Development of “CALNEO C”, the Light-weight DR Cassette Compatible with Conventional Cassette

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Abstract

We have developed a new digital radiography system FUJIFILM DR CALNEO C, of 384 × 460 mm in size and 14mm thick, equivalent to a CR (Computed Radiography) cassette. The other main features are the light-weight of 2.8 kg and high quality images with low dose. Since CALNEO C is the same size as a CR cassette, it can be set to an existing X-Ray Table and Stand. The 2.8 kg case having a light carbon & resin frame provides a user-friendly workflow to technologists. DQE (Detective Quantum Efficiency) of the ‘Irradiation Side Sampling (ISS) method’ FPD (Flat Panel Detector) shows a 1.7 times higher level than our existing model of FCR VELOCITY.

1. Introduction

We have been engaged in the development of all aspects of diagnostic X-ray modalities, which have evolved from Screen-Film (S/F) systems to FCR (Fuji Computed Radiography) and then to DR (Digital Radiography), and have been working on image quality improvement (lowering radiation dosage), diagnostic performance enhancement, and improvement of the workflow in X-ray examination rooms. For DR systems, we launched in April 2010 our new cassette digital radiography system “FUJIFILM DR CALNEO C”. In this system, we achieved higher image quality by adopting the ISS (irradiation side sampling) method for the X-ray Flat Panel Detector (FPD, hereafter), where the X-ray sensor is placed on the side opposite to that of the conventional detector, and the cassette size is compatible with the conventional CR cassettes and hence can be retrofitted. This system is a high image quality, high throughput cassette digital radiography system launched with an aim to replace the existing FCR/CR systems, with the DQE (detective quantum efficiency) about 1.7 times better than the conventional FCR systems, and with the capability to be retrofitted to the X-ray tables and stands already installed in hospitals. Using the technology we developed for the cases of CR cassettes as motifs, we realized a light-weight cassette case for this DR system, which enables an easy workflow with its excellent handling capability and which when operated give the same impression as the former FCR systems. In this report, we discuss the development of this light-weight cassette case, the image quality improvement technology for FPD, and the system features and performances of FUJIFILM DR CALNEO C (model type : DR-ID 600).

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Fig. 1 FUJIFILM DR CALNEO C.

2. Development of a Llight-weight Cassette Case for FPD Panel

2.1 Overview of the Case Structure

In CALNEO C, we succeeded in balancing very light weight, about 2.8 kg, with sufficient strength by adopting a modified version of the flexible structure case we designed for CR cassettes. We also succeeded in achieving high image quality by avoiding shielding of more X-rays than necessary, which we achieved by implementing a thermal diffusion structure and a noise shielding structure using minimal structural components.

2.2 Cassette Case Weight Reduction

There are two possible usage configurations of the DR cassette: one is the conventional imaging with the panel installed on an imaging stand in the upright or horizontal position, and the other is freely positioned imaging where the panel is placed directly in contact with the patient. In the case of freely positioned imaging, the radiologist needs to manipulate the DR cassette panel using only one hand, and therefore it is a prerequisite that the panel is sufficiently light. Moreover, in freely positioned imaging, the panel needs to have sufficient strength so that it can take the weight of the patient. Hence the biggest challenge in this development project was to achieve both strength and weight reduction.

In order to resolve this technical challenge, we took the following measures and succeeded in producing CALNEO C, that weighs only about 2.8 kg:

(1)The case: we optimized the strength of the "carbon board and resin frame" combination, which was successfully adopted for CR cassette, by adjusting the inserted frame and consequently the required total rigidity was achieved with minimum weight.

(2)The chassis: we empirically found a material that has no strength but yet has sufficient conductivity and noise shielding property. Structurally it consists of the lightest possible "thin metal sheet".

(3)The other parts are made as small and light weight as possible by giving the cassette itself a "flexible structure" which allows changes in the overall shape of the cassette.

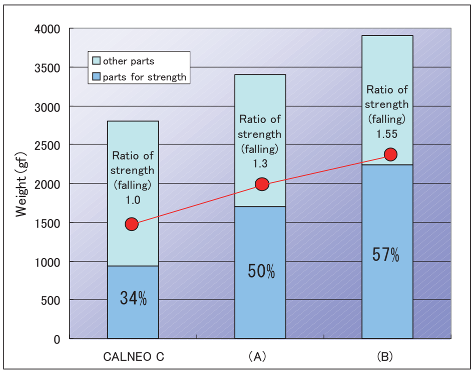
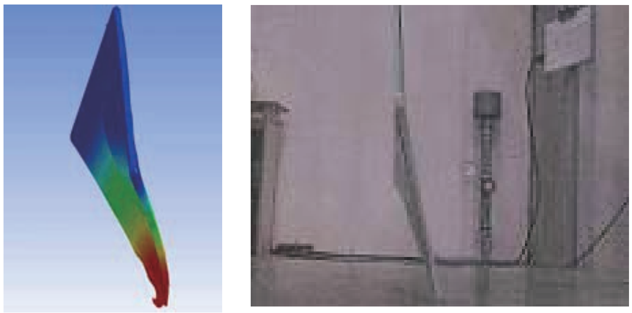


Fig. 2 Comparison of weight and strength.

Fig. 2 shows the relation between the weight and the strength against falling impact of DR panels of different manufacturers. In CALNEO C, the balance between the weight and strength are ensured by grouping together all the parts as those contributing for strength and others, and minimizing the weight proportion of parts for strength, which is the major factor in determining the weight of the entire system.

Fig. 3 shows the simulated panel deformation at the point of falling impact, and the result of a falling experiment imaged with a high-speed camera. One can see that the entire cassette bends and absorbs the impact. The amount of deformation of the case is adjusted so that the TFT glass and the circuit board do not reach the breaking limit, by optimizing the rigidity of all portions of the case.



Simulation Test

Fig. 3 Panel flexibility when falling.

2.3 Heat Dissipation Design

Providing for heat dissipation of internal circuitry is an important factor for operational stability of DR cassette over an extended period of time. Temperature increase inside the cassette will change the characteristics of the charge amplifier and the TFT (thin film transistor) panel, resulting in unevenness or noise in the produced images.

A key to achieving internal heat dissipation is minimizing the temperature differences within the TFT panel or within each charge amplifier, while at the same time reducing the absolute temperatures of the internal parts.

The cooling mechanism of CALNEO C employs the following measures for equalizing the internal temperature and for reducing the absolute temperature:

(1)The case is structured so that the back cover (non-imaging side) is the main heat dissipating surface. The heat transfer pathway and the heat capacity have been optimized using thermal simulation so that the residual heat is minimized.

(2)The electronic chassis is composed of layers of metal sheets with high heat conductivity and heat insulating materials so that the heat is distributed, making the temperature within the TFT panel surface uniform.

Fig. 4 shows the temperature distribution inside the panel before and after applying the optimization measures described above. By introducing these optimizations we achieved a temperature distribution on the surface of $\Delta T < 3k$ and the absolute temperature of $t < 40°C$.

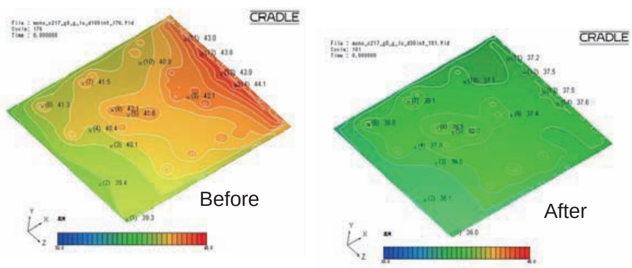


Fig. 4 Cooling effect (simulation).

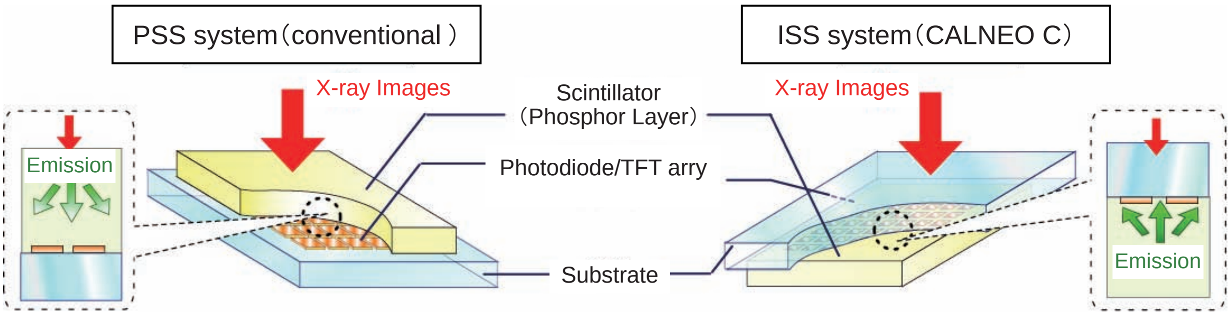


Fig. 5　Schematic view and cross section of conventional and newly developed flat panel detectors.

2.4　Noise Shielding Mechanism

A DR cassette has a structure that is very susceptible to external noise and statics because it consists of a TFT panel and a circuit board surrounded by a thin case. Therefore, we employed a shielding mechanism where each of the TFT devices and the circuit board is placed inside an enclosing shield of conducting material. The shielding parts are secured by screws or by caulking, and the outer periphery that may be opened for maintenance purposes is shielded completely by conducting gaskets.

With the structure described above, we could achieve sufficiently good performance to pass the EMC tests.

3.　Improvement of FPD Image Quality

3.1　FPD Installed in CALNEO C

CALNEO C is installed with an "indirect conversion FPD", which consists of a combination of a scintillator that converts X-ray to visible light, photodiodes that convert visible light to electric charge, and a TFT layer which is a readout circuit. An indirect conversion FPD has detection units composed of a scintillator and a photodiode detector that are integrated with the plane, making thinner and lighter systems possible. Conventional indirect conversion FPDs are built in the PSS (penetration side sampling) configuration, where the scintillator layer is placed on the side where X-rays strike the panel (the side toward the target), while the photodiode detector is placed on the side where the X-rays leave the panel[1). For the FPD of CALNEO C, our original "ISS method" is used instead, where the detector is placed on the side where the X-rays strike and the scintillator is placed on the reverse side (Fig. 5).

3.2　Features of the ISS Method and Comparison with the PSS Method

The possible approaches for improving image quality of indirect conversion FPDs include enhancing the X-ray absorption of the scintillator layer, increasing the efficiency of detection of the light generated by the X-rays, and designing the panel so that the diffusion of light is reduced to avoid blurring in images.

For enhancing X-ray absorption, increase in the thickness of the scintillator layer is effective, while for increasing the efficiency of detection of the generated light, minimization of the attenuation of the generated light before it reaches the detector is effective. The ISS method is a technology that provides improved image quality, developed by careful study of the detection mechanism of indirect conversion FPDs and applying the above two approaches at the same time.

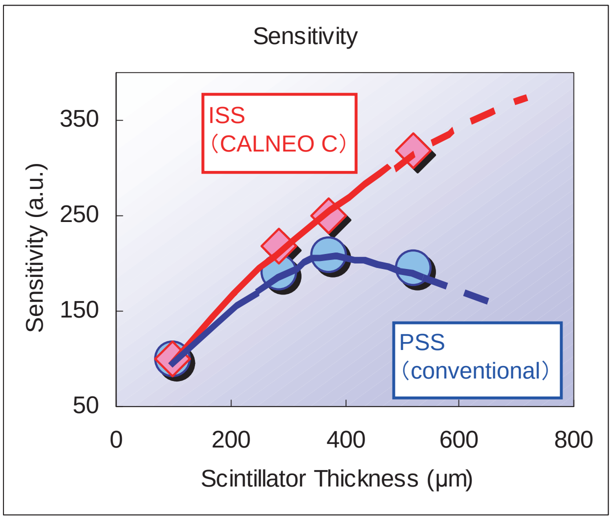


Fig. 6　Relation between scintillator thickness and sensitivity.

Since the X-rays projected on the scintillator layer are absorbed and attenuate exponentially as they proceed inside the layer, the amount of luminescence is much greater on the side where the X-rays strike and smaller on the opposite side. Moreover, there is attenuation caused by the scintillator layer itself of this design because it is packed tightly with grains of fluorescent material and these grains cause scattering of light.

Fig. 6 shows the relation between the thickness of the scintillator layer and the sensitivity. In the case of the PSS configuration, when the layer thickness is increased with the purpose of enhancing the X-ray absorption, the effect of scattering becomes very large because the points in the scintillator layer with the maximum amount of luminescence are those farthest from the detector. On the other hand, in

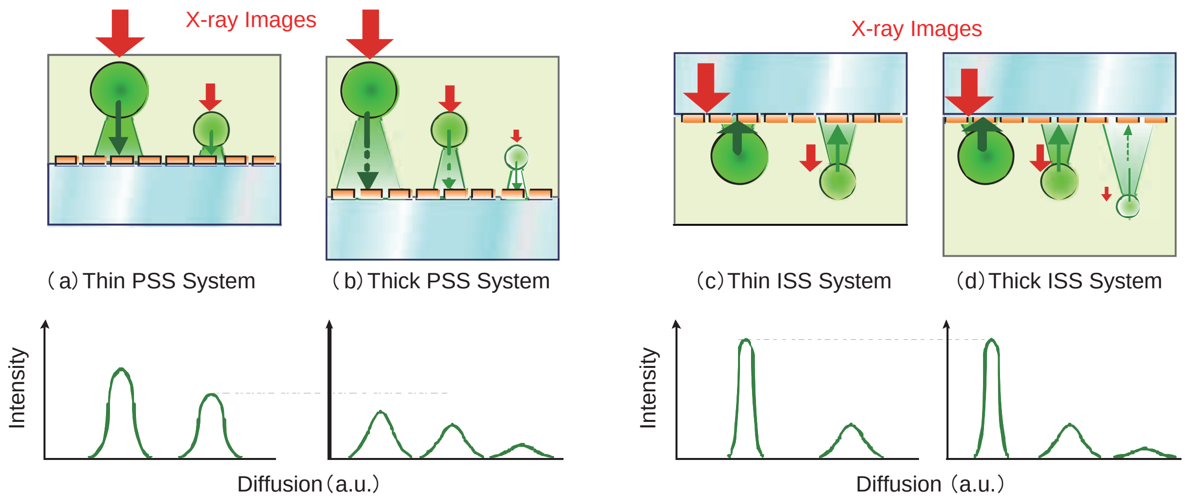


Fig. 8 Schematic diagram of intensity and diffusion of detected lights.

the case of the ISS method, the point with the maximum luminescence is closest to the detector and there is no decrease in sensitivity due to the increase in layer thickness (Fig. 8 (a), (c)).

The luminescent light generated by entering X-rays has isotropic luminosity and is diffused inside the scintillator layer. Therefore, the farther from the detector the luminescence is generated, the more diffusion, resulting in blurring.

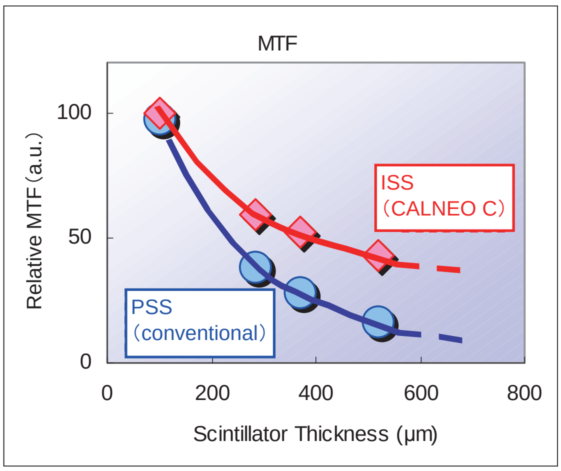


Fig. 7 Relation between scintillator thickness and MTF.

Fig. 7 shows the relation between the layer thickness and the MTF (modulation transfer function). In the case of the PSS method, when the layer thickness is increased, the light has diffused considerably by the time it is detected by the photodiodes. The luminescent light generated at the side where the X-rays strike has high intensity and light of a relatively high intensity will be detected even after being diffused, which causes significant blurring effects in images. On the other hand, in the case of the ISS method, the high intensity light generated at the side where X-rays strike is not diffused according to the layer thickness. Since the light diffusion is larger the deeper the point where the light is generated, the influence of diffusion on MTF is relatively small (Fig. 8 (b), (d)).

To summarize, the indirect conversion FPD with our new ISS configuration achieves higher image quality and higher resolution than conventional FPDs with the PSS configuration, and can greatly contribute to the image quality competitiveness of this type of product.

4. System Features of FUJIFILM DR CALNEO C

4.1 Image Quality Performance

Fig. 9 and Fig. 10 show the DQE and the MTF of CALNEO C and its predecessor FCR PROFECT CS. The applied radiation quality was RQA5 of the IEC standard[2], and the applied dose was 1mR. CALNEO C has about 1.7 times more DQE than that of FCR PREFECT CS, and the MTF of CALNEO C was about 1.25 times more. This means that by using CALNEO C it is possible to lower the radiation dosage while keeping the image quality equivalent to or better than the previous devices.

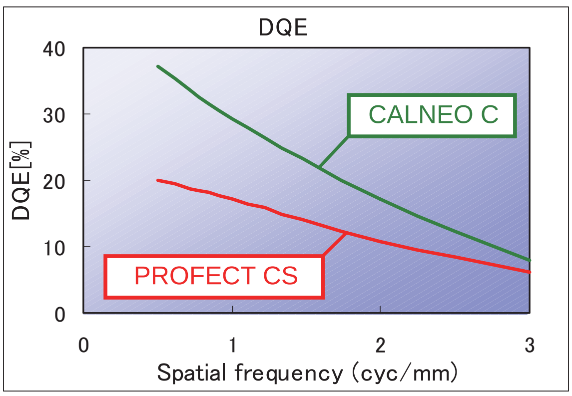


Fig. 9 DQE.

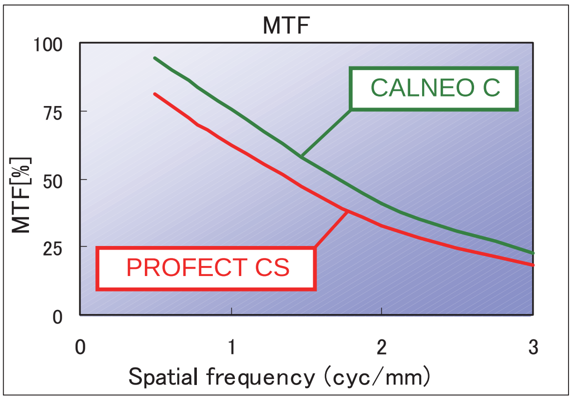


Fig. 10 MTF.

4.2 High Throughput

We succeeded in enhancing the throughput of CALNEO C almost as high as that of built-in CALNEO by applying measures for residual image reduction and for fast readout.

This allows for establishment of a workflow for institutions that does not undergo strain even with frequent imaging use.

4.3 Compatibility with FCR

For image data handling in CALNEO C, we adopted log data instead of the linear data which is normally used with DR, which makes it possible to use the image processing engine that we developed for FCR as is. This makes the procedures for CALNEO C images similar to those developed for our existing systems, allowing stable image processing and reduction of work for radiologists. Moreover, since it is possible to produce images using the same console as FCR systems, in institutions where FCR systems are installed alongside, the technologists can input patient information and carry out post imaging operations using a single console, which allows efficient workflow.

5. Conclusion

In this article, we gave an overview of the technology for the cassette case, the image quality enhancement technique, image features, and the system performance of our newly developed FUJIFILM DR CALNEO C. We expect that this system and related technologies, which contribute to the reduction of radiation dosage and improvement of workflow, will be chosen by many customers.

We hope to continue the quest for new technology and for more cost effective systems so that we can further contribute to the improvement of the quality of medical services and the enhancement of people’s quality of life.

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