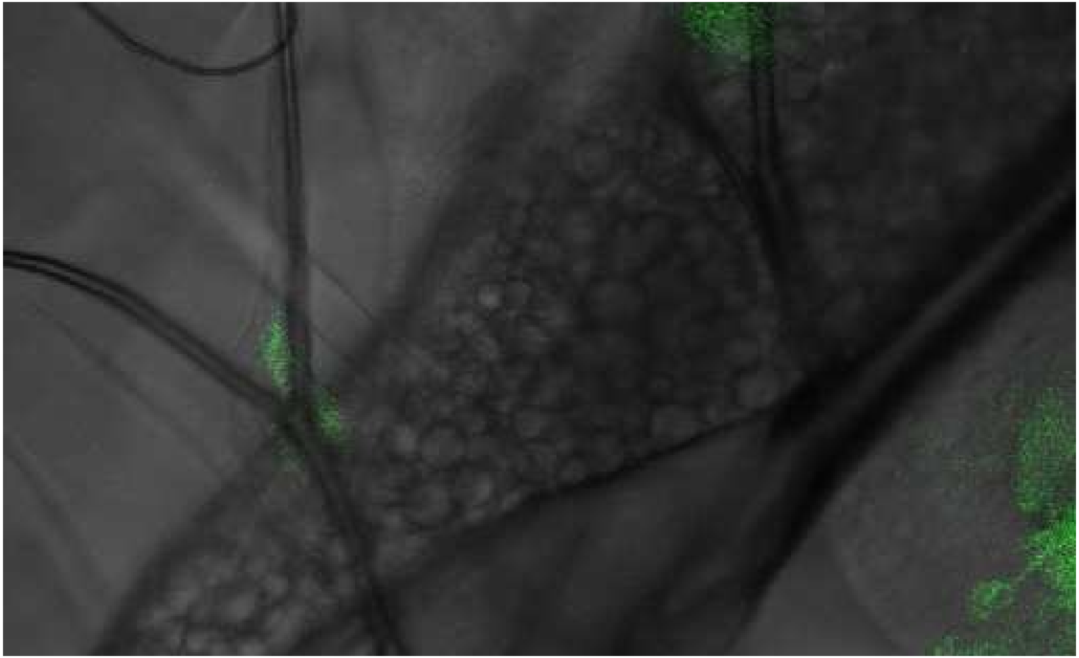
Bio and Medical Physics



Disordered and biological soft matter

Prof. Christof Aegerter

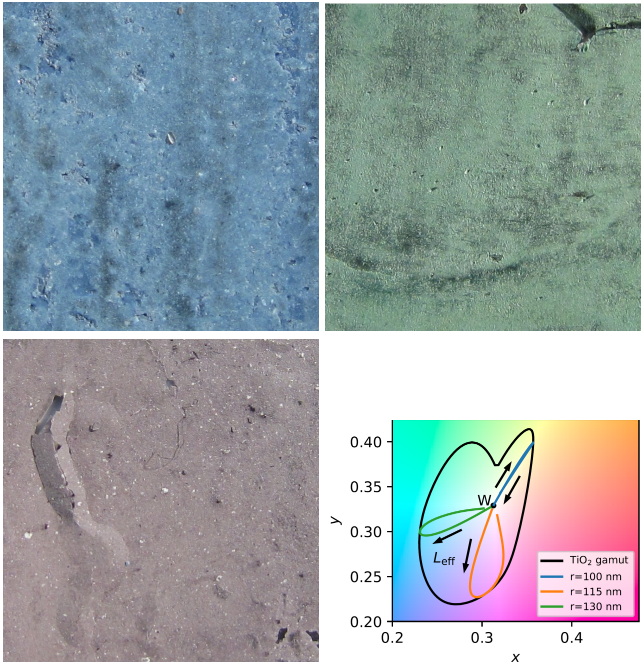
We study the properties of disordered and heterogeneous systems out of equilibrium. This encompasses light transport in photonic glasses, imaging in turbid media, as well as the elastic properties of growing biological tissues and their influence on development, e.g. in the regeneration of zebrafish 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 the production of colouration due to scattering rather than pigmentation in photonic glasses and natural systems.

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

Structural colours using photonic glasses

Many colours in nature are not due to pigmentation, but rather intricate nano-structures of low-index biological materials. This can give rise to very striking blues, such as in morpho butterflies, but also yellows and greens, such as in peacock's or duck's feathers. While photonic glasses can give rise to such colours, these are highly specific on the incident angle, while the natural example given above show the same colouration over very wide angles. Based on a model describing the scattering of individual particles as well as the effects of disordered packing in a photonic glass, we have created a model that can describe the colouration of photonic glasses made of almost monodisperse particles depending solely on the particle size and refractive index as well as their packing fraction.

We have tested this using polystyrene nano-particles of different sizes, where the obtained broad range colours



Images of structural colours using polysterene photonic glasses of different particle radii. Top left: mean radius of 196 nm giving a blue colour, Top right: mean radius of 236 nm giving green, Bottom left: mean radius of 250 nm giving red. The model describing the colouration of a photonic glass shows the range of possible colours using TiO_2 nano-particles with a refractive index of 2 is able to give the entire spectrum of colours (bottom right).

visible in the figure on the left are in good agreement with the expectations from the model. In addition, the model predicts that all shades of colours can be created using a high enough refractive index of the particle, as indicated by the bottom right panel of the figure for amorphous TiO_2 with a refractive index of 2. This shows that photonic glasses can be used as non-pigmented colouration for all kinds of colours in a simple and well understood manner.

Highlighted Publications:

1. Disentangling geometrical, visco-elastic and hyper-elastic effects in force-displacement relationships of folded biological tissues,
   F. Atzeni, F. Lanfranconi and C.M. Aegerter,
   Europ. Phys. J. E **42**, 47 (2019).

2. The Structural Colors of Photonic Glasses,
   L. Schertel, L. Siedentop, J.-M. Meijer, P. Keim, C.M. Aegerter, G.J. Aubry, and G. Maret,
   Adv. Opt. Materials **7**, 1900442 (2019).

3. Scattering lens for structured illumination microscopy,
   A. Malavalli and C.M. Aegerter,
   OSA Continuum **2**, 2997 (2019)

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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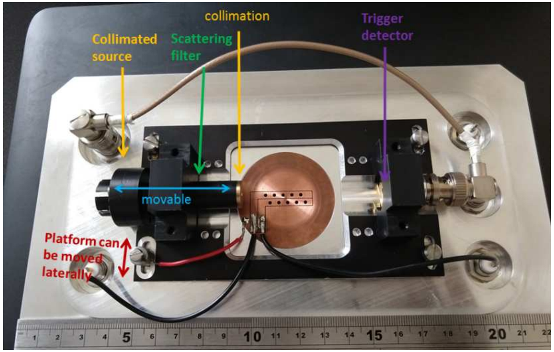
Currently we are developing a compact nanodosimetric detector (see figure) which can be used to quantify the number of ionizations in DNA, the so called cluster size distribution. For the purpose of relating the measurements to biological effects in patients we are developing a novel radiation action model. Additional research is conducted in the application of highly heterogeneous dose distributions to cancer patients. We are also developing novel radiation risk models for astronauts.



Highlighted Publications:

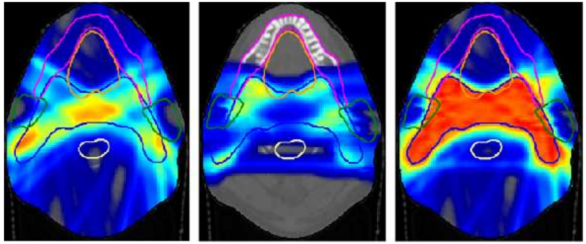
1. Track event theory: A cell survival and RBE model consistent with nanodosimetry, U. Schneider *et al.*, Radiat. Prot. Dosimetry **183**(1-2):17, 2019
2. Research plans in Europe for radiation health hazard assessment in exploratory space missions, L. Walsh *et al.*, Life Sciences in Space Research **21** 73, 2019

Medical Physics

Prof. Jan Unkelbach

Over the past 20 years, research in medical physics has improved the accuracy of radiotherapy for treating cancer patients tremendously. This includes the development of intensity-modulated radiotherapy with high-energy x-rays (IMRT) and protons (IMPT), which allows the delivery of highly conformal dose distributions to complex shaped tumors. More recently, the development of image guided adaptive radiotherapy has provided means to correct for geometric changes and organ motion over the course of therapy. The medical physics group contributes to these technological advances of radiotherapy.
https://www.physik.uzh.ch/g/unkelbach

We focus on three areas of research:
1) Treatment planning for IMRT and IMPT: In particular, we investigate treatments that combine x-rays and protons (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.
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.



Optimal combination (right) of x-rays (left) and protons (middle) to irradiate a tumor located in the oral cavity (blue contour) while minimizing radiation to the salivary glands (green contour). Ref: Fabiano et al., Radio. Onc. **145***:p81-87, 2020*