intelemed

intelligent telemedicine

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TECHNICAL WHITE PAPER

Laser vs CCD Film Digitizers

Is the difference worth the cost?

Overview

InTelemed is often asked “which is better, a laser or CCD digitizer”. That is easy to answer – a laser. However, there is a significant cost difference between a laser digitizer and a CCD digitizer. Hence, the question becomes “how MUCH better is a laser digitizer compared to a CCD digitizer, is it clinically significant, and is it worth the extra cost?”

To answer that question, it is important to understand the science behind both technologies. There is a significant difference between the technologies.

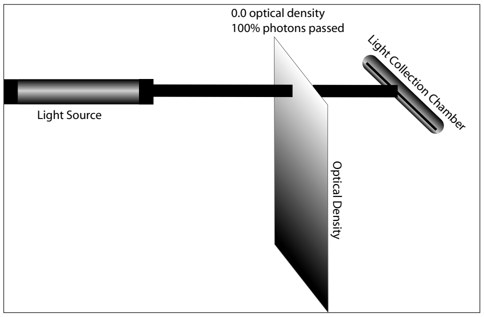
This document tries to clarify the explain the science behind CCD vs Laser digitizers, clarify how they are different, and help a medical professional to understand if these differences are clinically significant and worth the extra cost difference. Our goal is not to tell you which system works for your environment, but to provide you the background and knowledge to understand if the differences and make an intelligent determination of which technology works best for your environment.

The Basics

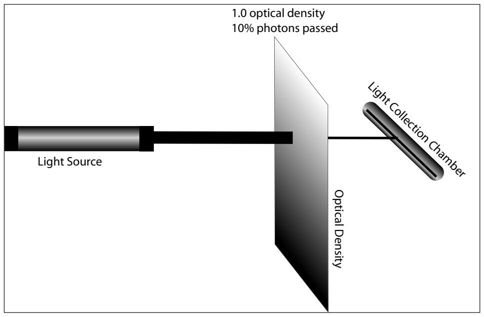
Let’s first consider the basics: how does a digitizer convert film densities into digital values? It’s important to know that optical density (OD) is a logarithmic function, which means that measuring higher densities with meaningful precision is not easy. At optical density 0, 100% of the incident photons (the light going through the film) are transmitted: at 1.0 OD, only 10% make it through; at 2.0 OD, only 1%, and at 3.0 OD only 0.1%.

Laser Light Source

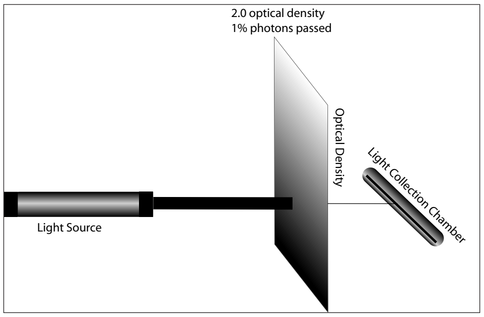
The advantage of using a laser as a light source is that a tremendous number of photons are produced. Just as important, they are all the same wavelength so the light is coherent and subject to less scatter. The point is, with such a large supply of photons, the laser film digitizer can accurately measure optical density from .03 to 3.8 or even 4.1 OD with .001 OD precision.



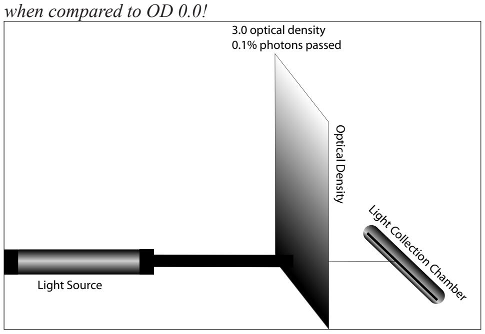
At OD 0.0, 100% of the light photons pass through the film.



At OD 1.0, only 10% of the light photons pass through the film.



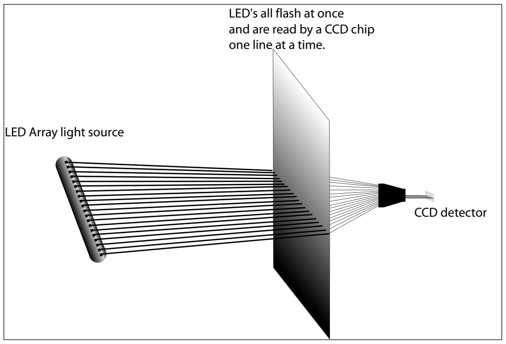
At OD 2.0, only 1% of the light photons pass through the film when compared to OD 0.0!



At OD 3.0, only 0.1% of the light photons pass through the film. Even with a strong laser light source, a very sensitive light detector is required to detect the light passing through the dark areas of the film.

LED Array Light Source

CCD scanners use an LED array light source. These light emitting diodes are spread across the back of the film and emit a flash of light at once. Several LED's flash at once and the CCD chip detects this flash of light. Each flash is normally one line in depth. The CCD detector is located behind a camera-style lens and when the LED's flash, the chip captures one line of the film, similar to a digital camera. LED's are prone to light scatter and are not coherent, focused beams of light. Hence you get light scatter from one pixel to the adjacent pixel.



Laser Light Source Advantage

The advantage of using a laser as a light source is that a tremendous number of photons are produced, all the same wavelength, the light is coherent, subject to less scatter. The point is, with such a large supply of photons, the laser film digitizer can accurately measure optical density from .03 to 3.8 or even 4.1 OD with .001 OD precision. The photomultiplier tube reads one pixel at a time, 2000 times across each line of the film. Since it reads only one pixel at a time, there is no light scatter from the adjacent pixels, hence very little noise, especially since your primary light source is a highly focused laser beam. With an LED light source the CCD picks up scatter from adjacent pixels as the light passes through the film. There are not nearly as many light photons striking the CCD chip, and some of those that are striking the chip are scatter meant for adjacent pixels.

Hence, from a scientific viewpoint, the laser/photomultipler combination has a signficicant advantage over an LED/CCD combination.

Density Precision

One measurement that is not talked about is exactly how precise the digitizer is at various optical densities. There is a big difference in density precision between the two technologies, especially in dark areas of the film where not many photons are getting through. A laser digitizer can make much more precise measurments in darker areas of the film, where there is much less light penetrating the film. CCD scanners can take more measurements in the very light areas of the film, but these are not as crucial since plenty of photons are passing through the film to be read. In the dark areas of the film the CCD does a very poor job of measuring the subtle differences in light passing through these areas. While the CCD may be advertised as being able to detect at a high optical density, the fact is that they are not very precise at these higher optical densities.

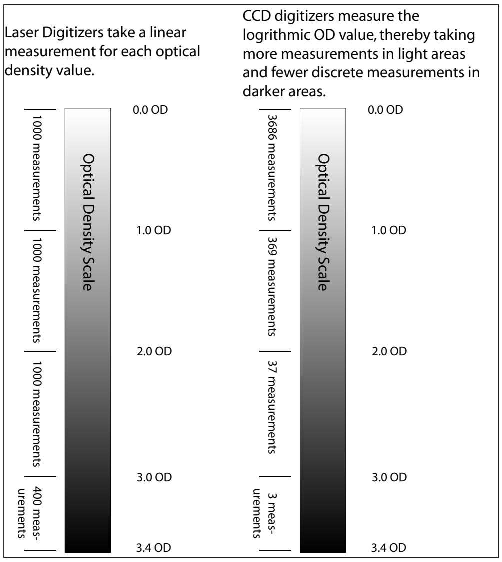
Laser- Precise Measurements Through Dark Film

The laser film digitizer converts each density measurement into a pixel value, which is 1000x the optical density at that point. Optical density 2 = 2000, 3.2 = 3200, etc. To put it another way, this means that there are

1000 levels from 0 to 1 OD
1000 levels from 1 to 2 OD
1000 levels from 2 to 3 OD
400 levels from 3 to 3.4 OD

CCD - Poor precision in dark areas of film

A CCD element is designed to produce voltage when it detects light (photons). This voltage level is digitized and the resulting digital value is supposed to be related to the density of the film at any given point. At optical density 0, maximum light passes through the film, so maximum voltage is produced by the CCD element. This is typically *calibrated* to be 10 volts. At optical density 1, only 10% of the light transmitted will be detected (optical density is a log function). This means the voltage output at optical density 1 is 1.0 volt.



If the CCD output is being digitized into 12 bits or 4,096 density levels, then the number of density levels between optical density 0 and optical density 1 is 3,686. This is calculated knowing that the full range of the CCD output is 10 volts = 4,096 density levels and 9 volts = 3,686 density levels (90% of 4,096).

This gets more interesting now. From optical density 1 (1 volt) to optical density 2 (.1 volt), the output of the CCD element is .9 volt which equals 369 density levels (9% of 4,096). From optical density 2 (.1 volt) to optical density 3 (.01 volt) the output is .09 volt or 37 density levels. From optical density 3 to optical density 4 (.001 volt) only 4 density levels are possible, which is meaningless. In other words,

3686 levels from 0-1 OD,
369 levels from 1-2 OD,
37 levels from 2-3 OD,
4 levels from 3-4 OD

In fact, it is generally accepted that typical CCD scanners are limited to a useful optical density range of 0 to 2.3, maybe 2.5. Camcorders use CCD detectors to record images on videotape. When the light level is very low, the image becomes fuzzy, contrast is poor, and color quality is significantly degraded. The same phenomena occur when scanning a dark film with a typical CCD scanner – there just aren't enough photons to provide useful information.

Real World Comparision

So now the question becomes "how is this relevent to clinical diagnosis?" You can digitize films and compare them, but unless you have a calibrated test film it may be hard to detect subtle differences in the film. Difficult to detect pathology such as a phnumothorax will generally be easier to find with a laser versus a CCD. Mamo films can only be scanned using a laser, since optical density quality is crucial to pathology detection.

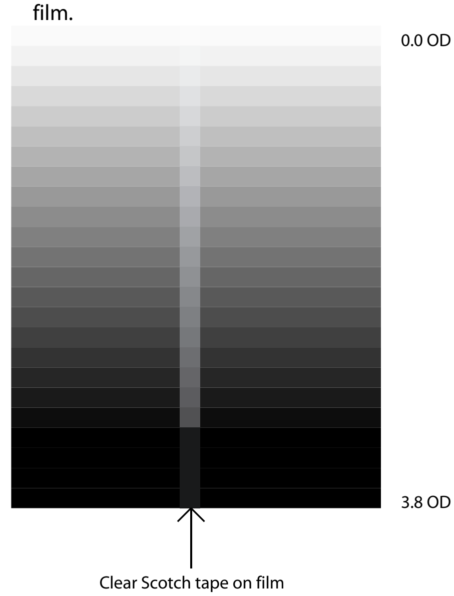
The Tape Test

One way to compare the image quality and detection capability is to do what we call the "Tape test". For this test you take a calibrated test film with known optical density measurements, normally from 0.0 OD up to 3.6 or even 4.0 OD. You can even check the film on a densitometer. Take a piece of clear scotch tape and tape it right down the center of a stepwedge film. Scan the film through both a CCD and Laser digitizer. The clear tape will create an optical density difference of approximately 0.03 OD.

In the lighter areas of the film you should be able to detect the tape on any good film scanner. As the optical density gets higher, a properly calibrated laser digitizer will detect the tape at it's highest optical density measurement. The CCD will be very difficult to detect the tape above about 2.4 or 2.6 OD. This is the area of the film where subtle differences can easily be missed.

TAPE TEST

Place a piece of clear Scotch tape on calibrated step wedge with OD of around 3.4 or 3.8. Digitize the film and then see if you can detect the Scotch tape in the dark areas of the film.



Cost Comparision

So there is little argument in the medical community that a laser scanner far outperforms a CCD scanner in terms of image quality. While both scanners my offer the same advertised resolution, the laser will have a much higher quality image with less "light scatter" from LED arrays. More importantly, the laser will enable the radiologist to detect very subtle contrast differences in darker areas of the film.

So, is this better performance worth the extra cost? That is up to the facility and radiologist to decide. For non-diagnostic teleradiology, either technology will suffice, since the radiologist normally overreads the actual film the next day. For primary diagnostic interpretations the laser offers clear advantages and less risk to the radiologist. The costs of laser digitizers have been dropping recently and while still not on the level of CCD digitizers, the cost difference is less than in the past. As a testimate to their extremely high quality of images, Kodak has over a 90% market share in all film digitizers. Kodak only offers laser digitizers. Hence, most facilities are using laser digitizers.

** based on white paper by John Burgess, Lumisys Corporation*