Phase contrast X-ray imaging in pulsed regime for high-resolution soft-tissue diagnosis

Description and context

Early detection of breast cancer is a major public health issue. The aim of this thesis project is to develop an ambitious technique based on phase-contrast X-ray imaging for high-performance diagnosis in this field. It combines scientific innovation, using high-coherence X-ray pulses to highlight low-dimensional tissue details (micrometric range), with technological innovation, incorporating new high-resolution X-ray detectors.

Phase-contrast X-ray imaging, a technique that has already proved its worth in research and industry, is particularly well-suited to imaging low-absorbency media such as soft tissue. It even stands out from other techniques when it comes to revealing infinitesimally small details [1,2]. The aim of this thesis is to demonstrate high spatial resolution and improve the quality of current X-ray images, in order to detect incipient tumors just a few micrometers in size, located in regions where absorption X-ray imaging is ineffective because it is less sensitive. This major advance would enable earlier diagnosis of cancers localized in tissues, such as breast cancer.

To achieve this, the PhD student will have access to an exceptional research environment, with access to highly coherent ultrashort X-ray sources produced by laser-plasma interaction [3] and also continuous X-ray tubes for comparison purposes. He will use simulation codes to optimally dimension the imaging bench. It will thus benefit from the expertise acquired through collaborative work between the LP3 and CEA-List laboratories. Finally, the key technological element in the project will be the use of CEGITEK's prototype detectors, made up of 75µm hybrid pixels - the smallest size currently available. A comparative analysis of phase images acquired on a breast cancer phantom will be carried out as a function of the X-ray source, the phase grating chosen for imaging, and for various detectors of different types (direct detection, indirect detection and hybrid technology), in order to highlight the advances in X-ray imaging made possible by this innovative approach.

Description of the resarch group and management team

A consortium combining the continuum of scientific expertise required for the project and technological innovation has been set up. It includes CEGITEK, based in Roquefort la Bédoule, which develops X-ray detectors at the highest international level, in particular for imaging applications, AP-HM - Marseille, which will supply the breast cancer phantoms and may position itself as an end-user, and the LP3 laboratory (Luminy), which specializes in the generation and implementation of high-cadence pulsed X-ray sources. LP3 is also involved in the Marseille Imaging institute, which could stimulate regional synergy by involving laboratories, public bodies and companies. In addition, with a view to development and outreach extending well beyond the region, the CEA-List (Paris-Saclay) will be involved in the image processing and analysis part of the project, thus enhancing the value of the scientific and technical developments achieved.

The thesis will be supervised by Dr. Amélie Ferré, Maitre de conférence. The thesis will be supervised by Dr. Olivier Uteza, CNRS Research Director at LP3. The thesis will be co-supervised by Cegitek, whose supervisor will be Johan Simoncini, the company's CEO.

Thesis work

This thesis project concerns the development of an X-ray imaging technique [5-7] for the early detection of breast cancer, using an innovative X-ray detector with very high spatial resolution. During the course of the thesis, there will be many regular exchanges between the socio-economic partner (Cegitek, a company specializing in the engineering sector, and in particular in X-ray detector systems), the laboratory and the PhD student.

- **CEGITEK training courses on X-ray detector technology**. The PhD student will invest time in the company (~several weeks/month for 4 months, then regular meetings on a monthly basis that can be adjusted on request).

- **Knowledge of high-intensity, high-rate laser-plasma interaction and the use of secondary X-ray sources** (8.04 keV and 17.5 keV) induced during such interactions for X-ray imaging.
- **Development and demonstration of imaging performance**, supported by access to simulation and analysis codes, will be carried out during its 2nd year.
- **Comparative X-ray imaging experiments with an X-ray tube source and a K alpha source**, at the same energies (8 keV, 17.5 keV),
- **Proof of imaging principle, demonstrating the relevance of the chosen approach**, will be performed on a **breast cancer phantom**.

REQUIRED SKILLS

Candidates must hold a Master's degree and/or an engineering diploma in one or more of the following fields: ionizing radiation/matter interactions and/or plasma physics, laser physics and/or optical methods, as well as skills in computer programming languages (Python/C, C++, Matlab, etc.).
Excellent interpersonal, writing and communication skills in English will be required, through the writing of scientific papers and participation in international conferences.
You'll also need a keen interest in experimental implementation and group work.

ACQUIRED SKILLS

Through this thesis, the student will develop his or her knowledge of laser physics, plasmas and X-ray-matter interaction. He or she will also develop strong skills in image processing, X-ray detectors and simulation, as well as in experimental implementation in a constrained environment.

CONTACTS

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