# PS-1 Laser Sensing in Environmental and Medical Research

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## Introduction

Laser spectroscopy provides many possibilities for advanced monitoring and diagnostics in the fields of environmental and medical research. In both areas, non-intrusive measurements in real time are desirable, and the activity can be considered to be remote sensing although at widely differing distances. Certain applications are reaching a state of maturity while others are at an early developmental stage. A broad range of applied laser spectroscopy is pursued at the Lund Institute of Technology and a brief survey of our recent work will be given with reference to published papers.

## Environmental Monitoring

### *Atmospheric lidar*

The Lund group has been pursuing atmospheric laser radar monitoring for a long time, including industrial and geophysical measurements. A review of some of the activities is given in Ref. 1. Recently, a full integration between plume-transect, integrated-gas-contents measurement and automatic wind assessment for total flux determinations at industries was achieved[2]. Extensive work on the monitoring of mining areas[3,4], geothermal fields[5,6] and active volcanoes[7,8] has been performed. In particular, the total fluxes from the Italian volcanoes Etna, Stromboli and Vulcano have been measured in shipborne campaigns, where Differential Absorption Lidar (DIAL), Differential Optical Absorption Spectroscopy (DOAS) and Correlation Spectroscopy (COSPEC) were intercompared. Present lidar group activities focus on hydrocarbon monitoring in the wavelength region around 3.4 $\mu$m using OPO techniques and difference frequency generation. We also use passive techniques employing gas correlation for spectroscopic imaging of gas in the IR region[9].

### *Fluorescence lidar*

The Lund group has performed extensive fluorescence lidar work regarding water quality[10,11], vegetation status[12-14] and historical building facades[15,16]. In particular, part of the Lund cathedral was scanned with a fluorescence lidar system for assessment of algal and lichen growth. Full fluorescence spectra were recorded in each image point and multi-variate analysis was employed for data presentation. A field campaign for similar measurements in Parma, Italy, is planned.

### *Diode laser spectroscopy*

Diode lasers provide convenient means for certain types of spectroscopic diagnostics. Normally, only line-of-sight path-integrated data are obtained, similarly as in DOAS[17], but this limitation can sometimes be overcome by tomographic reconstruction techniques, i.e. for mappings of flows[18]. A particularly high sensitivity in diode laser absorption measurements can be obtained in frequency-modulation (FM) spectroscopy, of which two-tone FM spectroscopy is a particularly convenient variety. We have focussed on a full characterization of the absorption lineshape, which allows the technique to be used under varying gas temperature and pressure conditions[19,20]. With the fast development of the semiconductor laser technology, new wavelength regions are becoming available. We recently demonstrated single-mode diode laser spectroscopy in the violet spectral range[21], and are now, like many other groups, focussing on the IR range, accessible by difference-frequency generation or directly by quantum cascade lasers. Diode lasers are also useful for full characterisation of aerosol particles, sensed simultaneously by their intracavity absorption and their diffraction patterns, captured by a ccd camera[22].

## Medical diagnostics

During recent years laser spectroscopy has found strongly increasing applications for medical diagnostics[23] and a large number of groups have embarked on the study of medical applications. The field includes the early diagnostics and demarcation of malignant tumours, the characterization of blood vessels for guiding interventional angioplastic procedures, and scattering spectroscopy for optical mammography, etc. Laser-induced chemistry (photodynamic therapy) can also be applied for the eradication of tumours (See, e.g. 24,25). Very recently, laser-produced X-rays have been studied for possible medical applications.

### *Fluorescence monitoring of malignant tumours*

On irradiation of tissue with UV or violet light, a broad-band fluorescence distribution is observed due to a multitude of molecular constituents (tissue autofluorescence). If fluorescent tumour-seeking agents (sensitizers) have been administered, spccific fluorescence, frequently featuring sharp peaks in the red spectral region, are observed from cancerogenous tissue. Fibre-optic point monitoring devices can be used to guide biopsy specimen sampling ("optical biopsy"), and multi-spectral imaging systems can provide a valuable overview for early malignancy detection[26-28]. A very compact medical fluorosensor has recently been developed and tested in the clinical environment[29].

### *Elastic scattering spectroscopy and optical mammography*

In the tissue optical window, ranging from about 0.6 – 1.4 μm, scattering strongly dominates over chromophore absorption, and new techniques for disentangling absorption and scattering properties of tissue are needed. The use of time-resolved spectroscopy in a lidar-like manner has proved to be quite powerful for tissue spectroscopy and gated- viewing imaging through strongly scattering tissue[30-32]. Tissue structures can be reveiled in this way, and absorption spectra be recorded decoupled from the scattering. The use of white laser light, generated from a high-power laser system employing self-phase modulation, has proved to be quite successful in the development of the techniques[33,34].

### *Laser-produced X-rays for biomedical applications*

If intense femtosecond pulses from a table-top terawatt laser[35] are focused onto a high-Z target, intense hard X-ray radiation is produced. The radiation consists of Bremsstrahlung and sharp characteristic lines[36,37]. We have employed such radiation in emerging biomedical applications[38], including ultrasharp imaging[39], differential absorption imaging[40] and gated viewing imaging[41] to suppress Compton-scattered X-ray photons. Very recently we also demonstrated the principle of gated-viewing X-ray tomography[42].

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