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#9-171 SmartX: Advancing Darkfield X-ray Imaging for Lung Disease Detection

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Lung diseases represent a significant global health challenge, with conditions like chronic obstructive pulmonary disease ranking as the third leading cause of death worldwide, according to the World Health Organization. The disease causes inflammation and destruction of lung tissue, making early detection of this and similar conditions crucial for reducing mortality and enhancing patient outcomes. However, conventional diagnostic tools, such as chest X-rays and computed tomography scans, are limited in their ability to detect early stages, particularly in assessing subtle changes in the alveolar structure. Spirometry, though widely used, is dependent on patient cooperation, making it unreliable in some cases. Therefore, innovative imaging methods are urgently needed to address these diagnostic gaps. Darkfield X-ray imaging is a novel technology that offers significant potential for visualizing early stages of these disease by exploiting small-angle scattering of X-rays. Unlike conventional imaging, which measures X-ray attenuation, darkfield imaging detects scattering patterns generated by microstructures, such as the alveoli in lung tissue. This makes it particularly valuable for assessing chronic obstructive pulmonary disease, where early changes often occur at the microscopic level. Several techniques have been developed to implement darkfield imaging, including interferometric approaches, analyzer-based techniques, and free-space propagation methods. These techniques require either highly monochromatic X-ray beams or microfocus X-ray sources, which are not readily available in clinical settings. A promising alternative is grating-based phase-contrast imaging, which uses three gratings to generate interference patterns and is compatible with conventional X-ray tubes. This method, has shown potential for clinical use and a feasible approach for lung imaging, but still faces limitations. The main of these is the requirement for an analyzer grating that absorbs half of the X-ray dose, reducing efficiency and increasing radiation exposure for patients. Recent progresses in nuclear instrumentation, particularly in the domain of micro- and nano-structured scintillators and single photon detection techniques, are opening the way to a quantum leap in ultra-high resolution X-Ray detection systems, and particularly in the very promising domain of phase contrast and dark field X-ray imaging. In this context the SmartX project, in the framework of a European Research Council Synergy Grant, aims to overcome the main limitation by developing a new detector technology that eliminates the need for the 50% absorbing analyzer grating. By combining nanostructured scintillation materials with Single Photon Avalanche Diode sensor technology, SmartX will enable direct resolution of the interference pattern produced by the reference grating. The proposed detector will present spectral features, which can further enhance diagnostic capabilities. We expect this approach not only improves the detection of the darkfield signal but also reduces the radiation dose by 50% compared to current methods, making it safer for patients. This work presents the first detector concept that will be developed in the coming years.

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