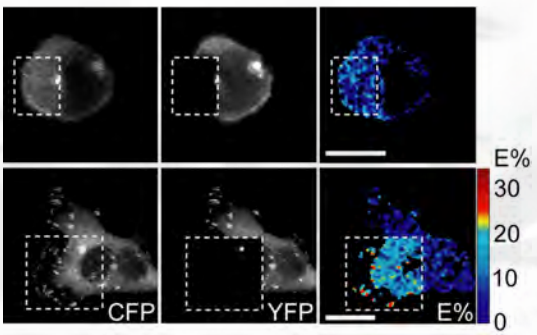
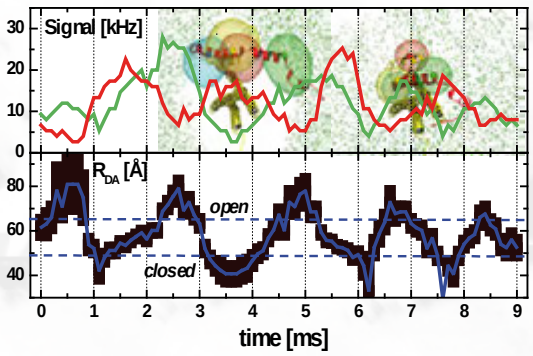
International Bunsen Discussion Meeting

Förster resonance energy transfer in life sciences

Handout

27.3. - 30.3.2011
Max Planck Institute for Biophysical Chemistry
Göttingen





Under the auspices of:

MAX-PLANCK-GESELLSCHAFT

IMPRS Physics of Biological and Complex Systems

DBG

GBM

Welcome to Göttingen!

On occasion of the 100th anniversary of his birth and 65 years after his first publication on resonance energy transfer we are honoring Prof. Theodor Förster's achievements by a discussion about FRET, a topic of his rich scientific legacy which began in this town.

During the years 1946 to 1948, Theodor Förster published papers in Naturwissenschaften and Annalen der Physik outlining the quantum-mechanical behaviour of the transfer of electronic excitation energy between two molecules in a solution. Förster's groundbreaking work in spectroscopy was built upon the earlier theories of J. and F. Perrin, and explained the non-radiative transfer of energy between two molecules. Förster's contribution, FRET, is an acronym for Förster resonance energy transfer or fluorescence resonance energy transfer. Equations determined by Förster were the basis for a quantitative interpretation of FRET and results in parameters that can be derived experimentally. FRET is a common and fundamental photophysical process in the life and materials sciences. After absorption of light, intrachromophore processes, such as radiative decay (e.g., fluorescence, phosphorescence) and radiationless transitions (e.g., internal conversion, intersystem crossing), dissipate the absorbed energy. FRET is an interchromophore relaxation process that transmits the electronic excitation from an initially excited donor to a ground-state acceptor.

While resonance energy transfer was first observed in fluorescence polarization studies in the 1920s, interest in FRET was limited to interpreting the concentration dependence of fluorescence depolarization. The intention of Förster's papers was to describe in a quantitative fashion the energy migration in molecular crystals and during photosynthesis in plants. Numerous manifestations and uses of FRET have been described over the ensuing years. Some notable examples include light harvesting in photosynthesis, design of high performance sensors, structural determination in macromolecules, and detection of biomolecular interactions in the life sciences. The number of citations using FRET measurements has increased almost 300-fold over the past 20 years.

We call this a “Discussion” Meeting because we will not have long plenary lectures but rather lively discussions after short presentations and around posters about your latest experimental results, ideas, or theories related to FRET. We warmly welcome you to our discussion meeting!

The organizing committee: Donna Arndt-Jovin, Stefan Hell, Thomas Jovin, Claus Seidel and Jürgen Troe

We thank for the scientific committee for helping setting up this program:

- Clegg, Robert (Department of Physics, University of Illinois Urbana Champaign, USA)
- Enderlein, Jörg (Department for Physics, Göttingen, D)
- Herrmann, Christian (Department for Chemistry, Ruhr-University Bochum, D)
- Lamb, Don (Department for Chemistry, Ludwig-Maximilians-University Muenchen, D)
- Schröder, Sabrina (MPIBPC Göettingen, D)
- Walla, Peter (MPIBPC Goettingen and Department for Chemistry, Technical University Braunschweig, D)
- and all members of the organizing committee

This conference is organized under the auspices of:

Max-Planck-Institut für Biophysikalische Chemie

International Max Planck Research School Physics of Biological and Complex Systems

German Society for Biochemistry and Molecular Biology
(Study Group Biophysical Chemistry)

Academy of Sciences and Humanities Göttingen

German Bunsen Society for Physical Chemistry

Theodor Förster: A giant of modern photochemistry

May 15th, 1910 - May 20th 1974

1933	Ph.D. (with Erwin Madelung) University of Frankfurt am Main
1942	o. Professor, the State University of Poznan
1946	Arrival in Niedernjesa, Kr. Göttingen (old school)
27.9.1946	First Publication on FRET **(now 65 years)** *Energy transport and fluorescence* [in German] Naturwissenschaften 33:166-175.
1.12.1947-30.4.1951	Max-Planck-Institute for physical chemistry, Göttingen, leader of the department for "structure research".
1948	Most cited work on FRET (4311 citations until 18.3.2011) *Zwischenmolekulare Energiewanderung und Fluoreszenz* [in German] Annalen der Physik 437(2): 55-75.
1.5.1951	Full Professor, Technical University Stuttgart
17.7.1952	External scientific member of the Max-Planck-Institute for physical chemistry

Three main research fields (77 Publications from 1933 to 1975)

1. Förster Resonance Energy Transfer (FRET),
2. the Förster cycle, linking protolysis and reprotonation of molecules in the excited state,
3. excimer formation by association of an excited with an electronic-ground-state molecule.

Literature (see our webpage: http://fret.uni-duesseldorf.de/cms/Literature.html)

1. Albert Weller, *Nachruf auf Theodor Förster*, Berichte der Bunsengesellschaft für Physikalische Chemie 1974, **78**(10): 969-971 [German].
2. Albert Weller, *In Memoriam Theodor Förster*, EPA Newsletter 1980, **9**(April): 6-19 [English].
3. Special Issue: Förster Resonance Energy Transfer, ChemPhysChem 2011, **12**(3) 421-719.

Program of the International Bunsen Discussion Meeting
"Förster Resonance Energy transfer in Life Sciences"
Göttingen, March 27-30, 2011

Sun, 27.03.		
18:00-19:00	**Get-together**	
19:00-19:15	Jürgen Troe	Introduction "The role of Theodor Förster in Physical Chemistry and the Bunsengesellschaft"
19:15-20:15	Robert Clegg	Plenary lecture "Energy transfer from the dark ages through enlightenment"
20:20-21:30	***Concert**: Hyperion-Trio (**www.hyperion-trio.de)***	
21:30-22:30	***Reception***	

Mon, 28.03.		
FRET in Photobiology / Updating Förster Theory, *Chair: Jürgen Troe*		
9:00-9:30	Peter Walla	Förster Energy Transfer and Multi-Photon excitation
9:30-10:00	Lennart Johansson	Extended Förster Theory: A Quantitative Approach to the Determination of Inter-Chromophoric Distances in Biomacromolecules
10:00-10:20	Karl-Heinz Drexhage	Long-range energy transfer from electric-quadrupole donors
10:20-10:50	***Coffee***	
FRET in Photobiology / Updating Förster Theory, *Chair: Alexander Demchenko*		
10:50-11:20	Rienk van Grondelle	Ultrafast Excitation Energy Transfer and the Mechanism of Non-Photochemical Quenching in Plant Photosynthesis
11.20-11:50	Biman Bagchi	Distance and orientation dependence of excitation energy transfer: From molecular systems to nanometal particles
11:50-12:10	Wolfgang Becker	FRET measurements by TCSPC FLIM
12:10-12:30	Felix Koberling	Lifetime-resolved FRET microscopy
12:30-14:00	***Lunch***	

14:00-17:00	***Poster session & coffee***	
FRET Imaging I, *Chair:* Vinod Subramaniam		
17:00-17:30	Enrico Gratton	FRET based biosensor: a comparative study of the phasor approach to FLIM with ratiometric analysis in live cells
17:30-18:00	Thomas Jovin	Two Faces of FRET: from QD biosensors to live-cell EGFR signaling
18:00-18:30	David Piston	Improving the sensitivity and efficiency of FRET measurements using spectral detection
18:30-18:50	Fred Wouters	Förster Resonance Energy Transfer Imaging in live cells
18:50-19:10	Fabien Pinaud	Specific *In Vivo* Single Protein Targeting and Tracking in Living *Caenorhabditis elegans* nematodes by single pair FRET-Complementation Activated Light Microscopy
19:10-19:25	***Meeting of the GBM study group Biophysical Chemistry***	
19:30-22:00	***Conference Dinner***	

Tue, 29.03.		
FRET Spectroscopy: FRET as Structural Ruler, *Chair: Stefan Hell*		
9:00-9:30	Helmut Grubmüller	Atomistic Simulations and Interpretation of Single Molecule Spectroscopy Experiments
9:30-10:00	Claus Seidel	Conformational dynamics and biomolecular structure studied by super-resolution FRET
10:00-10:20	Christian G. Hübner	The spectroscopic ruler revisited with frozen single molecules
10:20-10:50	***Coffee***	
FRET Spectroscopy: FRET as Structural Ruler, *Chair: Jörg Enderlein*		
10:50-11:20	Keith Weninger	Biomolecular modeling using FRET measurements
11.20-11:50	Marcia Levitus	Fluorescence fluctuation spectroscopy and FRET: Investigating biopolymer conformational dynamics
11:50-12:10	Don Lamb	Combining FRET experiments with pulsed interleaved excitation
12:10-12:30	Elisha Haas	Intramolecular distance distributions, fast fluctuations, conformational transitions and

		folding of proteins studied by time-resolved FRET based methods.
12:30-14:00	***Lunch***	
FRET Spectroscopy: Biophysical Chemistry, ***Chair: Roland Winter***		
14:00-14:30	Achillefs Kapanidis	Single-molecule FRET methods and studies of biomolecular dynamics
14:30-15:00	Bill Eaton	Single-Molecule FRET and Transition Paths in Protein Folding
15:00-15:30	Benjamin Schuler	Single Molecule FRET of Intrinsically Disordered Proteins
15:30-15:50	Werner Nau	Fluorescence Resonance Energy Transfer in the 10-Å Domain – A spectroscopic ruler for short peptides
15:50-16:30	***Coffee***	
Perspectives in FRET, ***Chair: Roland Brock***		
16:30-17:00	Michael Lin	Expanding the range of genetically encoded FRET with new green and red fluorescent proteins
17:00-17:30	Igor Medintz	Quantum dots and FRET: New sensing possibilities
17:30-17:50	Niko Hildebrandt	Lanthanides and Quantum Dots – FRET beyond Förster's theory
17:50-19:15	***Dinner***	
19:15-21:00	**Round table on probe development,** ***Chair: Markus Sauer***	
	Valdimir Belov	Photochromic Compounds for Aqueous Solutions and Focusable Light
	Karl-Heinz Drexhage	Organic dyes as fluorescent labels
	Markus Sauer	Photoinduced formation of dye radicals and their impact on fluorescence microscopy
	Ulrich Nienhaus	Fluorescent protein markers for optical imaging and FRET
21:00-open end	***Poster session & beer***	

Wed, 30.03.		
FRET Imaging II, ***Chair: Donna Arndt-Jovin***		
9:00-9:20	Steven Magennis	Global structure of forked DNA in solution
9:20-9:50	Philippe Bastiaens	The value of FRET in bridging scales in quantitative biology
9:50-10:10	Stephan Diekmann	*In vivo* FRET walking through the human kinetochore
10:10-10:40	***Coffee***	
FRET Imaging II, ***Chair: Yves Engelborghs***		
10:40-11:10	Theodorus Gadella	Third generation genetic encoded FRET probes based on FLIM screening and exploiting photochromicity
11:10-11:40	Maite Coppé	Spatio-temporal fluctuations of supranucleosomal state regulating accessibility of bromodomain to acetylated H4 in living cells by high-resolution FLIM
11:40-12:00	Jan Willem Borst	Exploiting the Rise Time of Acceptor Fluorescence by FRET-FLIM in Living Cells
12:00-12:20	Carsten Grashoff	Analyzing intracellular force-transduction using a FRET-based tension sensor
12.20-12:30	Thomas Jovin	***Concluding Remarks***
12:30-14:00	***Lunch***	
14:00-18:00	***Excursion:*** The Förster tourist "History of science in Göttingen": Paulinerkirche, Universitätsaula with Karzer, Göttingen University Astronomical Observatory (First director Carl Friedrich Gauß), Förster's original research labs in the Bunsenstrasse	
18:00-open end	***Visit of the old town***	

List of Posters

P1	**Al-Soufi, W.**	Supramolecular association dynamics studied by fluorescence correlation spectroscopy
P2	**Arndt-Jovin, D.**	Determination of dynamic ErbB receptor conformations in living mammalian cells using TCSPC FLIM
P3	**Balasubramanian, G.**	Scanning FRET microcopy using Diamond Color Center
P4	**Bates, M.**	Single-molecule localization methods for super-resolution fluorescence microscopy
P5	**Bergen en Henegouwen, van P.**	Ligand-induced EGF receptor oligomerization is kinase-dependent and enhances internalization
P6	**Birkedal, V.**	Single molecule FRET microscopy studies of tRNA annealing onto the HIV-1 genome
P7	**Blank, K.**	Stretched exponentials in single enzyme kinetics: An artefact of data processing?
P8	**Bogaart, G. van den**	One SNARE complex is sufficient for membrane fusion
P9	**Brock, R.**	FRET-based probes for measuring intracellular peptide degradation
P10	**Büning, S.**	Protein refolding dynamics and heat-shock response investigated in a living cell by Fast Relaxation Imaging (FReI)
P11	**Burger, M.**	Single molecule spectroscopy of membrane bound H+-ATPsynthases from E. coli
P12	**Cardo, L.**	Folding of a large ribozyme by FRET bulk experiments and single molecule characterisation
P13	**Cherny, D.**	Analysis of the data obtained from single molecule experiments with immobilized fluorophores
P14	**Constantinescu, D.**	MST1 and Nore1 Interactions in Apoptosis
P15	**Cordes, T**	Single-Molecule FRET Reveals Conformational Dynamics of the RNA Polymerase-DNA Open Complex
P16	**Demchenko, A.P.**	Molecular ensembles and homo-FRET
P17	**Díaz, S.A.**	Biocompatible Quantum Dots Photoswitchable by pcFRET. Single-Particle Characterization
P18	**Diekmann, S.**	In vivo FRET walking through the human kinetochore
P19	**Dsouza, R.**	Short-distance FRET in a 14-Mer Peptide: II. towards absolute end to end distance distributions and diffusion coefficients
P20	**Eggeling, C.**	STED Nanoscopy and Fast Single-Molecule Tracking Reveal Nanoscale Details of Membrane Interactions – Perspectives of FRET
P21	**Engelborghs, Y.**	Early aggregation steps in a synuclein as measured by FRET and Fluorescence correlation spectroscopy
P22	**Ernst, S.**	Studying the membrane insertion process of the Pf3 coat protein by the E. coli insertase YidC via single molecule FRET

P23	**Felekyan, S.**	Polarization resolved FCS and species cross correlation function highlight binding dynamics in biomolecules
P24	**Fitter, J.**	Native and Unfolded States of Phosphoglycerate Kinase Studied by Single-Molecule FRET
P25	**Flehr, R.**	Tailor-made peptides and DNA strands as a toolkit for resonance energy transfer probes: design and evaluation
P26	**Friedrich, T.**	Investigations of phycobilisome diffusion in cyanobacteria by fluorescence lifetime imaging microscopy
P27	**Geiger, A.**	Biophysical characterization of the FRET-based calcium indicator TN-XXL
P28	**Gietl, A.**	Single-Molecule Assay of DNA-Motor Proteins
P29	**Godt, A.**	Molecular rulers for the spectroscopic rulers DEER and FRET
P30	**Grashoff, C.**	Analyzing intracellular force-transduction using a FRET-based tension sensor
P31	**Haas, E.**	Intramolecular distance distributions, fast fluctuations, conformational transitions and folding of proteins studied by time-resolved FRET based methods.
P32	**Hengstenberg, C.S.**	Structural and dynamic features of the immuno-active GTPase hGBP1 studied by single molecule FRET
P33	**Hildebrandt, N.**	Multiplexed diagnostics and spectroscopic ruler measurements with semiconductor quantum dots as FRET acceptors
P34	**Hirschfeld, V.**	The spectroscopic ruler revisited with frozen single molecules
P35	**Hofmann, H.**	Single molecule spectroscopy of protein folding in a chaperonin cage
P36	**Hoischen, C.**	The kinetochore protein CENP-W: localization, dynamics, and neighborhood relations
P37	**Holzmeister, P.**	Single molecule spectroscopy meets DNA origami
P38	**Inal, S.**	Energy Transfer as a Probe for Studying the Phase Transition of Oligo(ethylene glycol) based Thermoresponsive Hydrogels
P39	**Jacob, M.H.**	Specific compaction in the early refolding of adenylate kinase studied by FRET and FRET donor–acceptor pairs with very short Förster radii
P40	**Jagutzki,O.**	Position and time sensitive photon counting detector with image charge delay line readout
P41	**Kalinin, S.**	Structure and dynamics of the RNA four way junction studied by sm FRET
P42	**Kemnitz, K.**	Multichannel Widefield-FLIM for homo- and hetero-FRET Monitoring
P43	**Kudryavtsev, V.**	Lifetime resolved FRET microscopy combining PIE and MFD for accurate SPFRET measurements
P44	**Langhals, H.**	Förster resonant energy transfer (FRET) in orthogonally arranged chromophores
P45	**Laptenok, S.P.**	Ultrafast fluorescence for intra-enzyme FRET studies using substrate-cofactor FRET pairs

P46	**Lemmens, P**	A molecular magnet confined in the nanocage of a globular protein
P47	**Lenger, K.**	Homeopathic Function by Resonance Energy Transfer through Photons detected in Homeopathic Remedies by Magnetic Resonance Methods.
P48	**Lerner, E.**	Inter-Domain Dynamics of E. Coli Adenylate Kinase at the Single Molecule level – µs to ms time range
P49	**Liao, J.**	Protein Interaction Affinity (Kd) Determination by FRET
P50	**Lillo, M.P.**	IRVALEC self-organize in the plasma membrane causing rapid loss of integrity and necrotic cell death in tumor cells .
P51	**Ma, Q.**	Quantitative FRET analysis using Multiparameter Fluorescence Image Spectroscopy
P52	**Magennis, S.W.**	Global structure of forked DNA in solution
P53	**Majoul, I.**	Unravelling connexin interactions with FRET
P54	**Malkusch, W.**	Improvements in a FRET Determination Tool for Faster and More Accurate Results
P55	**Mandal, P.**	Excitation Energy Transfer in a Core/Shell/Shell Quantum Dot – Dye Hybrid: Exploration at the Single Molecule Level
P56	**Nagy, P.**	Comparative analysis of Förster resonant energy transfer (FRET) and proximity ligation assay (PLA)
P57	**Naredi-Rainer, N.**	Ion-specific effects on α-helices
P58	**Nettels, D.**	Quantifying heterogeneity and conformational dynamics from single molecule FRET of diffusing molecules: recurrence analysis of single particles (RASP)
P59	**Norouzy, A.**	Simultaneous short distance FRET and collision-induced fluorescence quenching to quantify how peptide conformation and dynamics depend on side chain charg
P60	**Oort van, B.**	Different crystal packings lead to slightly different conformations of light-harvesting complex II as monitored by variations of the intrinsic fluorescence lifetime
P61	**Oswald, P.**	Incorporation of the H+-ATPsynthase from E. coli into a planar lipid bilayer and observation by spFRET
P62	**Peulen, T.**	Quantitative extraction of structural and dynamic properties in the protein hGBP-1 by single molecule FRET, fluorescence correlation spectroscopy and ensemble fluorescence measurements
P63	**Prokazov, Y**	Recent achievements in a wide-field FLIM/FRET detection techniques cells
P64	**Rei, A.**	Short distance FRET in a 14-MER peptide I. the factors that determine how end to end diffusion contributes to FRET
P65	**Ripp, S.**	Watching Single Enyzmes at Work: A Combination of Single Molecule FRET with Nanoelectronics
P66	**Rippe, K.**	Proximity measurements via FRET, pyrene excimer fluorescence and fluorescence cross-correlation spectroscopy in DNA duplex model systems
P67	**Rodnin, D.**	Dynamic Equilibrium of Initiation Factor 3: A single molecule study of the translation initiation complex

P68	**Saini, S.**	Excitation energy transfer in donor-acceptor systems involving metal nanoparticles: Effect of shape and orientation on distance dependence of energy transfer rate
P69	**Sanabria, H.**	Micro to millisecond conformational transitions of bacteriophage T4 lysozyme resolved by lifetime and polarization filtered fluorescence correlation spectroscopy
P70	**Schmid, S.**	Mechano-chemical cycle of HSP90 By single molecule triple FRET
P71	**Seidel, H.**	Coronavirus nsp7-nsp8 complex formation - a self-organizing process
P72	**Sloniec, J.**	A FRET-based method to probe biomembrane interactions of multimodal contrast agents
P73	**Soltysinski, T.**	Computational determination of four-way RNA junction´s structure by simulated annealing constrained by time resolved single-molecule FRET spectroscopy
P74	**Soranno, A.**	Charge interactions can dominate the dimensions of intrinsically disordered proteins
P75	**Subramaniam, V.**	Integrin-depemdent activation of the JNK signaling pathway by mechanical stress
P76	**Szabó, A.**	Titative characterization of the large scale association of ERBB1 and ERBB2 by flow cytometric homo -FRET measurements
P77	**Szöllősi, J.**	Coclustering of ERBB1 and ERBB2 revealed by FRET-sensitized acceptor bleaching
P78	**Thestrup, T.M.**	Evolutionary engineering of FRET-based calcium indicators
P79	**Tóth, K.**	Stability and dynamics of mononucleosome studied by single molecule FRET
P80	**Turriani, E.**	FRET as a tool to study the conformational transitions and the reaction pathway of the Mg2+-dependent 7S11 deoxyribozyme
P81	**Vamosi, G.**	MHC I organizes protein clusters and inhibits IL-2/IL-15 signaling in human T cells
P82	**Vitali, M.**	Wide-Field Multi-Parameter FLIM: Long-term minimal invasive observation of proteins in living cells.
P83	**Wei, W.**	Assessing the FRET Acceptor Potential of Various BODIPY Dyes for Europium as the FRET Donor
P84	**Werner, A.**	Monitoring RNA Dimerization by Fluorescence Correlation Spectroscopy
P85	**Winter, R.**	Membrane-Mediated Sorting of Signaling Proteins
P86	**Wintermeyer, W.**	Conformations of the signal recognition particle during membrane targeting as determined by FRET
P87	**Woehler, A.**	Optimization of SNR in quantitative spectral FRET imaging of live cells
P88	**Wuttke, R.**	Temperature-dependence of unfolded state dimensions in an alpha-helical protein from single molecule spectroscopy
P89	**Yang, J.**	Study the cytoplasmic tails interaction of Iga/Igb in BCR complex with IP-FCM FRET

P90	**Zeug, A.**	Model for the Oligomer Formation of Serotonin receptors based on quantitative LuxFRET measurements
P91	**Ziomkowska, J.**	Lifetime based FRET spectroscopy for in vivo and in vitro studies of bacterial transport systems