Technology Advances in Mammography Dose Reduction and Image Quality

Fujifilm's third generation full field digital mammography (FFDM) system, ASPIRE Cristalle, is based on Fujifilm's unique and innovative technologies that achieve optimum image quality at very low patient dose. These outcomes are made possible by a new detector technology that uses a hexagonal close pattern (HCP) architecture, coupled with analytical and adaptive image processing that automatically adjusts to each patient's breast composition. This paper highlights these recent advances in FFDM technology.

ASPIRE Cristalle FFDM System

Drawing on over 30 years of digital mammography detector and image processing expertise, Fujifilm's ASPIRE Cristalle (**Figure 1**) incorporates technological advances that can be instrumental in the early detection of breast cancer, while at the same time providing comfortable and low dose exams for the patient.

Figure 1: *ASPIRE Cristalle*

Hexagonal Close Pattern (HCP) detector

Fujifilm has developed a novel detector that uses hexagonal shaped pixels. The HCP design provides a 50 μm output, and yields improved detector sensitivity when compared to conventional square pixel FFDM detectors.

As shown in **Figure 2a**, due to the right angles associated with conventional square pixels, the electric field between these pixels demonstrates a weakness in intensity.

This weakness results in a reduction in collection efficiency as some of the converted x-ray information (in the form of electrical charges) will not be collected by the square pixels, but simply pass between them (**Figure 2b**)

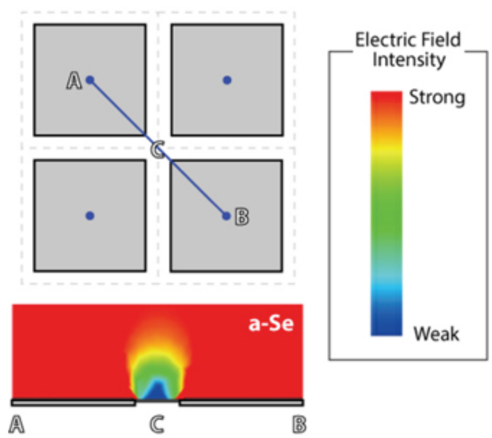

Figure 2a: *Conventional square pixels with corresponding electric field intensity*

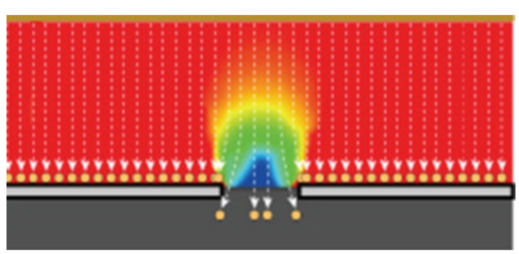

Figure 2b: *Conventional square pixels with reduced collection efficiency.*

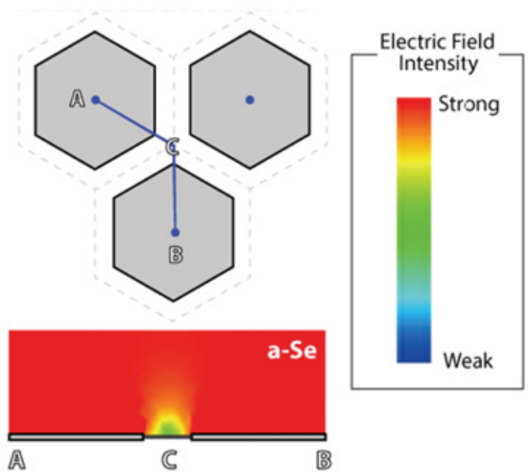

Figure 2c: *Fujifilm's hexagonal pixels with corresponding electric field intensity*

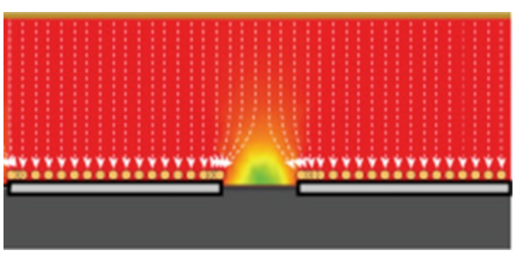

Figure 2d: *Hexagonal pixels with improved collection efficiency*

To improve the collection efficiency of the FFDM detector, the Cristalle detector uses the aforementioned HCP architecture, where, with no right angles on the hexagon-shaped pixels, the electric field between them is stronger (**Figure 2c**).

Using this approach, collection efficiency is increased as the electrical charges are "steered" to the hexagonal pixels under the influence of the stronger electrical field (**Figure 2d**).

Based on this unique approach to FFDM detector design, we have successfully reduced dose by approximately 20% when compared to conventional detectors that use square pixels.

Intelligent Automatic Exposure Control (iAEC)

Automatic Exposure Control (AEC) technology automatically determines the exposure conditions needed to achieve suitable diagnostic image quality. Typically, this is accomplished using fixed AEC sensors that are sampled during a pre-exposure. However, with this fixed sensor approach, it is sometimes difficult to determine the breast region of highest density due to patient positioning or other considerations (e.g., the existence of breast implants) which can result in over- or under-exposure of the breast.

To overcome the limitations associated with conventional AEC, ASPIRE Cristalle incorporates a more intelligent approach known as iAEC.

The iAEC algorithm performs a morphological analysis of the pre-exposure image. Through this analysis, iAEC is capable of differentiating between fibroglandular tissue, adipose tissue, pectoral muscle and implants, and then isolates the densest region of the breast. Once isolated, the exposure conditions are selected to optimize the image quality of the glandular tissue.

Using this unique analytical method, i-AEC can provide improved dose stabilization that is independent of breast composition or positioning.

Figure 3 demonstrates the results of iAEC's ability to localize the fibroglandular regions of various breast compositions, regardless of the presence of implants and foreign objects.

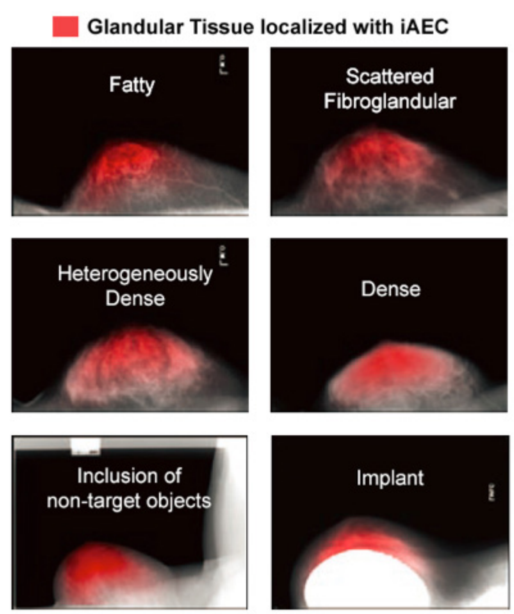

Figure 3: *Glandular Tissue localized with iAEC*

Patient Dose Reduction

To facilitate patient dose reduction and scale the exposure dose for individual patient considerations, ASPIRE Cristalle has three dose modes (H, N, and L) that can be selected by the technologist (N mode is typically used). These modes, coupled with the increased sensitivity of its HCP detector and improved dose stabilization of its iAEC method, enable ASPIRE Cristalle to demonstrate reduced patient dose when compared to a competitive FFDM system. Figure 4 shows comparative results of an independent evaluation of Average Glandular Dose (AGD) across a broad range of thicknesses.

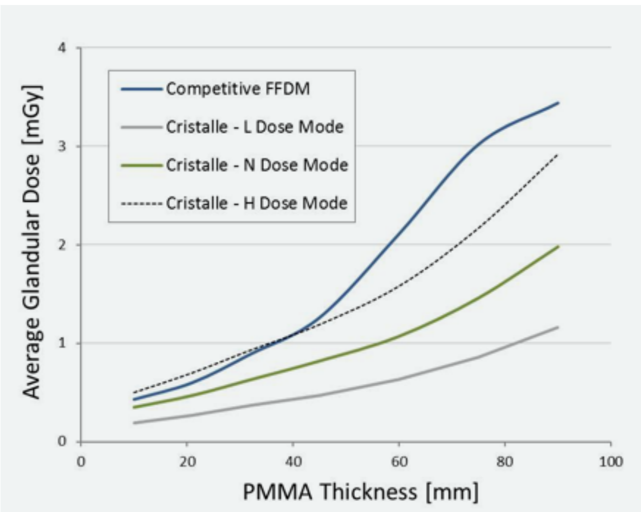

Figure 4: *AGD at 20% glandular equivalent, ASPIRE Cristalle vs. Competitive FFDM*

As can be seen in **Figure 4**, e.g., for the acquisition of the 60 mm equivalent breast thickness (PMMA, 20% glandular equivalent), the Competitive FFDM system results in an AGD that is 355% higher than ASPIRE Cristalle in L-mode and 210% higher than ASPIRE Cristalle in N-mode.

As expected, the AGD results between the competitive FFDM system and ASPIRE Cristalle in all dose modes remain similar when using BR50/50 (50% glandular equivalent) phantoms when compared to PMMA. These results are presented in **Figure 5**.

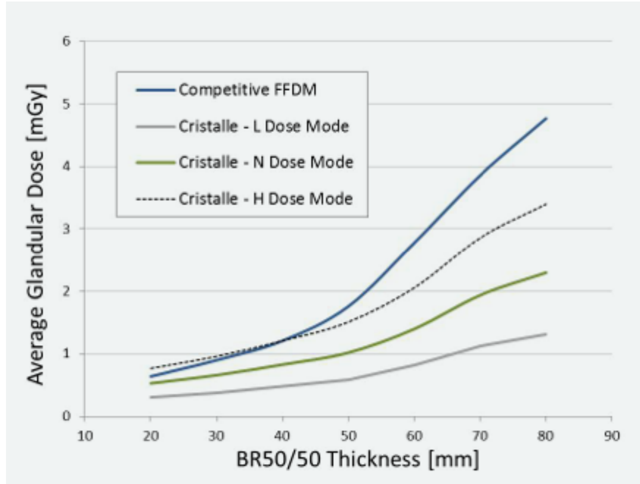

Figure 5: *AGD at 50% glandular equivalent, ASPIRE Cristalle vs. Competitive FFDM*

As shown in **Figure 5**, for a 60mm thick, 50% dense breast, ASPIRE Cristalle's N mode acquisition is almost 2 times lower than that of the competitive FFDM system, and 3 times lower in L mode.

"Adaptive" Image Processing

To produce consistent image quality across the wide range of patients, ASPIRE Cristalle incorporates image processing algorithms that automatically "adapt" to patient breast thickness and composition.

Using analytical processes similar to those used with iAEC, these algorithms localize the glandular regions in the acquired image, assess their contrast, and if needed, make minor adjustments to default processing parameters.

Demonstrations of these adaptive algorithms are shown in **Figures 6** and **7**.

The left side of **Figure 6**, shows a small and dense breast that has been processed with conventional processing parameters. Because of the fixed nature of these parameters, the contrast within the glandular tissue is weak, and the skin line slightly exaggerated. But, as shown on the right side of the figure, by applying adaptive processing, the contrast in the glandular region is improved and the skin line is more naturally presented.

Similarly, for the larger fatty breast shown in **Figure 7**, the conventionally-processed image on the left lacks skin line as well as contrast in the breast tissue. But, as shown on the right side of the figure, ASPIRE Cristalle's image processing automatically adapts and corrects for these deficiencies.

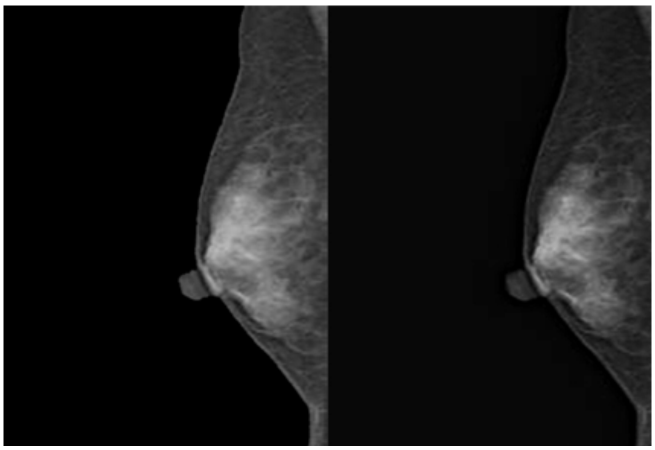

Figure 6: *Small Dense Breast, Conventional vs. Adaptive Processing*

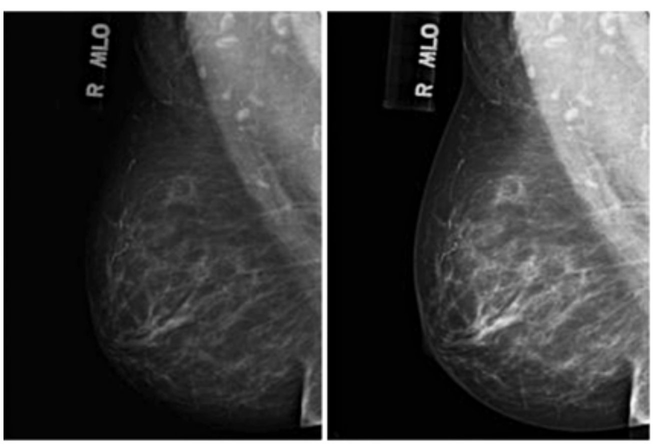

Figure 7: *Large Fatty Breast, Conventional vs. Adaptive Processing*

Image-based Spectrum Conversion (ISC)

In general, when compared to a tungsten (W) target, images that are acquired with a molybdenum (Mo) target produce images of higher contrast. This is because the Mo target produces a lower energy distribution, and can achieve higher image contrast. However, these lower energy x-rays are easily absorbed in the breast, resulting in a higher patient dose than with the W target (which produces a higher energy, more penetrating x-ray beam).

By performing an analysis of the energy distributions between the two types of target materials, Fujifilm has developed an image processing algorithm that takes advantage of the lower dose imaging of a W target, while at the same time providing the high contrast images of Mo. ASPIRE Cristalle introduces this new feature, known as Image-based Spectrum Conversion (ISC).

Figure 8 presents images acquired with a Mo target (left), and with a W target with ISC applied (right). The images are of the same quality, but patient dose of the W target with ISC image was 14% lower than the Mo image.

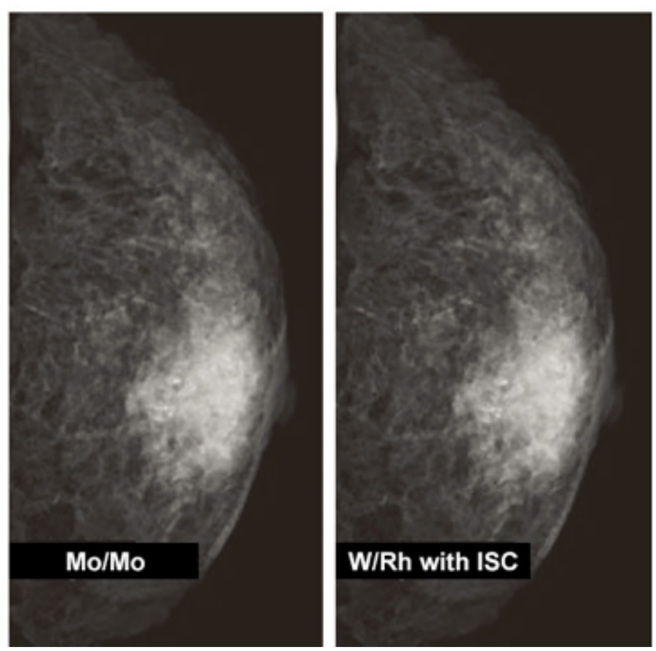

Figure 8: *Mo target image vs. W target with ISC*

One-Shot Phantom Quality Control Program

To facilitate a comprehensive mammography quality control program, all Fujifilm FFDM systems include a quality control package consisting of the One Shot Phantom M Plus (**Figure 9**) and corresponding QC software.

Through a single exposure of the One Shot Phantom M Plus, the QC software will automatically analyze the acquired phantom image and provide pass / fail results for the following system-related tests:

- Missed Tissue at Chest Wall
- Contrast-to-Noise Ratio (CNR)
- Sensitivity
- Geometric Distortion
- Uniformity
- Dynamic Range
- Spatial Resolution
- Low Contrast Detectability
- Linearity / Beam Quality

In addition to the automated evaluation of the test objects within the One Shot Phantom M Plus, the QC software also accumulates all QC results, supports all medical physicist-related testing, provides trending graphs for all individual tests, and can export all QC data to spreadsheet format.

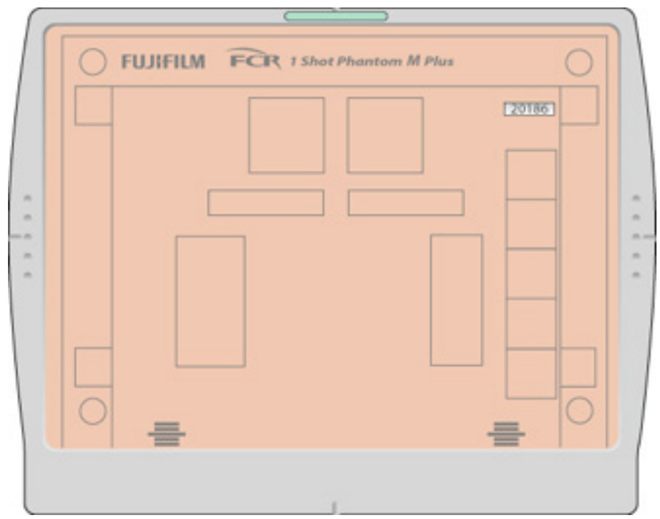

Figure 9: *One Shot Phantom M Plus*

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