Applied Wave Optics: Spectrometer and Interferometer

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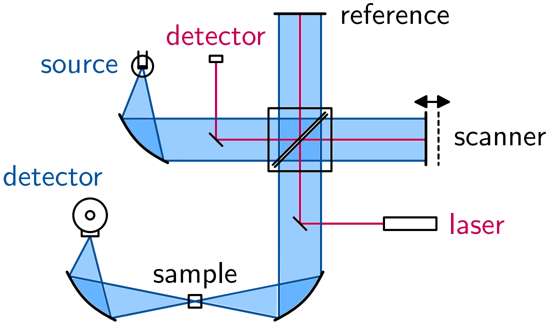
FTIR Spectrometer

Setup of a Fourier transform infrared spectrometer with white light source:

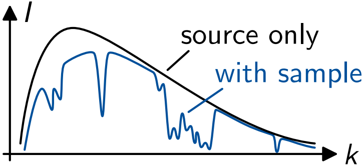


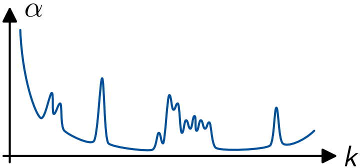
A reference laser is used to determine the mirror position with high precision.

FTIR Spectrometer (cont.)

Spatial interferogram of an FTIR spectrometer. The location of the maximum peak marks the point of equal path lengths:

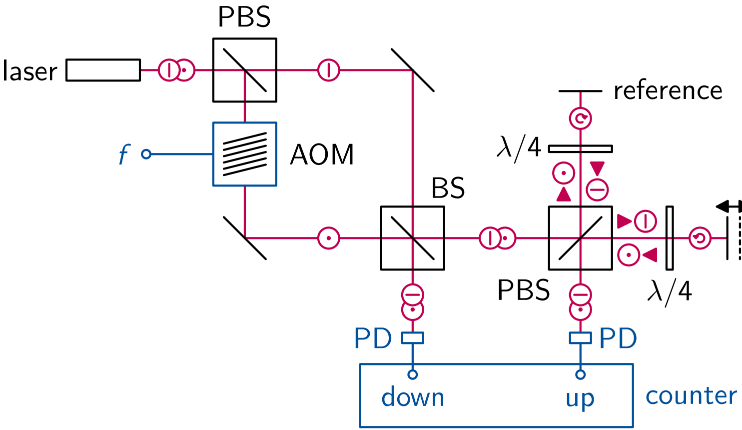
Based on the spatial phase factor $\exp(ikz)$, the Fourier transform of the interferogram delivers the wavenumber spectrum of the signal. The difference between source and sample spectrum is used to calculate the absorption spectrum of the sample:





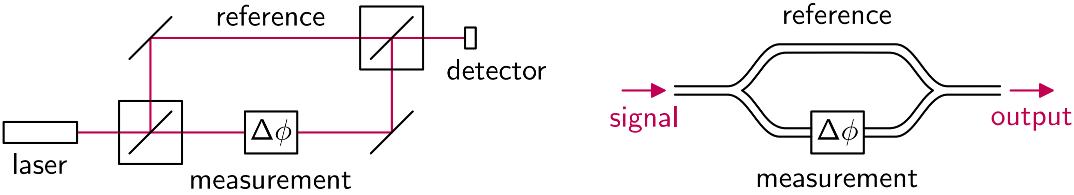
Heterodyne Interferometer

The beat frequency f between two laser beams with and without frequency shift is detected by photo diodes in a heterodyne interferometer. With the measurement mirror at rest, the counter stops. A moving mirror modulates the phase of the second signal which results in a changed counter value.



Mach-Zehnder Interferometer

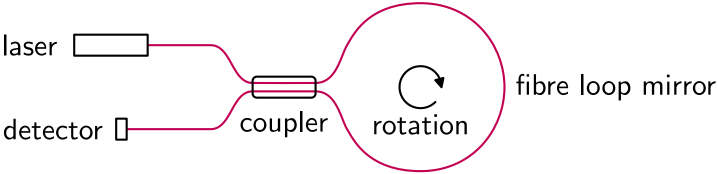
The Mach-Zehnder interferometer is a phase sensitive interferometer which uses a separate beam splitter and combiner. Symmetric conditions the signals from both arms reach the output without phase shift, resulting in constructive interference. A disturbance in one arm results in destructive interference for the output signal.



Note: The common-mode suppression is important for sensor applications. Mach-Zehnder structures are very common in planar integrated optical systems based on single-mode waveguides.

Sagnac Interferometer

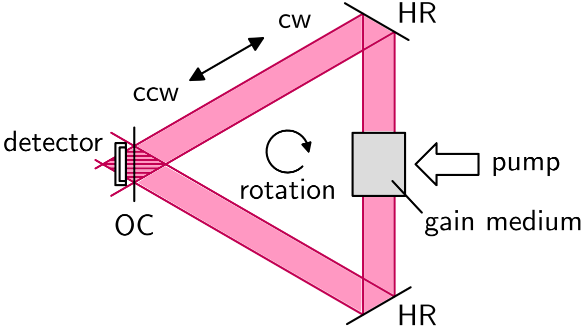
The signals travelling clockwise and counter-clockwise in the fibre loop reach the detector at the same time, when the Sagnac fibre interferometer is at rest. However, there is always a $\pi/2$ phase difference between the two signals leaving the fibre coupler. In case of a 50 % coupler this leads to destructive interference on the detector. An **angular velocity** results in a phase difference proportional to the rotational speed.



Note: A Sagnac interferometer in free space optics can use a conventional beam splitter, because the reflection at an interface to a medium with higher index also results in the required $\pi/2$ phase shift.

Laser Gyroscope

The clockwise and counter-clockwise travelling modes in a ring resonator result in a standing wave. The oscillation nodes are fixed in space. In the overlapping zone behind the partially reflecting output coupler OC these modes generate a fringe pattern recorded by an optical detector. The fringes move with the rotation of the resonator proportional to its **angular position**.



Comparison

- **Sagnac Interferometer:** Passive ring → measurement of angular velocity
- **Laser Gyroscope:** Active ring → measurement of angular position