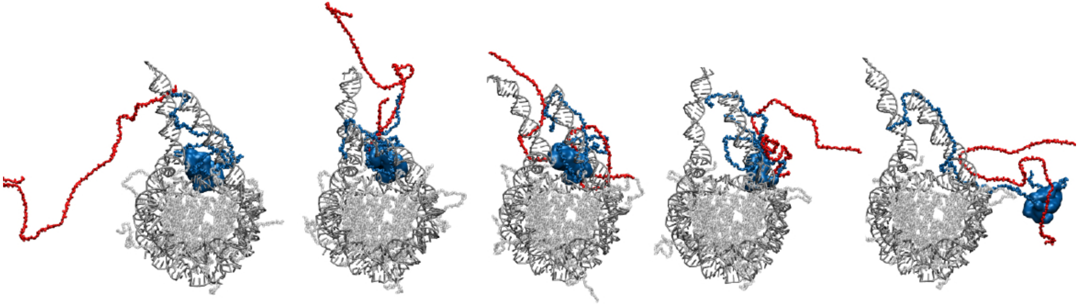
Bio and Medical Physics



Disordered and biological soft matter

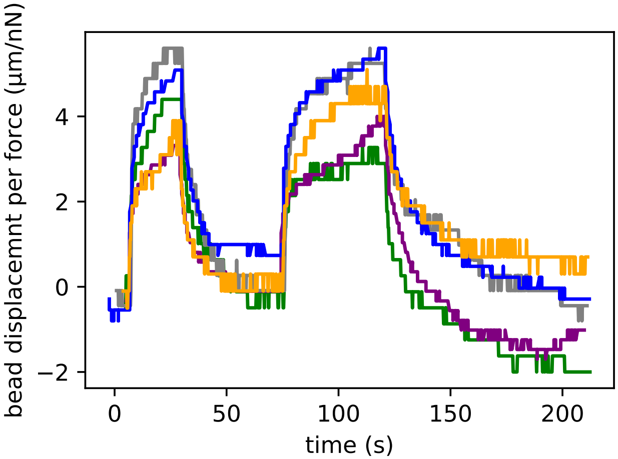
Prof. Christof Aegerter

We study the properties of disordered and heterogeneous systems out of equilibrium. This encompasses light transport in photonic glasses, imaging in turbid media, as well as the elastic properties of growing biological tissues and their influence on development, e.g. in the regeneration of zebrafish fins or the process of dorsal closure in drosophila embryos. In all these fields our investigations are mainly experimental, however we also use computational modeling to guide these experiments. Our studies of light transport in disordered media have two main foci consisting of enabling imaging in turbid media, where we use wave-front shaping of the light to counter-act the effects of multiple scattering and optimisation of light absorbing materials for energy harvesting.

https://www.physik.uzh.ch/g/aegerter

In-vivo force determination of MyosinII waves in Drosophila embryos

The mechanical properties and the forces involved during tissue morphogenesis have been the focus of much research in the last years. Absolute values of forces during tissue closure events have not yet been measured. This is also true for a common force producing mechanism involving MyosinII waves that result in pulsed cell surface contractions. Our patented magnetic tweezer, CAARMA, integrated into a spinning disc confocal microscope, provides a powerful explorative tool for quantitatively measuring forces during tissue morphogenesis. Here, we used this tool to quantify the *in vivo* force production of MyosinII waves that we observed at the dorsal surface of the yolk cell in stage 13 *Drosophila melanogaster* embryos. In addition to providing for the first time quantitative values on an active Myosin-driven force, we elucidated the dynamics of the MyosinII waves by measuring their periodicity in both absence and presence of external perturbations, and we characterised the mechanical properties of the dorsal yolk cell surface.



Bead traces of pulling experiments on the yolk cell cortex in five different embryos (different colours are different embryos).

As an example, the relaxation dynamics displayed by the pull-and-release experiments on the cortex of the yolk cells showed that the elastic cortex restructures on a timescale of about 10 seconds at stage 13. This suggests that the cortex behaves elastically if deformed on a timescale shorter than 10 seconds, while it shows viscous deformation on larger timescales. Dividing the viscosity of the yolk cytoplasm by the characteristic time of cortex relaxation, we obtained a value of E =1.9±0.4 Pa for the elastic modulus of the cortex. This defines a solid-like behaviour of the yolk cell cortex during the dorsal closure stages 13/14, compared to its soft structure during the cellularization stage. We believe that the design and the approach we have established here can be applied widely to different cell types and development stages in Drosophila embryos as well as in other organisms, indicating that it will be a useful tool for analysing a wide range of cell/embryo functions affected by cytoskeletal forces and importantly also for modelling purposes.

Highlighted Publications:

1. Influence of hydrodynamic stress on ray bifurcation and regeneration in zebrafish,
   P. Dagenais, S. Blanchoud, D. Pury, C. Pfefferli, T. Aegerter-Wilmsen, C.M. Aegerter, and A.Jazwinska,
   Journal of Exp. Biol. **224**, jeb242309 (2021)
2. Clean carbon cycle via high-performing and low-cost solar-driven production of freshwater,
   V. Mazzone, M. Bonifazi, C.M. Aegerter, A.M. Cruz, A. Frattalocchi,
   Advanced Sustainable Systems **5**, 202100217 (2021)
3. In-vivo force measurements of MyosinII waves at the yolk surface during Drosophila dorsal closure,
   L.Selvaggi, M. Ackermann, L. Pasakarnis, D. Brunner, and C.M. Aegerter,
   Biophysical Journal **121** (2022)

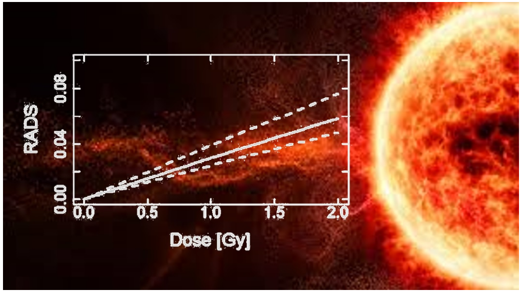
Medical Physics and Radiation Research

Prof. Uwe Schneider (Hirslanden)

We are conducting research and development in **Medical Physics, Theoretical Biology** and **Medical Modelling**. We are involved in projects which pursue research towards next generation radiotherapy and imaging. Our main topics are: Development of radio-biological models, radiation research, Monte Carlo simulations and dosimetry for radiotherapy and imaging and the development of novel detector systems.

https://www.physik.uzh.ch/g/schneider

Currently we are developing an alternative approach for the radiation health risk assessment of astronauts. The new quantity, Radiation Attributed Decrease of Survival (RADS), representing the cumulative decrease in the unknown survival curve of astronauts, forms the basis for this approach (shown in the figure). We are also working on a compact nanodosimetric detector, which can be used to quantify the e biological effects of radiation. Additional research is conducted in the application of highly heterogeneous dose distributions to cancer patients.



RADS cancer risks for male astronauts, calculated for an age at exposure of 40 years, an attained age of 65 years (1 Gy is a typical dose for a Mars exploration) using a mixed ERR and EAR model.

1. A bespoke health risk assessment methodology for the radiation protection of astronauts, L. Walsh *et al.* Radiat Environ Biophys. 2021 May;60(2):213-231
2. A Novel Analytical Population Tumor Control Probability Model ..., S. Radonic *et al*, Int J Radiat Oncol Biol Phys. 2021 Aug 1;110(5):1530-1537

Medical Physics

Prof. Jan Unkelbach (University Hospital Zurich)

Radiotherapy is one of the mainstays of cancer treatment and a highly technology-driven field of medicine. In our research group, we contribute to the further development of radiotherapy technology by applying concepts from physics, mathematics, statistics, and machine learning to problems in medical imaging and radiation oncology.

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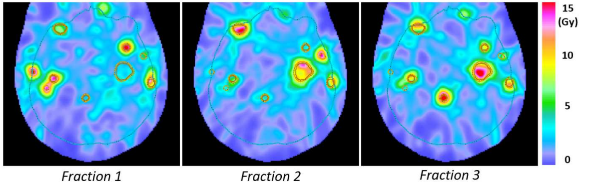
We focus on three areas of research:

1) Radiotherapy treatment planning: We work on mathematical optimization methods to optimally combine x-ray and proton beams [2], and to optimally distribute radiation dose over multiple treatment days (see Figure).

2) Target delineation and outcome prediction: Here, we focus on quantitative analysis of medical images such as MRI, CT, and PET, with the goal of precisely defining the region to be irradiated and predicting the patient's response to treatment [1].



Fraction 1 Fraction 2 Fraction 3

Our work on Spatiotemporal fractionation, illustrated for a patient with many brain metastases treated in 3 fractions.

3) Adaptive radiotherapy: Our department is the first in Switzerland to install a MR-Linac, a combination of MRI scanner and radiotherapy device. This allows to acquire images of a patient during treatment and irradiate moving tumors (e.g. in the lung) more precisely.

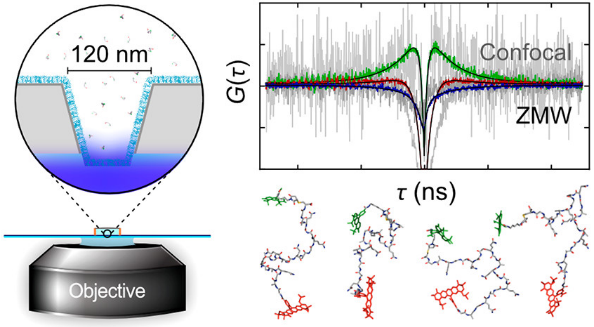
1. A hidden Markov model for lymphatic tumor ...
   R. Ludwig *et al.*, Scientific Reports, 11(1):p1-17, 2021
2. Combined proton-photon treatment for breast cancer,
   L. Marc *et al.* Phys. Med. Biol., 66(23): 235002, 2021

Molecular Biophysics

Prof. Ben Schuler (Department of Biochemistry)

We study fundamental aspects that govern the structure, dynamics, and functions of biomolecules, especially proteins, the nanomachines of life. Towards this goal, we integrate information on nanoscopic distances, forces, and dynamics from advanced single-molecule laser spectroscopy with other physical and biochemical methods, often in close combination with theory and simulations.

https://schuler.bioc.uzh.ch



Single-Molecule Fluorescence Spectroscopy of Biomolecules

A main technical advance in 2021 was the development of a new technique based on nanophotonics that allows us to probe previously inaccessible nanosecond motion in proteins [1] (see Figure). An important discovery was a new mechanism of protein interactions that is involved in how DNA is regulated [2].

1. Single-molecule detection of ultrafast biomolecular dynamics with nanophotonics,
M. F. Nüesch *et al.*, J. Am. Chem. Soc. **144**, 52 56
2. Release of linker histone from the nucleosome driven by polyelectrolyte competition with a disordered protein, P. O. Heidarsson *et al.*, Nat. Chem. https://doi.org/10.1038/s41557-021-00839-3