ImageVue DR50 flat panel detector (FPD)

Abstract

IDEXX and Fujifilm have partnered to develop the ImageVue™ DR50 Digital Imaging System, which includes the ImageVue™ DR50 indirect-conversion flat panel detector (FPD) that uses a thallium-doped cesium iodide (CsI:Tl) scintillator layer combined with Fujifilm's unique Irradiation Side Sampling (ISS) technology. Like the predecessor Fujifilm FDR D-EVO system with its GOS scintillator, sensitivity, and sharpness are improved through use of the ISS method, with further improvements achieved by the ImageVue DR50 FPD's use of a CsI:Tl scintillator that is adhesively coupled to the TFT substrate. The result is a digital radiography FPD that requires lower radiation dose than other conventional CsI:Tl FPDs.

Introduction

With the increasing popularity of digital radiography, some manufacturers now offer both fixed and portable FPD models. In 2010, Fujifilm released its first cassette-sized DR system, the FDR D-EVO, which combined a GOS scintillator with Fujifilm's unique ISS technology. Most recently, IDEXX and Fujifilm have released the higher-grade ImageVue DR50 FPD, a wireless FPD that applies the ISS method to a CsI:Tl scintillator.

Features of the ImageVue DR50 FPD

The ImageVue DR50 FPD uses a CsI:Tl scintillator, which converts x-rays to light. The lateral spread of the light is contained within the columnar structure of the CsI:Tl crystals and produces highly sharp images. By incorporating Fujifilm's ISS technology, the scintillator output is sampled on the irradiated side where the light output is sharper and stronger.

This novel CsI:Tl FPD, which combines an adhesively coupled structure with the ISS method, shows significant improvement to image quality when compared to conventional CsI:Tl FPDs, while enabling the ability to reduce x-ray exposure to the patient.

ISS method vs. CSS method

For indirect-conversion FPDs, it is essential to enhance x-ray absorption efficiency and be able to sample the scintillator light with less attenuation and scatter at the photodiode elements of the TFT substrate.

In a conventional FPD, increasing the thickness and density of the scintillator layer improves x-ray absorption, but because the generated light must travel a farther distance, it is more susceptible to attenuation (signal loss) and lateral spread (blurring). When incident x-rays are absorbed and attenuated, the luminescence of the generation light is high at the FPD's incident (irradiated) side and low at the FPD's exit side. Additionally, the light is scattered as it travels through the scintillator layer.

Figure 1 shows simplified schematic models for the detected light's intensity and blurring behavior (Lubberts effect)[1] caused by x-ray attenuation and light scattering within the conversion layer thickness. With the conventional side sampling (CSS) method shown in figures 1A and 1B, increasing the thickness of the scintillator layer enhances x-ray absorption but decreases intensity and sharpness through attenuation and scattering. This is because of the distance that the high-intensity light from the x-ray incident side must travel before reaching the photodiodes. In contrast, with the ISS method shown in figures 1C and 1D, increasing the thickness of the scintillator has little effect on the intensity and sharpness of the light generated at the x-ray incident side. The luminescence produced by x-ray photons absorbed in the additional thickness has little effect on the sharpness provided by the x-ray incident side because their intensity is relatively low due to the extended attenuation length and blurring.

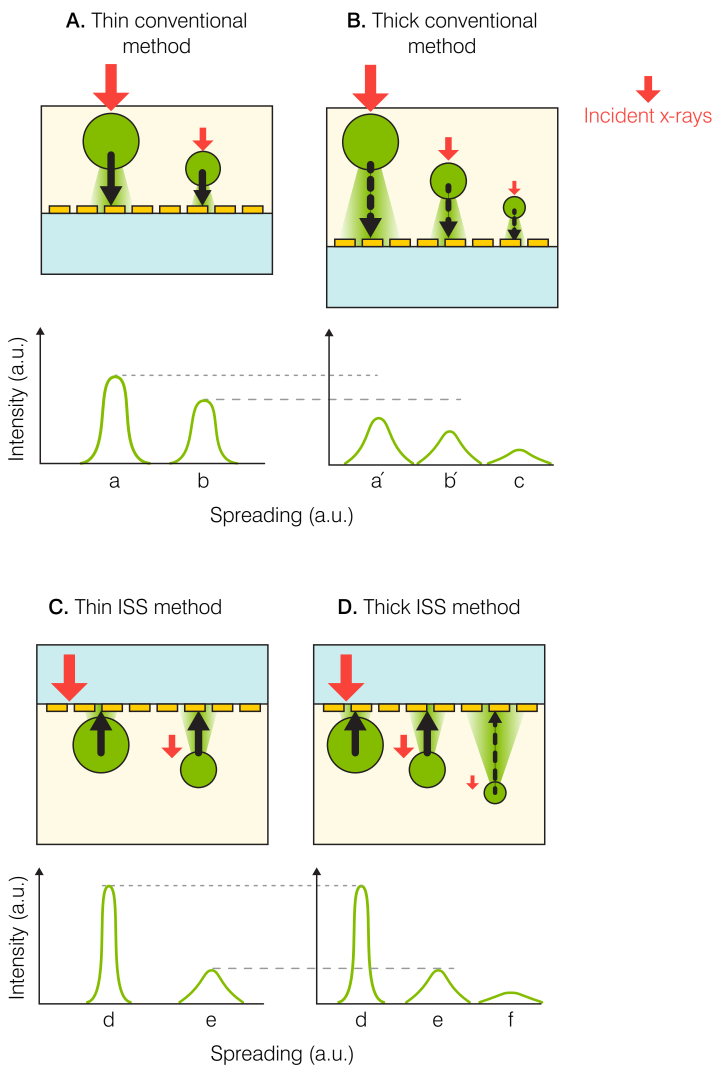
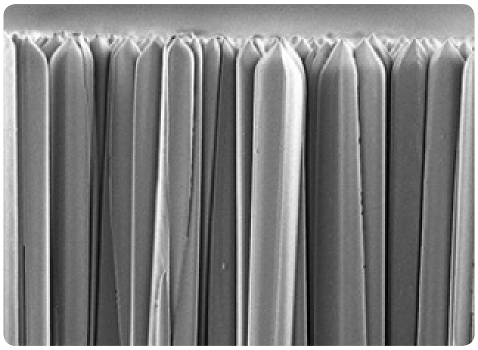


Figure 1. Simplified schematic models of the attenuation and spreading of light for conventional side sampling (CSS) and Fujifilm's Irradiation Side Sampling (ISS) methods.

When compared to the CSS method, the ISS method offers an improvement to sensitivity with less degradation to sharpness when the scintillator layer thickness is increased. These advantages of the ISS method, which were first demonstrated with Fujifilm's FDR D-EVO (Gd2O2S:Tb scintillator),[2] are now incorporated into the ImageVue DR50 FPD (CsI:TI scintillator).

Adhesively coupled structure

For CsI:TI FPDs, high sharpness is achieved because the lateral spread of light is contained within the columnar crystals.



SEM image of CsI crystals

As can be seen in figure 2A, conventional CsI:TI detector scintillator layers are directly deposited on top of the TFT-photodiode substrate. Though the upper portion of a CsI columnar crystal is uniform, the lower portion, near the crystal's base, is flared and exhibits poor crystallinity. Because of this, though there is good light transfer down through most of the columnar crystal, the light will suffer from some attenuation and scatter at the crystal's base, just before reaching the photodiodes. This degradation can be further compounded if the bases of neighboring crystals are fused together.

With the ImageVue DR50 FPD, the tips of the columnar crystals are adhesively coupled to the photodiode array as shown in figure 2C. Using the ISS method, the poorly column-crystallized section is avoided because the light output is sampled at the tips of the columnar crystals. This results in little sensitivity loss and blurring caused by the attenuation and scattering in the poorly column-crystallized section of the crystals. In contrast, with the direct deposition structure, in which CsI:TI scintillator layer is deposited directly over the TFT-photodiode substrate, luminescence is severely attenuated and scattered in the poorly column-crystallized section.

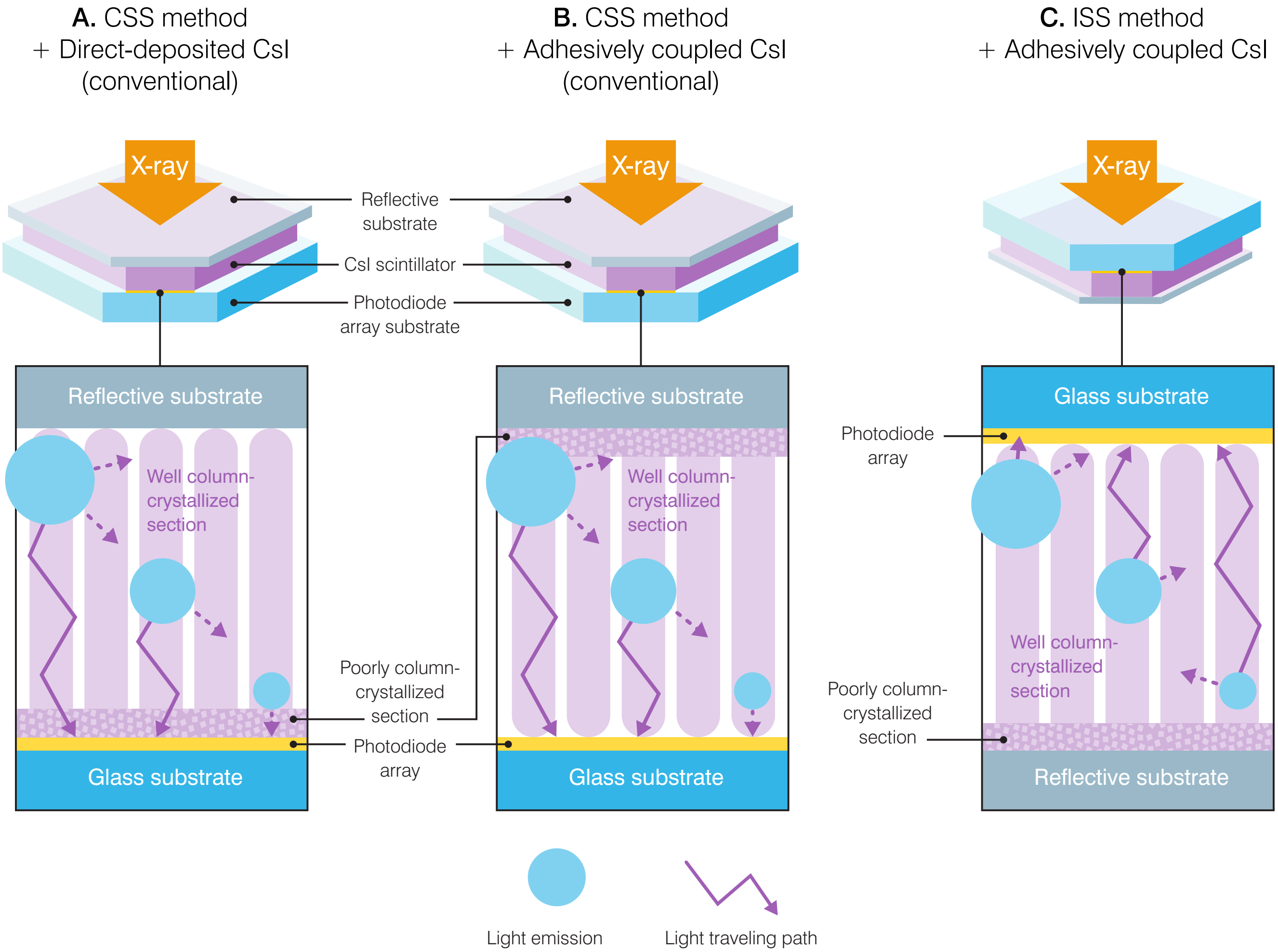


Figure 2. Schematic models of conventional CsI FPDs and Fujifilm's CsI FPD.

Thickness of the adhesive layer

For the stability of image quality, CsI:Tl scintillators are required to be located at the same distance from the TFT substrate, and the columnar crystals should not be corrupted through surrounding temperature fluctuations, impact shock, and weight load. In this detector, the CsI:Tl scintillator and TFT substrate are coupled with pressure-sensitive adhesive. This adhesive layer protects the tips of the CsI:Tl crystals. If excessive pressure is loaded locally, the tips of the crystals will not make contact with TFT substrate and will not break.

When the adhesive layer has an adequately high transmittance, increasing the adhesive layer thickness will degrade sharpness but improve granularity. As a result, detective quantum efficiency (DQE) does not degrade. The adhesive layer thickness of this detector has been optimized by taking both sharpness and image stability into consideration.

CsI:Tl scintillator + ISS method + adhesively coupled structure

Figure 3 shows a comparison of the sensitivity and modulation transfer function (MTF) dependence on CsI:Tl scintillator thickness between "ISS method + adhesively coupled structure" and two CSS methods.

The lower sensitivity and the MTF of the CSS direct deposition structure can be attributed to the effects of the poorly column-crystallized section of the columnar crystals. And the difference between the ISS method and the CSS method in the adhesively coupled structure group can be partly attributed to the difference of attenuation and scattering in the poorly column-crystallized sections.

The ImageVue DR50 FPD's ISS method + adhesively coupled structure makes it possible to enhance sensitivity by increasing scintillator thickness with a little degradation of MTF. This allows for the potential of dose reduction without detriment to image quality.

Performance of the ImageVue DR50 system

Figure 4 shows the DQE and MTF results of our detector and a conventional CsI:Tl FPD (Canon CXDI-55C Digital Radiography System) performed under the same evaluation conditions. The x-ray beam quality is RQA5 as specified by IEC standard,[3] at a dose of 1mR. The ImageVue DR50 FPD shows about 1.4 times the DQE performance as the Canon CXDI-55C system at 1 cycle/mm and makes it possible, in principle, to reduce x-ray exposure to the patient. The ImageVue DR50 FPD also shows better MTF performance in the 1–2 cycle/mm range, improving the visualization of fine anatomical structure, such as bone trabeculae, pulmonary blood vessels, etc.

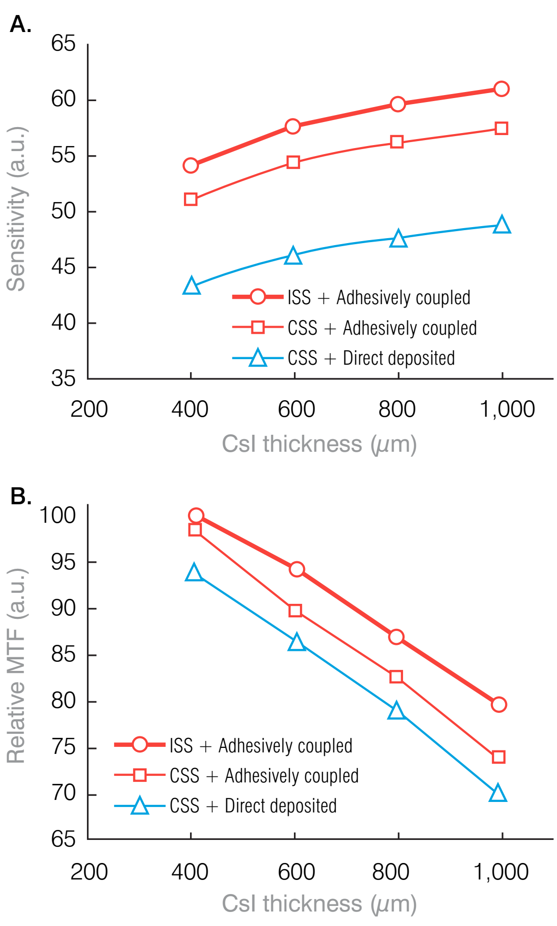


Figure 3. Sensitivity (A) and MTF (B) dependence on CsI:Tl scintillator thickness of ISS and conventional FPDs. [RQA5 1mR, 1 cycle/mm]

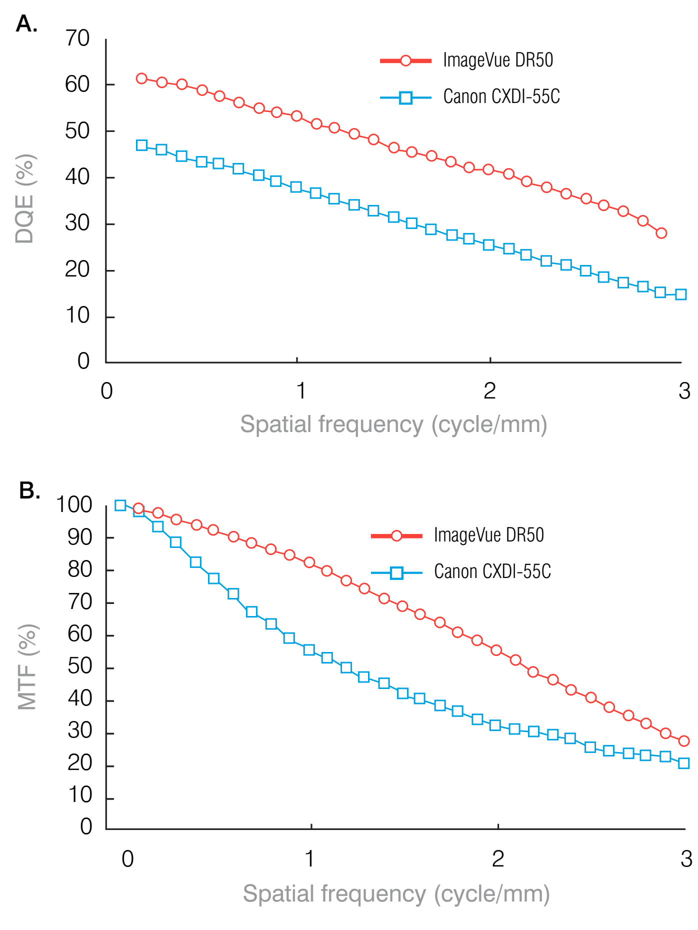
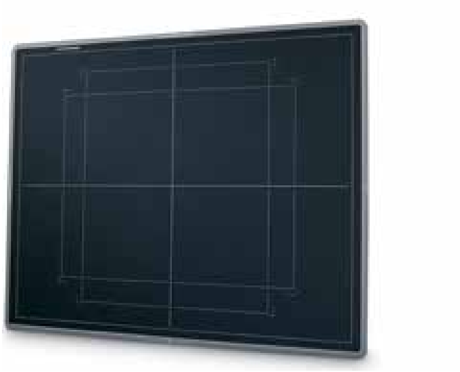


Figure 4. EQE (A) and MTF (B) curves of the ImageVue DR50 system and conventional FPD.

Summary

IDEXX and Fujifilm have partnered to develop a higher-grade FPD model called the ImageVue DR50 FPD. It takes advantage of the potential of CsI:TI scintillators that is lost in conventional FPDs. It shows a DQE performance that is 1.4 times that of conventional FPDs, enabling the potential for reduced dose. IDEXX is dedicated to the veterinary market, and building partnerships with companies, like Fujifilm, who continue to develop novel technologies and high-performance products supports our mutual vision to advance the quality of medical care.



ImageVue™ DR50 Digital Imaging System

References

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2. Sato K, Nariyuki F, Kuwabara T, et al. Development of “CALNEO”, an indirect-conversion digital radiography system with high-conversion efficiency. *Fujifilm Res Dev.* 2010; 55:10–13.
3. International Electrotechnical Commission. *IEC 62220-1-1: Medical Electrical Equipment—Characteristics of Digital X-ray Imaging Devices—Part 1: Determination of the Detective Quantum Efficiency.* Geneva, Switzerland: International Electrotechnical Commission; 2003.