Conf-751130--37

UCRL - 77074

PREPRINT

LAWRENCE LIVERMORE LABORATORY

University of California/Livermore, California

AN ACTIVE READOUT KAP X-RAY SPECTROMETER

L. N. Koppel, L. M. Richards, and D. E. Campbell

October 6, 1975

MASTER

This Paper was Prepared for Submission to
the APS Meeting, St. Petersburg, Florida,
November 10-14, 1975

OT W-7405-ENG-48

DIST...

AN ACTIVE READOUT KAP X-RAY SPECTROMETER

L. N. Koppel, L. M. Richards, D. E. Campbell

To Be Presented At: APS Plasma Physics Meeting
November, 1975
St. Petersburg, Florida

ABSTRACT

We have found that a new type of solid-state detector known as the self-scanning photodiode array can be used to obtain the active readout of data in wavelength-dispersive x-ray spectrometers. We will report on the use of this device to recover x-ray spectral data for glass microspheres heated by Lawrence Livermore Laboratory's CYCLOPS laser.

The self-scanning photodiode array is a product of the MOS electronics fabrication technology. It consists of an array of semi-discrete diffused junction photodiodes deployed along a line on a silicon chip. The signals generated in the array of diodes are serially-scanned and multiplexed by a scanning circuit built on the chip. We have previously reported on the sensitivity and other aspects of the response of the photodiode arrays to low-energy x-rays.

We have used the photodiode array in conjunction with a flat KAP single-crystal in a series of spectrometry experiments. Of particular interest has been the analysis of the hydrogen-like and helium-like 1s-2p radiations of silicon in the neighborhood of 2 Kev.

Work performed under the auspices of the U.S. Energy Research & Development Administration under contract No. W-7405-Eng-48.

AN ACTIVE READOUT KAP X-RAY SPECTROMETER

This presentation will be given in a poster session. We plan to prepare a poster of text and illustrations for each of the major topics outlined below.

I. The Role of Single Crystal X-Ray Spectrometers in Laser-Fusion Diagnostics

A. X-ray spectrometers can measure the electron density and temperature of laser-fusion plasmas.

B. These instruments measure the line profiles and relative intensities of the prinicpal and satellite characteristic radiation of high temperature target materials.

II. The Response Characteristics of a Flat Crystal Spectrometer

A. This instrument has high sensitivity over a limited range of photon energies.

B. The range of the KAP spectrometer is chosen to include the H and He-like radiation of silicon.

C. In this range the resolving power is usually limited by the extended source size rather than by the crystal diffraction profile width or instrument dispersion function.

D. Advantages that accrue through the use of a spatially-resolving active detector are:

1. An improvement in the accuracy of the intensity measurement,
2. A consistent transformation from film position to photon energy,
3. A more expedient recovery of data.

III. [illegible] Array in a Flat [illegible]

A. [illegible] detector is a linear array of [illegible]. The outputs of the [illegible] are [illegible] by a scanning circuit in the detector.

B. The detector shows appreciable sensitivity to x-rays with energies in [illegible].

C. The detector response is a linear function of x-ray dose.

D. The resolving power of the [illegible] instrument will be limited by the diffusion of photoelectrons and signal dispersion in the bulk of the detector.

E. The [illegible] is amenable to recovery of data by a microprocessor-controlled digital system. We have implemented such a system.

F. The active [illegible] spectrometer and digital system have recorded spectra for irradiated [illegible] filled glass microspheres.

APS Poster I

At the Lawrence Livermore Laboratory glass microspheres containing fusible fuel mixtures of gaseous deuterium and tritium are imploded by pulses of light from high-brightness solid state lasers. Two important parameters of the target plasmas are the temperature and density of electrons at the instant of maximum compression. A significant fraction of the energy radiated by the laser-induced plasmas can appear as the characteristic x-rays of the highly-ionized target materials and gases or tracer elements loaded with the D-T fuel. It has been proposed that electron temperatures can be deduced by measuring the intensities of resonance and two-electron satellite lines of target elements such as silicon, and that electron densities can be obtained by observing the Stark-broadened line profiles of tracer elements such as argon. We will describe [illegible] [illegible] x-ray spectrometer that can be used to obtain these data.

[illegible] II

[illegible] high-resolution spectra can be obtained by Bragg [illegible] crystal. An analyzer crystal will reflect with high [illegible] only a narrow band of photon energies whose location in the spectrum is determined by the angle of incidence of the X-ray beam on a principal crystal plane. In our instrument a long flat crystal of KAP is located 12.7 cm from the laser-fusion [illegible] plane of the crystal [illegible] interplanar spacing of 1.332nm. The crystal is inclined at a 14° angle with respect to the line-[illegible] to the target, and the divergence of radiation from the target causes X-rays with energies between 1.50 keV and 2.30 keV to be analyzed at a "film plane" behind the crystal. This range of energies includes the principal characteristic lines of [illegible] silicon. Since the angle subtended by the radiating [illegible] is [illegible] than the diffraction profile width of KAP at these energies, and the magnification of the instrument is greater than one, the energy resolution is limited by the extended source size to 3.7 eV at 2 keV.

[illegible] photographic film is the medium on which spectrograms are recorded. Instead, we have chosen to use a spatially-resolving solid-state detector known as [illegible] array. Using a solid-state detector in this application [illegible] the following advantages:

1. [illegible] intensity measurement is improved. Film is not a very [illegible] detector, since a wide margin of error must be allowed to account for variations in the manufacture and developing of the film.

2. The correlation between location in the "film plane" and photon energy is consistent from shot to shot. The detector need not be removed from the instrument to recover data.

3. The recovery of data is more expedient. The signals from the detector are available instantly, without the processing and analysis required by film.

The signal format of the self-scanning photodiode array is amenable to recovery of data by a microprocessor-controlled digital system. We have implemented a system in which an Intel 8080 microprocessor acquires and prepares for distribution the data from the spectrometer. The chores performed by the microprocessor include:

1. The digitization of the photodiode signal levels.

2. The subtraction of dark current levels from the signal levels.

3. The distribution of the data to an X-Y plotter, a CRT display monitor, a page printer, and a paper tape punch.

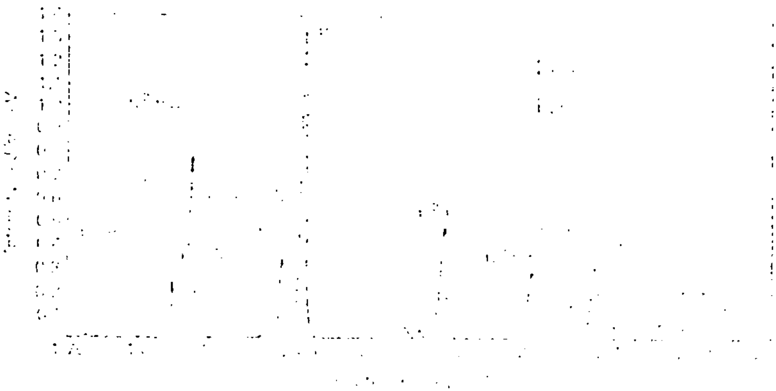
(The work described in the next paragraph has not been performed at this time.)

The active readout KAP spectrometer has been used to recover spectra for D-T filled glass microsphere targets irradiated by the Lawrence Livermore Laboratory's CYCLOPS laser. The CYCLOPS is a Nd/Yag laser that typically places 50 Joules of 1.06 micron light on target, in pulses of less than 100 picoseconds duration. We have found the data taken with the active readout spectrometer to be of a quality comparable to those recovered with photographic film.

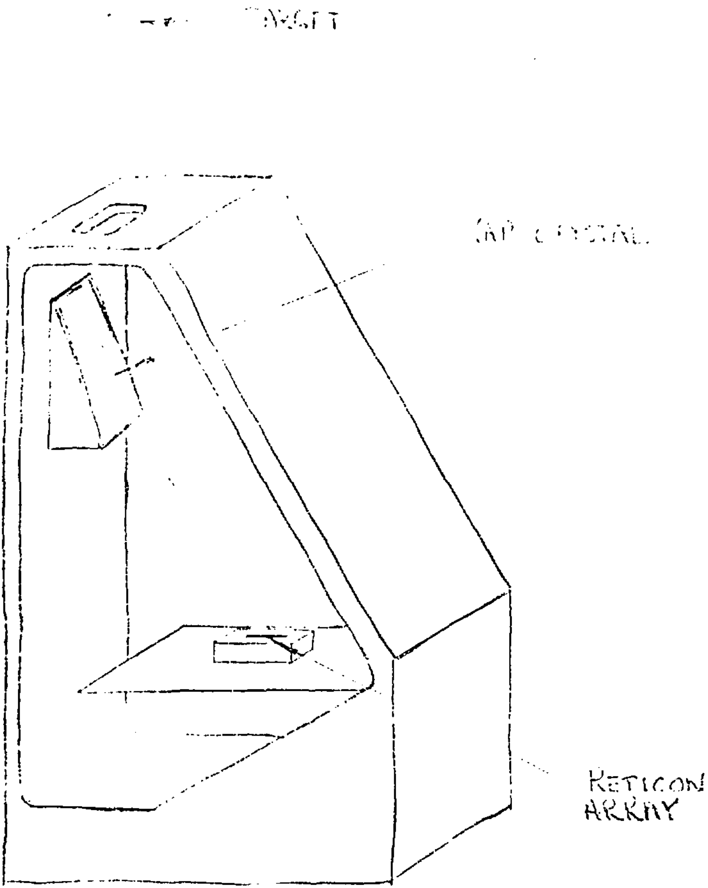
The sensitive portion of the self-scanning photodiode array is a linear ensemble of diffused P^+N junction photodiodes, built upon a common silicon substrate. There are 512 photodiodes in the array, each having a width of 25.4 microns in the plane of dispersion. A logic network of transistors built up on the detector board and multiplexes the signals from the photodiodes. The spectral response of the detector is controlled by the manner in which the X-rays' energies are deposited in the silicon at or near the photodiode junctions. Calculations and experimental measurements have shown that the detector has appreciable sensitivity to X-rays with energies in the range from 1.5 keV to above 10 keV. We have found that the detector's response is a linear function of X-ray dose.

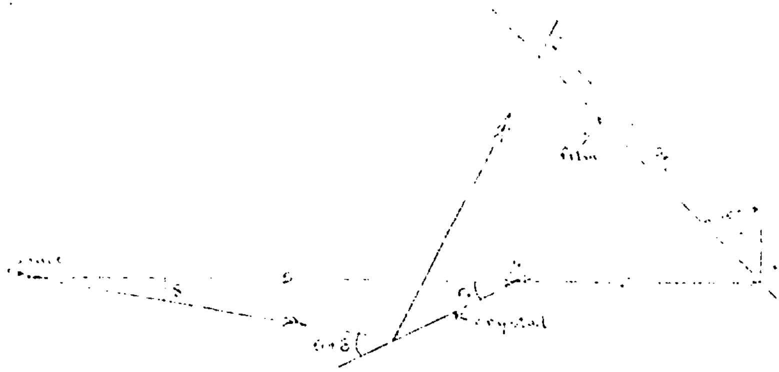
A fraction of the spatial resolving power of the detector is lost when it is used to sense penetrating radiation. Some of the photocharge generated in the bulk of the silicon below the photodiode junctions can diffuse laterally and be sensed by photodiodes adjacent to the element to which the signal would otherwise be attributed.

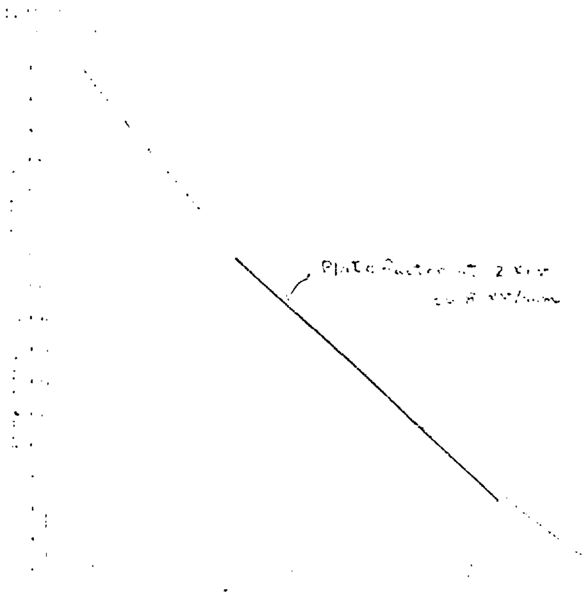
For 2 keV X-rays, about 7% of the signal is smeared in this manner. This effect and the width of the photodiodes imply an energy resolution of about one eV in the "film plane". Hence, in the present instrument the energy resolution is limited by the finite size of the target source rather than by the choice of sensing medium.



ENGINEERING NOTE




film
crystal



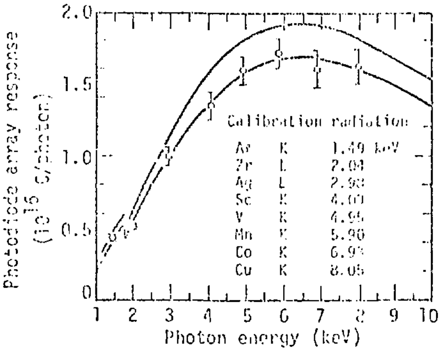


Fig. 3. Average spectral sensitivity of the Reticon array as a function of photon energy. The points are experimental results and the smooth curves are the original and corrected calculational results.

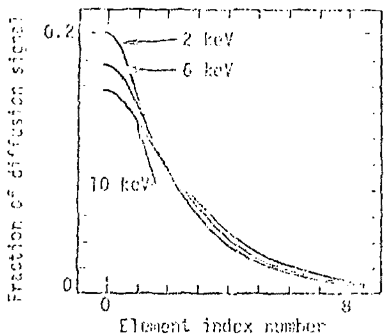
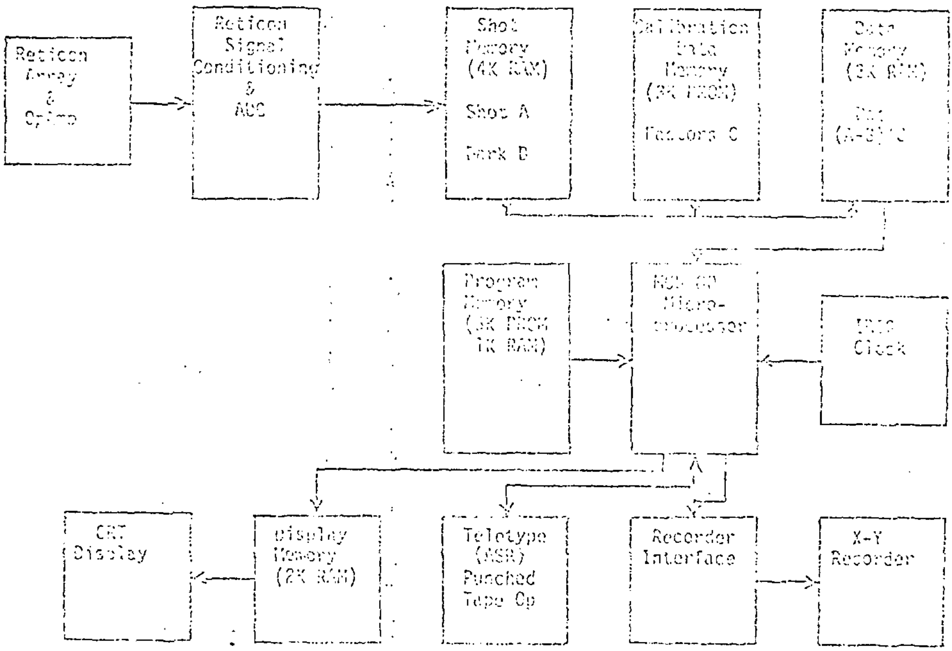


Fig. 4. Calculated dispersion of signal in the diffusion region.



Reticon
Signal
Conditioning
&
Shot
(4K RAM)
Shot A
Calibration
(A-B)
Factors C
Micro-
Clock
CRT
Display
Display
(2K RAM)
Teletype
(ASR)
Punched
Recorder
Interface
X-Y
Recorder