Design of a Spiral-Shaped Mach-Zehnder Interferometric Sensor for Refractive Index Sensing of Watery Solutions
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The design of a spiral-shaped Mach-Zehnder Interferometric sensor (sMZI sensor) for refractive index sensing of watery solutions is presented. The goal of the running project is to realise a multi-sensing array by placing multiple sMZIs in series to form a sensing branch, and to place several sensing branches in parallel. In such an arrangement it is possible to use a single light source for several sensors. Each sensor will contain an electro-optical modulator, which makes it possible to separately interrogate and accurately read-out each sensor in the same sensing branch.

Introduction
The potential of the classical “straight” Mach-Zehnder Interferometric (MZI) sensor, as shown in Fig. 1, is large: the achieved resolution in refractive index changes obtained in the past at the IOMS group is in the order of $\delta N \sim 10^{-8}$ [1]. The two branches of the device are made as equal as possible to minimise the effect of fluctuations in temperature.

![Figure 1. Top-view of a classical “straight” IO Mach-Zehnder Interferometer.](image)

The straight MZI layout is not suitable for compact integration into multi-sensing arrays, mainly due to the device length (typically 4 cm). The large device length makes the sensor more vulnerable to process non-uniformities.

Spiral-shaped MZI layout
The goal of the running project [2] is to realise a multi-sensing array by placing multiple spiral-shaped MZIs in series to form a sensing branch, and to place several sensing branches in parallel, as is illustrated in Fig. 2. In such an arrangement it is possible to use a single light source for several sensors. Each sensor will contain an electro-optical modulator, which makes it possible to separately interrogate and accurately read-out each sensor in the same sensing branch.
Figure 2. Top-view of a sensor array of spiral-shaped Mach-Zehnder Interferometers. Sections for electro-optical modulation (not displayed) lead to a larger sensitivity and the possibility to read out all sensors in a sensor branch separately.

The spiral-shaped layout of the MZI has several advantages: a long sensor window length can be placed in a compact sensor chip: within an area of $1 \times 1$ cm$^2$ lengths of several tens of centimeters are feasible. Moreover, the spiral shape has the advantage that if both MZI branches are identical (except for the sensor layer) the sensor should be very insensitive to temperature gradients across the chip. Another advantage is that the compactness owing to the spiral shape also allows cascading of several sensors. A parametrised sMZI has been designed such that the position, slope, and curvature are continuous.

### Photolithographically defined immunolayers

The sensors can each be coated with e.g. a specific immunolayer to be able to detect changes in concentration of viruses, bacteria or enzymes. In this project, technology is being developed for the immobilisation and photolithographical patterning of such immunolayers, which should result in a demonstrator to monitor the ripening process of cheese by measuring changes in the concentration of several different enzymes involved in this process.

### Concluding remarks

A spiral-shaped MZI (sMZI) is being developed having the following features:
- Insensitivity for temperature gradients across the two branches
- Compact device layout
- Cascaded into multisensing arrays

### References


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