

# Ultrafast Spectroscopy in Biomedical Research – Shining Light on Drug Activation and Release



**Prof. Benjamin Dietzek**

**Institute for Physical  
Chemistry,**

**Friedrich Schiller University  
Jena,**

**Jena, Germany**

Light-driven drug activation or release might present interesting paths to follow in order to achieve temporally and spatially specific targeting. Designing efficient drugs for, e.g., photodynamic therapy or nano-containers for light-controlled drug delivery requires (from a mechanistic point of view) an in-depth understanding of the photodriven processes. This talk will highlight our recent research endeavors in achieving such in-depth mechanistic insights into the photochemistry and photophysics of drug delivery and drug activation.

The first part of the presentation will focus on experimental approaches to characterize the role of specific and non-specific drug-solvent interactions on the excited state dynamics of the drugs. In order to derive a solid research methodology in this context, we will first focus on a class of photoactive transition metal complexes, which shows a highly robust photochemistry. Nonetheless, one member of the class of photoactive Rull complexes, TLD1433, has matured into a phase II clinical trial. Thus, I will discuss our approach to study the photophysics of this class of complexes in increasingly complex environments up to (fixed) human cancer cells.

The second part of the talk will consider our recent attempts to realize a light-activated nano-container for drug delivery. In particular the talk will address challenges related to the biomedical requirement that light within the biological window should be used for triggering drug release. This however is in conflict with photochemistry, which offers more efficient ways to activate release upon UV light absorption. Hence, I will elaborate on the potential of using low-energy triplet-triplet upconversion in an all-polymer system that can be used in nano-containers.

## SHORT BIOGRAPHY

### Synopsis of Professional Achievements:

Since 09.2011	Professor (W2) for Physical Chemistry Spectroscopy in the Condensed Phase - Molecular Photonics at the Friedrich Schiller University Jena
Since 07.2013	Head of the Research Department Functional Interfaces at the Leibniz Institute of Photonic Technology
Since 05.2017	Deputy Scientific Director of the Leibniz Institute for Photonic Technology
2009-2012	Scientific Coordinator of the Jena Research Consortium PHOTOMIC
2012-2016	Chair of the European COST Action CM1202 PERSPECT-H2O
Since 07.2017	Coordinator of the Integrated Training Group for PhD Student Education and Young Researcher Training within the CRC 1278 POLYTARGET
Since 11.2018	Chair of the International Training Network, Marie-Curie-Action LogicLab
Since 07.2018	Co-Spokesperson of the Collaborative Research Center CRC/TRR 234 CATALIGHT (jointly with Prof. Dr. Sven Rau, Ulm University)

Editor of Chemical Physics Letters, Member of the Board of the Division of Photochemistry of the German Chemical Society, Member of the Ständiger Ausschuss der Bunsengesellschaft (German Society for Physical Chemistry).

(Local) Organizer of various conferences including the 118. Bunsentagung (2019), the 25th Lecture Conference in Photochemistry (2017) and the *Manfred-Eigen-Nachwuchswissenschaftlertgespräche - Molecules, Light and Life* of the *Deutsche Bunsengesellschaft* (2012).

Supervision of 13 Bachelor theses, 16 Master-/Diploma theses, 34 PhD theses and mentor of two Habilitations .

>250 peer-review publications, >5400 citations, H-index 41 (Web of Science, September 3rd 2019)

## Education:

- 10.1998 - 07.2001 Study of Physics at the University Würzburg, Germany
- 08.2002 Master of Arts in Physics at the State University of New York at Stony Brook  
A diode laser system for production of metastable Helium atoms in Rydberg states using Stimulated Raman Adiabatic Passage supervised by Prof. Dr. Metcalf (Stony Brook)
- 01.2003 Diplom in Physics at the University Würzburg, Germany (Grade: very good)
- 02.2003 - 11.2005 PhD Studies at the Institute for Physical Chemistry at the University Würzburg in the working group of Prof. Dr. Dr. h.c. W. Kiefer, topic: Ultrafast linear and non-linear spectroscopy: From biological light-receptors to artificial light-harvesting systems
- 04.2005 - 06.2005 Research stay at the University Lund, Sweden, in the working group of Prof. Dr. V. Sundström (Department of Chemical Physics)
- 22.11.05 PhD Defense (Grade: summa cum laude)
- 07.2010 Habilitation in Physical Chemistry and Promotion to Privatdozent at the Institute for Physical Chemistry, Friedrich Schiller University Jena.

## Professional Affiliations and Duties:

- 01.2006 - 12.2006 Postdoctoral Researcher in the working group of Prof. Dr. V. Sundström at the Department of Chemical Physics, Lund University, Sweden
- 01.2007 - 12.2007 Postdoctoral Researcher in the working group of Prof. Dr. A. Tokmakoff at the Department of Chemistry, Massachusetts Institute of Technology, Cambridge, USA
- Since 09.2011 Professor (W2) for Physical Chemistry *Spectroscopy in the Condensed Phase - Molecular Photonics* at the Friedrich Schiller University Jena
- Since 07.2013 Head of the (newly founded) Research Department *Functional Interfaces* at the Leibniz Institute of Photonic Technology Jena
- Since 05.2017 Deputy Scientific Director of the Leibniz Institute of Photonic Technology Jena
- Since 07.2018 Co-Spokesperson of the Collaborative Research Center CRC/TRR 234 CATALIGHT (jointly with Prof. Dr. Sven Rau, Ulm University)
- Since 11.2018 Coordinator of the International Training Network, Marie-Curie-Action *LogicLab*
- Since 04.2019 Deputy Director of the *Jena Center for Soft Matter*

## Fellowships and Honors:

- 04.2001 - 12.2002 Fellowships of the *Evangelischen Studienwerkes Villigst e.V.*
- 06.2003 - 09.2005 PhD Fellowship of the *Studienfonds der Chemischen Industrie Deutschlands*

04.2005 - 06.2005	Short-term PhD fellowship of the <i>DAAD</i> (German Academic Exchange Service)
06.2006	Price of the Faculty for Chemistry and Pharmacy at Würzburg University for outstanding PhD thesis
01.2007 - 12.2007	Feodor-Lynnen Fellowship of the Alexander-von-Humboldt Foundation
09.2007	Liebig-Fellowship of the <i>Fonds der Chemischen Industrie Deutschlands</i> (declined)
10.2008	Support by the Friedrich Schiller University, program of the Vice-President to support young scientists
04.2010	Support by the Friedrich Schiller University, program of the Vice-President to support young scientists
02.2011	Call to fill the W2-Professorship for Physical Chemistry, denomination: <i>Molecular Spectroscopy in the Condensed Phase</i> , at the Friedrich Schiller University Jena, Germany
03.2011	<i>IPHT-Price 2011</i> for Outstanding Scientific Achievement
04.2011	<i>Science Price of the Beutenberg Campus 2011</i> for outstanding young scientists in physics and the life sciences
2013	Research Prize of the State of Thuringia for Applied Research
2014	Call to fill the position of a Senior Reader (equivalent to a W2-Professorship) in <i>Physical Chemistry</i> at the Heriot-Watt University, Edinburgh, UK (declined)
2018	<i>Prix Forcheurs Jean-Marie Lehn</i> awarded by the French Embassy in Germany and the French-German University in collaboration with the Leopoldina and the French Academy of Sciences
Since 09.2019	Fellow of the Royal Society of Chemistry

### **Bibliometric data**

Web of Science (January 30th, 2020) Total citations 5754 H-index 42

Google Scholar (January 30th, 2020) Total citations 7337 H-index 45

### **List of 10 most significant publications:**

Publications as (co-)corresponding author are marked with an (\*).

1. Sittig, M.; Schmidt, B.; Görls, H.; Bocklitz, T.W.; Wächtler, M.; Zechel, S.; Hager, M.D.; Dietzek, B. Fluorescence upconversion by triplet-triplet annihilation in all-organic poly(methacrylate)-terpolymers, *Phys. Chem. Chem. Phys.* (2020) doi: 10.1039/d0cp00232a.(\*)

2. Zedler, L.; Mengele, A.K.; Ziems, K.-M.; Zhang, Y.; Wächtler, M.; Gräfe, S.; Pascher, T.; Rau, S.; Kupfer, S.; Dietzek, B. Unravelling the Light-Activated Reaction Mechanism in a Catalytically Competent Key Intermediate of a Multifunctional Molecular Catalyst for Artificial Photosynthesis, *Angew. Chem. Int. Ed.* (2019) 58, 13140-13148. (\*)
3. Reichardt, C.; Monro, S.; Sobotta, F.H.; Colón, K.L.; Sainuddin, T.; Stephenson, M.; Sampson, E.; Roque III, J.; Yin, H.; Brendel, J.C.; Cameron, C.G.; McFarland, S.; Dietzek, B. Predictive Strength of Photophysical Measurements for in Vitro Photobiological Activity in a Series of Ru(II) Polypyridyl Complexes Derived from  $\pi$ -Extended Ligands, *Inorg. Chem.* (2019) 58, 3156-3166. (\*)
4. Bold, S.; Zedler, L.; Zhang, Y.; Massin, J.; Artero, V.; Chavarot-Kerlidou, M.; Dietzek, B. Electron transfer in a covalent dye-cobalt catalyst assembly - a transient absorption spectroelectrochemistry perspective, *Chem. Commun.* (2018) 54, 10594-10597. (\*)
5. Lefebvre, J.F.; Schindler, J.; Traber, P.; Zhang, Y.; Kupfer, S.; Gräfe, S.; Baussanne, I.; Demeunynck, M.; Mouesca, J.M.; Gambarelli, S.; Artero, V.; Dietzek, B.; Chavarot-Kerlidou, M. An artificial photosynthetic system for photoaccumulation of two electrons on a fused dipyrrophenazine (dppz)-pyridoquinolinone ligands, *Chem. Sci.* (2018) 9, 4152-4159. (\*)
6. Reichardt, C.; Schneider, K.R.A.; Sainuddin, T.; Wächtler, M.; McFarland, S.A.; Dietzek, B. Excited state dynamics of a photobiologically active Ru(II) dyad are altered in biologically relevant environments, *J. Phys. Chem. A* (2017) 121, 5635-5644. (\*)
7. Chakraborty, S.; Agrawalla, B.K.; Stumper, A.; Veg, N.M.; Fischer, S.; Reichardt, C.; Kogler, M.; Dietzek, B.; Feuring-Buske, M.; Buske, C.; Rau, S.; Weil, T. Mitochondria targeted protein-Ruthenium photosensitizer for efficient photodynamic applications, *J. Am. Chem. Soc.* (2017) 139, 2512-2519.
8. De la Cadena, A.; Davydova, D.; Tolstik, T.; Reichardt, C.; Shukla, S.; Akimov, D.; Heintzmann, R.; Popp, J.; Dietzek, B. Ultrafast in cellulo photoinduced dynamics processes of the paradigm molecular light switch [Ru(bpy)2dppz]2+, *Sci. Reports* (2016) 6, 33547. (\*)
9. Reichardt, C.; Sainuddin, T.; Wächtler, M.; Monro, S.; Kupfer, S.; Guthmüller, J.; Gräfe, S.; McFarland, S.; Dietzek, B. Influence of protonation state on the excited state dynamics of a photobiologically active Ru(II) dyad, *J. Phys. Chem. A* (2016) 120, 6379-6388. (\*)

10. Reichardt, C.; Pinto, M.; Wächtler, M.; Stephenson, M.; Kupfer, S.; Sainuddin, T.; Guthmuller, J.; McFarland, S.A.; Dietzek, B. Photophysics of Ru(II) dyads from pyrenyl-substituted imidazole[4,5-f][1,10] phenanthroline ligands, *J. Phys. Chem. A* (2015) 119, 3986-3994. (\*)