# Optical MEMS filter for infrared gas detection

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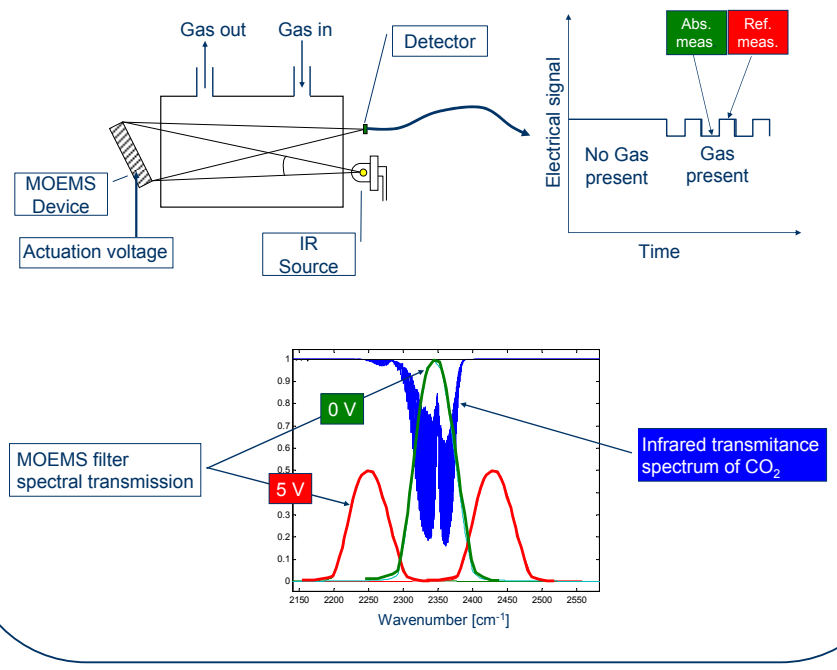
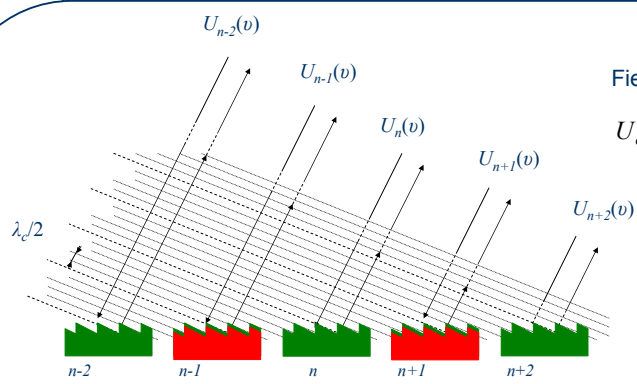
## Abstract

An optical filter is proposed, which can be adapted to infrared detection of various gases. The filter is based on a diffraction grating structured on a micro-electro-mechanical system (MEMS) which can be switched between two states by applying an external actuation voltage of 0-5V. The optical grating is etched into silicon, and has a period and a depth adapted to the gas to be detected. The grating presented in this poster is a two-level binary grating designed to give a reflection spectrum centred at a 2μm wavelength. It has 500nm deep grooves and has a period of 5-10μm. The grating is structured on top of an array of silicon beams, where every second beam can be moved vertically. The filter switches between two states by applying an actuation voltage of 0V and 5V. The optical spectrum of the diffracted light changes according to actuation voltage. By deflecting every second grating element 500nm (λ/4) vertically, the filter can be switched between a function with a single band which peaks at a certain centre wavelength, and a function with two sidebands positioned on either side of the centre wavelength. The single band can be designed to coincide with the absorption lines of the gas to be detected, while the sidebands are positioned outside of the absorption region of the gas. By illuminating the gas with light diffracted off this filter and switching between the two filter states, an intensity modulation of the light is achieved which is dependent upon the amount of gas present in the transmission path of the light. The proposed filter provides a robust, flexible, and potentially low cost solution for infrared gas detection of a wide range of gases.

## Gas measurement with a two-state filter




## Optical principle

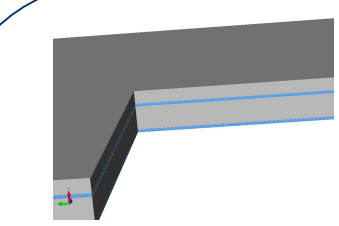



Field at detector:

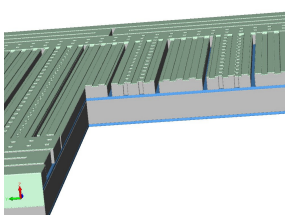
$$U_{\det}(\upsilon) = \sum_{n=1}^{N} U_n(\nu)$$

- Deformable hologram consisting of silicon elements covered by several grooves of a diffraction grating
- Two States
  - Elements at same vertical position → fields from each element interfere constructively at λc at the detector position
  - Every other element pulled down by λc/4 → fields from each element interfere constructively in two sidebands on both sides of λc at the detector position
- Position of the central peak and of the two sidebands can be adjusted by changing the period of the movable elements and the number of grating grooves on each element

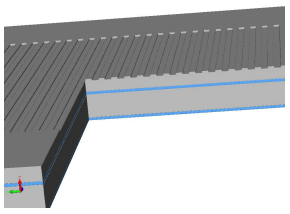
## Fabrication



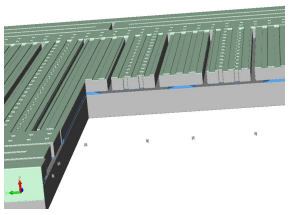
a) Silicon-On-Insulator wafer



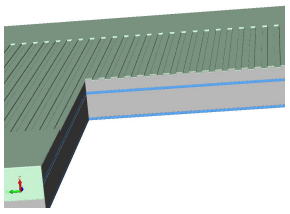
d) Pattern and etch metal and silicon



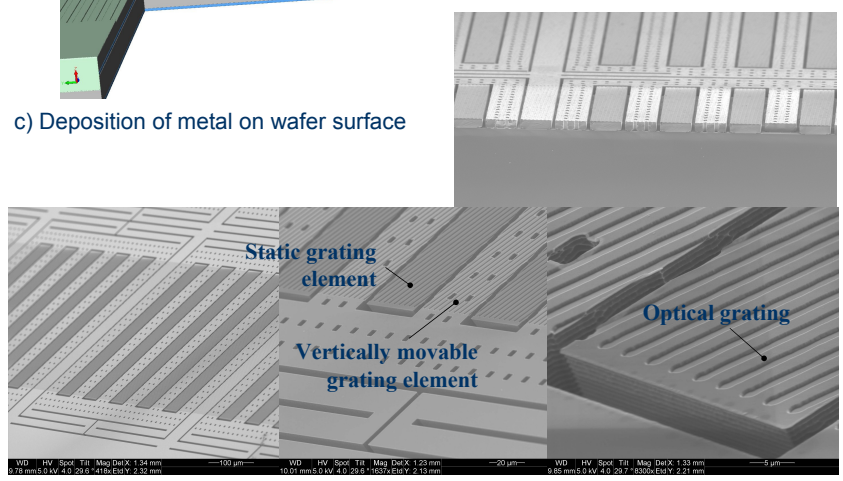
b) Pattern and etch diffraction grating



e) Release using vapor phase HF etching

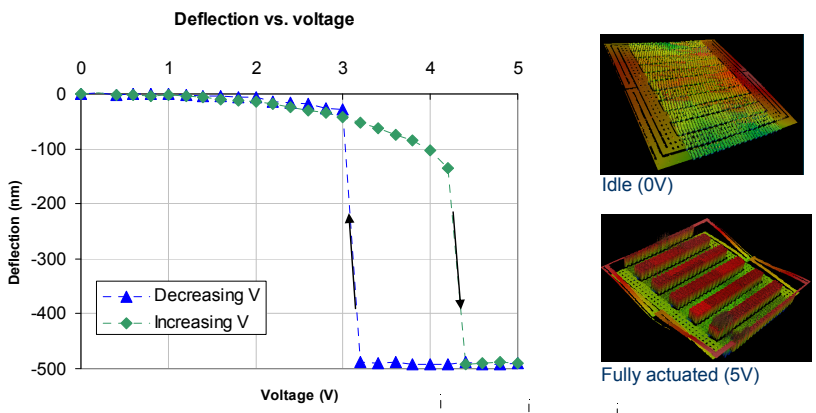


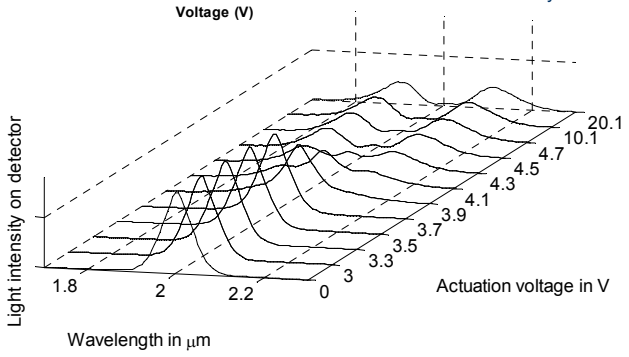
c) Deposition of metal on wafer surface




Scanning electron microscope (SEM) pictures of finished devices

## Characterisation




## Conclusion

- Fabrication and demonstration of a micromechanical optical filter
- The mechanical structures can be moved between two stable positions, which makes the sensor easy to fabricate and robust
- The optical properties of the two states of the filter can be adjusted so that a variety of different gases could be measured with this principle