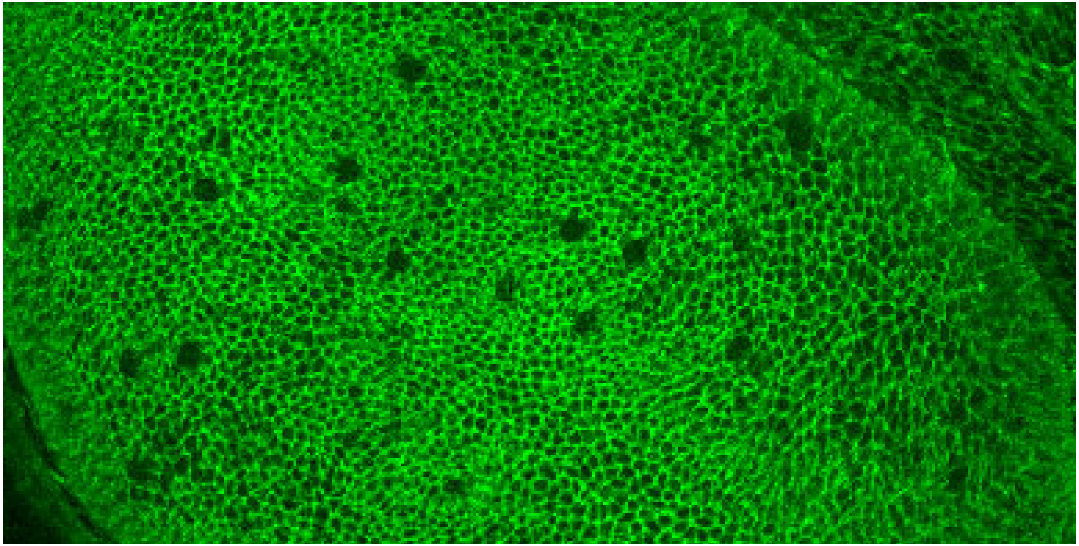
Bio and Medical Physics



Disordered and biological soft matter

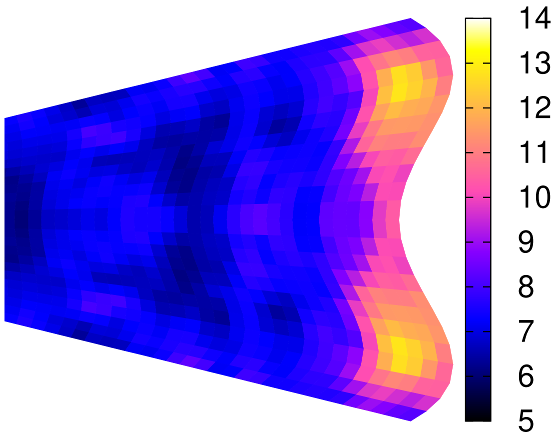
Prof. Christof Aegerter

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

The influence of hydrodynamic forces on zebrafish fin regeneration

Zebrafish have the interesting property that they are able to regenerate their fins after amputation or injury. This regeneration is remarkably robust in that the final size and shape of the regenerate closely follows the original fin. Using changes in flow speeds during regeneration as well as flow changes due to different amputation geometries or biochemical treatments leading to narrower fins, we have however been able to show that this process also shows some plasticity driven by the hydrodynamic forces present from the water flows acting on the swimming fish during regeneration. To study this further, we have measured the full three-dimensional stress distribution on a fin using particle tracking velocimetry, which allows us to determine all components of the stress distribution. One such example for the proximo-distal stress on the side of a fin is shown in the Figure.



Stress map of the absolute proximo-distal component, $|\sigma_{pd}|$, acting on the side of a fin-shaped flexible hydrofoil mimicking the elastic properties and geometry of a zebrafish caudal fin. Stress values in mPa are color-coded according to the depicted colourbar. Using such measurements on the spatial distribution of forces on differently sized and shaped fins, we are able to assess the possible influence of hydrodynamic forces during regenerative growth of zebrafish caudal fins..

Determining these force distributions for differently sized and shaped fins, we are then able to study the possible influence of these forces on growth and patterning of regenerating fins, where we find that the dorso-ventral stress component along the tip of the fin is fully consistent with acting as a growth activator during fin regeneration.

Highlighted Publications:

1. How shape and flapping rate affect the distribution of the fluid-force on a flexible hydrofoil
   P. Dagenais, and C.M. Aegerter,
   Journal of fluid mechanics **901**, 489 (2020)
2. Mechanochemical modelling of dorsal closure reveals emergent cell behaviour and tissue morphogenesis
   F. Atzeni, L. Pasykarnakis, G. Mosca, R.S. Smith, C.M. Aegerter, and D. Brunner,
   bioRxiv 2020.01.20.912725 (2020)
3. Hydrodynamic stress distributions on the surface of a flexible fin-like foil
   P. Dagenais, and C.M. Aegerter, PLoSOne **16**, e0244674 (2021)

Medical Physics and Radiation Research

Prof. Uwe Schneider

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.

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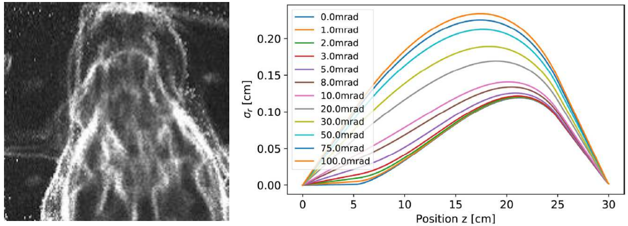
In 2020 one of the active research topics was the improvement of medical imaging with protons and Helium ions. In particular we were investigating the impact of air gaps for proton and Helium radiography and tomography, respectively. We are also developing novel radiation risk models for astronauts and a compact nanodosimetric detector which can be used to quantify the biological effectiveness of various radiations.



Proton radiography of the head of a dog on the left and spatial resolution which could be achieved with 200 MeV protons for different initial angular confusions (angular spread) on the right.

Highlighted Publications:

1. First Measurements of Ionization Cluster-Size Distributions with a Compact Nanodosimeter,
   Vasi F, Schneider U., Med Phys Lett. 2021 Jan 28
2. Investigation of the effect of air gap size on the spatial resolution in proton- and helium radio- and tomography ,
   Radonic S, Hälg RA, Schneider U., Z Med Phys. 2020 Jun 3; S0939-3889(20)30031-3

Medical Physics

Prof. Jan Unkelbach

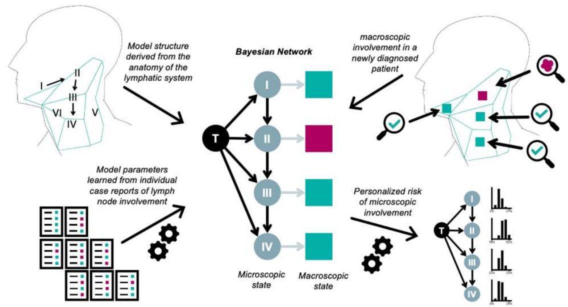
Radiotherapy is one of the mainstays of cancer treatment and a highly technology-driven field of medicine. In our research group, we contribute to the further development of radiotherapy technology by applying concepts from physics, mathematics, statistics, and machine learning to problems in medical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

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

We focus on three areas of research:

1) Radiotherapy treatment planning: We conduct research on mathematical optimization methods for radiotherapy planning to further improve treatment planning systems. In particular we investigate methods to optimally combine x-rays and protons.

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.



Machine learning model of the lymphatic progression of cancer in the neck (from J. Unkelbach et al.*, Radiotherapy & Oncology,* **153***:p15-25, 2020)*

3) Adaptive radiotherapy: Our department is the first in Switzerland to install a MR-Linac, a combination of MRI scanner and radiotherapy device. MR images of a patient can be acquired during treatment such that moving tumors (e.g. in the lung) can be irradiated more precisely.