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# Soft X-ray Radiography of Biological Materials

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**Abstract**

We have demonstrated experimentally the adaptation of NX2 plasma focus x-ray source in Plasma Radiation Lab, Natural Sciences, NIE, as the soft x-ray of sufficient power for application in microscopic illumination of biological samples. The NX2 is a multiple radiation source. The project has been offered to a wide range of students (secondary school) and course participants (advanced diploma).

## Introduction

X-ray, electromagnetic radiation of very short wavelength and very high-energy, is commonly used to take pictures of human bone structures for medical reasons. The images created by x-rays show different features of the body in various shades of grey according to their absorption. X-radiation has the ability to pass through all forms of matter to a certain degree. The amount of x-radiation absorbed is determined by the wavelength of x-ray and the material. The main aim of this project was to adapt the NX2 Plasma Focus as the soft x-ray source of sufficient power far student projects in radiology of biological samples.

## Theory

NX2 Plasma *Focus.* Plasma consists of a collection of

electrons and ions and is formed when matter is brought to a highly ionized state. In the NX2, a powerful electrical discharge is used to produce the hot plasma. Special electrodes are used to focus the plasma into a filament (pinch) in front of the anode. The plasma focus is unique in the fact that it can produce x-rays from a wide range of solid and gaseous elements. In contrast, conventional x-ray tube can only have anodes made of conducting elements.

*X-ray ranges for biomaterials.* There is no clear definition of soft and hard x-ray ranges. An x-ray with low photon energy is considered as soft, and is more suitable for biological materials which are not dense and are very thin. To achieve a significant contrast in microscopy of biological samples it is necessary to use soft x-rays. However developments in this area have been curtailed due to a lack of suitable sources and imaging elements. Of interest for small biological samples is the 2.4 to 4.3 nm water window allowing the use of soft x-ray for the microscopy of living tissues which differentiates between carbon and water. Other common wavelength regions of interest differentiate between bone and soft tissue or artificially introduced substances and normal tissue.

For the purpose of this investigation, we will define the following x-ray ranges with its corresponding biomaterials:

| x-ray range | Biomaterials |
|---|---|
| extremely soft | Very small thickness e.g. cells, spores |
| very soft | Not dense and very thin e.g. plant tissue, soft tissue, insects |
| soft | Not dense with slight thickness e.g. small animals with bones |
| hard | Thick and dense e.g. medium sized animals, humans |
| very hard | Very thick and dense e.g. big animals, cows, elephants |

The plasma focus x-rays in this investigation would vary between the extremely soft to the soft range.

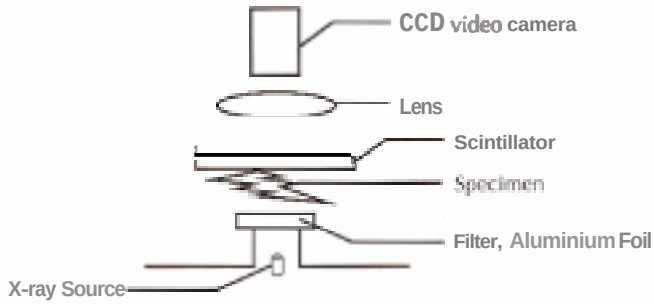
In order to obtain a clear image, the following factors have to be taken into consideration:

- Size of source. A point source would give a clearer radiograph compared to a bigger source.
- Distance between source and object. The further the source from the object, the clearer the radiograph.
- Distance between object and detector. The nearer the detector to the object the clearer the radiograph.
- Type of detector used. In this investigation the scintillator $CaWO_4$ was used with a video camera. The scintillator converts x-rays to visible light. The video camera has fairly low resolution and limits the quality of our pictures.

## Experimental Method

The plasma focus operated at 11kV with argon has significant emission close to 3-5keV. The size of the emitting areas viewed end is less than a millimetre and the intensity high enough so that an image could be obtained with a single discharge. Because the source is pulsed and operates at a relatively low voltage, it is extremely safe in terms of operator exposure to radiation.

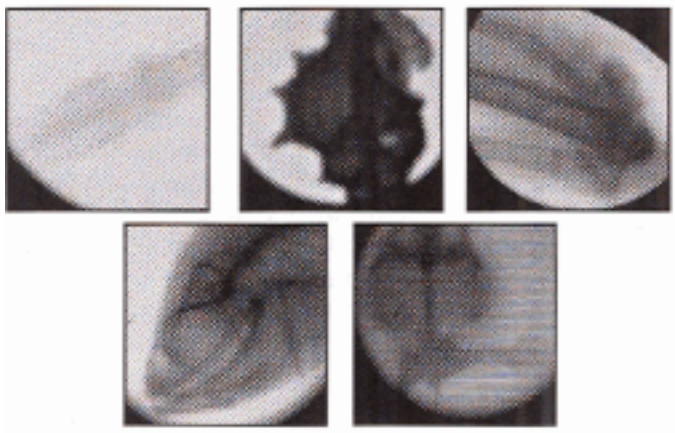
Set-up for capturing images of biological specimens :




## Materials

Different types of biological materials were obtained for the purpose of this investigation based on different thickness, density and substance compositions. These include grasshopper, sea shell, chicken wing, fish and terrapin

## Results and Discussion



Radiographs of a grasshopper, seashell, chicken wing, fish and terrapin

The radiograph of the grasshopper captured was not clear, The internals of the grasshopper cannot be differentiated by contrast in the radiograph. This is because the x-ray emitted by the NX2 plasma focus is too hard for this specimen. The seashell and terrapin gives a very dark picture in the radiograph. The substance which makes up the shell, mainly calcium carbonate, absorbs most of the x-ray emitted by plasma focus. The x-ray is too soft for this specimen. The radiographs of the chicken wing, fish are relatively clear. The x-ray emitted gives a clear contrast in the radiograph between the various parts of the organism. The thin hollow bone of the chicken which is mainly made of calcium phosphate absorbs most of the x-ray, while the surrounding tissues tend to transmit the most of the x-ray emitted resulting in a clear contrast in the radiograph.

## Conclusion

We have analysed biological samples that would give a clear contrast in the radiographs from NX2 source. The results show that the method is relatively efficient for suitable biological specimens and is non-destructive. Since the NX2 plasma focus x-ray is a multiple source x-ray, the range of the x-rays emitted can be varied by introducing appropriate

elements into the plasma focus chamber for a wide variety of biological samples with different range of softness with respect to x-ray transmission. As the NX2 plasma focus is a pulsed x-ray source, x-rays of moving biological specimens can be captured. Future investigations can be made in these potential areas of applications.

**Team Members:**

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