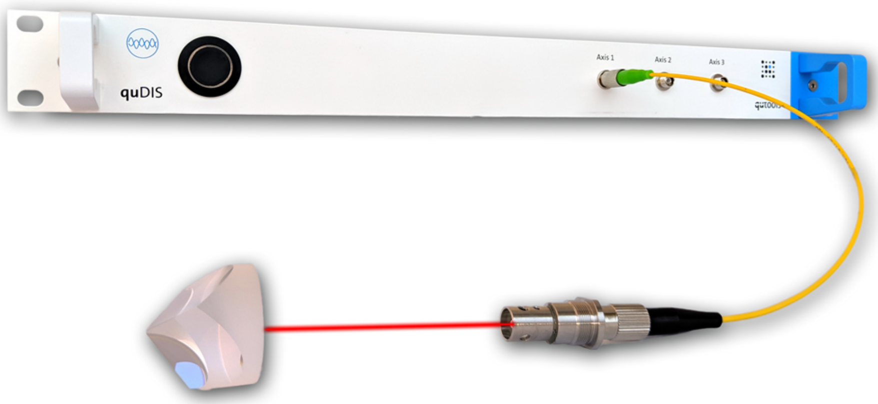
quDIS - Interferometric distance measurement

Method of interference spectroscopy and operation principle

qutools GmbH • www.qutools.com

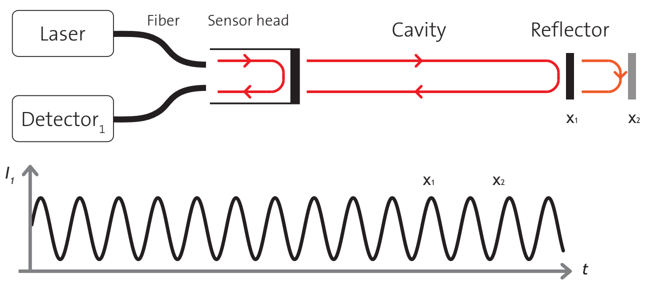


Interferometry - Sub-nanometer accuracy

Interferometry is by far the best method when length measurement has to be performed with highest accuracy. The use of stable lasers with low bandwidth and superposition of its coherent radiation allow the observation of interference phenomena. The detected signal corresponds to the optical path length with sub-nanometer resolution.

Superposition principle

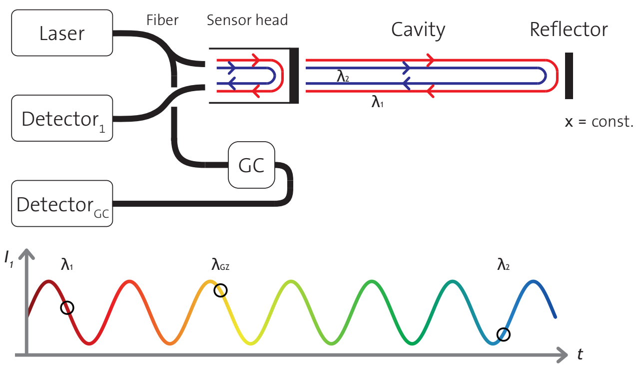
All kinds of interferometers make use of the same principle. A laser beam with high coherence length is split up in two different paths, one reference arm and one measurement arm. When the two beams are superimposed again, constructive and destructive interference ***I(x)*** can be observed in dependency on the modification of the optical length of the measurement arm. But changes in the interference pattern can also be an alternation of the target reflectivity or adjustment drifts due to movement. This method does also not indicate the direction of a target movement and has the uncertainty of the periodicity the interference pattern.



The interferometer is inspired by a Fabry-Perot-Interferometer. Fiber coupled laser light leads to a sensor head where 4% of the light is reflected back to the detector. The rest passes the cavity, is reflected and also guided to the detector. The graph shows the interference signal of a constantly moved mirror.

Interference Spectroscopy - Frequency analysis and relative distances

Beside the optical path length changes, modification of the laser wavelength at a constant path also leads to signal modulations by interference $I(\lambda, x_{const})$. The wavelength is swept by electric laser control, introducing an artificial motion over multiple wavelengths that avoids the relative blindness in static situations. We call this feature "interference spectroscopy".



Tuning the wavelength also causes a similar interference pattern as moving the mirror. The absorption lines of a acetylene cell are used for precise wavelength control.

qutools

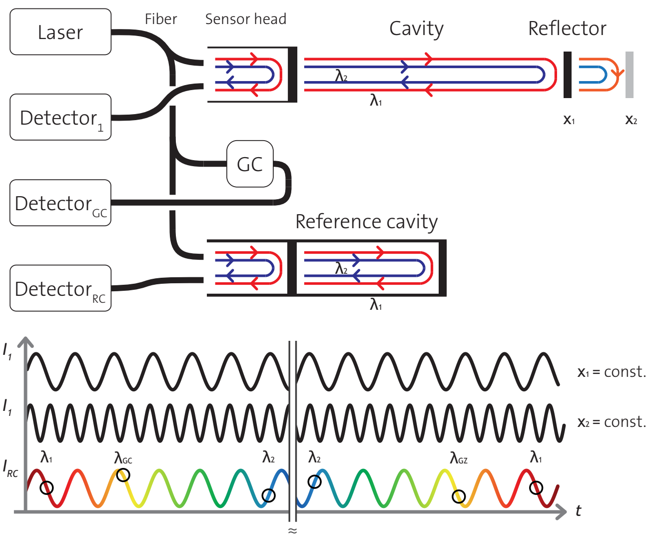
qutools GmbH • Kistlerhofstraße 70 (Geb. 88) • 81379 München, Germany
phone: +49 89 321 649 59 0 • e-mail: info@qutools.com

quDIS - Interferometric distance measurement

Changing the laser wavelength in a fast up and down sweep ***Δλ/Δt ≫Δx/Δt***, relative length changes of the optical path can be determined simply by counting the interference fringes in the pattern and determining the phase at a fixed wavelength. An internal optical reference cavity stabilizes the wavelength change into a linear wavelength sweep. This measurement method is not affected by the contrast nor the intensity of the detected signal. Other methods only monitor the intensity (arcsin) or its deviation (arctan) at a constant wavelength leading to typical periodical error patterns.

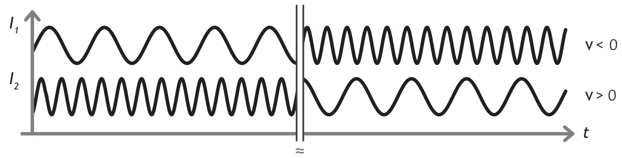
Internal reference cavity - Laser stabilization and absolute distances

The use of "interference spectroscopy" in combination with a gas cell with well defined absorption lines also enables absolute distance measurement. The number of fringes in the interference pattern, the well-known wavelength due to the gas cell at one instance and the linear wavelength change via the build-in reference cavity with its constant length give all parameters to calculate the absolute length of the measured path.



The fiber-based set-up is completed by an internal reference cavity. The graph shows the signal of the internal reference with adjusted wavelength change in color and the two cavities in black. Analyzing the interference pattern, a lot of information is revealed about the measured cavity.

The "interference spectroscopy" conducted by fast up and down wavelength sweeps and a moving reflector target show a Doppler-like effect. When the measurement distance decreases and also the wavelength increases within the up sweep, the number of fringes in the interference pattern decreases, depending on the reflector velocity. The instantly following down sweep with decreasing wavelength shows the opposite, a rising number of fringes in the pattern.



The interference patterns show a Doppler-like effect over the up and down sweep of the laser wavelength. First graph I_1 shows a constant negative velocity of the target, the second one I_2 a constant movement in the other direction.

Moreover, the "interference spectroscopy" paves the way for further analysis. In addition to position, velocity and acceleration also information on refractive index, reflectivity or surface tilts can be derived from the signals in real time.

Key Features

- < 0.05 nm signal stability *1
- < 200 nm signal stability absolute measurement *2
- 25 kHz bandwidth *3
- 0.03 ... 20 m working distance *4
- 1 m/s target speed *4
- 3 sensor axes, multiple devices

*1: relative distance RMS@ 100Hz, 2s, 200mm *2: absolute distance RMS@ 100Hz, 200mm
*3: @ 1000mm, distance dependent *4: sensor head dependent

Applications

- Interferometric distance measurement
- Vibration analysis
- Beam interrupt compensation
- Gap and edge measurement
- Environment analysis
- Angular measurement

qutools GmbH • Kistlerhofstraße 70 (Geb. 88) • 81379 München, Germany
phone: +49 89 321 649 59 0 • e-mail: info@qutools.com