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THE LIXISCOPE: A POCKET-SIZE X-RAY IMAGING SYSTEM

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16. Abstract
A Low Intensity X-ray Imaging device with the acronym LIXISCOPE is described. The Lixiscope has a small format and is powered only by a 2.7V battery. The high inherent gain of the Lixiscope permits the use of radioactive sources in lieu of x-ray machines in some fluoroscopic applications. In this mode of operation the complete x-ray imaging system is truly portable and pocket-sized.

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THE LIXISCOPE: A POCKET-SIZE X-RAY IMAGING SYSTEM

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Instrumentation Note

Short Title: Lixiscope

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ILLUSTRATIONS

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1. Introduction

This note describes a low intensity x-ray imaging device with the acronym Lixiscope. This device was originally conceived for use in x-ray astronomy where single-photon imaging is required; however, the extension of its capabilities to medical and dental radiography soon became evident. The high sensitivity and large gain of the Lixiscope makes it possible to reduce the patient dose by $\sim 10^3$ in certain diagnostic procedures as compared to conventional practice. Such extensive dose reduction not only allows safe fluoroscopic examinations, but also enables the use of radioactive sources in lieu of x-ray machines. Furthermore, because the Lixiscope produces a visible-light output image, it can be easily recorded on fast instant-processing films or used in conjunction with any other image recording and processing devices. As will be shown, the small format of the Lixiscope in conjunction with a minute radioactive source provides a truly portable, nearly pocket-size fluoroscopic system.

2. The Lixiscope

The prototype Lixiscope is extremely simple in concept (Fig. 1). Each x-ray photon is converted into a large number of visible-light photons by means of a phosphor screen, in this case, Lanex. The phosphor screen, shielded by an opaque material, is in contact with the input fiber-optics face plate of a second generation night-vision (visible-light) image intensifier. (The image intensifier was generously loaned to us by the Night Vision Laboratory, Fort Belvoir, Va., and the Lanex screen was given to us by the

Eastman Kodak Research Laboratory, Rochester, N.Y.). In this manner, both the high conversion efficiency of the Lanex screen and the high visible-light gain ($\sim 4 \times 10^4$) of the rugged night-vision intensifier are fully utilized without either loss of x-ray quantum efficiency through a window or introducing contaminants and fragility into the intensifier.

The night-vision intensifier used here consists of an input fiber-optics face plae with <5 μm diameter fibers. On the back face (vacuum side) of the input fiber-optics plate is a S-25 photocathode. The initial x-ray image is thus converted first into a visible-light image by the Lanex screen and then to an electron image by the photocathode with little loss of resolution. Furthermore, in these conversions each absorbed x-ray produces a large number of photoelectrons. Thus the probability of information loss is neglible after the initial absorption.

The photoelectrons are multiplied by a microchannel plate (MCP) electron multiplier operated in the unsaturated mode with an average gain of roughly 10^3. The microchannels are 12 μm in diameter, have a length-to diameter ratio of 40, and a center-to-center distance of 14.5 μm. The output electrons of the MCP are accelerated by ~ 5 kV across a 1.3 mm gap to impinge on an aluminized P-39 phosphor screen deposited on the output fiber-optics face plate. The aluminized phosphor prevents visible light feedback to the photocathode.

Both the input and output fiber-optics face plate also serve as vacuum seals ($\sim 10^{-9}$ torr). The output plate brings the final intensified image to a plane flush with the viewing surface of the intensifier thus making it easy to couple with any form of image recording device. The intensifier provides a 1 : 1 intensified image with an inherent resolution of about 30 lp/mm.

The night-vision intensifier shown in Fig. 2 has also an electrostatic inversion lens between the photocathode and the input of the MCP. The purpose of the lens is to produce an upright image when the intensifier is used with night viewing optics. It is not necessary in the present application. The elimination of the inversion lens will result in a wafer tube device that is much more compact with a thickness of only ~1.5 cm, and an improved inherent resoltuion.

The entire intensifier is powered by a single 2.7 V battery and has a light gain of $4x10^4$. Electronic circuitry which supplies voltages to the various stages of the intensifier as well as protects the phosphor screen and photocathode from accidental overexposure is encased in silicon rubber around the external cylindrical wall of the intensifier.

Previously (Gould et al. 1976, 1977), the MCP itself has been used directly to convert x-rays into photoelectrons. Unfortunately, in this energy region, the quantum efficiency of such direct conversion is low (~ 10%); and, in addition, the incident x-ray beam must be attenuated further (perhaps around 30%) by an entrance window to the vacuum tube. Because such a large information loss (>90%) cannot be retrieved at later stages, increased patient dose becomes necessary to maintain image quality.

Another design (Woodhead and Eschard 1971) intorduces the x-ray phosphor inside the vacuum tube. In this case a fragile window is still necessary. In contrast, the Lixiscope has no x-ray window and combines the high efficiency of the x-ray phosphor screen with the high gain and ruggedness of the night-vision intensifier.

The radioactive source shown in Fig. 2 is a 20 mCi I^{125} source manufactured by Amersham/Searle Corp. in their standard point-source configuration. Henrikson (1967) has shown that of suitable radioisotopes the energy of I^{125} x-rays (27 keV) are most suitable for dental applications.

3. Preliminary Results

The results shown in Fig. 3 were obtained to demonstrate the feasibility of the Lixiscope concept without any attempt at the present time to optimize either the experimental conditions or the components of the Lixiscope itself. Dental radiographs were taken because in this area immediate application of the Lixiscope seems most promising. All three photographs in Fig. 3 were obtained from the same dental phantom (see Fig. 2).

Photographs 3A and 3B were taken at the Bureau of Radiological Health, Rockville, MD using a calibrated x-ray generator operated at 60 kVp. The dental phantom was placed 200 cm from the x-ray source, and dosimeter readings were made at the phantom position. Fig. 3A shows a 12 sec exposure on Kodak Ultraspeed DF-57 dental film with the x-ray tube operating at 10mA. The measured radiation exposure was 162 mR which is within the recommended exposure range. Next, the phantom was examined by the Lixiscope with the x-ray tube operating at 60 kVp and 0.65 mA. Using an available Polaroid oscilloscope camera which has an image reduction ratio of 0.7 and an object-to-lens distance of 19 cm, a good quality photograph of the Lixiscope image was obtained at f/4.5 and 0.1 sec on ASA 3000 (Type 107) film. The measured radiation exposure in this case was 0.1 mR, giving a reduction factor of $> 10^3$. Unfortunately, the positive image and its reduced size makes comparison with the dental negative difficult. Therefore we recorded the Lixiscope image on 35 mm Tri-X (ASA 400) film as shown in Fig. 3B.

Fig. 3C shows the Tri-X film recording of the Lixiscope image using the 20 mCi I^{125} source in the configuration of Fig. 2 a a source-to-teeth distance of 3 cm. A comparable Polaroid photograph using I^{125} source was obtained at 0.2 sec with a measured radiation exposure of about 0.3 mR. However, because of the nearly monoenergetic (27 keV) spectrum of the I^{125} source, the image in Fig. 3C shows better contrast than that of Fig. 3B.

From Figs. 3B and 3C it is obvious that the resolution of the Lixiscope is inferior to that of the dental film. The measured resolution of this prototype Lixiscope using either the x-ray machine or the I^{125} source is about 4 lp/mm. Since the inherent resolution of the night-vision intensifier is about 30 lp/mm the resolution of this prototype Lixiscope is essentially limited by the Lanex phosphor screen.

The measured output luminance of the Lixiscope using the 20 mCi I^{125} source at 4.4 cm from the Lanex screen is 1.75 fL. The background without the radioactive source is 3.6×10^{-4} fL.

4. Discussion

These preliminary results demonstrate the feasibility of a low-dose, compact, rugged and fully portable x-ray image intensifier system which is suitable for both laboratory and field use. The entire system is fabricated solely from available components. It is important to note that in this prototype system, no effort has been made to optimize the performance characteristics such as signal-to-noise, gain, spectral sensitivity and efficiency, MTF, contrast and spatial resolution. These problems are presently being investigated in our laboratory.

The potential applications of the Lixiscope in radiography and fluoroscopy are most promising in areas where small format and portability are desirable. Restricting our attention to the dental example, for instance, the Lixiscope in combination with an intraoral, collimated radioactive source equipped with an on/off shutter will not only eliminate all unnecessary exposures to other sensitive organs which are unintentionally irradiated by conventional extraoral x-ray machines, but also provides a low-dose rate means of in-situ instantaneous observation of surgical progress in root canal and other operations where high resolution is not required. Furthermore, and perhaps more importantly, the Lixiscope in combination with radioactive sources will make fluoroscopy and radiography available in regions where electricity is not generally accessible.

5. Acknowledgements

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Woodhead, A.W., and Eschard, G., 1971, Acta Electronica 14, 181.

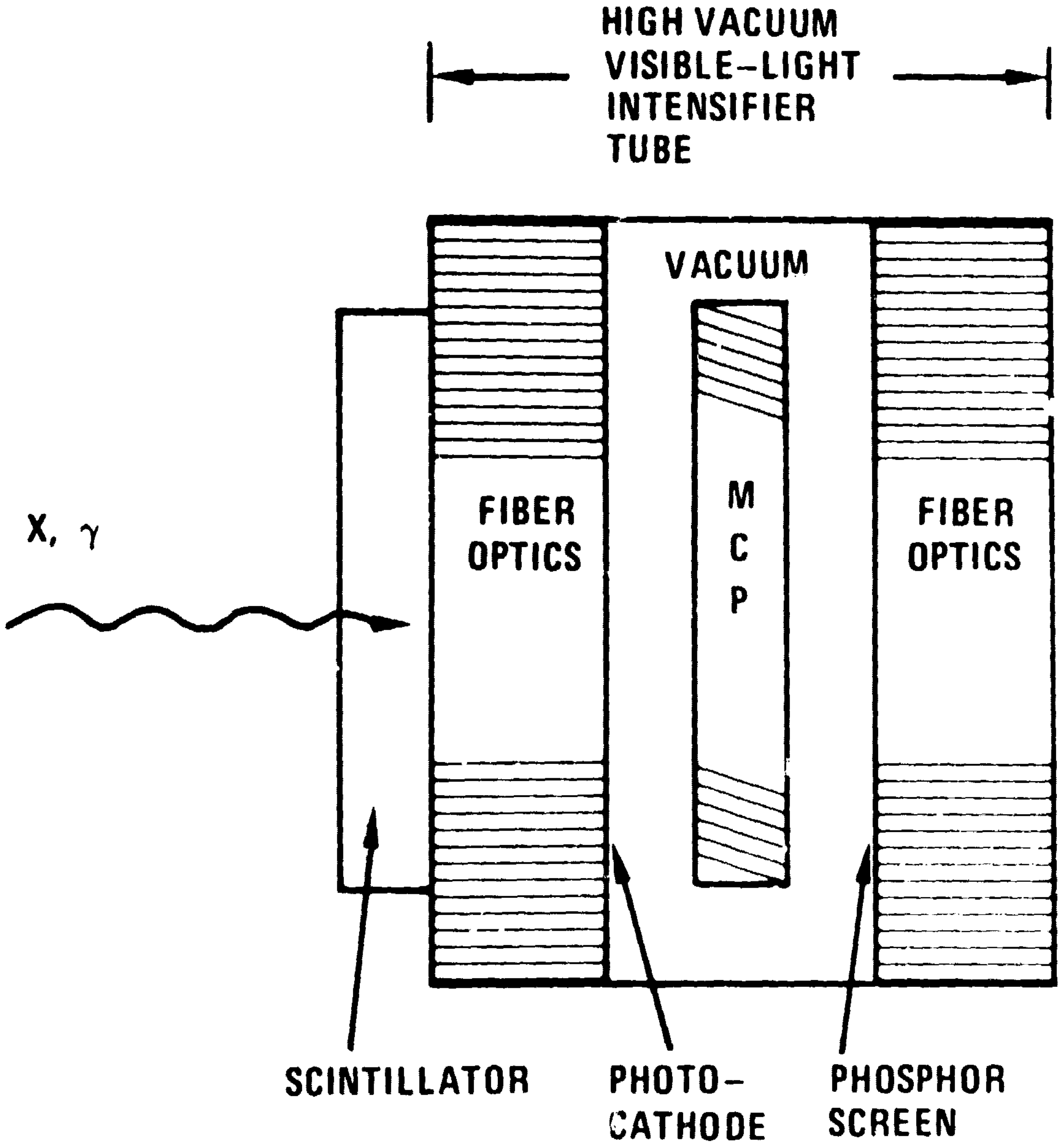

Figure 1. Schematic showing the major components of the Lixiscope.

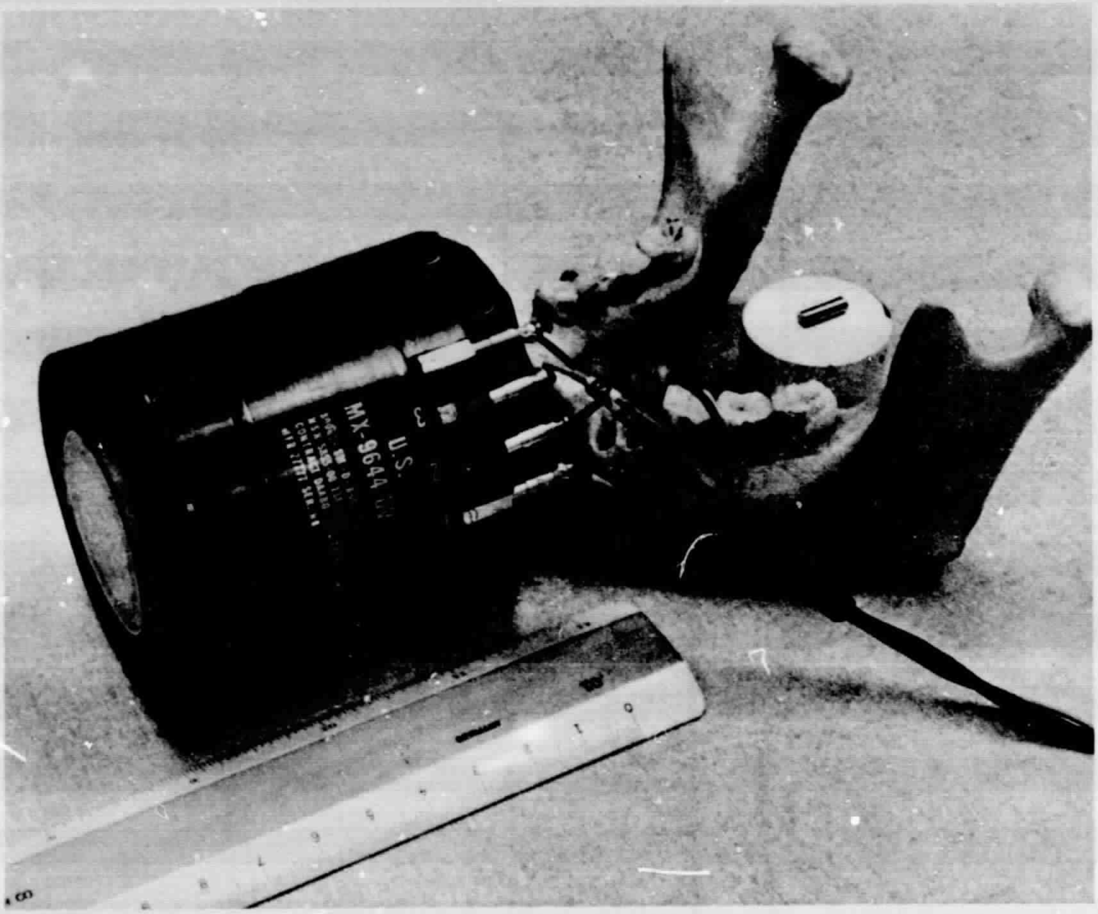

Figure 2. Prototype Lixiscope with an I^{125} radioactive point source and dental phantom.

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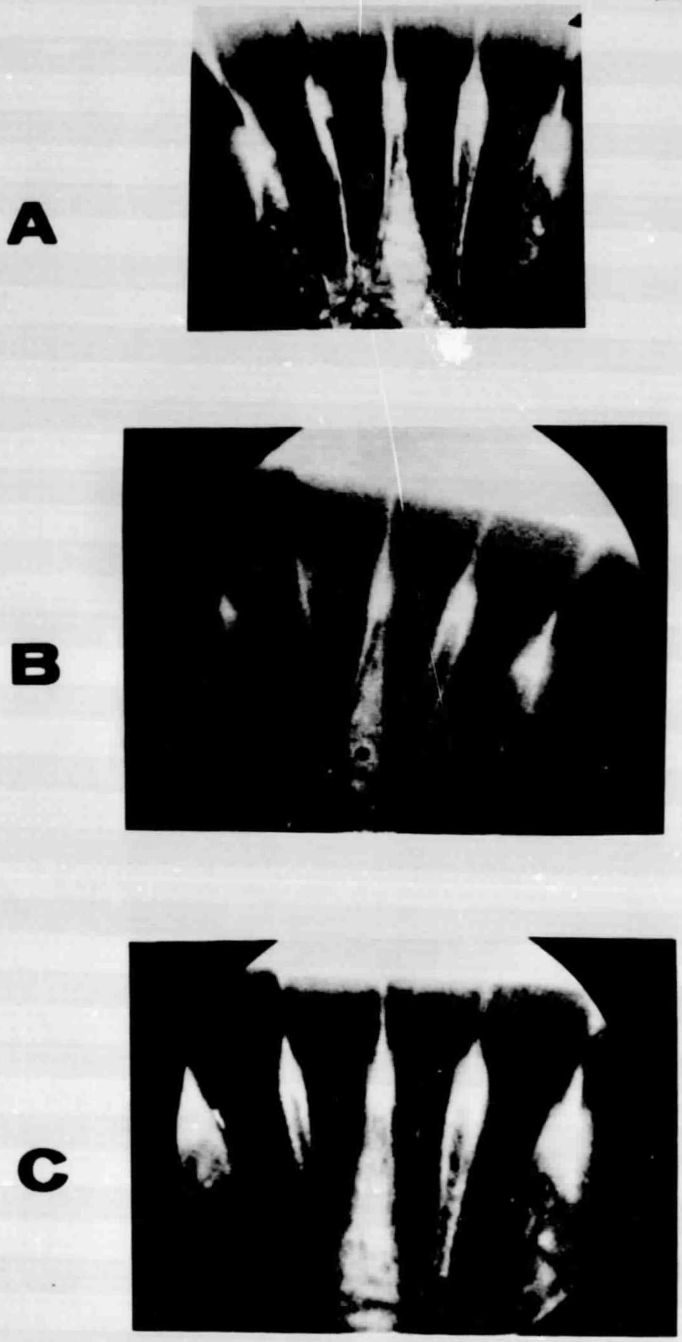

Figure 3. (A) Image of dental phantom from Kodak Ultraspeed DF-57 dental film with x-ray tube operating at 60 kVp and 10 mA. (B) Image of dental phantom from Lixiscope with x-ray tube operating at 60 kVp and 0.5 mA. (C) Image of dental phantom from Lixiscope using 20 mCi I^{125} point source at 3 cm.