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AN ACTIVE READOUT KAP X-RAY SPECTROMETER

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MASTER

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AN ANALYSIS IN ADDITION TO X-RAY SPECTROMETER

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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.

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AN ACTIVE READOUT K_A 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 principal 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 FAP 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. The realization of a linear array of photodiodes using a flat SiO_2 substrate.

- A. The detector is a linear array of photodiodes connected in series. The outputs of the diodes are utilized by a readout circuit in the detector.
- B. The detector shows appreciable sensitivity to beams with energies in the range 0.1-10 MeV.
- C. The detector response is a linear function of beam dose.
- D. The resolution power of the detector instrument will be limited by the density of photodiodes and signal dispersion in the bulk of the detector.
- E. The signal level is amenable to recovery of data by a computer or microprocessor controlled digital system. We have implemented such a system.
- F. The active chip structure and digital system have been developed specifically for irradiated wet filled glass microspines.

APS Poster 1

At the Lawrence Livermore Laboratory glass microspheres containing fusible fuel mixtures of gaseous deuterium and tritium are imploded by pulses of light from non-brightened 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 as 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 an active resist x-ray spectrometer that can be used to obtain this data.

The lines in the spectrum exhibit a dispersion of energy, as obtained by Bragg diffraction from a single crystal. An analyzer crystal will reflect, with high efficiency, 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 NaF is located 12.7 cm from the laser-focus to the detector plane, a plane of an analyzer crystal 48 cm from the interplanar spacing of 1.774 nm. The crystal is inclined at a 14° angle with respect to the line-incident by the target, and the divergence of radiation from the target causes X-rays with energies between 1.88 keV and 2.36 keV to be analyzed on a "film plane" behind the crystal. This range of energies includes the principal characteristic lines of copper, nickel and cobalt emission. Since the angle subtended by the radiating target is 0.1°, the resolution of the diffraction is the width of NaF at these energies, and the resolution of the instrument is greater than 0.1%, the energy resolution is limited by the extended source size to 2.7 eV at 2 keV.

The detector and film is the medium on which measurements are recorded. In our design we have chosen to use a partially-resolving solid-state detector known as the "film" being just a thin layer. Using a solid-state detector in this application gives the following advantages:

1. The resolution of the intensity measurement is improved. Film is not a very sensitive detector, since a wide range 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 constant from spot to spot. 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 8020 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 outlined in the next paragraph has not been performed at this time.)

The active readout XAD spectrometer has been used to recover spectra for B-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-cleaning photodiode array is a linear array of n - p junction photodiodes, built upon a $\langle 100 \rangle$ silicon substrate. There are 512 photodiodes in the array, each having a width of 25.4 microns in the plane of deposition. A logic network of transistors built up on the detector wafer and multiplies 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 photoelectrons 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 "fill 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.

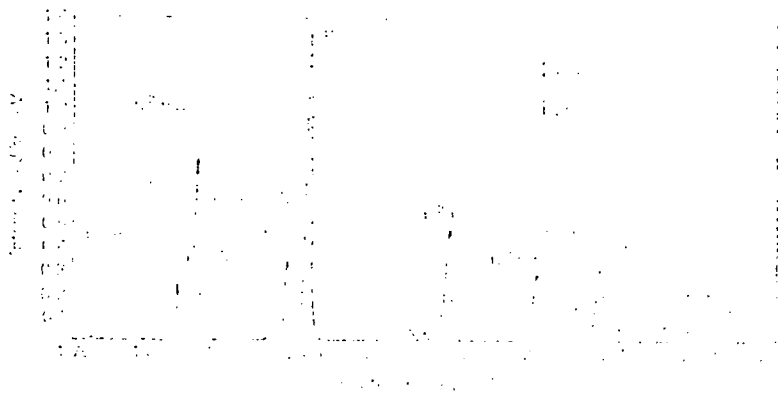
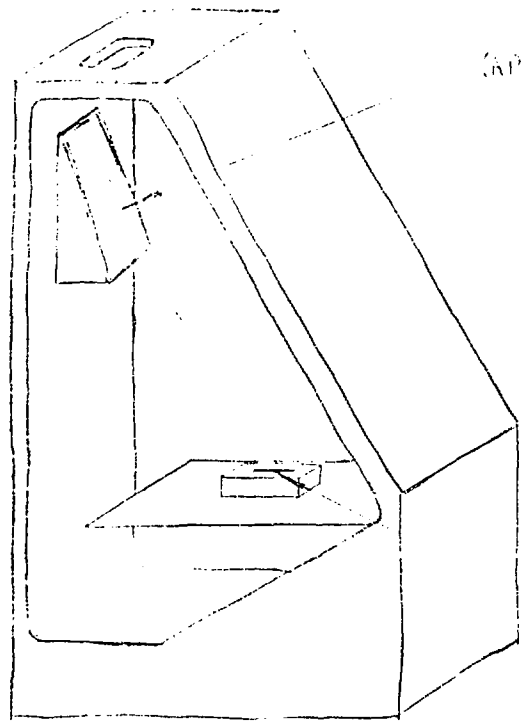


Fig. 2. Variation of the ratio of the maximum to the minimum value of the function $f(x)$ versus the parameter α .

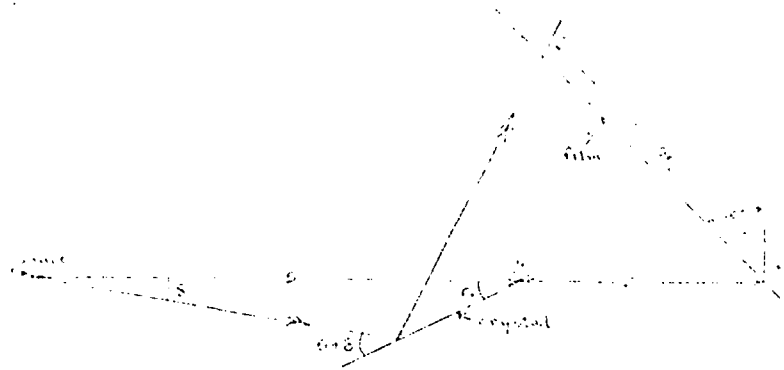
ENGINEERING NOTE

TARGET

AP CRYSTAL

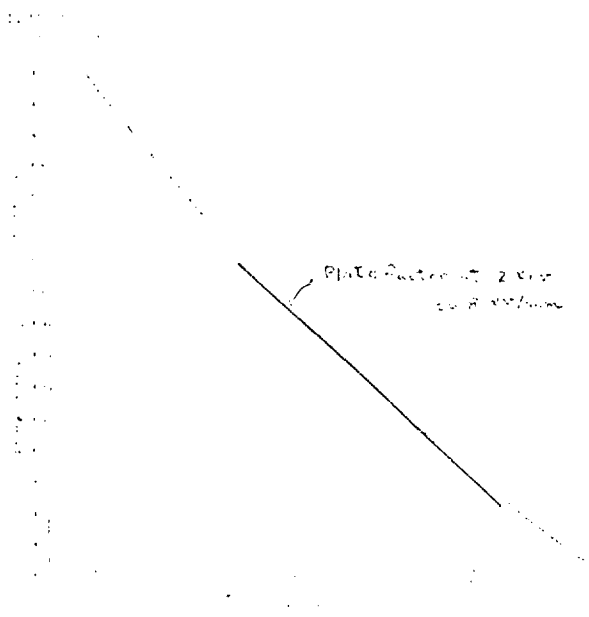


RETICON
ARRAY



$$d = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

a = lattice constant
 h, k, l = Miller indices



1. The first part of the document discusses the importance of maintaining accurate records of all transactions and activities. It emphasizes that proper record-keeping is essential for transparency and accountability, particularly in financial matters. The text notes that without clear documentation, it becomes difficult to track expenses and revenues, which can lead to misunderstandings and disputes.

2. The second section focuses on the role of communication in ensuring that all parties involved are kept informed and aligned. It suggests that regular updates and clear communication channels are crucial for the success of any project or organization. The author highlights that effective communication helps in identifying potential issues early on and allows for timely adjustments to be made.

3. The third part of the document addresses the need for flexibility and adaptability in the face of changing circumstances. It states that while having a plan is important, it is equally important to be able to pivot when necessary. The text provides examples of how organizations have successfully navigated unexpected challenges by remaining open to new ideas and solutions.

4. The final section discusses the importance of collaboration and teamwork. It argues that no single individual can achieve all the goals of an organization; instead, it is the collective effort of a diverse team that leads to innovation and growth. The author encourages fostering a culture of mutual respect and support, where team members feel empowered to contribute their unique skills and perspectives.

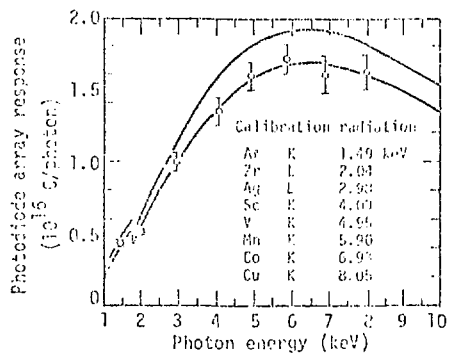


Fig. 3. Average spectral sensitivity of the Hecicon array as a function of photon energy. The points are experimental results and the smooth curves are the original and corrected calculational results.

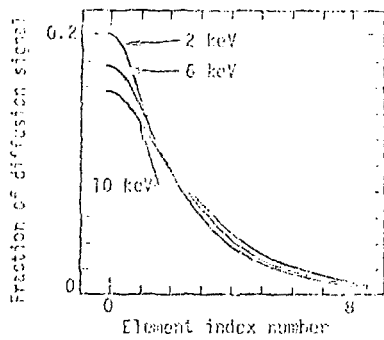


Fig. 4. Calculated dispersion of signal in the diffusion region.

