Fall 2005

Laser Centre Vrije Universiteit

visitors guide

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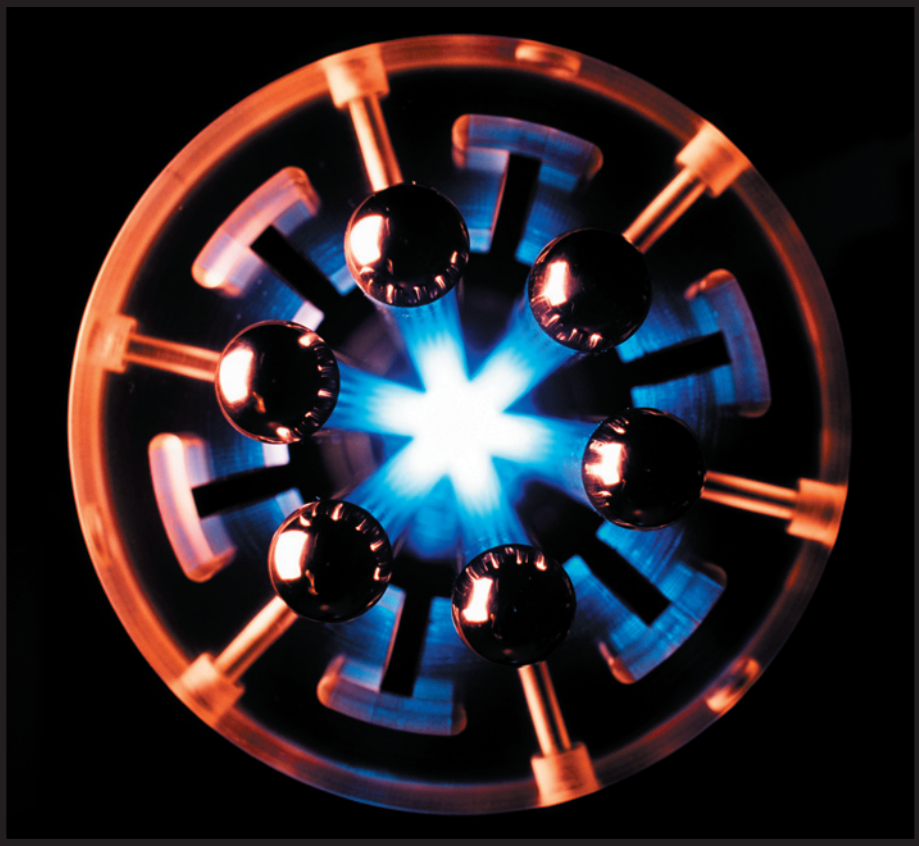
INTRODUCTION



Welcome to LCVU

It is my great pleasure to present you the Visitors Guide 2005 of the Laser Centre Vrije Universiteit (LCVU) of the Vrije Universiteit Amsterdam. This guide provides you an up-to-date description of the various research and educational activities at LCVU. LCVU has operated very successfully during the last few years, demonstrated by the rising number of high-profile publications, the success in attracting research funding and the arrival of several new young staff members. Furthermore, LCVU has been integrated in a new consortium of 17 leading laser centres in Europe: LaserLab-Europe. The participation of LCVU in LaserLab-Europe demonstrates the leading role of our institute in laser and photonic related interdisciplinary research in the Netherlands and beyond. As you may learn from this guide LCVU has a broad scope of laser-oriented research: besides development of lasers and fundamental and applied laser spectroscopic research, the specific application of lasers in life sciences is a topic of increasing activity within LCVU.
The information on the organisation, science and education at LCVU is presented in concise form in this visitors guide, more details can be found on the website of LCVU: http://www.nat.vu.nl/~laser.

On behalf of the board and management team of the LCVU I wish you a pleasant reading.

Prof. Dr. Wim Ubachs
Director of LCVU

September 2005

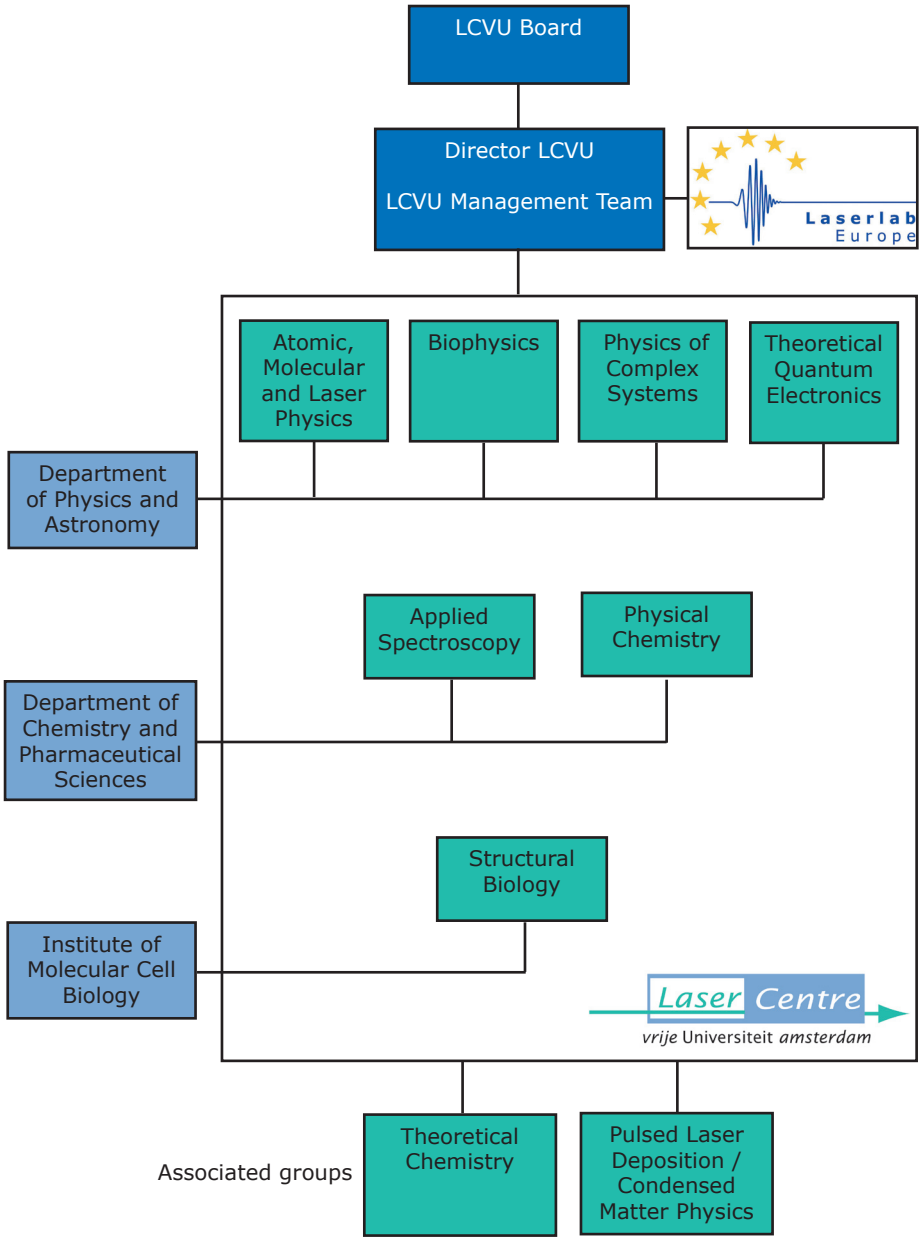
Historical Note

The Laser Centre Vrije Universiteit was founded in 1992 when several research groups within the Department of Physics and Astronomy and the Department of Chemistry moved their laser-based research to a joint infrastructural facility in the Sciences building at the VU-campus. The restructuring of the building and the installation of the laboratory facilities was supported by the Board of Directors of the Vrije Universiteit and financed in part by the Ministry of Education. Professor Wim Hogervorst initiated LCVU and has acted as director of LCVU during the first decade. Since 2001 Professor Wim Ubachs has taken over the directorship.
Initially the groups of Atomic and Laser Physics, Biophysics, Applied Spectroscopy and Physical Chemistry moved to the newly constructed laboratories, whereas the Theoretical Quantum Electronics group also took part in the scientific activities of LCVU. At three occasions after the initial construction the laboratory floor space of LCVU was expanded to house additional laser facilities, purchased

via major investment grants acquired by the research groups. At present the LCVU has nearly 2000 m^2 of laboratory space.
During the past decade the VU developed a research policy putting more emphasis on Life Sciences. In line with that policy the Physics Department opened a chair in Physics of Complex systems and the Biology Department opened a chair in Structural Biology. These groups, headed by Professor Christoph Schmidt and Professor Holger Lill respectively, have become part of LCVU. Furthermore, associated with LCVU are the Pulsed Laser Deposition group and the Theoretical Chemistry group. The LCVU-institute crosses borders of the VU-organization, encompassing groups in Physics, Chemistry, and Biology that are part of the Faculty of Sciences (FEW) or the Faculty of Earth and Life Sciences (FALW).

LCVU is located on the campus of the Vrije Universiteit in the southern part of Amsterdam, very close to Schiphol Airport, and with direct tram and metro connection to the historical centre of Amsterdam

Organogram


LCVU Board
Director LCVU
LCVU Management Team
Laserlab Europe
Atomic, Molecular and Laser Physics
Biophysics
Physics of Complex Systems
Theoretical Quantum Electronics
Department of Physics and Astronomy
Applied Spectroscopy
Physical Chemistry
Department of Chemistry and Pharmaceutical Sciences
Structural Biology
Institute of Molecular Cell Biology
Laser Centre
vrije Universiteit amsterdam
Associated groups
Theoretical Chemistry
Pulsed Laser Deposition / Condensed Matter Physics

LCVU-organisation

Board	Management Team	Management-Assistant
Prof. C. Gooijer (Chairman)	Prof. W. Ubachs (Director)	Mrs. P.P. de Gijsel
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Prof. Ch.F. Schmidt	Dr. Y. Bollen	
Prof. S. Stolte	Dr. E.J.G. Peterman	
	Dr. T.D. Visser	

Future and Policy

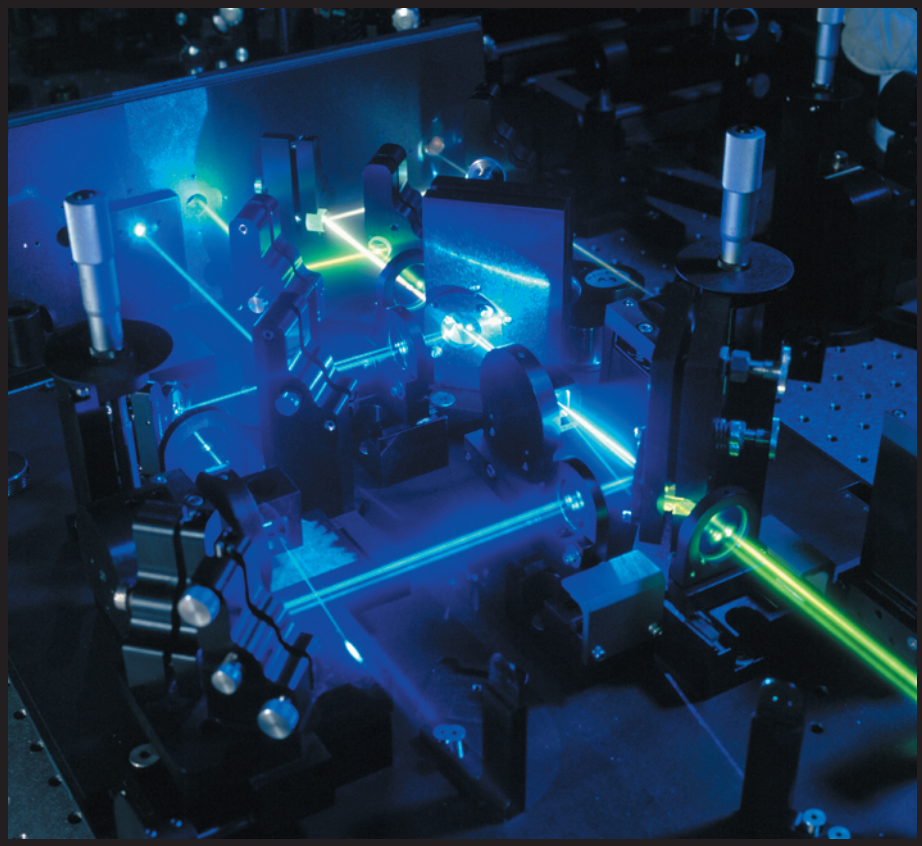
The board and management team aim at maintaining and expanding LCVU as a national stronghold of laser-oriented research in collaboration with the major laser centres in Europe. We receive strong support from the Board of Directors (CvB) of the Vrije Universiteit, which recognizes LCVU as a major facility on the VU campus, fitting in the VU research policy. As was formulated in our 2004 policy document (The "VU-ture" Laser Centre) LCVU strives to become a European top institute for research and education at the interface of multi-disciplinary laser sciences and life sciences. A goal of LCVU-policy is the expansion of LCVU research activities towards applications of lasers in (bio)-medical research.
In the discussions on the restructuring of the science and research landscape in the Netherlands and the Amsterdam region, LCVU aims at a further concentration of laser-oriented activities at the VU campus. The reconstruction of the VU-sciences building in 2006-2007 provides an opportunity for upgrading the facilities for the present groups and for accomodating new ones.

This visitors guide

In the following chapters of this guide the research themes (Chapter 2), the international collaborations, including those within the EU-Access programs (Chapter 3), the educational activities (Chapter 4), the sources of financial support (Chapter 5), and the present staff, permanent staff as well as young scientists (Chapter 6) will be presented.

2

RESEARCH THEMES



Research themes

LCVU covers a broad scope of laser-oriented research. It ranges from the theoretical study of nonlinear dynamics in semiconductor lasers and singular optics, to the development of specialized lasers at extreme ultraviolet wavelengths and advanced frequency comb lasers, from laser spectroscopic research on fundamental atomic systems to chemical reaction dynamics and laser analytical chemical applications. Increasingly, the use of lasers in the life sciences is expanding the variety of multi- and interdisciplinarity of research topics in LCVU. For a full list and description of all the experimental facilities at LCVU see also: www.nat.vu.nl/~laser/experimental_facilities.html. In this chapter the research activities at LCVU are described covering 27 themes, which can be divided into two general categories.

Lasers and fundamental research of matter

Lasers and life sciences

Publications

LCVU scientists publish extensively and in highly-ranking journals. In 2004 LCVU produced over a hundred scientific papers, which are listed on the website: www.nat.vu.nl/~laser/Pubs2004.html.
Here some highlights of recent LCVU-publications are given.

Highlights of recent LCVU-publications

Directional dynamics in the photodissociation of oriented molecules, Science 303 (2004) 1852.

Deep ultraviolet quantum-interference metrology with ultrashort laser pulses, Science 307 (2005) 400.

The bipolar mitotic kinesin Eg5 moves on both microtubules that it crosslinks, Nature 435 (2005) 114.

The native architecture of a photosynthetic membrane, Nature 430 (2004) 1058.

Uncovering the hidden ground state of green fluorescent protein, Proc. Natl. Acad. Sci. USA 101 (2004) 17988.

Bacteriophage capsids: tough nano-shells with complex elastic properties, Proc. Natl. Acad. Sci. USA 101 (2004) 7600.

Highly accurate H_2 Lyman and Werner band laboratory measurements and an improved constraint on a cosmological variation of the proton-to-electron mass-ratio, Phys. Rev. Lett. 92 (2004) 101302.

On the connection between phase singularities and the radiation pattern of a slit in a metal plate, Phys. Rev. Lett. 93 (2004) 173901.

Capillary elecrophoresis coupled on-line with ultraviolet resonance Raman spectroscopy, Anal. Chem. 75 (2003) 5697

Singular optics, near-field optics and coherence theory

In recent years it has become increasingly clear that wavefields display all sorts of features that are smaller than the wavelength. Examples of such structures are surface plasmons and optical vortices. We analyze the transmission of light through sub-wavelength-sized apertures with the help of a rigorous Green tensor formalism. This allows us to study the intriguing connections between surface plasmons, optical vortices and other phase singularities. Recent results include the connection between vortices of the Poynting vector field and the anomalously large transmission through narrow apertures; and the discovery that singularities of correlation functions can evolve into singularities of the field amplitude.

Furthermore, the propagation, diffraction and scattering of partially coherent wavefields are studied both from a fundamental point of view and with an eye to applications such as novel imaging modalities.

There is an active experimental collaboration with the group of Prof. Han Woerdman at Leiden University.

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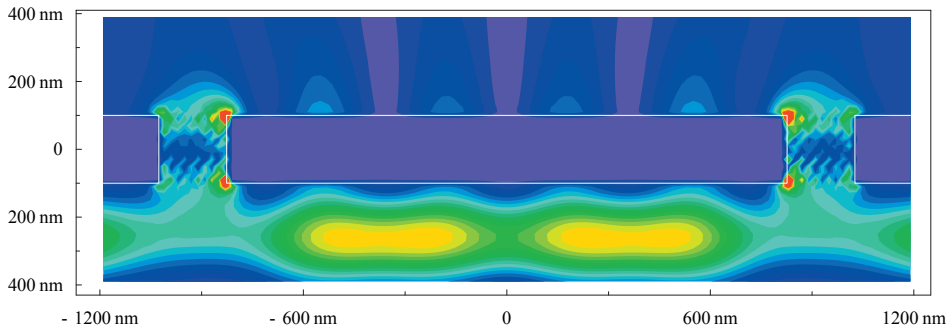
Theoretical Quantum Electronics



The field intensity near two sub-wavelength slits in a thin metal plate. Visible on the top of the interface is a standing wave pattern caused by interfering surface plasmons. [After Schouten et al. Physical Review Letters, vol. 94, 053901 (2005).]

Dynamics of semiconductor lasers in complex configurations

Semiconductor lasers are the most widely used lasers, with applications ranging from high power laser sources, spectroscopy, telecommunication, optical signal processing and consumer products (CD, DVD, pointers) to low-power interconnects, efficient spectrally narrow light sources, and personal devices. In all applications the laser is coupled to an environment so that it is often part of a rather complex network. The dynamical behaviour of a semiconductor laser, i.e. the emitted light (phase, intensity and polarization), depends very much on the type of optical feedback caused by this coupling.
We perform systematic studies of these dynamics based on delay-differential rate-equations. The goal is to understand the nature and origin of the various types of dynamics. We use the most recently developed and most powerful mathematical tools for the bifurcation analysis, the results of which give insight into how different regimes of operation are interconnected. Such knowledge is indispensable for successful control of the laser dynamics in complex network applications.
A very important generic configuration studied by us is a laser, which receives optical feedback from a distant mirror, where the mirror can be just a specular reflector, a grating reflector, or a more complicated active or passive filtering device. Other important configurations studied are lasers with injected light and coupled lasers.

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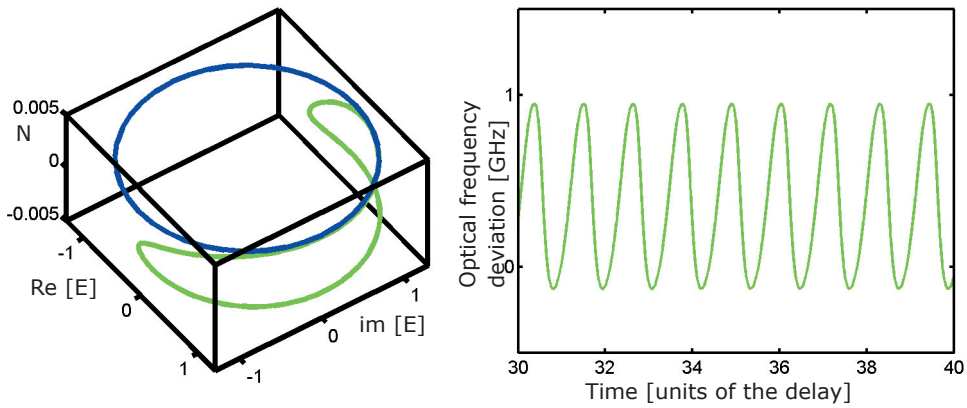
Theoretical Quantum Electronics



Numerical demonstration of a laser output with constant intensity and oscillating frequency. This highly unusual type of output light was first measured at LCVU and reported in Phys. Rev. Lett. 92 (2004) 023901(1-4). This dynamics is exclusively due to the presence of delayed filtered feedback. The left figure shows in green the orbit in phase space spanned by the real (Re[E]) and imaginary (Im[E]) part of the optical field and the inversion (N). Projection of this orbit on the N=0 plane lies on a circle. The right figure shows the oscillating frequency versus time.

Ultra high precision metrology using frequency combs

The invention of the principle of the frequency comb some years ago has brought a revolution in frequency metrology. A frequency comb is based on a phase and repetition rate stabilized mode locked laser. With this device it is now possible to measure optical frequencies of hundreds of THz directly in comparison to an atomic clock. Such a frequency comb is now available at the LCVU and it is used in two different ways.
The first one is as a facility to calibrate lasers at the LCVU for precision experiments. These experiments include a search for variation of the fundamental constants α (fine structure constant) and μ (the proton-to-electron mass ratio) by precision spectroscopy in molecular hydrogen and ions. In these cases laser light is transported by optical fibers to the frequency comb, which is then used to count the frequency relative to a GPS-disciplined Rb atomic clock.
The other line of research aims at extension of the frequency comb principle to much shorter wavelengths for which no narrow bandwidth lasers exist, such as extreme ultraviolet (< 100 nm). This would make more precise tests of quantum-electrodynamic and nuclear size effects possible in the ground state of helium and hydrogen-like ions. The idea here is to use the pulses from the frequency comb itself for excitation. Because of the high peak power of those (amplified) pulses, it is possible to generate short wavelengths by harmonic generation. The frequency of the transition is measured by analysing interference effects between excitation contributions due to a train of those phase-locked pulses. This principle was demonstrated recently at the LCVU with an experiment on krypton [S. Witte et al., Science 307, 400 (2005)].

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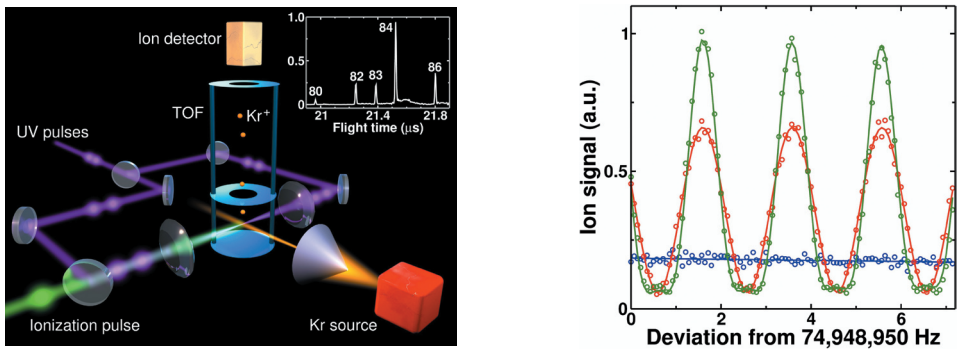
Atomic, Molecular and Laser Physics



Quantum interference experiment (left) where a train of phase locked ultraviolet pulses (at 212.6 nm) excites atomic krypton. Right side: the resulting ion signal for 1 (blue), 2 (red), and 3 pulses (green), as a function the pulse repetition rate near 75 MHz, from which the resonance position is deduced.

Phase controlled terawatt lasers and ultra-fast X-rays

The aim of this project is to generate ultra-short pulses of X-rays, ranging in wavelength from 1 nm to 100 nm, for dynamical studies of matter and studies of non-linear optics under extreme conditions. For this purpose high-harmonic generation is employed based on focusing fully phase controlled few cycle (< 10 fs) terawatt infrared laser pulses in a noble gas. The development of the required laser system is an important part of the project.
The starting point of the system is a frequency comb laser (11 fs pulses at 800 nm) which is carrier-envelope phase controlled. Pulses from this laser are amplified in a non-collinear chirped-pulse parametric amplifier system (running at 1 kHz and at 30 Hz repetition rate). It consists of a synchronized and frequency doubled Nd:YAG picosecond laser system which acts as a pump laser for the parametric amplification process in two 5 mm long BBO crystals. Pulses of the frequency comb are amplified from ~1 nJ to 25 mJ with a spectral bandwidth that greatly surpasses the capabilities of traditional Ti:sapphire amplifier systems. As a result, 10 fs pulses can be generated with terawatt peak power (about 10 mJ after compression) at 30 Hz.
Spectral phase control is achieved by a 640 element LCD 4f-shaping device just before the parametric amplifier. This means that full computer control over the electromagnetic field of the amplified pulse is available. Such control can be used for the optimisation of the pulse length (dispersion compensation), but also for optimisation of nonlinear optical processes driven by the laser pulses. This laser system is used in combination with a X-ray monochromator to study and apply the short wavelength radiation obtained from high harmonic generation.

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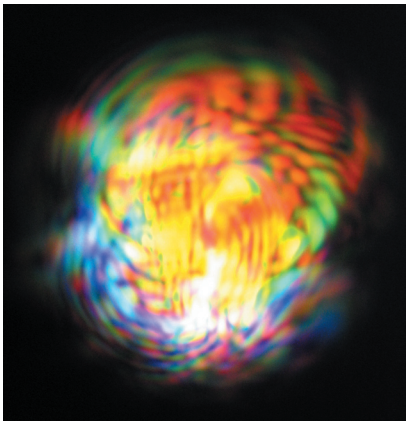

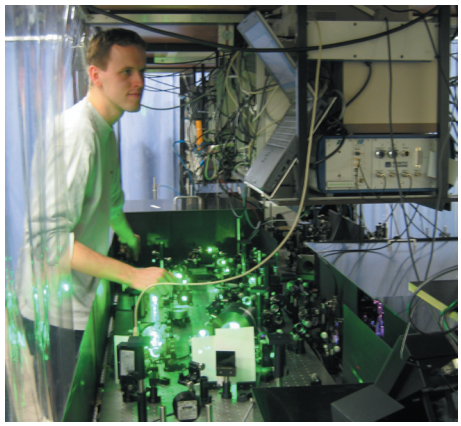

On the left the result is shown of multiple filament continuum generation by loosely focusing the terawatt laser beam in air. The right side shows a part of the terawatt chirped pulse parametric amplifier system.

Ultra-high resolution XUV spectroscopy

The narrowband extreme ultraviolet (XUV) laser at LCVU is used in a number of studies that all focus on precision inquiries of highly excited states in gas-phase molecules. The bandwidth of the system is better than can be achieved at any synchrotron in the world.
In molecular nitrogen and in carbon monoxide, the most strongly bound molecules in nature, the absorption spectrum lies at short wavelengths, primarily in the XUV-domain. In both molecules Rydberg states and valence states of singlet and triplet symmetry strongly interact and give rise to a wealth of (pre)-dissociation phenomena that bear a great impact: N_2 in the Earth atmosphere absorbing the light from the sun, and CO in the interstellar medium absorbing the light from nearby stars. The pre-dissociation processes are investigated in detail with our setup.
Molecular hydrogen, the most abundant molecule in the universe, exhibits strong XUV absorption as well, via the so-called Lyman and Werner systems. Ultra-precise transition frequencies, measured with the XUV-laser are compared with the red-shifted spectral observations from quasars. This study has led to the most stringent limit on a possible variation of the proton-to-electron mass ratio (μ) on a cosmological time scale: $\Delta\mu/\mu = -0.5 +/- 3.6 \times 10^{-5}$ (2σ) [Ubachs and Reinhold, Phys. Rev. Lett. 92 (2004) 101302].

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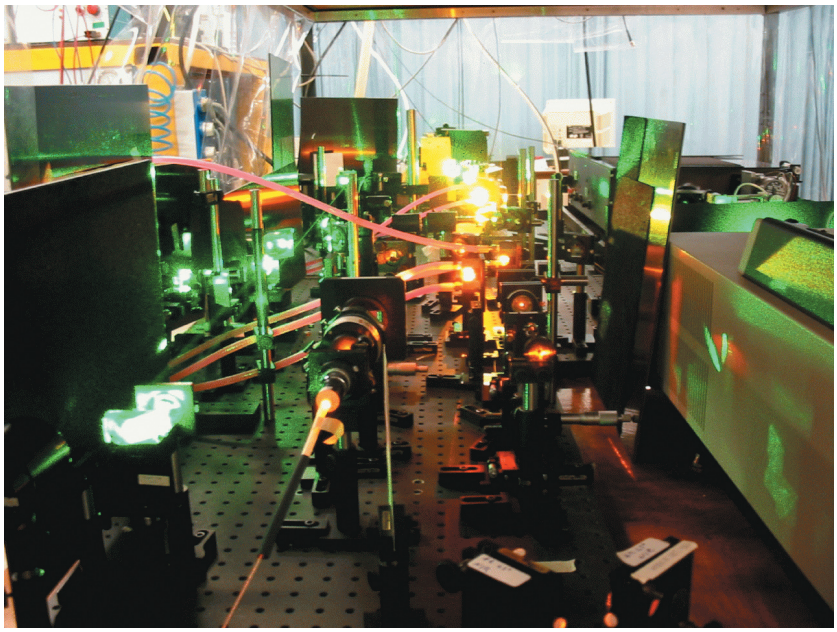
Atomic, Molecular and Laser Physics



Experimental setup of the pulsed dye amplifier laser system used for producing Fourier-transform limited laser pulses in the visible range, and for further upconversion into the extreme ultraviolet range.

A molecular fountain clock

Frequency is the most accurately measured quantity in physics. High-resolution spectroscopic measurements on atoms and molecules serve therefore as stringent tests of various fundamental physics theories. Ultimately the resolution of any measurement is limited by the time a molecule spends in the measuring device. At the LCVU a molecular fountain is being set up. In this device a beam of molecules is decelerated and cooled using switched electric fields and subsequently directed upwards. The molecules will fly upwards some 30 cm before falling back under gravity thereby passing a microwave cavity twice; as they move up and down. The effective interrogation time in such a scheme includes the entire flight time between the two traversals through the driving field and is typically a second. This long interaction time allows for a very high accuracy.
One of the molecules that will be investigated is ammonia. The microwave transition in ammonia is a measure for the rate at which the protons tunnel through the barrier between the two equivalent configurations of the molecule and is exponentially dependent on the ratio of the proton mass to the electron mass (μ). The inversion frequency is therefore a very sensitive probe for a possible variation of this ratio.

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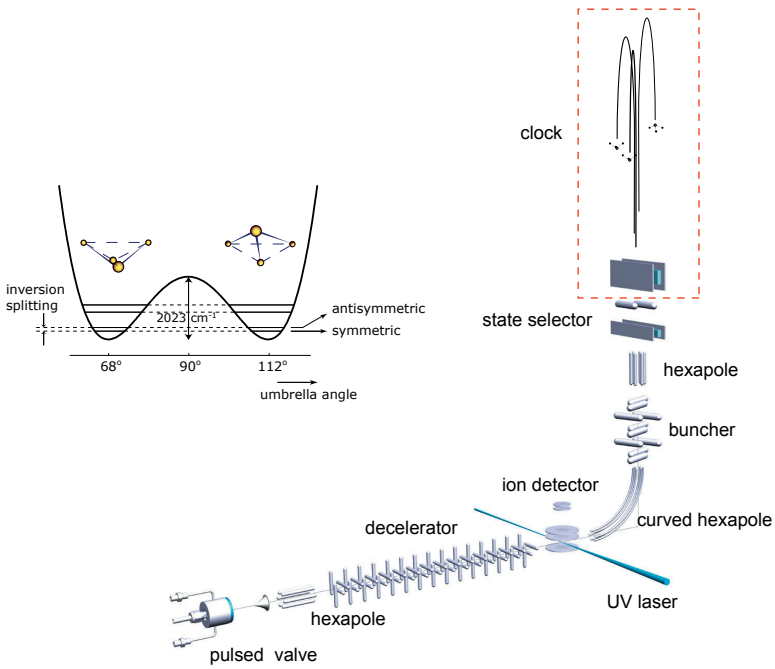
Atomic, Molecular and Laser Physics



Experimental scheme of the fountain clock that will be used to measure the inversion frequency of ammonia.

Bose-Einstein condensation of ultracold metastable helium atoms

In the cold atoms section of LCVU fundamental research is performed on a dilute helium gas (in the metastable 2 3S1 state: He*) close to absolute zero temperature. Applying laser cooling techniques 10^8 - 10^9 helium atoms (^{3}He, ^{4}He as well as mixtures) are cooled and trapped in a magneto-optical trap (MOT). The experimental setup allows detection of the cold cloud by absorption imaging on a CCD camera but also allows detection on two microchannel plate (MCP) detectors. One MCP detector measures ions, produced by collisions inside the cold cloud, whereas a second MCP, mounted 17 cm below the cloud, detects He* atoms directly.
In case of the bosonic isotope (^{4}He) the cloud from the MOT, which has a temperature of 1 mK, is transfered to a magnetic trap and subsequently cooled by evaporative cooling to a temperature of 1 μK, where Bose-Einstein condensation (BEC) is observed. At a pressure of 10-11 mbar in the UHV chamber the cloud in the magnetic trap has a lifetime of ~3 minutes. Preliminary measurements show that a condensate contains about 10^6 atoms.
Future research aims at understanding the physics of this fascinating macroscopic quantum state. Parallel research aims at cooling ^{3}He* fermions (via sympathetic cooling with ^{4}He* atoms) to similar temperatures and densities allowing studies of a ^{3}He* Fermi-degenerate gas as well as Bose-Fermi mixtures.

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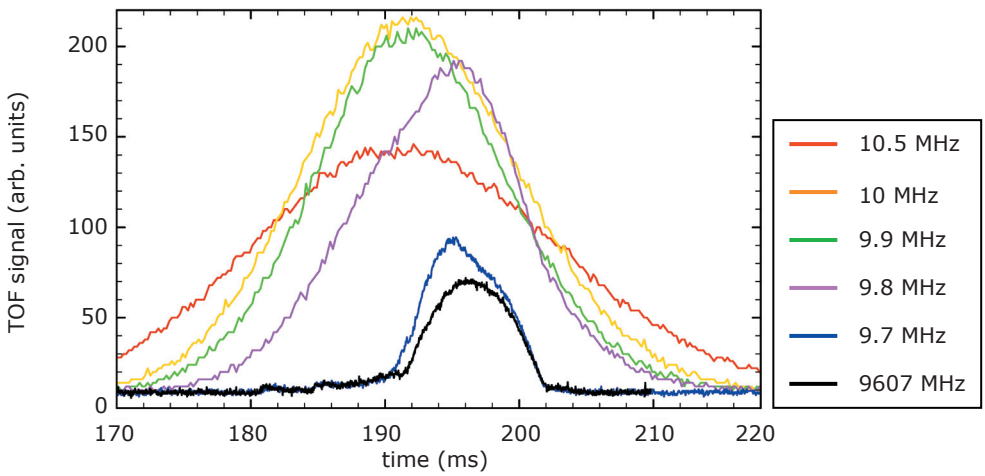

Time-of-flight spectra of a cloud of ultracold He atoms after 30 s evaporative cooling from an initial radiofrequency of 90 MHz to several end frequencies corresponding to colder and denser clouds. The changing shape in the < 9.9 MHz data reflects the appearance of a Bose-Einstein condensate.*

Laser isotope separation

Laser Isotope Separation (LIS) is of interest for elements that do not have a chemically stable gaseous form and therefore can not be enriched in centrifuges. We investigate commercially feasible LIS routes leading towards small-scale production of rare isotopes, such as Calcium-44, Gadolinium-152, Ytterbium-168 and Palladium-102. These isotopes are precursors for short-lived radioactive isotopes, which find wide-scale application in medicine, such as cancer treatment and monitoring studies.
Spectroscopic investigations are performed to find a suitable route leading to ionization of only the desired isotope. This route has to be sufficiently efficient such that only a few photons are required to ionize the atom. We make use of Nd:YAG pumped high-repetition rate (>18 kHz), narrow-band Titanium-Sapphire lasers. These lasers provide high power at the fundamental wavelength (~800 nm) as well as at the second- (~400 nm) and third harmonic (~270 nm). So far for Ytterbium and Gadolinium suitable routes leading to separation have been found. Samples of 96.5 % pure Ytterbium-176 have been produced at 10 mg/h production rates.

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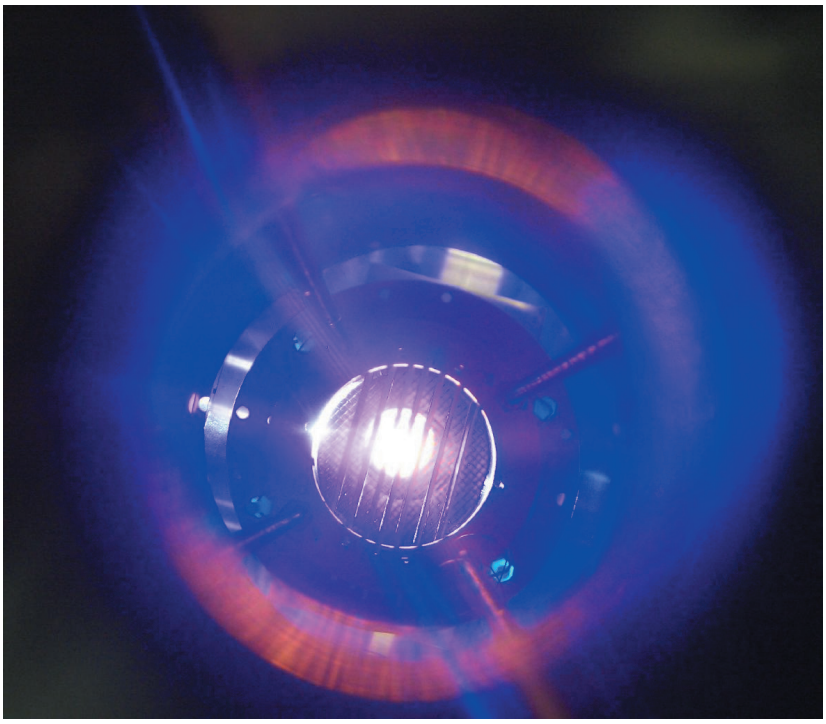
Atomic, Molecular and Laser Physics



A view of the Gadolinium oven. An atomic beam is formed at 1800 K.
The glowing Gd and the blue laser-induced fluorescence are clearly visible.

Pulsed laser deposition

Pulsed lasers can be used to deposit thin films of complex composition. Guiding the laser beam to an UHV deposition chamber accommodated with four targets we can make multilayer films of several complex compositions.
Using a 248 nm excimer laser with a fluence of 1 J/shot at 50 Hz, the surface of an irradiated target is ablated: i.e. a thin surface layer is transformed in a hot dense plasma which condenses on a substrate. Special beam optics is used to make a uniform beam profile and thereby conserve the stoichiometry in the deposition process. As in ion-sputtering, the target degradation in pulsed laser deposition (PLD) is due either to a phase transformation at the target surface or to preferential diffusion of one of the constituents towards the target surfaces. A uniform laser fluence allows one to ablate at the lowest possible fluence without suffering from either of these effects. As a result, superconducting $YBa_2Cu_3O_7$ thin films can be made reproducibly, allowing for an analysis or their critical current behaviour [B. Dam et al., Nature 399 (1999) 439].
To investigate the microstructural properties of Switchable Mirrors, we deposit YH_2 films in-situ. In this case we make use of the hydrogen dissolved in the target. The PLD process preferentially desorbs hydrogen during ablation. At the substrate the metal combines with the impinging reactive hydrogen and forms a nano-crystalline metalhydride film.

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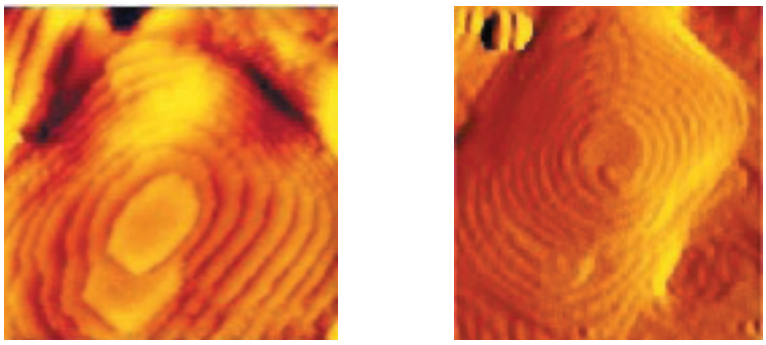
Pulsed Laser Deposition/Condensed Matter Physics



Surface morphology of a thin superconducting $YBa_2Cu_3O_7$ film, showing growth steps with unit-cell step height. Due to a change in the reactive pressure, a transition from 2D-nucleation and growth (left) to spiral growth (right) is observed. (Atomic Force Microscopy, 200 nm scan width.)

Imaging of oriented and quantum-state selected photodynamics

We use velocity map ion-imaging to study the quantum state-to-state photodynamics for several gasses which play a role in atmospheric chemistry. New experimental results on the photochemistry of OCS, which is considered to be a source of sulphur in the stratosphere, have been acquired recently. In collaboration with visiting guest T.P. Rakitzis (FORTH, Crete) we obtained a microscopic view of bond breaking of OCS in the molecular frame. OCS molecules in a molecular beam were spatially oriented in the laboratory frame using an electrostatic quantum vice. A polarized laser dissociated the OCS molecules in CO and S fragments. The three-dimensional recoil of CO fragments, measured with ion imaging, was strongly asymmetric. For the first time, an unambiguous picture of the molecular bond breaking was obtained revealing the curved trajectory of the recoiling CO fragment. This new experimental approach can similarly be applied to study and control the three-dimensional dynamics of photoinitiated reactions of fixed molecules or molecules oriented by emerging techniques like shaped ultrafast laser pulses. The experimental apparatus is equipped with a fast high-voltage gate on the two-dimensional detector which makes it possible to slice through the three-dimensional recoil distribution. This new experimental design opens up new experiments on oriented molecular photodissociation where there are no implicit symmetry requirements.

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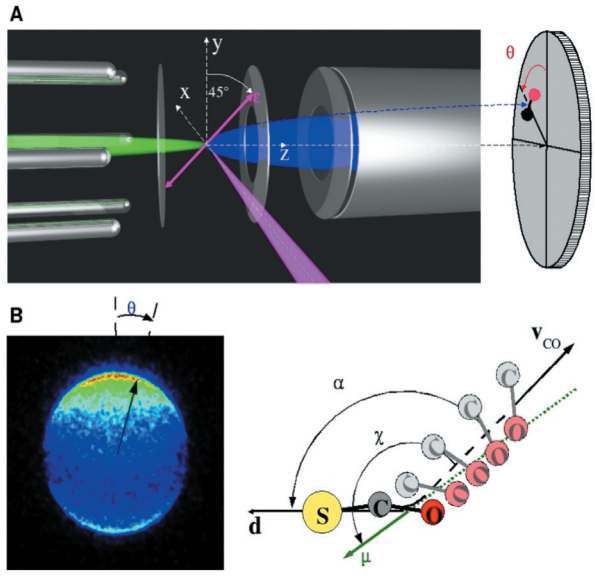
Physical Chemistry



A. Experimental set-up to spatially orient the molecular axis of freely rotating molecules. B. An experimental image showing the striking up-down asymmetry in the recoil and the various molecular frame vectorial properties and correlations that can be extracted from these experiments (Science 303 (2004), 1852).

Femtosecond coincidence imaging of optimal control in chemical dynamics

The use of femtosecond laser pulse shaping is currently proliferating as a tool for the research on photodynamics of molecules. Complex pulses can be obtained by a Fourier-domain shaping technique with the use of a Liquid-Crystal Display (LCD). We will use the same device for polarization shaping of femtosecond laser pulses. The spectral phase modulation can be imposed independently onto two orthogonal polarization directions with a two-layer LCD, therefore giving rise to time-varying polarization states in the laser pulse. The shaped pulses will be used to study and control photodynamics and photoionisation of molecules. The most complete information on such processes can be obtained with the photo-electron/photo-ion coincidence imaging technique. Coincidence imaging is a technique in which both the recoiling photo-electron and the correlated ionic photofragment originating from isolated dissociation/ionisation events are detected. It generates three dimensional energy- and angle resolved images, which reveal the energy distribution over the different photofragments and correlations between them. With this information it is possible to extract the photo-electron angular distribution in the molecular frame. A change in this distribution over time directly reflects the photodynamics of the system under investigation.
The new laboratory will integrate the pulse shaping with an advanced coincidence molecular beam apparatus to learn about mechanisms in optimal control of ultrafast chemical dynamics.

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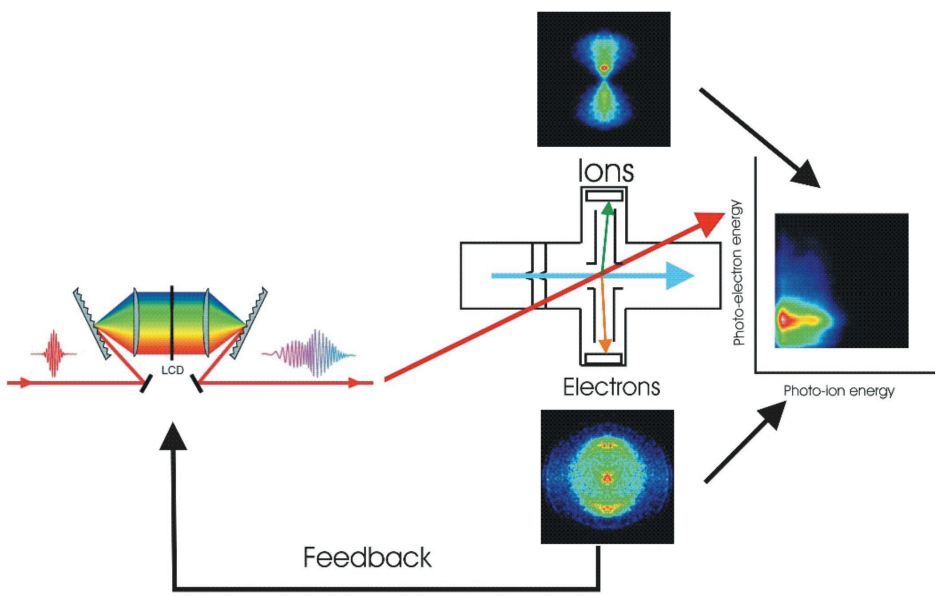

Photo-electron/photoion coincidence imaging combined with laser pulse shaping.

Cavity ring down spectroscopy of interstellar species

In the last year a new laser spectroscopic setup has been assembled, capable of producing highly unstable species in large abundances under laboratory controlled conditions. Long and highly unsaturated carbon chain radicals – as identified by radio astronomy in dense interstellar clouds - are generated in a special planar plasma expansion, by discharging a high pressure gas pulse that expands supersonically through a long and narrow slit. Cavity ring down spectroscopy with optical lasers is used to monitor the electronic transitions of these species at rotational resolution and to search for matches with the so called diffuse interstellar bands.

The project is a collaboration between the Department of Physical Chemistry and the Department of Atomic, Molecular and Laser Physics and supported by FOM. In collaboration with our partner in FORTH we have been able to study the rich chemistry taking place in the expansion mass spectrometrically. In addition, we found that the source not only produces unstable species but also is a good starting point for the spectroscopy of vibrationally and/or electronically excited species [Int. J. Mass Spectrom. 232 (2004) 25, Phys. Scripta 69 (2004) C37)]. Meanwhile the first spectra of carbon chain radicals have been observed.

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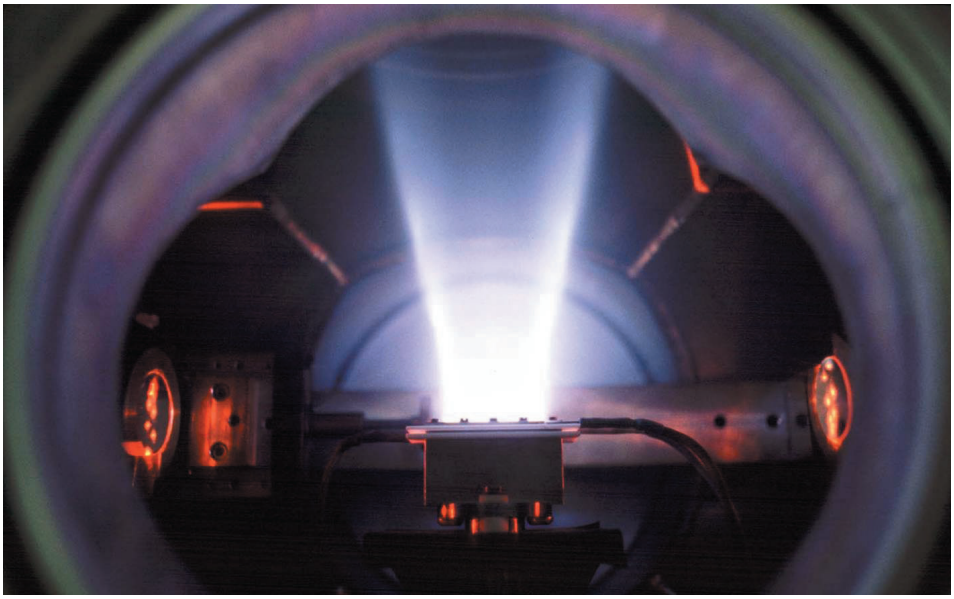

A supersonic planar plasma expansion of a discharged acetylene mixture in He.

State-to-state steric asymmetry of inelastic collisions

In everyday life collisionally induced processes are non-directional. Specific orientations seem not to play a role as all orientations are present in a sample. However, one expects that nature will have directional preferences. For example, the collisional behaviour of an NO molecule is expected to be somewhat different when the N-end or the O-end is hit. These orientational dependencies are important to unravel the dynamics of inelastic and reactive collisions. Nowadays, directional dependencies can be studied up to the level of individual quantum states using state-of-the-art experimental and theoretical techniques. Careful initial molecular state preparation, using sophisticated molecular beam techniques, allows experiments with quantum state controlled molecules and high resolution laser spectroscopic probes, such as ion-imaging techniques make it possible to study reaction products state-specifically. In the figure ion images (obtained after resonant ionization) are shown for hexapole state selected NO molecules depicting the angular dependence of its inelastic scattering distribution upon collisions with He.

It has been a long-standing goal in our group to fully understand orientation effects in collisions of diatomics (e.g. NO) and rare gasses (e.g. Ar or He). Studies in recent years showed a striking oscillatory behaviour of the so-called steric asymmetry parameter (that describes the difference between a 'head' or a 'tail' collision) as function of the rotational state that is observed after the collision: collisions with the N-end (head) in forward direction prefer rotational transitions with a ΔJ = even and collisions with the O-end (tail) in forward direction prefer ΔJ = odd transitions. In a recent study [Chem. Phys. 301 (2004) 293] the sign of the state-to-state steric asymmetry parameter of rotationally inelastic atom-molecule collisions has been described in full detail and currently studies are in progress to explain the oscillatory behaviour in terms of quantum interferences.

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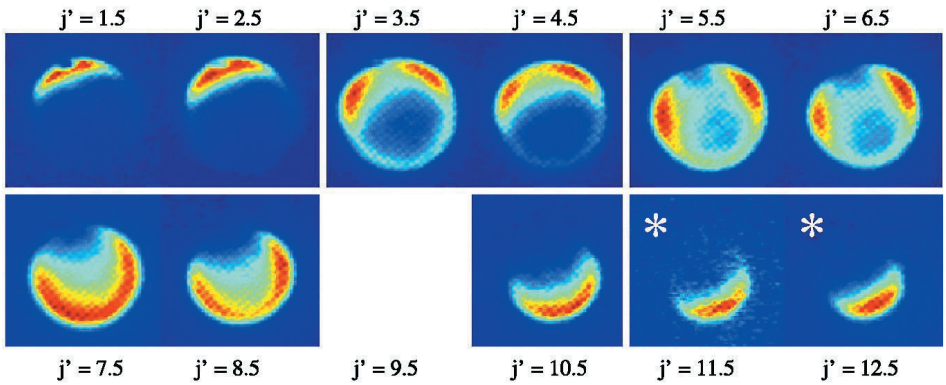

Ion images of the angular resolved scattering of NO (j') in various final rotational states j' from an inelastic collision of state-selected NO with helium.

High-resolution molecular spectroscopy at cryogenic temperatures

Conventional fluorescence spectra in liquid solutions are usually broadbanded and contain little spectral information. Two approaches are being used to improve the spectral resolution: Shpol'skii spectroscopy and fluorescence line-narrowing (FLN) spectroscopy. The resulting spectra can be used for fingerprint identification, for studying fundamental photophysical processes, or to obtain detailed information on the local environment of the fluorophore. The setup consists of a XeCl excimer/dye laser tunable excitation source, a 5 K closed-cycle refrigerator, and a triple monochromator with an intensified CCD camera for sensitive, time-resolved detection.

In Shpol'skii spectroscopy, polycrystalline matrices such as frozen n-alkanes are used. The technique was used to study ultrafast intramolecular proton tunneling rates in 3-hydroxyflavone and its derivatives. Subtle broadening effects in the excitation and emission spectra and comparison with the spectra after deuteration allowed us to determine the femtosecond tunneling rates.

In FLN spectroscopy a variety of amorphous frozen matrices can be used and laser excitation into the first excited state is carried out to select an iso-energetic sub-population of fluorophores. Current emphasis is on the interactions of fluorophores with their nano-environment. FLN spectra were used to determine the orientation of the pseudo-estrogenic hydroxybenzo[a]pyrenes within the estrogen receptor (collaboration with the Dept of Molecular Toxicology) (see figure).

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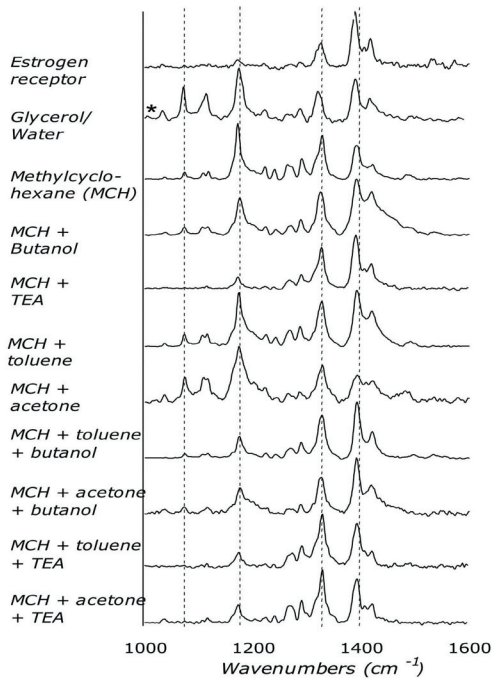

Normalised FLN spectra of 3-hydroxybenzo[a]pyrene in the estrogen receptor ER, top) and in various solvents (or solvent combinations). Similarity to the spectrum in methylcyclohexane plus triethylamine (+TEA) indicates a largely non-polar receptor pocket and H-bonding to histidine.

Coupling analytical separation with spectroscopic detection methods

When very complex mixtures need to be analysed, separation techniques can be coupled with molecular spectroscopy for detection and/or identification. For example, in recent years the following systems have been developed:

- Liquid chromatography (LC) and capillary electrophoresis (CE) coupled to laser induced fluorescence in the visible and in the UV range, including miniaturization for chip-based analysis.
- CE with quenched phosphorescence detection, offering low detection limits (also suitable for chiral, mirror-image analytes).
- Liquid flow systems coupled with time-resolved fluorescence resonance energy transfer (TR-FRET) for the screening of biological activity of enzyme inhibitors.
- LC or CE separation in combination with surface-enhanced Raman spectroscopy, using new silver-coated substrates.
- LC-Raman applying a liquid core waveguide (LCW) for increased optical pathlengths.
- LC and CE combined with deep-UV Raman. At those short wavelengths fluorescence interference is strongly reduced, and via the resonance enhancement phenomenon a strong increase in sensitivity can be obtained, as well as extra selectivity over the solvent matrix.

An exciting new development (collaboration with Atomic, Molecular & Laser Physics) is the use of cavity ring-down spectroscopy (CRDS) in the liquid state. A 2-mm detector cell was constructed from two concave mirrors and connected to an LC separation system. Short, 532-nm pulses will bounce back and forth inside the cavity; a small fraction leaks out of the cavity and is measured by a fast detector. The resulting decays (typically of the order of 10-100 ns, corresponding to an effective pathlength of 2-20 m) are analyzed after each laser pulse. A shorter-than-usual decay time indicates that an extra absorbing species passes the cavity; with this setup extremely low absorbances can be detected (see figure).

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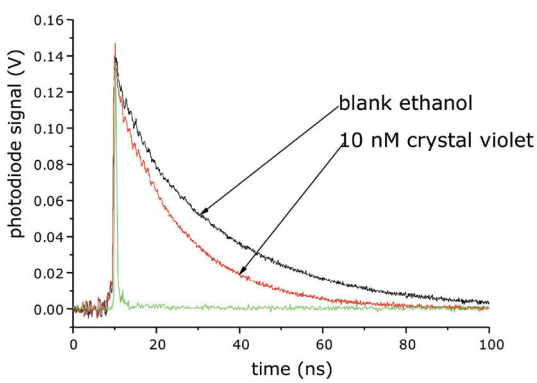

The cavity ring-down signal as measured on the oscilloscope for pure ethanol (blank; black curve) and after injection of a 10 nM CV-ethanol solution (red curve). Also displayed is the detector response curve (green). [After Bahnev et al., Analytical Chemistry, Vol. 77, 1188-1191 (2005)]

Raman spectroscopy of redox proteins

A spectroelectrochemical flow cell was developed for simultaneous study of electrochemical properties and vibrational structures of heme proteins. A Raman microscope with an Ar laser and a recently obtained Kr laser, which allows for 413 nm excitation of the intense Soret bands of the heme group, is crucial for this research. Much effort is put into the development of surface-enhanced resonance Raman spectrosocopy (SERRS)-active silver surfaces, covered with self-assembling mono- and bilayers (alkanethiols and phospholipids) to which the proteins can be bound to avoid denaturation. Electrochemistry is used both for the necessary roughening procedures of the silver surface to get a good SERRS effect, and for cyclic voltametry. Research is currently focussed on the alkaline transition of cytochrome c, a conformational change of the protein induced by pH changes which is thought to play a role in apoptosis. Within the context of the Chemistry of Complex Molecules (CCM) program, human cytochrome P4502D6, an important enzyme for drug metabolism responsible for the breakdown of about 30% of currently marketed medicins, is studied in collaboration with the Molecular Toxicology group. Detailed information about changes in spin state, coordination state, and oxidation state of the heme Fe, could be obtained for the first time for this protein. Changes of these properties, as well as in other vibrational features (for instance frequencies and intensities of vinyl side chains of the heme) were found upon substrate binding. Future plans include the development of supported phospholipid bilayers for the study of integral membrane proteins, and a systematic study of silver coated, deposited silica nanospheres, to optimize the conflicting requirements of good electrochemical properties and good surface enhancement.

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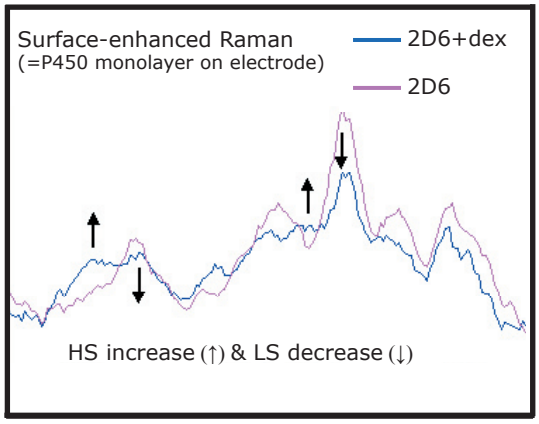

SERRS spectrum showing spin marker bands of the Fe-heme moiety in P4502D6 with and without bound substrate. In the resting state (no substrate bound; purple spectrum) the Fe is predominantly in the low spin(LS) state, due to binding with water as the sixth ligand. Substrate binding changes the spin state and redox potential of Fe, making an electron transfer possible from P450 reductase.

Time-resolved fluorescence of complex systems

Dynamical processes in proteins are studied by time-resolved fluorescence techniques. Fluorescence lifetimes and time-resolved fluorescence spectra can be measured on a picosecond time scale using a ps Ti:sapphire laser, both by time correlated single photon counting (time resolution about 15 ps), and by means of a fast-gated CCD camera (resolution 200 ps). Dynamics on a nano to millisecond time scale can be triggered by a Temperature Jump (T-jump) system, based on a Raman shifted nanosecond pulse from a Nd:YAG laser. Several systems are under investigation within the context of the Chemistry of Complex Molecules program in the chemistry department, in collaboration with the Molecular Toxicology and Biochemistry groups: substrate binding to cytochrome P4502D6, and chaperone-assisted folding dynamics of the capsid protein gp23 of the T4 bacteriophage. The T-jump method is currently used to study the dynamical behavior of melittin and flavodoxin (in collaboration with the Biology department) on a microsecond timescale. Fluorescence methods are also used to study ligand binding and conformational changes in the H1 histamine receptor, in collaboration with the Medicinal Chemistry group. Other topics of interest are excited-state proton transfer in salicylic acid derivatives and azo dyes, and photophysical properties of H1 agonists and antagonists.

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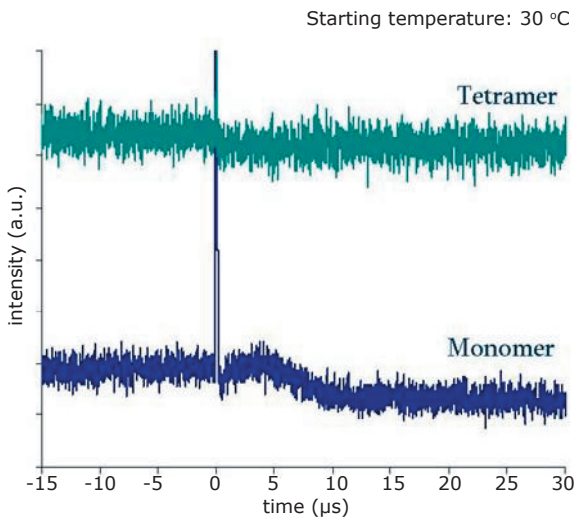

Changes in fluorescence intensity of monomeric and tetrameric mellitin, following a nanosecond temperature jump of ~6 °C. Monomeric melittin shows complicated behavior on a microsecond time scale that is absent for the tetramer. With the current set-up it is possible to measure changes in fluorescence intensity, and in fluorescence lifetimes.

Elementary reactions in biology studied with ultrashort laserpulses

Elementary reactions in biology, like the transport of protons and electrons, the breaking or formation of a hydrogen bond or the rearrangement of some molecular groups, occur on an ultrashort timescale: 10^{-14}-10^{-8} s. To study such processes in real time photoactive biomolecules in which the process can be initiated with an ultrashort laserpulse are required. Examples of biological events that are studied in the LCVU include energy and electron transfer in photosynthesis, isomerization of p-coumaric acid in the Photoactive Yellow Protein, early events in light-driven signal transduction, etc. In a typical experiment, the system is excited with a short laser pulse, the 'pump', while the response of the system is monitored by a 'probe' pulse that arrives at the same spot of the sample after a well-defined delay. Often the 'probe' is a spectrally broad 'white' pulse, which after passage through the sample is dispersed by a spectrograph and imaged on a diode array. By repeating the experiment for different delays of the probe, the spectral evolution of the system under study is obtained. A schematic view of the pump-probe experiment is shown below.

The Biophysics group has recently extended the spectral detection window to the mid-IR (1000-2000 cm^{-1}), which allows us to measure transient absorption changes due to structural changes in chromophores, the response of cofactors and amino acids to electron and proton transfers, etc.

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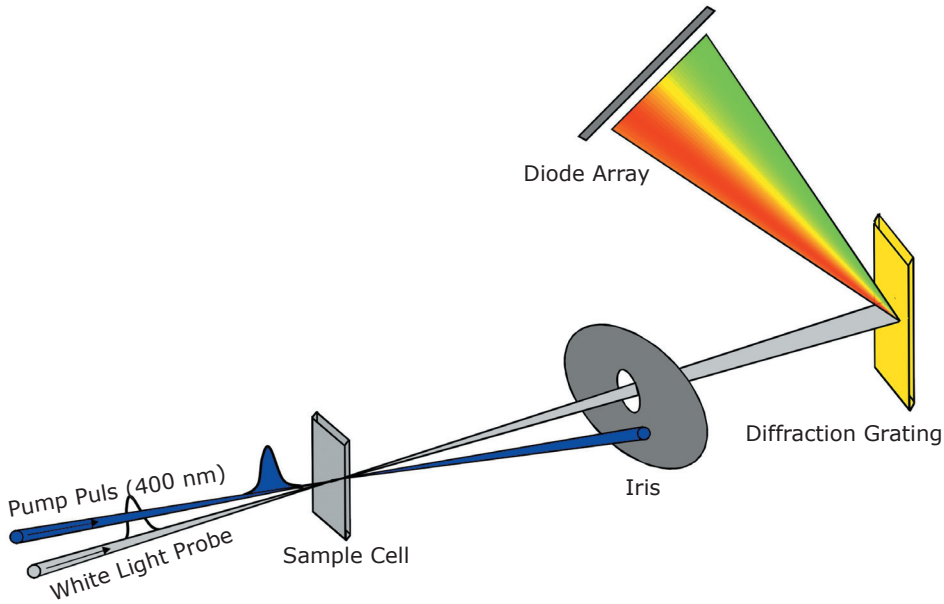

Schematic view of a pump-probe experiment.

Ultrafast events in carotenoids

Carotenoids are a highly colored (red, orange, and yellow) group of fat-soluble pigments and occur in all organisms that rely on the sun for energy. Their anti-oxidant effects enable these compounds to play a crucial role in protecting organisms against damage during photosynthesis - the process of converting sunlight into chemical energy. The basic structure of a carotenoid is that of a polyene with alternating single and double bonds. The structure of a typical carotenoid is shown in Fig. 1. In photosynthetic systems carotenoids display a plethora of functions. They absorb solar photons in the region around 450-550 nm (Fig. 2) and transfer the electronic excitation, on an ultrafast time-scale, to a neighboring chlorophyll, where it can be used to drive photosynthesis (Fig. 3). Maybe even more importantly, they efficiently remove harmful triplets (Fig. 3) that can be created by light on chlorophyll and otherwise would give rise to the formation of poisonous singlet oxygen.

The electronic states and the ensuing dynamics of carotenoids are highly complex, in particular within the first picoseconds after excitation. Biophysics studies the excited-state dynamics of carotenoids both in situ and in vitro using a multitude of ultrafast spectroscopic techniques employing short (~50 fs) laser pulses, in particular pump-probe absorbance difference spectroscopy, with detection in the visible or infrared parts of the spectrum, and more advanced techniques like pump-dump-probe spectroscopy, in which a certain excited state is 'dumped' with a second laser pulse arriving shortly after the first. Results obtained in our laboratory have revealed the existence of new ultrafast states and processes in several types of carotenoids.

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Fig. 1

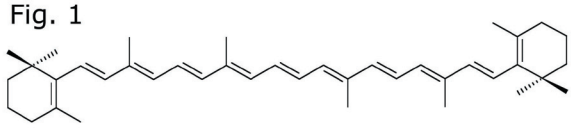

Fig. 2

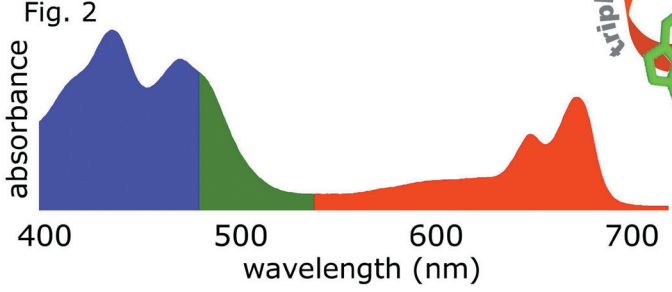

Fig. 3

The primary processes of photosynthesis

A few billion years ago photosynthetic bacteria developed the process of photosynthesis, allowing them to capture the energy of the sun for driving processes of life. Photosynthesis occurs in a complex set of membrane-bound proteins, in which solar photons are absorbed by a light-harvesting 'antenna', and the electronic excitation is transferred, within a few tens of picoseconds, to a reaction center, where it drives a charge separation that ultimately leads to the formation of a trans-membrane electrochemical potential. Recently atomic structures have been obtained for the most important photosynthetic reaction center and antenna complexes. The research focus of Biophysics is to display the time-evolution of the system down to the femtosecond time range, by employing ultrafast laser pulses to monitor fast absorption changes in the visible or infrared parts of the spectrum (pump-probe), or to monitor fast fluorescence transients (see figure below), and to develop physical models for the elementary events. Major research topics concern the mechanism of charge separation in photosynthetic reaction centers, specifically how the charge separation process is initiated. A second major research theme concerns the process of excitation energy transfer in the antenna complexes, with a focus on the dynamic interplay between the various proteins.

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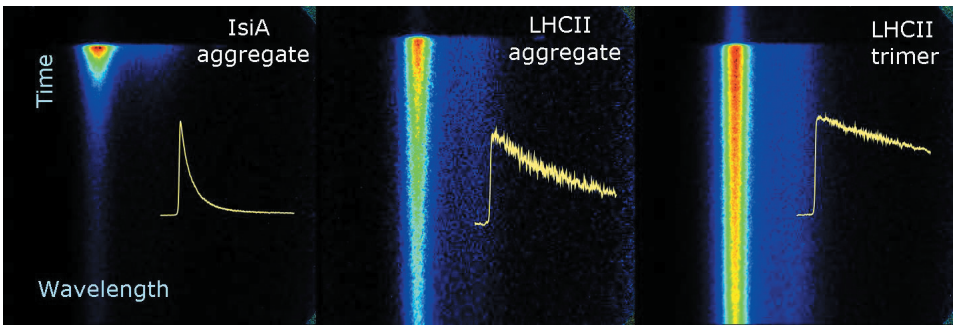

Time-resolved fluorescence of three types of light-harvesting proteins obtained from iron-starved cyanobacteria (IsiA) and green plants (LHCII trimer and aggregate), measured with a streak camera set-up. This set-up allows a simultaneous recording of the decay (with a time-resolution of about 3 ps, vertical axis) and wavelength (horizontal axis). The data indicate a much faster decay of the fluorescence in the IsiA aggregate than in the LHCII complexes.

How photoreceptors detect photons

Living organisms must interact with their environment: they must sense the temperature, light quality, certain chemicals, etc. Once triggered, they initiate a cascade of signal transduction events leading to a response. Photoreceptors represent an important class of receptors because they can be triggered with light, allowing us to study their response over a time window from femtoseconds to seconds. Photoactive Yellow Protein (PYP) is a small cytosolic photoreceptor thought to be responsible for the negative phototactic response of its host organism *Ectothiorhodospira halophila*. The availablity of structural information for different functional states and the relatively simple photocycle make PYP an ideal "laboratory" for the detailed study of biological light detection and the relation of structural change to protein function. It also holds considerable promise for optical data storage and computing applications. Optical excitation of the intrinsic chromophore in PYP, p-coumaric acid, leads to the initiation of a photocycle that comprises several distinct intermediates. The dynamical processes responsible for the initiation of the PYP photocycle have been explored by the Biophysics group with several time-resolved techniques. Ultrafast electronic spectroscopies, such as pump-visible probe, pump-dump-visible probe, and fluorescence upconversion, are useful in identifying the timescales and connectivity of the transient intermediates, while ultrafast vibrational spectroscopies link these intermediates to dynamic structures.

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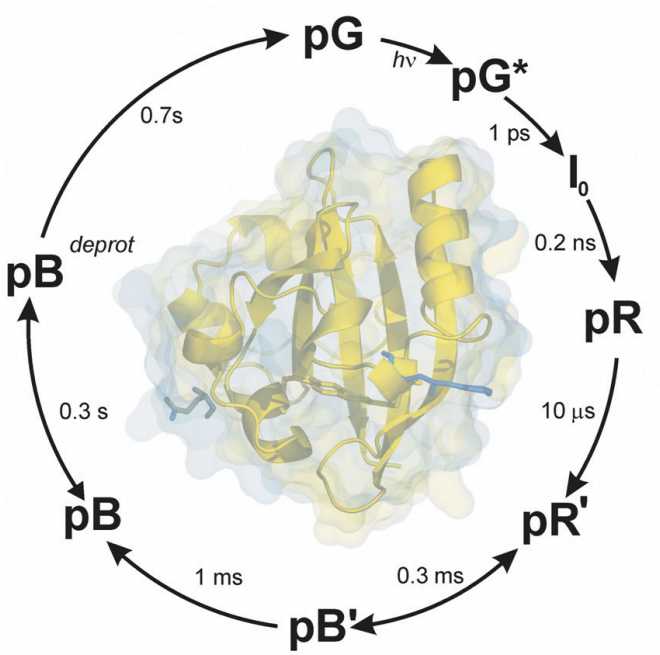

Detailed overview of the partial reactions in the photocycle of PYP.

Global and target analysis of time-resolved spectra

In (bio)physical/(bio)chemical research time-resolved spectroscopy is used to disentangle complex kinetics. To extract maximal information from the overwhelming amount of data that is generally obtained, a model based analysis is mandatory. A model characterized by assumptions regarding the measurement process and physico-chemical knowledge is formulated in our approach using building blocks representing different aspects of the system at a variety of levels. Often employed building blocks include an instrument response function and a compartmental description of the kinetics. By parameterizing the system in greater detail (including more, or more complicated, building blocks), the fit between data and model is often improved. For example, by parameterization of both the kinetic and the spectral aspects of the system, a spectro-temporal model is obtained whose application allows more precise parameter estimation compared to a purely kinetic model. Parameter estimates obtained by fitting models for time-resolved spectra to experimental data provide a concise description of the system that yields insight into the underlying dynamics.

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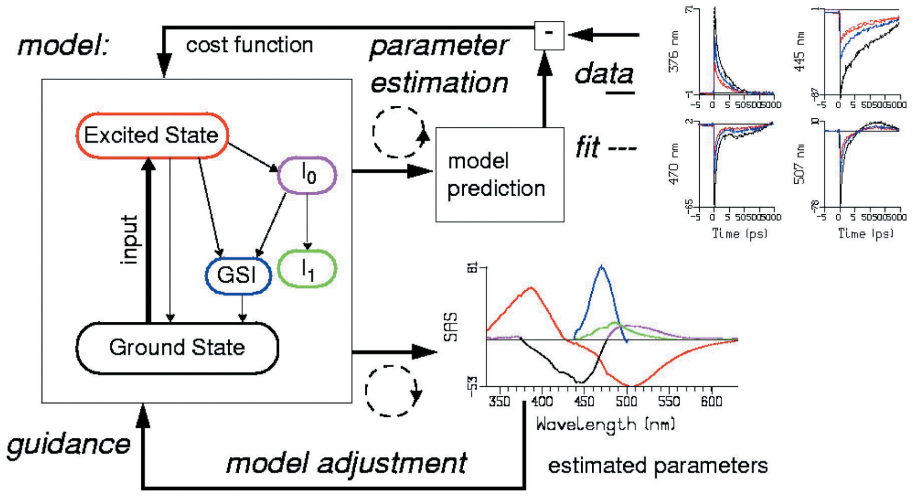

Flow chart of modeling the initial photocycle of Photoactive Yellow Protein (PYP). Traces at 4 wavelengths are shown at the top right. The kinetic model scheme comprises of five states (indicated by the color of the box), of which the Species Associated Spectra (SAS) and rate constants have been estimated.

Motor proteins: molecular mechanisms and roles in cellular processes

We study biological motor proteins in single-molecule experiments with the goal of understanding the physical principles of biological force generation in a multitude of active transport processes. Motor proteins are the ubiquitous nanometer-scale mechanical engines at the basis of many crucial processes of life. Examples are intracellular transport processes, cell division, cell locomotion, and in complex large scale assemblies also macroscopic motion, such as muscle contraction, or flagellar motion. The non-equilibrium dynamics of these specialized enzymes, usually embedded in a complex regulatory and functional environment, are the essence of their function.
Observing dynamic events on the scale of single protein molecules is a major experimental challenge. We use light microscopy, combined with optical tweezers and laser interferometry to determine the position of sub-micron probe particles to which motor proteins are attached with nanometer spatial and microsecond temporal resolution.
We also use single-molecule fluorescence techniques to extend the range of dynamic parameters we can measure.
A current topic of our interest is the mechanism of processivity of conventional kinesin (a motor protein involved in transport in nerve cells). We also focus on kinesin-like motor proteins that are involved in cell division, such as Eg5 and ncd. These motors are thought to play a role in mitotic spindle formation by cross linking microtubules. The exact mechanism of these motors and their cooperativity is a key focus of our current experiments.

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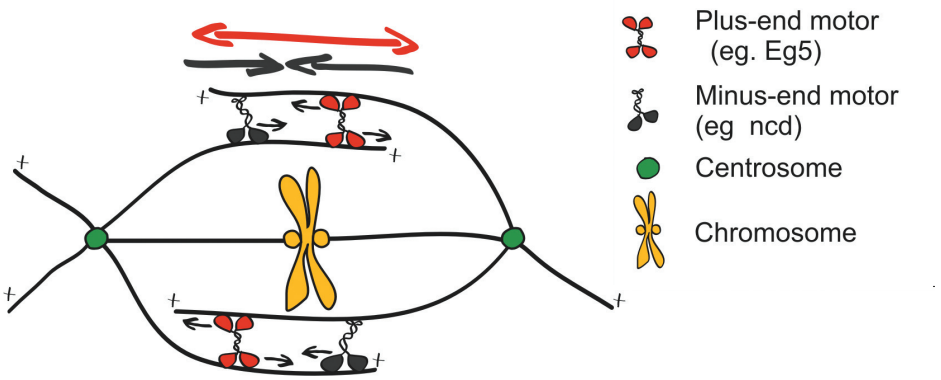

The role of kinesin motors in mitotic cell division. Both Eg5 and ncd motor proteins cross link microtubules originating from centrosomes. Eg5 slides the microtubules apart, ncd pulls them together.

The dynamics of DNA-binding proteins

The genetic information of an organism is encoded in the base-pair sequence of its DNA. Many specialized proteins are involved in handling DNA and processing the vast amounts of information on the DNA. In order to do this swiftly and correctly, these proteins have to move quickly and accurately along and/or around the DNA. Some examples are: DNA replication during cell division by DNA-polymerase, bacterial defense against invading viral DNA by restriction endonucleases and the search for and repair of UV-induced damage of DNA by uvrABC enzymes. Other proteins such as histones (in eukaryotes) and nucleoid-associated proteins (in bacteria) bind more rigidly to DNA to compact it and to regulate the expression of genes.
We use advanced single-molecule techniques such as optical tweezers, scanning-force microscopy and single-molecule fluorescence to study the mechanism of DNA-binding proteins. Currently we investigate the mechanism of restriction enzymes, enzymes that cut DNA when they encounter a specific sequence. Furthermore we focus on so-called nucleoid-associated proteins (such HU, H-NS, IHF and Fis) that are thought to be of essential importance for the dynamic organization and compaction of bacterial chromatin and play roles in the regulation of gene expression. Finally we study the function of proteins involved in DNA repair mechanisms, such as Rad51.

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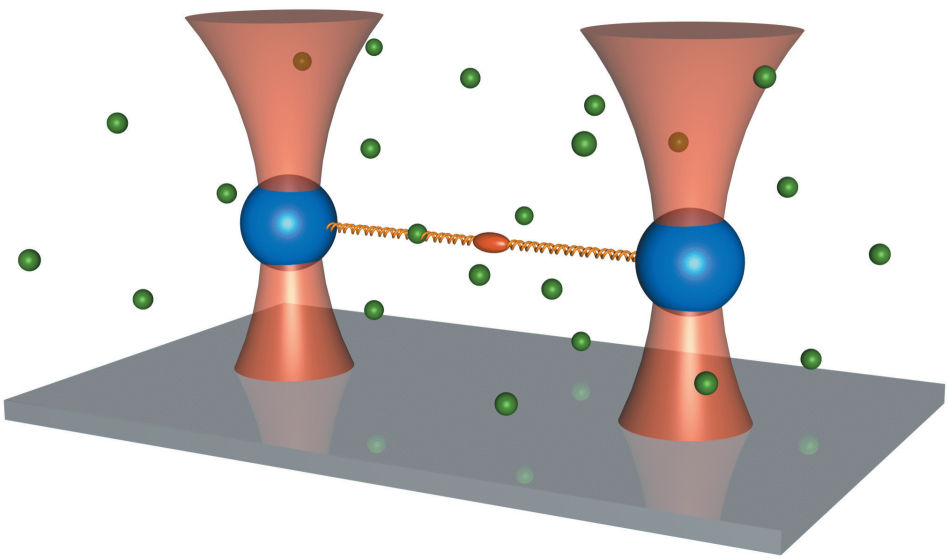

Cartoon representing the experimental layout to study the working of DNA-binding proteins (green and orange spheres) on a piece of DNA (orange double helix) that is held in two optical traps by two beads attached to the DNA ends.

The visco-elastic properties of polymer networks and living cells

The cytoskeleton of eukaryotic cells consists of a complex assembly of filamentous proteins, interacting with a multitude of accessory proteins, effecting for example crosslinking, length control, bundling, and polymerization control. This composite polymer structure governs the internal organization of most plant and animal cells, serves as a transport network for active intracellular transport, and drives cellular motility. It is also responsible for the mechanical rigidity of cells and the response of cells to external mechanical stresses. The major components of the cytoskeleton are microtubules, actin and intermediate filaments. The intact cell cortex is able to resist mechanical stresses exceeding 1000 Pa. The actin network is a dynamic, typically highly non-linear structure, locally assembled and disassembled, which plays a crucial role in cellular response to stresses.
We use light microcopy and manipulation with laser optical tweezers to study the dynamics of isolated filaments. We also use laser-based microrheology to measure viscoelastic properties of networks and of more complex composites such as lipid membranes coated with polymer networks, or active assemblies where molecular motors are added to the passive structural materials. Furthermore we study whole living cells, e.g. the mechanisms of mechanosensing in bone or blood vessels. In general, we aim to progress from simple (single component) systems to more and more complex, multi-component systems, approximating nature. In the process we want to understand the mechanics of cells, but we also want to explore biological construction principles for technical (bio)materials, and we want to develop new physics, necessary to describe these complex, non-equilibrium systems.
Current projects study systems from synthetic rod-like polymers, worm-like micelles, filamentous virus solutions to actin filaments, neurofilaments, microtubules and DNA, as well as polymer networks coupled to lipid membranes, and whole cells (osteocytes, vascular endotheliel cells).

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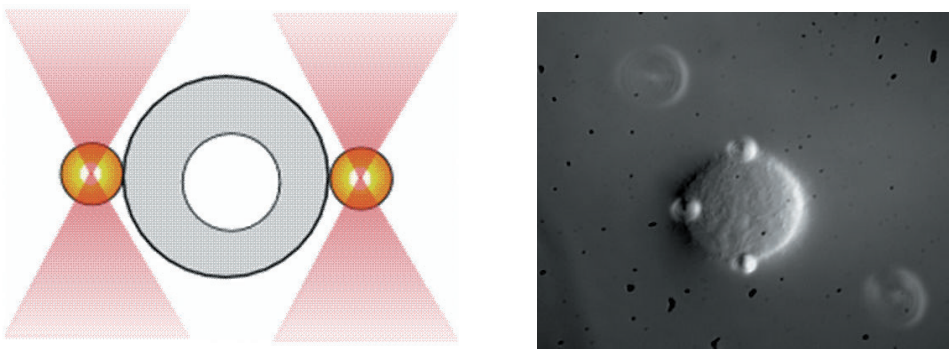
Physics of Complex Systems



Cartoon and image showing how a mechanosensitive bone cell (osteocyte) can be stimulated mechanically with beads steered with optical traps.

ATP synthase: a bio-molecular power station

We study energy conversion by a bio-molecular power station: the enzyme ATP synthase. This enzyme provides our body (and bacteria, plants and animals) with the universal energy currency of life, the compound called ATP.
The enzyme is a highly unusual machine: one part, referred to as F_0, works like an electro-motor: When protons (H^+ in Fig. 1) move as indicated by the black arrow, the reddish part of the enzyme rotates. Another part of the enzyme, called F_1 acts like no machine ever build by man: mechanical energy (rotation) is used to synthesize a ATP.

It is possible to remove the F_1 part from ATP synthase. F_1 alone splits ATP leading to rotation of the γ part (Fig. 2). As the enzyme is too small to be observed directly, a large probe (red ball in Fig. 2) is attached to the rotating γ part and observed by optical microscopy. We succeeded in changing the speed of the rotation by addition of an external chemical signal (oxidation-reduction, antibiotic inhibition), which may open the possibility for future usage of this molecular machine (or others) for nano-technological purposes.

For synthesis of 1 molecule ATP the energy of 3-4 protons is necessary. The enzyme must thus be able to store the energy of the first protons by an unknown mechanism. We plan to gain insight into structural changes involved in energy storage by using ATP synthase labelled with two fluorescent dyes whose intensity depends on their relative distance and orientation (FRET method).

ATP synthase is the target for several antibiotica, plays a role in providing energy for cancer cells and is reported to be involved in cholesterol metabolism. By attaching fluorescent dyes (FRET method) we plan to examine how the enzyme responds to these stimuli and how e.g. an antibiotic influences ATP synthase in the context of the whole cell (Fig. 3).

Contact: Dirk Bald, e-mail: dirk.bald@falw.vu.nl
Structural Biology

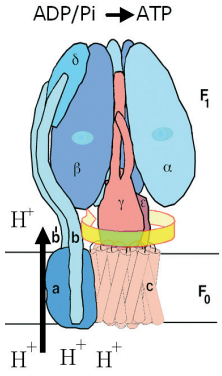


Fig.1: Overview of ATP synthase.

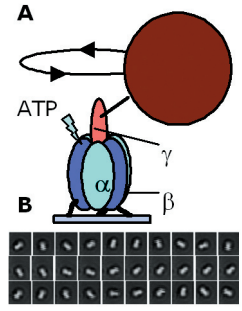


Fig.2: A. Method used to observe rotation of F_1
B. Control of rotation: fast (row 1), slow (row 2) and again fast (row 3).

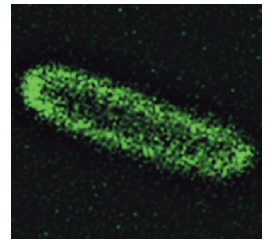


Fig. 3: a bacterium with ATP synthase fused to Green Fluorescent Protein.

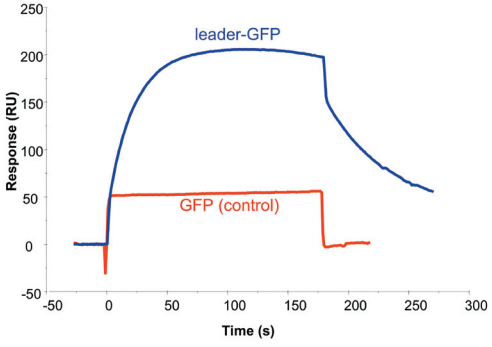
The Twin-arginine protein transport system

In bacteria, a variety of sophisticated membrane-bound complexes have evolved to transfer proteins across membranes. The majority of transported proteins cross membranes in an unfolded state. In contrast, only the Twin Arginine Translocation (Tat) pathway is capable of transporting folded and even multimeric proteins across a membrane that maintains a proton gradient. Our aim is to elucidate the mechanism by which the *E. coli* Tat machine transports folded proteins across the cytoplasmic membrane. For this purpose we make use of sophisticated optical techniques.

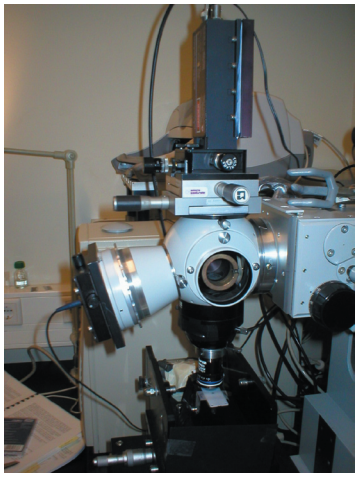
Proteins that are exported by the Tat system bear a specific leader peptide. This peptide begins with a positively charged region, which contains the name-giving double-arginine motif. The positive region is followed by a hydrophobic region. We studied the interaction of different leader peptides with model phospholipid membranes by Surface Plasmon Resonance Spectroscopy (SPRS). We showed that leader peptides interact firmly with membranes. These results suggest an important role for peptide-membrane interaction early in the transport process.

The Tat complex is dynamic in nature; its composition depends on the conditions. We use Total Internal Reflection Fluorescence (TIRF) microscopy to study these dynamics. TIRF is especially suitable to study processes in membranes, because it excites only those molecules that are within a very short distance (typically 100 nm) from a surface, which drastically reduces background fluorescence. Tat subunits will be labelled with fluorescent dyes, and time-resolved Fluorescence Resonance Energy Transfer (FRET) experiments will reveal interactions of subunits under different conditions.

Contact: Yves Bollen, e-mail: yves.bollen@falw.vu.nl, and Holger Lill, e-mail: holger.lill@falw.vu.nl
Structural Biology



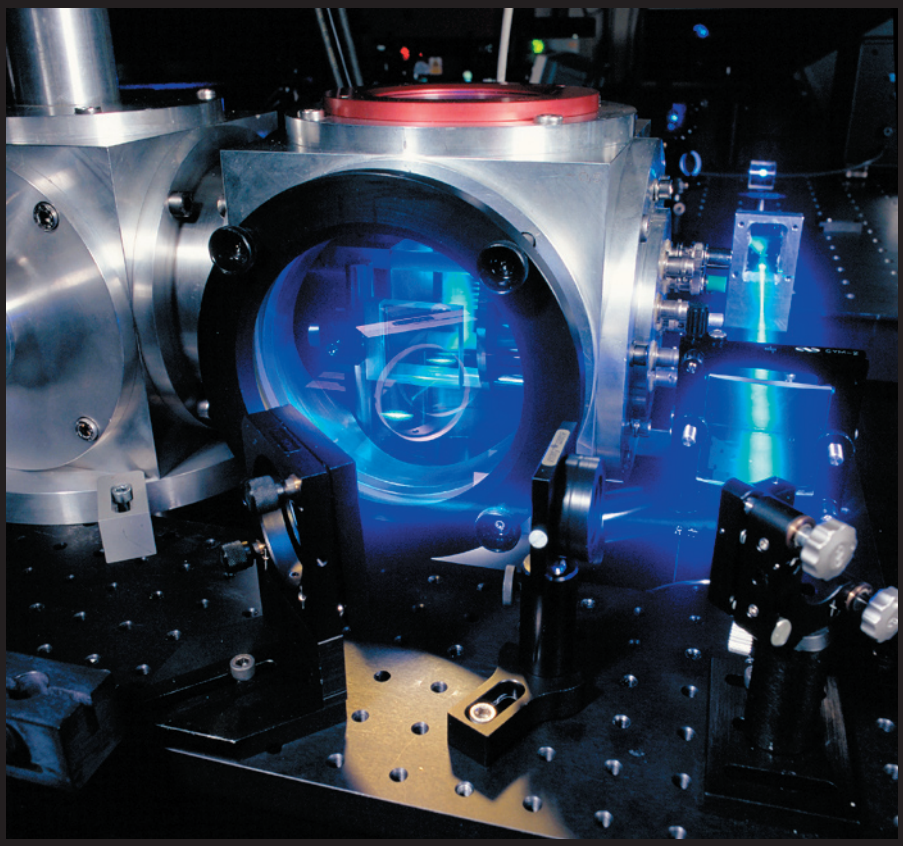
SPRS shows that green fluorescent protein (GFP) with a leader peptide binds to a membrane, whereas a control GFP without a leader peptide does not bind.



TIRF microscope with 2-colour detection.

3

INTERNATIONAL COLLABORATIONS



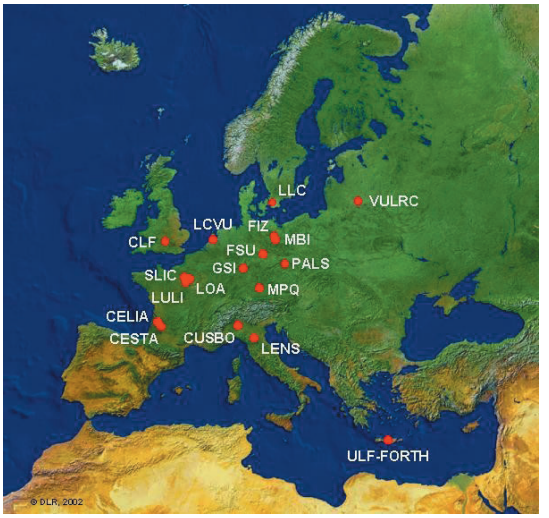
LASERLAB-Europe

LCVU is one of 17 major Laser Centres in Europe (see map) participating in LASERLAB-Europe (LLE), an Integrated Infrastructure Initiative (I3) of the EU, directed by Professor Wolfgang Sandner of the Max Born Institute Berlin. LCVU plays a major role in the ACCESS activity, hosting a large number of visitor projects, in the Joint Research Activity on the "Frontiers of Optical Science: Controlling of Intense Light", as well as in the organisation of the I3, where LCVU hosted the annual meeting of the Participants Council of LLE in February 2005 and a LLE users meeting in September 2005.

LASERLAB-Europe Participants Council meeting at LCVU, February 2005

Access

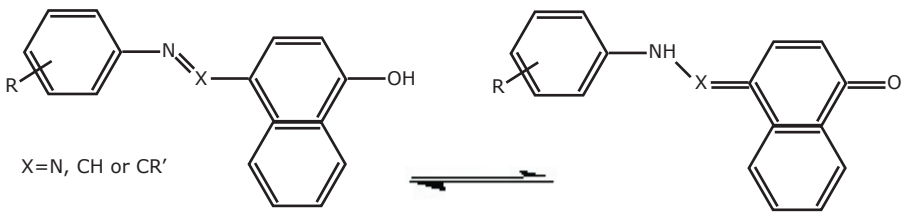
Within the 6th Framework Programme of the European Union, LASERLAB-Europe provides support to EU researchers in the field of laser research. For the period January 1st 2004 through December 31st 2007 the participating laboratories offer opportunities for research teams from European member states or associated states to obtain access to individual major research infrastructures. Adequate scientific, technical and logistic support to external users is provided. Access, typically for a period of 1-3 weeks, is offered free of charge; expenses for travel and subsistence are covered by the host institution. Access is granted on the basis of proposals, which are reviewed by an external panel of referees chaired by Professor Demtröder.
For more information on the available facilites for access and proposal submission see: http://www.laserlab-europe.net. Some highlights of Access projects carried out at LCVU, as well as a list of collaborative projects are presented in this chapter. The list also contains international projects funded from other sources, such as the European Science Foundation.



Cluster of 17 laser centres, collaborating in LASERLAB-Europe

Highlight: Excited-state proton transfer in azo dyes and Schiff bases

Excited state proton transfer reactions in polar and protic solutions are currently not well understood. **Prof. L. Antonov's** research focuses on the properties of a class of such so-called tautomeric compounds: azo dyes and Schiff bases, some of which also find commercial applications as food dyes. During his visits to the LCVU, research has focused on temperature and solvent dependent effects on the absorption, and the stationary and time-resolved fluorescence properties of these compounds. A number of these compounds show dual fluorescence: fluorescence with different emission maxima, and emission lifetimes, that can potentially be used in applications as sensors: inhibition of one of the forms of fluorescence by prohibiting the proton to transfer in the excited state. Future plans include the development of signaling devices based on this principle. Coupling the azo-dye to a crown ether which upon binding of Ca^{2+} inhibits proton transfer would make it possible to measure Ca^{2+} concentrations under physiological conditions. [J. Chem. Soc. Perkin Trans. 2 (2001) 2303 and J. Photochem. Photobiol. A 152 (2002) 183].



Highlight: Observation of heavy Rydberg states

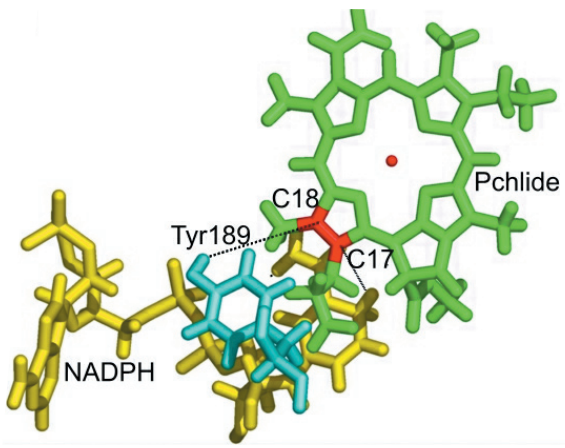
In a project, performed by **Dr. Elmar Reinhold**, of the Laboratoire Aimé Cotton in Orsay (France) so-called heavy Rydberg states were investigated experimentally. Such states are associated with the 1/r Coulombic potential of negatively and positively charged parts in a molecule (also referred to as ion-pair states) giving rise to an infinite series of states with principal quantum numbers n. As a test system H^+H^- was chosen, that can be considered as a hydrogen atom, in which the electron e^- is replaced by the heavier H^- particle. Coherent wave packets of manifolds of the heavy Rydberg states were excited in the presence of DC-electric fields, in a two-laser scheme also involving the tunable XUV-laser system, and their dynamics was probed by pulsed electric fields. Characteristic oscillations were observed with frequencies matching those calculated by the linear Stark effect for the hydrogen atom, scaled to a larger mass. This experiment [Phys. Rev. Lett. 88 (2002) 013001] constitutes the first observation of heavy Rydberg states in the bound regime.

List of external collaborators that have recently made use of the experimental facilities at LCVU

Name	Project Title	Home Institution	Source of funding
L. Antonov & V. Petrov	Tautomerism in some azo dyes and Schiff bases containing an intramolecular hydrogen bond	National forestry University, Sofia, Bulgaria	FP5-access
D. Arraez & A. Segura-Carretero	Hyphenation of capillary electrophoresis and surface enhanced Raman spectroscopy	University of Granada, Spain	FP5-access
K. Baldwin	Photo-dissociation of atmospheric nitrogen	Australian National University, Canberra, Australia	Australian grant
L. Bañares	Multichannel photodissociation of small molecules studied by femtosecond imaging	Universidad Complutense de Madrid, Spain	FP5-access
J. Breton	Femto-IR of primary photosynthetic reactions	CEA-Saclay, Gif-sur-Yvette Cedex, France	FP6-access
C. Carrasco	Microtubules and MAPs studied with scanning force microscopy	Universidad Autonoma de Madrid, Spain	FP6-access
D. Chandler	Imaging chemical dynamics	Combustion Research Facility, Sandia Natl. Labs, USA	NWO visitor grant
A. Demchenko	Fundamental aspects of ultrafast Excited-State Intramolecular Proton Transfer reactions	TUBITAK Research Institute, Turkey	ESF-ULTRA grant
G. Desmet & D. Clicq	Development of optically-gated injection for use in ultra-rapid on-chip liquid chromatography	Vrije Universiteit Brussel, Belgium	FP5-access
M. Elioff	Imaging the differential cross section of inelastic scattering with oriented molecules	Combustion Research Facility, Sandia Natl Labs, USA	US/Sandia and LCVU
A. Evilevitch	Mechanical properties of viral capsids	Lund University, Sweden	FP6-access
A. Fischer	Experiment control of nonlinear dynamics and chaos in a semiconductor laser	Université de Paris 13, France	FP5-access
A. Fischer	Experimental period doubling route to chaos in a semiconductor laser	Université de Paris 13, France	FP6-access
P. Galadja	Optical manipulation of photosynthetic complexes	Hungarian Academy of Science, Hungary	European Science Foundation
A. Gall	What are the structural elements that modulate the fluorescence spectral fluctuations of LH2?	University of Glasgow, UK	FP6-access
F. Giammanco	Realization of a high intensity, narrow-band tunable XUV laser source	University of Pisa, Italy	FP6-access
K. Gibasiewicz	Low-energy states and excitonic coupling in photosynthetic light-harvesting systems.	Adam Mickiewicz University, Poznan, Poland	FP6-access
D. Heyes	Characterisation of the early events of light dependent protochlorophyllide reduction	University of Sheffield, UK	FP5-access
A. Holzwarth	The role of delocalized vibrational states in energy transfer and optical dephasing in antennas	Max-Planck-Institut für Strahlenchemie, Germany	FP5-access

Highlight: Ultrafast enzymatic reaction dynamics in protochlorophyllide oxidoreductase

POR (protochlorophyllide oxidoreductase) is a light-driven enzyme involved in the biosynthesis pathway of chlorophyll in green plants. **Dr. D. Heyes** and **Prof. C. N. Hunter**, biochemists from the University of Sheffield, have succeeded in over-expressing this enzyme, enabling the detailed study of its function. At the LCVU-Biophysics group experiments were conducted initiating catalysis with a 50 fs laser pulse. It appeared that the catalytic mechanism, involving formation of a transition state and proton and hydride transfer (from the protein and NADPH, respectively, to protochlorophyllide), proceeds with time constants of 3 and 400 ps, demonstrating that in a biological system such events can proceed on an ultrafast timescale. Two reaction mechanisms are available to the enzyme, a 'fast' concerted process and a 'slow' sequential process, where the proton is followed by hydride transfer. These were the first ultrafast visible pump-probe data on this enzyme [Nature Structural Biology (2003) 10,491], that may serve as an important generic model for enzymatic reaction dynamics.



The POR enzyme active site, showing PChlide with the C17=C18 double bond which is reduced by a proton from a tyrosine residue and a hydride donated by NADP

Highlight: Filtered optical feedback induced frequency dynamics in semiconductor lasers

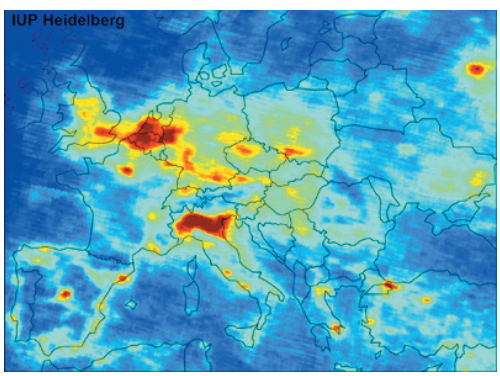
In a combined experimental and theoretical project **Dr. Alexis P. A. Fischer**, from Université de Paris XIII (France) has studied the effects of spectral filtering of the delayed optical feedback into a semiconductor laser. It was found that one can elicit novel dynamics in the frequency of the laser output light on a time scale that is set by the delay time of the feedback. In particular, it was shown that through a judicious choice of the filter bandwidth, and its frequency relative to that of the laser, one can produce controlled oscillations in the frequency of the light from the laser. This work [reported in Phys. Rev. Lett. 92 (2004) 023901] constitutes the first analysis and observation of this effect.

Name	Project Title	Home Institution	Source of funding
M. Jones	Characterization of protein-cofactor conformational changes in reaction centres	University of Bristol, UK	FP6-access
R. Jost	Symmetry breaking by isotope substitution in NO_2	University of Grenoble France	FP6-access
R. Jost & P. du Pre	The A-X conical intersection in NO_2	University of Grenoble, France	FP5-access
H. Knöckel	High precision frequency measurements of spectral lines of I_2	Universität Hannover, Germany	FP6-access
G. Kodis	Energy transfer mechanisms in artificial carotenoid-containing light harvesting complexes	Institute of Physics, Vilnius, Lithuania	FP5-access
M. Kumke & C.Dosche	Shpol'skii spectroscopic studies on zig-zag [N} phenylenes	University of Potsdam, Germany	ESF en LCVU
M. Kumke & B. Marmodee	Fluorescence line narrowing spectroscopy of lanthanide complexes (europium, benzoic acid derivatives)	University of Potsdam, Germany	FP6-access
J. Kwiecinska	Laser interferometry for two-bead, microrheology in complex fluids, optical tweezer	University of Warsaw, Poland	FP5-access
B. Kwok & T. Kapoor	The mechanism of the mitotic motor protein Eg5	Rockefeller University, New York City, USA	HFSP (Human Frontier Science Program)
L. Lipciuc	Velocity map imaging of the K-state dependence of methyl iodide photodynamics	Al.I.Cuza University, Iasi, Romania	FP5-access
B. Mik	Oxygen quenching effects in blood	Academisch Medisch Centrum, Amsterdam, Netherlands	AMC and LCVU
F. Neuwahl	UV Pump-IR probe transient spectroscopy of branched double ESIPT in [2,2'-bipyridyl]-3,3'-diol	LENS, Florence, Italy	FP5-access
F. Neuwahl	Exciton dynamics in laser dye labelled dendrimers	LENS, Florence, Italy	FP5-access
M. Nolte	Biophysical ultrafast studies	University of Heidelberg, Germany	European Science Foundation
A. Oriňák & I. Talian	The use of a new interface to hyphenate TLC, μ-HPLC and CE with Raman spectroscopy	University of P.J. Šafarik, Košice, Slovakia	FP6-access
B. Parsons	Imaging the state-to-state nonadiabatic photodynamics in methyl bromide	Combustion Research Facility, Sandia Natl. Labs, USA	US/Sandia and LCVU
A. Pascal	Ultrafast energy transfer processes in fucoxanthin-chlorophyll a/c-proteins	Ecole Normale Supérieure, Saclay, France	FP5-access
B. Pergolese & M. Muniz-Miranda	Spectroscopic investigation of SERS-active bimetallic substrates	University of Trieste & University of Firenze, Italy	FP6-access
T. Polivka	Excited state dynamics of carotenoid peridinin in solution and protein	Lund University, Sweden	FP6-access
L. Premvardhan	Fluorescence properties of Photoactive Yellow Protein and related model chromophores	CEA-Saclay, Gif-sur-Yvette Cedex, France	FP6-access

Highlight: Spectroscopy of jet-cooled NO_2 isotopologues

A regular visitor of the LCVU is **Dr. Remy Jost** of the University of Grenoble who is interested in high resolution laser electronic spectroscopy of NO_2 and $^{x}O^{y}N^{z}O$ isotopologues. In a number of successful measurement campaigns more than 250 rotationally fully resolved rovibronic transitions in the A^2B_2 <- X^2A_1 electronic band of $^{16}O^{15}N^{16}O$ have been identified. For this a unique LCVU facility is used that has been designed for laser spectroscopy of expensive or toxic gasses [Chem. Phys. Lett. 391 (2004) 106].

The spectroscopy of NO_2 and its isotopologues is a 'hot topic'. In October 2004 measurements of NO_2 concentrations measured by the European Envisat satellite became available that showed that the Netherlands is highly polluted with NO_2. This pollution is due to the intense traffic, high population density and industry in and around the Netherlands. Detailed spectroscopic knowledge of NO_2 (that is harmful to human health at relatively low levels) is necessary to understand the atmospheric processes that are involved in forming and destroying this gas.



Remote sensing experiments are only possible following detailed spectroscopic studies. At LCVU - situated in one of the most polluted areas - measurements are performed to identify new spectra of NO_2 isotopologues.

The observed spectrum is much denser than one would expect for an electronic transition of a simple triatomic molecule and is due to a strong vibronic coupling between the ground state and the lowest electronically excited state via the anti-symmetric stretch coordinate of the molecule. Different spectra are expected for different isotopologues, because vibrational spacings and rotational progressions reflect minor changes in molecular force constants and moments of inertia. In addition, selection rules are different for the symmetric (x=z) and asymmetric (x≠z) species, resulting in symmetry forbidden or allowed transitions. A symmetry breaking is considered to be important as a possible cause for anomalous isotopic distributions in the Earth's atmosphere. This is a well known fact for ozone and related to the difference in zero-point energies between isotopologues. For NO_2 isotopologues, however, atmospheric observations are largely missing, because of lacking spectroscopic data. The present experiment changes this situation and provides additional tools to understand the complex spectroscopy of the NO_2 molecule.

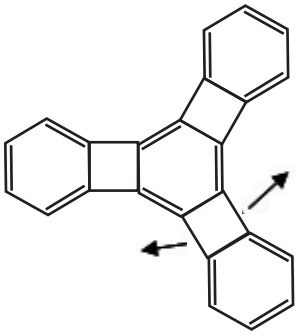
Name	Project Title	Home Institution	Source of funding
T. Rakitzis	Interference effects in the state-to-state photodissociation of polyatomic molecules	University of Crete, Greece	FP5-access
E. Reinhold	Investigation of ion-pair states (H^+H^-) of the hydrogen molecule	Laboratoire Aimé Cotton (CNRS), France	FP5-access
A. Ruban	Stark spectroscopy of LHCII complex of higher plants	University of Sheffield, UK	FP5-access
R. Shiell & F. Magnus	Coherent evolution of weakly-bound ion pair states of the HF molecule	University of Sussex, Brighton, UK	FP6-access
M. Snels	High resolution infrared spectroscopy of the protonated water dimer	Istituto di Scienze dell'Atmosfera e del Clima, Roma, Italy	FP6-access
M. Sterzel	Experimental and theoretical studies of the electronic structure of naphthaleneimides	Jagiellonian University, Krakow, Poland	FP5-access
M. Suh	Fluorescence line narrowing and fluorescence lifetime studies of BODIPY-based protein dyes	Sung Kyun Kwan University, Suwon, South Korea	SKKU and LCVU
A. Szemik-Hojniak	Photophysical properties of nitramino and alkylamino pyridine N-oxides	University of Wrocław, Poland	FP6-access
L. Tchang-Brillet	Lifetimes of excited states of nitrogen	Observatoire de Paris, Meudon, France	FP5-access
L. Valkunas	Modelling of energy transfer in photosystem I	Institute of Physics, Vilnius, Lithuania	NWO visitor
D. Verdes	High resolution infrared spectroscopy of the proton bound complex Ar-DN2+	University of Zurich, Switzerland	FP6-access
A. Witkiewicz	Laser trapping and interferometry to study mutated kinesin motor proteins	Warsaw University, Poland	FP5-access
S. Zapotoczny	Studies of the antenna effect in polymer molecules	Jagiellonian University, Krakow, Poland	FP5-access
S. Zapotoczny	Photophysical properties and proton transfer processes in pyrazolo [3,4-b] quinoline	Jagiellonian University, Krakow, Poland	FP5-access

Highlight: The effect of viral genome length and cations on the mechanical properties of phages

In this work, performed by **Dr. Alex Evilevitch** from Lund University (Sweden) in collaboration with Dr. Gijs Wuite, we are interested in understanding the coupling between the stability and strength of phage viruses in relation to the electrostatic and bending energy stored in its packaged genome. In order to obtain insight into this issue we employ Atomic Force Microscopy (AFM) and Optical Tweezers (OT) techniques. Using AFM force-distance curves are taken of empty phages as well as capsids filled with varying amounts of DNA. The critical indentation forces before breaking have also been determined, which gives insight into the tensile strengths of the capsids. These data are combined and used for building a model that illustrates the stability of viruses in relation to different genome lengths. The length of packaged genome is connected to the packaging density, which in turn seems to be related to the strength and survival of the phage virus.

Highlight: Shpol'skii spectroscopic studies of zig-zag [N] phenylenes

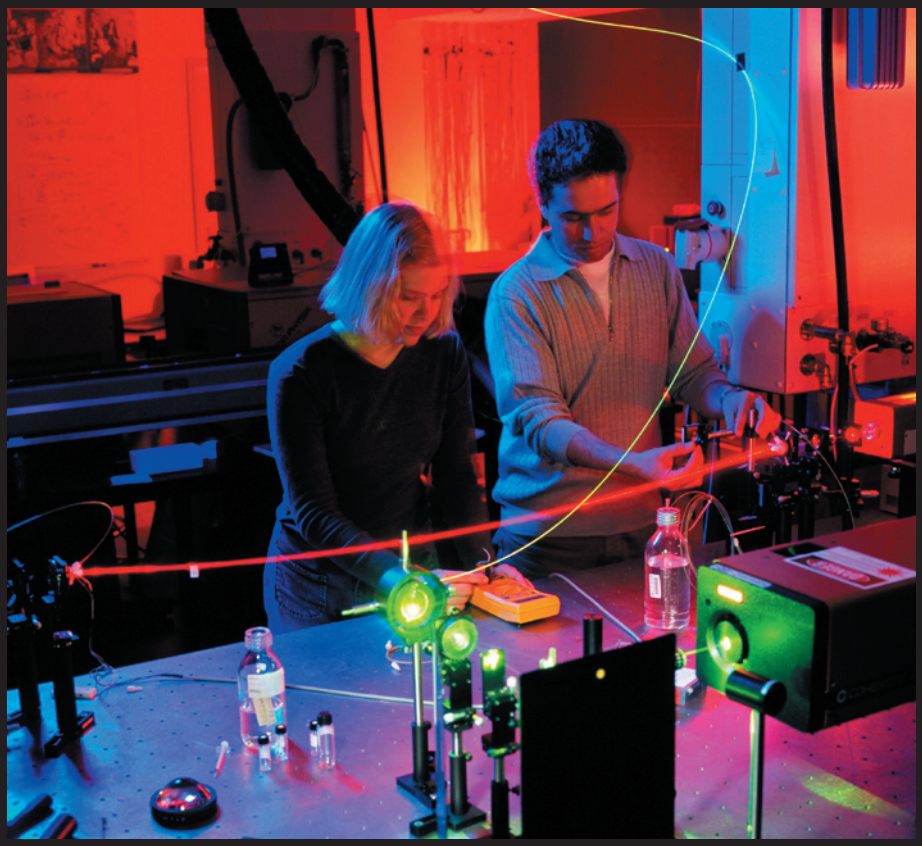
Dr. Michael Kumke and **Carsten Dosche** of the University of Potsdam, Germany visited LCVU in order to record vibrationally resolved fluorescence spectra of four angular [N] phenylenes. Because of the alternating character of aromatic and antiaromatic units according to Hückel's rule, these compounds are of considerable photophysical and spectroscopic interest. High-resolution laser excited Shpol'skii excitation- and emission spectra were recorded in a polycrystalline matrix of n-octane at 10 K. DFT calculations of the ground state vibrational frequencies were made. Deuterated derivatives were also studied to confirm the vibrational assignments. The calculated vibrational modes were in reasonably good agreement with the experimental data. A new very low-frequency vibration of approximately 100 cm^{-1} was predicted and experimentally confirmed. This vibration seems to be unique for [N] phenylenes and is attributed to an in-plane movement of the carbon backbone. [C. Dosche et al. Phys. Chem. Chem. Phys. 5: 4563-4569 (2003) and ibid. 6: 5476-5483 (2004)]



triangular[4]phenylene

4

EDUCATION AND TRAINING

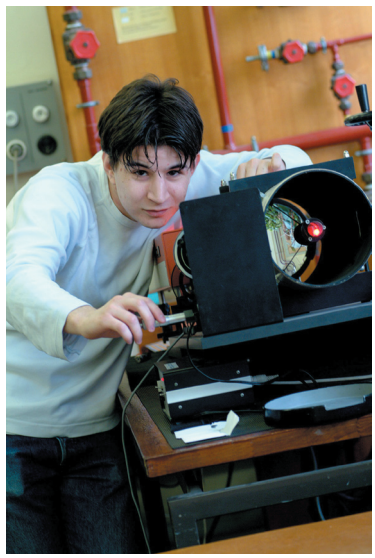


Education and training at LCVU

Education and training of Master and PhD students in the interdisciplinary research fields of LCVU is of utmost importance. The coherence and critical mass of scientific staff assembled within LCVU makes it possible to offer a modern educational programme with courses presenting the latest developments in fundamental studies and applications of laser and photonics oriented multidisciplinary research.

LCVU is strongly involved in the two-year masters program Laser Sciences/ Molecular Photosciences, offered in collaboration with the University of Amsterdam. The program can be entered by all students with a bachelor degree in Physics or Chemistry. The main part of the program consists of a one-year research project in one of the research groups involved in this program. At the end of this project a Masters Thesis will be produced. The program consists furthermore of a literature study and of a number of basic, advanced and optional courses. For the most up-to-date description of the courses and programme see: http://www.nat.vu.nl/~wim/masters/intro.html. All courses are taught in English.

LCVU is also involved in a Master track in Analytical Sciences; emphasis is on the application of molecular spectroscopic techniques such as advanced Raman and fluorescence modes in modern analytical chemistry. More information can be found at http://www.mastersanalyticalsciences.nl. Furthermore, LCVU participates in Master tracks in Biomolecular Sciences, Biomedical Sciences, and Biology. In these tracks, LCVU focuses on the fundamentals of optical techniques, in particular fluorescence spectroscopy and microscopy, and their application in biological research. More information can be found at http://www.falw.vu.nl/student/index.cfm.



Students being trained in optics

Advanced education and courses for PhD students are offered by the research schools Holland Research School of Molecular Chemistry and Biocentrum Amsterdam. For European PhD students the LCVU has operated as a Marie Curie Training Site (EU FP5 program TAILOR) hosting a number of PhD students for short (3-12 months) research training projects at LCVU.

Marie Curie Host Site Fellows at LCVU

Name	Project Title	Home Institution
Blagovest Bahnev	Cavity-Ring down spectroscopy in the liquid phase	University of Sofia, Bulgaria
Martynas Barkauskas	Harmonic generation with picosecond pulses	Vilnius Laser Centre, Lithuania
Carolina Carrasco	Laser trapping of kinesin motors	Universidad Autonoma de Madrid, Spain
Miguel Cornelles Soriano	External noise in semiconductor lasers	Vrije Universiteit Brussels, Belgium
Dan Dordai	Mechanosensing and signalling by osteocytes	Babes-Bolyai University, Cluj-Napoca, Romania
Christian Horn	Dual-stage ultrafast NOPA	Kassel University, Germany
Marta Mazur	The mitotic motor protein Eg5 studied with sliding motility assays	Wroclaw University of Technology, Poland
Natalia Pawlowicz	Femtosecond VIS-pump IR-probe spectroscopy	Poznan University, Poland
Daniel Perez Calero	Separation of harmonics in the 45-90 nm range	Universidad Autonoma de Madrid, Spain
Vesselin Petrov	Spectroscopy of azo dyes and Schiff bases	National Forestry University, Sofia, Bulgaria
Josselin Philip	VUV studies of heavy Rydberg dynamics	University Paris XI, France
Jeffrey Phillipson	A stable magnetic field for a Bose condensate	University of Sussex, UK
Angela Pirri	High harmonic generation with two-color laser fields	University of Pisa, Italy
Kinga Sznee	Dichroism studies of cytochrome bc1 complex	Warsaw University, Poland
Piotr Wasylczyk	Development of femtosecond NOPA system	Warsaw University, Poland
Karelina Zabrocka	The ATP turnover over of kinesin studied with (single-molecule) fluorescence assays	Wroclaw University of Technology, Poland

Since November 2004 LCVU participates in the "ATLAS" network (Advanced Training in Laser Sciences) for PhD students, also funded by the Human Resources and Mobility Activity of the EU (FP6) by means of the Marie Curie program (see http://www.iesl.forth.gr/mc-sites/atlas/). This Marie Curie Early Stage Training Network is carried out in collaboration with laser facilities in Heraklion (Greece), Florence (Italy) and Vilnius (Lithuania). In this program, PhD students will be able to receive advanced training in ultra fast lasers, molecular imaging, biomolecular dynamics and nanotechnology.

Furthermore, LCVU regularly organizes small workshops and summer schools. An advanced summer school on Modern Developments in Spectroscopy is organized every 2-3 years, in collaboration with the Holland Research School for Molecular Chemistry and supported by the European Science Foundation. This "TULIP" summer school offers advanced lectures and tutorials by renowned specialists in various fields. For the most recent info on the Tulip school consult http://erbium.chem.vu.nl/tulip.html.

Participants and lecturers at the Tulip School 2003

In 2003 PhD students organized a Young Atom Opticians school in Amsterdam to give young physicists the opportunity to present their work on a European level, while the absence of a senior scientific bias stimulated a free discussion of radical new ideas. See: http://www.nat.vu.nl/~yao2003/.

Contact: Jan Dekker, e-mail: JP.Dekker@few.vu.nl
Educational Board, Faculty of Sciences

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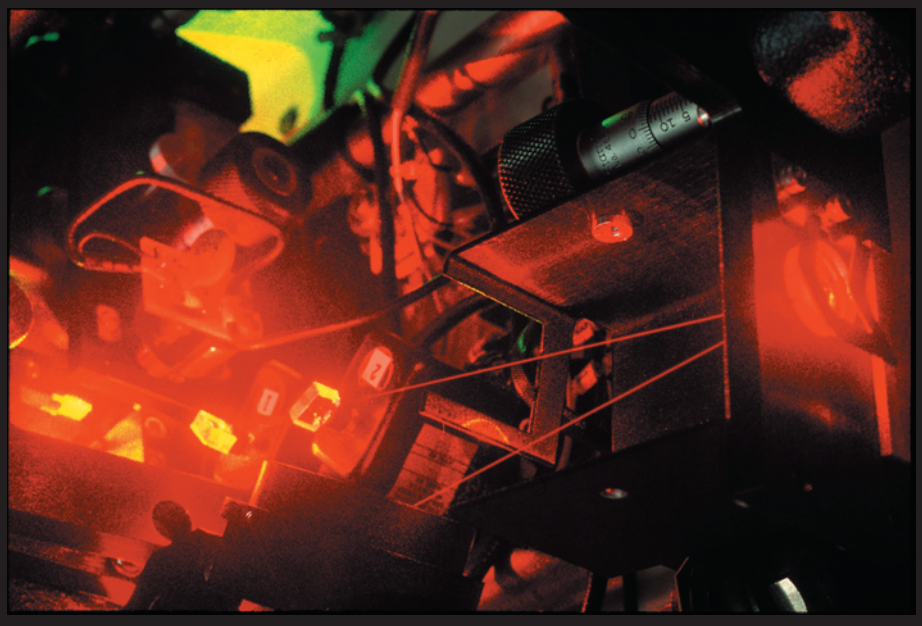
FINANCIAL SUPPORT



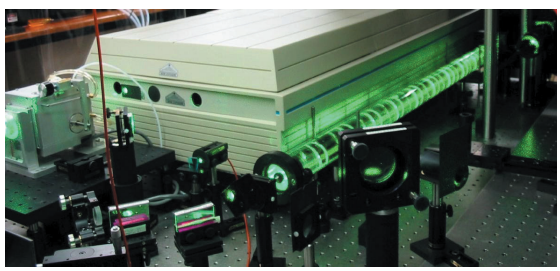
Financial support

The research groups collaborating in LCVU all have their own financial sources.
Salaries of senior scientific staff, technical support staff, some PhD students and some support for running costs are provided by the Departments of Physics, Chemistry and Biology. For research investments and salaries of young scientists the groups have obtained funds from competitive granting agencies from the Netherlands, such as NWO, FOM, CW, ALW, SRON and STW, from the European Union, and through contacts with industry. LCVU groups have been extremely successful on all levels in recent years, thanks to the excellent infrastructural basis provided by the university board and investment grants of funding agencies.

In addition LCVU has attracted funding on an institute-broad basis, i.e. bringing in support for the entire infrastructure for the benefit of the collaborating groups. Some important grants are mentioned here:

Netherlands Organisation for Scientific Research

- Strategic Investment subsidy from the VU Board of Directors (CvB) in the framework of the VU research policy ("VU-ster").
- FOM investment grant for large-scale infrastructures within the Netherlands.
- CALORIE: an EU FP-5 program establishing LCVU as a Large Scale facility providing access to European scientists (see Chapter 3).
- TAILOR: an EU FP-5 program establishing LCVU as a Marie Curie Training Host Institute (see Chapter 4).
- LASERNET: a European Coordinated Network of Laser Infrastructures, providing the basis for a "European Virtual Infrastructure" in the field of Laser Science (see Chapter 4).
- LASERLAB-Europe: an EU FP-6 program for an "Integrated Infrastructure Initiative" of major Laser Centres in Europe (see Chapter 3).
- ATLAS: an Eu-FP-6 "Early-Stage Training Network jointly with the Laser Centres in Vilnius, Florence and Crete (see Chapter 4).



Personal grants awarded to young staff members at LCVU

Over the last few years several young researchers at the LCVU have been awarded personal grants via competitive funding programs of the Netherlands Organisation for Scientific Research (NWO) and the Netherlands Foundation for Fundamental Research on Matter (FOM) by meansof their 'Vernieuwingsimpuls', 'Veni/Vidi/Vici' and 'Springplank' programs. Through these grants they have been able to start or expand their own research lines at the LCVU. These young staff members are:

dr. Kjeld Eikema
NWO Vernieuwingsimpuls

dr. Hendrick Bethlem
NWO VENI

dr. Marloes Groot
NWO VIDI

dr. Maurice Janssen
NWO VICI

dr. ir. Erwin Peterman
NWO VIDI

NWO
Netherlands Organisation for Scientific Research

FOM

dr. ir. Gijs Wuite
NWO Vernieuwingsimpuls

dr. John Kennis
NWO VIDI

dr. Harold Linnartz
FOM Springplank

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LCVU STAFF

Scientific staff

LCVU currently has 28 senior scientific staff members (see list), working full-time in laser-oriented education and research.

Name	Group	Email
Dr. K. Allaart	Theoretical Quantum Electronics	K.Allaart@few.vu.nl
Dr. F. Ariese	Applied Spectroscopy	F.Ariese@few.vu.nl
Dr. D. Bald	Structural Biology	Dirk.Bald@falw.vu.nl
Dr. Y. Bollen	Structural Biology	Yves.Bollen@falw.vu.nl
Dr. J. Bulthuis	Physical Chemistry	J.Bulthuis@few.vu.nl
Dr. B. Dam	Pulsed Laser Deposition	B.Dam@few.vu.nl
Dr. J.P. Dekker	Biophysics	JP.Dekker@few.vu.nl
Dr. E.J. van Duijn	Atomic Molecular and Laser Physics	EJ.van.Duijn@few.vu.nl
Dr. K.S.E. Eikema	Atomic Molecular and Laser Physics	KSE.Eikema@few.vu.nl
Prof. dr. C. Gooijer	Applied Spectroscopy	C.Gooijer@few.vu.nl
Prof. dr. R. van Grondelle	Biophysics	R.van.Grondelle@few.vu.nl
Dr. M.L. Groot	Biophysics	ML.Groot@few.vu.nl
Prof. dr. W. Hogervorst	Atomic Molecular and Laser Physics	W.Hogervorst@few.vu.nl
Dr. M.H.M. Janssen	Physical Chemistry	MHM.Janssen@few.vu.nl
Dr. J.T.M. Kennis	Biophysics	J.Kennis@few.vu.nl
Prof. dr. D. Lenstra	Theoretical Quantum Electronics	D.Lenstra@few.vu.nl
Prof. dr. H. Lill	Structural Biology	Holger.Lill@falw.vu.nl
Dr. H.V.J. Linnartz	Physical Chemistry	HVJ.Linnartz@few.vu.nl
Dr. Ir. E.J.G. Peterman	Physics of Complex Systems	EJG.Peterman@few.vu.nl
Prof. dr. C.F. Schmidt	Physics of Complex Systems	CF.Schmidt@few.vu.nl
Dr. I.H.M. van Stokkum	Physics Applied Computer Science	IHM.van.Stokkum@few.vu.nl
Prof. dr. S. Stolte	Physical Chemistry	S.Stolte@few.vu.nl
Prof. dr. W. Ubachs	Atomic Molecular and Laser Physics	WMG.Ubachs@few.vu.nl
Dr. W. Vassen	Atomic Molecular and Laser Physics	W.Vassen@few.vu.nl
Dr. T.D. Visser	Theoretical Quantum Electronics	TD.Visser@few.vu.nl
Prof. dr. S. Völker	Biophysics	SL.Volker@few.vu.nl
Dr. Ir. G.J.L. Wuite	Physics of Complex Systems	GJL.Wuite@few.vu.nl
Dr. G. van der Zwan	Applied Spectroscopy	G.van.der.Zwan@few.vu.nl

In addition there are a number of part-time and guest professors that bring their specialized expertise to LCVU:

Name	Group	Email
Prof. E.A.A. Aben	Atmospheric physics and chemistry	E.A.A.Aben@few.vu.nl
Prof. B. Krauskopf	Nonlinear laser dynamics	B.Krauskopf@few.vu.nl
Prof. K.J. Hellingwerf	Photobiology	khelling@science.uva.nl
Prof. C. A. de Lange	Molecular physics	CA.de.Lange@few.vu.nl
Prof. K.A.H. van Leeuwen	Quantum optics	K.A.H.v.Leeuwen@few.vu.nl
Prof. N.M.M.Nibbering	Mass spectrometry	N.Nibbering@few.vu.nl
Prof. A.J.W.G. Visser	Fluorescence studies of biological systems	Ton.Visser@falw.vu.nl

Technical staff

The scientific staff is supported by 9 technicians (see list), which are closely associated with the research groups and work on a day-to-day basis within the LCVU laboratories. In addition technical support is provided by the Mechanical and the Electronic workshops, housed in the same building at the VU-campus.

Technicians within LCVU. Top row from left to right: Arjan Wiskerke, Sandrine d'Haene, Joost Buijs, Iris Jaspers. Bottom row from left to right: Harro Wong Fong Sang, Vincent Tuinder, Hennie van Roon, Jacques Bouma

Name	Group	Email
J. Bouma	Atomic Molecular and Laser Physics	
J. Buijs	Applied Spectroscopy	JB.Buijs@few.vu.nl
S. d'Haene	Biophysics	S.d.Haene@few.vu.nl
I. Jaspers	Physics of Complex systems	I.Jaspersdekker@few.vu.nl
H. van Roon	Biophysics	HM.Roon@few.vu.nl
J. Thieme	Biophysics	J.Thieme@few.vu.nl
V. Tuinder	Physical Chemistry	V.Tuinder@few.vu.nl
Dr. A. Wiskerke	Applied Spectroscopy & Physical Chemistry	AE.Wiskerke@few.vu.nl
H. Wong Fong Sang	Structural Biology	harro.wong.fong.sang@falw.vu.nl

Young scientists

Most of the actual laser-based research is carried out, as in all modern laboratories, by young scientists, PhD students and Post-Docs (see list). Special for LCVU is the university setting and the close connection between research and education, bringing in Masters and even Bachelors students carrying out projects in a learning environment. Traditionally VU has been strongly involved in International Cooperation and Development as well as in European exchange (Erasmus, Socrates) bringing large numbers of foreign students to LCVU. In recent years LCVU has been a Marie Curie Host Institute and currently participates in a Marie Curie Early-Stage-Training Network.

PhD students and postdocs

Applied Spectroscopy	
Arjen Bader	Fluorescence probing under high-resolution conditions
Alois Bonifacio	Raman spectroscopy of redox proteins
Evtim Efremov	Deep-UV and time-resolved Raman spectroscopy
Junko Hirata	Bioassays based on fluorescence resonance energy transfer
Dr. Natalia Haraszkiewicz	Spectroscopy and molecular modelling of receptor-ligand binding
Joost de Klerk	Low-temperature, high-resolution fluorescence spectroscopy
Diego Millo	Electrochemistry and Raman spectroscopy of redox proteins
Eva de Rijke	Analysis of flavonoid compounds in wetland ecosystems
Lineke van der Sneppen	Optical ringdown techniques for detection in liquids
Aike Stortelder	Time-resolved fluorescence spectroscopy of protein dynamics

Atomic Molecular and Laser Physics	
Dr. Rick Bethlem	Molecular fountain
Sandro Hannemann	XUV/UV-precision spectroscopy
Dmitry Ityaksov	Spectroscopy of interstellar molecules
Tom Jeltes	Bose-Einstein condensation of helium
Dr. Irena Labazan	XUV-laser spectroscopy and quasars
John McNamara	He3-He4 cold atom statistics
Dr. Joop Mes	Laser isotope separation
Dr. Elmar Reinhold	XUV-laser spectroscopy and quasars
Edcel Salumbides	Molecular clocks
Lineke van der Sneppen	Optical ringdown techniques for detection in liquids
Arjan Sprengers	Nitrogen in the Earth atmosphere
Roland Stas	Helium cold atom physics
Andrei Tychkov	Bose-Einstein condensation of helium
Stefan Witte	Frequency comb laser
Roel Zinkstok	Frequency comb laser

Biophysics	
Maxime Alexandre	Signal generation and propagation in biological sensors
Dr. Elena Andrizhiyevskaya	Fluorescence and pump-probe spectroscopy of photosystem II
Rudi Berera	Regulation of photosynthetic energy conversion
Cosimo Bonetti	Structural dynamics of carotenoids in photosynthesis
Toh Kee Chua	Dynamic-structural basis of biological sensing
Dr. Mariangela di Donato	Photosystem II dynamics studied with femto-IR spectroscopy
Dmitrij Frolov	Pump-probe spectroscopy of bacterial reaction centers
Magdalena Gauden	Mechanisms of light activation in flavin-based photoreceptors
Denitsa Grancharova	Ultrafast spectroscopy of light-harvesting complex II
Dr. Jason Key	Structural dynamics of biological sensors
Dr. Manolis Papagiannakis	Dynamics of carotenoids
Natalia Pawlowicz	Charge separation in reaction centers with femto-IR
Elisabet Romero	Stark spectroscopy of photosystem II
Alisa Rupenyan	Cytochrome P450 enzyme dynamics
Danielis Rutkauskas	Confocal microscopy of bacterial light-harvesting complexes
Olga Sytina	POR enzyme dynamics
Kinga Sznee	AFM and LD studies of photosynthetic membranes
Luuk van Wilderen	PYP and GFP structural dynamics
Chantal de Wit	Dynamics of photosynthetic membranes and supercomplexes

Physical Chemistry	
Arjan Gijsbertsen	Steric and quantum effects in inelastic scattering
Daniel Irimia	Imaging of ultrafast molecular dynamics
Dmitry Ityaksov	Cavity ring down spectroscopy of radicals
Laura Lipciuc	Imaging of quantum state-selected photochemistry
Dr. Wim Roeterdink	Coincidence imaging of femtosecond dynamics
Harald Verbraak	Infrared spectroscopy of ionic complexes
Erik Volkers	Fluorescence spectroscopy of isotopomers
Arno Vredenborg	Imaging of coherently controlled photochemistry

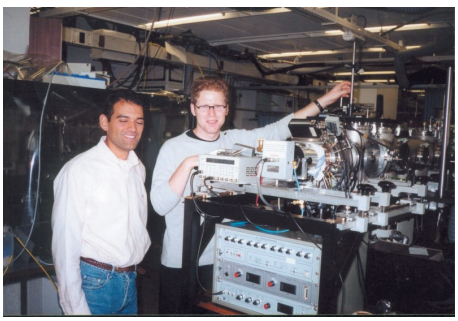
Physics of Complex systems	
Maryam Atakhorrami	Microrheology of actin networks and model systems
Matthew Baker	The mechanism of kinesin motor proteins involved in cell division
Bram van den Broek	The molecular mechanism of restriction enzymes
Dr. Remus Dame	Bacterial nuleoid-associated proteins
Irena Ivanovska	The mechanical proporties of viral shells
Lucas Kapitein	The mechanism of kinesin motor proteins involved in cell division
Mikhail Korneev	The mechanism of kinesin motor proteins involved in cell division
Dr. Stefan Lakämper	The molecular mechanism of kinesin motor proteins
Joost van Mameren	Force and fluorescence measurements of DNA-binding proteins
Dr. Daisuke Mizuno	The visco-elastic properties of living cells
Maarten Noom	Force measurements of DNA-binding proteins
Iwan Schaap	Scanning force microscopy of proteins and DNA
Dr. Catherine Tardin	Visco-elastic properties of complex fluids
Sander Verbrugge	Kinesin motor proteins studied with single-molecule fluorescence
Karen Vermeulen	Optical tweezers in biophysics
Siet van den Wildenberg	Protein folding machines studied with single-molecule fluorescence

Structural Biology	
Anitha Shanmugham	Protein translocation in bacteria

Theoretical Quantum Electronics	
Hartmuth Erzgräber	Nonlinear dynamics of diode lasers
Dr. Greg Gbur	Near-field optics and coherence
Dr. Miranda van Iersel	Nonlinear dynamics of diode lasers
Hugo Schouten	Near-field optics and coherence
Wenfeng Wang	Nonlinear dynamics of diode lasers

Best paper of the year

To encourage and reward the young scientists at LCVU a yearly prize is established for the "Best paper of the year". A diploma and an award of 500 Euro is presented during the yearly Laser Centre Symposium, held at the end of the year. Prize winners in 2003 and 2004 were:



Alrik van den Brom (right) won the 2004 award for his paper:
Directional dynamics in the photodissociation of oriented molecules, published in Science in 2004. On the left his co-author Peter Rakitzis from FORTH, the Crete Laser Centre

Fernando Brandi won the 2003 award for his paper:
High-order harmonic generation yielding tunable extreme-ultraviolet radiation of high spectral purity, published in Physical Review Letters in 2003.

How to get at LCVU

LCVU is located in the K-wing of the Science building on the campus of the Vrije Universiteit. The Vrije Universiteit is located in the southern part of Amsterdam, very close to Schiphol Airport, and with direct tram and metro connections to the historical centre of Amsterdam.

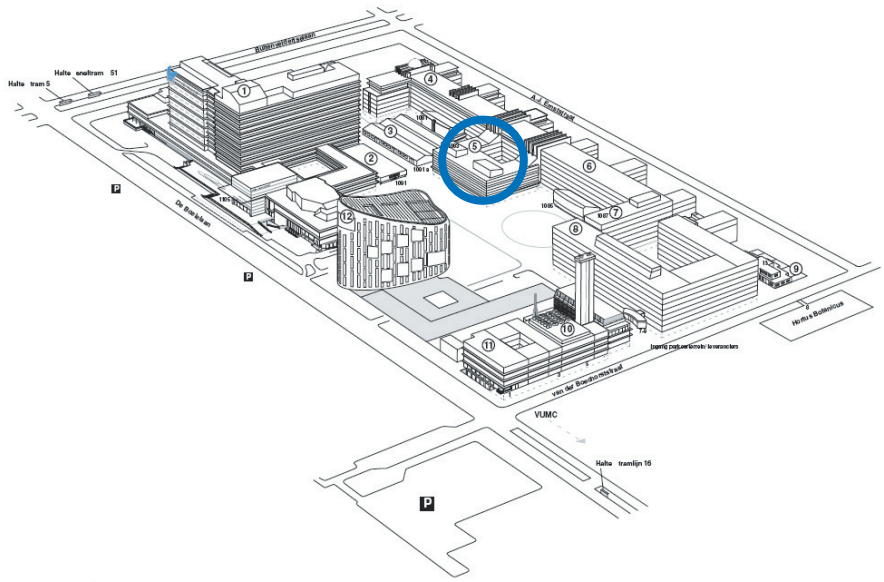
From Schiphol Airport
Travellers arriving at Schiphol Airport can take a local train ('stoptrein') to Station Zuid/WTC. Trains leave every 10-15 minutes, directly underneath the airport terminal.

From Station Zuid/WTC
- express tram 51 (1 minute), direction Amstelveen Westwijk
- tram 5 (1 minute), direction Amstelveen Binnenhof
- From Station Zuid/WTC it is a 10-minute walk to the Vrije Universiteit

From Central Station
- express tram 51, direction Amstelveen Westwijk (16 minutes)
- tram 5, direction Amstelveen Binnenhof (25 minutes)

By car
The A-10 Amsterdam ring road can be reached from all directions. Follow the A-10 to the Zuid/Amstelveen exit S 108. Turn left at the end of the exit ramp onto Amstelveenseweg: after about three hundred meters (at the Vrije Universiteit Hospital building) turn left again onto De Boelelaan. Paid parking is available on the streets around the VU-campus. The Vrije Universiteit Amsterdam can be reached via city routes S 108 and S 109.

For more detailed information see: www.few.vu.nl/organisatie/bestuur/locatie-en.html



VU-campus