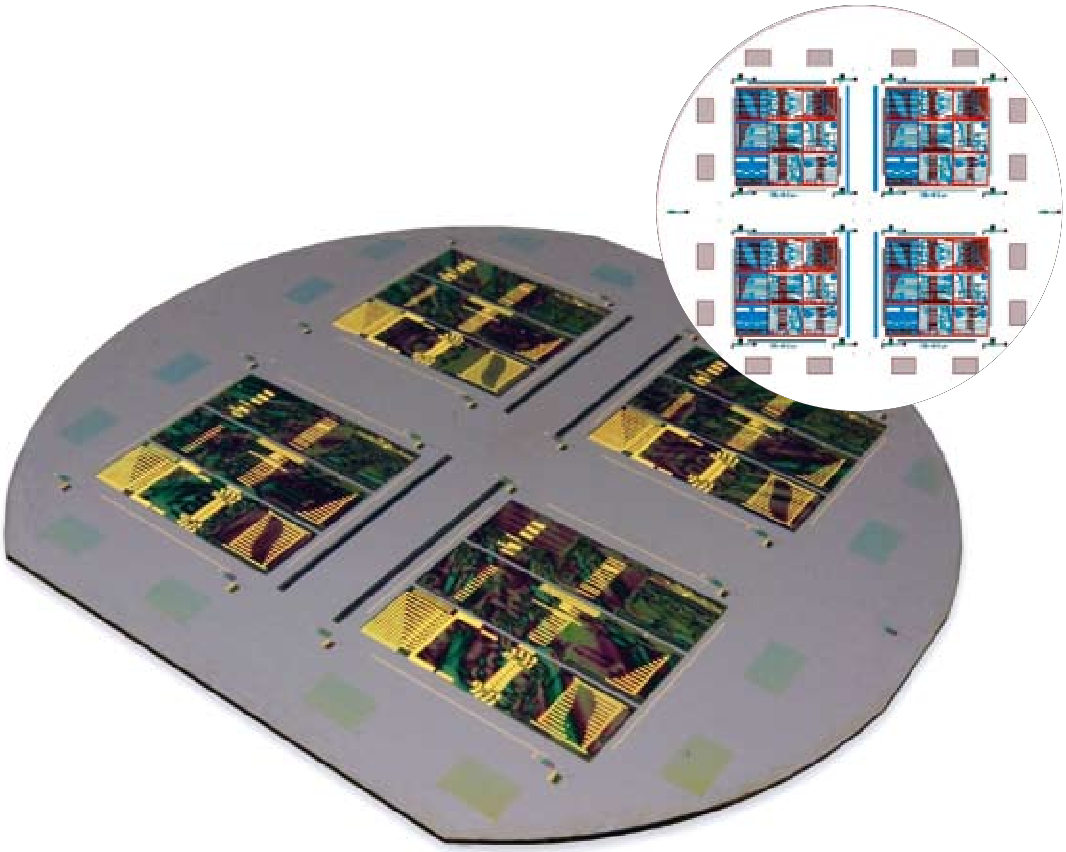


Mask layout and processed wafer containing photonic integrated circuits.

Project number: IPD100025
Project name: Coarsely and finely tuneable laser for gas sensing (TULGAS)
Goal: to develop a gas-sensor demonstrator with a tuneable laser for the wavelength region of 1.8-2.2 microns using generic integration technology

Demonstrator of a gas sensor *based on a tuneable laser*

Gas sensors can detect certain molecules within a sample based on the principle that those molecules have a specific light-absorption peak. By sending light of that particular wavelength through the sample and measuring how much of it arrives at the other end, they can determine the presence and even the number of those molecules. Until now, separate lasers have had to be designed for each specific molecule, however. The IOP project 'TULGAS' will develop a gas-sensor demonstrator with a tuneable laser that can be used for a wide range of gas-sensing applications.

Molecules such as carbon dioxide, ammonia, methane and nitrogen oxides play a role in monitoring greenhouse gases and exhaust gases. Those molecules are also important for measuring the gaseous emissions from livestock buildings, such as pig farms, where the discharge of ammonia is restricted by law. In healthcare, gas analysis offers a promising means of diagnosing certain medical conditions. The presence of ammonia in one's breath can indicate kidney failure, for instance. Using breath tests to monitor patients could reduce dialysis time, potentially leading to a substantial decrease in total dialysis costs.

"Gas analysis offers a promising means of diagnosing certain medical conditions such as kidney failure"

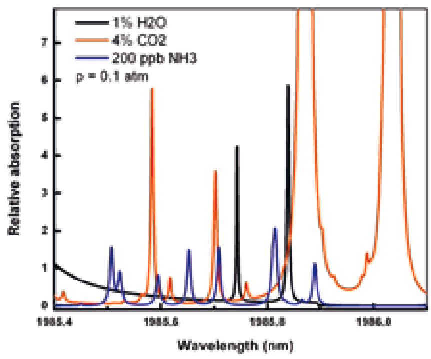
Single generic device

By sending light of a wavelength that approximates the absorption peak of a specific type of molecule through a sample, it is possible to detect those molecules within the sample. The amount of light that reaches a detector at the other end is indicative of the number of those particular molecules present. "The problem with gas sensors, however, is that a laser can only emit a specific wavelength. Consequently, a gas sensor can only be used to detect one type of molecule," says Dr Huub Ambrosius from the Department of Electrical Engineering at the Eindhoven University of Technology (TU/e). "So, based on the expected presence of certain different molecules, you have to use multiple specific lasers to trace them all." To solve this problem, the TULGAS project aims to create a single laser that can be tuned to cover a certain wavelength range, thus replacing the number of different lasers that are currently needed. "More specifically, we want the laser to be wavelength-tuneable at between 1.8 and 2.2 microns. That is the wavelength region in which you will find the absorption bands of carbon dioxide, ammonia, methane and nitrogen oxides." Ultimately, this project should lead to a single generic device that can monitor a multitude of molecules. A demonstrator of such a gas sensor, which should be able to trace molecules in the parts-per-billion range, will be built and tested during this IOP project.

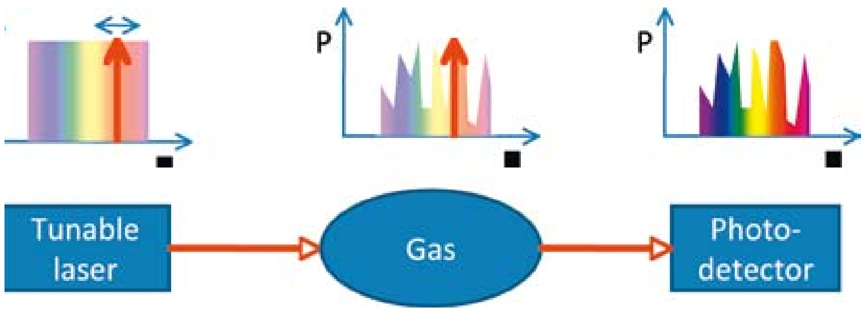
Continuously tuneable

Roughly four steps will be necessary to realise such a demonstrator: conducting the research on the proposed laser, designing and producing an optical chip – a photonic integrated circuit – containing the tuneable laser, the packaging of that chip and, finally, testing the resulting device. The members of the project consortium cover this entire supply chain.

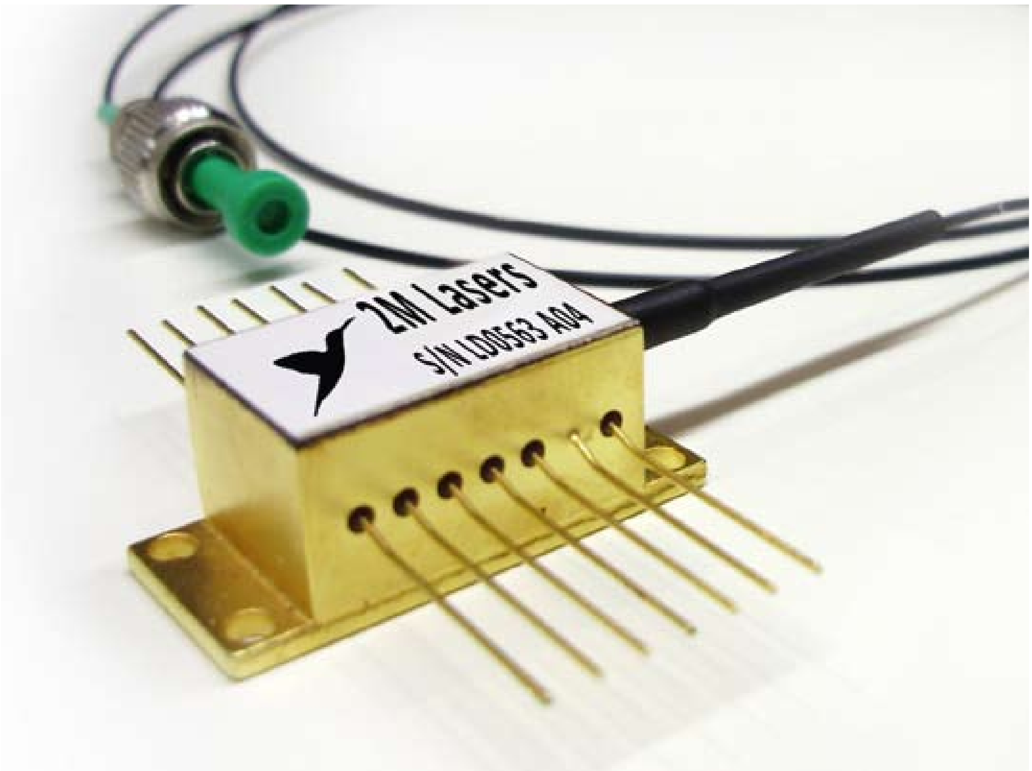
"The proposed laser will be an adaptation of one that was developed at TU/e and that is discreetly tuneable at around 1.5 microns," Ambrosius says. "We want to upgrade this wavelength region to the area around 2 microns and make the laser continuously tuneable so that we can scan the wavelength region several times per second. This will enable the gas sensor to monitor any changes in the sample in real time."



Molecules such as ammonia and carbon dioxide have an absorption peak of around 2 microns (2000 nm).



By sending light of a wavelength that approximates the absorption peak of a specific type of molecule through a sample, it is possible to detect those molecules within the sample. The amount of light that reaches the detector is indicative of the number of molecules.



Example of a packaged photonic device.

This part of the project will be carried out at TU/e. In the second part – the design and production of the optical chip – EFFECT Photonics will be heavily involved. This spin-out from TU/e focuses on the design and prototyping of next-generation optical chips. The company will be using a generic fabrication platform that was developed by COBRA in Eindhoven. “The development and production of optical chips is very much comparable to that of chips in the semiconductor industry,” says Ambrosius. “The same steps are followed: the wafer production, the lithography, the slicing of the wafers into chips, and the packaging. In this case, however, the basic material is not silicon but indium phosphide (InP). Our COBRA Photonics and Semiconductor Nanophysics group, which is also participating in the project, is highly experienced in the epitaxial growth of this material.” Similarly, the COBRA Photonic Integration group will be adding its expertise in the area of designing and processing optical chips to the project.

Flip-chip bonding

In order to be able to use the optical chip in a device for gas sensing, the chip will need to be packaged together with the necessary electronics. Because this is normally the most expensive part of a semiconductor laser, the design of the package is critical. 2M Engineering will contribute to this part of the project, using a technique called flip-chip bonding. They will also develop the thermal and mechanical package that will enable the fine and coarse tuning of the laser. “Not only do they have specific expertise in those areas, but they will also act as our interface with potential gas-sensor producers and users,” Ambrosius explains. Last but not least, the project partner Radboud University Nijmegen will define possible applications for the gas sensor, and its Trace Gas Research group will test a functional prototype.

Participants:
- Eindhoven University of Technology
- Radboud University Nijmegen
- 2M Engineering
- EFFECT Photonics

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