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INVITED: X-ray Dark-Field Imaging: From Basic Principles to First Clinical Applications

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The basic principles of X-ray image formation in radiography have remained essentially unchanged since Röntgen discovered X-rays over a hundred years ago. The conventional approach relies on X-ray attenuation as the sole source of contrast and uses only ray or geometric optics to describe and interpret image formation. This approach ignores another potentially more useful source of contrast, namely phase information. Phase-contrast (and Dark-Field) imaging techniques, which can be understood using wave optics rather than ray optics, offer opportunities to improve or complement standard attenuation contrast by incorporating phase information.

This talk will review the basic physics, milestones and state of the art of grating-based X-ray phase-contrast and dark-field imaging in general, focusing in particular on our recent efforts to evaluate X-ray dark-field contrast for clinical applications in radiography and computed tomography.

We will discuss in more detail the results of the first clinical evaluations, for which we built a novel dark-field chest X-ray system for patients that can also take a conventional chest X-ray at the same time. With this system, the first of its kind in the world, we are currently conducting several patient studies, among others on chronic obstructive pulmonary disease (COPD), severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and lung cancer.
These findings are also important from a societal perspective, as diseases of the respiratory system are a major cause of chronic disease and mortality worldwide. While modern medical imaging techniques now provide detailed diagnostic information, there is still a lack of a low-dose, rapid and cost-effective option for early detection and/or follow-up.
As an outlook, we then discuss the further development of a first human prototype for dark-field computed tomography, where the use of novel spectral hybrid pixel photon counting detectors is of particular interest. These offer several technical advantages that can be expected to significantly improve the image quality, especially for dark-field imaging.

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