On-Chip Interferometry

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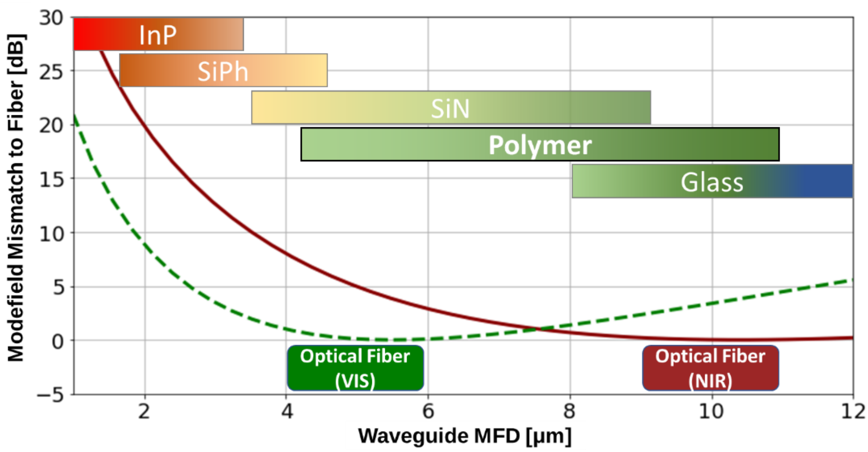
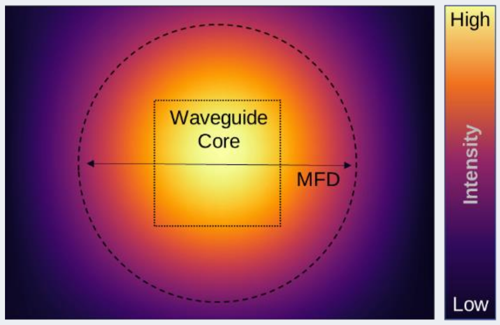
Miniaturization of optical sensors using Planar Waveguide Technology

Integrated polymer photonics

On-chip photonic integration has opened up the potential for low-cost, high-performance photonic sensor devices.
A diverse landscape of various technologies and material platforms are available, each providing different strengths and limitations in terms of properties and functions.





*The **modefield diameter** (MFD) of a waveguide or fiber describes the area, at which the optical intensity of the mode has dropped to $1/e^2$ of its maximum intensity. Most of the optical power is transmitted through this area, which is why the MFDs at any interface (e.g. fiber-waveguide coupling) have to be matched for efficient coupling.*

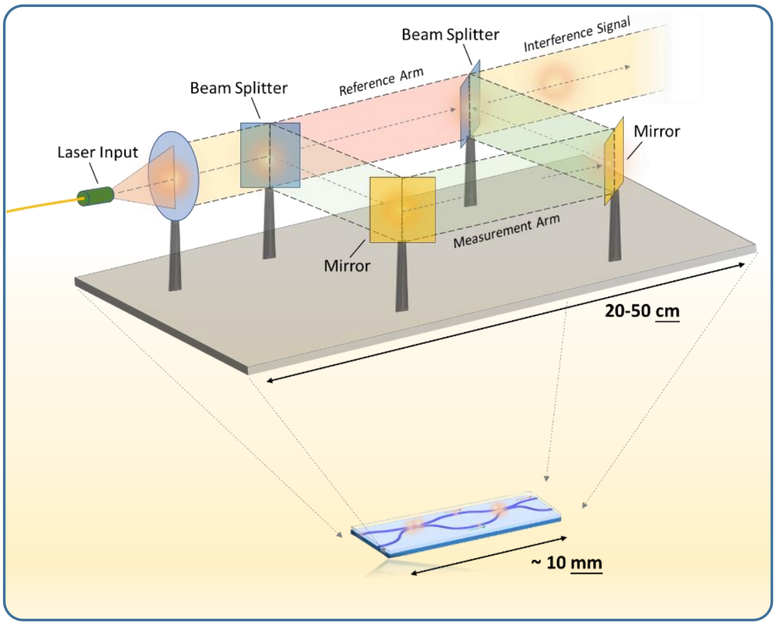
Polymer waveguides exhibit MFDs between 4 – 10 µm. It can be adjusted for efficient coupling to standard optical fibers (e.g laser sources or other components), which lowers assembly efforts and costs.

Interferometry

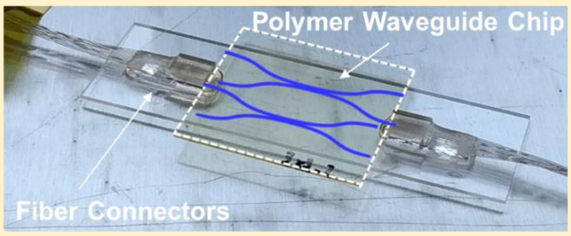
is a widely used measurement technique in industry and science, employed in a multitude of applications including spectroscopy, distributed fiber sensing and environmental sensing.

Waveguide-based interferometers are based on so-called directional couplers, which can be used to realize on-chip Mach-Zehnder-interferometers (MZI), offering several advantages:

- **Small footprint & low cost**
  High integration density
- **Increased stability, No thermal drift**
  Compact design, no moving parts
- **Versatile design**
  Customizable for various applications



Waveguide Evaluation Boards



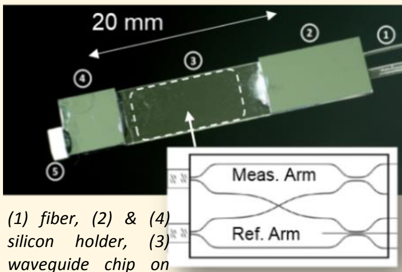
*The portfolio offered by **vario-optics** consists of different pre-designed building-blocks of couplers and interferometers at common wavelengths and split ratios (e.g. 1310/1550 nm). These structures can be fiber-pigtailed for easy use in demonstrators or directly integrated into EOCBs for low-cost, compact sensor units.*
Contact us for evaluation boards and custom-request!

Applications of Waveguide-Interferometers

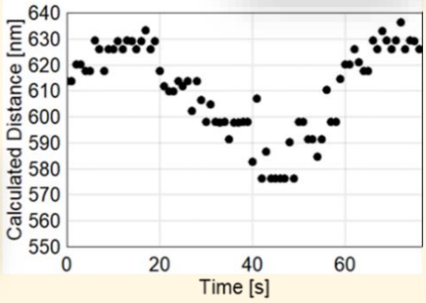
Examples of interferometric sensors realized using ***vario-optics*** waveguides include displacement sensors [1], gas sensors, temperature sensors [2] and thermo-electric switches.

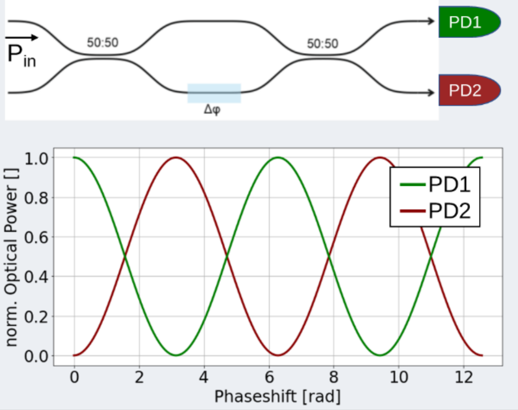
Sensor Application: Miniaturized interferometric displacement sensor

The MZI waveguide chip can easily be accessed by laser sources and photodiodes by fibers.
In the example shown on the right, an MZI is coupled to a fixed (reference arm) and moving (measurement arm) micro-mirror. This way, precise **distance changes (< 1 nm)** or **vibrations** can be detected [1]



(1) fiber, (2) & (4) silicon holder, (3) waveguide chip on glass, (5) fixed mirror





Phase-Shift

*The **phase-shift Δφ** describes the **optical path difference (OPD)** between the light waves in the two arms of an interferometer. It can be induced via various physical processes and quantities (temperature, local refr. Index change etc.)*

Any phase shift changes the power at the output ports, which can be read-out and converted to the sensor-parameter of interest.

Using waveguide interferometers results in highly sensitive sensors, limited mostly by the noise of the laser source and the read-out electronics.

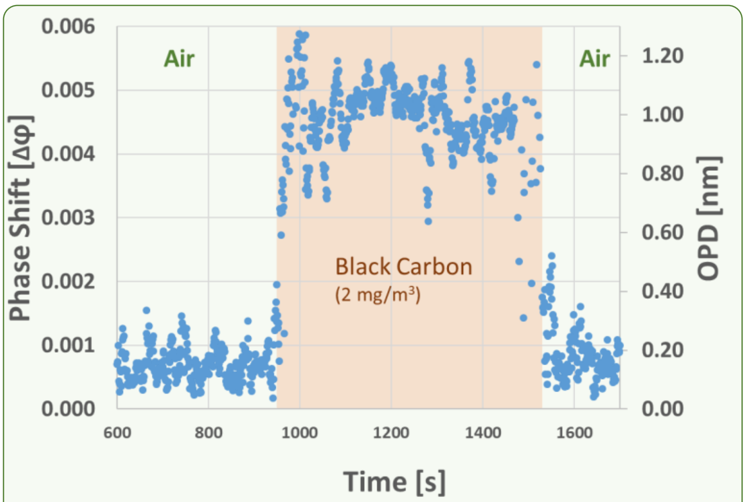
Sensor Application: Environmental Gas Sensing

Interferometric sensors are excellent tools to measure various gas- and particle concentrations both indoors and outdoors. Researchers at the FHNW Institute for Sensors and Electronics are developing new measurement methods for detecting atmospheric soot particles (e.g. Black Carbon).

Their approach is based on so-called **photothermal interferometry (PTI)**. In this process, light is absorbed by particles in the air causing them to heat up as well as the surrounding air. This results in a change of the refractive index, which can be detected as a phase shift using interferometers.

PTI is a process with excellent **sensitivity** and **specificity**, and thus allows to measure various light absorbing species and trace gases.

Combining the advantages of the **PTI process** with the benefits of **integrated waveguide interferometers** enables the development of compact, low cost sensors with outstanding performance.



*Measurement of Black Carbon using a waveguide interferometer operating at 1310nm. Due to the low noise level (Δϕ < 0.001 rad) optical path differences of **< 0.2 nm** can be detected.*

References

[1] J. Kremmel, N. Crameri, T. Lamprecht & M. Michler, "Passive aligned assembly of an integrated optical displacement sensor based on a reflective Mach–Zehnder interferometer with a 3×3 directional coupler," Opt. Eng. 57(8), 2018

[2] J. Kremmel, M. Michler, T. Lamprecht, and N. Crameri, "Polymer optical waveguide based thermo-optical switch on a metal-core pcb-substrate," in *Advanced Photonics 2017 (IPR, NOMA)*, p. PTh1D.1, OSA, 2017

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