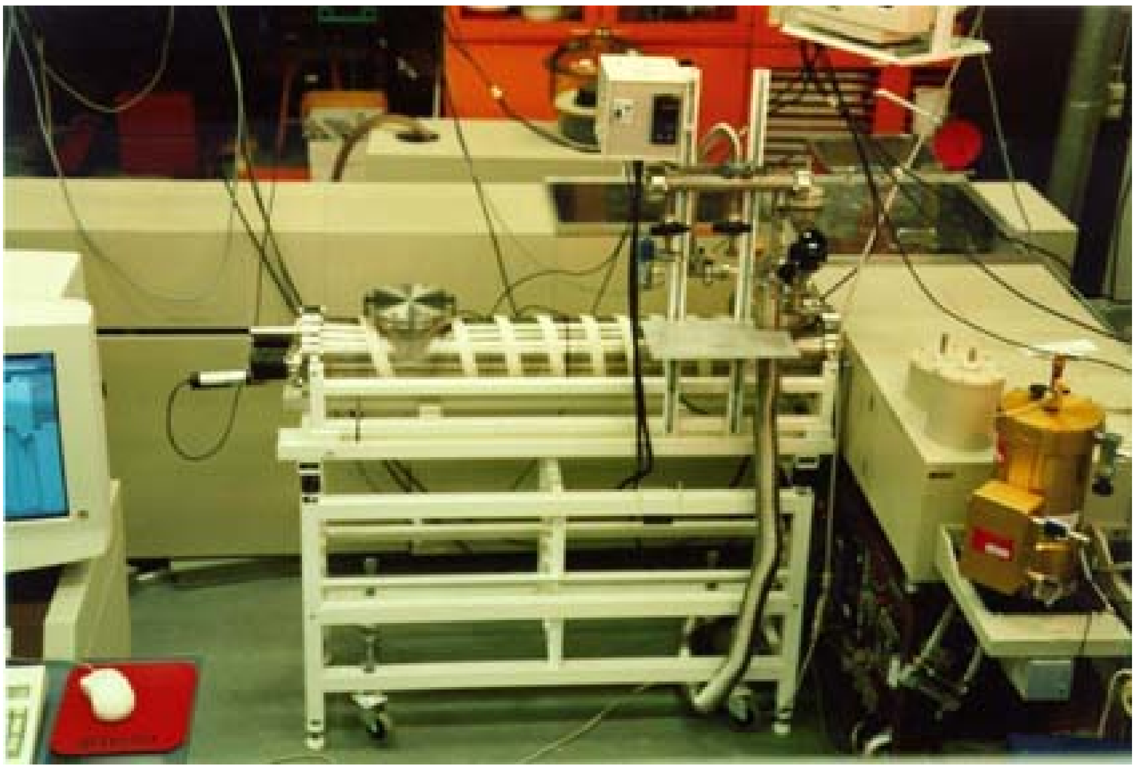

Fig 2. The cell installed into the spectrometer in the Infrared laboratory of Oulu.

Details

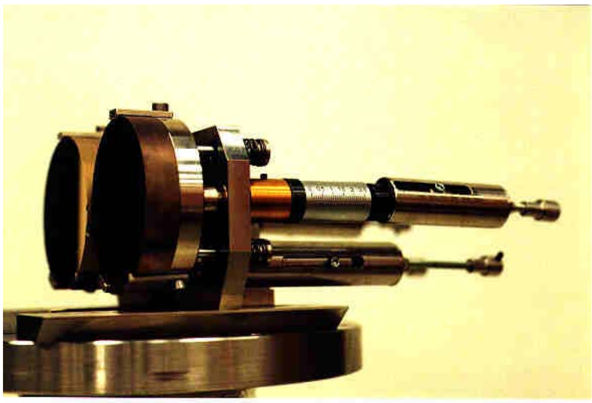

Fig 3. Micrometers with precision of .001mmand flexible axles have been used in the alignments of the mirrors.

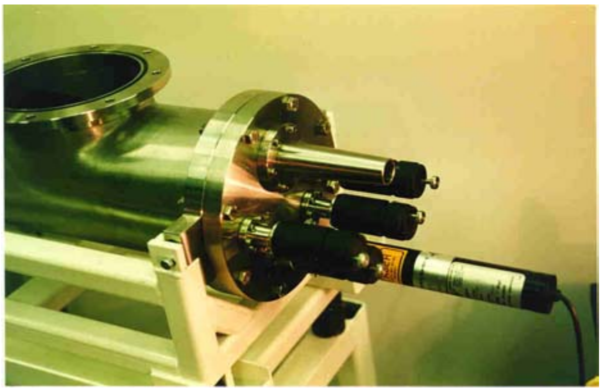

Fig 4. Back-end mirrors are aligned from outside of the cell with commercial feedthroughs (Hundington Mechanical Labs. Inc.) . Pathlegth is controlled with a HeNe-laser.

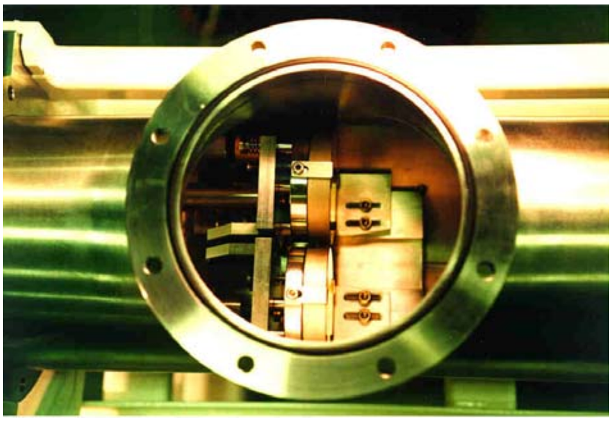

Fig 5. Installation and pre-alignment is made through the openings above the front- and back-end mirrors

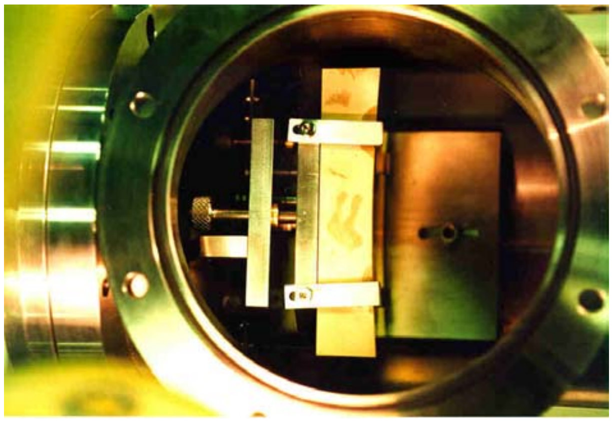

Fig 6. T-mirror inside the cell.

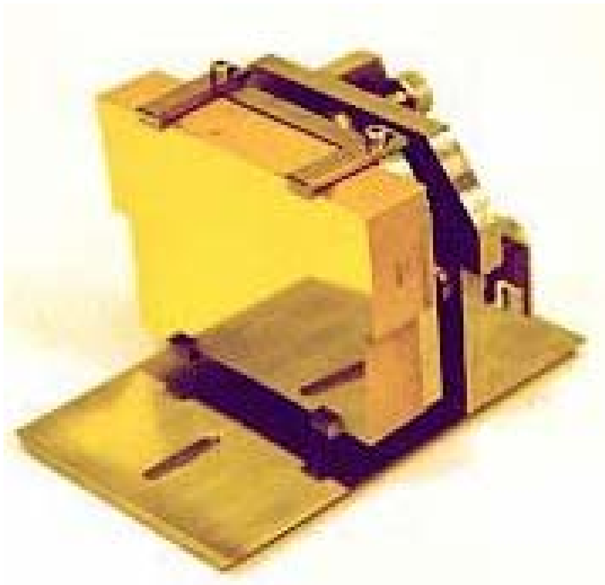

Fig 7. Front-end stand with a gold coated T-mirror.

The cell itself and all possible parts inside have been made from acid-resistant steel. All mechanical work has been made by our workshop of Physics.

The cell mirrors have been manufactured by Optical surfaces Ltd. (England). Fore- and post-optics and spare cell mirrors, too are made by Teknofocus Oy (Finland). All mirrors are gold coated. Measured reflection coefficient is 0.986-0.988.

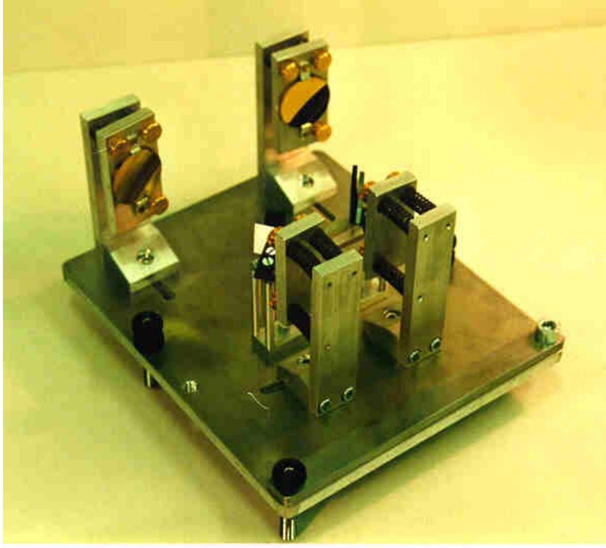

Fig 8. Divergence of radiation is fitted for the cell optics with the fore-optics and then with the post optics it is returned to its initial state. The optics has been mounted on the aluminium plate, which is installed into the sample compartment of the IFS 120 spectrometer. Optics is not symmetric, but after small modifications the same optics can be used on the both side of the spectrometer, however.

Fig 9. The cell windows have been mounted into the frames. When the window is changed, the whole frame is changed. Quick fixing of the frames is made with DN25KF flanges.

Signal damping

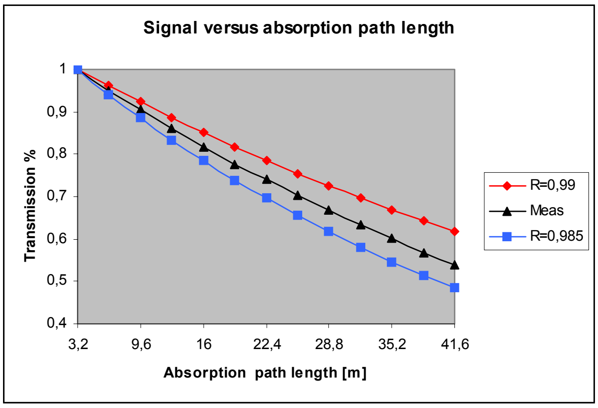

Fig 10. Measured signal as a function of absorption path length. Transmission corresponds well to reflection loss in the mirrors. So image broadening due optical errors has really been minimized. Wavenumber region is 600-1100 cm^{-1}.

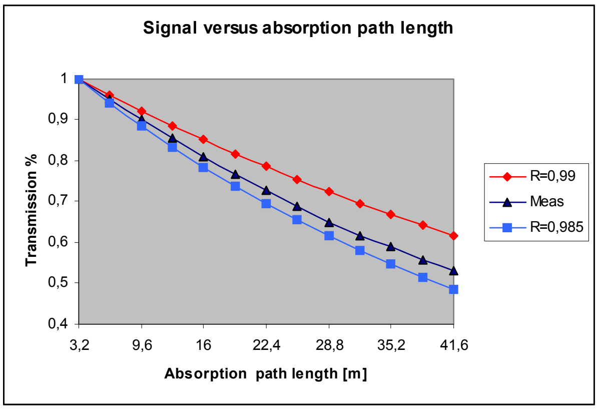

Fig 11. Measured signal versus number of paths in the wavenumber region 2100 – 2500 cm^{-1}.

The measurements show (Fig. 8 and 9) that the transmission losses of the cell are due to the reflection losses at the gold coated mirrors.

Results in measuring real spectra

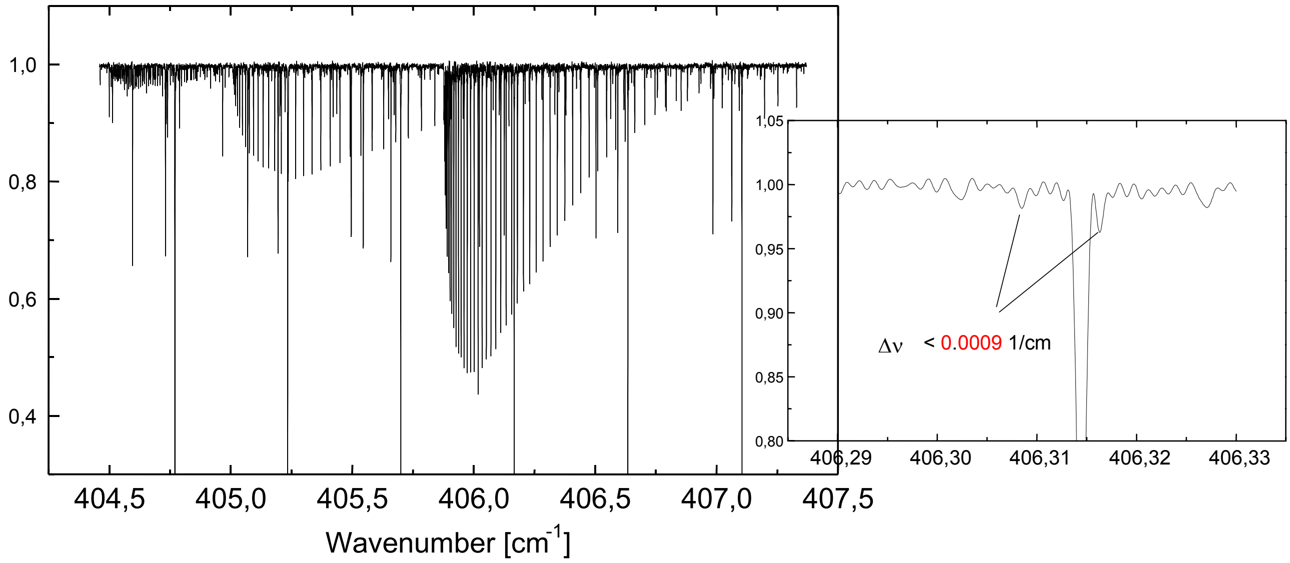

Fig 12. Part of the CS_2 spectrum in the region of ν_2. APL=16 m, P = 0.001 Torr. The measured spectral resolution $\Delta\nu < 0.0009$ cm^{-1} for weak lines. S/N is about 90 for strong peaks. The spectrum has been measured in the Infrared laboratory of Oulu with a Bolometer (made by Infrared laboratory Inc.) at 1.8 K. The scanning time was about 44 hours.

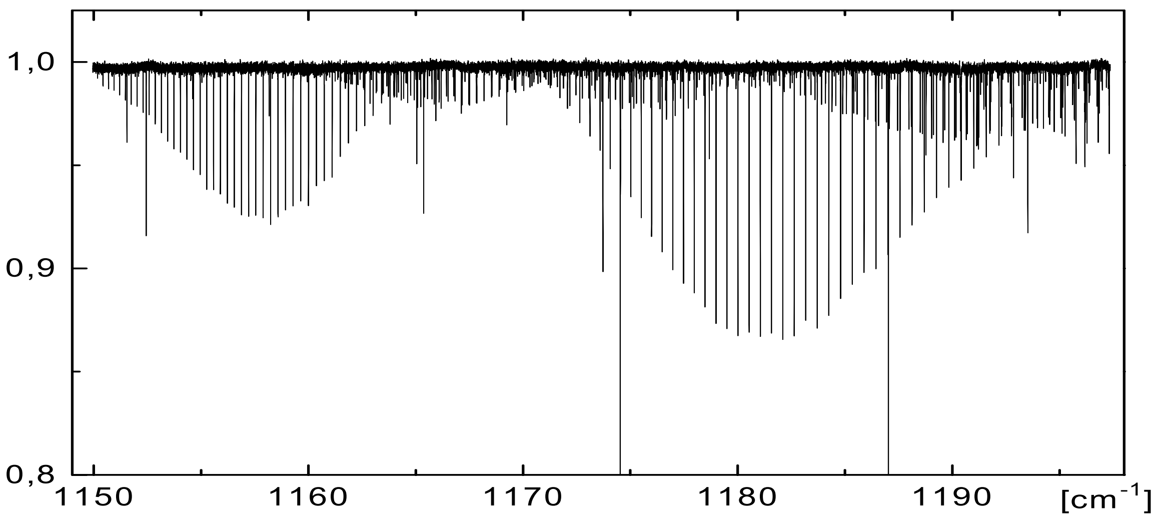

Fig 13. The weak $3\nu_2$ band of $^{13}CS_2$ measured with the new cell connected to IFS 120 of Oulu. APL = 41.6 m, P = 3 Torr, MCT, scanning time 112 h.

During the last years many other measurements have been performed with the cell for infrared spectroscopic molecular research, for example [4-8].

Working with synchrotron radiation in the Max-laboratory

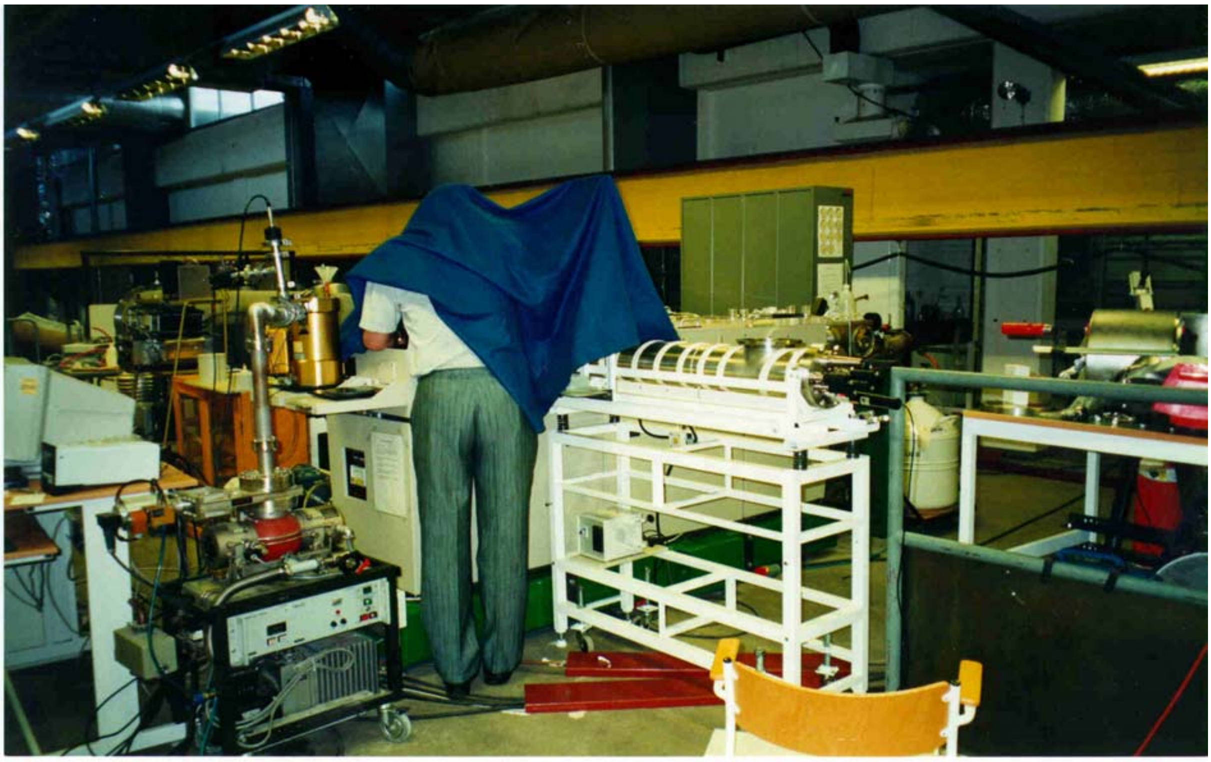

Fig 14. The cell can be used also in Max lab. in Lund with synchrotron radiation. The cell has just been mounted and alignment is going under a blue curtain.

Fig 15. The cell is ready for measurements in Lund. Mr. Schroderus is preparing the first high resolution measurement with synchrotron radiation of torsional band of methyl-silane.

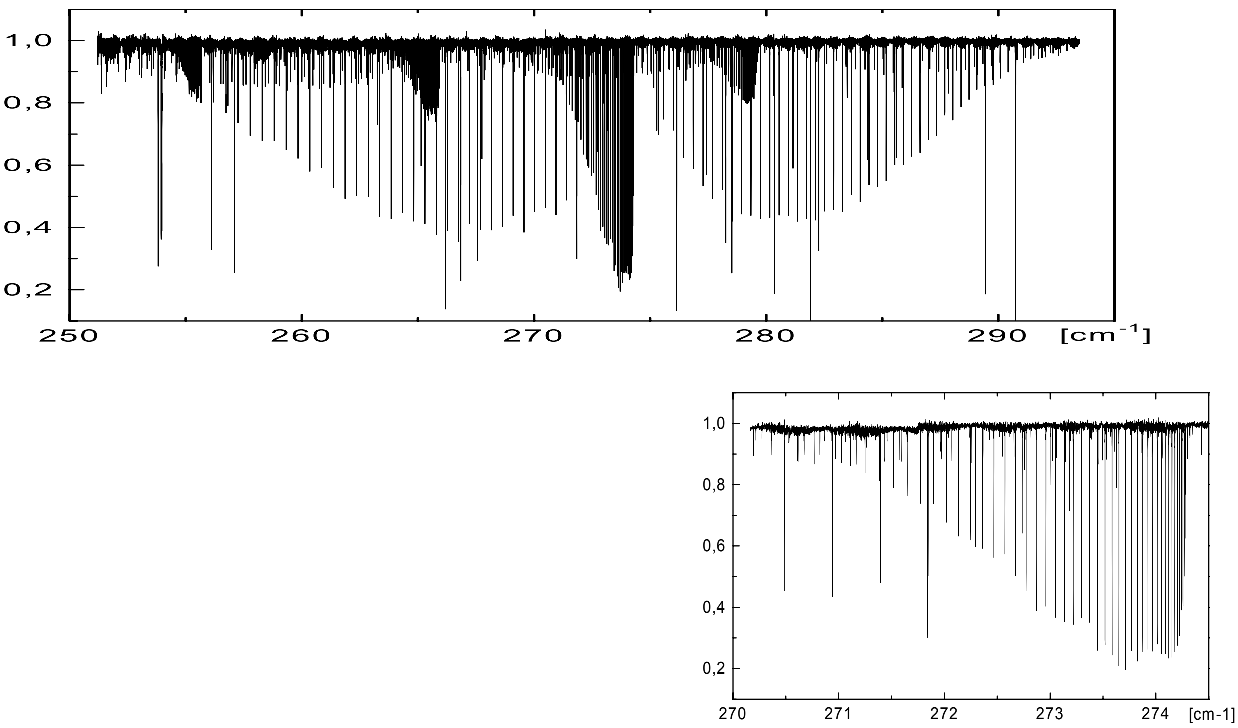

Fig 16. The $\nu_1 - \nu_2$ band of $^{13}CS_2$ measured in Max lab. with synchrotron radiation source. Q-branch in the detail fig. APL = 9.6 m, P = 0.9 Torr, scanning time 12 h. A window between high vacuum and the spectrometer was Si and a huge interference damping was caused by it. That is why there are noise packets in the spectrum.

Acknowledgements

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