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# Digital Radiography Systems (DRS)

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## ORIGINS AND TECHNOLOGICAL EVOLUTION

In 1984 Dr. Francis Mouyen from Toulouse (France), patenting the concept of an intra-oral radiographic sensor featuring instant image capture, gave birth to Digital Radiography System (DRS).<sup>19</sup>

The first radiographic image capturing device was an image sensor based on a large silicon matrix integrated circuit. This was based on the principle of a charged coupled device (CCD). This sensor was assembled with a scintillator, a device made up of a surface of phosphor atoms, which, triggered by incident X-rays, emit a luminous radiation.

This image is transferred through optical fibers from the scintillator itself to the CCD sensitive elements. The first system was not computer-linked. It allowed to see images only on a video screen, but it could not save them on a computer (Trophy 1988).<sup>20</sup> The first computer-linked system was the Visualix by Gendex (1992) This, in its turn, is linked directly, through a connector, to the computer. Here it goes through an

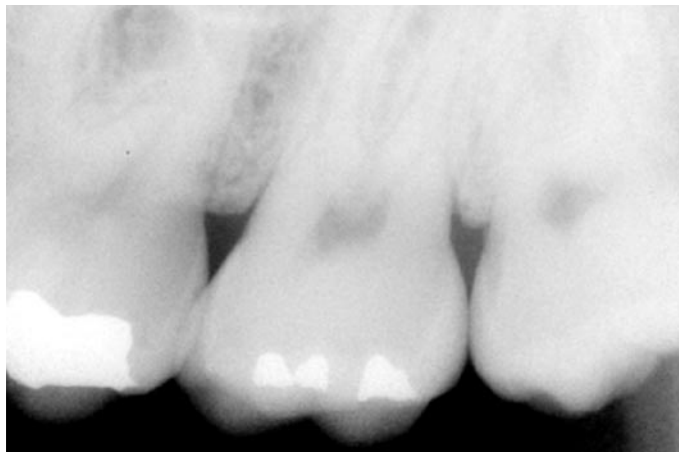


Fig. 6.1. The reduced size of the sensor did not allow an optimum framing and the definition was insufficient.

electronic card which transforms the electronic signal coming from the sensor into a digital one, which can be memorized, containing the image. These data, which make up the captured image, can be converted by the software into one of the various standard graphic formats (.TIF, .JPEG, .PCX, .BMP, .PIC, etc.) differing from one another mainly for the features of information compression.<sup>17,18</sup>

During the first development stages, one of the first problems for the researchers was the need to adapt the then commercially available CCD to the operative needs in dentistry. The said CCD, deriving from a B & W 9x13 mm telecamera, was too small in size to cover the area corresponding to the size of a single tooth. To remedy this drawback, it was decided to create a scintillator equipped with a sufficient 16x27 mm area. The scintillator was to be connected to a smaller area CCD by a bundle of optical fibers shaped as an inverted pyramid trunk functioning as a lens. These optical fibers were made of lead glass capable of fully blocking the X radiation, harmful for the chemical-physical CCD structures.

The first devices, derived from these prototypes, made and marketed by Trophy in 1988, featured a sensor with an overall 20x40 mm size and a 14 mm thickness. Their actual sensitive area, however, was only 16x27 mm (Fig. 6.1).<sup>9</sup>

The tapered optical fiber bundle in a short time was no longer necessary, following the development of CCDs featuring a bigger size, about 20x39 mm, sensitive window. This allowed to reduce the thickness of the optical fiber bundle down to 0.8 mm, the absolute minimum to block X-rays (Figs. 6.2 and 6.3).

Users requested sensors as thin as possible, whereas manufacturers needed structures with a lower mechanical fragility and a lower risk of loss of functional integrity due to the X-ray action.<sup>21</sup>

Researchers, then, had to adopt a particular techno-

logy aiming at hardening the CCD structure (hardened device) which allowed to eliminate the fiberglass layer. The present day CCD technological development provides sensors with an actual capture area of over 36x25 mm and thickness up to 5 mm. Moreover, the width of the outline edge has been further reduced (Figs. 6.4 and 6.5).

The first systems envisaged an electrical coupling with the X-ray generator, so as to be able to synchronize the image capture with the emission of rays.<sup>21</sup>

Most present day devices, on the contrary, work in a totally asynchronous way: the sensor is actually capable of synchronizing automatically as soon as it picks up the presence of radiation.<sup>23</sup>

Microscopic silicon cells make up the structure of the CCD sensitive matrix. At present CMOS

[Complementary MOS (Metal Oxide Semiconductor chip)] sensor feature 40 $\mu$  pixel whereas CCD sensor feature 20 $\mu$  pixels.<sup>33</sup> The Visualix HDI CCD by Gendex features 20 $\mu$  pixels and it can work both in high and in standard resolution. In the later case pixels are coupled. Each of these cells corresponds, in practice, to a photosensitive element (pixel), the basic component of an electronic image. At first it was thought to use smaller size silicon cells, less than 20 $\mu$  each, which, combined in groups of four, made up the area corresponding to a pixel. Technical difficulties and no actual compliance in terms of obtainable quality moved the choice towards the present size of cells.<sup>1,2</sup>

This technical solution gives a theoretical output up to a maximum of 25 pairs of lines per millimeter in terms of space resolution when referring to 20 $\mu$  pixels. At

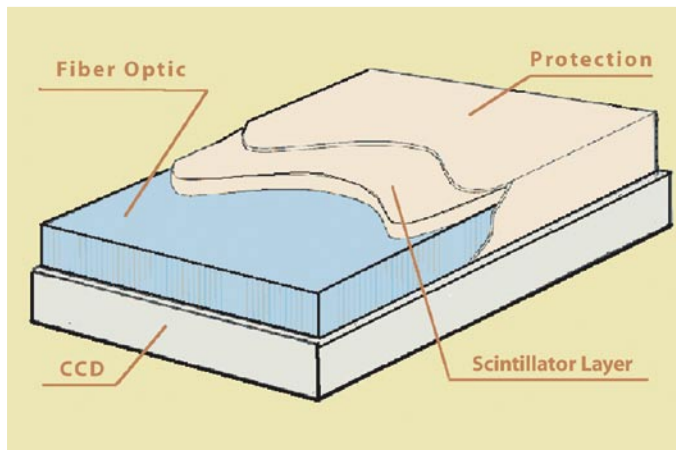


Fig. 6.2. Structure of a CCD sensor.

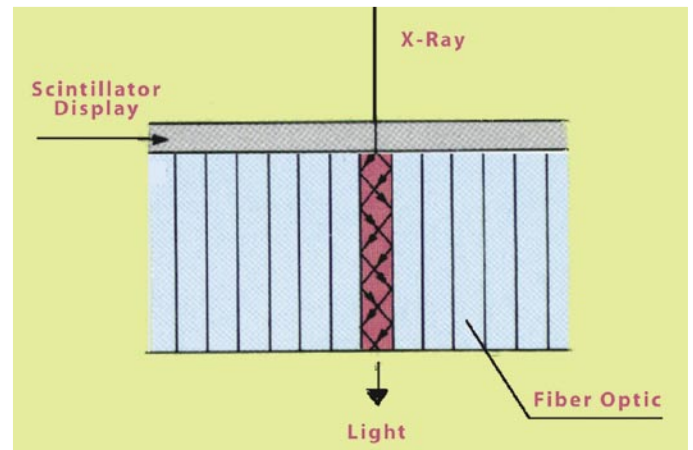


Fig. 6.3. The optical fiber protects the CCD from non-absorbed X-rays, it reduces light dispersion and, therefore, it increases spatial resolution.

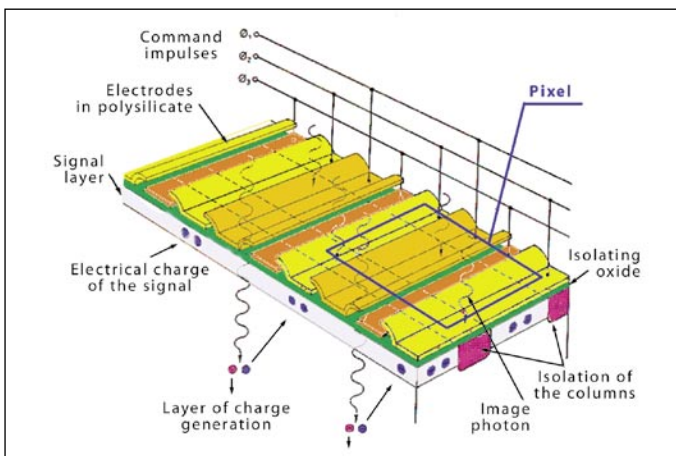


Fig. 6.4. Structure of a CCD.

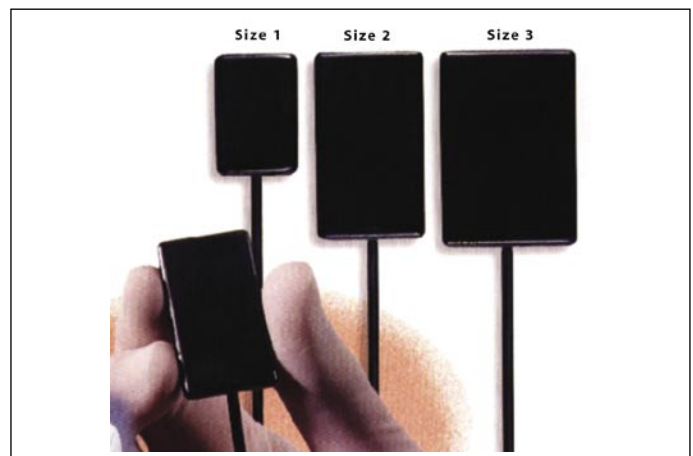


Fig. 6.5. Last generation sensors (in the picture, those produced by Schick Technologies) feature an excellent ratio between overall size and sensitive surface.