Physical Symposium Wuppertal

Chirped Pulse Microwave Spectrometer

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Introduction

Chirps

• Signals with rising or falling frequency (up/down-chirps)

• Consider linear chirps with instantaneous frequency

\[ f_{inst}(t) = f_0 + \alpha \cdot t \]

• sweep rate \( \alpha = \frac{\text{bandwidth}}{\text{pulse duration}} \)

→ induce molecular transitions by sweeping through the frequency
Motivation

- Absorption or emission spectroscopy of molecules of astrophysical and astrochemical relevance e.g.
  - HCN / HNC
  - FeOH
  - CH$_3$CN
  - C$_3$H$_6$O$_3$

- Fast and broadband scanning with sweep rates up to $\alpha \approx 100 \text{GHz/s}$

- Detection of several molecular transitions with one chirp

- Same molecule production conditions for one chirp when using supersonic jets and laser ablation techniques

Predicted rotational spectrum ($X^6\Delta@10K$) [HBJ] and possible geometry of FeOH [HNW]

[HBJ] T. Hirano, P.R. Bunker et al., The predicted spectrum of FeOH in its Renner-degenerate $X^6\Delta_i$ and $A^6\Delta_i$ electronic states, Journal of Molecular Spectroscopy, 256, 2009, 45-52
Contents

• Microwave Components

• Experimental Setup

• Measurements

• Summary and Outlook
Microwave Components  | Experimental Setup  | Measurements  | Summary and Outlook
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### Twin-channel Arbitrary Waveform Generator (AWG)

- Generation of arbitrary signals by sampling stored waveforms → chirps
- 400 MSamples/s sample rate
- 145 MHz analog bandwidth → chirp bandwidth

![NI PXIe-5451 AWG](image)

### VDI Synthesizer

- output frequency between 8 GHz and 20 GHz
- output power 16 dBm – 20 dBm
  
  → Use synthesizer RF as carrier for the chirps

![VDI S0037 Synthesizer](image)

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### I/Q-Modulator

- Mixing of the chirps (I/Q-waveform) with carrier signal

- Output signal: \( \cos(2\pi [f_{Chirp} + f_{Carrier}] t) \)

- 2 – 26 GHz RF input and output

- DC – 500 MHz IF-bandwidth

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### Signal detection

<table>
<thead>
<tr>
<th>Detector</th>
<th>WR-42</th>
<th>WR-8.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency range [GHz]</td>
<td>18.0-26.5</td>
<td>90-140</td>
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- Measurements above 140 GHz are available as well with a terahertz chain
- Teflon windows and lenses are used.
W-Band

- foil windows and teflon lenses are used
Spectrum of N2O @ 100.49174 GHz

- 50.0-50.66667MHz chirp in 600 µs
- 256 averaging, gain 20 @ preamp
- 3.3x10^-2 mbar in background
- 50 Hz repetition, 800 µs open
Four acetonitrile transitions are detected between 91.96998 GHz and 91.98998 GHz.
Ammonia measurements (15 % in He)

Chirp-Jet-Spectrum of NH3 @ 23,8701 GHz

- 50-54 MHz chirp in 600 µs
- 16 averaging, gain 50 @ preamp
- 1.8x10^{-2} mbar in background
- 10 Hz repetition, 800 µs open
Microwave Components

Experimental Setup

Measurements

Summary and Outlook

Chirp-Jet-Spectrum of NH3 @ 22.6883 GHz

- 50-54 MHz chirp in 600 µs
- 32 averaging, gain 50 @ preamp
- 1.9x10⁻² mbar in background
- 30 Hz repetition, 800 µs open
Outlook

• Optimization of experimental setup and techniques concerning power, bandwidth and measurement time

• Use of faster nozzles in order to obtain shorter pulses and therefore reduce measurement time

• Use of a discharge nozzle to produce astrophysical and astrochemical interesting molecules

• Measurement of HCN, HNC, FeOH, CH$_3$CN, ...

• Extension of the setup to emission spectroscopy with acquisition of molecular FID signals
Summary

• Design layout of a chirped pulse microwave spectrometer

• Fast and broadband investigation of molecular transitions

• Using the spectrometer in combination with supersonic jets

→ improved investigation of rotational and inversion transitions

• Investigation of ammonia, acetonitrile and nitrous oxide via chirp jet measurements
Thank you for your attention!