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TITLE: USE OF A CADMIUM TELLURIDE DETECTOR IN A NEW TINY PERSONAL RADIATION CHIRPER

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USE OF A CADIUM TELLURIDE DETECTOR
IN A NEW TINY PERSONAL RADIATION CHIRPER

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ABSTRACT

By use of a CdTe crystal coupled to newly designed, low power electronics, we have developed a new personal radiation chirper that is superior to existing instruments. The device emits audible chirps or beeps at a rate proportional to the photon radiation exposure to the wearer. The device is small (6.2 cm high by 3.2 cm wide by 1.7 cm thick) and of low mass (50 grams) and is made to be clipped to the shirt collar of the wearer. The instrument has long continuous-use battery life and is sensitive over a large photon energy and exposure rate span.

I. INTRODUCTION

When working in facilities that process or use large amounts of radioactive materials, it is a good safety practice to carry or have radiation survey instrumentation while in the work area. Due to the large size of such instruments, smaller, and more convenient, radiation warning devices, sometimes called "chirpers," were designed many years ago. These "chirpers" could fit easily into a man's palm or clip to a shirt pocket or waist belt. The instruments gave off an audible chirp or beep, with a chirp rate proportional to the photon exposure rate to the wearer. These instruments generally had as a radiation detector a gas filled Geiger-Muller (GM) tube. Appropriate electronics amplified the radiation signal from the detector and applied it to an integration circuit. After a given radiation exposure, as monitored by the integration network, a signal was applied to an audible device that warned the wearer that a given radiation exposure had been encountered. The chirp rate was usually calibrated in units of so many chirps per minute per milli Roentgen per hour (mR/hr). By the addition of a continuous integration circuit, the device could also provide the wearer with a digital (electronic or mechanical) readout of the total exposure to the individual since the instrument was switched on. Due to the nature of the detector, a high voltage circuit was required to power it with concomitant added circuit complexity, physical size, and battery requirements. Through the use of a CdTe detector, coupled to new electronics, we have reduced considerably the physical size and mass of such an instrument, while at the same time improving the performance.

II. BENEFITS OF CADMIUM TELLURIDE

CdTe is a semiconductor, room temperature, photon sensor that can be used directly with solid state circuitry. It requires much lower bias voltages (5.2 volts in this application) compared to traditional GM tubes biased at several hundred volts or more. This feature allows for a simplified electronics package (no high voltage step-up circuitry) that is also smaller and less power-hungry than circuits found in the usual GM tube device. Secondly, because of the high density of the CdTe crystal (5.2 g/cc), a very small crystal (8-20 mm^3) can provide sensitivities equal to much larger gas-filled GM tubes. This also reduces space requirements. One final added attraction of using CdTe in this application is that no energy resolution is required for the much simpler detection of only the presence of radiation. (Recall that GM tubes have no energy resolution either.) Therefore, the poorer crystals of the CdTe industry can be used effectively, thereby utilizing lower cost CdTe crystals and, eventually, providing lower chirper costs.

III. ELECTRONIC DESIGN AND PERFORMANCE

The electronic circuit is shown in Fig. 1 and is powered by four 1.35-volt mercury cells that provide over 2100 hr (~3 months) continuous use at normal background chirp rates. The CdTe detector is shown in the upper left-hand quadrant of the figure. Current drain is <0.2 mA when the chirper is not activated and <0.5 mA when it is. We are now substituting smaller lithium batteries for the mercury cells. This reduces the package size somewhat and improves the environmental temperature performance of the chirper, but at a sacrifice in battery life to about 6 weeks continuous use or 25 work weeks at eight hours use per work day. The sensitivity of the instrument [(chirps/min)/(mR/hr)] can easily be calibrated by specifying resistor R_s in the lower left-hand quadrant of Fig. 1. The energy discrimination threshold (which also determines sensitivity) can also be changed by varying resistor R_t in the upper right-hand quadrant of Fig. 1.

IV. PHYSICAL CHARACTERISTICS AND HYBRID CIRCUIT

Our latest chirper prototype is shown in Fig. 2. Also shown in Fig. 2 is the hybrid circuit used in the instrument. A coin and an inch/cm rule give the relative size of the prototype and the hybrid circuit. The prototype has dimensions of 6.2 cm high by 3.2 cm wide by 1.7 cm thick at the audio transducer location. The hybrid circuit has the two calibration resistors, R_s and R_t, strapped to the circuit board for ease of calibration change. The chirper has a mass of less than 50 grams.

V. RADIATION DETECTION PERFORMANCE

We have measured the performance of the chirper as a function of exposure rate as well as photon energy. The chirp rate vs exposure rate can be made as linear as desired by lowering the sensitivity of the instrument; i.e. lowering the number of chirps given off for each mR/hr. Because we shut off the amplifier during each chirp, to avoid the tendancy of microphonic feedback to the CdTe detector, we have a measurable saturation at rates dependent on the sensitivity. For a pure audio warning device, however, we do not feel this is a problem. The chirper has been tested to 1700 R/hr rates without failure. At this level, only a continuous tone is heard.

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Figure 3 shows the chirper response as a function of photon energy. For low photon energies below 100 keV, the 300-kV x-ray machine in the H-1 Dosimetry Section at LASL was used with appropriate aluminum filters and elemental radiators. The radiators and their respective K x-ray energies were: Ba, 33 keV; Gd, 44 keV; Yb, 54 keV; Ir, 67 keV; Pb, 77 keV; and Th, 96 keV. The high point at lead (77keV) on Fig. 3 repeated each time, so we feel it is real. The absolute exposure rate at each x-ray energy was measured with a free air ionization chamber. Above 80 keV the sensitivity response is flat out to at least ^{60}Co energies (average 1.25 MeV). The response at 0.662 keV (^{137}Cs) and 1.25 MeV was measured at the LASL Radiation Instrument Calibration Range. The data of Fig. 3 were acquired by feeding the electronic chirper pulses into a timer/scaler. Each data point is an average of three measurements.

For the data of Fig. 3, the CdTe crystal had dimensions of 10 mm in diameter by 2 mm thick. Our latest prototype has a crystal that is 2 mm cubed. (See Fig. 2) The data of Fig. 3 had the CdTe crystal covered by 0.5-mm thick Cu foil for electrostatic shielding. With this foil and our normal electronic discriminator setting, the sensitivity ratio between 44 keV and 96 keV (and above) was 0.075. Removing the foil improved this ratio slightly to 0.092. By lowering the discriminator somewhat, this ratio improved to 0.27. If low photon energies must be sensed, the chirper can be adjusted via the threshold control.

VI. ACKNOWLEDGEMENTS

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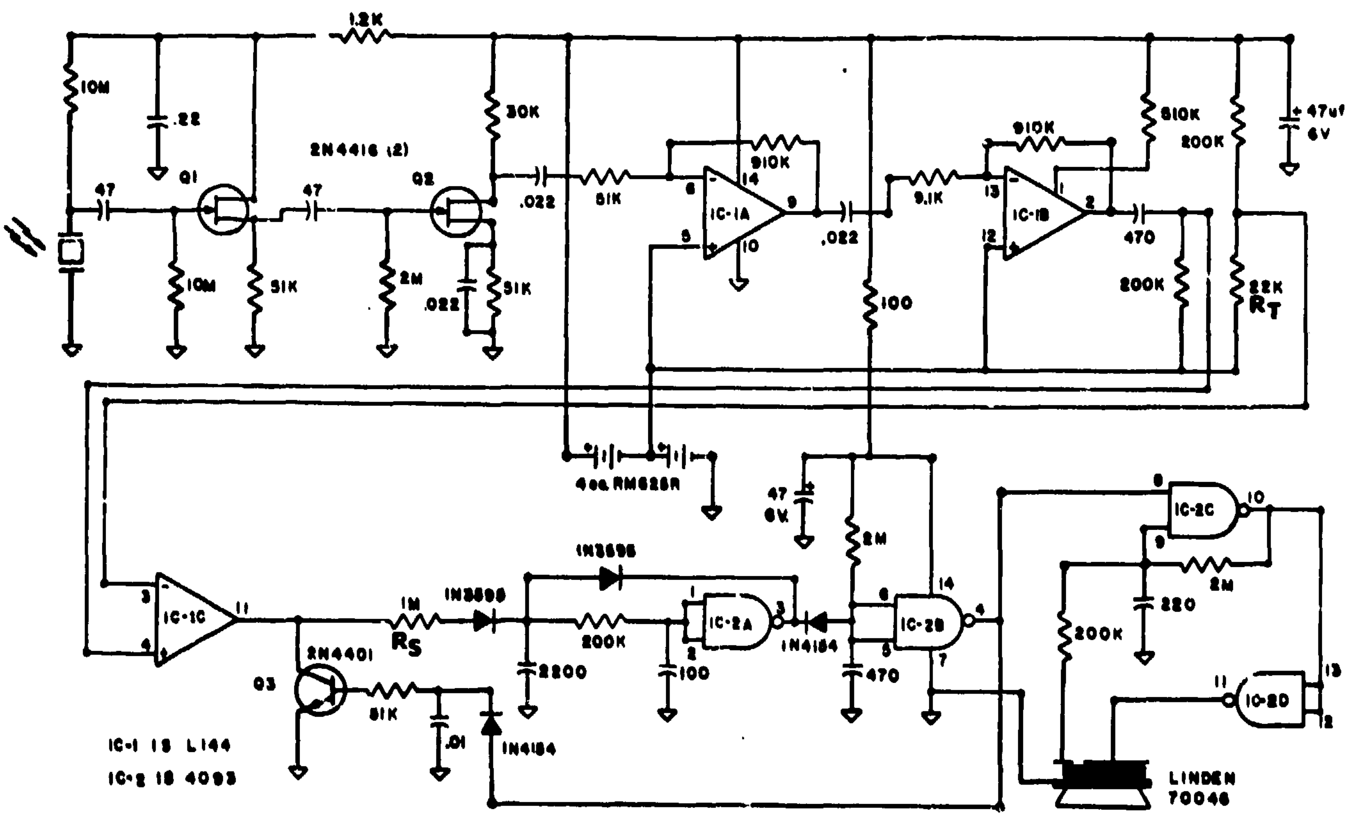

Fig. 1. Electronic diagram for the new personal chirper.

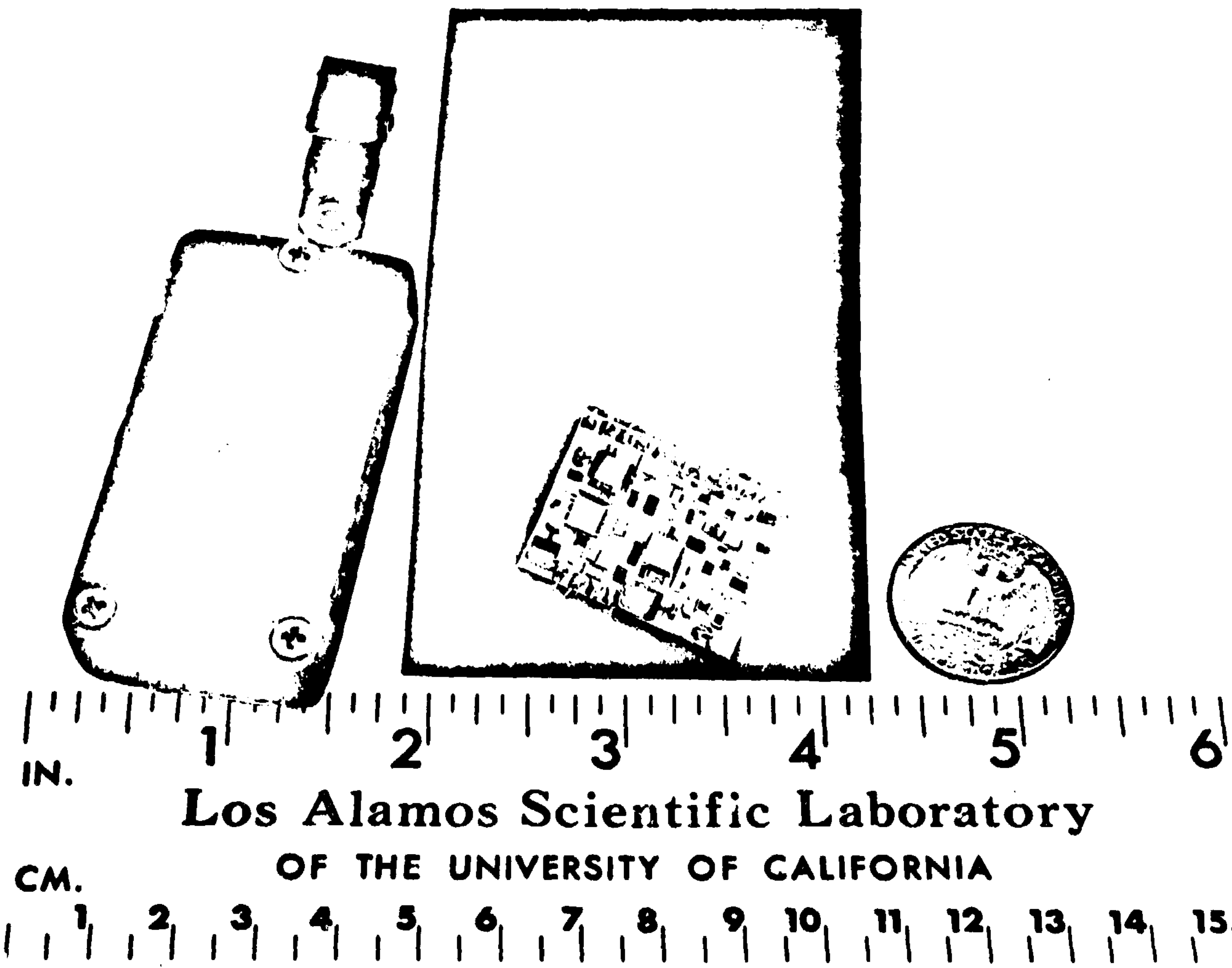

Fig. 2. Photograph of the tiny personal chirper next to its hybrid circuit, a coin, and an inch/centimeter rule for size comparison. The CdTe detector (2 mm cubed) is located on the bottom right-hand corner of the hybrid circuit.

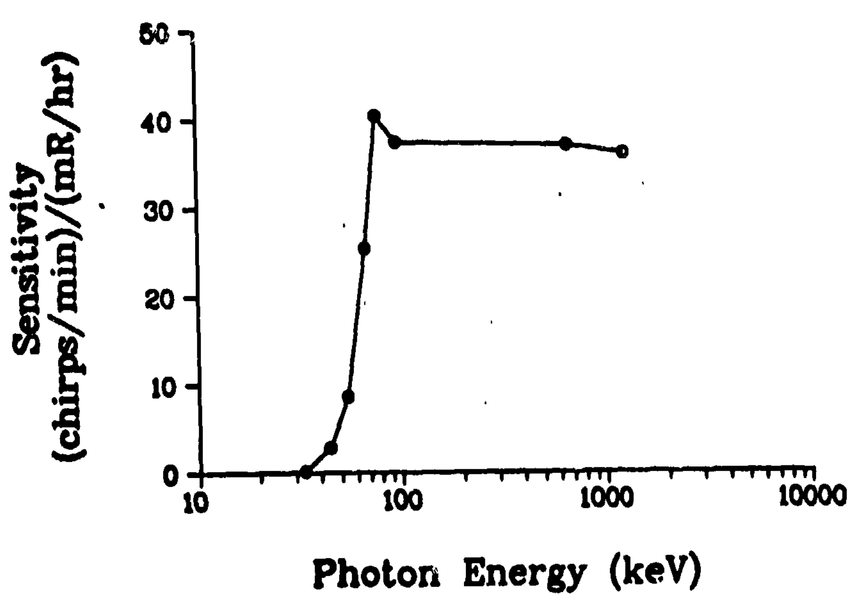

Fig. 3. Sensitivity data for the chirper as a function of photon energy. The CdTe crystal had a 0.05 mm thick Cu foil for electrostatic shielding. Results of removing this foil, as well as lowering the energy discrimination threshold, are described in the text. The essentially monoenergetic photon sources used in determining this data are also detailed in the text.