

Quantum4Health

Quantum Imaging System for Intraoperative Highly Effective Diagnostics Allowing Gentle Tumour Surgery and High Impact for Healing

G. Meineke¹, K. Gerwert², A. Grisard³, K. Pantzas⁴, D. Polishchuk⁵, P. Winnand⁶

¹Fraunhofer ILT, ²betaSense GmbH, ³Thales RT, ⁴CNRS, ⁵Saxion University, ⁶Uniklinik RWTH Aachen

Quantum4Health aims to develop a novel intraoperative diagnostic device for real-time assessment of facial skin tumour margins. The approach combines spectrally resolved mid-infrared (MIR) quantum imaging with undetected photons (QIUP) and a new orientation-patterned Gallium Phosphide (OP-GaP) nonlinear material platform. Its goal is to help surgeons to distinguish tumour from healthy tissue during surgery, enabling complete yet minimally invasive tumour removal.

Clinical Motivation

Every year, approximately 4.4 million people worldwide undergo facial surgery to remove skin tumours. To preserve both aesthetic and function, the aim is to perform surgery in a way that preserves as much tissue as possible, whilst not increasing the likelihood of tumour recurrence. However, 15% of surgical patients require a second operation due to incomplete tumour resection, as no established method exists for intraoperative tumour cell detection. This places a significant burden on patients. Quantum4Health aims to close this diagnostic gap and thus ensure complete tumour resection during surgery.

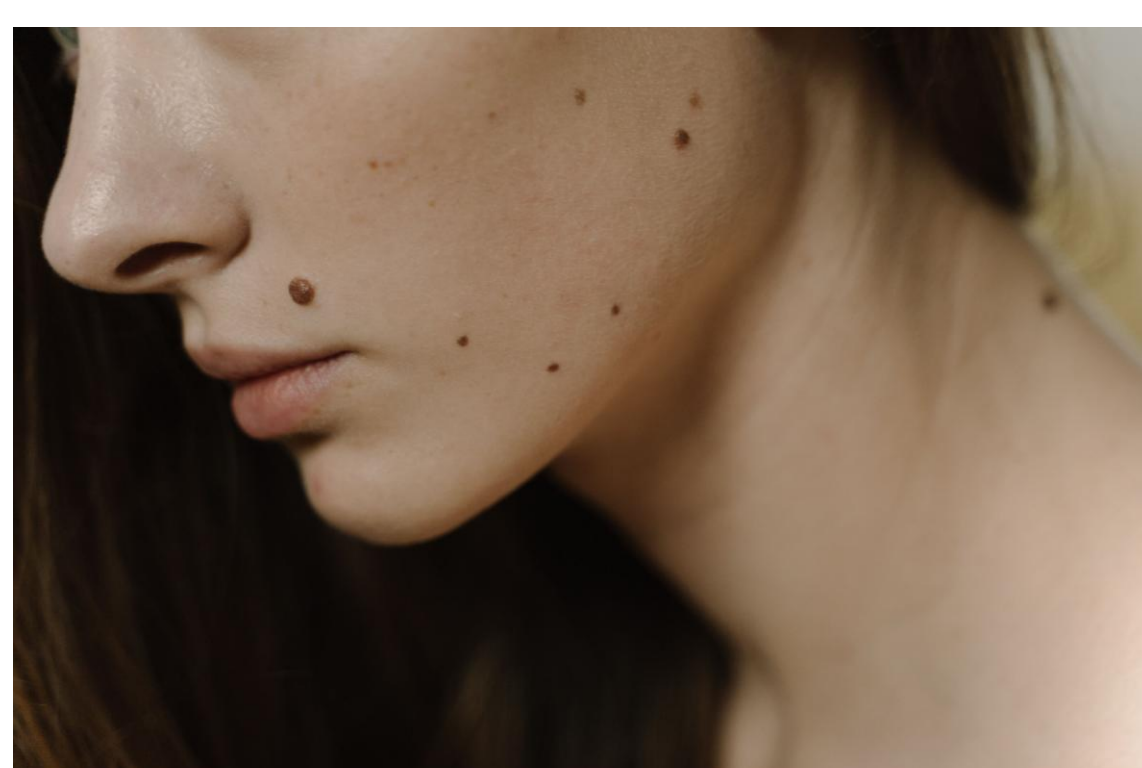


Fig. 1: A woman with skin lesions that are suspected to be cancerous

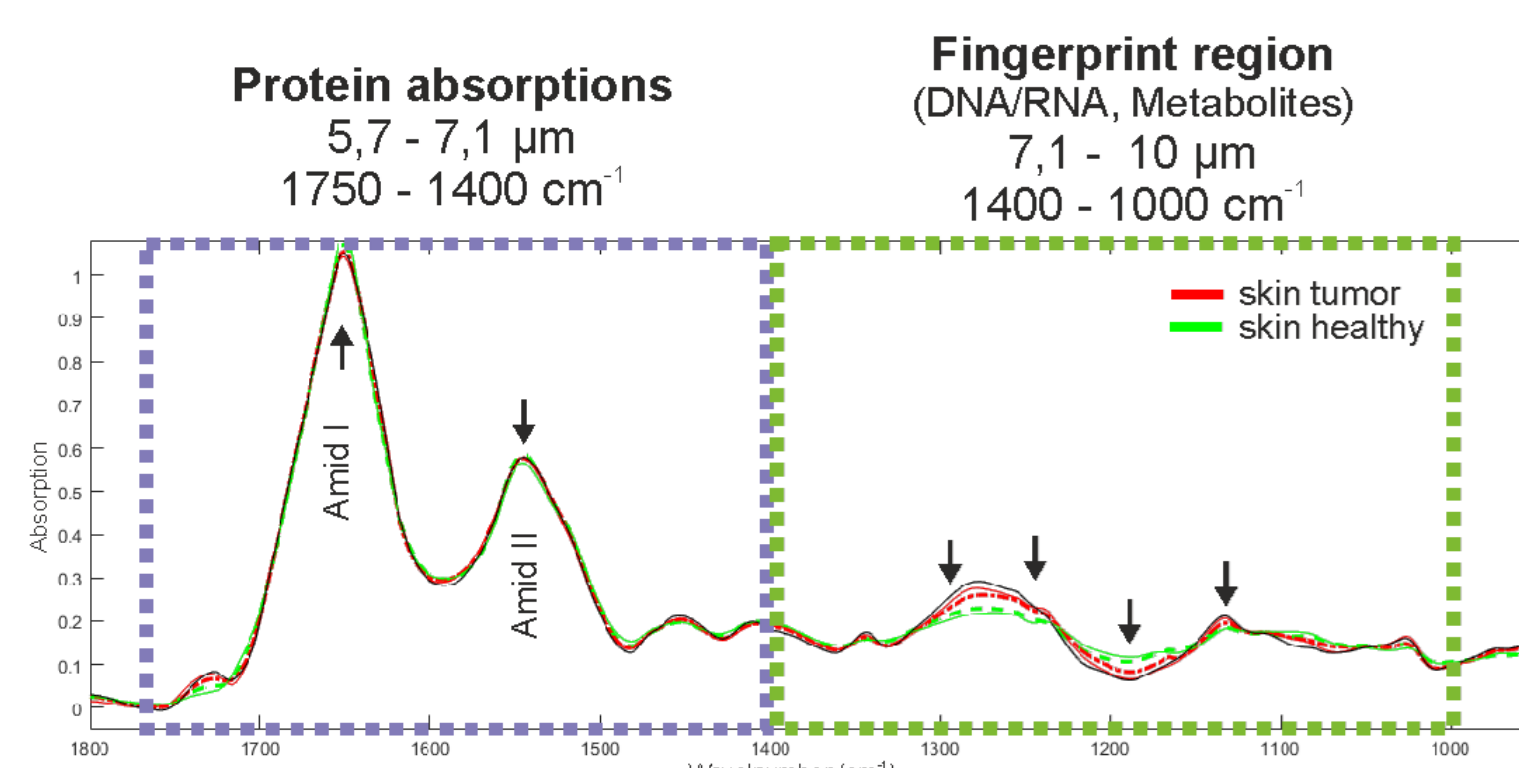


Fig. 2: Absorption spectra of healthy skin and skin tumours in the mid-infraredⁱ

Approach

Tumour tissue differs from healthy tissue in terms of morphology and metabolism. One method of measuring these differences without contrast agents is marker-free MIR spectroscopy, as proteins, DNA/RNA and metabolites exhibit characteristic absorption bands in the spectral range of 5.7 μm – 10 μm, see Fig.4. These have already been used to detect tumours, tumour subtypes, driver mutations and predictive markers such as microsatellite instability in colorectal carcinomas. Until now, however, this technology has relied on the use of slow FTIR spectrometers or expensive quantum cascade lasers.

Quantum4Health technology enables intraoperative marker-free tumour detection by

1. Highly efficient generation of entangled NIR/MIR photon pairs
2. Scanning of the resected tissue with the MIR photons based on the principle of attenuated total reflection (ATR)
3. Transfer of the absorption information to NIR photons via quantum interference
4. Detection of the absorption spectra using high-performance NIR detectors

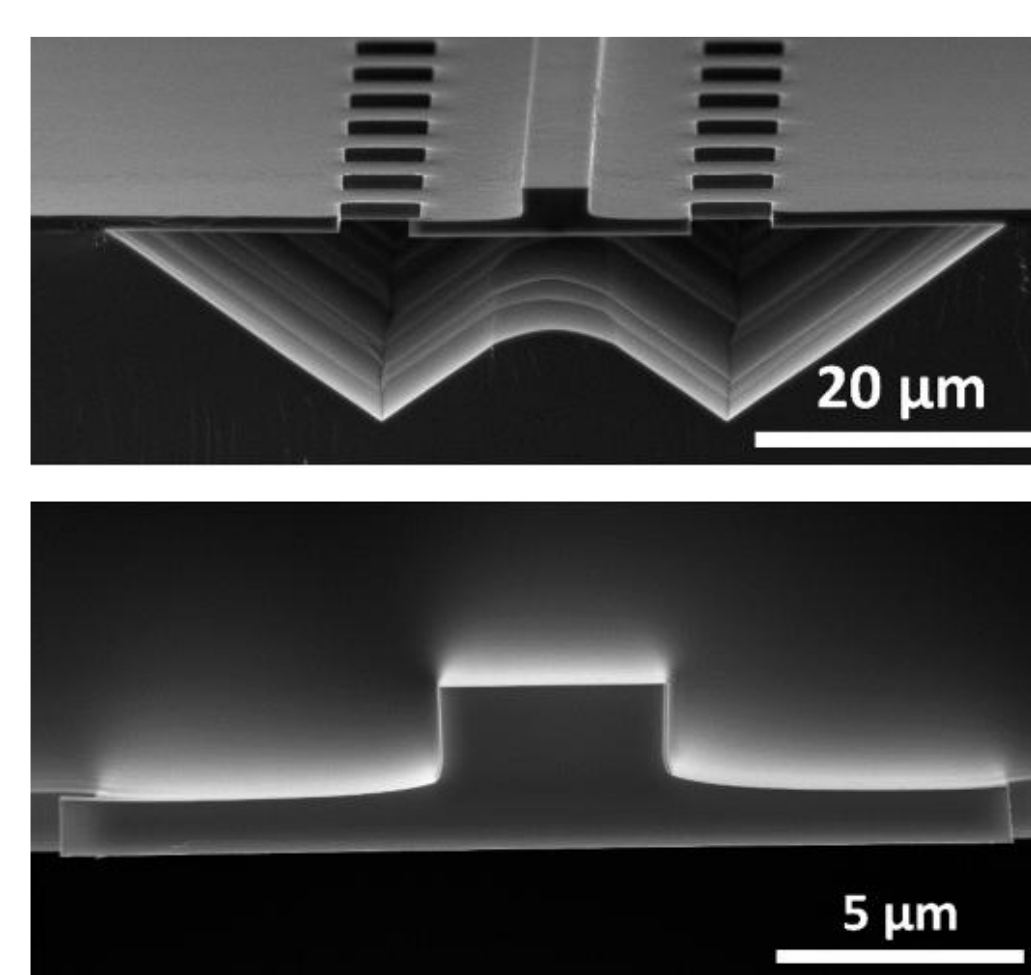


Fig. 3: OP-GaP waveguide for conversion between 1.55 μm and 775 nm

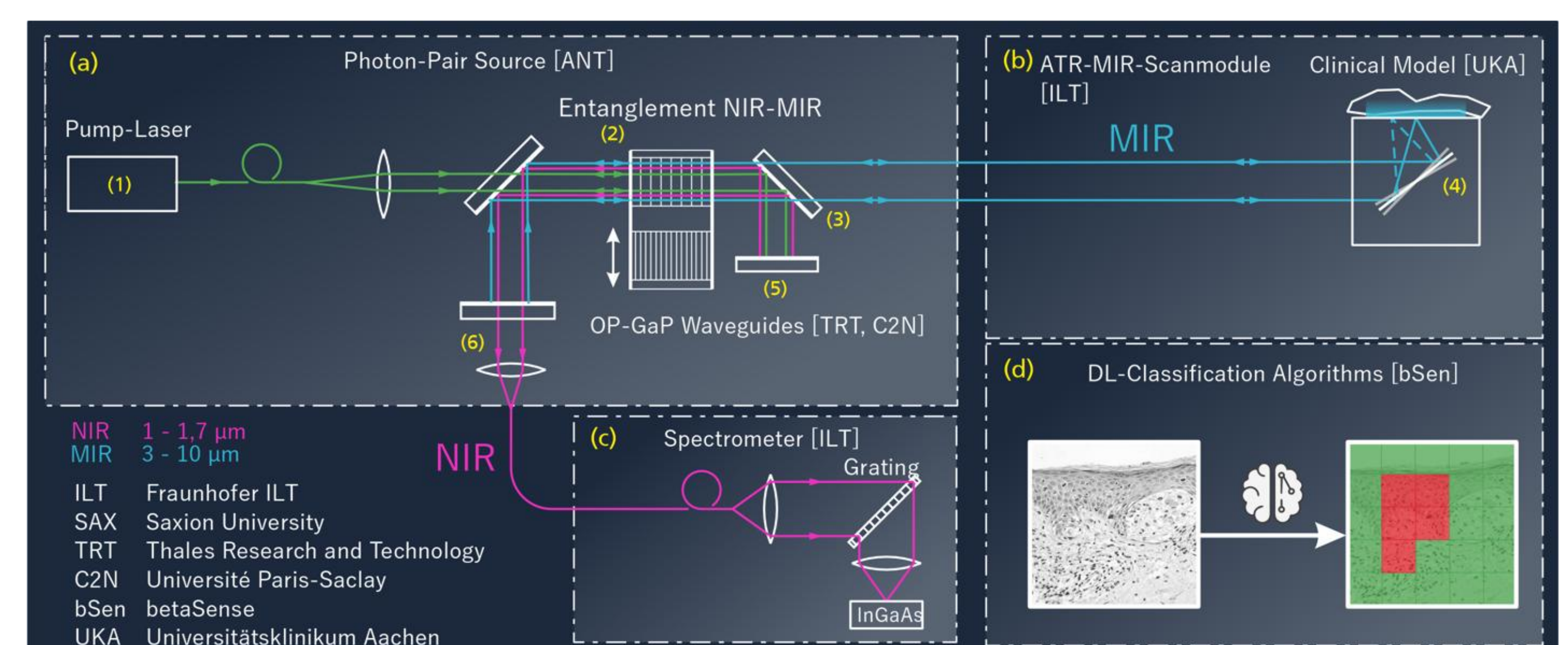


Fig. 4: System architecture and key components of the Quantum4Health quantum imaging system

Goal

The four objectives of Quantum4Health are

- Design and fabrication of non-linear waveguides made of orientation-patterned gallium phosphide (OP-GaP) for generation of NIR/MIR photons (5.7–9 μm) and building a source for QIUP
- Integration of the NIR/MIR source into an attenuated total reflection (ATR) measurement setup to provide spatially resolved spectral information
- Deep learning models for analysing ATR-IR spectra aiming for a novel MIR classification method using a limited number of spectral regions
- Proof of concept at the Department of Oral and Maxillofacial Surgery using patient samples

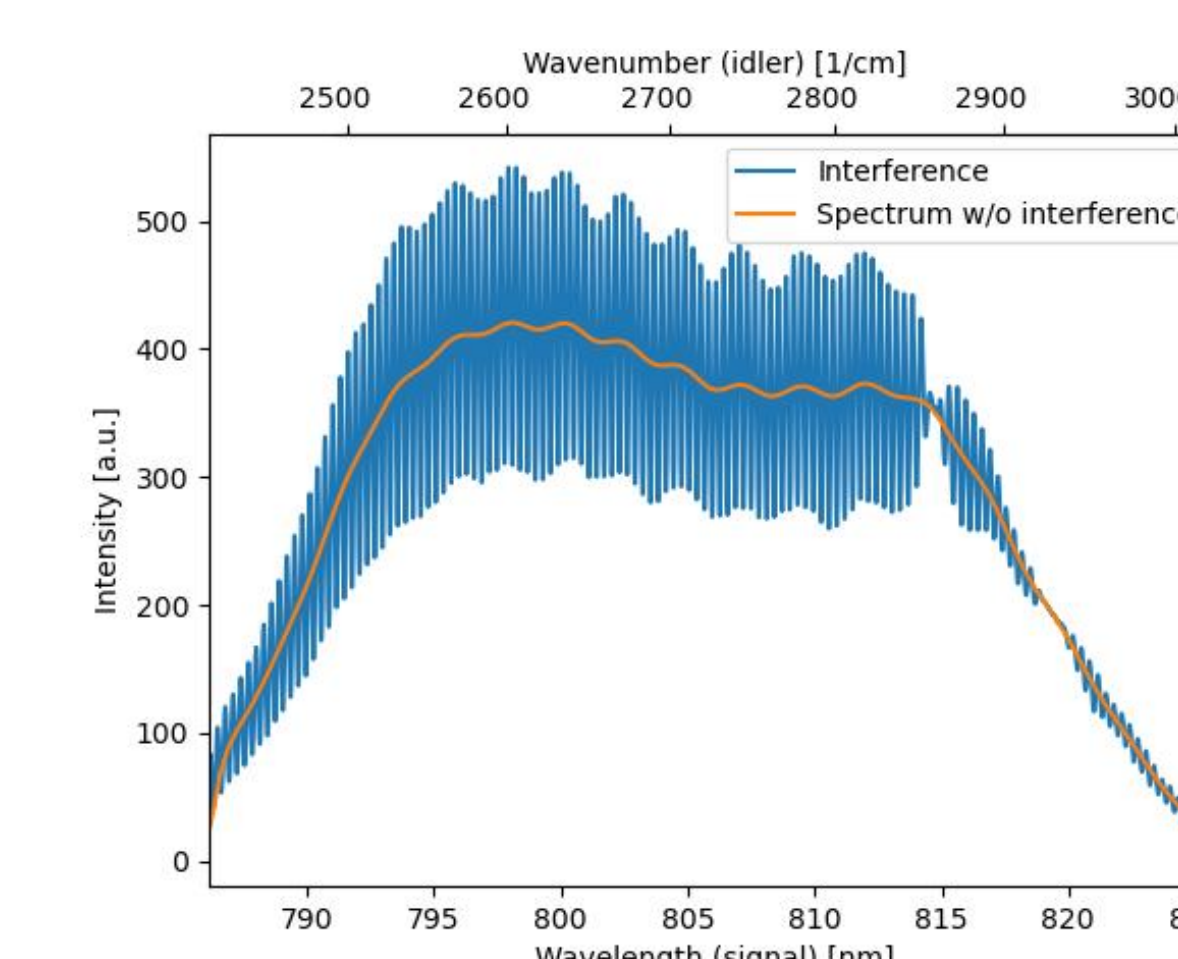


Fig. 5: Quantum interference spectrum of PE foil

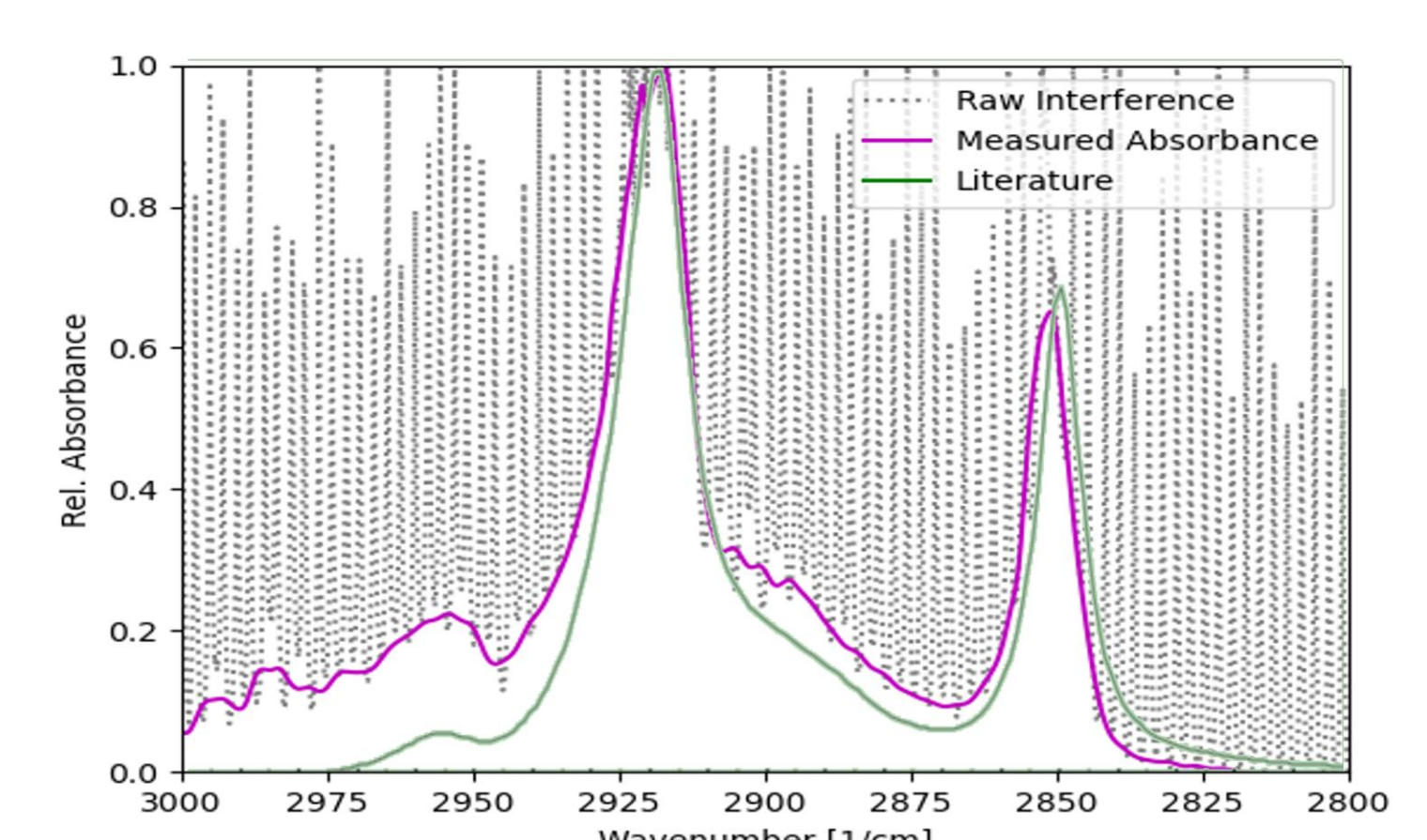


Fig. 6: Absorbance spectrum of PE measured using quantum-enhanced spectroscopy and compared to data from literature

In preliminary work, the basic principle of operation was demonstrated by recording quantum interference spectra in the NIR and calculating the absorption bands of PE in the spectral range between 3000 cm⁻¹ and 2000 cm⁻¹ wavenumbers.

Contact

Dr. Georg Meineke
 Laser Medical Technology &
 Bioanalytics
 Tel. +49 241 8906-8084
 georg.meineke@ilt.fraunhofer.de



ⁱ Kowalski, Th., "Infrared Imaging for Dermatopathology: Observer-Independent Cancer Detection for Clinics and Research", PhD thesis, Ruhr University Bochum, Department of Biophysics & Center for Protein Diagnostics, Supervisor: Prof. Dr. Klaus Gerwert, 2024.