Project Overview

Laser Spectroscopy Group

http://laser-spectroscopy.ucc.ie

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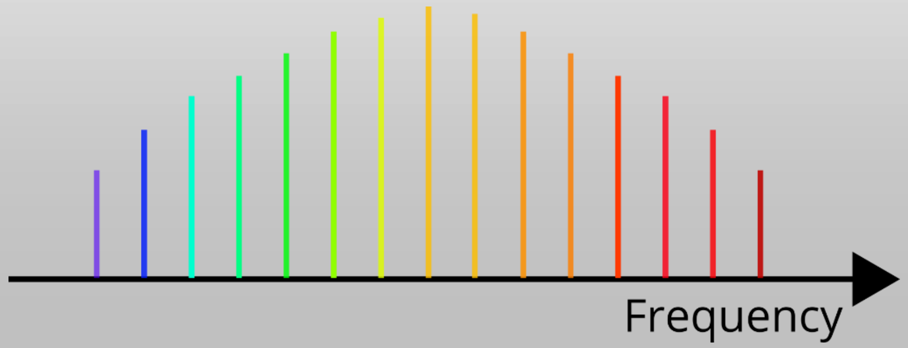
Project 1

From optical cavity mode structure to dual comb spectroscopy

Motivation

Frequency combs consist of a series of spectrally equidistant lines of narrow bandwidth. They are a useful tools in metrology and spectroscopy.

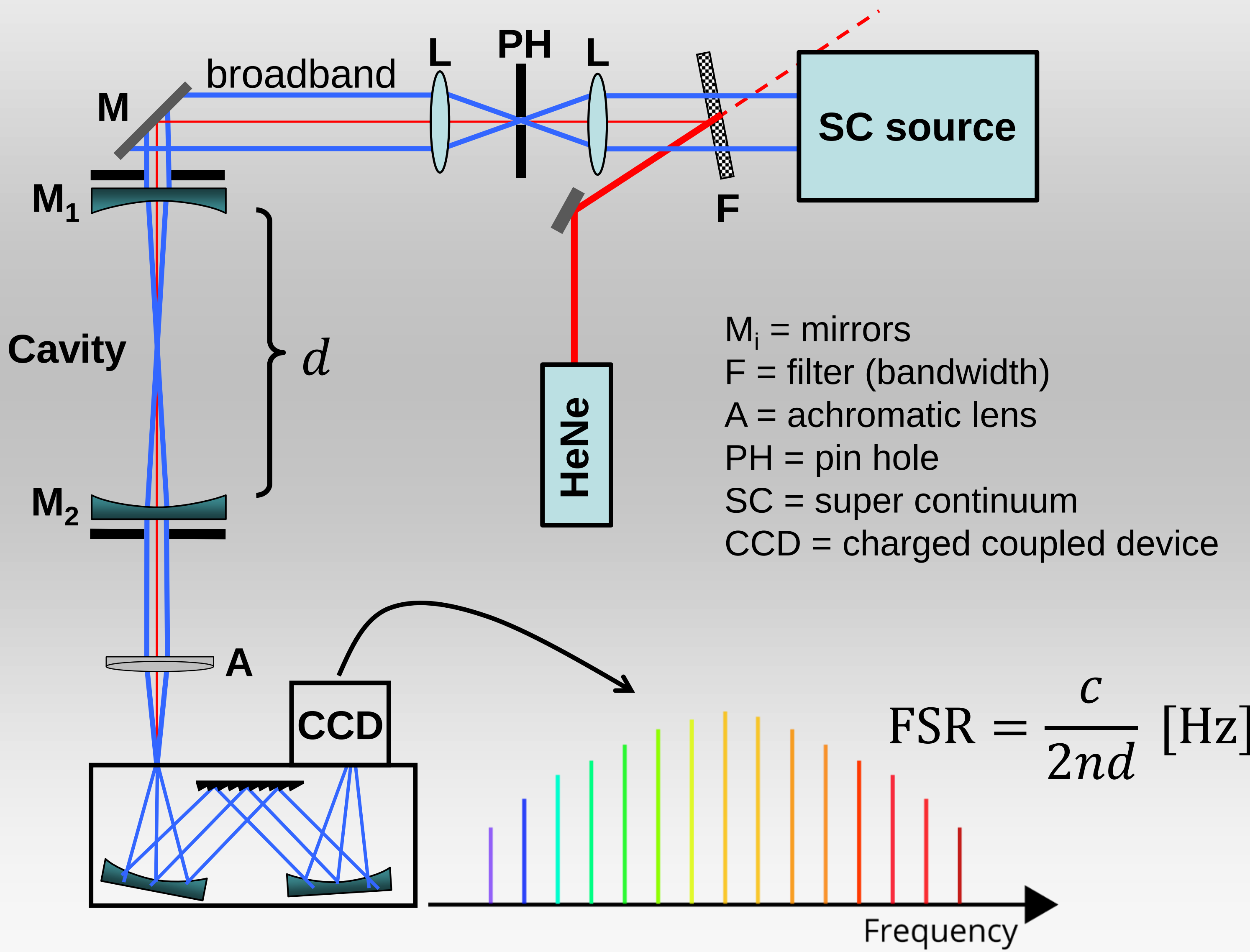
(Nobel Prize 2005
Hänsch and Hall)



There is different ways of creating frequency combs which are (more or less) complicated. Commercial frequency combs are still rather expensive.

This project aims at generating and characterizing the mode structure of a short optical cavity and using it as a “frequency comb” in a dual comb optical experiment.

Schematic of Optical Cavity Setup

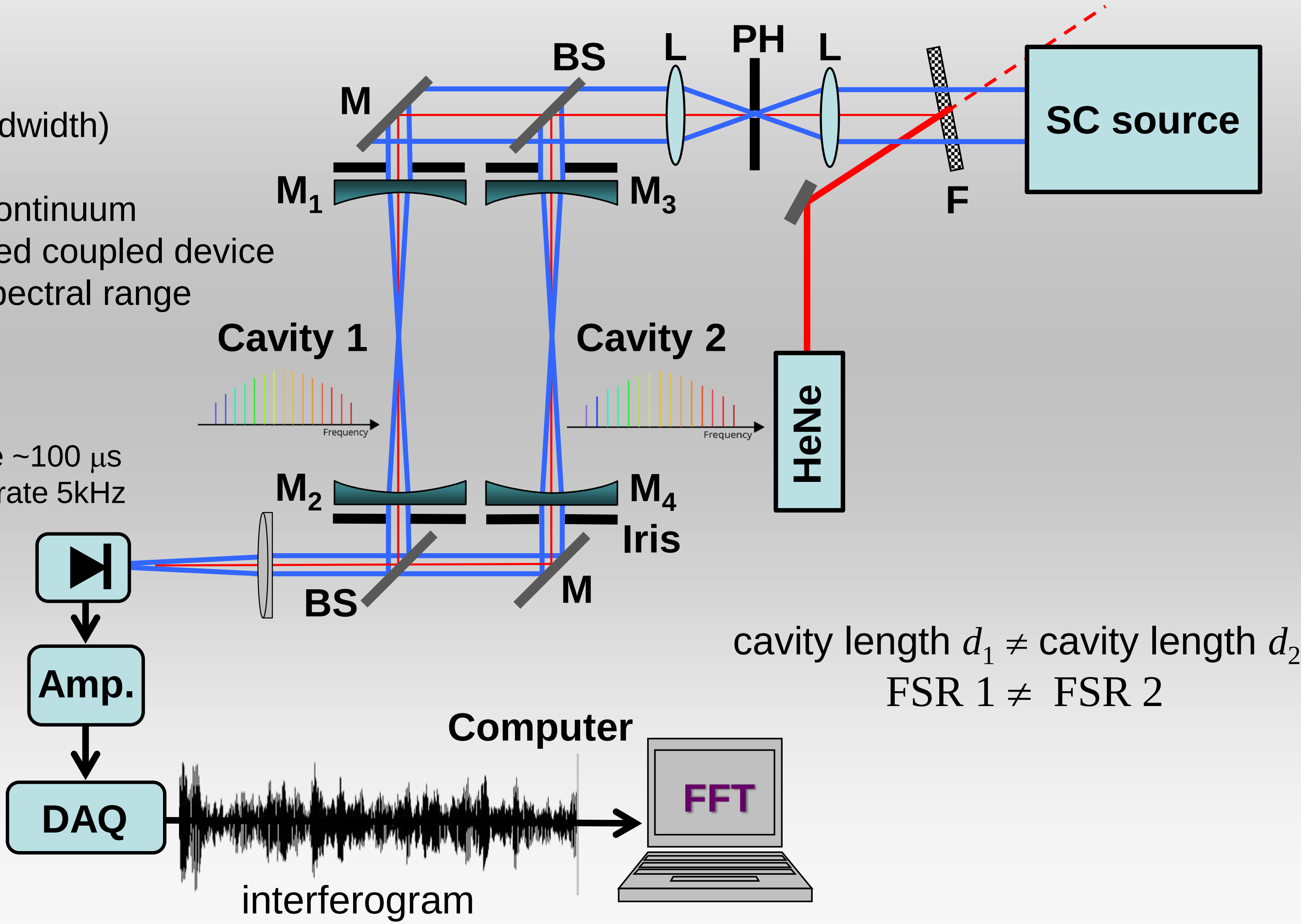


New FT Setup Schematic

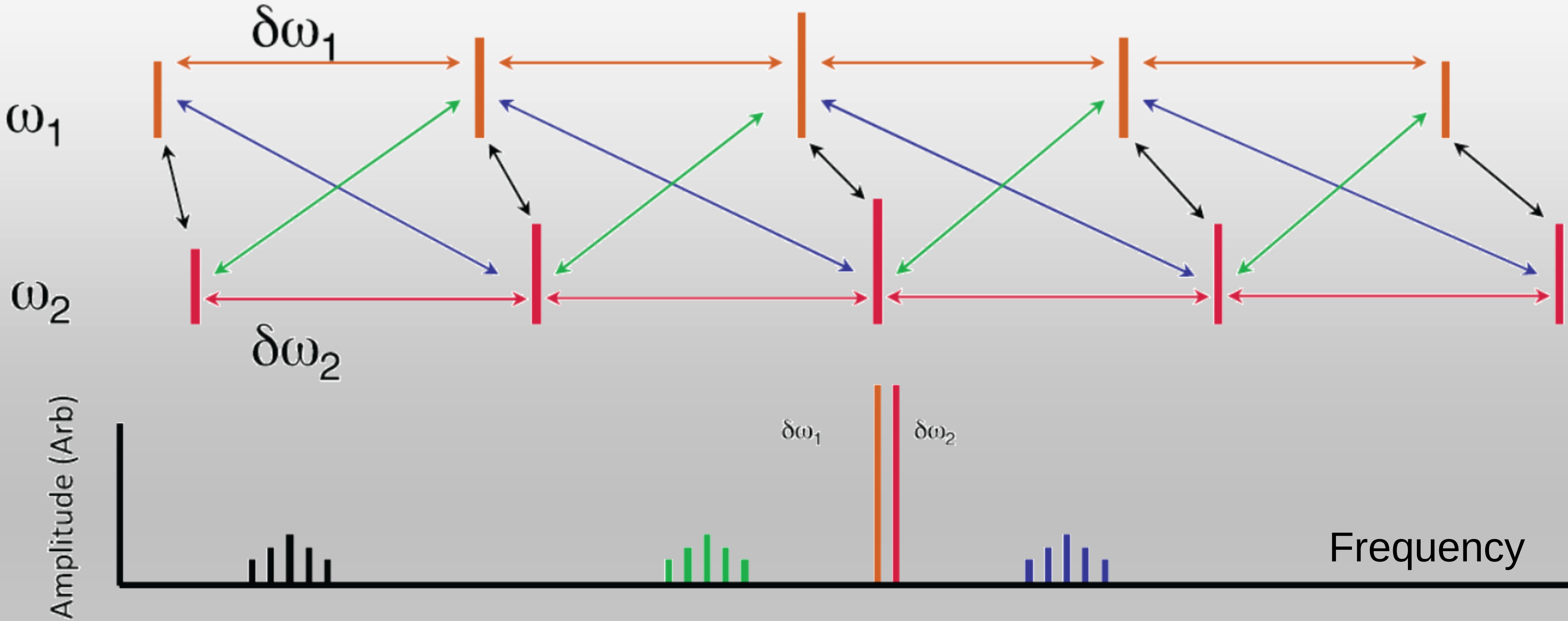
M_i = mirrors
F = filter (bandwidth)
PH = pin hole
SC = super continuum
CCD = charged coupled device
FSR = free spectral range

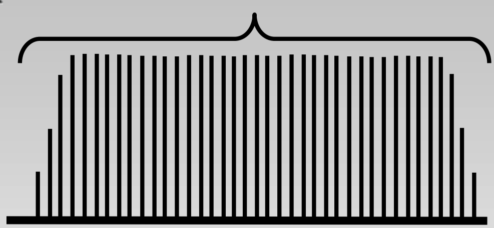
Integration time ~100 μs
High sampling rate 5kHz

Mode beat pattern detected

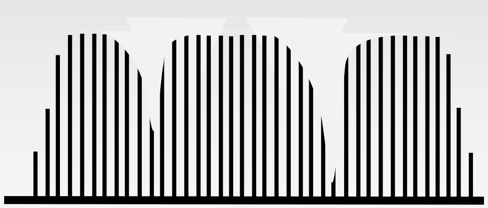


Mode beating





spectrum empty cavities



spectrum with absorption

Very high resolution spectra possible with cavity enhancement, i.e. very long path lengths and high sensitivity.

Objectives:

- Set up a cavity and measure the mode structure.
- Characterize the mode structure:
  - (a) function of beam position
  - (b) cavity length
  - (c) stability (i) thermal & temporal
    (ii) mechanical
  - (d) optical power and throughput
- Set up dual cavity setup and measure interferogram and Fourier Transform spectrum. Interpret the results.
- Attempt a proof of principle experiment with H_2O as absorbent in the near infrared.

Project is designed for 12 weeks

Project 2

Absorption spectrum of ammonia by Fourier Transform cavity enhanced absorption spectroscopy

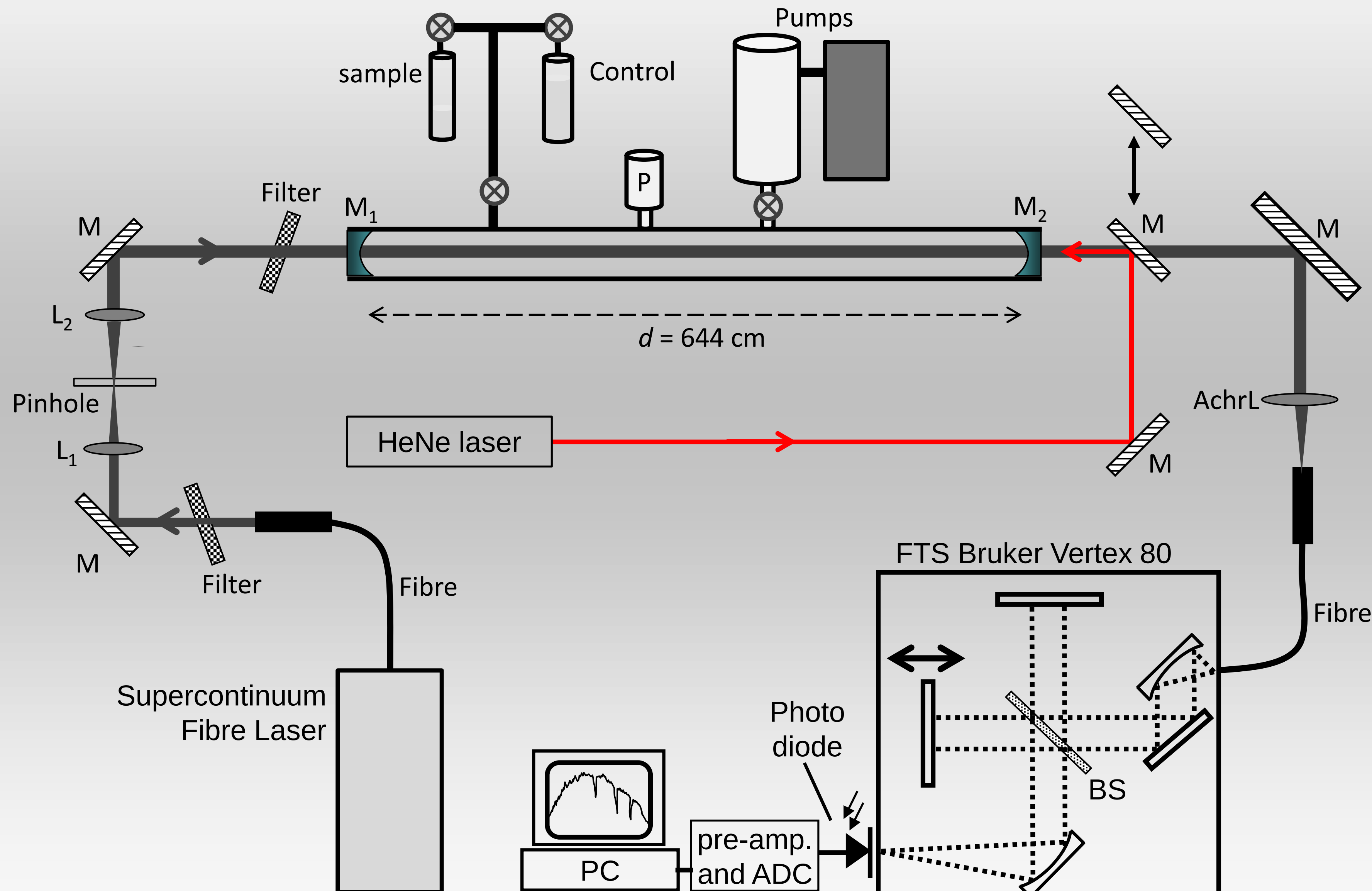
Motivation

Ammonia (NH_3) is a hazardous and corrosive substance used in food, agricultural and pharmaceutical industries. Worldwide over 170 mill. tons are produced annually.

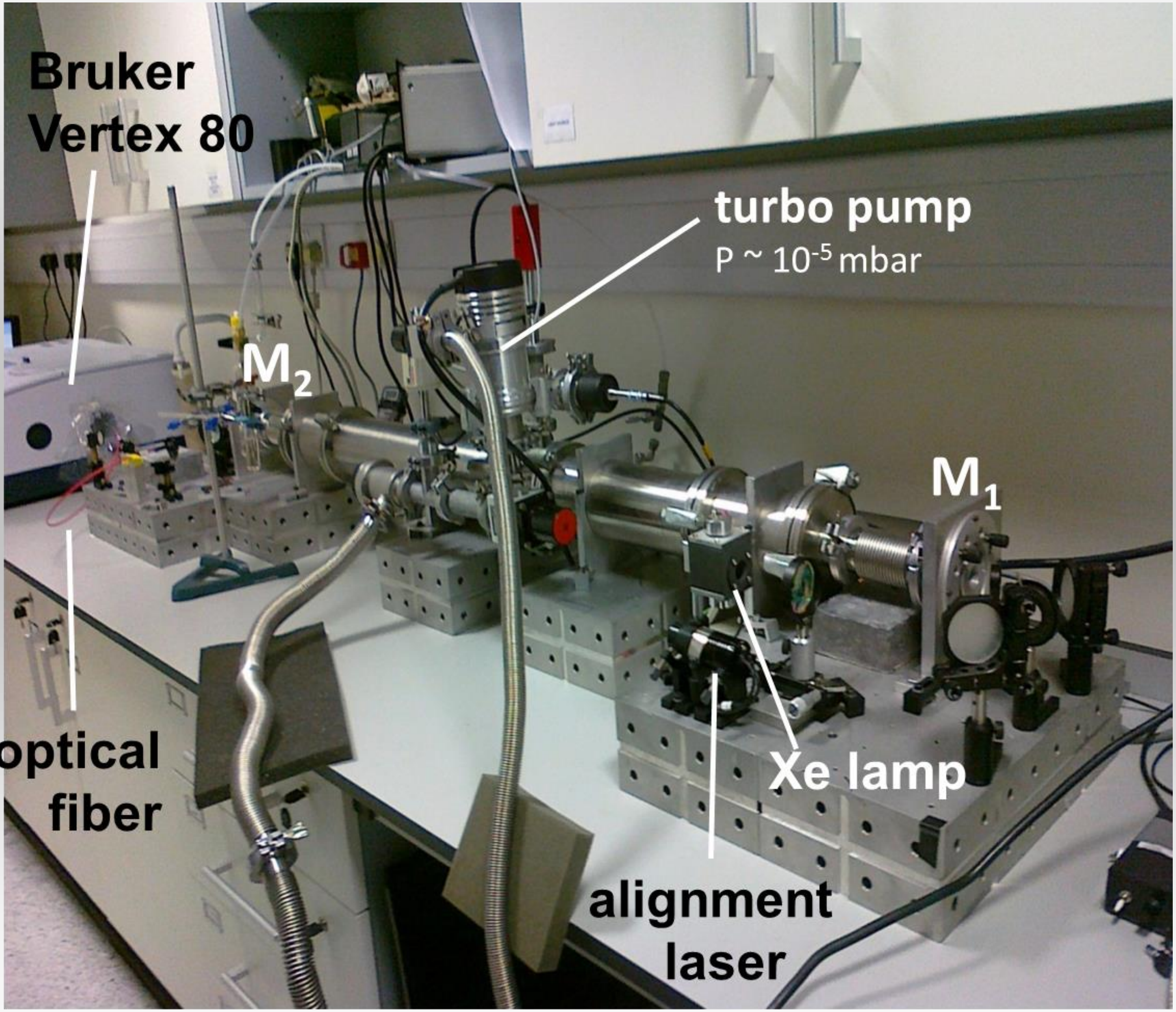
It is a gaseous trace species and difficult to detect *in situ* with extractive methods owing to its stickiness and reactiveness. Inlet losses of detection systems are difficult to quantify.

This project aims at measuring an ammonia “fingerprint” spectrum using a long optical cavity. A proof of principle experiment is planned that shows that ammonia can be detected in the open atmosphere with optical methods in the near infrared.

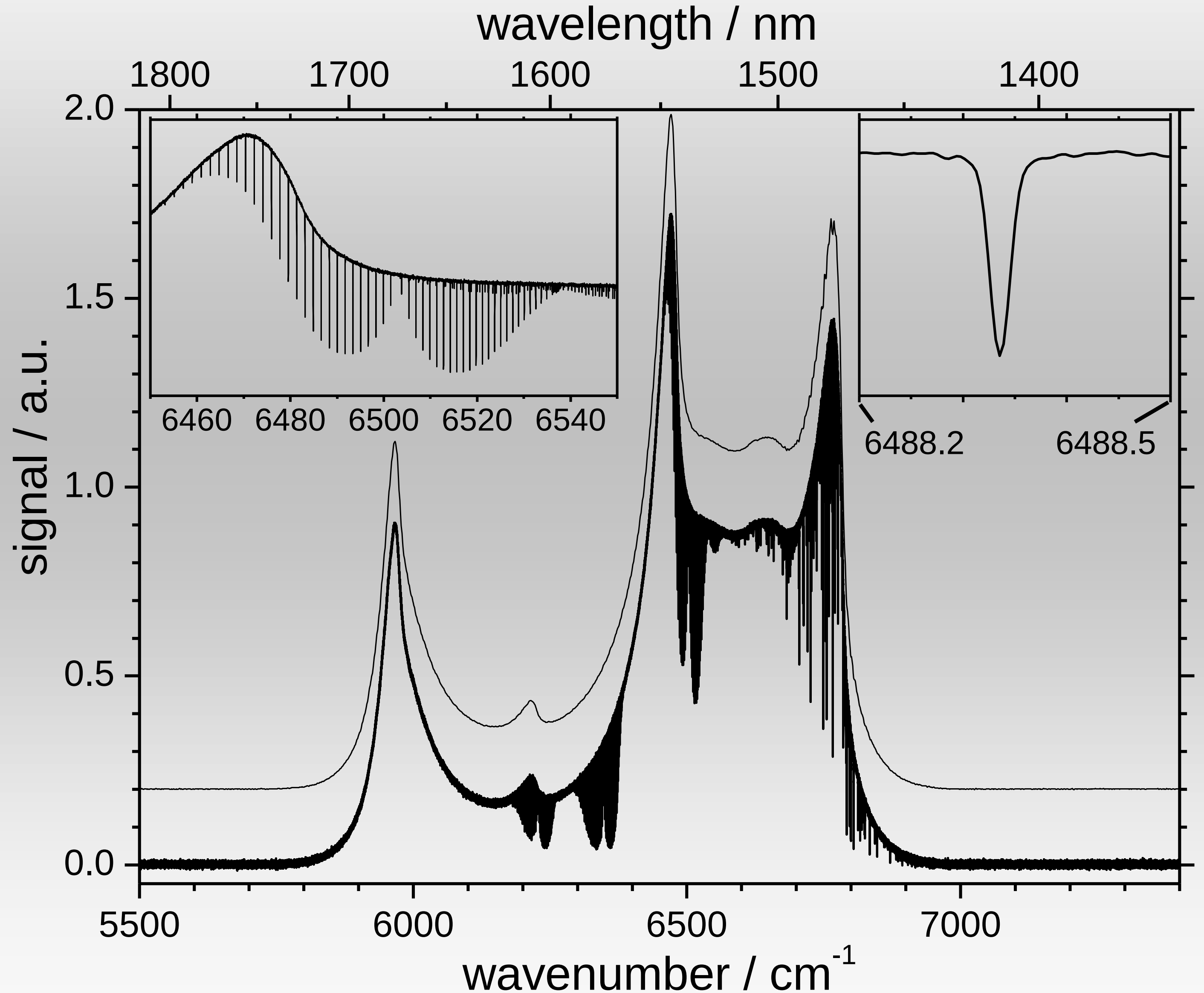
Experimental scheme



Photograph of FT-IBBCEAS instrument



Example spectrum CO_2



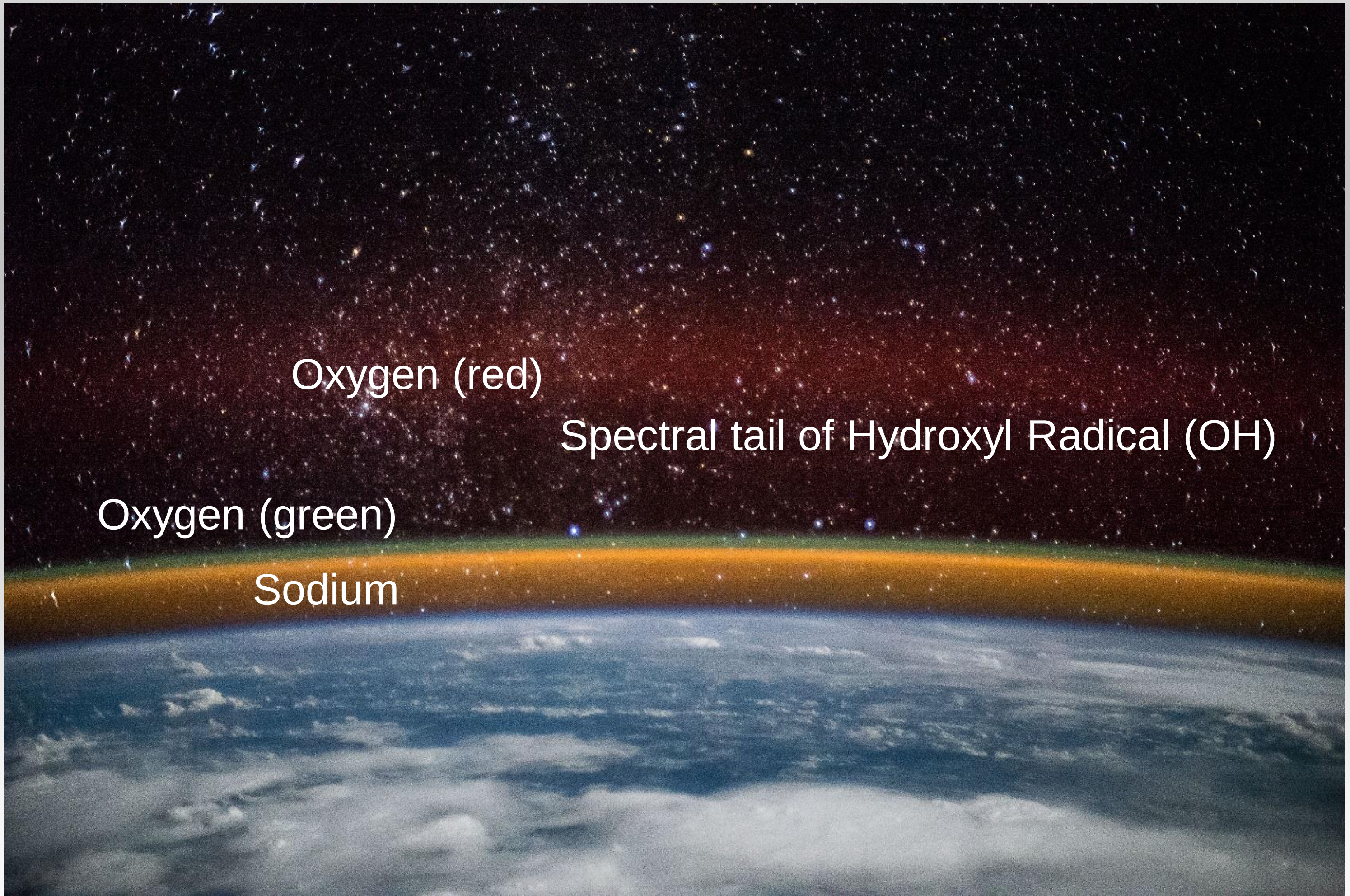
Objectives

- Set up the vacuum chamber and align the cavity. Learn how to run the experiment.
- Develop a way to fill traces of ammonia into the cavity.
- Measure ro-vibrational overtone spectra of ammonia in the near IR around 5050 cm^{-1} and identify the ammonia "fingerprint" pattern.
- Take measurements at different pressures up to 1 atm. Establish pressure broadening coefficients.
- Characterize the setup (detection limit, precision) and evaluate its applicability in field trials.

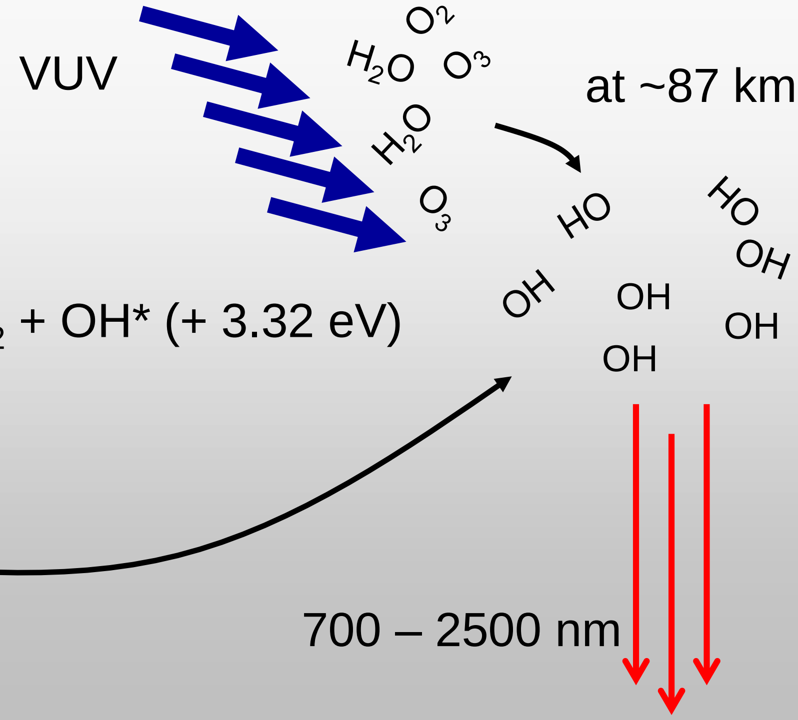
Project is designed for 6 weeks

Project 3

Detection of air glow emissions from the mesosphere



Observation of the mesosphere



$O_3 + H \rightarrow O_2 + OH^*$ (+ 3.32 eV)

Thermosphere/ Ionosphere (>90 km)

Mesopause (~90 km)

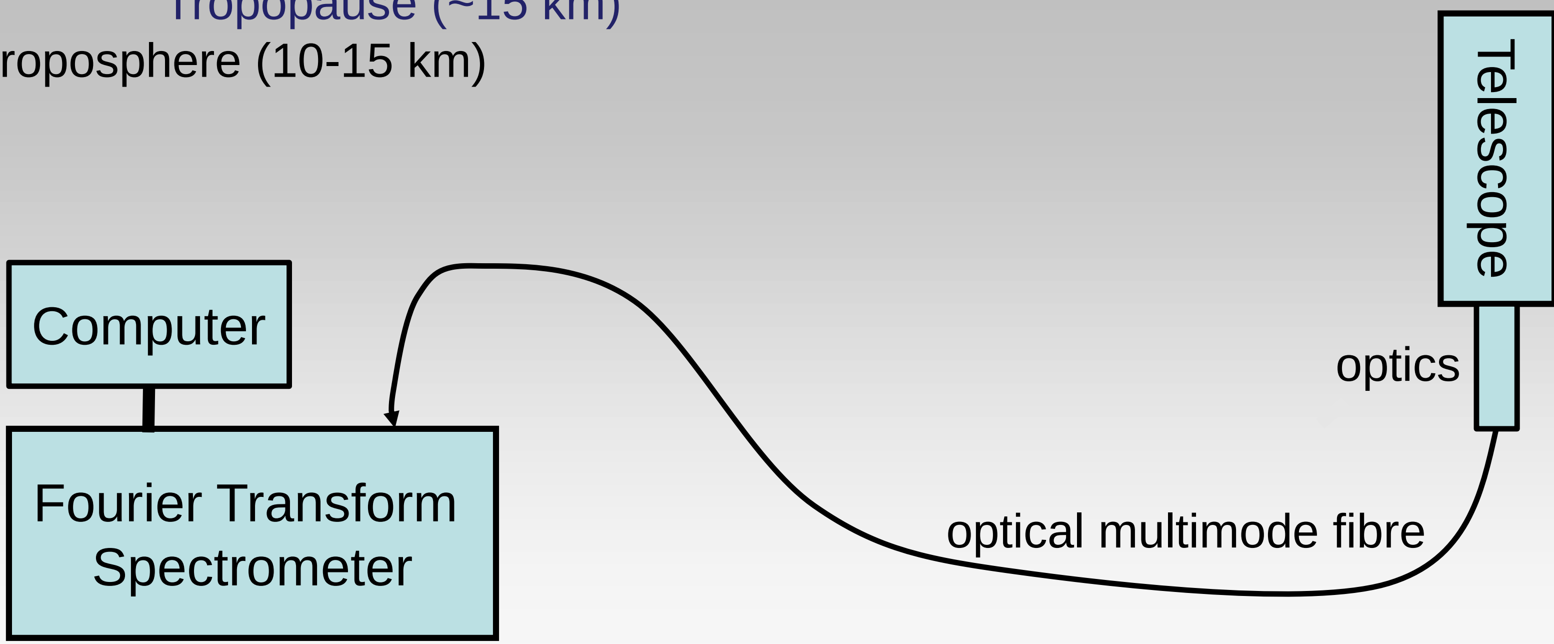
Mesosphere (50-90 km)

Stratopause (~50 km)

Stratosphere (15-50 km

Tropopause (~15 km)

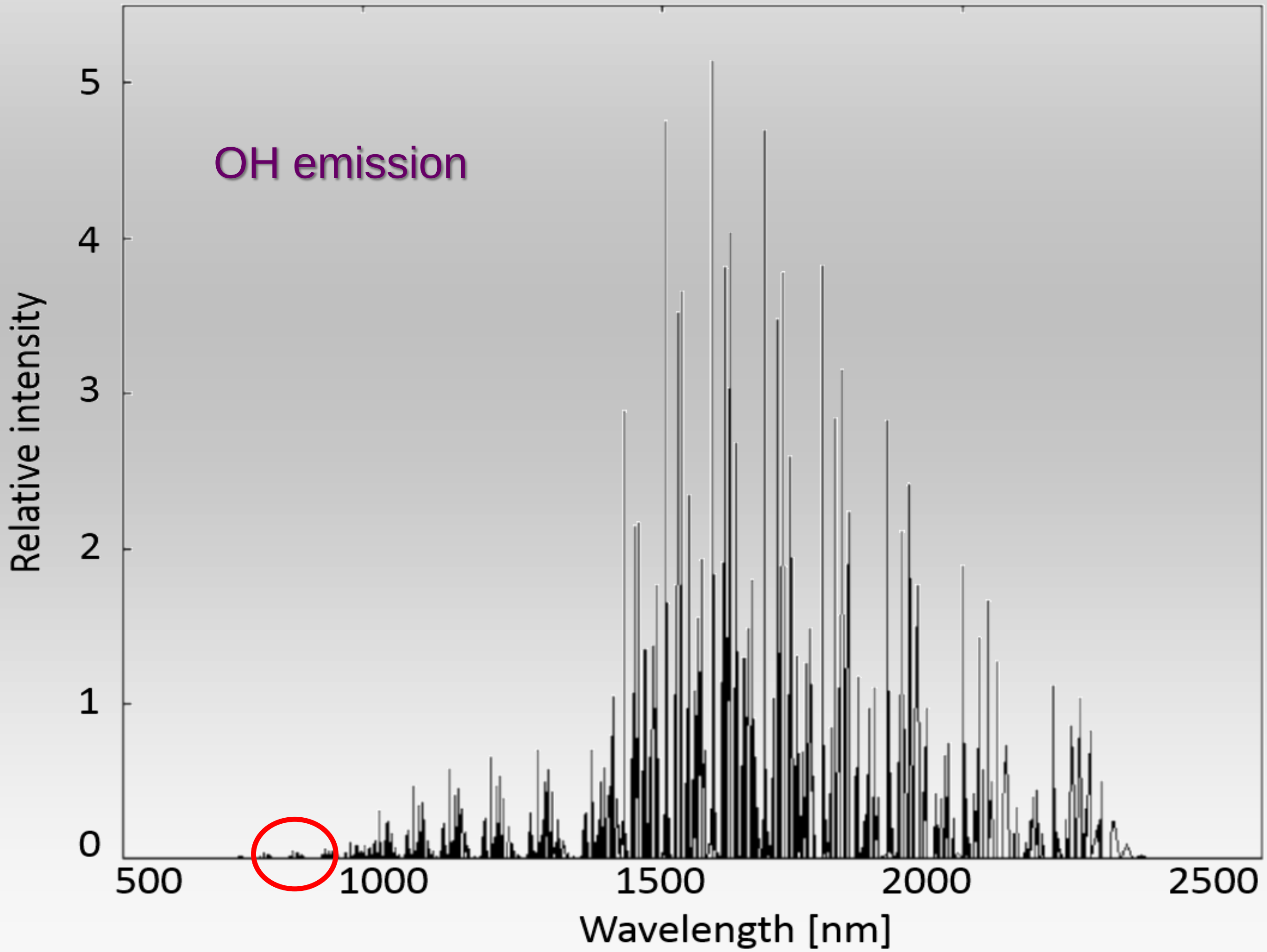
Troposphere (10-15 km)



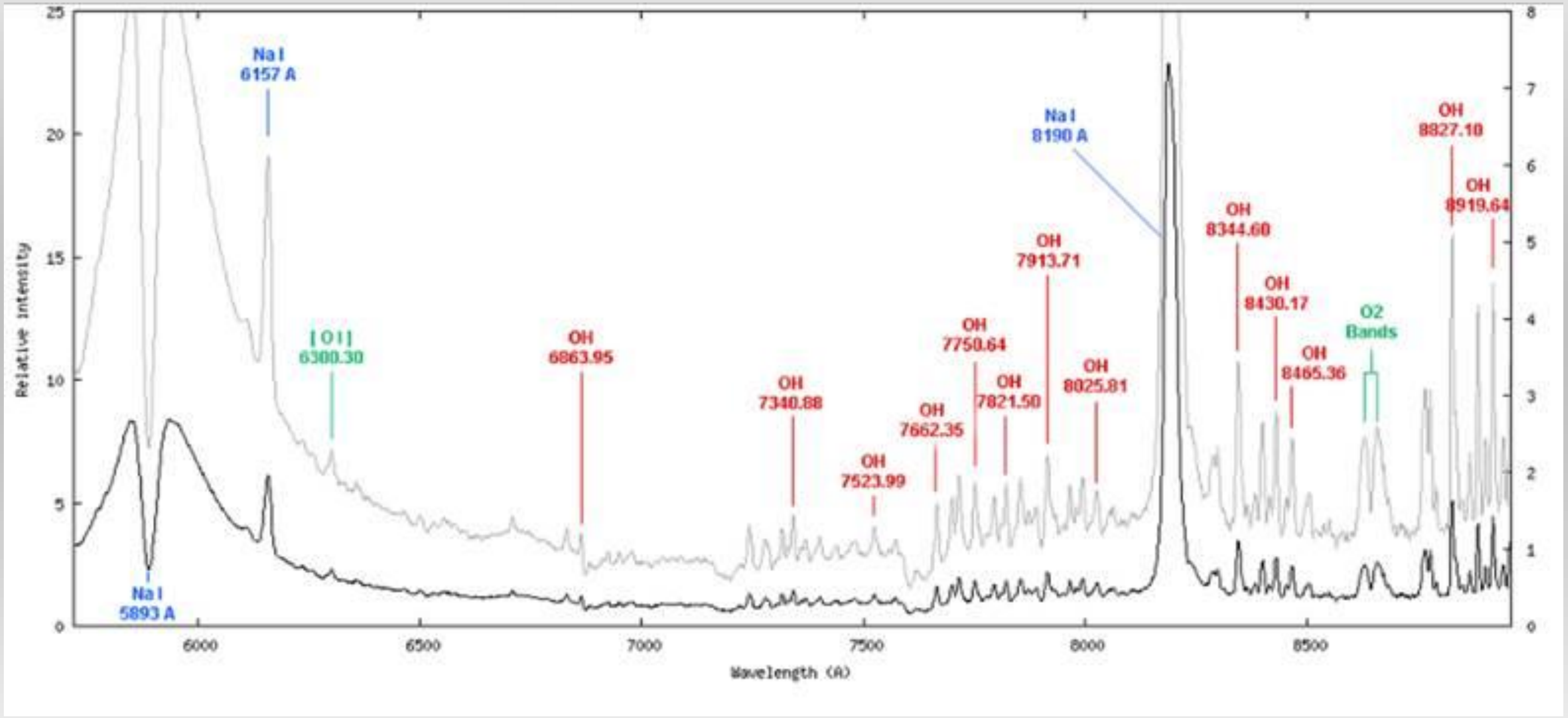
Overview spectrum of the OH emission

The hydroxyl radical (OH) is formed in Earth's upper atmosphere following the reaction of atomic hydrogen (H) and ozone (O_3).

Brightness of this OH*-airglow varies between 10^{-6} to 10^{-4} $Wm^{-2}sr^{-1}$ – rather bright!



OH emission features at λ > 700 nm



Objectives

- Set up the telescope, optics and spectrometer.
- Measure OH spectrum in an appropriate spectral window (>700 nm) with high resolution.
- Vary conditions of the measurement (observation of different regions, spatial and spectral resolution, diurnal cycles).
- Spectral analysis and line assignment based on literature data where possible.
- Estimate the temperature in the mesosphere/mesopause on the days of the measurement based on the spectra obtained.

Project is designed for 12 weeks