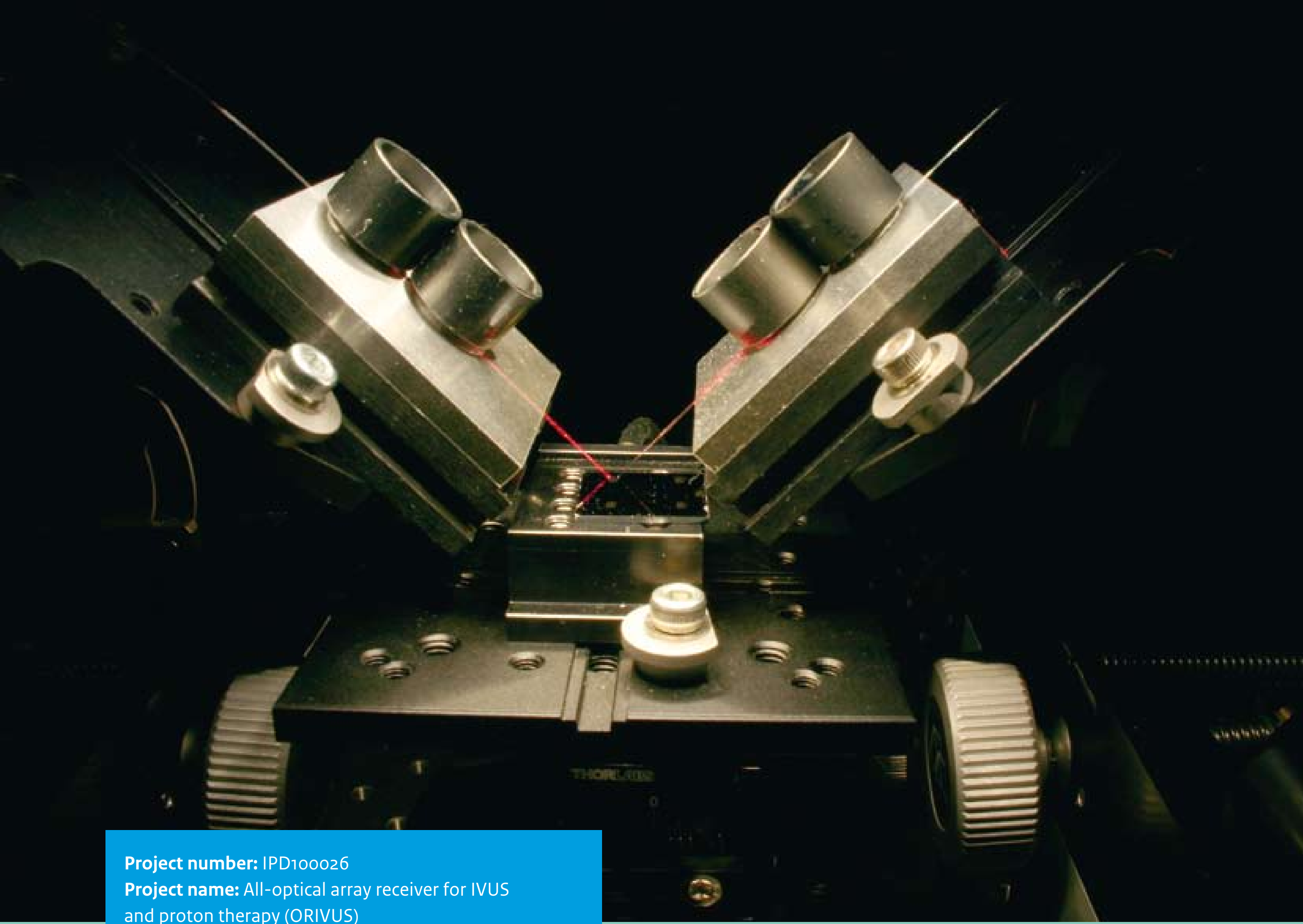


Project number: IPD100026
Project name: All-optical array receiver for IVUS and proton therapy (ORIVUS)
Goal: to develop a small all-optical array receiver - a photonic NanoPhone - based on integrated nanophotonics

Setup for optical characterisation of the acoustic sensor

Photonic NanoPhone
for proton therapy and IVUS

The photonic NanoPhone, an all-optical array receiver containing several hundreds of small and sensitive yet inexpensive acoustic sensors, will be beneficial to at least two important medical applications. In proton therapy, the NanoPhone will enable the monitoring and adjustment of both the trajectory and the strength of the proton beam during treatment. In intravascular ultrasound imaging, it will afford a much higher lateral resolution than conventional piezo-based sensors do. Moreover, since the NanoPhone will be insensitive to electromagnetic interference (EMI), it will also be suitable for use in an MRI environment. This research project will focus primarily on its application in proton therapy.

With the aim of stopping tumour growth, more than 50% of all cancer patients receive electromagnetic radiation therapy. However, estimates show that about 10–15% of the cancer patients in the Netherlands would benefit from proton therapy, since charged particles such as protons can be directed more accurately and with a more carefully regulated dose. “In the current form of proton therapy, the trajectory and strength of the proton beam are established beforehand, based on images from MRI or CT scans in combination with computer models,” says Paul Urbach, Professor of Optics at the Delft University of Technology and project leader of the IOP project ‘ORIVUS’. “However, since dose control is crucial to avoid damaging healthy tissue, it would be highly preferable to obtain direct feedback and make the adjustments during the treatment itself.”

“The acoustic sensors can be made inexpensively using existing CMOS mass-fabrication technology”

Blurred images

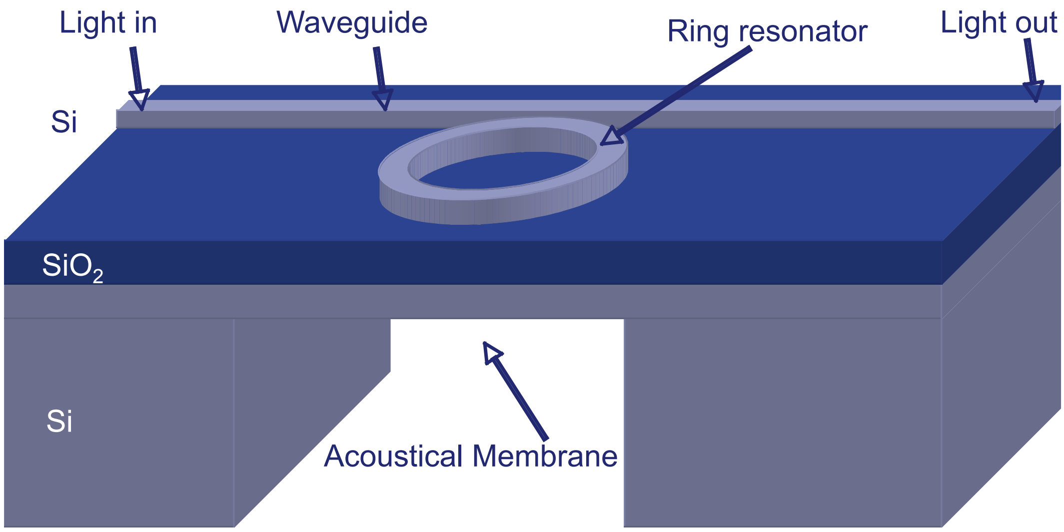
Fortuitously, the deposition of proton energy happens to generate a low-amplitude acoustic wave field. Paul Urbach: “Using an array of small but highly sensitive acoustic sensors, you can detect and measure that acoustic wave field with a high degree of accuracy. On the basis of images derived from the acoustic waves, a medical specialist can deliver the protons very accurately in carefully regulated doses.”

Another medical procedure that could stand to benefit significantly from the photonic NanoPhone is intravascular ultrasound imaging (IVUS). “In current practice, a cylinder-shaped probe is brought through the blood vessel to the heart to localise vulnerable plaque. But the resulting images do not have the desired resolution and are often even heavily blurred. Due to the patient’s breathing and the flow of blood through the vein, the catheter is continuously moving,” Paul Urbach explains. “Using many more sensors - several hundreds as is the case with the NanoPhone - will drastically improve the resolution of the images, since the acoustic waves can then be measured from multiple positions simultaneously.” Moreover, the all-optical system allows read-outs from an array of sensors using a single optical fibre.

Tailoring

The sensors in the NanoPhone are approximately 30 microns each and consist of a thin elastic silicon membrane with an integrated optical ring resonator on top. When hit by an acoustic wave field, both the membrane and the ring resonator will deform, causing a shift in the optical resonance frequency of the ring. That shift in frequency will be monitored by an external interrogator system and can be interpreted as an acoustic signal. “Using a large number of sensors allows you to determine the acoustic wave field much more accurately. Earlier research has shown that the sensitivity of such sensors is very promising,” says Paul Urbach. “On top of that, they can be made inexpensively using existing CMOS mass-fabrication technology. So the production price will not be a problem.”

To understand the influence of the acoustic wave on the deformation of the membrane and thus of the ring resonator, fundamental research is needed. The so-called elasto-optic effect has to be taken into account as well, since that also influences the frequency shift. By tailoring the design of the membrane and the shape, thickness and length of the resonator, the sensitivity of the sensor can be optimised. “It will take a substantial effort to model all these variables, but I have high expectations. Our PhD students are exceptionally qualified for the job.”



A possible configuration of a ring resonator on top of an acoustic membrane.

Non-destructive testing

The ultimate goal of 'ORIVUS' is to deliver a prototype of the detector, including data acquisition and data processing, and to validate the principle with preliminary tests.
To attain this ambitious goal, the Optics Research Group and the Acoustical Imaging & Sound Control Group of the Delft University of Technology are working together with the Nano-Instrumentation Expertise Group at TNO and the SMEs Technobis and HQSonics. In order to explore and test the possibilities of the NanoPhone in the medical field, the project will cooperate with Erasmus MC.
As TNO has extensive know-how in the field of integrated optical sensor systems, its contribution to the project will be essential. In connection with proton therapy, collaboration has been established with the Holland Proton Centre (HollandPTC).

This centre is one of three initiatives that aim to offer proton therapy in the Netherlands. HollandPTC itself brings together the expertise of three highly respected medical centres, including the two largest cancer centres in the Netherlands. If all goes according to plan, the first patients will be able to receive proton therapy treatment in 2013.
The usefulness of the NanoPhone will however not be limited to the medical field, says Paul Urbach.
"The NanoPhone is a general acoustic detector that is both small and highly sensitive. That makes it also very suitable for the non-destructive testing of materials, especially in restricted or hostile environments such as oil and gas pipes."

Participants:
- Delft University of Technology
- TNO
- Technobis
- HQSonics
- HollandPTC

Contact:
Prof. dr H.P. Urbach
T: +31 (0)15 278 94 06
E: h.p.urbach@tudelft.nl