AN ACTIVE READOUT KAP X-RAY SPECTROMETER

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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 XAP 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.

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 Plasmas
   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 PAP spectrometer is chosen to include the $\text{II}$ and $\text{Re-Li}$ radiation of silicon.
   C. In this range the resolving power is usually limited by the extended crystal 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.
The detector response is a linear function of energy level.

The resolving power of the detector will be limited by the details of photonics and signal dispersion in the bulk of the detector.

The signal is amplified and converted to a staircase signal by a microprocessor-controlled digital system. We have in mind a high-speed system.

The entire system, from analog and digital systems, was produced by specialists for an initial set filled with fresh responses.
At the Lawrence Livermore Laboratory, glass microspheres containing fusible fuel mixtures of gaseous deuterium and tritium are irradiated by pulses of light from neodymium-glass solid state lasers. Important parameters of the target plasmas are the temperature and density of electrons at the instant of current compression. A significant fraction of the energy radiated by the laser-induced plasmas can appear as the characteristic x-rays of the high-ionized target materials and as neutral or ionized species issued from the D-T fuel. It has been proposed that electron temperatures can be deduced by measuring the intensities of resonance and the electron satellite lines of target elements such as silicon, and that electron densities can be obtained by observing the neutrino-induced line features of tracer elements such as argon. We will describe an interrelated x-ray spectrograph that can be used to obtain these data.
A diffractometer is then used to measure the energy characteristic lines of the sample. The diffractometer is composed of a radiation source, a sample target, and a detector. The radiation source emits X-rays, which are diffracted by the sample target. The diffracted X-rays are detected by the detector, which records the energy and intensity of the X-rays. The data collected by the detector is then analyzed to determine the crystal structure of the sample.
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 8086 microprocessor acquires and prepares for distribution the data to 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 data described in the next paragraph has not been performed at this time.)

An active readout N3L spectrometer has been used to recover spectra for 97 filled glass microsphere targets irradiated by the Lawrence Livermore Laboratory's CYCLONE laser. The CYCLONE is a Nd/Yag laser that typically places 50 joules of 1.06 micron light on target, in pulses of less than 100 nanoseconds 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 silicon microphotoelectric array is a linear array of diode p-n junction photodiodes, built upon the surface of a silicon substrate. There are 512 photodiodes in the array, each having a width of 25.4 microns in the plane of detection. A row of nine or transistors built up on the detector sense and differentiate 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 view penetrating radiation. Some of the photons generated in the bulk of the silicon below the photodiode junctions can diffuse laterally and be sensed by silicon 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 keV in the "filter 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. 5. 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 diffraction region.