Chapter one

Introduction

: Introduction 1.1

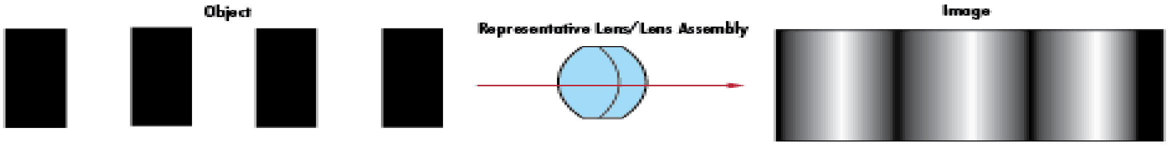
A photograph's detail is an integral part of its appeal. Many photographers spend a great deal of time, energy and money acquiring equipment to make sharp images. Back in the film era, if 35mm didn't satisfy them, they invested in medium format, 4x5, 8x10, or larger. The digital versus film debate is now mostly settled, but there is still some debate over the relationship between the number of megapixels and image quality. The sharpness of a photographic imaging system or of a component of the system (lens, film, image sensor, scanner, enlarging lens, etc.) is characterized by a parameter called ***Modulation Transfer Function (MTF)***, also known as spatial frequency response. We present a unique visual explanation of .MTF and how it relates to image quality

Spatial Resolution 1.1.1

Is a measure of the sharpness and detail of the image .and is a term which characterizes the ability to accurately resolve spatially separated radioactive sources*.* Resolution is performed weekly and assesses the ability to produce image detail and sharpness. This test is performed similar to the uniformity test. The images are assessed .qualitatively to evaluate the resolution acceptability

Resolution is an imaging system's ability to distinguish object detail. It is often expressed in terms of line-pairs per millimeter (where a line-pair is a sequence of one black line and one white line). This measure of line-pairs per millimeter (lp/mm) is also known as frequency. The inverse of the frequency yields the spacing in millimeters between two resolved lines. Bar targets with a series of equally spaced, alternating white and black bars (i.e. a 1951 USAF target or a Ronchi ruling) are ideal for testing system performance. For all imaging, when imaging such a pattern, perfect line edges become blurred to a degree (Figure 1). High-resolution images are those which exhibit a large amount of detail as a result .of minimal blurring. Conversely, low-resolution images lack fine detail

(Figure 1: Perfect Line Edges Before (Left) and After (Right



Resolution imaging machine 1.1.2

When there is need to compare the performance of optical systems, a commonly used measure is the modulation transfer function (MTF). MTF is used for components as simple as a spherical singlet lens to those as complex as a multi-element telecentric imaging lens assembly. In order to understand the significance of MTF, consider some general principles and practical examples for .defining MTF including its components, importance, and characterization

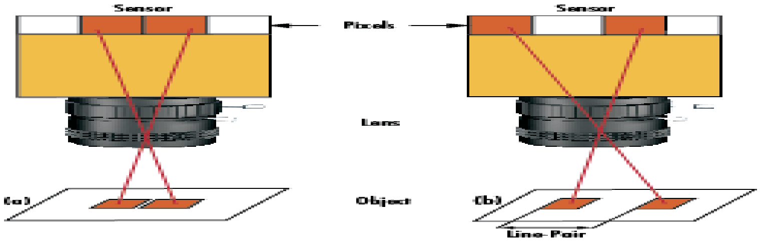
The component of MTF 1.1.3

To properly define the modulation transfer function, it is necessary to first define two terms required to truly characterize image performance: resolution and contrast

The Modulation Transfer Function (MTF) is an important aid to objective evaluation of the image-forming capability of optical systems. Not only that the MTF provides a means of expressing the imaging quality of optical systems objectively and quantitatively\, but it can be calculated from the lens design data. In this way it allows optical and systems designers to predict reliably the performance of the optical systems. The manufacturers can compare the image quality of the .manufactured lenses with the design expectations

The Modulation Transfer Function (MTF), describing the resolution and performance of an optical system is the ratio of relative image contrast divided by relative object contrast MTF = Relative Image Contrast/ Relative Object Contrast. When an object (illuminated target or reticle) is observed with an optical system, the resulting image will be somewhat degraded due to inevitable aberrations and diffraction phenomena. In addition, a real lens will not fully conform with the design data. Manufacturing errors, assembly and alignment errors in the optics will deteriorate the overall imaging performance of the system. As a result, in the image, bright highlights will not appear as bright as they do in the object, and dark or shadowed areas will not be as black as those observed in the original patterns. In general an illuminated target can be defined by its spatial frequency (number of bright and dark areas per millimeter) and the contrast (the apparent difference in .(brightness between bright and dark areas of the image

A practical way of understanding line-pairs is to think of them as pixels on a camera sensor, where a single line-pair corresponds to two pixels (Figure 2). Two camera sensor pixels are needed for each line-pair of resolution: one pixel is dedicated to the red line and the other to the blank space between pixels. Using the aforementioned metaphor, image resolution of the camera can now be .specified as equal to twice its pixel size



Problem of the study 1.2

The diagnostics x-ray machine produces electromagnetic radiation used to image the body in case of pathology, therefore this exposure were justified. But if the exposure parameters were not chosen satisfactory the image has to be repeated where the patient subjected to a substantial amount of radiation. In case of resolution were ever the exposures were repeated the quality will not be improved, therefore assessing the exposure factors that provides the optimum resolution will help in the judgment. Moreover MTF will give a complete description of system performance over the FWHM as well as the

Objectives 1.3

The general objective of this study was to assess the digital x-ray machine resolution using MTF in order to have an objective method superior to the full .(width at half maximum (FWHM

- .To generate x-ray bar phantom images using variable Kv unit

- To generate a line transfer function (LTF) using phantom x-ray image profile .for the line with different thickness and kV
- To generate an algorithm that can compute the Modulation Transfer Function using line transfer function
- To measure the x-ray machine resolution using the frequency of the image .object at 3% MTF
- To find the relationship between the Kv and the resolution at different object .(thicknesses (cycles/mm

Significance of the study 1.4

The purpose of evaluation is to detect changes in the performance of planer x-ray machine that may adversely affect the interpretation of clinical studies

overview of the study 1.5

This study consisted of five chapters, chapter one is an introduction; which introduce briefly the modulation transfer concept in respect to resolution, problem and objective of the study and it is significant. Chapter two is literature which includes scholarly literature about x-ray resolution and MTF. Chapter three described the material, method used to collect data. Chapter four result presentation of the study finding presented in figure and table, finally chapter five .included result discussion, conclusion and recommendation

Chapter two

Literature review

X-ray imaging is the most widespread and well-known medical imaging technique. It dates back to the discovery by Wilhelm Conrad Röntgen in 1895 of a new kind of penetrating radiation coming from an evacuated glass bulb with positive and negative electrodes. Today, this radiation is known as short wavelength electromagnetic waves being called X-rays in the English speaking countries, but

“Roengten” rays in many other countries. The X-rays are generated in a special vacuum tube: the Xray tube, which will be the subject of the first subsection. The emanating X-rays can be used to cast shadows on photographic films or radiation sensitive plates for direct evaluation (the technique of planar X-ray imaging) or the rays can be used to form a series of electronically collected projections, which are later reconstructed to yield a 2D map (thus, a tomographic image). This is the so-called CAT or CT technique (J. Rueckel, M.stockmar, F.pfeiffer, J.Herzan (2014), .(Spatial resolution characterization of X-Ray micro CT system

A typical X-ray tube is depicted in Figure 1. It consists of an evacuated glass bulb with a heated filaments (*glødetråd* in Danish) as the negative electrode and a heavy metal positive anode. Thermic electrons emitted by the heated filament are accelerated across the gab to the anode. (J. Rueckel, M.stockmar, F.pfeiffer, (J.Herzan (2014), Spatial resolution characterization of X-Ray micro CT system

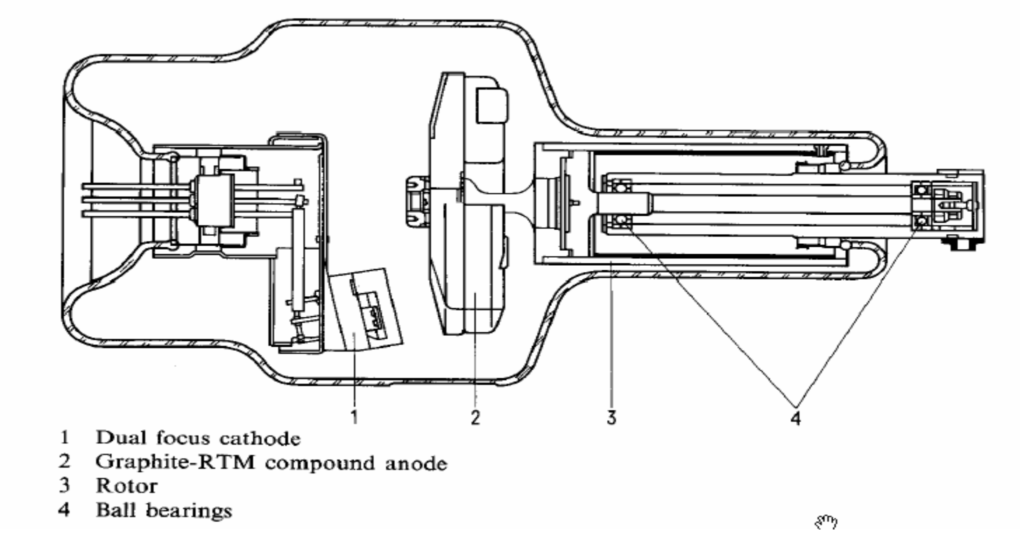


Figure 1 X-ray emission from Wolfram anaode X-ray tube. Observe that for a given tube voltage, the higher the energy of the photons, the less there are. And if the number of photons are to increase, then the tube voltage should increase

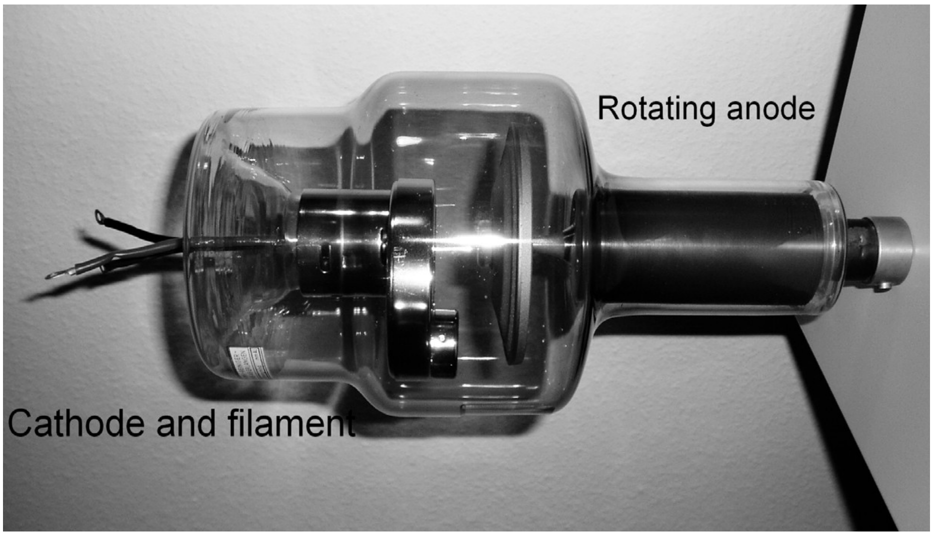


Figure 2 Rotating anode X-ray tube. "RTM" anode designates a Molybdenum anode mixed with 5% Rhenium to improve the thermal stability. The metal anode is .supported by graphite to improve the total thermal capacity. Source: Siemens

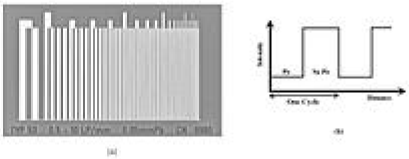
If the voltage between cathode and anode is U volts and the current in the tube being I amperes, each electron will be hitting the anode with a kinetic energy of U eV. The power deposited in the anode will be I times U, and the total energy .transferred to the anode in an exposure lasting t seconds will be IUt

The electrons will be slowed down in the anode material, mainly releasing their energy as heat, but to a small degree (few percent) the energy is transformed to either *Bremsstrahlung* or *characteristic X-rays*. The Bremsstrahlung originates from the sudden deacceleration and direction changes of the primary electrons in the field of the anode atoms, the characteristics X-rays originates from the knockout and subsequent level filling of inner electrons in the atoms of the anode material. The highest possible quantum energy of emanating X-rays (measured in eV) will be equal to *U*. Typical energy spectra as a function of voltages are shown in Figure 2. Please note that the spectra are all taken at the same current, only the voltage has been varied. This demonstrates that the total number of X-ray photons are heavily dependent on tube voltage. In addition to the information in Figure 2, a general rule of thumb says that 15 keV increase in voltage corresponds to a doubling of the photon output. For practical medical applications, the low energy part of the photons are normally not used but removed by filtering either inside or just outside the X-ray tube. Normal filter materials are either aluminium or copper. The thicker the filter and the higher the atomic number of the filter, the greater the cut-off of .low energy photons

The description of the exposure characteristics of a given X-ray tube will comprise the voltage (in units of kV), the current (in units of mA), the time of exposure (in units of s) and the degree of filtering (for example a plate of Al, one mm thick next to a plate of Cu, 0.5 mm thick). As the total number of photons produced for a given high voltage setting only depends on the product of current and time this is .often stated as a product in units of mAs

Spatial Resolution

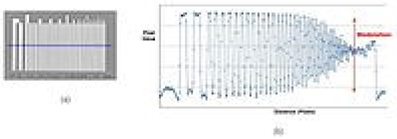
Spatial resolution refers to the ability of a radiographic imaging system to record fine detail. Obviously, detail is a pre-requisite for clinical images of excellent quality. However, it should be appreciated that not all image receptors .demonstrate the same performance in this regard



.Fig. 2.1 A spatial resolution test object

The maximum spatial resolution of an imaging system can be readily obtained by imaging a resolution test object - an example of which is shown in Figure 2.1. The test object consists of narrow parallel slits in a lead sheet at spacings which decrease to beyond the maximum resolution of the image receptor. The minimum spacing resolved in images is called the Limiting Spatial Resolution and can be .determined to be about 3.5 line pairs/mm from the figure

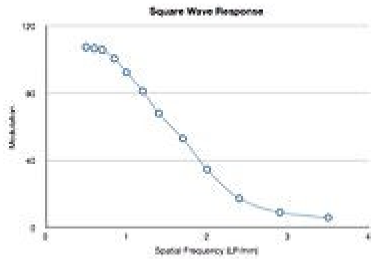
Note that the width of each slit in the test object is the same as that of the adjacent piece of lead, so that the radiation intensity transmitted through the test object can be considered in profile to be represented by a square wave - see panel (b). A Spatial Period (usually measured in mm) can be used to characterize this square wave and is equal to the width of one line pair, i.e. the width of a slit plus its adjacent piece of lead. Its reciprocal is called the Spatial Frequency, which is .generally expressed in line pairs/mm (LP/mm) or cycles/mm



.Fig. 2.2: Profile (in blue) through a radiograph of a lead bar test object

An amplitude profile through an image of the test object allows the modulation at each spatial frequency to be determined - see Figure 6.6 - and can be used to .provide more complete information than the limiting resolution on its own

Here, the modulation is obtained from the difference between the maximum and minimum pixel value at each spatial frequency and expressed in the form of a Square Wave Response (SWR) as shown in Figure 6.7. The modulation is seen to be relatively constant at low spatial frequencies and then to decrease rapidly towards zero. The SWR allows the spatial imaging capabilities to be expressed for both broad, relatively uniform objects, i.e. those with low spatial frequencies, and fine detail, i.e. those with high spatial frequencies, as well as features with .intermediate frequencies



.Fig. 2.3: A square wave response

A more complete and elegant approach to the assessment of spatial resolution is provided by Fourier methods. These computations can be used in the mathematical analysis of factors which contribute to and detract from the .generation of images with excellent spatial resolution

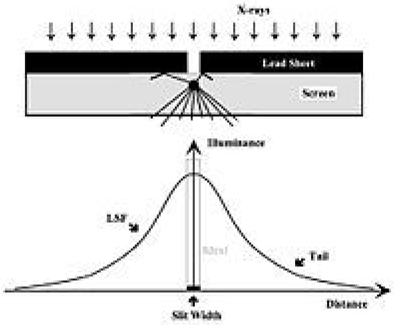
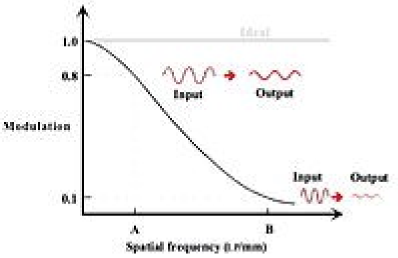


Fig. 2.4: The Line Spread Function (LSF) and its origin for an X-ray intensifying .screen

Fourier methods can be used to analyse the response of an imaging system to a square wave input using a narrow slit in a sheet of lead, for instance. Remember that a square wave is the equivalent of the sum of an infinite number of sine waves. The imaging of such a slit is illustrated in Figure 6.8 where the transmitted radiation is seen to excite fluorescence in an intensifying screen. The fluorescent light is emitted in all directions and the image of the slit therefore becomes spread out over a broader area than is ideal. The effect is seen in the illuminance profile which consists of a central peak, as expected, with tails extending around it. This type of profile is called the Line Spread Function (LSF). The effect on the slit's image as a result is seen as a slight tinge of greyness around the slit's edges to an extent given by the tails of the LSF. Better performance can therefore be seen as a .narrowing in the LSF and a suppression of its tails

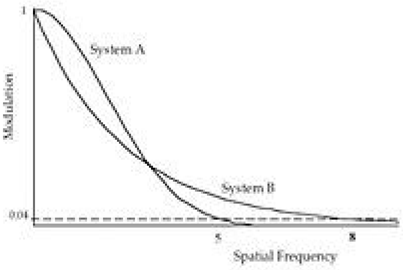
The same type of data can be obtained for 2 dimensions using a small hole in a .(sheet of lead and is called the Point Spread Function (PSF



.(Fig. 2.5: The modulation transfer function (MTF

When the Fourier Transform of an LSF is calculated, then the imaging system’s response to sine waves of all spatial frequencies is obtained. This response is called the Modulation Transfer Function (MTF) - see Figure 6.9. It can be seen that the modulation falls off with increasing spatial frequency, as was seen with the Square Wave Response, but as a continuous curve representing all, and not just .discrete, spatial frequencies

The response of an ideal imaging system is also shown in the figure. Its constant value of 1.0 at all spatial frequencies implies that all details in the patient will be imaged perfectly, unlike our real intensifying screen whose modulation drops by 20% at spatial frequency, A, and by 90% at frequency, B, for example - whatever .their absolute values might be



.Fig. 2.6: MTFs of two hypothetical image receptors

Spatial frequency, B, in Figure 6.9 can be considered to be approaching the extreme of the resolving capability of an imaging system. The limiting spatial resolution is sometimes defined as the frequency where the modulation drops to 4%. When the resolving ability of two different image receptors is compared, as in Figure 6.10 for instance, we could infer from measuring the limiting resolution alone that system B was superior to system A, at 8 compared to 5 LP/mm. An MTF comparison would reveal however that system B in fact provides superior quality at frequencies less than about 3 LP/mm, which is where many features of clinical .interest said to lie

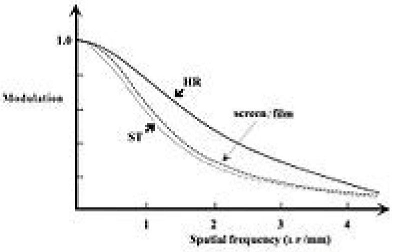
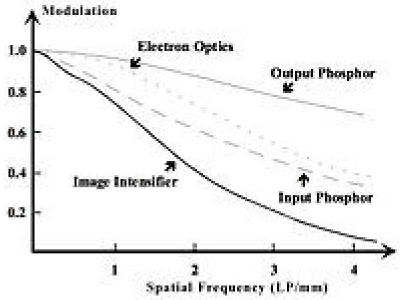


Fig. 2.7: MTFs for phosphor plates used in CR. Curves are for high resolution (HR) and standard (ST) plates. The MTF for a 400-speed film/screen receptor is also .shown for comparative purposes

The MTF performance of film/screen radiography is compared with Computed Radiography (CR) in Figure 6.11. It can be seen that the standard resolution CR system (ST) is about equivalent to a regular film/screen receptor across the frequency range. It can also be seen that the HR computed radiography system provides an improvement of ~20% at the intermediate spatial frequencies, while it .approaches the performance of the other two receptors above 4 LP/mm



.Fig. 2.8: The MTFs of components of an X-ray image intensifier

A major advantage of the MTF concept is that for an image receptor with a number of image transduction stages, the overall MTF can be obtained from the product of the individual component MTFs. This feature is demonstrated in Figure 6.12, which shows the component MTFs for an X-ray image intensifier. It can be seen that the contrast at high spatial frequencies is limited by the behaviour of the input phosphor and not the output phosphor in this hypothetical case. Thus, from a design point of view, a reduction in veiling glare in the input phosphor should improve the overall MTF of the XII. As an example of the multiplicative property of the MTFs, with reference to the figure, note that at a spatial frequency of 3 LP/mm :the MTF of the image intensifier is

.Modulation = 0.78x0.55x0.48 = 0.21

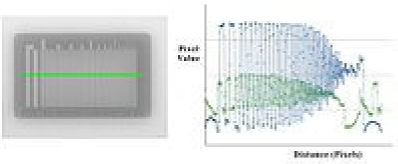


Fig. 2.9: Profile (in green) through a radiograph of a resolution test object imaged .in scatter conditions. The no scatter case is shown in blue for comparison

In the presence of scatter, we can expect the reduction in contrast to give rise to reduced modulation at all spatial frequencies and a reduced ability to discriminate fine detail. This is illustrated in Figure 6.13 where modulation reduction is quite .evident

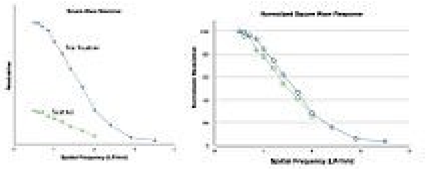


Fig. 2.9: The absolute SWR in scatter and no scatter conditions is shown on the left, .while a normalised plot is shown on the right

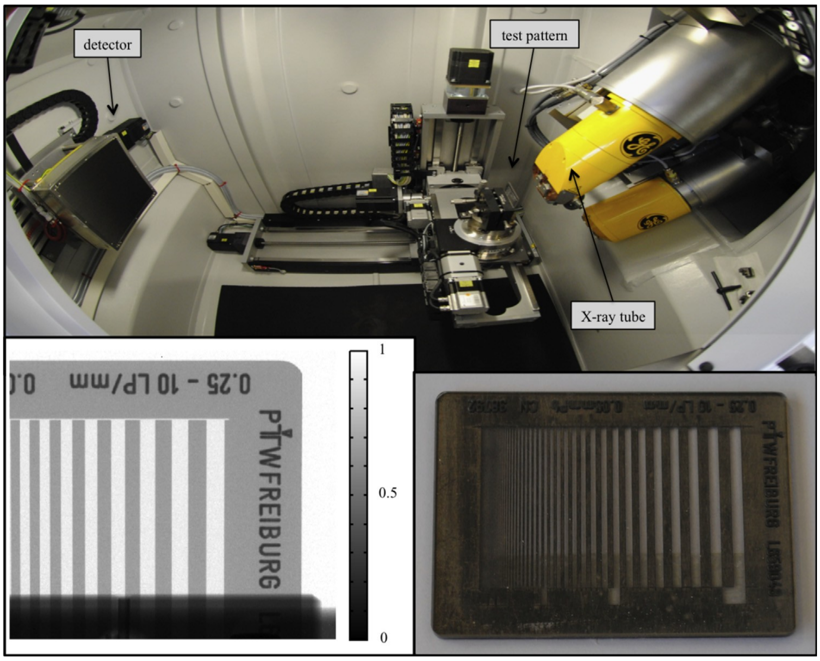
The impact on the square wave response is shown in Figure 6.14. It can be seen that scatter reduces the amplitude of the SWR and eliminates the modulation at .frequencies above 2 LP/mm, in this case, so that they can no longer be resolved

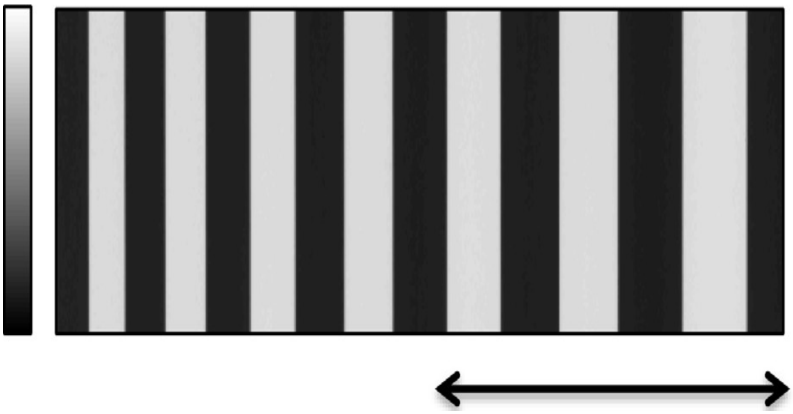
Note that a large reduction in modulation at very low spatial frequencies can be inferred from the figure. This phenomenon is generally referred to as the **Low Frequency Drop** and could conceivably be used as an indicator of scatter (and .veiling glare) levels

Raynald G, Spatial Resolution of X-Ray Images, This new program computes the complete x-ray spectra from the simulation of electron scattering in solids with various types of geometries. MC X-Ray allows for more than 100 different regions in materials with shape of spheres, cylinders and combinations of horizontal and vertical planes. All these regions can have a different composition. MC X-Ray includes the Bremstrallung cross-sections of Ding – Statham to compute the emitted background x-ray intensity in order to generate a synthetic X-Ray spectrum. Then, a true EDS spectrum detected by a SDD detector can be simulated using the absorption of photons and the subsequent diffusion of the photo-electrons in the x-ray detector using the synthetic spectra. MC X-Ray simulates the true noise of EDS spectra without using Gaussian noise techniques, as classically done in others softwares. As a result, complete EDS maps can be simulated for a given number of emitted photons per pixel. In this work, EDS images were simulated for embedded spheres of Cu in C of diameter of 50, 20, 10 and 5 nm at 10 keV for various number of emitted photons per pixels in 128 X 128 images having a size of 140 X 140 nm

J. Rueckel et al, (2014), Spatial resolution characterization of X-Ray micro CT system ,The experimental procedure was based on the assumption that the spatial resolution of the underlying radiographic projections is fundamentally limiting ,The highest achievable spatial resolution of subsequently reconstructed CT slices. Therefore, the influence of different X-ray tube parameters on the spatial resolution of two-dimensional radiographic projections was studied quantitatively by analyzing the modulation transfer function (MTF) for asset of different X-ray tube parameters. A rectangular test pattern(produced by PTW-Freiburg and providing spatial frequencies up to 10l p/mm) consisting of a lead foil embedded between two plastic layers was used for the experiments ,see Figs. 1and2. The lead foil provides sharp edges that wererotatedthrough1–31 against the vertical pixel boundaries with the aidofaspecimen holder. The rotation enable finer edge sampling (Dössel, 2000). All X-ray projections were corrected for dark current and normalized to the incident radiation intensity. The MTF relates the spatial frequency (denoted in object coordinates) to the corresponding contrast loss .The normalized intensity line profile perpendicular to the lead foil edge provides the edge spread function(ESF), the Fourier transformation of its first derivative finally provides several values of the wanted MTF, see Fig. 2. The relation is given by

MTF. For each measurement, the MTF raw data points were determined by the mean value of the corresponding MTF values which were separately calculated or multiple pixel rows. This procedure additionally allows the determination of standard deviations for the finally obtained MTF raw data points as a measure for the error. The standard deviations were too small for graphic error bar illustrations in the presented results (standard error of the mean smaller than 1% for the MTF raw data points). Furthermore ,we defined the MTF1/2 value as the spatial frequency corresponding to a contrast loss of 50% ,calculated by a Gaussian curve fit on the basis of the already obtained MTF values. To test isotropy of the focal spot, the MTF was determined in vertical as well as horizontal directions for a few data points and no significant deviation was found. The following results are based on a vertical edge alignment and there by consequently quantify the spatial .resolution in horizontal direction





G. Aswan Kumar, (2011) ,EVALUATION ON X-RAY EXPOSURE PARAMETERS CONSIDERING TUBE VOLTAGE AND EXPOSURE TIME, Tests are being conducted and measurements are being observed on a GE X-ray Generator High frequency inverter type generator with a rating of 80kW, For Radiographic purpose tube voltage of (40 - 150 kV) and tube current of 1000 mA. In our study we concentrated on High kVp technique to reduce the radiation dose to the subject. Absorption by the body is the essence, the more mAs (quantity), the more the absorption of the body. The kVp is the (quality) energy behind the mAs. The greater the push, the more penetration to the body, the less that are absorbed (i.e. lower the dose). The use of high kVp which is above 100 comes with a requirement .to use grid to reduce the amount of high energy scatter reaching the film

The assessment of subject's doses in diagnostic radiology involves statistical data collection, recording of dose metric measurements. Some of reliable information has been gathered from various health care diagnostic centers. This study basically following the guidelines of AERB was conducted in different x- ray .machines

Initial phase of our work has been concentrated on collection of data of different subjects undergoing x-ray radiation. The data collected was primarily focused by systematic random method representing reasonably good geographic spread and size. For each X-ray room, machine specific data such as model, manufacturer, year of installation, waveform, added filtration and other parameters are recorded. The following x-ray projections were studied in our work. Posterior- Anterior (PA) Chest, Lateral (LAT) Skull, PA Skull, AP Pelvis, Hand wrist, Anterior- Posterior (AP) Abdomen, Anterior – Posterior (AP) Forearm and Knee Joint (LAT) and Femur Joint are taken for our study. In all these cases were taken for those whose image .quality is diagnostically acceptable

The results shown in this work allows us to identify the main exposure parameters in different radiological projections. Tube potential results are below 125 kVp. Increasing the kVp attracts more electrons from the filament, increasing the rate of x-ray production. The potential (kVp) at which the machine was operatedradiation output increases strongly with potential. The adjustment of the kilovolt value at the operating console also has a important effect on the dose if a high kilovolt setting is chosen; the radiation is “Harder” that is rich in energy and more able to pass through the body. Increasing the kVp resulted in radiation dosage to get to .the other side of the patient and be recorded

Kandarakiset al, (1997),Evaluating x-ray detectors for radiographic applications: A comparison of ZnSCdS:Ag with Gd_2O_2S:Tb and Y_2O_2S:Tb screens, The performance evaluation of radiographic phosphor screens comprised three main stages. First, the phosphor’s efficiency as an x-ray to light converter was studied by determining the intensity of light emission (luminescence) with respect to the incident x-ray beam intensity. The latter is related to the radiation dose delivered to the patient. Second, the phosphor’s coupling efficiency to optical photon detectors used in radiography (films, photodiode arrays) was evaluated by measuring the emitted optical spectrum and determining how well this spectrum is captured by optical detectors. Third, the image information transfer efficiency of the phosphor, giving the information content of the produced diagnostic image, was studied by evaluating the MTF, QNTF, and DQE for both general radiographic .and mammographic imaging

D.A. Bradley et al,(2000),Evaluating the quality of images produced by soft X-ray units, A major limiting factor on image resolution is the size of the focal spot. In our present evaluations of the focal spot size of UMFX1 we have used a pin-hole camera formed from a brass disc. The smaller, 300 mm, opening dimension of the tapered pin-hole was made to face the source, while the larger openings faced towards the receptor. The design of pin-holes for use in determining the characteristics of focal spots in diagnostic X-ray tube assemblies for medical use has been discussed in some detail in a British Standards Institution document, (1984), and in the International Electrochemical Commission document IEC 336 (1982). In present studies of the focal spot of UMFX1, the pin-hole was covered with a thin aluminized layer to exclude the possibility of electrons participating in the image formation process. To determine the resolution due to all limiting factors, including the finite size of the focal spot and receptor performance, we have used an X-ray bar phantom, model 07-553 (Nuclear Associates). This measurement device takes the form of several groups of plastic-encased regular grid lines of increasing spatial frequency, each grid line being made of Pb of 50 mm thickness. The range of spatial frequencies offered by this phantom is from 0.25 lp/mm (line pairs per millimeter) up to 10 lp/mm. Subsequent measurements were found to be necessary, using a system which offered higher spatial .(frequencies (022 lp/mm

Results have shown that the two imaging systems are able to resolve to better than 10 line-pair per mm, this being the ®nest spaced pairs provided by the Nuclear Associates bar phantom, model 07-553. Finer spacing were obtained by making use of transmission electron microscope grids. Two grades of grid were used, one having grid spacing of 0.1 mm (equivalent 10 line-pairs per mm) and the other having spacing of 0.045 mm (equivalent to 22.2 line-pairs per mm). Both grids showed the individual grid lines could be observed. Observation of images of the second grid (with the aid of an optical microscope) revealed that both systems produced images on Kodak Industrex AA film in which the grid lines could be resolved. It is therefore apparent that both systems have resolving power exceeding 22.2 line-pairs per mm. Current efforts to estimate the focal spot size of UMFX1, using the pin-hole camera described earlier in this paper, have shown small angle photon scattering from the tapered sides of the brass pin-hole to be a problem. In particular, it can be noted that elastic scattering cross-sections becoming increasingly large with decrease in photon energy, to the extent that a source of 08 keV photons impinging on what is in effect an annular brass target, will produce appreciable scattering. The outcome is an apparent image of the pin-hole some several times larger than expected. Employing film digitization and ,gray scaling (or pseudo color) one is able to observe a smaller, clearly demarcated

Chapter three

Methodology

Material 3.1

-:X-Check FLU phantom 3.1.1

The phantom X-check FLU is universal test tool including test objects for testing of geometrical characteristics, high resolution, gray scale, low contrast and optical .densities

Different tissue simulating and attenuating phantom layers are available for particular applications .using the PMMA attenuation layer the X-check FLU is . physically constructed in a compatible way to the phantom NORMI 4

-:Design of the study 3.2

This is an analytical study of a case control type, where the frequency of the object in the image will be compared to a reference frequency represents the actual (object size (control

-:Population of the study 3.3

A digital x-ray machine with a fine focus and constant mAs =15 and KV ranging from 50 ,55 ,60 ,65 ,70 ,75 and 80 and digital image receptor; to overcome image conversion when using scanner for analog film as well as the problem of .intensifying screen

-:Duration and place of the study 3.4

This study was conducted at Antalia medical center, Khartoum state, Sudan. in the .period from august 2014 to February 2015

-:Method of data collection 3.5

To determine the spatial resolution in order to find the optimum KV, the phantom was placed on the detector surface, and a uniform x-ray used to irradiate the bar phantom where the focus to film distance was 1 mm, an image was acquired with constant mAs equal to 15, and Kvp setting ranging from (50 ,55 ,60 ,65 ,70 ,75 and 80. The x-ray images were extracted from the machine using mass storage media. Then the digital images were read by user application program generated by the author in Interactive Data Language (IDL) software platform. A profile through a bar graphs were taken for different bar thickness and groups at different Kv. The profiles then plotted as a function of intensity; line transfer function (LTF); this function (LTF) then converted to frequency domain using Fast Fourier Transform Function (FFT) to find the MTF as follows; $\text{MTF}(f) = | \text{FFT (LTF)} |$. The frequency of the bar image object that match the frequency of the actual object located at 3% .MTF

Chapter four
Results

Figure 4-1 scatter plot show the relationship between the Kv and resolution of a bar with a frequency of 0.5 cycle/mm. the trend line direct a direct linear relationship with increment of resolution by 0.1 .percent per Kv

Figure 4-2 bar graph show the effect of increasing the Kv on resolution for a an object with a frequency .of 0.5 cycle/mm

Figure 4-3 scatter plot show the relationship between the Kv and resolution of a bar with a frequency of 0.56 cycle/mm. the trend line direct a direct linear relationship with increment of resolution by 0.95 .percent per Kv

Figure 4-4 bar graph show the effect of increasing the Kv on resolution for an object with a frequency of .0.56 cycle/mm

Figure 4-5 scatter plot show the relationship between the Kv and resolution of a bar with a frequency of 0.63 cycle/mm. the trend line direct a direct linear relationship with increment of resolution by 0.59 .percent per Kv

Figure 4-6 bar graph show the effect of increasing the Kv on resolution for an object with a frequency of .0.63 cycle/mm

Figure 4-7 scatter plot show the relationship between the Kv and resolution of a bar with a frequency of 0.71 cycle/mm. the trend line direct a direct linear relationship with increment of resolution by 0.38 .percent per Kv

Figure 4-8 bar graph show the effect of increasing the Kv on resolution for an object with a frequency of .0.71 cycle/mm

Chapter five

Discussion, conclusion, recommendation

The main aim of this study was to assess resolution of digital x-ray machine using modulation transfer function which gives a complete description of the x-ray machine performance. The phantom bar used has several thicknesses that can be used to probe the compatibility of the x-ray which included three groups each consisted of four groups (each one contains five similar lines) with the following .frequencies 0.5, 0.56, 0.63 and 0.71 cycle/mm

Discussion 5-1

The resolution of the 0.5 cycle/mm groups get better as long as the Kv increases from 60 to 90 in step of 5 with a constant mAs that equal to 15 (Figure 4-1). The increments of resolution were linearly ≈ 0.1percent/kv starting at 93%. As shown in Figure 4-2 the resolution reaches 100% at 85 and 90 kv. This result dictated that the increase in the x-ray energy increases the signal to noise ratio as well since the radiation energy get stronger for the thickest object rays can penetrate the object evenly and to be .recorded as input signal

The second groups 0.56 cycle/mm which is thinner than the first one but with a higher frequency it is resolution still follows the same essence where it increases as the result of Kv. Resolution increased by 0.96%/kv starting at 10.5% (Figure 4-3). Although the increases in the resolution were better than the previous group per Kv but resolution start at a very low limit and start to rise till it reach 94% at 90 kv .(Figure 4-4) where signal to nose ration reached a good proportion as increment of radiation quanta

Similarly for group three 0.63cycle/mm which is thinner than the previous groups and a higher frequencies; resolution continue to increase as the result of Kv increases by 0.59%/kv starting at 25.8% (Figure 4-5) which is lower than the previous groups in case of rising. Where it scores 80.1% as a highest resolution (Figure 4-6), the last groups 0.71 cycle/mm; that represents the thinnest object and highest frequencies also their performances showed an increase with the kv increment by a coefficient equal to 0.39%/Kv (Figure 4-7) starting at 36.5% which is lowest than the previous groups. The .(resolution scored 75% at 90 Kv (Figure 4-8

The results of this study in summary showed that resolution get better as the Kv increase from 60 to 90 where at 90 better resolutions were scored. At the same time as the object size decreases from 1 mm to 0.7 mm (0.5 cycle/mm – 0.71 cycle/mm) resolution decreases. The best resolution scores at 0.5 cycle object at 85 and 90Kv

Conclusion 5.2

The main objective of these study was to assess the resolution of digital X-ray machine using bar phantom with thicknesses that can be used to probe the compatibility of the x-ray which included three groups each consisted of four groups (each one contains five similar lines) with the following frequencies 0.5, 0.56, 0.63 and 0.71 cycle/mm. ant it was conclude that resolution get better as the Kv increase from 60 to 90 to 90, . At the same time as the object size decreases from 1 mm to 0.7 mm (0.5 cycle/mm – 0.71 cycle/mm) resolution decreases. So low kv is better for small object .size , and height kv can produce better resolution for large object size

Recommendation 5.3

- .All diagnostic X-Ray machine should undergo QC test regularly
- Evaluation of X-Ray machine resolution should be done using objective method like MTF
- Similar study can be done using variable of thicknesses as well as .variable kv and to be performed in different types of X-Ray machine

References

Raynald G, (2008). Spatial Resolution of X-Ray Images ,microscopical socity .of Canada Mc Gill university , montreal, quebec, Canada from may 20 – 30

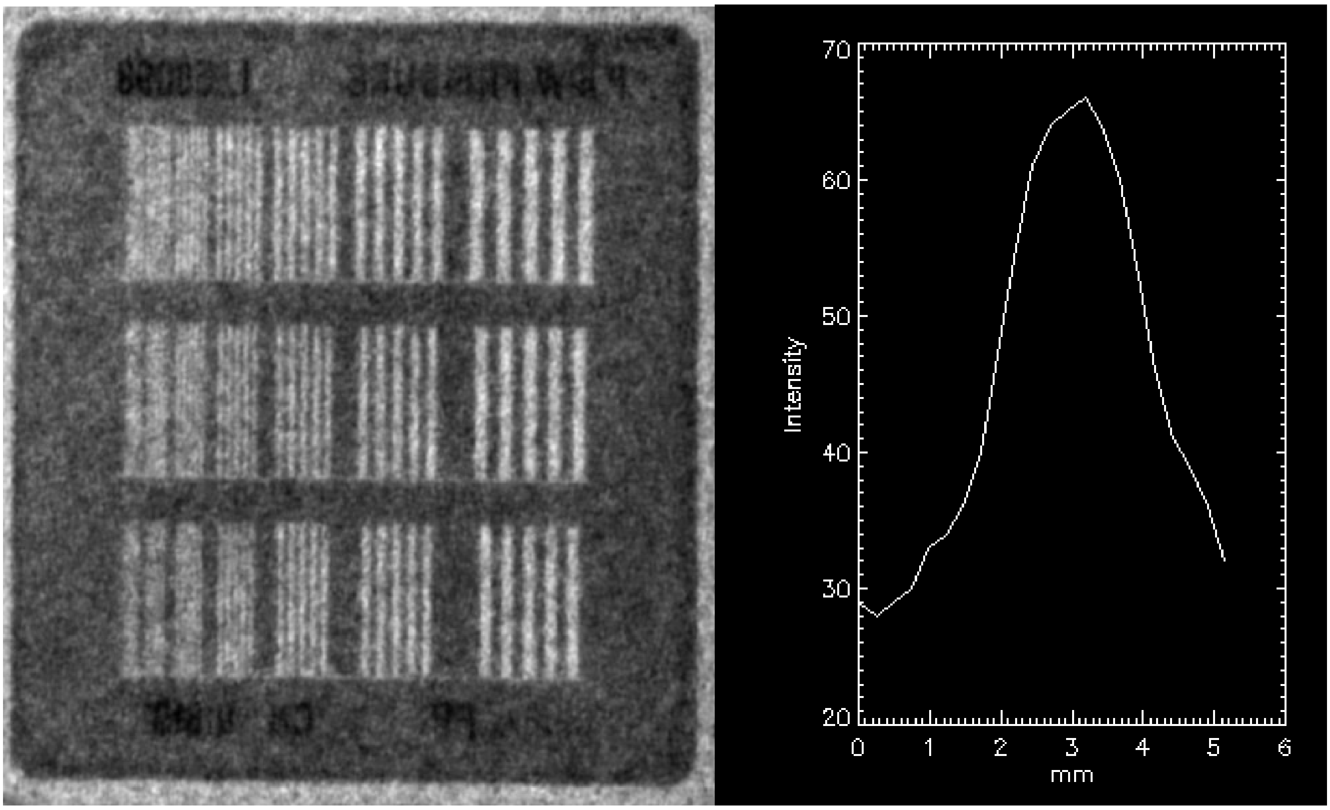
J. Rueckel, M.stockmar, F.pfeiffer, J.Herzan (2014), Spatial resolution characterization of X-Ray micro CT system (2014)Applied radiation and isotopes vol.94:230-234,doi:10.1016

G. Aswan Kumar, (2011) ,EVALUATION ON X-RAY EXPOSURE PARAMETERS CONSIDERING TUBE VOLTAGE AND EXPOSURE TIME, international journal of engeneering science and technology, ISSN:0975-5462:32103215

I.Kandarakis, D.Cavouras, G.S.Panayiotakis, C.D Namicos, (1997), valuating x-ray detectors for radiographic applications, A comparison of ZnSCdS:Ag with Gd2O2S:Tb and Y2O2S:Tb screens,phys. Med. Biol. 42 1351. Doi:10.1088/00319155/42/7/009

D.A. Bradley, Wong CS, Ng KH (2000), Evaluating the quality of images .produced by soft X-ray units,APPI Radiat isot 2000 ,Oct –Nov ;53(4-5):691-7

Appendix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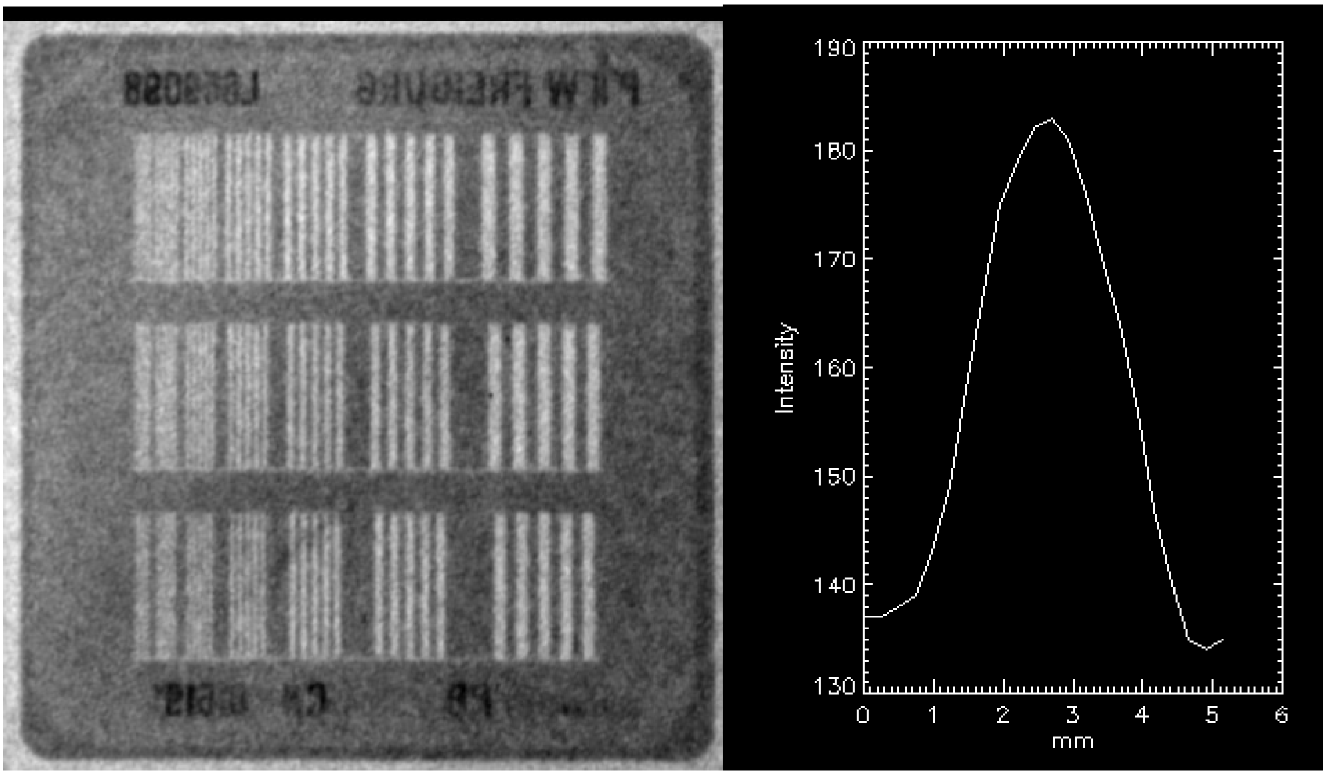
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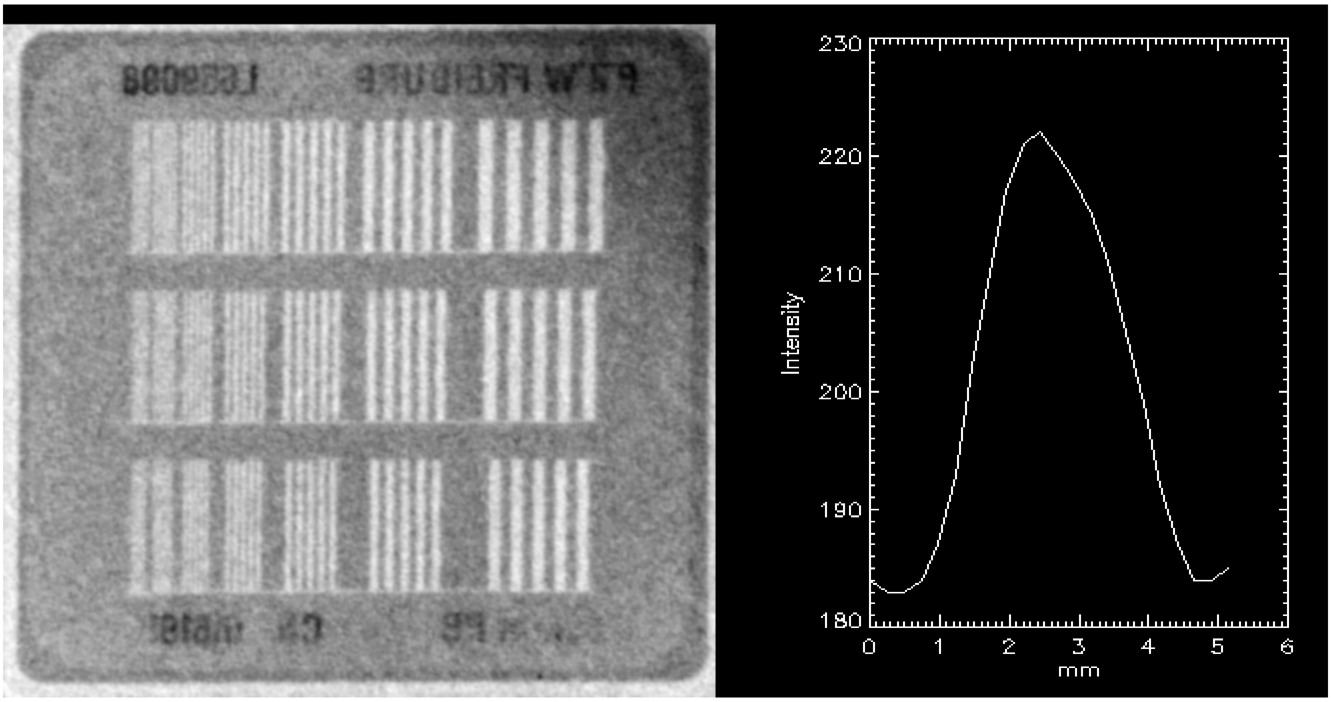
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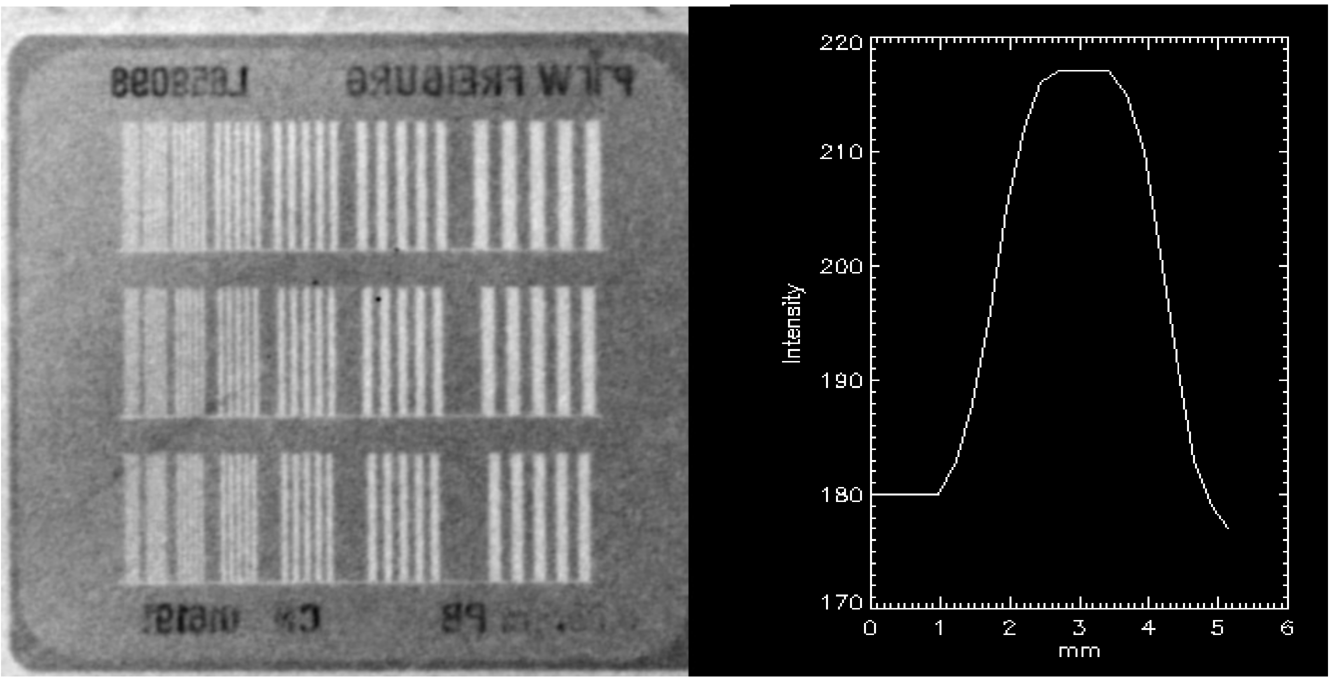
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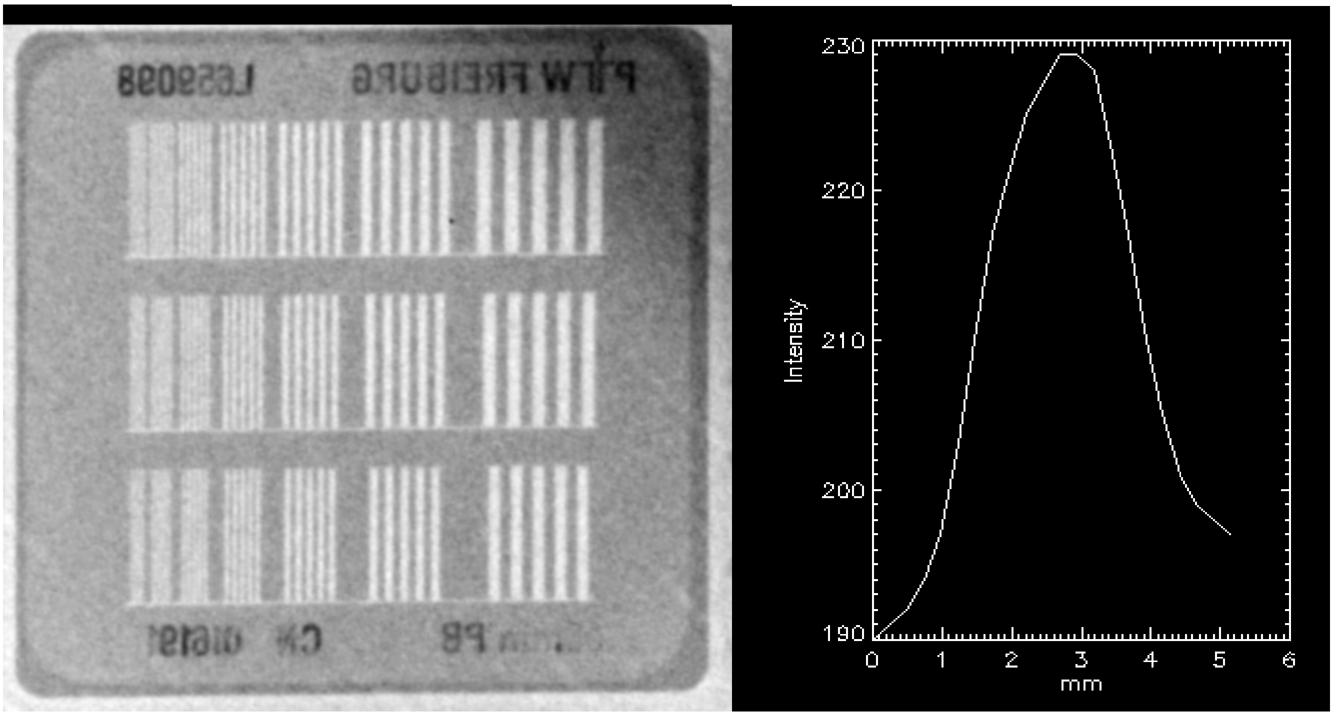
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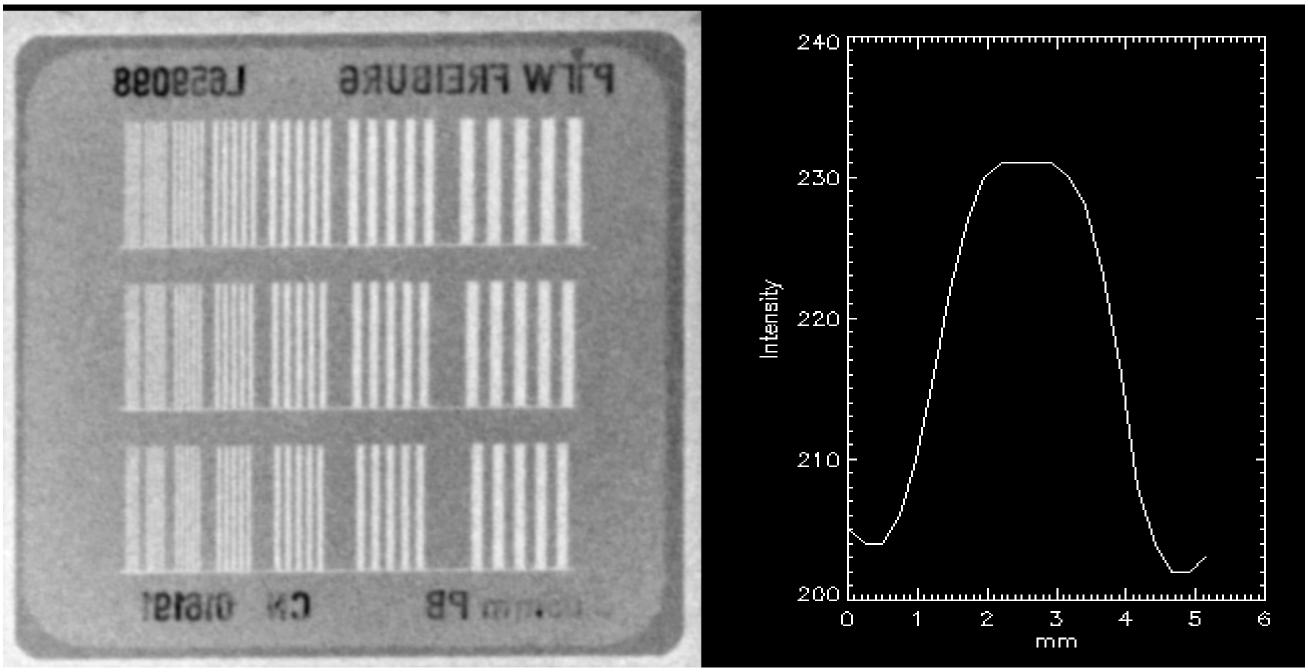

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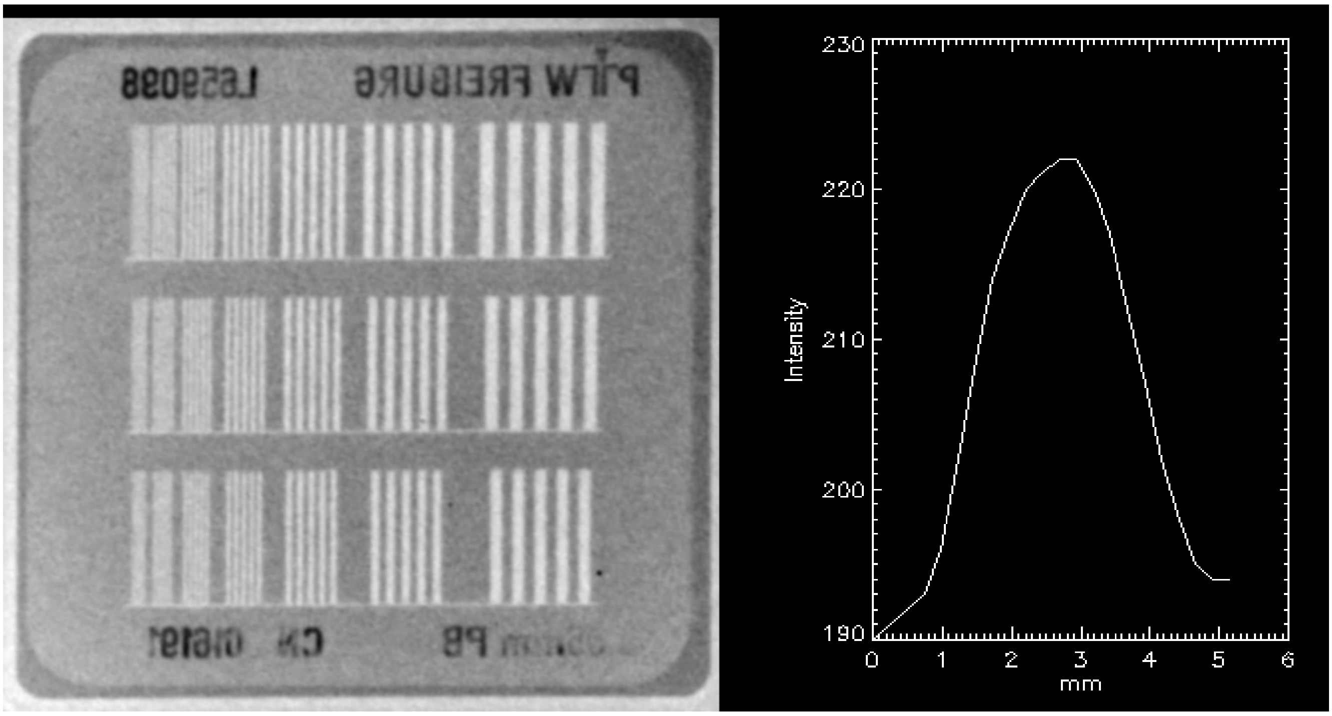

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