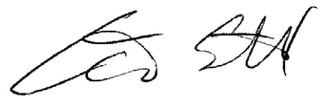
COMPLEX LIGHT CONTROL

PHASE ONE

Dear reader,

What is your first association with the word »CLiC«? Perhaps Lucky Luke shooting faster than his shadow? Or a concrete-block apartment house, where you can enjoy hearing the neighbour turning on a light switch? Or a cuckoo clock with its classic sound ringing out before the wooden or metallic bird starts its tender song? Or the computer, which lets you change the world with a click? Or is it the idea you need for this change? You are right, your guess is not bad at all because this CLiC is an elegant mixture of all that. Do not worry, it is not about bombs, despite the Frankfurter Rundschau's humorous writing about colleague Heckel in 2008. In fact, it is about being faster than Lucky Luke in turning on a light switch at the right moment to change the inner world of a molecule or a cell – without disturbing its environment. A brilliant idea, right? Nevertheless, CLiC does not stop at the manipulation of a cell but deliberately aims for the transformation of whole organisms, in particular a cohort of scientists conducting their PhD projects in the early stage of their professional life. In retrospect, it will be interesting to learn when the young colleagues' ideas CLiC(ked), and whether it has been light which made them successful in the end. I hope you enjoy browsing through the brochure, and believe me: if you are looking for the right CLICK, then you are in the right place!



Prof. Dr. Enrico Schleiff
Vice President,
Goethe University Frankfurt

funded by
DFG

Photo: Uwe Dettmar

Structured doctoral studies

All together instead of everyone for themselves

»CLiC« (»Complex Light Control«) is the first research training group (Graduiertenkolleg) Goethe University has obtained funding for by the German Research Foundation (DFG) after a pause of several years. CLiC started in November 2014. A research training group represents a special kind of research funding. In contrast to »individual PhD projects« (which are also an option), here the emphasis is not only placed on excellent research but also on consciously shaping and developing the research process itself. Therefore, the PhD students and their development are in the focus of the training group. Due to the temporal synchronisation of the PhD projects, the students go together through this development – as a »cohort«. Thus, beyond of each PhD student's affiliation to a research group, an overarching team spirit emerges, which is essential for the entire scientific project, as its success depends on a highly cross-linked network of collaborations between different disciplines. A wide-ranging interdisciplinary understanding develops through shared scientific training provided by CLiC, such as workshops and mentoring. Specifically targeted training elements foster methodological competence respective the analysis, presentation and defence of one's research, as well as the ability to operate within complex networks of collaboration partners. These aspects are as much part of research as the strategic development of the scientific ideas and the experimental work itself.

Prof. Dr. Alexander Heckel
Speaker of the DFG Research Training Group CLiC

Photo: Uwe Dettmar

The scientific idea

Bringing light into the darkness

We need new »tools« if we want to find out more in detail how nature functions in and around us. The example of the pendulum can serve as an analogy here. Imagine that we own a pendulum locked in a deflected position, without knowing how it works. Releasing it, the pendulum would start swinging back and forth, and we could study its movement. Eventually, however, the pendulum would come to a standstill. It would be a lot more interesting if we could raise the pendulum again to make additional observations or if we could restart it periodically – like a child on a swing, learning to shift the weight at the right moment to swing even higher. It would be even more interesting if we had a network of pendulums, in which the pendulums influence each other. And it would be really exciting to be able to nudge just one or a group of pendulums at a precisely chosen point in time – with free selectable force.

LIGHT – HIGHLY SELECTIVE AND VERSATILE

This is precisely the basic idea when light is used to control molecular processes. Light is a wonderful »addressing mechanism« for stimulating something in a very precise spatial, temporal and dose-dependent manner. When used correctly, light is highly selective because typically very few natural systems react to light. Nowadays, a multitude of techniques allows the production of light of very specific quality and high intensity, which permit the delivery of light to places such as test tubes, specimen under a microscope, tissues or whole organisms. For example, think of the use of lasers in microscopes or endoscopes.

MOLECULES – BLOCKED AND ACTIVATED

The aim of »CLiC« (»Complex Light Control«) is to perfect these technologies and to apply them to specific research questions. The central idea is »caging«. This approach uses molecules temporarily inactivated through the attachment of a chemical group, which can be removed again by light. Such compounds can be activated at will inside the system under investigation – when and where you want. For example, until recently the standard practice was to use light of a single wavelength, a single colour, which limited us to a single effect. Now we have access to a »colourful spectrum« of options for selective stimulation within a single experimental specimen, enabling us to turn on or off several processes. This thought inspired the design of the CLiC logo.

THE COLOURFUL SPECTRUM OF POSSIBILITIES

A particular focus of our research is, for example, a new form of light stimulation, which we called VIPER (VIbrationally Promoted Electronic Resonance)*. This approach uses infrared pulses as well as light in the visible range and excites only specifically marked molecules. We are also developing methods which can be used for light regulation in the red region of the spectrum, aiming for application in body tissues. This in particular is chemically challenging but would enable deep tissue penetration – as anybody can test by holding a hand over an electric torch and seeing the hand glow red. This does not work with green or blue light. Another challenge we are working on is nonlinear two-photon activation. This approach uses ultrashort pulse lasers and is able to produce a point of light, in contrast to normal light sources which generate a beam of light. These points of light only allow the achievement of true three-dimensional resolution.

FOLDING, INCORPORATION AND METHODS

These new methods of light regulation allow us to investigate, for example, the folding landscapes of proteins and RNA. Both are highly complex biomolecules with a multitude of tasks within our body. As with origami – the art of paper folding which lets emerge different figures from the same sheet of paper – the functions of proteins and RNA are often determined by the multifaceted process by which these molecules can be folded and unfolded. Another focus of our research are molecules which are embedded in biological membranes. We study reactions which allow targeted modifications of the lipid molecules' shape in membranes. The spatial interplay of proteins in living cells can be orchestrated through tiny light-regulated lock-and-key elements within these proteins. This allows us to investigate the triggered biological functions. We also develop a new method of time-resolved mass spectrometry*, which we use to investigate the reaction of molecules in minute droplets inside a droplet trap. A laser beam then triggers specific chemical reactions. For a time-resolved analysis, this droplet then is exploded by a second laser shot allowing us to examine the charged fragments.

INTERACTION OF THE DISCIPLINES

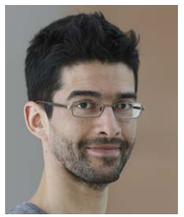
All this only can succeed if theory, synthesis, spectroscopy and application are combined. Therefore, we are developing new methods for predicting photochemical behaviour. Based on these predictions, we design and synthesise new compounds with interesting photochemical properties, we trigger complex photochemical effects and investigate the behaviour of the molecules using complex spectroscopic methods. We then integrate the newly obtained light triggers into biological systems.

A wonderful interdisciplinary field for a research training group.

Scientific terms marked with * in the text are explained in the glossary (page 82).

PhD students

Andrés Arriagada



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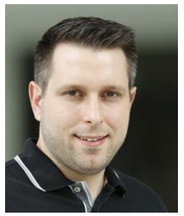

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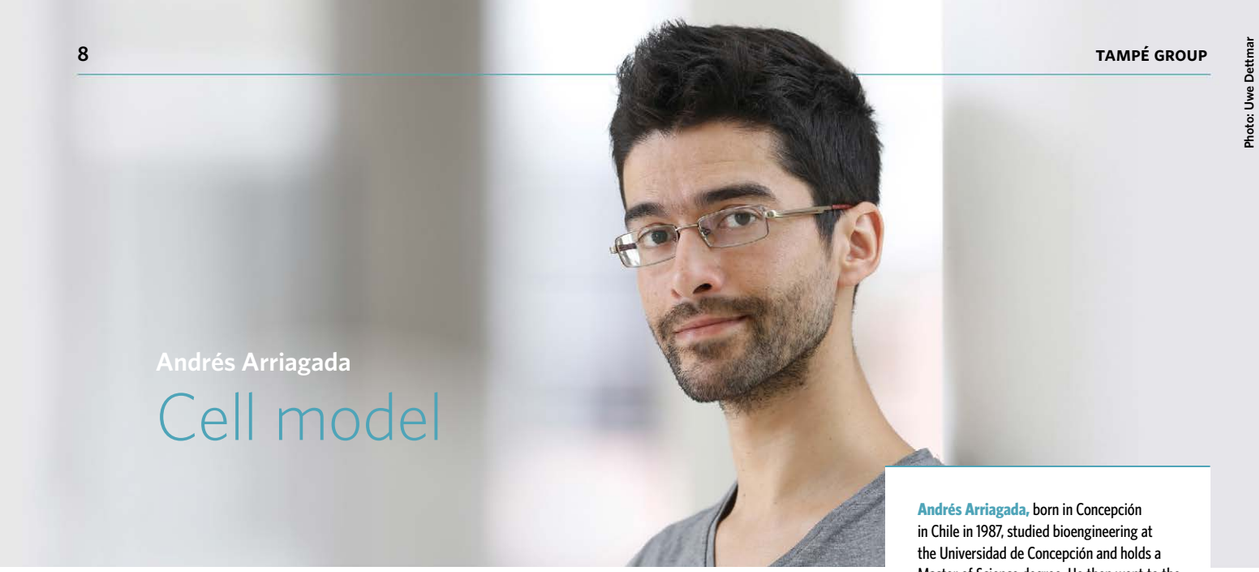


Photo: Uwe Dettmar

Andrés Arriagada

Cell model

Andrés Arriagada, born in Concepción in Chile in 1987, studied bioengineering at the Universidad de Concepción and holds a Master of Science degree. He then went to the Agriaquaculture Nutritional Genomic Center in Temuco/Chile and also worked at the University of Chile. Since 2014 Arriagada has been working on his PhD project at Goethe University in the group of Robert Tampé at the Institute of Biochemistry.

Photo-activatable dimerization of membrane proteins The aim of my research is to control the interaction between proteins by using light-induced processes, which provide a high spatio-temporal resolution. The most important milestone in this project is the incorporation of novel light-activatable chelating compounds* into membrane proteins*. To achieve this, we use anchor sites on the protein, which contain several histidine amino acids. The modified proteins can be activated by light. The method enables two membrane proteins to link up to each other in a highly specific manner without being influenced by the presence of other proteins and amino acids. In our project we use a membrane complex derived from the bacterium *Thermus thermophilus* and embedded it in artificial cell membranes. The results provide us with a better understanding of the organisation of membrane proteins.

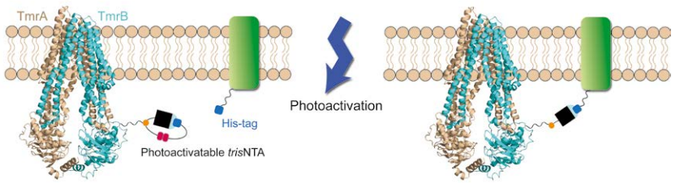


Photo-activatable dimerization of the membrane protein TmrAB: TmrAB is modified with the self-inhibiting and light-activatable compound trisnitrilotriacetic acid (trisNTA). Dimerization is induced via the histidine-rich anker site.

Photo: Val Bromann, choosingfigs.com

What brought you to Frankfurt and to Goethe University?

My parents strongly advised me to go abroad for a while, after completing my Master thesis. So I looked for a suitable position, and with the help of the German Academic Exchange Service (DAAD) I found the research group of Prof. Dr. Robert Tampé.

How would you describe yourself as a scientist? And how as a private person?

The positive side: I am very precise and very motivated for doing research. The negative side: I am stubborn and slow in finding collaboration partners. Besides science, I like having my family nearby, going out with friends and playing basketball.

Which person comes to your mind when you hear the word »successful«?

Jesus. He lived and died for what was important to him, and even many generations later millions of people try to live the way he thought was the best. I also like Maria, the mother of Jesus, because she helped him to fulfill his obligations.

Do you like travelling?

I love to travel. I already visited many areas of Chile, from the Atacama Desert down to Patagonia. I have also been to Macchu Picchu and to the Bolivian Salar de Uyuni, the largest salt flat on earth. And now I am looking forward to travelling through Germany and Europe.

Are you more of a city person or a country person?

Definitely a city person. I like the countryside but I cannot imagine to live on a farm. I enjoy the amenities of the city, and I think it also is the best place to do research.

How do you like Frankfurt? And Germany in general?

I think that Frankfurt has many interesting buildings. Personally, I like Goethe University's Riedberg Campus very much. Especially because of the good infrastructure, which is good for my work. But I also like the historic buildings in Frankfurt such as the cathedral. And I like, of course, the many unusual skyscrapers. The sophisticated German transport system makes it possible to visit beautiful places and regions, such as Lake Constance, Neuschwanstein Castle or the Kleinwalsertal in Austria.

»I love to travel. I already visited many areas of Chile, from the Atacama Desert down to Patagonia.«

Photo: fotolia.com/prat

»Cycling helps to clear your mind.«

Which other discipline, far from your own, is of particular interest to you and is perhaps a source of inspiration?

In my spare time, I like riding my road bike, and I am interested in all aspects of cycling as a sport. Cycling helps to clear your mind, and sometimes a good idea pops up spontaneously.

Is there a goal you want to achieve?

With respect to my work, I'm aiming for gaining my PhD in this CLiC project. Apart from this goal, I would like to do reasonably well in the cycling race on 1st of May. I took part last year, too. This year I registered for the 100 km distance including Feldberg.

If you had to summarise your research in five words, which would you choose?

Maths, paper, formulas, programing, coffee.

Which entrance music would you choose for your own boxing match?

I have to say that I do not know anything about boxing and am also not a great music expert. I probably would simply choose »Eye of the Tiger«. You surely cannot go wrong with that.

What do you find hilariously funny?

I am a big fan of stand-up comedy, which certainly is in that category. Of course, I also like funny movies and series.

What does the first hour of your day look like?

After getting up in the morning, I have a relaxed breakfast.

Photo: Uwe Dettmar

Jan von Cosel

Targeted prediction

Jan von Cosel was born in Frankfurt am Main in 1989, he studied chemistry at Goethe University and completed his Master of Science in 2014. He started his PhD project in the group of Irene Burghardt at the Institute of Physical and Theoretical Chemistry in November 2014. Von Cosel is a cycling sport fan.

About the theory of vibrationally promoted electronic resonance, VIPER In my project I am applying theoretical methods to understand specific aspects of vibrationally promoted electronic resonance (VIPER*), the new technique which is also investigated with spectroscopic methods by colleagues. In our group we use software programmes, which we developed ourselves as well as software that can be bought off the shelf. Work with pen and paper still plays an important part, too. Using these methods, we aim to understand what happens with a molecule, when it first has been vibrationally excited by infrared light, and subsequently is exposed to visible or UV light. The vibration changes the way the molecule absorbs the light. We use this effect to selectively excite a specific type of molecule in a sample with light and thereby trigger a chemical reaction. Our goal is to be able to predict whether a molecule is suitable for this purpose. Because then we can specifically optimise molecules for this purpose »on paper« and suggest them for synthesis to the experts.

Example of the change in the distribution of electrons within a molecule following optical excitation.

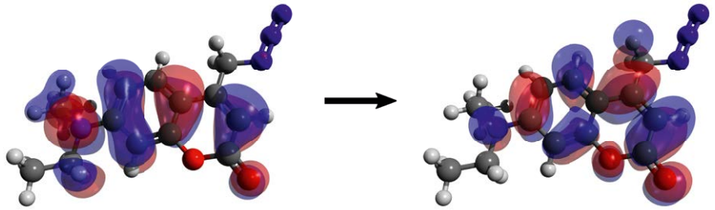


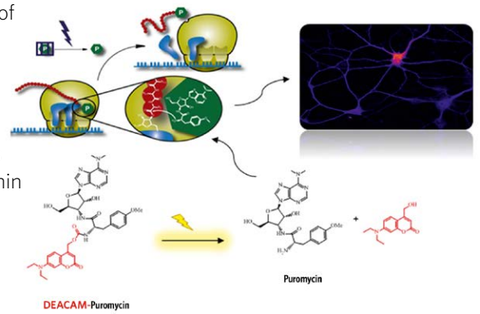
Photo: Uwe Dettmar

Isam Elamri

Inhibited growth

Isam Elamri was born in Casablanca, Marocco, in 1981. After studying chemistry and French for a teaching degree at the University of Hassan II in Casablanca, and subsequently obtaining the certificate »German as a foreign language« at the Goethe Institute in Casablanca, he took an assessment test at a preparatory college at Potsdam University to have his Moroccan A-levels recognised. In 2009 he began to study chemistry at the Goethe University Frankfurt. In 2015 he completed his Master of Science in chemistry in Frankfurt and started his PhD project in the group of Harald Schwalbe at the Institute of Organic Chemistry and Chemical Biology. Elamri has two children and is also a certified translator for German, Arabic, and French.

Temporal and spatial control of puromycin as an indicator of new proteins Proteins have diverse and very specialised functions in the cell. They determine the shape and structure of the cells and control almost all life processes. Proteins help cells to protect themselves against invaders, to monitor and regulate cell functions and to repair damage. Because of these diverse tasks, the biosynthesis of proteins – ie the formation of the polypeptide chain* and its subsequent folding into a specific three-dimensional structure – is one of the most significant cell processes. The antibiotic puromycin is able to inhibit the growth of the polypeptide chain and to bind to the new shorter proteins. Therefore, puromycin is used in experiments in cell biology and microbiology as an indicator of new proteins. We can equip puromycin with a photolabile protecting group, which can be removed again with light of a certain wavelength. This allows the temporal and spatial control of the activity of this drug, both as an antibiotic and as an indicator of new proteins. In this project the paths of three research groups intersect: spectroscopic studies of photolysis of protecting groups, synthesis and optimisation of photolabile puromycin derivatives, and their application as an indicator of newly synthesised proteins within a single nerve cell.



Light-labile puromycin for the spatial and temporal control of newly synthesised proteins.

Photo: Uwe Dettmar

»Chemistry is really cool.«

Who are your role models?

My role model is the prophet Mohammed. Especially his modesty, love of truth and trustworthiness are important to remember. In terms of my work, I also try to be always honest, helpful, not to give up when problems occur, and to wish my colleagues only the best, even if they get better research results than me.

Was there a decisive impetus for your decision to study chemistry?

Originally, I wanted to study medicine, but now I am very glad that my final grade was not sufficient. Chemistry is really cool.

How would you describe yourself as a scientist? And how as a »private person«?

Not very differently. I try to do the right thing to the best of my abilities, I often practise self-criticism and try to do better.

Have you ever had a pet?

The only pet I had as a child was a canary. I still remember his beautiful song after all these years. Today, however, I would not want to keep such a freedom-loving animal in a cage.

What are your strengths? And what are your weaknesses?

Oh dear ... the classic job interview question. I still have to prepare for it. Anyway, I read in an article that one should not give funny answers such as one of my weaknesses is eating crisps or something like that. Interviewers don't like that ...

Photo: Uwe Dettmar

Konstantin Falahati

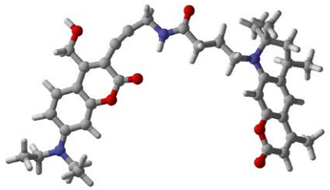
Easily calculated

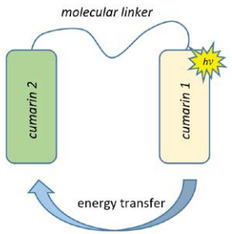
Konstantin Falahati was born in Münster in 1990. He studied chemistry at Goethe University and completed his Master of Science in 2014. During his studies, he focused particularly on theoretical and computational chemistry. Falahati was granted stipends from the Studienstiftung des Deutschen Volkes and the Stiftung der Deutschen Wirtschaft. He started his PhD in the research group of Irene Burghardt at Goethe University in 2015. Since school Falahati has been a dedicated musician. Not only he led the school orchestra but also other orchestras from 2011 onwards, some of them he had founded himself. Currently he is the conductor of the orchestra »Junior Philharmonics« founded by him as well.

Computer-aided quantum chemical investigation of photochemical processes In order to better understand photochemical processes in molecules, various methods can be used, such as computer-assisted quantum chemical analysis.

For this purpose, we use the latest ab initio and density functional methods*, which enable us to describe the electronic structure of molecules. We examine the excited states and select those which are involved in reactions. For example, one aspect of the project is concerned with the light-triggered ultrafast dissociation of carbon monoxide from a myoglobin* model complex: a reaction is completed within just a few femtoseconds*. The adequate description of the so-called wave-packet dynamics of such a transition metal complex is especially challenging, since the electronically excited states show a very complex behaviour.

In addition, we are interested in the description and characterisation of suitable coumarin systems, which we want to use for light-controlled Förster resonance energy transfer (FRET*) as well as for light-activation. Our investigations take, for example, also into account that changing the spatial arrangement in a molecule has an influence on the absorption spectra.





Geometry (left) and a schematic mechanistic diagram (right) of a coumarin-based uncaging system.

Photo: Photocase/hasselblad15

Who are your role models?

There have been several people in my life, who I consider role models. I would like to thank here my former chemistry teacher, Dr. Ruthard Friedel, who with lots of humour and enthusiasm shaped my decision about what subject to study. In addition, I would like to highlight two people at Goethe University: Professor Bertram Schefold, whom for various reasons I consider one of the last true »polymaths« in the traditional sense, as well as Professor Andreas Terfort, whom I would consult when encountering particular tricky chemical questions.

Is there a goal you want to achieve?

I definitely want to learn to play the cello before I retire.

During which activities are you especially efficient (in flow)?

I think I am able to develop a good »flow« in everything that fascinates and inspires me, privately as well as professionally. In the latter case, presently it is my work with coumarins and porphyrins.

Do you like travelling?

Due to my personal cultural background, I generally »travel« a lot between the Orient and the Occident, mentally as well as physically. Furthermore, one of the major global climatic challenges of the coming years will probably be to find travel destinations, where the natural snowfall is sufficient for skiing.

Where do you see yourself in five or ten years?

My grandfather (God bless him) always responded to such questions evasively with, »Preferably as an aristocrat in the age of Pericles!« In our present age, a job in the chemical industry or a permanent position in the higher civil service would presumably also be acceptable.

What do you find hilariously funny?

Much to the chagrin of my colleagues, I have a strong penchant for good to black British humour in the style of the series »Blackadder« (with Rowan Atkinson) on the one hand, and of the monumental epic »The Big Lebowski« by the Coen brothers on the other.

»I definitely want to learn to play the cello before I retire.«

Photo: private

»My most demanding tour so far has been the ascent of Mount Blanc. It has shown me that for some goals you have to go beyond your limits.«

What does research give you?

Research is very fulfilling for me because together we explore the highly complex natural processes. I find it very exciting to work together with international companies and research groups on new technologies and their development. In general, it is very important to me that old polluting technologies are replaced through research.

Which person comes to your mind when you hear the word »successful«?

I do not think about a specific person, neccessarily. For me, people are successful, who manage to combine career and family.

What do you do in your spare time?

I like to visit thermal baths, and I love to go hiking. For a few years now, I have been going on high alpine and snowshoe tours with the German Alpine Club. My most demanding tour so far has been the ascent of Mount Blanc together with my brother. This has been one of the biggest challenges in my life, and it has shown me that for some goals you have to go beyond your limits.

What do you find hilariously funny?

I find it funny that people sometimes behave like animals and, for example, puff up like a peacock or behave like a troop of wild monkeys.

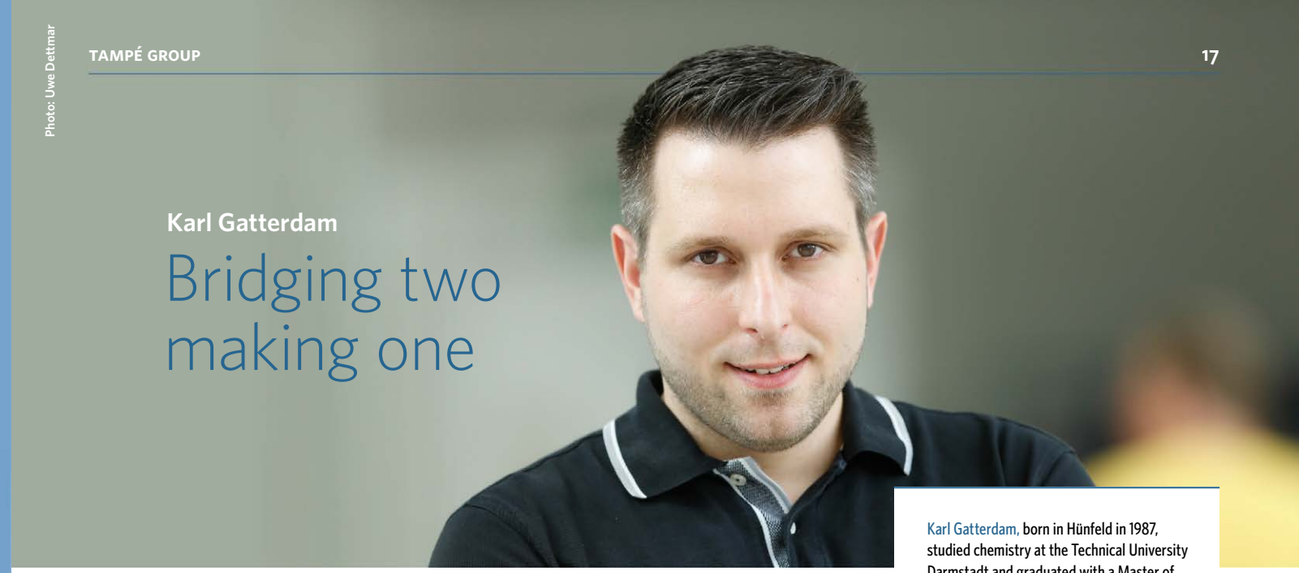


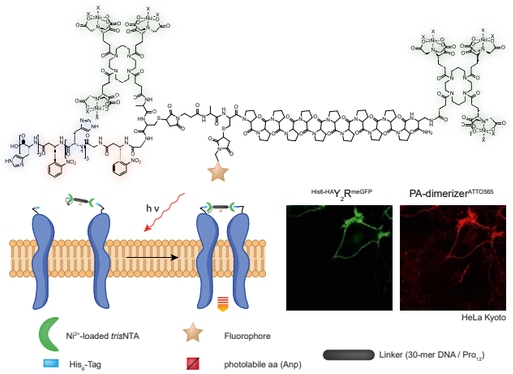
Photo: Uwe Dettmar

Karl Gatterdam

Bridging two making one

Karl Gatterdam, born in Hünfeld in 1987, studied chemistry at the Technical University Darmstadt and graduated with a Master of Science degree. In 2013 he started his PhD project at the Institute of Biochemistry at Goethe University in the group of Robert Tampé. Since 2011 he also has been working in quality management for the Hessian company Fulcoline KG. Gatterdam is a passionate hiker and mountain climber.

Light-induced dimerization Signals are mostly transmitted in cells via entire signalling cascades, ie in numerous successive steps. Such signalling cascades play a central role in homeostasis*, cell division and differentiation. Chemical biology uses small synthetic molecules, which either initiate or inhibit certain reactions with the aim to modify the interactions between proteins – within as well as outside the cell. Important characteristics of these molecules are: reversibility, specificity, stability plus the ability to spatially and temporally control their interaction with the proteins. Chemically induced dimerization (CID) connects two proteins through a small molecule serving as a »bridge«, and is used to manipulate and analyse specific transport processes in cells. The control of this dimerization of two proteins through the use of small lock-and-key elements is essential, so the proteins bind to specific locations in the cell. We develop CID based on a pair of molecules, which can be activated or deactivated by light. It binds very strongly to the proteins and thus contributes to the site-specific assembly of receptors*. In my project I synthesise various »tools« for the dimerization. These molecules differ in the length and flexibility of the »bridge« they form between the interacting proteins. They then can be used to dimerize the receptors in a light-regulated manner.



Chemical structure of a light-activatable polyprolin-based trisNTA dimerizer (tris-N-nitrilotriacetic acid). Before exposure to light, the N-terminal light-activatable trisNTA is completely inactive. After exposure to light, a stable dimer can be reversibly formed with a His-tagged protein.

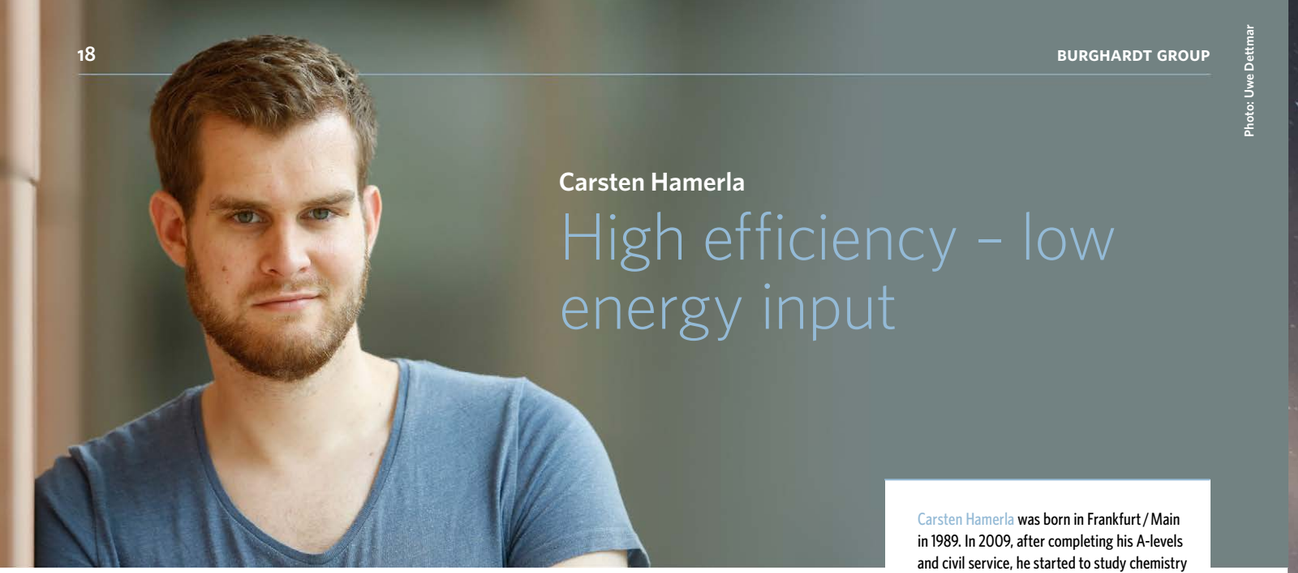


Photo: Uwe Dettmar

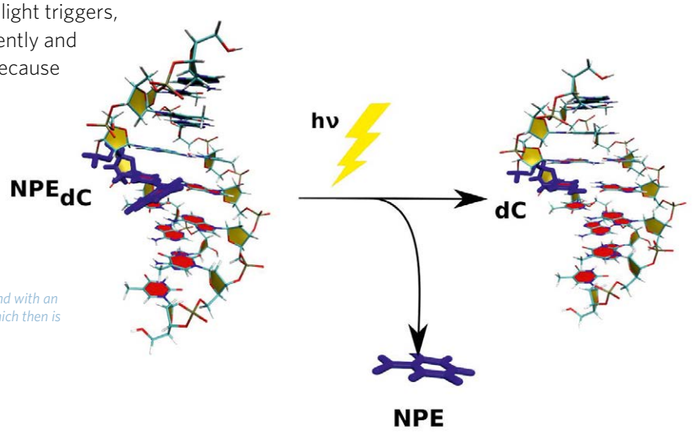
Carsten Hamerla

High efficiency – low energy input

Carsten Hamerla was born in Frankfurt / Main in 1989. In 2009, after completing his A-levels and civil service, he started to study chemistry at Goethe University. In 2016 he completed his Master of Science and began his PhD project in the group of Irene Burghardt at the Institute of Physical and Theoretical Chemistry.

Computer-aided studies of the formation of DNA structures

Deoxyribonucleic acid (DNA*) is the carrier of the hereditary genetic information in all living organisms. In order to fulfill its function, DNA must adopt a specific spatial structure. A common pattern in nature is the double-stranded helical structure. By inserting a light-cleavable molecule as an inhibitor into the DNA, one can prevent the formation of the double strand. Through targeted irradiation with light this inhibitor can be removed again, allowing the DNA to adopt its helical structure. In my work I simulate the destabilisation of the DNA caused by the inhibitor, and also the chemical reactions which occur when the inhibitor is cleaved off with light. I investigate the influence of different caging molecules as well as the influence of the length of the caged DNA region on the stability of the double strand. The aim is to find light triggers, which can be cleaved off more efficiently and with less energy. This is important because DNA can be damaged by irradiation with high energy light.



Shown is a DNA double strand with an incorporated light trigger, which then is cleaved off (»uncaging«).

Photo: fotolia.com/hui_u

If you could study again, would you choose the same subject? Or maybe something completely different?

I definitely arrived in a position, where I am happy. The work is demanding but always interesting and varied. Apart from a few exceptions, I would not want to miss my chemistry studies.

What do you appreciate about the local research conditions?

I particularly appreciate the good co-operation between the different research groups and PhD students. This allows quick exchange of information, and different projects can be worked on by theoretical and synthetic chemistry research groups together. In addition, I am pleased about the many opportunities to attend seminars and conferences, also abroad. The chance to present my work there and to get into contact with other scientists, even personally, always is very helpful.

Where do you feel at home?

Home is a very flexible term for me. I can feel at home anywhere as long as I have a good social environment. In other words, I can definitely imagine to go abroad for some time after my PhD or to permanently emigrate to another country. Of course, I nevertheless feel attached to Frankfurt, otherwise, I think, I would not have been able to spent so much of my life here.

Do you have a favourite film? A favourite book? Why?

I am a big fan of the »The Lord of the Rings« series. Tolkien's books have revived a forgotten genre and influenced a whole generation of writers. The imaginary world created by him is thought-provoking and results in much more need for discussion than one would first assume. As a result, I have probably seen the movies ten times since their release. I still find them exciting and am discovering new aspects about them.

What gives you a thrill or makes you nervous?

If other people around me worry unnecessarily and are exceedingly nervous, then sometimes, this attitude is passed on to me. But generally I am a rather even-tempered person.

»I can feel at home anywhere as long as I have a good social environment.«

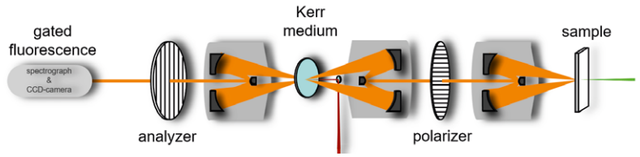
Photo: Uwe Dettmar

Christopher Hammer

Stimulating colours

Christopher Hammer was born in Caracas, Venezuela, in 1988. After his A-levels, he completed his civil service at an inclusive kindergarten. He then studied Chemistry at Goethe University and completed his Master of Science in 2014. During his MSc course, he spent three months at Merck KGaA in Darmstadt. He started his PhD project in the group of Josef Wachtveitl at the Institute of Physical and Theoretical Chemistry in November 2014.

Colour-tunable photolabile protecting groups I am specialised in the use of time-resolved spectroscopical methods, which are able to measure processes lasting from only femtoseconds* to seconds. By comparison, light travels just a fraction of the breadth of a hair within a femtosecond. Using my measurement methods, I follow such fast processes. In my PhD project I study the optical properties of novel photolabile protecting groups. These groups, called »cages«, are able to »imprison« biologically active substances, and thereby inactivate their biological function. Through exposure to light the confined substances can be released from the cage and become active again. A novel aspect of my photolabile molecules is a special kind of antenna, which should facilitate light activation. The antenna can be activated through light of different wavelengths – which corresponds to different colours – and thus makes the system colour-tunable. Especially interesting for biological applications is the excitation with intensive (infra-)red light due to its deep tissue penetration.



Schematic principle of the Kerr shutter, which allows the time-resolved investigation of subpicosecond fluorescence.

Was there a decisive impetus for your decision to study chemistry?

During school I was already fascinated by chemistry. Experiments, which combine practice with theory, were particularly exciting to me. Ultimately, the teacher has significant influence on whether you like a subject at school or not. I was very fortunate that I had a very good chemistry teacher in high school. This led to my decision to study chemistry early on.

What do you appreciate about the local research conditions?

I like the interdisciplinary way of working, and the proximity to co-operation partners. This makes it quick and easy to discuss, for example, results of measurements. Another factor is the wide range of excellent equipment available at Goethe University, enabling us to carry out most of the experiments on site.

During which activities are you especially efficient (in flow)?

I tend to be efficient with everything I enjoy. In terms of work, it is the lab work in particular, which I enjoy most.

Which movie did you see at the cinema recently?

»Passengers«, which is a movie I really liked. Especially the fact that for the most part the film is with two actors only. I found the inner conflict of the main character very interesting, and I imagined my reaction in such a situation.

Do you have a favourite place on Riedberg Campus?

Not really. Most of the time, I am in the office or the lab anyway. Nevertheless, the campus has some nice spots, where students can relax between lectures.

Which entrance music would you choose for your own boxing match?

»Boom« by P.O.D. However, like the band in the video, I would play table tennis and not participate in a boxing match.

Do you have a favourite sport?

In my spare time, I play football and also train a youth football team at the same club. American football is another one of my favourite sports, but in this case I limit myself to watching the games.

Photo: private

Photo: Uwe Dettmar

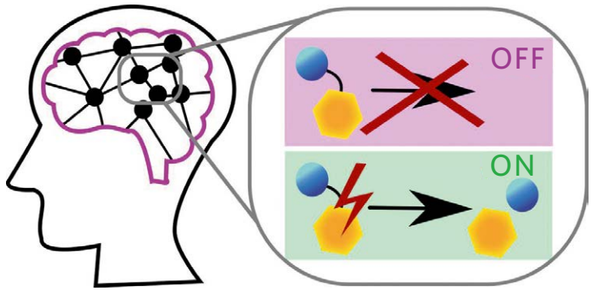
Lisa-Marie Herzig

Antibiotics under control

Lisa-Marie Herzig was born in Fulda in 1988. She studied chemistry at Goethe University and completed her Master of Science in 2014 at the Institute of Physical and Theoretical Chemistry, after spending six months on an internship at Merck in Darmstadt. She started her PhD project in the group of Josef Wachtveitl in 2014. Herzig is interested in oil painting, creative crafts such as knitting, and in training with her dog Murphy.

Targeted control of protein biosynthesis with protected antibiotics

Protein synthesis is a key process in the cell. Many applications would become possible, even in brain research, if one could control this synthesis. Some antibiotics, which inhibit protein synthesis, are already available. However, before using these compounds in experiments to switch off protein biosynthesis, one has to ensure that their action can be precisely controlled. To achieve this control, a so-called protecting group is attached to the antibiotic molecule, which suppresses its effect. With the help of light the protective group then can be selectively removed, whereupon the activated antibiotic immediately stops the protein synthesis. In my PhD project I examine how the release of the light-sensitive protecting groups proceeds at the molecular level. For this purpose, I use different optical measuring methods with a very high temporal resolution of one quadrillionth of a second. This allows the fast chemical reactions to be studied very closely.



Reaction of a light-sensitive protecting group (yellow) bound to an antibiotic (blue).

Photo: private

Do you want to stay in science?

We all ask ourselves this question, when we come near to the end of our PhD projects. Science is appealing because you can conduct research within your own project largely without any restrictions. Industry lures with very varied job offers for scientists. My path will probably lead into the private sector as I have already completed a six-month industrial internship, and I am very interested in the combination of scientific thinking and economic activity.

What do you think would improve the framework conditions for researchers?

An increase in research funding would lead to more freedom and creativity in research.

Do you listen to music while working? If yes, what type?

I really like listening to music. This is why I also listen to music when I have to do creative work. Especially when I prepare presentations and pictures for publications. The right music selection supports the productive process. I listen, for example, to Led Zeppelin, Foo Fighters, The Strokes or Radiohead. However, when I have to concentrate very hard, then music is too much and I prefer to work in silence.

When and where did you spend your last vacation?

My last vacation I spent in the US in the summer of 2016. First, I attended a spectroscopy conference in Santa Fe in New Mexico for a week. Santa Fe is not a typical American city as its entire architecture is inspired by the Pueblo culture. A very colourful city with many art galleries and cultural events, which I probably would have never visited without the conference. Afterwards, I went on a road trip from New Mexico to San Francisco. I particularly liked the stopover at the Grand Canyon. The incredible size and the wonderful colours of the canyon were so memorable, it was an amazing experience.

Do you have a pet?

I have a dog, called Murphy, who needs a lot of exercise. Our long walks are a wonderful balance to everyday life's pressures.

»My path will probably lead into the private sector as I am very interested in the combination of scientific thinking and economic activity.«

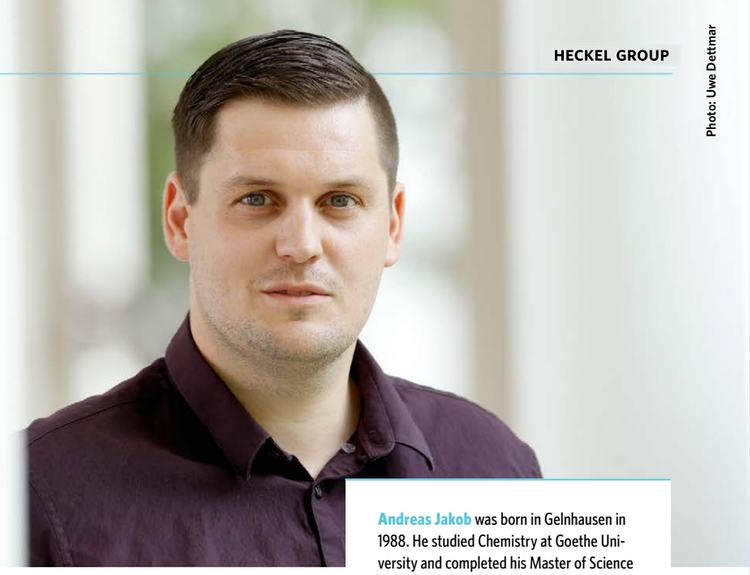


Photo: Uwe Dettmar

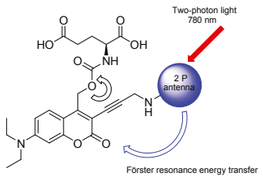
Andreas Jakob

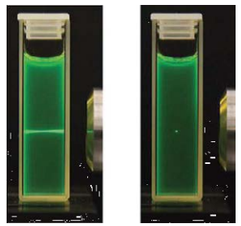
Light collector

Andreas Jakob was born in Gelnhausen in 1988. He studied Chemistry at Goethe University and completed his Master of Science course in 2014. He started his PhD project in the group of Alexander Heckel at the Institute of Organic Chemistry and Chemical Biology towards the end of 2014. Jakob plays handball in the Ballsportverein TV Langenselbold and is also involved in the club's sponsoring activities and events organisation.

Two-photon excitation of photolabile protecting groups

In my PhD project I am working on the synthesis of protecting groups, which can simultaneously absorb two light particles, so-called photons. When both photons hit the molecule at the same time during irradiation, the molecule becomes activated and a photochemical reaction occurs. Two-photon excitation is relevant for medical technology because of its three-dimensional resolution and its high penetration depth into skin and organs. With this technique it becomes possible to selectively release two-photon activatable substances at a precise location within the body by using light. To achieve this effect, strong but short laser pulses are required as well as a complicated design of the protecting groups. Because only molecules with a very specific structure are able to capture two photons at the same time. To increase this effect, I attach antennae to the molecules in a specific sequential arrangement. These antennae collect the light better, and then pass it on to the protecting group within the same molecule.





Left: A neurotransmitter is cleaved off through two-photon excitation via a Förster resonance energy transfer.

Right: A comparison of irradiated samples using either one-photon technology (left cuvette) or two-photon technology (right cuvette). Irradiation at 730 nm results in a three-dimensionally resolved activation spot (green).

Photo: private

Who are your role models?

Bill Belichick, the American football coach of the New England Patriots, Football USA, and the NBA player Lebron James. The two are hard to beat in terms of professionalism.

What do you appreciate about the local research conditions?

That the equipment is high-quality, and that you have everything on your doorstep. Most of the time you do not even have to leave the building or the floor to discuss a research problem with your co-operation partners or other research groups.

During which activities are you especially efficient (in flow)?

While doing column chromatography in order to purify my synthesised molecules, and while I plan new synthesis routes for my PhD project. And also while I write schedules for my undergraduates about their work for the day and the week ahead.

What do you do in your spare time?

Lots of sports – especially handball and fitness training – and enjoying the company of friends, family and teammates during sport or while watching sport. I also like to spend time on my snowboard, in a deck-chair on the beach or on a surfboard.

Do you have a favourite film?

»Any Given Sunday« – a beautiful movie by Oliver Stone about American football on Sundays in the US. It delves deeply into the thinking of men, myths, and illusions. It describes the glittery world of professional American football without omitting the dark side of the business. Especially the last speech of the coach to his players is impressive, when he tells them that they as a team can achieve everything possible, »either, we heal, now, as a team or, we will die as individuals.«

Where do you see yourself in five or ten years?

In a five years' time span as the head of a laboratory in the chemical industry, and later on in higher executive positions of a large company.

»... you have everything on your doorstep.«

Do you want to stay in science?

I would like to work in research funding and envision a job in science coordination.

What do you think would improve the framework conditions for researchers?

The lack of job security is currently one of the problems; I am thinking, for example, about temporary contracts and the Wissenschaftszeitvertragsgesetz. I am also critical of the sometimes very strong focus on a single field of expertise. It would be preferable to have better networking and communication between research areas. In my opinion, research training groups as well as scientific conferences, which clearly aim for bringing together researchers from different fields, can contribute to this.

How does your research benefit society?

Respective my specific project, it contributes to society since I am searching for specific building blocks, which can be used for a technique to investigate something. At first glance this sounds like being high up in the »ivory tower«. This »something« can be, for example, biological systems, therefore you arrive quickly at major questions: How does this work? How does this protein function, or a cell, or life in general? However, I also find it valuable to understand the physical effects we want to utilise as they are another piece of the puzzle, which is our complex concept of the world, and to gain a better idea of where it might fit.

Which person comes to your mind when you hear the word »successful«?

When I hear »successful«, I think of Robert Falcon Scott. He was a British polar explorer, who lost the race to the South Pole. The Norwegian Roald Amundsen not only was the first to reach the South Pole but Scott and his expedition team even died in the ice on their way back. Yet Scott was worshiped as a great British hero for quite some time. His end was perceived as tragic but also as very heroic. Later, several biographies were published, which described Scott as incompetent and as an irresponsible leader of a doomed enterprise. More recent assessments provided evidence that he indeed had to deal with exceptional bad weather, amongst other things. All in all, this man's fate not only demonstrates the effects of pursuing success at all costs but also the fact that often success is determined by the reception of posterity.

»When I hear ›successful‹, I think of Robert Falcon Scott.«

Photo: Herbert George Ponting

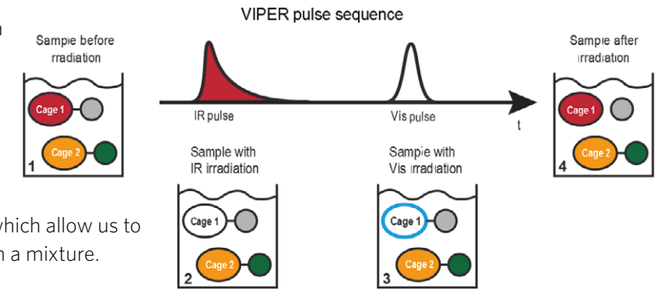
Photo: Uwe Dettmar

Daniela Kern-Michler

A bit like cherry-picking …

Daniela Kern-Michler started to study biophysics at Goethe University in 2009, after finishing school, and completed her studies with a Master of Science degree in 2014. She started her PhD project in the group of Jens Bredenbeck at the Institute of Biophysics at Goethe University in November 2014.

Strategies for the removal of photolabile protecting groups based on the VIPER method My work is part of a project, in which we are using the new VIPER-2D-IR spectroscopy technique to release a specific type of molecule within a mixture of molecules from its photolabile protecting group, its so-called »cage«. This allows for new strategies of controlling light-induced reactions by combining infrared and visible light. The infrared light chosen is very specific to certain molecules, while the visible light provides the energy necessary for the reaction. The positions and mass of the individual atoms within a molecule determine the wavelength the absorbed infrared light needs to have. Through incorporating isotopes – which are atoms with the same chemical properties but a different mass – at different points within a molecule, we manage to produce molecules with very similar properties, which nevertheless can be selectively excited by infrared light. My job within the project is to identify a suitable molecule, to find suitable isotopomers* and to determine the appropriate experimental conditions, which allow us to selectively release individual compounds in a mixture.



Detachment of photolabile protecting groups based on the VIPER technique
Pulse sequence: Infrared light (IR pulse) in red, visible light (Vis pulse) in blue.

- *1: Mixture of two photolabile protecting groups (cages)*
- *2: Cage 1 is excited by the IR pulse*
- *3: Cage 1 is excited by the Vis pulse*
- *4: The leaving group of cage 1 (grey circle) has been removed by the exposure to light, but not that of cage 2.*

Photo: Uwe Dettmar

Sara Keyhani

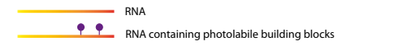
To fold at will

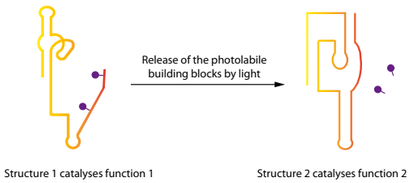
Sara Keyhani was born in Teheran in 1988 and lives in Germany since 1997. She studied chemistry at Goethe University and completed her Master of Science course in 2014. She started her PhD project in the group of Harald Schwalbe at the Institute of Organic Chemistry and Chemical Biology in 2014. Keyhani's favourite leisure activities include reading, travelling and sports.

Control of RNA function using photolabile building blocks

For a long time, scientists were convinced that DNA* is the carrier and RNA* merely the transmitter of the genetic code, the hereditary information. During the last thirty years, RNAs have been discovered which can do a lot more: they regulate and speed up important reactions in the cell. Therefore, it is of great interest to control the function of such RNAs in the cell.

The function of RNA is highly dependent on its spatial structure. This gives us the opportunity to control its function by incorporating photolabile protecting groups in such a way into the RNA that they block those parts of the molecule which are important for its correct folding, thereby changing the shape of the RNA. The structure is restored, when the photolabile protecting groups are removed through irradiation with light. In our project we demonstrate this with an RNA which can adopt two different structures. The photolabile groups take up space, block interactions and force the RNA into the first structure, in which the RNA has a specific function. The removal of the photolabile groups through irradiation allows this RNA to fold into the second shape, which has another function. Thereby we achieve a temporal as well as a spatial control of RNA function.





This RNA can adopt two shapes, each with a different function. When the photolabile building blocks are attached, the RNA adopts structure 1 and when they are absent, it adopts structure 2.

Photo: Photocase/ghlap

»I have a thousand thoughts connected by many bridges.«

Who are your role models?

There are many exemplary people, in the present as well as in the past. Mahatma Gandhi, for example, because of his nonviolent resistance, or Joanne K. Rowling, who wrote a bestseller as a single mother living on social security benefits; and Johanna Quaas, the oldest female competitive gymnast in the world.

Which other discipline, far from your own, is of particular interest to you and is perhaps a source of inspiration?

While at school, I had great fun with translating German literature from the German lessons and Kafka's short stories into Persian. This allowed me to share my knowledge with my relatives and friends living in Iran. When I finished school, I thought about becoming an interpreter. However, my strengths have always been the natural sciences.

On lolmythesis.com, PhD students summarise their work in a single, often humorous sentence. What would that sentence be?

I have a moody RNA under my control.

What do you do in your spare time?

I exercise, dance, watch series or visit my family. I like to travel very much and to learn international dishes en route, which I like trying out at home.

What does your circle of friends look like? Are they mainly scientists or rather mixed?

My circle of friends is fairly mixed.

If you were a city, which one would that be and why?

Venice. I have a thousand thoughts connected by many bridges.

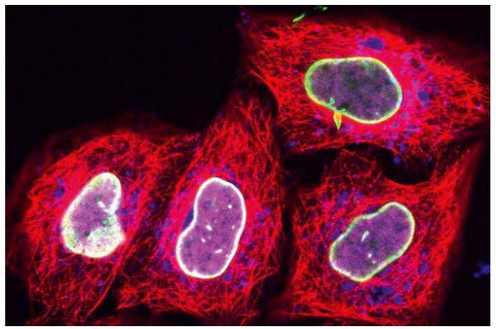
Photo: private

Alina Klein

Small and precise

Alina Klein was born in Kirchheimbolanden in 1987 and studied Biomedical Science at Philipps University Marburg. She received her Master of Science degree there in 2012 and started her PhD project in the group of Robert Tampé at the Institute of Biochemistry at Goethe University in 2013. She started to work as project manager in the area of clinical development at BioNTech AG in Mainz in summer 2017. Her recreational activities include the martial art Krav Maga and Tough Mudder, an obstacle course in which you participate as a team. She also likes to take pictures, and she writes and draws.

Protein labelling in living cells under high pressure It is very difficult to observe specific proteins in a living cell and to follow their mobility. The biggest challenge is to introduce probes for protein labelling into the cells. Together with colleagues from the Massachusetts Institute of Technology (MIT, Cambridge, USA), we have used a microfluidic method to deliver fluorescent markers into living cells with high pressure and in a precisely dosed manner. With a precision of a few nanometers* these synthetic molecules then bind to a protein, which has a very specific matching sequence of amino acids. The probe is tiny – it has a diameter of about one nanometer – and therefore does not interfere with the function of the labelled protein. This method enables us to mark cells in a high-throughput manner and to study them subsequently under the microscope. Together with the group of Mike Heilemann, we were even able to take high resolution images of living cells. Using light, we can also control the precise moment, when the probe is activated and binds to the target molecule.



The fluorescent probe trisNTA (green) precisely labels the nuclear envelope protein Lamin A. At the same time, other labelling methods are used to make visible the microtubules of the cytoskeleton (red), lysosomes (blue) and the nucleus (magenta) of the cells.

Photo: Alina Klein

»As a scientist, I think, you can learn quite a bit from marketing.«

Which other discipline, far from your own, is of particular interest to you and is perhaps a source of inspiration?

As a scientist, I think, you can learn quite a bit from marketing. The simpler and more interesting you can present your research results, the more colleagues will be interested and able to use them.

Do you listen to music while working? If yes, what type?

Yes, when I am alone, I like to listen to hip-hop and rap, such as early in the morning or while working at the microscope. When my colleagues are around, I rather chat with them. An exception is cell culture: then music is compulsory, as one can easily spend several hours there.

Where do you feel at home?

Generally, I feel at home where most of my things are. However, my favourite place is the reading corner in the cosy attic.

Do you have a favourite place on Riedberg Campus?

Yes, the room where I take my fluorescence images. It is quiet there and usually colorful.

Photo: Uwe Dettmar

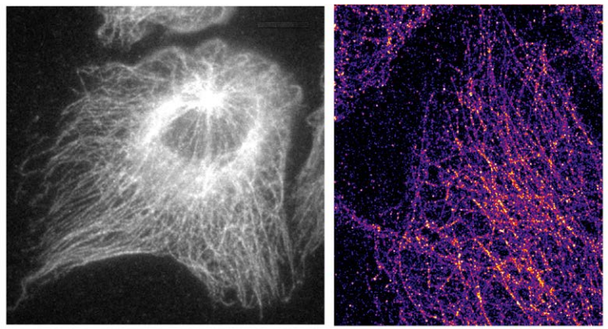
Dean-Paulos Klötzner

Glowing dyes

Dean-Paulos Klötzner was born in Offenbach am Main in 1987. He studied chemistry at Goethe University and received his Master of Science degree in 2014. Klötzner has been working on his PhD project in the group of Alexander Heckel at the Institute for Organic Chemistry and Chemical Biology since then. His additional qualifications – certified project manager for industrial chemistry/GDCh as well as knowledge in GMP and quality management – demonstrate his interest in economic contexts. Klötzner is an enthusiastic scuba-diver, a hobby which can be combined very well with his love for travelling and photography.

Structure and dynamics of modified nucleic acids and design of new fluorophores In four sub-projects of my PhD project I am synthesising modified nucleic acids – DNA* and RNA* – the carriers of the genetic information. These biomolecules have a defined biological function. We can regulate their function by introducing photolabile protecting groups, which can be removed again by light irradiation. In collaboration with other research groups, we analyse our samples with nuclear magnetic resonance (NMR*), which provides us with new insights into the structure and dynamics of the molecules.

In another sub-project I develop new dyes, so-called fluorophores. These are luminescent molecules which are used in high-resolution fluorescence microscopy. With super-resolution fluorescence microscopy* tiny components of cells can be made visible with a precision which is not achievable with ordinary optical microscopes. When designing and synthesising fluorophores, I first consider specific criteria such as water solubility and stability, and then investigate them for their suitability for microscopy.



Cells labelled with photo-activatable fluorophores. The wide-field image (left) shows a whole cell with some adjacent cells. The high-resolution image (right) shows a section of a cell, in which the delicate structures of the cytoskeleton are visible.

Photo: private

How does your research benefit society?

The biomolecules, which I synthesise, can be used, for example, for the regulation of vital life processes such as gene expression. Society benefits from the newly gained knowledge if such essential processes can be regulated with precision inside organisms. It has become possible to apply light in a very precise manner. This is a precondition for being able to use light-controlled gene regulation in the future to cure various diseases.

What does research give you?

My research gives me a valuable sense of achievement and enrichment. Through research I experience ups and downs in a new way. At the beginning, you are faced with many complex questions. One starts with considering them systematically thus receiving first results, which later are assembled into a complete picture.

It is a varied job that constantly presents me with new, demanding tasks, which need to be mastered. Due to the strong project-related character of my research, I often collaborate with other PhD students, which makes the work as interactive as it is interdisciplinary.

On lolmythesis.com, PhD students summarise their work in a single, often humorous sentence. What would that sentence be?

Teaching substances to swim, which flash at the touch of a button before they break.

What does your circle of friends look like?

My circle of friends mainly consists of non-scientists. This mixture often makes it all the more interesting and entertaining, when a computer scientist, a tax adviser, a media designer and a scientist exchange their points of view about their everyday's life.

What gives you a thrill or makes you nervous?

The uncertain outcome of an important reaction, skydiving, boxing (on TV), shopping with my wife, too little time between connecting flights, increased rain probability on summer weekends.

Do you have hobbies?

To relax and recharge my batteries, I love to travel, take pictures and scuba-dive in my spare time. Getting to know foreign cultures in distant places, experiencing local lifestyles and enjoying nature – above or below water: That's what makes travelling special to me. Always with the camera in my luggage, I love to explore cities, strolling through the streets of a historic city centre, and resting in a small cafe away from the tourist bustle.

»Always with the camera in my luggage, I love to explore places.«

If you could study again, would you choose the same subject? Or maybe something completely different?

I studied biomedical chemistry in Mainz. The course consisted mainly of chemistry plus some lectures in biology, pharmacy and medicine. Initially, as an undergraduate I found it rather confusing. However, I benefited enormously from it during my PhD project. In our research group there are PhD students from various fields of science, and many research projects are interdisciplinary. Therefore, it is very helpful if the degree course is interdisciplinary, too. So I would study it again.

What do you think would improve the framework conditions for researchers?

I am essentially satisfied with the framework conditions.

Do you listen to music while working? If yes, what type?

I really enjoy listening to music while I synthesise compounds or prepare presentations. The type of music is quite diverse. Depending on my mood, it ranges from techno to hip-hop and sometimes – if the mood is exuberant – even to pop songs.

What makes you nervous?

For me, oral presentations in front of a large audience or with many new people are still quite agitating. If I have the opportunity I like to go into the room before the event, to get used to the position and the view from the speaker's desk.

Do you have hobbies?

I love to run half marathon, marathon and obstacle races. Running helps to clear the mind from things that worry me, and I can relax and come up with new ideas. Besides, running with friends can be very communicative, and one can motivate each other to achieve more ambitious running goals.

My number one hobby normally is dressage and show jumping. Unfortunately, it is very time-consuming, so I am taking a break. I hope to resume it with a horse of my own, after my PhD graduation.

Photo: Sportograf.com

»Running helps to clear the mind.«

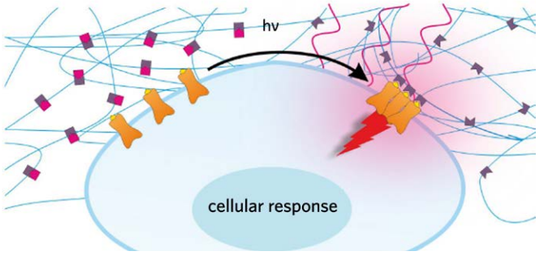
Photo: Uwe Dettmar

Heike Krüger

Wrapped cells

Heike Krüger was born in Mainz in 1990, studied biomedical chemistry at Johannes Gutenberg University in her hometown and graduated with a diploma in 2016. She started her PhD project in the group of Ralph Wieneke at the Institute of Biochemistry of the Goethe University in March 2016. Heike Krüger was a youth group leader in the German scouts movement during her degree course. Running is one of her favourite leisure activities, especially half marathons and marathons, but she also likes dressage and ballroom dancing.

Defined structuring of surface proteins on living cells The behavior of cells is highly dependent on their environment. This includes the so-called extracellular matrix, ie the space between cells, which also contains numerous proteins. This matrix affects the fitness of the cell, whether it divides, changes its metabolism, or even dies. My research project aims not only to systematically mimic the direct environment of a cell but also to influence it by spatial and temporal control of protein organisation. For this purpose, the cells are embedded in hydrated polymers, so-called hydrogels, which contain light-activatable lock-and-key pairs. When the hydrogel is irradiated at defined points with a laser, selective activation (opening) of the pairs takes place. At the exposed areas the released substance then interacts with the proteins of the cell membrane. This allows a non-invasive, spatially-defined structuring of surface proteins of the cell membrane by using light. The aim is to control protein networks in living cells in order to be able to examine them in a targeted manner.



The embedding of cells in a light-activatable hydrogel allows a spatially defined structuring of surface proteins, whereby protein networks in living cells can be influenced and investigated.

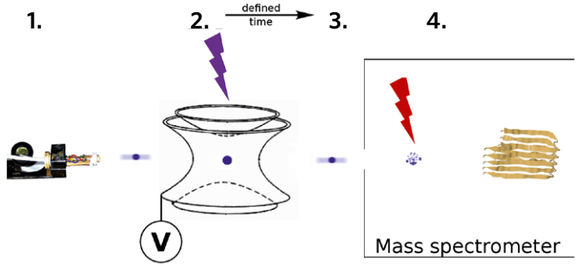
Photo: Uwe Dettmar

Tobias Lieblein

Exploding water droplets

Tobias Lieblein was born in Offenbach am Main in 1988 and started to study biophysics at Goethe University in 2008. He completed his studies with a Master of Science in 2013. Since 2014 he is working on his PhD project in the group of Nina Morgner at the Institute of Physical and Theoretical Chemistry. For many years, Lieblein was an active member of the voluntary fire brigade of his hometown Hainstadt, especially caring about youth work.

Time-resolved mass spectrometry In order to understand biological processes, one should not only ask the question, »Which substances are involved?« but also, »How fast do these processes happen?« To study this, I refine the mass spectrometry (MS) method LILBID*. This method uses tiny water droplets in which the biological sample is enclosed. The droplets are injected into the mass spectrometer and irradiated with a high power laser. The absorbed laser energy leads to the explosion of the water droplet, which enables us to identify the biological sample. To obtain an indication of the speed of biological processes, one needs to be able to take measurements in a time-dependent manner. For this purpose, we use strong electric fields which are similar to the strength of power lines. They serve as an electrical trap and keep the droplet flying contactless. Laser light then irradiates the sample and starts a reaction. The droplet is released from the trap into the MS device after precisely defined times, and the reaction is investigated at different times. This gives us a picture of the time course of the reaction.



1: Generation of the droplets;
2: Capture in the electric field and irradiation with the laser;
3: Release from the trap;
4: Analysis in the mass spectrometer.

If you could study again, would you choose the same subject? Or maybe something completely different?

If I had to choose again the subject I would like to deepen my mind in, the result probably would be the same. I would also choose the same explicit discipline, as I think that biophysics covers the very interesting interface between the three conventional natural sciences: chemistry, biology and physics.

What do you appreciate about the local research conditions?

In Frankfurt, all natural science faculties and two Max Planck institutes are located on the same campus, with several companies in the immediate vicinity. This favors strong networking and co-operation, which becomes apparent in collaborative research centers and graduate schools. I think that strong co-operation as well as sharing of skills and knowledge provide good research conditions leading to successful science.

Which person comes to your mind when you hear the word »successful«?

Professor Stefan Hell. Despite many ups and downs, I think, you are successful in what you are doing if your dream or idea ultimately turns out to be correct and feasible, and if it is rewarded. And which reward can be greater than the Nobel Prize? I think that constantly searching for security hinders your ability to think freely, and this can block good science. It must be allowed to think creatively and to pursue a dream, an idea – with necessary stamina but without disconnecting from reality.

Are you a city or a country person?

I think both places have their advantages and disadvantages, which are certainly dependent on the stage of one's life. As a young adult, I enjoy the vitality and all the opportunities of city life. However, if you want to settle down and have a more quiet life, I can imagine to do that in the countryside. For sure not far away from a metropolitan area and thus still close to all its urban opportunities, but in a quieter, safer and cleaner environment than in the heart of the city.

What does the first hour of your day look like?

I take my time and try not to rush, which usually works well for me. I definitely need a shower to become properly awake and to have a positive start into the day. After that, I enjoy a cup of good coffee, definitely listen to music playing in the background. I reflect about the day's tasks and try to plan roughly what I want to achieve. Then I leave the house, and the day begins.

Photo: Fotolia.com/Martin Bergsma

»It must be allowed to think creatively and to pursue a dream, an idea.«

Photo: Uwe Dettmar

Julian de Mos

From a cone to a cylinder

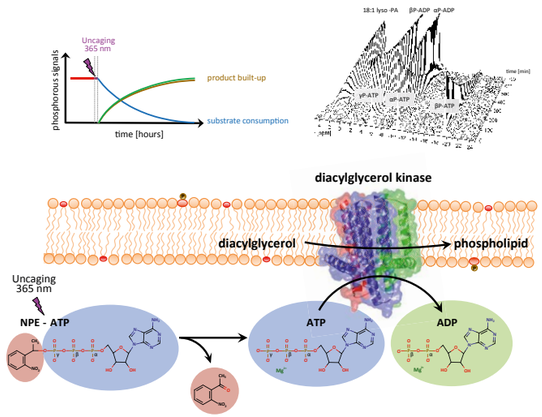
Julian de Mos, born in Darmstadt in 1988, studied biochemistry at Goethe University, where he received his diploma in 2014. He wrote his diploma thesis in the group of Hartmut Michel at the Max Planck Institute of Biophysics in Frankfurt. During his studies, he spent time in Anthony Watts' lab at the University of Oxford, in Manuel Grez's lab at the Georg Speyer House in Frankfurt, in Holger Lößner's lab at the Paul Ehrlich Institute in Langen and in Dieter Steinhilber's lab at Goethe University. In 2014 he started his PhD project at Goethe University in the group of Clemens Glaubitz. De Mos is a keen sailor and skier.

Studies on the activity of a membrane enzyme Most biological lipids* consist of lipophilic hydrocarbon chains and a polar hydrophilic headgroup. If there are too many lipids without a headgroup in the cell membrane, then the structure of this largely flat double layer of lipids is disturbed. The reason: The shape of lipids without a headgroup is not cylindrical but conical, in contrast to other lipids.

The membrane enzyme diacylglycerol kinase* transfers a phosphoryl group from ATP*, the energy source of the cell, to lipids without a headgroup and thus converts them into more membrane-compatible cylindrical phospholipids.

We investigate this reaction in more detail by following the enzyme activity with the aid of phosphorus solid-state nuclear magnetic resonance spectroscopy*. To start the reaction within the spectrometer, we used protected substrates, which do not interact with the enzyme. We were able to successfully convert these substrates to the actual substrate by illumination in the spectrometer, which cleaved off the photolabile protecting group.

The enzymatic transfer of the phosphoryl group within a membrane system consisting entirely of lipid substrate was carried out without losses, such as release of phosphate by ATP hydrolysis.



UV light splits off NPE, and ATP becomes accessible to the diacylglycerol kinase. Subsequently, the consumption of ATP and the formation of phospholipids can be monitored by means of time-resolved phosphorus solid-state nuclear magnetic resonance spectroscopy.*

Photo: Photocase/Dirk Hinz

»For me, the fascination of sailing lies in the contrast of technology and strength, theory and feeling.«

What do you do in your spare time?

When I take a vacation, it is usually to go sailing or skiing. For me, the fascination of sailing lies in the contrast of technology and strength, theory and feeling. Experiencing nature in places, which humans cannot reach without effort and technical help, probably describes the longing and motivation for sailing as well as for skiing. My regular sailing club close to home is the Segel Club Rüsselsheim.

Being able to participate actively in a non-profit association, to teach others how to sail, to see their joy in learning and their sporting successes, is an additional motivation for me since becoming a youth leader in 2012.

Do you have hobbies? Which and why?

In addition to sailing or work, my technophile, creative vein comes through at home, too. As soon as an idea gets stuck in my head, and I start to think about it, it drives me, and it is very hard to get it out of my head without putting it into practice and perfecting it. Especially when it comes to sailing boats, club websites, electronic gadgets or lighting. True to the motto: The goal is set up, it is not outlandish, thus it must be feasible.

If you were a city, which one would that be and why?

An interesting question: one has to think about it. Who has ever reflected over being compared to a city? And who is not tempted to seek an ideal? Oxford, Heidelberg, Berlin, Mettmann ... Maybe the city where one lives describes the person the best: after all, he or she is part of it. Therefore, I would choose Frankfurt, this big city, which is not conceited but which also presents itself initially as uncommunicative, brusque and unapproachable. Frankfurt with all its rough edges and contrasts becomes tangible, when you engage with it, and you understand that this city is open-minded towards everyone. Especially, when you do not expect it.

Photo: Uwe Dettmar

»The physics degree course also offers a lot of choices in terms of optional modules and subsidiary subjects.«

If you had to summarise your research in ten words, which would you choose?

Pulsed lasers, infrared spectroscopy, data analysis, publications, setup construction, programming.

Do you listen to music while working? If yes, what type?

A colleague in our office often turns on his radio, so I listen to music while I'm there. Usually, it is Hitradio FFH.

How does your research benefit society?

Basic research enables us to gain new insights also into areas of science, which cannot be exploited directly for commercial purposes. By this means, scientific progress develops from a broad basis, which will enable sustainable development in the future as well.

The VIPER pulse sequence, which I study as part of the research training group, also contributes to this goal. Respective its use in uncaging, VIPER provides a way to select a particular kind of molecule from mixtures of different species with indistinguishable visible absorption spectra, and it releases its protecting group without affecting the other species. This technique is interesting for a whole range of applications in chemistry and biology.

If you could study again, would you choose the same subject? Or maybe something completely different?

I would study physics again. A physics degree course teaches you from a scientific point of view how the world functions, and thus you gain a broad understanding of many interesting physical effects and phenomena. The physics degree course also offers a lot of choices in terms of optional modules and subsidiary subjects. Already after completion of the foundation training, every student enrolled in the undergraduate course can specialise in the areas of personal interest.

What do you think would improve the framework conditions for researchers?

One of the biggest disadvantages in research is the fact that scientists usually do not receive permanent positions until they are appointed to a professorship. Employment contracts issued for a duration of several years would help to better plan one's professional and personal future.

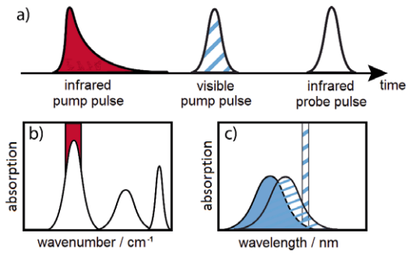
Photo: Uwe Dettmar

Carsten Neumann

The search for the largest signal

Carsten Neumann studied physics at Goethe University and completed his Master of Science course in early 2014. In May 2014 he started his PhD project in the group of Jens Bredenbeck at the Institute of Biophysics.

Analysing and optimising the VIPER effect The aim of my PhD project is to better understand and to optimise the VIPER* effect, which stands for »VIbrationally Promoted Electronic Resonance«. If a sample contains several molecular species, which cannot be distinguished by spectroscopic methods in the visible spectral range, it was impossible to excite only one of these species electronically. The VIPER pulse sequence now provides this option by using two consecutive laser pulses for excitation. The first laser pulse is in the infrared range and allows excitation of only one species. Upon vibrational excitation the absorption spectrum in the visible range is changed to be resonant with the following visible pump pulse. When the visible laser pulse then hits these excited molecules, it provides them with enough energy to trigger a photoreaction. In addition to photochemistry, there are also applications of VIPER in spectroscopy as it allows to study chemical processes in equilibrium for a much longer period of time than before. Examples of parameters, which I examine in order to optimise the VIPER effect, include the time interval between the laser pulses, their polarisation, energy, and wavelength. Furthermore, I am developing another experiment to directly measure the influence of the infrared pump pulse* on the visible absorption spectrum.



a) VIPER pulse sequence consisting of the infrared pump pulse, the visible excitation pulse, and the subsequent infrared detection pulse.

b) Excitation of a vibrational mode in the infrared spectral range, with the red bar indicating the infrared pulse.

c) Shift of the visible absorption spectrum caused by vibrational excitation, with the blue hatched bar indicating the visible pulse.

Photo: Uwe Dettmar

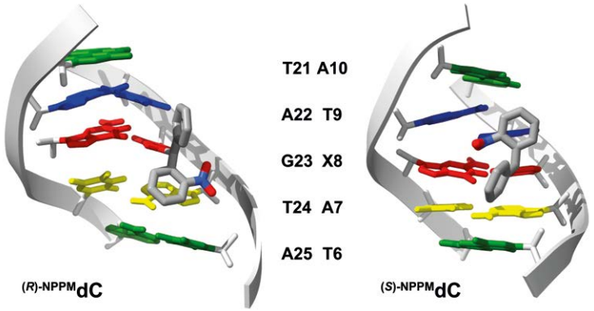
György Pintér

Better protection

György Pintér was born in Szeged, Hungary, in 1987. He studied chemical engineering at the University of Budapest and graduated in 2013 with a Master of Science degree. He then started his PhD project at Goethe University in the group of Harald Schwalbe at the Institute of Organic Chemistry and Chemical Biology. Pintér plays squash in the amateur league. As a passionate hobby chef, he likes to experiment with exotic spices and recipes. Among his favorite readings are short stories of contemporary literature.

Structural analysis of »caged« DNA We are looking for new photolabile protecting groups which are suitable for biomolecules, especially for DNA* and RNA*. The reason: With such protecting groups it is possible to control biochemical processes in the cell with the help of light. Currently, we need many different protecting groups in a single biomolecule to turn on or off a particular biochemical process. This is unfavourable as it requires a high-power laser irradiation.

With NMR spectroscopy* I can contribute to the design of better protecting groups. This method allows me to study the thermodynamics* and the three-dimensional structure of the »caged« DNA with the attached protecting groups. By that means, I can understand the structural and thermodynamic changes at the atomic level. How does a protecting group or its different chemical components affect the biomolecule? This teaches us the direction we should move in order to achieve further improvement of the protecting groups.



Three-dimensional structures, determined by NMR measurements, of two photoprotected DNA molecules, which differ solely in the configuration (R left, S right) of the bond of the photocage.

Photo: Photocase/VICUSCHKA

»Frankfurt with its many skyscrapers really is a unique city in Europe – I really like the skyline.«

What brought you to Goethe University?

England and Germany have been my favorites when I looked for research opportunities abroad. Germany in particular, because it not only has a long tradition in NMR spectroscopy but also has very established and well-equipped NMR centers. I then found some very interesting projects on »Naturejobs«, including the add by this graduate programme. This project not only gives me the opportunity to conduct my own research but also to work in a multifaceted environment at the same time.

What do you appreciate about the local research conditions?

The research conditions are great. The laboratories are very well equipped. But that's not all. Equally important are the experts, who are always ready to help. My supervisor encourages everyone to develop own ideas and to try them out – I think that's great!

How would you describe yourself as a scientist? And how as a »private person«?

As a scientist, I am indeed an NMR spectroscopist. I love to solve structural biological problems with this versatile and very powerful method. I like both: finding answers to interesting structural biological questions and developing new methods.

As a private person, I love sports, especially squash. Or I go to the fitness center or hiking in the summer and skiing in the winter. I really like cooking for my friends and having a good time eating together – and tasting wines during our meals.

Are you a city or a country person?

I am definitely a city person. I enjoy the numerous museums and other cultural events. And I am able to find all the different exotic spices, fruits and vegetables I need for my hobby, cooking.

How do you like Germany and Frankfurt?

I really like Germany! The people are always friendly and helpful. That makes it easy to find friends.

There are many beautiful places in Germany, and above all: it is located in the center of Europe. France and Belgium are just a stone's throw away. I like to visit big cities like Munich or Berlin, but also smaller places like Aschaffenburg or Heidelberg. The countryside offers many beautiful hiking areas. My favourite is the Odenwald.

Frankfurt with its many skyscrapers really is a unique city in Europe – I really like the skyline. It is an international city, which makes it is easy to feel at home here. Although it is a big city, you can find plenty of green areas. The Taunus with its hiking opportunities is not far, or you can take a walk along the banks of the Main and lie down on one of the meadows – many opportunities for a relaxing weekend. In winter, I especially like the Christmas market. It makes you feel like being on holidays. Enjoying a couple of mugs of Glühwein with friends is the best!

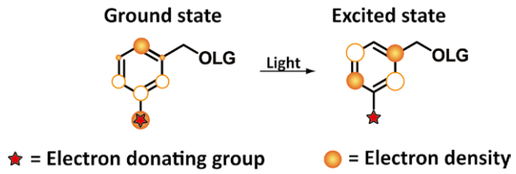
Photo: Uwe Dettmar

Matīss Reinfelds

New and optimised

Matīss Reinfelds was born in Riga, Latvia, in 1990. He studied chemistry in Riga, went for three months with the Erasmus programme to work at the University of Oulu in Finland and completed his Master of Science in 2014. In November 2014 he started his PhD project in the group of Alexander Heckel at the Institute of Organic Chemistry and Chemical Biology. Reinfelds' hobbies include analog photography. He also loves nature and likes hiking.

Synthesis of light-activatable compounds My PhD project is about the design of new photolabile protecting groups (PPG). The development of PPGs requires a combination of organic, physical and theoretical chemistry. Five decades ago, chemists already knew that the reactivity of the ground state differs from the one of the excited state. The so-called meta effect is one example, and my scientific interest is focused on investigating the scope and limitations of this effect. I prepare different molecules and then carry out photochemical experiments, such as, for example, the determination of the molar extinction coefficients* and the quantum efficiency* of photoreactions. I collaborate with the CLiC members of the Burghard research group to explain the observed properties. The results of their calculations help me to explain trends I have observed in my experiments. Only through co-operation of the different research areas we can reach our *magnum opus*.



The meta effect: In the ground state, the electron density is not the same as in the excited state. This change in the electron density distribution after irradiation with light can be used to facilitate a photochemical reaction.

Photo: private

Was there a decisive impetus for your decision to study chemistry?

I have always been interested in science. At the end of high school, I only had to choose between chemistry and medicine. In the end, I chose chemistry and really enjoyed it. During my university studies, I relished to learn more about the laws of chemistry and nature in general.

What brought you to Goethe University?

After my master's degree in Latvia, I wanted to discover new horizons to learn how people conduct research outside the borders of my country. Germany was an obvious choice because of its long-standing tradition in chemical research. During my search for a position, which would fit my interests and training, I came across CLiC. I found the concept of a graduate programme very interesting. The invitation to the CLiC interview was very exciting. Three months later, I started my first day as an employee of Goethe University.

How would you describe yourself as a scientist? And how as a »private person«?

Scientific work gives me the freedom to pursue new ideas. The ability of the human mind to create new ideas is unlimited. I very much enjoy experiencing this with my own intellectual work. It is very satisfying to observe the impact of my theoretical knowledge in practice and to apply it in my own research. I like sharing all this with the students I work with. My professional life has a positive effect on my spare time. For example, one of my hobbies is analog photography, and I like to prepare the chemical solutions for the development of films. There are always new things to learn here, too. Of course, I also need time to process everything that I have learned. I enjoy sports, nature, travelling, music, and above all, spending time with my family and friends.

How do you plan your day?

I have developed my favorite routine: a hot drink while finalising my daily plans. I like to carry out my experiments in the morning, and to spend the afternoon with the analysis of the results.

»The ability of the human mind to create new ideas is unlimited.«

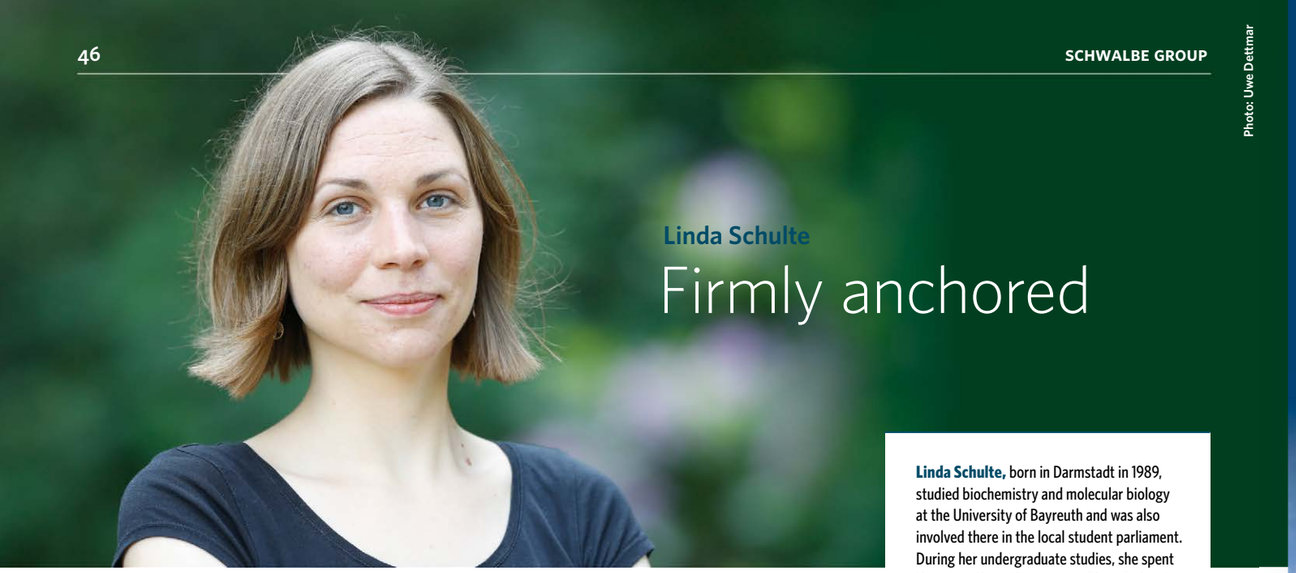


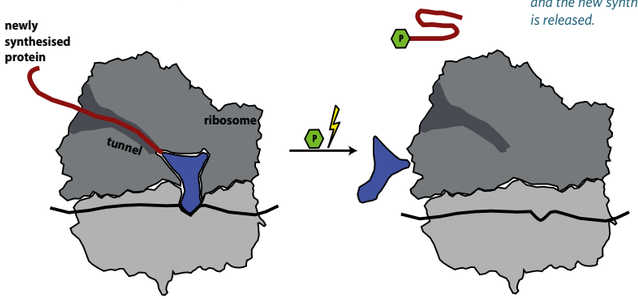
Photo: Uwe Dettmar

Linda Schulte

Firmly anchored

Linda Schulte, born in Darmstadt in 1989, studied biochemistry and molecular biology at the University of Bayreuth and was also involved there in the local student parliament. During her undergraduate studies, she spent three months in the group of Oliver Fiehn at the University of California in Davis, USA. During her Master of Science course, she went for six months to the group of Marcellus Ubbink at the University of Leiden in the Netherlands. In 2014 she received her MSc degree and then started her PhD project in the group of Harald Schwalbe at Goethe University. Sports such as climbing, running and volleyball are some of her leisure activities, as well as playing the guitar, going to concerts, reading and cooking.

Folding of proteins in the ribosomal tunnel We want to explore how a protein assumes its three-dimensional structure and its function. Proteins are synthesised in the cell by ribosomes*. The growing peptide chain is channeled through a tunnel in the ribosome and usually begins to fold simultaneously. By using a peptide sequence, which »arrests« the peptide chain* in the tunnel, we want to anchor protein chains of different lengths to the ribosome. We then can study the folding of the anchored protein at atomic resolution using NMR spectroscopy*. This technology allows us to investigate whether the protein is folded or unfolded. Due to the different lengths of protein chains used, we can also see the point of the ribosome, where the folding starts. The release of the protein chain from the ribosome should be obtained by the antibiotic puromycin, which has been deactivated by adding a photolabile protecting group. By irradiation with light of a specific wavelength, we can remove this protecting group and release the protein chain. This allows us to examine the process as it occurs inside the cell, in contrast to earlier studies using full-lenght proteins, which first were unfolded and then refolded again.



The protein is synthesised at the ribosome and anchored to the transfer RNA (blue) by means of a peptide sequence. By adding puromycin (green hexagon) and light, the anchoring is removed and the new synthesised protein is released.

Photo: Photocase/bernjuer

What brought you to Goethe University?

After I graduated from the University of Bayreuth, it was time to see something new, to get to know another research group and to do my PhD at a larger university. As I wanted to study proteins using nuclear magnetic resonance spectroscopy, Goethe University was a good choice as it provides optimal conditions for such research. During my Erasmus exchange programme, Professor Schwalbe's group was recommended to me, not only because of the equipment but also because of the extensive specialist knowledge available in this group.

Was there a decisive impetus for your decision to study biochemistry?

Already at school I was fascinated by learning about the metabolic pathways. I found it exciting that reactions are very specifically catalysed by only one enzyme, and I was amazed how this occurs on a molecular level. I think this is why structural biology is so interesting to me because we actually can tell how a mechanism works, down to the last detail.

What do you appreciate about the local research conditions?

I appreciate in particular that there are considerably more research groups and collaborations than at the University of Bayreuth. This environment made it possible for me to learn many new methods and to find the right contacts, whenever I needed help with any problems I encountered.

Where do you feel at home?

This is difficult to answer. I think home is, where you feel comfortable. For now I feel very much at home here in Frankfurt. I think you can feel at home in many places, important is that there are people who make this possible for you.

What does your circle of friends look like? Are they mainly scientists or more mixed?

Many of my close friendships were formed during my years of study, therefore most of my friends are scientists. Of course, you live in a kind of a bubble but scientists tend to have much in common. For example, you know the kind of issues others are currently dealing with, and your experiences are similar. Of course, one leaves this bubble from time to time, for example, for doing sports or voluntary work.

Where do you see yourself in five, ten years?

Wow, actually, I am the kind of person who does not really plan the whole life in advance. Most of the time I'm just waiting for things to happen. Of course, one needs to set goals in life but usually things turn out differently than anticipated. One goal of mine, obviously, is to complete the PhD. Also I would like to go abroad again for one or two years. But I have not really planned beyond that yet. My goals are quite simple: to have an exciting job, which pushes me but also leaves enough spare time, and to meet nice people while doing it.

»I think you can feel at home in many places, important is that there are people who make this possible for you.«

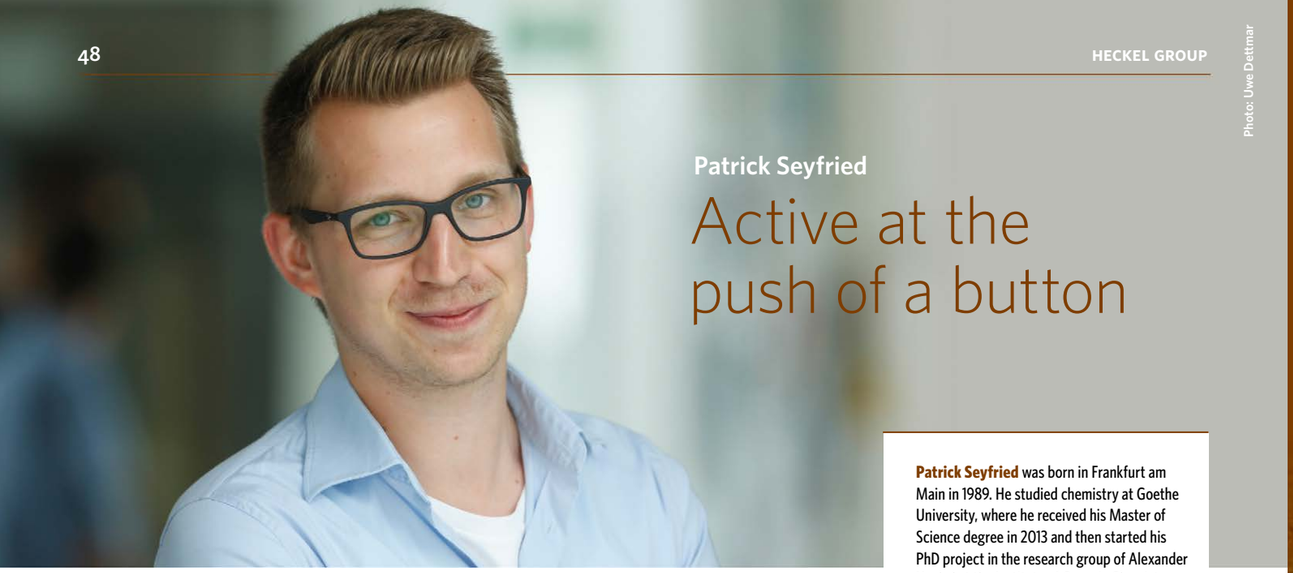


Photo: Uwe Dettmar

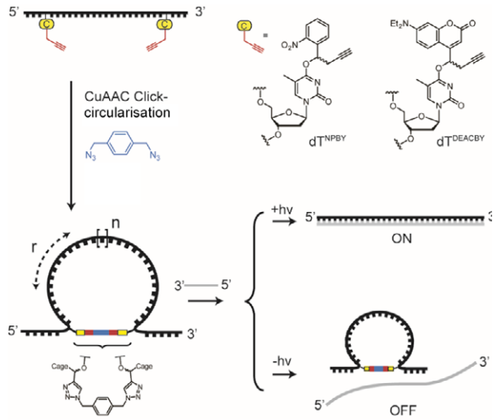
Patrick Seyfried

Active at the push of a button

Patrick Seyfried was born in Frankfurt am Main in 1989. He studied chemistry at Goethe University, where he received his Master of Science degree in 2013 and then started his PhD project in the research group of Alexander Heckel at the Institute of Organic Chemistry and Chemical Biology. Seyfried received a GDCh Abiturientenpreis in 2008 and a PhD scholarship of the Fonds der Chemischen Industrie in 2014. Seyfried is interested in web design and programming. Playing the piano is one of his most important pastimes, in addition to running and cycling.

Cyclization of DNA and RNA and reactivation using light

DNA* and RNA* not only play a central role in storing and processing the genetic code but also control numerous cellular processes. Many of these processes depend on the ability of nucleic acids* to form stable double helix structures. In my project I chemically alter such nucleic acids to create strained and knotted ring structures. Ideally, nucleic acids are not biologically active in this state. Light-labile protecting groups were incorporated into the ring structures, and therefore they respond to irradiation with light. Pushing a button, the inactive DNA or RNA can be switched back with light to its natural active state. With this method I can control, for example, the interaction of DNA probes with cell surfaces, and I also use it to try regulating the biosynthesis of proteins in cells.



Photocaged DNA or RNA is converted by click reaction into a cyclic structure. In this state, no binding to the target molecule takes place. Irradiation with light abolishes the cyclization and the biological activity is restored.

Photo: Photocase/Bratscher

How does your research benefit society?

Building blocks of DNA and RNA are not only interesting for basic research but also play a role in pathological changes in the body. Therefore, I hope that in the future light-activatable nucleic acids will primarily serve for treating diseases while causing very little side effects.

What do you appreciate about the local research conditions?

I really appreciate the technical equipment available on Riedberg Campus and especially in our research group. When I encounter an interesting problem, I quickly find a way to solve it. Many opportunities for collaboration arise through the proximity of different research groups working on theory, biology or physics, as well as the Max Planck Institutes of Biophysics and Brain Research.

If you had to summarise your research in seven words, which would you choose?

The search for the perfect DNA ring.

Do you have a favourite film? A favourite book? Why?

It is hard to single out one favourite movie or book. A film which I found very touching is, for example, »Labyrinth of Lies« by Giulio Ricciarelli: it is very different from Hollywood movies. It deals with a less well known and gripping aspect of German history, including the one of my hometown Frankfurt.

What childhood memory has particularly influenced you?

During my childhood, I lived in a school because my parents worked there as caretaker and cleaner. For me, it was fascinating to watch the teachers and students through the windows during their afternoon classes.

It certainly was no coincidence that after my A-levels I had first enrolled for teaching math and chemistry. I still like to teach. Laboratory research in particular offers many opportunities to convey knowledge, both in theory and practice.

If you could change something about yourself, what would it be?

I'm glad that I learned some frustration tolerance and perseverance during my chemistry course and the PhD project. In some situations, however, I would like to be a bit more patient and serene. And I would like to be able to pronounce the Spanish »rr«!

»Laboratory research in particular offers many opportunities to convey knowledge, both in theory and practice.«

Photo: Tri Dinh Photographie

»When looking back at my time at the university, I would like to be able to say that I put in enough work and time, experienced satisfying and amusing moments at work while having fun.«

Who are your role models?

I cannot single out one role model because there are many, in my scientific as well as in my sports environment. In general, I would consider all those persons as role models, who have achieved something I am still working on, from whom I can learn something. I do not mean this in a strictly hierarchical way but also include people who follow a similar path like me, and who are prepared to pass on their knowledge and experience.

Is there a goal you want to reach?

In a few years, when looking back at my time at the university, I would like to be able to say that I put in enough work and time, experienced satisfying and amusing moments at work while having fun. And if it all works out fine: after having completed my PhD project, I'm looking forward to going to the Registration Office and to adding the newly acquired title to my name – that would be alright, too.

If you had to summarise your research in a few words, which would you choose?

Time-resolved spectroscopical study of the functionality of a »zipper-protein«.

Are you a city or a country person?

I am used to city life as I was born and raised in Frankfurt, and I love it. I would be reluctant to exchange this for the benefits of a life in the countryside – but that does not mean that I would spend my vacations exclusively in a big city.

Which entrance music would you choose for your own boxing match?

I can think of a number of songs which motivate me. Depending on the mood of the day, it could be one of the following: »Numb / Encore« by Linkin Park & Jay Z, »Remember the Name« by Fort Minor – or something by Daft Punk.

What do you find hilariously funny?

I tend to find a lot of things funny – even bad jokes. In particular, I like to laugh when being surrounded by familiar faces. Often it's about funny stories from our common past, and I do not mind laughing about myself and my own mistakes.

Photo: Uwe Dettmar

Dinh Du Tran

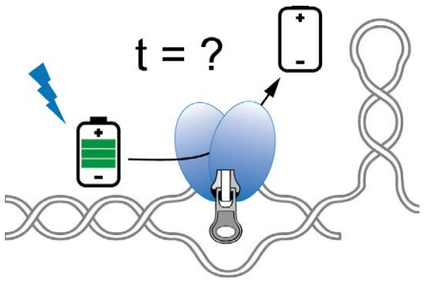
The zipper principle

Dinh Du Tran, born in Frankfurt am Main in 1988, studied chemistry at Goethe University and completed his Master of Science degree in 2014. Since then he has been working on his PhD project in the group of Josef Wachtveitl at the Institute of Physical and Theoretical Chemistry. He spends his spare time with Vovinam, a Vietnamese martial art; he is instructor of the youth section and also represents Frankfurt or Germany at Vovinam tournaments.

Studies on the function of a helicase The fastest human being can run just over 100 meters in ten seconds. You can watch the athlete and take a photo of him while he is running. Many chemical reactions are already completed in that timeframe, and therefore more complex techniques than just a fast camera are needed to study them. For my research I use light in the shape of lasers as a tool because light is much faster: it covers a distance of almost three billion meters in these ten seconds!

I focus on a protein, more specifically an enzyme, which works like a zipper. This enzyme is called a helicase* because it »unwinds« a double-stranded ribonucleic acid (RNA*) – which is arranged in the spiral shape of a helix – and then unzips it into two single strands.

Just like the sprinting athlete the helicase can only work when it has been supplied with energy. Therefore, a special energy provider, which is released through a flash of light, plays an important role in my study. It allows me to trigger the reaction with a starting flash, comparable to a starting signal, and to observe the subsequent unwinding and separation of the two strands.



The figure shows schematically how the investigated enzyme (blue) functions. It unwinds an RNA (grey). A flash of light releases its energy provider – represented by a battery – and the reaction can start.

Photo: Eric Schmitt

What brought you to Goethe University?

Already in high school I knew that I wanted to study biochemistry. I chose Frankfurt partly because of the vicinity to my family but mainly because of the impressive equipment and the strong links to other institutes. I became even more enthusiastic, when I learned about the small class size and friendly atmosphere of the biochemistry degree course in Frankfurt, and about the good supervision by the professors.

What do you appreciate about the research conditions on site?

I do not know about research conditions at other universities, but during my PhD project I learned to appreciate the extensive communication and scientific exchange between the different research groups and departments here. Not only are the scientists happy to pass on their experience to colleagues beyond their own research group but also there is lots of support when you want to use specific equipment. As an NMR spectroscopist, I enjoy, of course, that the university is equipped with so many state-of-the-art NMR spectrometers. Without this high standard our research would not be possible.

What does the research give you?

My relationship to research is somewhat ambivalent. On the one hand, I am motivated by curiosity about the natural sciences and by enthusiasm for the elegant mechanisms that nature has evolved. On the other hand, research with all its unknown factors and unexplored paths can also be cruel, and this causes frustration for many PhD students.

Probably it is just this mixture that makes research attractive. If research were too simple, you would not be able to appreciate successful results to the same degree.

Where do you see yourself in five or ten years?

Phew, that's always a tough question. At the moment, I do not have a specific job in mind. But I very much hope to find one, which enables me to convey my enthusiasm for science to other people, and to bridge somewhat the gap between »the scientists« and the general public.

Can you laugh at yourself? And what can you stand only with a sense of humour?

Of course, I am able to laugh at myself. It is important to not take yourself too serious all the time; it helps you to stay down-to-earth. People probably do not realise that many scientists can be very entertaining at times, despite or perhaps due to the serious nature of our work. A certain kind of nerd-humour is definitely part of daily life in our research group – for example fun games for the Christmas party or the next mortarboard-decoration project to celebrate a successful PhD defence – a good dose of humour has to be part of our work.

»If research were too simple, you would not be able to appreciate successful results to the same degree.«

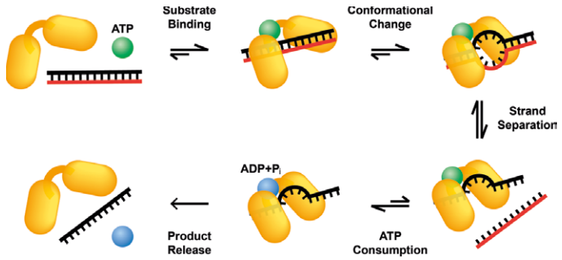
Photo: Uwe Dettmar

Heidi Zetzsche

Unfolding movie

Heidi Zetzsche was born in Leipzig in 1989 and raised in Thuringia and Bavaria. She studied biochemistry at Goethe University and received her diploma in 2014. During her studies, she won a Deutschlandstipendium from Goethe University. She started her PhD project with Boris Fürtig at the Institute of Organic Chemistry and Chemical Biology in 2015. Zetzsche was a student representative in various committees of the Faculty of Biochemistry, Chemistry and Pharmacy, and of Goethe University between 2010 and 2014.

Investigation of the unwinding of RNA by using laser-assisted nuclear magnetic resonance spectroscopy When a bacterial cell no longer needs its RNA* molecules, they are degraded by the so-called degradosome*. This complex, which consists of several enzymes, works like a shredder, which cuts RNA into small fragments. However, the RNA has to be unfolded first, similar to an origami paper. The RNA helicase* RhlB plays a central role here. The helicase binds to the RNA and separates the two RNA strands from each other, consuming energy-providing molecules of adenosine triphosphate (ATP*) in the process. Our project examines how exactly the structure of the RNA changes during this multistepreaction. We use laser-assisted nuclear magnetic resonance spectroscopy* because this method enables us to analyse RNA at atomic resolution. By using photo-protected ATP, we are able to control the unwinding process. This allows us to track the structural changes of the RNA strand in real time. In the end, we obtain a »video« of an RNA molecule while it is unwinding.



In a multi-step process, the helicase RhlB (yellow) separates the two RNA strands (red/black) from each other and releases them one after another under ATP consumption (green → blue).

The Network

A decisive factor in CLiC is that the PhD students work together beyond the boundaries of the traditional disciplines. This scientific network is formed by the core expertise the PhD students bring along with them (green) and through their newly acquired expertise in neighbouring fields (blue).

Principal investigators

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Associated principal investigator

Andreas Dreuw

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Coordinator

Christian Grünewald

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Photo: Uwe Dettmar

Jens Bredenbeck

How do molecules move?

Molecular dynamics in chemistry and biophysics My research is driven by my curiosity about how the world functions on the level of the molecules, which make up our biotic and abiotic environment. The question of how molecules move, change and interact with each other has occupied me since my schooldays. A chemistry degree – with some physics thrown in – was therefore an obvious choice. My first job as a student assistant in theoretical chemistry involved the calculation of potential energy surfaces for reactions. My diploma project in theoretical molecular physics dealt with the tunnel effect* in isomerization*. But do things really happen the way calculations and models predict? For my PhD project I searched for a method to directly »watch molecules at work«, and I found it in ultrafast spectroscopy. I am still working in this fascinating field with my research group today. We are applying the spectroscopic techniques, which we develop, to a wide variety of subject areas, including catalysis, photochemistry, the study of information transfer in proteins, the study of intermolecular interactions in liquids, and the dynamics of photoreceptors. In the CLiC projects we not only observe molecular processes with light but also control them with light. A combination of infrared and visible light pulses allows us to single out specific molecules for reactions from within a group of similar molecules – a dream for photochemistry.

Jens Bredenbeck was born in 1975 and studied chemistry in Darmstadt and Göttingen. After completing his diploma thesis in the Department of Theoretical Molecular Physics at the MPI for Fluid Dynamics, Bredenbeck moved to the Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy in Berlin to do his PhD, and later on to the Institute of Physical Chemistry at the University of Zurich. He then worked as a postdoc at the University of Zurich and the Institute for Atomic and Molecular Physics (AMOLF) in Amsterdam. After winning the Sofja Kovalevskaja Award granted by the Alexander von Humboldt Foundation, Bredenbeck headed a junior research group from 2007 to 2010. He is a W3 professor at the Institute of Biophysics in the Physics Department of Goethe University Frankfurt since 2010.

Photo: private

Why are you participating in CLiC?

My research group works almost exclusively on the interactions of molecules with light, so of course, I am in my element when it comes to »Complex Scenarios of Light Control«. In CLiC we have an inspiring combination of research groups working on theory, spectroscopy, synthesis and application of light-driven molecular systems. This provides the PhD students with plenty of opportunities for interactions related to their own project. CLiC is the first graduate programme I am participating in. I find the planning of projects from the perspective of PhD students and their PhD projects an exciting challenge.

How do you judge the progress of CLiC so far?

It was wonderful to see how quickly the PhD students took the initiative and started to network within CLiC. I think that the collaboration within CLiC particularly fostered their ability to take responsibility for their own projects and to drive them forward. Wonderful joint projects have developed, and I am looking forward to see how it will continue.

Who are your role models?

I prefer to choose my own path, and it is very important for me to encourage my PhD students to do this, too, and to support them doing it.

How can the dialogue between science and the general public succeed?

Of course, there are many channels for this communication. Often it is important to first arouse an interest in this dialogue. I believe that scientists have a responsibility to initiate the dialogue. The channel choosen depends on the topic as well as on personal abilities and possibilities. I find direct interaction particularly interesting and effective, for example, during the Night of Science. Further examples are the internships we offer for high school students. They get an idea of research, and perhaps they become multipliers of knowledge.

What do you do outside of work?

I like outdoor activities and have a special affinity to the mountains – eg hiking, climbing, snowboarding, and involvement in the German Alpine Club – as well as to the water. It is wonderful that my whole family shares these preferences. My wife and I love to explore the world with our two children – four and seven years old – while travelling as well as at home. Sometimes, this becomes a bit scientific as my wife is a biologist. And I play classical guitar since the age of 10, which is a good way to relax.

»My wife and I love to explore the world with our children – while travelling as well as at home.«

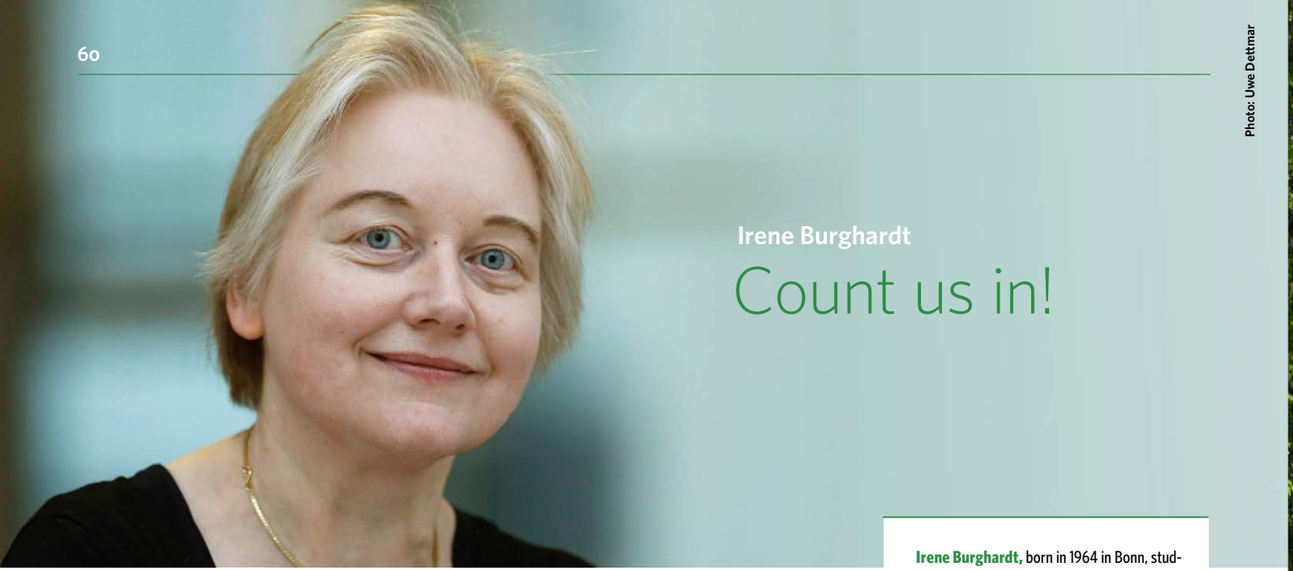


Photo: Uwe Dettmar

Irene Burghardt

Count us in!

Complex Computational Scenarios From the viewpoint of a theoretical chemist, photochemistry is highly complex even in small molecules. Photochemistry goes deeply into the quantum realm and often does not allow simple mechanistic explanations. Hence, the computational study of photochemistry and its control in biological systems is a »grand challenge problem«. So we've been prepared for many new questions when embarking on CLiC.

From today's perspective, I feel that our CLiC projects are a big success, speaking both for our PhD students and for myself. We now have a much better understanding of how photocontrol in biosystems works, and how specifically engineered molecular building blocks fit together. Our PhD students are investigating the photocontrol of DNA* and the photocleavage of carbon monoxide from myoglobin*, in collaboration with experiment. They learn how to use the right approximations, given that the complexity of computation mirrors the complexity of the systems under study. Finally, we have contributed to the design of a new laser control scheme, implemented by our colleagues of the Bredenbeck lab, which makes photocontrol highly specific.

For our PhD students, the close collaboration between theory and experiment has become the highlight of CLiC, and they feel that they are on a special mission. I believe that this is exactly our gauge of success, and it is the proof that this research training group keeps its promise.

Irene Burghardt, born in 1964 in Bonn, studied chemistry at Bonn University and carried out her diploma project in laser spectroscopy at the University of Oxford. She received her PhD in chemistry in 1992 from the University of Lausanne, on the topic of nuclear magnetic resonance spectroscopy. Moving towards theoretical chemistry, she conducted her postdoctoral research at the Center for Nonlinear Phenomena and Complex Systems, Brussels, in 1992–1995, followed by research fellowships at the Universities of Bonn and Heidelberg in 1996–1998. From 1999 to 2011, she held a Centre National de la Recherche Scientifique (CNRS) research position at the Département de Chimie of the Ecole Normale Supérieure (ENS) in Paris, and was appointed CNRS research director in 2007. She took a habilitation in theoretical chemistry at the University of Paris VI in 2006 and at Heidelberg University in 2007. After 20 years abroad, she moved to Goethe University Frankfurt in 2011 where she holds a professorship in theoretical chemistry. She benefits from many international research collaborations and, as ERASMUS coordinator, conveys the enjoyment of an international perspective to the younger generation.

Photo: fotolia.com/seb.howguimian

Why are you participating in CLiC?

CLiC offers a perfect opportunity for us to apply the full repertoire of theoretical chemistry to the light control of highly complex chemical and biological systems. Photochemistry is one of our favorite research domains, and with CLiC we are moving towards new and challenging systems and methods. It's exciting to see that our »bottom-up« approach is actually able to answer experimental questions, and even to make predictions that guide experiments.

Which added value does CLiC bring for your research?

CLiC has made us move towards new and unexplored directions, and in that sense the added value is immense. We started new collaborations with spectroscopists and synthetic chemists – and also with colleagues from theoretical chemistry. In particular, we have engaged in a very successful collaboration with Dr. Fabrizio Santoro from a research lab of the Consiglio Nazionale delle Ricerche in Pisa.

How to you judge the progress of CLiC so far?

I think that CLiC is a real success story, not only in the sense of tangible progress in our research but also – and perhaps mainly – in the sense of personal development of our PhD students. They are very independent-minded, constructive, and enthusiastic to be part of CLiC.

If you had to summarise your research in a single – humorous – sentence, what would that sentence be?

We are educating molecules and people by using maths and computer codes.

Where do you feel at home?

I feel at home with my »scientific family«, including my group and collaborators in Frankfurt, and many other international collaboration partners.

Can you identify a biographical moment, which was especially important for your research or your path to science?

Yes, when I started my postdoc, I went from experiment to theory, and at the time I understood this as an exploratory and temporary move. A year later, I was sure that I would stay in theoretical chemistry because by then I was thrilled by gaining a deeper understanding of the border between quantum and classical reality.

Which other discipline, far from your own, is of particular interest to you and is perhaps a source of inspiration?

I am a great fan of French literature, since I lived in French-speaking areas for almost 20 years. I think that the awareness of language structures and expressions is an inspiration for my research.

»CLiC has made us move towards new and unexplored directions.«

Why are you participating in CLiC?

Observing light-induced chemical and biochemical processes on a molecular level using NMR spectroscopy has fascinated me since I was a PhD student. CLiC now offers the opportunity to further refine the methods developed during that time and to apply them to new questions. I am pleased to be able to convey this exciting technology of combining light control with NMR spectroscopy also to others, and to be in uncharted waters together with the PhD students.

What added value does CLiC bring to your research?

CLiC cross-links the research groups involved at the level of the PhD students, all of which deal with light regulation from different points of view and different perspectives. This opens up new paths within the research projects, and ideas are realised which would not have come up without this network. The links thus established radiate into the whole research group.

How do you judge the progress of CLiC so far?

In my opinion it is the best and most thought-out training programme provided for PhD students in the natural sciences at Goethe University Frankfurt. It is a first step moving from individual PhD training without quality control towards a transparent training programme, which is up to international standards.

What do you do in your spare time?

I love spending time with my family. And I like to spend time in the forest as it helps me to clear my mind; I either go running or I timber the wood, the latter I do with great passion.

Can you laugh at yourself? And what can you stand only with a sense of humour?

I often laugh at myself, sometimes because of crude ideas, or when something in the lab does not go according to plan. As the saying goes, scientific breakthroughs are not announced by »Eureka!« but by »Oh, that's funny.« Research can only be endured with a sense of humour. When science is the one experiment that works among 99 experiments, then you have to take it with humour.

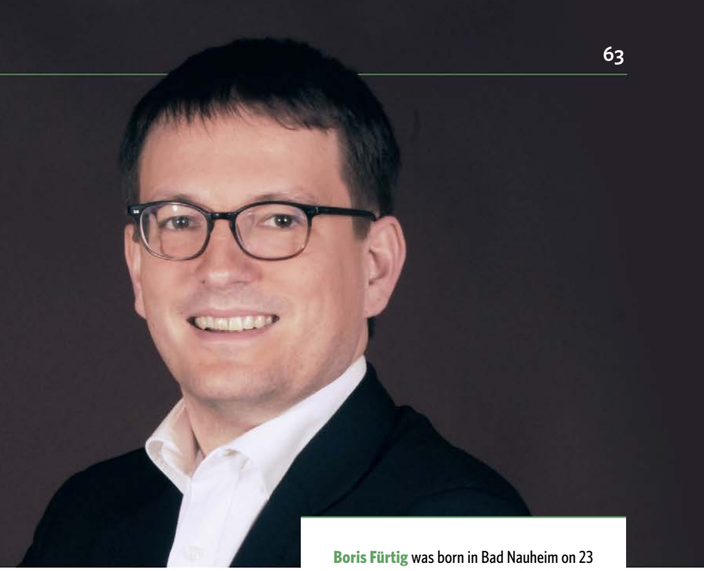
Do you have a favourite book?

John Irving's »The Water Method Man« is a must-read, not only for PhD students. Few books have resulted in me laughing so loudly and heartily, and yet it is also very touching. It simply is an absurdly beautiful book.

»For relaxing, I love being in the woods, either for running or lumbering and splitting wood, the latter I do with great passion.«

Photo: fotolia.com/Alena

Photo: private



Boris Fürtig

Wiggling molecules

Atomic mini magnets and light The American physicist and Nobel Prize laureate Richard Feynman said, »everything that living things do can be understood in terms of the jigglings and wigglings of atoms.« In a way we trace this sentence with our research. We want to understand how RNAs* and proteins alter their structures to fulfill their biochemical function. With the help of nuclear magnetic resonance spectroscopy (NMR*), a technique in which the molecules are introduced into a very strong and very homogeneous magnetic field, we can visualise the individual atoms of RNAs and study their motion. For this to succeed, all the molecules we are studying must move uniformly. One way to achieve this synchronisation of molecular motion is by photochemical modifications. These unnatural changes of the RNAs and proteins virtually force them to the starting block of our experiment. A light signal then gives the starting signal, the molecules start to move, and we can characterise their movement. The combination of light and NMR spectroscopy is very exciting, since reactions at equilibrium – which are found especially frequently with RNAs – cannot be studied at atomic resolution with any other experimental technique.

Boris Fürtig was born in Bad Nauheim on 23 May 1978. He studied biochemistry at Goethe University Frankfurt and completed his PhD at the Institute of Organic Chemistry in 2007. He then worked as a postdoc at the Max F. Perutz Laboratories of the University of Vienna. He returned to Frankfurt in 2011, and since then he has been postdoc and junior group leader at the Institute for Organic Chemistry and Chemical Biology. Fürtig is married and has a three-year-old daughter and a baby son.

Photo: Uwe Dettmar

Clemens Glaubitz

En-Lightment in the cell membrane

Clemens Glaubitz, born in 1969, was passionate about astrophysics as a schoolboy and also as a physics undergraduate in Leipzig. But his enthusiasm for biophysics gradually took over during his degree course. He then went to Oxford University on a Rhodes Scholarship and completed his PhD in biophysical chemistry there in 1998. After his postdoc positions in Oxford and Stockholm, he became an Emmy Noether junior research group leader at the Leibniz Institute for Molecular Pharmacology in Berlin. Since 2002 he is Professor of Biophysical Chemistry at the Goethe University Frankfurt. He is director of the Centre of Biomolecular Magnetic Resonance (BMRZ) since 2006 and was elected dean of the Faculty of Biochemistry, Chemistry and Pharmacy in 2017. Clemens Glaubitz is married and has two daughters.

Study of biochemical reactions in a time-resolved manner

Membrane proteins* have manifold functions: they are involved in cell-to-cell communication, relay signalling or transport substances across the cell membrane. My research interests focus particularly on transport proteins, GPCRs*, lipid regulators* and microbial rhodopsins*. All these proteins undergo complex cycles to be able to perform their function. For a detailed picture of the molecules, spectroscopic methods are needed, which allow these membrane proteins to be observed directly in the membrane, both in the ground state and during the reaction. A special type of NMR spectroscopy* plays a role here, in which samples are rotated very quickly at the magic angle* in a magnetic field (Solid-State NMR/Magic-Angle-Spinning (MAS) NMR). Our interest in CLiC is to develop approaches to trigger biochemical reactions with light during the NMR experiment, which can then be observed in a time-resolved manner. Experiments include, for example, the light-controlled release of ATP* in the membrane, light-controlled pH jumps but also changes in the membrane properties affected by photosensitive lipids*. With these methods we can collect important kinetic data needed to understand how the investigated membrane proteins function. An example are reaction rates of enzymatic reactions catalysed directly in or on the membrane. Another focus of our work is placed on proteins, which are naturally light-dependent, such as the photoreceptors.

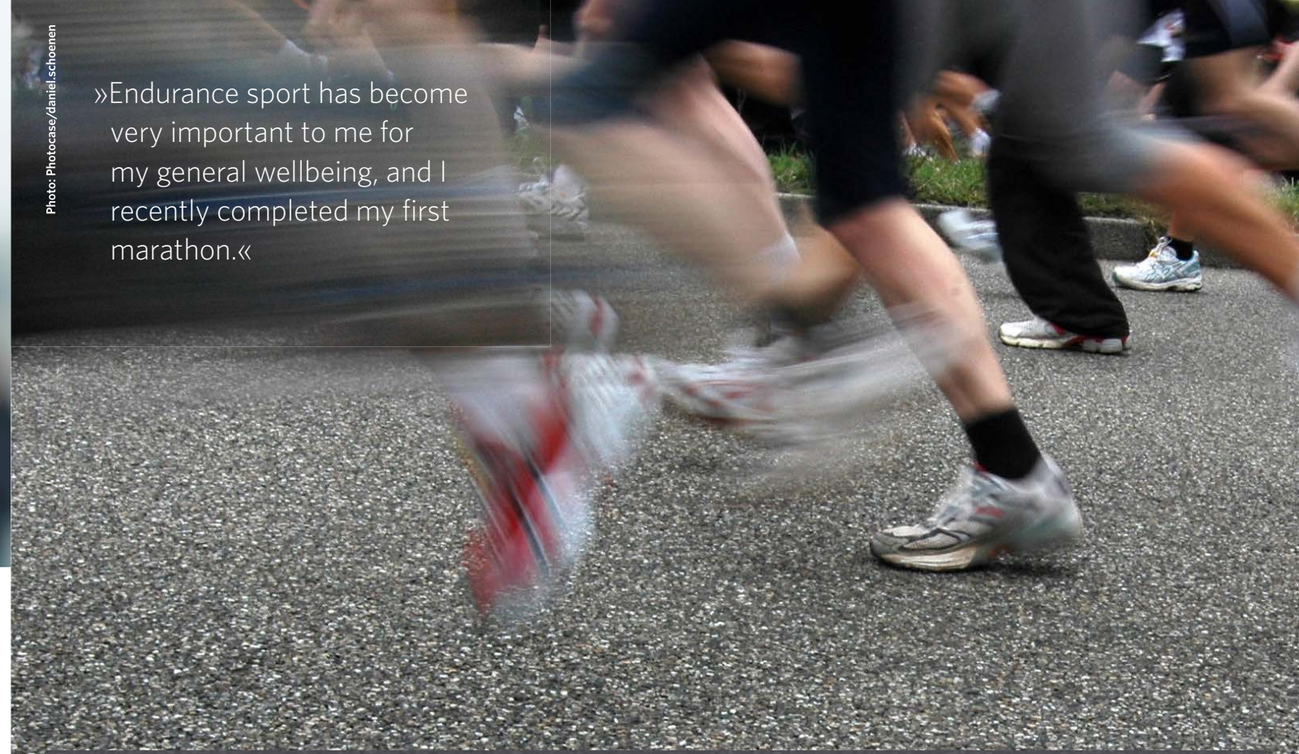


Photo: Photocase/daniel.schoenen

»Endurance sport has become very important to me for my general wellbeing, and I recently completed my first marathon.«

Why are you participating in CLiC and what added value does CLiC bring to your research?

I can only conduct research projects if I receive funding through projects such as CLiC, which can be used to fund a PhD project for young scientists. The special benefit of CLIC is the close networking between the PhD students, who are grouped around a larger thematic context.

If you could study again, would you choose the same subject? Or maybe something completely different?

Probably yes. However, as our societal problems can only be partially solved with purely scientific approaches, perhaps I might be closer to subjects such as economics, philosophy or medicine today than I was as a scientifically-minded high school student and undergraduate. However, one probably makes the biggest contributions in those fields one is enthusiastic and fascinated about. Therefore, I probably would opt for physics again – but with a stronger molecular component.

How can the dialogue between science and the general public succeed?

Significantly higher investment in education is basically needed at all levels. Above all, science is run by people, who are part of the population. Accordingly, one encounters a wide spectrum of opinions and behaviours. A great example of open science is the Night of Science on Riedberg Campus because the enthusiasm for science becomes tangible here.

If you could choose a travel destination, what would that be and why?

I find the black hole in the center of the galaxy very appealing. Alternatively, I am also interested in the countries of Asia, which I know too little so far. Likewise, the Shetland and Faroe Islands as well as Iceland in the North Atlantic have a certain appeal to me because of their supposed seclusion.

What do the first hours of your day look like?

Getting up at 6:00 am, getting the kids ready, having breakfast together, bringing them to school and kindergarten, and cycling to university at 8:20 am.

What do you do outside of work?

I have little spare time. Endurance sport has become very important to me for my general wellbeing, and I recently completed my first marathon.

What do you appreciate about the Riedberg?

Basically, the short distances – and my job and my immediate employees. We have managed to establish an efficient and highly optimised laboratory for our research. In addition to that, many of my co-operation partners work locally, and I live in the immediate vicinity, so no time is lost with commuting after long working days.

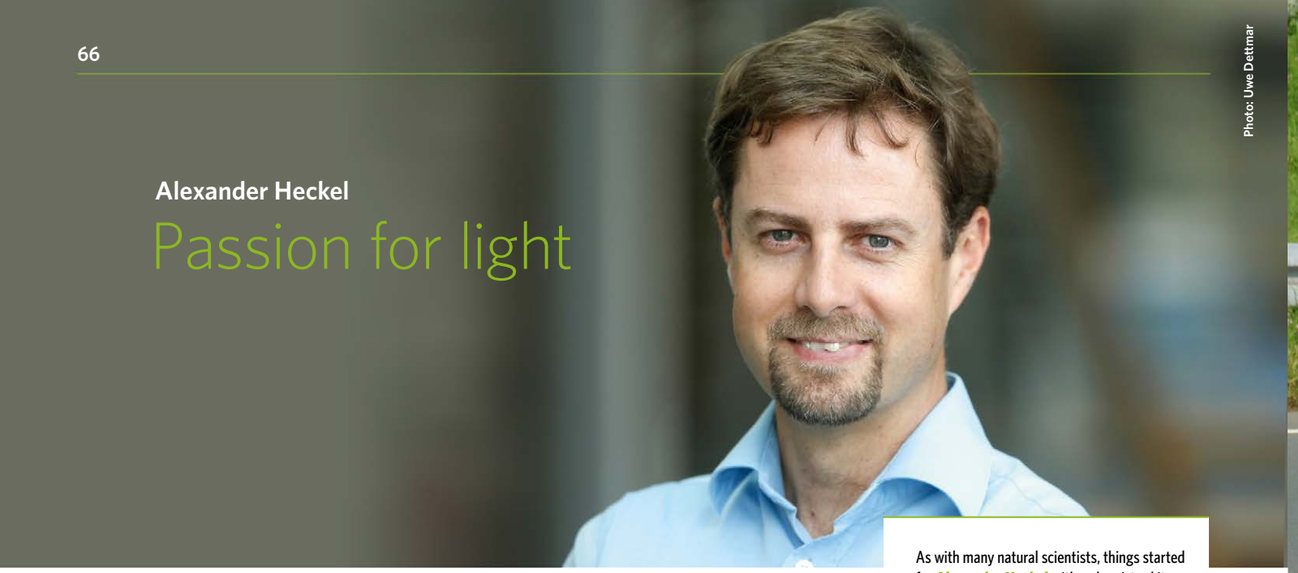


Photo: Uwe Dettmar

Alexander Heckel

Passion for light

As with many natural scientists, things started for **Alexander Heckel** with a chemistry kit. Born in 1972 and raised in Lindau on Lake Constance, he began experimenting at the age of ten. High school was followed by a chemistry degree in Konstanz, a PhD at the ETH Zurich in Switzerland, and a postdoc at the California Institute of Technology in Pasadena, USA. From 2003 to 2007, Heckel was first Liebig and then Emmy Noether Junior Research Group Leader at Bonn University. In 2007 he joined the Institute of Organic Chemistry and Chemical Biology and the Institute of Pharmaceutical Chemistry at Goethe University Frankfurt. For 26 years, the passionate diver has been dedicated much of his spare time to emergency medical services of the German Red Cross, on land as well as on and under water.

Photochemical regulation of biological effects Photochemistry is mysterious and often enigmatic – this is what I was thinking during my studies. And it was hard to find access to this fringe subject of chemistry. Nevertheless, photochemistry has fascinated me from the beginning. During my postdoc in Pasadena, when I had to decide which direction my independent research should take, I was thrilled to combine this »underexposed« passion of mine with the wonderful world of nucleic acids*, which I got to know there. Fifteen years from that time on, this very enthusiasm still is going strong.

Nowadays, there is a very wide range of light-reactive chemical building blocks, which we incorporate into DNA* and RNA*. As a result, the degree of complexity and hence also the potential regulation of biological effects has increased enormously since my Pasadena days. The newly discovered and developed light regulation scenarios now are not only applied in cell culture but we can even use them in living mice, for example, to treat wound healing disorders. And our methods are very useful for gaining a deeper understanding of basic biological processes.

I am especially pleased to be working on this exciting research topic in the context of a research training group funded by the Deutsche Forschungsgemeinschaft. Since 2014 a research community of PhD students has emerged here, whose level of intense networking is hard to beat.

PHD STUDENTS: JAKOB, KLÖTZNER, REINFELDS, SEYFRIED

Photo: private

»My work for the German Red Cross has taught me to follow unconventional paths in my professional life.«

What do you expect from a young person in the CLiC Research Training Group?

I expect a lot of enthusiasm for the subject: in-depth commitment to one's research topic as well as an interest to gain knowledge of the range of topics through intensive networking. I expect a willingness to work hard and productively, and to embrace the CLiC concept, which has been designed with the objective of excelling together.

How do you judge the progress of CLiC so far?

It was great to see how a group of individuals quickly became a research community; an additional level of identity was added on top of the roots everybody has taken in the respective group – beyond established boundaries in form of floors and in the mind. We are just at the beginning of the »harvest phase«, and I am looking forward for things to come.

Do you have a favourite place on Riedberg Campus?

My office and my labs! I have been able to set up everything exactly the way that my group and I can work efficiently and feel well there. And the views across Frankfurt and the Taunus are simply fantastic.

What do you do outside of work?

In my spare time, I work a lot for the rescue service of the German Red Cross, on land as well as on and under water. My speciality is the tactical planning and management of emergency medical services required for large events, as well as the training of search and rescue boat drivers, search and rescue divers, and executives on all leadership levels. My latest hobbyhorse is to establish a motorcycle group for first responder operations.

Which other discipline, far from your own, is of particular interest to you and perhaps a source of inspiration?

During the last 26 years, I have learned a lot about dealing with people through my work for the German Red Cross – especially as head of operations, but also through the frequent contact with people in extreme situations. This taught me to sometimes act in a rather unconventional manner in my professional life. For example, it is an unusual practice to advise PhD students on their personal development, especially regarding the interplay between advancing as a personality and progressing in a science career.

Photo: Uwe Dettmar

Nina Morgner

Understanding molecular machines

Nina Morgner was born in Oakland, California, in 1976. She studied physics at the Universities of Freiburg and Amherst, Massachusetts, and completed her PhD at the Goethe University Frankfurt in 2008. She went to Cambridge as a postdoc in 2008, and then to Oxford. In 2013 Nina Morgner returned to Frankfurt as a junior professor of the Cluster of Excellence »Macromolecular Complexes«. In 2013 her innovative work was awarded an ERC Starting Grant of the European Union. Nina Morgner is a liaison professor of the Friedrich Ebert Foundation. She likes skiing, is a science fiction fan and enjoys cooking with or for family and friends.

Mass spectrometry of protein complexes In every cell many processes are constantly ongoing, which keep the cell alive and allow it to fulfill its tasks in the organism. These processes are controlled by molecular machines, which consist of proteins interacting with each other. To understand the function within the cell, one therefore needs to understand the structure of the molecular machine and its interactions with its surroundings. Many research groups are working on this, using many different methods. Mass spectrometry* is a method which has become established in recent years for the study of such protein complexes. A critical aspect of this method is the ion source, which allows the transfer of such complexes from the native liquid phase to the gas phase, where they can be measured. We work with an established method called »nano electrospray ionization« (nESI*) as well as with a newer and in many aspects complementary method called »Laser Induced Liquid Bead Ion Desorption« (LILBID*), whose further development I am very interested in.

In the context of CLiC we are working on a method which allows mass spectrometry investigations of fast reactions. For this purpose, we will use the light-switchable compounds developed by other CLiC groups.

Photo: Photocase/Mr. Nico

»There are the many big or small moments – successes just as well as failures – which all together shape you and teach you how to deal with diverse situations.«

Why are you participating in CLiC?

CLiC allows me to provide a PhD student with a very exciting topic, and it also offers additional training opportunities for the PhD students. The CLiC consortium provides a great basis for the collaboration of groups with very different expertise. As our group works on instrument development, such collaborations are extremely important for us. We rely on them to obtain the biological samples, which we then study with our instruments.

How do you judge the progress of CLiC so far?

Very well so far. The team spirit among the CLiC PhD students is very good: they discuss their problems with each other and find solutions. Overall the group has made great progress, scientifically as well as in terms of personal development.

Is there a biographical moment that was formative for your research or your path into science?

There has not been one single moment. There are the many big or small moments – successes just as well as failures – which all together shape you and teach you how to deal with diverse situations.

Can you laugh at yourself? And what can you only stand with a sense of humour?

Situations in which I can laugh at myself happen from time to time – for example, if I have done something silly because I was tired. Then it is time to stop and go home.

If you could choose – under the same research conditions – in which city would you like to live?

I like Frankfurt – I enjoy living here.

What makes you nervous?

For example, when something we have planned/prepared/built for a long time is being tested for the first time. That can be very exciting.

Harald Schwalbe

Unique insights

Structure and dynamics of biomacromolecules To better understand the chemical biology which happens in each of our cells, we are examining underlying mechanisms of biomacromolecules. Our key analytical technique is nuclear magnetic resonance spectroscopy (NMR*), which from our point of view provides unmatched insights into the structure and dynamics of biomacromolecules. A special focus of our group is to find out the speed at which the folding of proteins, RNA*, DNA* and their complexes takes place. Therefore, the research topic of the research training group CLiC is at the center of many of our scientific studies. We have coupled different lasers to our NMR spectrometers and can thus trigger (folding) reactions with light directly in the NMR spectrometer. The systems we study range from the protein rhodopsin*, which is responsible for the absorption of light in our eyes, to artificial and natural RNA* and DNA* systems, and to the synthesis of antibiotics, which are activated in the cell through light.

Harald Schwalbe was born in Frankfurt in 1966, studied chemistry at Goethe University and completed his PhD there in 1993. He then went to Oxford University, UK, for two years before returning to Frankfurt in 1995 to work on his habilitation. In 1999 he accepted an assistant professorship at the Massachusetts Institute of Technology (MIT) in Cambridge, USA. In 2001, as an associate professor, he accepted the offer of a C4 professorship in organic chemistry at Goethe University. Harald Schwalbe was director of the DFG Cluster of Excellence »Macromolecular Complexes« from 2009 to 2013. Since 2011 he also coordinates the Frankfurt Collaborative Research Centre »Molecular Principles of RNA-based Regulation«. Harald Schwalbe is EU representative of Goethe University and liaison professor of the German Academic Scholarship Foundation. In his spare time, he likes to make music with his family, he sings and plays the piano. And he accompanies his sons to handball matches.

PHD STUDENTS: ELAMRI, KEYHANI, PINTÉR, SCHULTE

Photo: private

Why are you participating in CLiC?

CLiC is pursuing a new concept in the training of PhD students: a cohort of PhD students is formed per year. All start at the same time, accompanying each other during their PhD projects, and together they form a team. This brings the PhD students and their research groups together under one roof of joint research. CLiC is exemplary in this regard.

Does your research benefit from CLiC?

Due to CLiC the PhD students of my group engage with the methods and topics of the other groups. There is a lively exchange. It is nice when concepts and basic strategies are shared.

What do you wish for a young person in the CLiC Research Training Group?

I hope that the PhD students have fun and that they are committed to their topic. That they mature with their task and advance their own questions, their own approaches, their own solutions. I hope that these young people will be infected by the fascination of science and that this scientific spark, the unbiased, curious, knowledge-hungry approach will be preserved in them, whatever they may do later.

How important is the image of your science in public to you?

It is important that we are aware of our function as role models. We cannot simply shrug off the question about this image by delegating it to others. At the same time, it's not about converting anybody. Principally, I am convinced that the major problems of our society can be solved by research. I am convinced that science will be able to solve problems, such as cancer, AIDS, diabetes, CO_2, energy, ozone, overpopulation, and so on – regardless of whether the causes of the problems are man-made or not. I do not know if this hypothesis is correct, but following it is essential because a paralysing fear of science does not solve anything. Our research system, despite criticism of specific aspects of it, is able to provide answers to the most important questions of our present age. I am deeply convinced of that.

Which role models have inspired you?

People: my brother, my parents, my teachers of German, Latin, music, religion and chemistry; my professors in organic chemistry, quantum mechanics* and group theory, inorganic chemistry and biochemistry. Literature inspires me: fictitious as well as real heroines and heroes in these books. Friends inspire me, within my family and beyond.

What does music mean to you?

A lot.

Photo: Uwe Dettmar

Robert Tampé

Understanding the choreography

Light in cellular processes and the adaptive immune response

Every day each of us is fighting successfully against pathogens, without being aware of the complex molecular processes in the background. The immune system has developed efficient defence strategies for the successful detection of infected or canerous cells. The adaptive immune response – that is the acquired immune defence – involves the processing of antigens* in the shape of fragments of the cellular proteome* in a control centre and their presentation on the cell surface. These antigens are recognised by T-killer cells and show whether a cell is healthy or ill, whether it is a friend or an enemy.

Our goal is to understand the flow and distribution of antigens in space and time. For this purpose, we combine methods of chemical biology, biochemistry, cell biology, immunology and structural biology. In the context of CLiC we are working specifically on light-activated triggers and modulators, which allow temporal and spatial control of the transport and interaction processes. This gives us the opportunity to »expose« complex biological processes more accurately and thus to better understand their choreography in the adaptive immune response.

During the first funding period, we were able to develop molecular tools in the shape of light-activated modulators of the immune system, which enabled the clustering of receptors*. We achieved ground-breaking results thanks to the outstanding commitment of the PhD students.

Robert Tampé was born in Seligenstadt in 1961. After studying chemistry and completing his PhD in biochemistry in 1989 at the TU Darmstadt, he was a Max Kade Fellow and a DFG postdoctoral fellow at Stanford University from 1990 to 1991. From 1992 to 1998, he was junior group leader at the Max Planck Institute of Biochemistry in Martinsried and at the TU Munich, where he habilitated in 1996. From 1998 to 2001, he was professor at the Institute of Physiological Chemistry at Marburg University, and in 2001 Tampé was offered a professorship at the Institute of Biochemistry at Goethe University. He was awarded an honorary visiting professorship of the University of Kyoto, Japan and was a visiting research fellow at Merton College and the Department of Biochemistry at Oxford University from 2017 to 2018. In addition to his interest in music, art and literature, Tampé is curator of the Einhard Prize (European Biography) as well as of the Paul Ehrlich and Ludwig Darmstaedter Prize for Young Researchers (Biomedical Research). He would like to have more time for his family, for piano playing, mountaineering and sailing.

PHD STUDENTS: ARRIAGADA, GATTERDAM, KLEIN

What do you expect from a young person in the CLiC Research Training Group?

... to be open for and curious about the unexpected. Because scientific progress rarely follows predetermined programs. Many discoveries are totally unexpected but they have to encounter a prepared mind in the right stimulating environment. Curiosity for unexpected discoveries, keeping in mind Julius H. Comroe's quote, »Serendipity is looking in a haystack for a needle and discovering a farmer's daughter.«

How do you judge the progress of CLiC so far?

Due to the close connections within the research training group, collaborations have emerged, which have not been planned and were unexpected. For the PhD students, the activation barrier for transdisciplinary work is significantly reduced thus speeding up their projects. There still is much to discover, especially at the intersections between physics, chemistry, biology and medicine.

Do you have a favourite place on Riedberg Campus?

The Minerva Bistro, which offers a variety of excellent cooking, including gluten-free food, and which is always a good place for conversation.

What do you do outside of work?

... I would like to play music more often, and it is a shame that there is not enough time for this. My dream would be to join a band again or an orchestra or a choir. By attending concerts and similar events, I can enjoy music at least passively. Other favourite distractions include travelling, hiking in the mountains, sailing and first of all, of course, my family and good friends.

Which other discipline, far from your own, is of particular interest to you and perhaps a source of inspiration?

For more than ten years I have been the curator and chair of the jury for the Einhard Prize, awarded by the foundation of the same name, which is the only award dedicated to biographical literature with a European background. I also curate and chair the jury for the selection of the Paul Ehrlich and Ludwig Darmstaedter Prize for Young Researchers.

I would like to pass on my own positive experiences and promote young scientists. They are an essential part of the future organisation of research and teaching. I think this can be achieved by dissolving rigid hierarchical systems, early involvement in academic structures such as tenured assistant professorships, targeted mentoring in critical phases, and by building a creative, closely interlinked, internationally visible environment.

Photo: Christel Tampé

»Due to the close connections within the research training group, collaborations have emerged, which have not been planned and were unexpected.«

Photo: Uwe Dettmar

Josef Wachtveitl

More Light!

Molecular dynamics of photochemical reactions Light is an ideal tool to control biological processes with a high spatial and temporal resolution through selectively activating introduced photolabile or light-switchable groups. Time-resolved optical spectroscopy, which is the main method used by our group, allows the tracking of light-triggered dynamics of molecules without gaps – from the fastest events to the biological response. Another focus of our research is placed on naturally occurring photoreceptors. We want to find out which basic biophysical principles enable them to harvest the energy of sunlight. Through optimisation of the receptor structure and skillful variation of the reaction sequence, a variety of processes can be realised. Examples include the conversion of sunlight into chemical energy during photosynthesis, adjusting the day/night rhythm, and the visual process. Currently, we are investigating the visual pigment rhodopsin* and the light-activated ion channel* channelrhodopsin.

Josef Wachtveitl, born in Waldkirchen in 1960, is married and has two sons. He studied physics at Regensburg University and completed his PhD project at the Max Planck Institute of Biochemistry in Martinsried in 1992. He then moved to Ludwig Maximilian University Munich, where he worked as a postdoc at the Institute of Medical Optics. During this postdoc, he also spent time at the Argonne National Laboratory and the Centre d'Études Nucleaires de Saclay. He habilitated in physics in 1998 and was appointed Professor (C3) for Physical Chemistry at Goethe University in 2000. In 2004 he was promoted to C4. From 2004 to 2010, he was also a professor at the Institute of Biophysics and co-founded the biophysics degree course at Goethe University, which started in 2008.

PHD STUDENTS: HAMMER, HERZIG, TRAN

Photo: privat

Why are you participating in CLiC?

The research topics investigated within CLiC lie at the center of my research interests: therefore the scientific motivation is self-evident. The research training group provides a close network of synthesis, experiment and theory. Networking was encouraged in CLiC from day one. The cohort principle and the scientific presentations of the participating groups in front of all PhD students at the start of CLiC promoted the acceptance of networking among all participants.

What added value does CLiC bring to your research?

As a research group focused on biophysical methods, collaborative work has a high priority for us. The close networking within CLiC allows the PhD students an intensive examination of the respective topic beyond their own discipline, and it promotes the readiness to tackle problems together.

How do you judge the progress of CLiC so far?

During the regular mentoring meetings and the annual summer schools, one can see the scientific progress of the participating young people, and also that they realised and accepted their role as members of a larger research network. For me, CLiC's biggest success is that it has created a very well-functioning team that likes to work together.

Is there a biographical moment that was formative for your research or your path into science?

At the end of my PhD, my supervisor Dieter Oesterhelt handed me a vial with a yellow powder. It contained a peptide hormone of the gastrointestinal tract modified with a photoswitch. The fact that – as it soon turned out – the activity of this molecule could be influenced by light, fascinated me because it provided a method how biological processes can be controlled by light, rather than just observed with it. This moment was certainly formative for my decision to start an independent research project on the topic of photoswitches in the context of my habilitation. The principle of »photo-control« remains at the core of my research interest to this day and forms the basic motive of the CLiC projects.

If you could choose – under the same research conditions – in which city would you like to live?

Regensburg, Sorrent, Vancouver – in alphabetical order, my preference tends to change with the season. But maybe not in a city, but rather in a small village in the mountains.

What do you do in your spare time?

I try to spend as much as possible of my scarce spare time with my family. We like to travel together, and we share hobbies like skiing, hiking in the mountains, tennis and diving.

»We like to travel together, and we share hobbies like skiing, hiking in the mountains, tennis and diving.«

Photo: Uwe Dettmar

Ralph Wieneke

Molecular torches

Ralph Wieneke grew up in the small town Uslar in southern Lower Saxony, where he went to school. After his civil service, he studied chemistry at Philipps University Marburg. He completed his PhD in bioorganic chemistry on the synthesis and characterisation of natural products involved in biomineralisation, in Marburg in 2009. For a short period, Wieneke worked at the Georg-August University Göttingen before starting a postdoc at the Institute of Biochemistry at Goethe University Frankfurt in 2010. Since 2014 he successfully attracted financial support to fund his own research. At the Institute of Biochemistry, his research focus is on chemical biology with a special emphasis on the development of synthetic molecular tools to understand biological processes at membranes. In his spare time, he likes running, cooking and spending time with the family.

Study of biological processes with small light-activatable molecules

Cells communicate with each other in many ways and thus pass on information. How such processes are triggered, interact and coordinated is fascinating because everything takes place in a tiny space and is mediated by small molecules such as proteins. We are therefore interested in the design, synthesis as well as the application of small synthetic molecules, which can be used as tools to specifically influence or visualise biological processes. Particularly interesting are tools which emit light signals from the cell or absorb them from outside. Such molecular »torches« or sensors enable us to visualise biological processes in greater detail. Moreover, they allow us to influence and regulate such processes more precisely. Very appealing to us is to test our developed tools, which we generated by the aid of chemical synthesis, in a biological context. To achieve this, we use biochemical methods, cell biology as well as modern imaging techniques. We have already been able to employ one of our light-activatable tools in living cells to label proteins in a spatially and temporally controlled manner. Within CLiC we now get the opportunity to equip our molecular toolbox with additional small »torches« and sensors. Ultimately, we hope to gain a deeper understanding of crucial biological processes with the help of our tools.

Photo: Photocase/VICUSCHKA

»One way to start a dialogue is to combine research with issues relevant to people's daily lives: problems which directly affect or interest the general public.«

Why are you participating in CLiC?

The close contact between chemists, theorists and biochemists/molecular biologists in CLiC offers excellent opportunities to connect applied organic chemistry with biological as well as methodological research topics. This makes it an ideal environment for interdisciplinary collaborations and innovative questions. Especially the focus on light-activatable compounds – incl. their synthesis, characterisation as well as their biological application – is very attractive for me, as it exactly complements my research interests. In addition, the communication between PhD students and PIs is very good and enables us to discuss new ideas and approaches in an »uncomplicated« manner, and to synergistically implement them.

What added value does CLiC bring to your research?

As chemists working in the field of chemical biology, we use organic synthesis to develop molecules with a defined structure and function. The focus is on light-controlled interaction pairs in order to shed »light« on complex biological questions. CLiC provides younger scientists like myself the opportunity to implement one's own ideas. Furthermore, I benefit from the highly interdisciplinary orientation of CLiC, the good communication and the support of experienced scientists. These collaborations assist us enormously.

How do you judge the progress of CLiC so far?

Right from the start, the co-operation between the PhD students was very good, which in turn has promoted scientific progress. Interdisciplinarity as well as application-oriented research are the strengths of CLiC, which support the PhD students in their training as well as promote their personal development.

What do you do in your spare time?

I spend all my spare time with my family. Our joint activities help me to clear my mind, and this in turn helps me to develop new ideas. I also enjoy cooking with my family. If there is some time left, I like to go cycling or running.

If you were to summarise your own research in one – humorous – sentence, what would that sentence be?

Things will turn out differently than expected; if one thinks!

How can the dialogue between science and the general public succeed?

One way to start a dialogue is to combine research with issues relevant to people's daily lives: problems which directly affect or interest the general public. The public relations work done by the Goethe University and CLiC are an important step to familiarise the general public with our research and its complex content.

Why are you participating in CLiC?

CLiC is about controlling chemical processes with light. This is also the central focus of my own research group, for which we develop quantum chemical calculation methods. We try to orientate ourselves towards the questions of the experimenters, and thereby work in a problem-related manner. The CLiC projects are very challenging for theoretical chemistry and have come up repeatedly with new questions allowing us to test our methods. This is extremely thrilling for us. In addition, Alex Heckel and Sepp Wachtveitl have asked me very nicely whether I would continue to participate despite my move to Heidelberg.

What added value does CLiC bring to your research?

The CLiC topics are central research topics of my working group anyway. Being an associated researcher of CLiC, provides me with the advantage of working with Frankfurt colleagues on cutting-edge photochemical research questions. I very much appreciate the lively exchange with the CLiC colleagues and the resulting research projects.

How do you judge the progress of CLiC so far?

CliC is an exemplary graduate school. With his enthusiasm and commitment, Alexander Heckel succeeds in inspiring all PhD students and PIs for CLiC. I think the training concept and its implementation by CLiC is absolutely outstanding.

If you could study again, would you choose the same subject? Or maybe something completely different?

I would try to study something more interdisciplinary, such as a 50/50 chemistry/physics or chemistry/math course. I am not sure if I would like the tight corset of the new chemistry bachelor course, and I might prefer to go for a route, which would take me from physics to theoretical chemistry. Looking back, however, I am definitely very satisfied with my diploma course in chemistry.

Do you have a favourite place on Riedberg Campus?

I have written many publications on a bench in the courtyard of the biocenter. I always liked to sit there. But that was a few years ago and might not be up to date anymore.

If you could choose – under the same research conditions – in which city would you like to live?

Cologne. I like the mentality of the people in Cologne, the Rhine, and Cologne cathedral. The first thing I would do is to buy a season ticket for 1. FC Köln football club. But I do not like Kölsch.

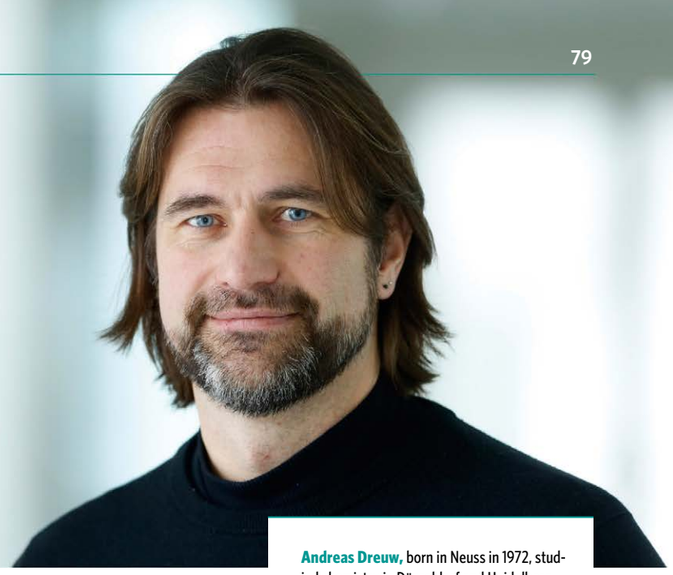
What do you do in your spare time?

I go running a lot and am also into other sports, preferably endurance sports. And I like hiking, as I discovered recently.

»I like the mentality of the people in Cologne, the Rhine, and Cologne cathedral. But I do not like Kölsch.«

Photo: Eric Schmitt

Photo: Uwe Dettmar



Andreas Dreuw

Exact and instantaneous

Andreas Dreuw, born in Neuss in 1972, studied chemistry in Düsseldorf and Heidelberg and received his PhD in 2001 from Heidelberg University. With a stipend from the DFG Emmy Noether Programme, he worked first for two years as a postdoc at the University of California at Berkeley, and then until 2009 as an independent junior group leader at Goethe University Frankfurt. In 2007 he habilitated at the Institute of Theoretical and Physical Chemistry at Goethe University. He was a Heisenberg professor from 2009 to 2011. In the spring of 2011, he moved from Frankfurt to Heidelberg University after being offered the Chair of Theoretical and Computational Chemistry at the Interdisciplinary Center for Scientific Computing. He has been the center's managing director since 2017. During lunch breaks, he likes to go running along the river Neckar together with colleagues.

Theoretical and computer-aided chemistry Our research group focuses on the development of quantum chemical methods for excited electronic states and molecular properties as well as their application in chemistry, biology and materials science. The goal is to develop workable and easy-to-use methods, which are accurate enough to allow us to compare their results directly with the experimental data and measured spectra. Here we focus on perturbation theory methods*, which provide electron affinities*, ionization energies* or excitation energies. Over the last years, we have developed a computer-aided toolbox for photochemistry. We are using these methods to study cage molecules, two-photon compounds, N-heteropolycycles, DNA photo-damage and repair, non-linear spectroscopy, and more recently also X-ray spectroscopy and the decay of electronic states. Recently, we have also done some work on mechanochemistry*, ie with compounds whose reactions are triggered by mechanical forces.

Photo: Uwe Dettmar

Christian Grünewald

Stimulating mixture

Christian Grünewald was born in Offenbach in 1979. After graduating from high school in Offenbach, he studied chemistry at Goethe University Frankfurt, received his Dipl.-Chem. degree in 2006, followed by a PhD in organic chemistry at the Institute of Organic Chemistry and Chemical Biology. Afterwards Grünewald taught several practical courses and seminars, and he was working on the synthesis of modified RNA in the context of the Collaborative Research Center 902. Since 2014 he is the coordinator of CLiC. Grünewald has been a city councilor in Offenbach since 2011 and a volunteer in the German Federal Agency for Technical Relief since 1997. He used to be a trainer at the rowing club Hellas Offenbach when he was a student.

Administration, research and teaching Currently, my work consists of coordinating the research training group and working for the Collaborative Research Center »Molecular Principles of RNA-based Regulation« (CRC 902) funded by the DFG. I do not teach a lot at the moment.

In the SFB I have the opportunity to continue some of the research I started during my PhD, and also to share my expertise. My PhD involved chemical synthesis of RNA molecules modified with a specific fluorescent molecule. By now I also synthesise RNAs, which carry a so-called spin label* as a reporter molecule, so that the RNA can be studied with EPR spectroscopy*.

I do not have my own CLiC project but can provide scientific support in many areas, such as small-molecule organic syntheses or the synthesis, purification, and manipulation of DNA and RNA. An essential part of my job as a coordinator is the administrative work. I am always happy when we succeed in providing the PhD students with a good basis for their work, may it be through courses for self-organisation and presentation of their own work, through inviting stimulating scientific guests, through good mentoring, through great events like the summer schools, and so on. These multifaceted organisational tasks round up my work at the interface between research, teaching and administration.

Photo: Photocase

»History has always interested me. I hope that individuals as well as societies can learn from mistakes and do not run into the same problems again and again.«

Which other discipline, far from your own, is of particular interest to you and perhaps a source of inspiration?

History has always interested me. The quote, »History does not repeat itself« might be true but I believe that there are patterns that are repeated over time, in societies and also in people. And I hope that individuals as well as societies can learn from mistakes and do not run into the same problems again and again.

Was there a decisive impetus for your decision to study chemistry?

No, it was more of a gradual development. Fortunately, I had very good chemistry teachers at school: one had a PhD in chemistry, and the other one also taught biology and was always able to connect the two subjects. Chemistry is the subject that combines theory and practice in the most natural way. I think that was the decisive point: The intellectual challenge of the theory, such as the basics of quantum mechanics, combined with practical work such as conducting analyses and syntheses in the lab.

Do you listen to music while working? If yes, what kind?

Oh, sometimes, this is a touchy subject because usually two or more scientists share a lab. Ideally, they have a similar taste in music, and if that is not the case tolerance helps. During practical work I sometimes like to listen to pop music or electronic music, but when I have to concentrate more I prefer no music or classical music. German schlager music, hip hop or opera are not my favourites.

Where did you spend your last vacation?

We spent it on Crete. This island offers a wonderful mixture of nature and culture: beautiful beaches, great mountains for hiking, and a lot of history – from the cultural beginnings until today – to explore and experience. And the Cretans are very hospitable. The food is simple but very, very good. A beautiful spot in the Mediterranean, where European culture originated.

What does your circle of friends look like? Are they mainly scientists or more mixed?

Well, my wife also has a PhD in chemistry. Nevertheless, our friends are a mixed bunch: biology, business administration, (food) chemistry, computer science, dentistry, law, physiotherapy, psychology, teaching, to name just a few specialties – in alphabetical order.

Can you laugh at yourself? And what can you stand only with a sense of humour?

I need it to cope with the fact that I cannot laugh at myself. Seriously, I laugh – even at myself – when people, who consider themselves very important and take themselves too seriously, are been caught up by human fallibility. I do not mean Schadenfreude but rather the pleasure of being brought back down to earth by reality. I think humor always helps reducing pressure and tension in oneself and others.

Glossary

Ab initio method Term derived from theoretical chemistry, which includes all methods of describing atoms, molecules and solids that initially do not use parameters adapted to the experimental data.

Antigens Foreign proteins against which the immune system forms antibodies.

ATP Adenosine triphosphate is the most important form of storage of chemical energy in the cells of a living organism.

Chelating compounds Compounds, which bind to a central atom at two or more sites. They form very stable complexes.

Degradosome Bacterial protein complex, the best-known function of which is the degradation of mRNA (messenger RNA).

Density functional theory method Computational quantum mechanical method, which by applying certain assumptions and approximations allows the determination of the energies of more complex molecules. This method is therefore one of the most important ones in theoretical chemistry.

Deoxyribonucleic acid → nucleic acid

Diacylglycerol kinase Enzyme, which catalyses the conversion of diacylglycerol to phosphatidic acid, utilising ATP in the process.

DNA → nucleic acid

Electron affinity Energy difference between the ground state of a neutral atom and the ground state of the associated negatively charged ion – ie a measure of the energy needed to turn a neutral atom into an ion with a single negative charge.

EPR spectroscopy Electron paramagnetic resonance spectroscopy is a method for the investigation of paramagnetic substances – ie substances with unpaired electrons. The absorption of microwaves by a sample is measured in a static magnetic field.

Extinction coefficient Measure for the attenuation (extinction) of electromagnetic waves by a medium, based on distance travelled through the medium and on the concentration of the substance in the solvent. The extinction is due to scattering and absorption.

Femtosecond One femtosecond equals 0.000 000 000 000 001 seconds. In a femtosecond light travels 0.00033 mm, while in one second it travels 300000 kilometers.

Fluorescence microscopy Sensitive measurement method to study structural and in particular dynamic properties of biomolecules. The fluorescent light emitted by the sample is observed instead of the light absorption (→ extinction coefficient). The atoms of the sample to be examined are brought into an excited state by electromagnetic radiation, from which they return to the ground state by spontaneous emission of fluorescent light.

FRET Förster resonance energy transfer is a physical process of energy transfer. The energy of an excited dye (donor) is transferred to a second dye (acceptor).

GPCR G protein-coupled receptors (G protein: guanosine triphosphate-binding protein). An important family of membrane proteins, which convert a variety of external signals (such as hormones) into cellular signaling cascades. An important target of pharmaceuticals.

Helicase Helicases are enzymes, which alter the structure of double-stranded nucleic acids. They are, for example, important for the reproduction of genetic material or gene expression (gene expression: translation of the genome into active molecules).

Homeostasis The ability of a system to adjust its internal environment to maintain a state of dynamic constancy optimal for the functioning of the organism.

Ion channel Protein complex embedded in the cell membrane and usually selectively permeable to specific ions. Ion channels span the entire thickness of the cell membrane and can thus permit or prevent in a targeted manner the passage of certain ions or molecules into the cell.

Ionization energy Energy required to ionize an atom or molecule, that is, to separate an electron from an atom or molecule.

Isomerization The conversion of a compound into a different isomeric form, ie a molecule with the same formula but a different arrangement of atoms.

Isotopomer An isomer of an organic compound differing only in the position of the isotopes (→ Isomerization).

LILBID Laser Induced Liquid Bead Ion Desorption mass spectrometry, a mass spectrometry method, in which ions are gently transferred from the liquid phase into a vacuum. For this purpose, microdroplets are exploded with the help of laser radiation. As a result, ions from the liquid reach the vacuum, where they can be analysed by mass spectroscopic methods.

Lipid Basic building block of biological membranes. Most important are phospholipids but also lecithin and cholesterol. All lipids have poor solubility in water but can be easily dissolved with non-polar organic solvents such as acetone, methanol, ether or chloroform. In aqueous solution, double layers form spontaneously macroscopic phases, the basis for the development of cells.

Lipid regulator Membrane-integrated or -associated proteins, which modify membranes with regard to their lipid composition and properties.

Magic angle A common term in magnetic resonance for the angle θ of 54.7 °, at which the space-mediated dipolar coupling between the magnetic moments disappears.

Mass spectrometer → Mass spectrometry

Mass spectrometry The underlying principle of mass spectrometry (MS) is based on the ionization of particles and their subsequent separation into electric and magnetic fields according to their mass and charge.

Mechanochemistry The branch of physical chemistry, which deals with the chemical behaviour of substances under mechanical impact.

Membrane protein Proteins bound to or embedded in the cell membrane. The cell membrane is the »covering« that separates each cell from its environment.

Myoglobin Muscle protein, which as a red muscle dye reversibly binds oxygen. Myoglobin has approximately 6-fold higher affinity for oxygen than hemoglobin and serves as an oxygen reservoir in muscle tissue.

Nanometer A billionth of a meter. The ratio of a nanometer to a meter is about the same as that of the diameter of a 1 cent coin to the diameter of the Earth.

nESI Nano-electrospray ionization. A technique used in mass spectrometry, where the dissolved sample is sprayed through a tiny positively charged needle into a vacuum chamber, sucked into the spectrometer and positively charged in the process. In the vacuum the solvent droplets evaporate until only the molecules of the sample are left.

NMR → NMR spectroscopy

NMR spectroscopy Nuclear magnetic resonance spectroscopy. Method for the analysis and identification of substances as well as for the structure determination of mostly organic compounds. It is based on the different behaviour of magnetically active atomic nuclei under the influence of a strong external magnetic field.

NPE Nitrophenyl ethyl group. A simple and widely used photocleavable compound.

Nuclear magnetic resonance (NMR) → NMR spectroscopy

Nucleic acid Nucleic acids are macromolecules composed of individual building blocks, the nucleotides. They are the carriers of the genetic information in all organisms. Depending on the nature and function of the building blocks, a distinction is made between DNA (deoxyribonucleic acid) and RNA (ribonucleic acid).

Peptide Organic chemical compound composed of amino acids linked by peptide bonds. Polypeptides larger than 100 amino acids are called proteins. The great majority of the most important biological functions are fulfilled by proteins and polypeptides. Insulin is an example for a medically important polypeptide.

Perturbation theory Theoretical physics method for the approximate calculation and determination of the motion of quantum physical systems.

Phosphorus solid-state nuclear magnetic resonance spectroscopy → NMR spectroscopy

Polypeptide chain → peptide

Proteome The entire set of proteins in a living organism, a tissue, a cell or a cell compartment, under exactly defined conditions and at a specific point in time.

Pump pulse Excitation pulse. A typical femtosecond experiment consists of a sequence of two pulses: a »pump pulse« (excitation pulse), which brings the molecule into an excited (dynamic) state, and a delayed »probe pulse« (interrogation pulse), which provides the dynamic information of the system at different points in time.

Quantum efficiency Relationship between the number of defined processes, which are triggered by the absorption of photons (light quanta), and the total number of absorbed photons. The quantum efficiency is less than (or in rare cases equals) one.

Quantum mechanics Quantum mechanics, also called quantum theory or quantum physics, is a fundamental theory in physics, which describes the behaviour of matter at the atomic and subatomic level.

Receptor A protein or a protein complex, to which signalling molecules can bind, thereby triggering signalling processes inside the cell.

Rhodopsin A visual pigment in the retina of the eyes of vertebrates and in the photoreceptors of invertebrates. In the human eye, it is responsible for light and dark adaptation of the rods of the retina. It is a membrane protein with retinal as chromophore and can fulfill a variety of light-driven functions (ion pumps, ion channels, sensors).

Ribosome Cell organelles, which occur in all living organisms and conduct the last step in protein biosynthesis, ie the reading and translation of the mRNA into amino acid chains (proteins).

RNA → nucleic acid

Spin label Organic molecules typically have only paired electrons. Spin labels are the rare exceptions and have one unpaired electron, therefore have a different magnetic behaviour – they are paramagnetic.

Thermodynamics A branch of physics concerned with thermal phenomena, ie all processes, which are influenced by temperature or changes in temperature. It deals with the theory of energetic processes, and its core statements are summarised in the so-called laws of thermodynamics.

Tunnel effect A quantum mechanical phenomenon, which cannot be explained by the laws of classical physics, in which a particle tunnels through a barrier although the kinetic energy of this particle would classically not be sufficient.

Vibrationally promoted electronic resonance The electronic transition of a molecule (absorption of light) in the ultraviolet or visible range is shifted to shorter wavelengths (»red light«) by prior absorption of infrared radiation.

VIPER → Vibrationally promoted electronic resonance.

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