

# A Microwave Fourier Transform Spectrometer for the Lower K-band

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We report on the first experiments with Fourier Transform technique in K-band. Due to the limited performance of some components frequencies up to 20.5 GHz only could be reached. Some  $T_2$ -relaxation measurements are given.

We extended the range of our microwave Fourier transform (MWFT) spectrometer [1–3] from the range of 5.4 to 18 GHz to the lower K-band.

In the last years our instrument has proved to be useful in the investigation of the rotational spectra of more than 30 molecules due to its higher resolution compared with conventional Stark modulated spectrometers and because of the possibility to carry out  $T_2$ -relaxation measurements [4]. The sensitivity is also superior to Stark spectroscopy as lines of methane with an absorption coefficient of less than  $3 \cdot 10^{-11} \text{ cm}^{-1}$  can be observed [5].

The experimental setup of the spectrometer is given in Figure 1. It follows the usual construction [1–3].

All waveguide parts have an inner cross section of  $10.67 \times 4.32 \text{ mm}$ , which is standard for the range of 18 to 26.4 GHz. This was necessary especially for the parts 16, 17 and 19\* and 7, 16 and 21 connected to the sample cell to avoid higher modes. The sample cell itself was made of a square guide of  $13 \times 13 \text{ mm}$  inner cross section to reduce wall broadening of the lines and cell attenuation. It is connected by vacuum tight tapers 22 with the parts of standard cross section. The windows 21 were installed at those ends of the tapers which have standard cross section. At the ends of the square cell, mode filters 23 were inserted to suppress the degenerate mode  $\text{TE}_{01}$  polarized perpendicular to

the normal one. This mode may be produced by mode conversion. In the filter sections 23 the square guides were slit (1 mm) along their centre line on the top and bottom side to hinder the wall currents of the unwanted mode. We expect that higher modes of the type  $\text{TE}_{20}$  and  $\text{TE}_{02}$  exist for frequencies above 23 GHz. For these frequencies the cell should be replaced by one of smaller cross section. The modes  $\text{TE}_{11}$  and  $\text{TM}_{11}$  with a cutoff near 16.3 GHz do not seem to disturb the measurements.

We tested the instrument up to 20.5 GHz, as the gain and transmission of the MW-amplifier 25 specified up to 18 GHz vanished at this frequency. The microwave switches 13 and 15, also specified up to 18 GHz, showed a sufficient performance. The mixer 26 may also be a limitation for higher frequencies. The output power of the travelling wave tube amplifier between one and two watts is just sufficient to polarize lines not too far offresonant (some MHz).

In a second version we tested the performance of two mixers 51 replacing 26 and 38. These mixers double the MW local oscillator frequency. Thus MW local oscillators from 9 to 13.2 GHz may be used for K-band. No degradation of performance was noticed.

We tested the spectrometer with HCN,  $\text{HC}^{15}\text{N}$  (enriched  $^{15}\text{N}$ ),  $\text{CDF}_3$  [5],  $\text{H}^{13}\text{C}^{15}\text{N}$  (enriched  $^{15}\text{N}$ , natural  $^{13}\text{C}$ ),  $\text{SO}_2$  and  $^{34}\text{SO}_2$ . In Table 1 we report  $T_2$ -measurements of  $\text{SO}_2$ . They were evaluated according to [6]. The  $T_2$ -value of the line  $37_{8,30} - 38_{7,31}$  fits to the general trend reported in [7] Figure 5. The value of the other line is out of the expected range.

\* Numbers refer to Figure 1.

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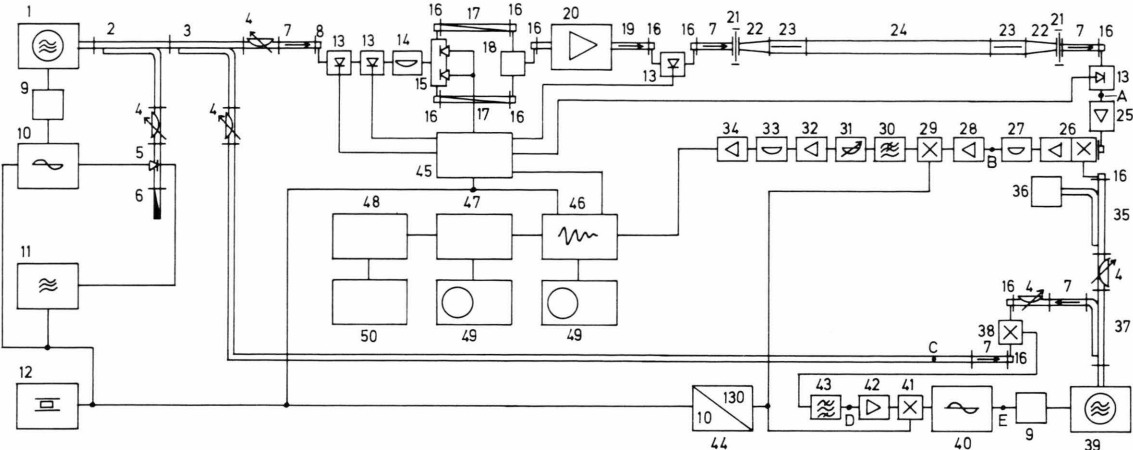


Fig. 1 a. Microwave Fourier transform spectrometer for the lower K-band.

Fig. 1 b. Modified version with local oscillator in the X-band and even harmonic mixers.

1 Signal Oscillator, Sweeper, K-band, Hewlett-Packard, 8690 B with 8696 A; 2 Directional coupler, 10 dB; 3 Directional coupler, 10 dB; 4 Variable attenuator; 5 Mixer; 6 Termination; 7 Uniline; 8 Waveguide to coaxial adapter (SMA); 9 RF-filter; 10 Synchronizer, Rohde and Schwarz, XKG; 11 Signalgenerator, Synthesizer, 0.1–990 MHz, Hewlett-Packard 8656 A; 12 Reference Quartz monitored by Mainflingen station, DCF 77, Rohde and Schwarz, XSD2 and XKE2; 13 PIN-switch, Hewlett-Packard, 33144 A with TTL-driver 33190 B\*; 14 Coaxial attenuator, 20 dB\*; 15 SPDT PIN-switch, General Microwave, F 8928\*; 16 Waveguide to coaxial adapter (SMA); 17 Twist 90 degrees; 18 Coaxial power combiner, TRM, DMS 285-20\*\*; 19 Waveguide isolator; 20 TWT Amplifier, K-band, Hughes, 1077H11, 1 Watt; 21 Vacuum waveguide window, MW shielded; 22 Taper, K-band to 13 × 13 mm square waveguide; 23 Mode filter, 13 × 13 mm waveguide; 24 Sample cell, 13 × 13 mm waveguide, 5.7 m long with vacuum system; 25 Microwave amplifier, 12.4–18 GHz, Dixel, DXA-5119-01, noise figure 8 dB, gain 27 dB\*; 26 Balanced mixer, 12.4–18 GHz, RHG, Orthoguide WMP12-18BG54\*, with integrated 160 MHz IF amplifier and waveguide to coax transition; 27 Fixed attenuator, 3 dB; 28 IF-amplifier, 160 MHz, RHG, ICFV 16060, noise figure 3 dB, gain 23 dB; 29 IF-mixer, Minicircuits, ZAD-1; 30 Low pass filter, 55 MHz; 31 Variable attenuator; 32 Amplifier, gain 20 dB, AvanteK, GPD 462 and 463; 33 Attenuator, 3 dB; 34 Amplifier, gain 30 dB, AvanteK, GPD 461–463; 35 Directional coupler, 30 dB; 36 Power meter, Hewlett-Packard, 432 A; 37 Directional coupler, 20 dB; 38 Mixer, RHG, DM1-18B\*; 39 Local oscillator, Sweeper K-band, Hewlett-Packard, 8690 B with 8696 A; 40 Synchronizer, Schomandl, FDS 30; 41 IF-mixer, Minicircuits, ZAY 3; 42 IF-amplifier, 160 MHz, noise figure 2.5 dB, gain 40 dB; 43 Bandpass filter, 160 MHz; 44 Frequency converter, 10 MHz to 130 MHz; 45 Experiment control; 46 Transient recorder, 1024×1 bit, average system 1024×16 bit; 47 Output buffer; 48 Minicomputer, Texas Instruments, TI 990/10; 49 Oscilloscope; 50 Terminal; 51 Even harmonic mixer, RF 1–18 (26) GHz, LO = RF/2, RHG, DME 4–18; 52 Coaxial isolator, 8–12.4 GHz; 53 Directional coupler, 10 dB; 54 Directional coupler, 20 dB; 55 Directional coupler, 6 dB; 56 Fixed attenuator, 6 dB; 57 Waveguide to coaxial adapter, 8–12.4 GHz; 58 Variable attenuator, 8–12.4 GHz; 59 Local oscillator, BWO, CSF, 8–16 GHz, with power supply.

\* Specified to 18 GHz. \*\* Specified to 20 GHz.

Table 1. Measurement of the pressure dependence  $\beta$  [ $\mu\text{sec}^{-1}\text{mTorr}^{-1}$ ] of the dephasing relaxation time  $T_2$  for sulphur dioxide,  $\text{SO}_2$ .  $1/T_2 = \beta p + \alpha$ . Temperature  $293 \pm 2$  K. Standard deviation of the fit is given. 4% additional uncertainty for  $\beta$  from pressure and temperature.

$JK_K - J'K'_K$	$\nu$ [MHz]	$\beta$ [ $\mu\text{sec}^{-1}\text{mTorr}^{-1}$ ]	pressure range [mTorr]
$37_{8,30} - 38_{7,31}$	19637.064	0.0952 [10]	4.7 – 19.1
$12_{3,9} - 13_{2,12}$	20335.407	0.1108 [16]	5.4 – 21.3

We think that the whole K-band could be covered if parts specified for frequencies up to 26.4 GHz would be used.

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