



PASSIVE GAMMA SCANNER TECHNOLOGY FROM MACRO INC.

INTRODUCTION:

Macro Inc. provides high performance gamma scan systems for nuclear fuel manufacturers, primarily for LWR, uranium and MOX systems. We have worked on both passive and active gamma scan systems.

Our customers include Westinghouse Nuclear Fuels Columbia SC Site, Shaw Areva MOX Services, British Nuclear Fuels and Korea Nuclear Fuels.

SCOPE OF SUPPLY:

We can consult on gamma scanning system design.

We can **modify existing gamma scan systems**: Replacing detectors and/or nuclear electronics for greater performance and flexibility, and much less maintenance.

We can provide **basic component gamma scan instruments**: Detectors and electronics are combined with Profibus (or similar) interface to provide a single profile of gamma data (Figure 1) collected and composited from all detectors, along the length of a fuel rod for subsequent analysis by customer systems. Any number of detectors can be used to meet any speed and accuracy requirement the customer might have. **Figure 2** shows such a component that controls 10 detectors, each with 2 PM tubes. This system is connected to a Process Control system via a single Profibus cable as shown.

We can provide **complete gamma scan inspection systems**, making accept/reject decisions on nuclear fuel rods. These can be integrated into existing manufacturing facilities: reading bar codes on fuel product, interfacing to material handling systems, getting fuel rod design and inspection criteria from plant databases based on fuel rod ID, reporting inspection results to plant control systems, and archiving inspection data to plant file servers.

We can also provide **through transmission** type systems using gamma and X-ray sources. We have applied for a patent on a system to inspect pellet surfaces for missing material, after being clad in fuel rods.

We can provide as little (basic gamma scanner) or as much (scanner, rod inspection analysis software, material handling) as you need.

TECHNICAL FEATURES:

SCANNING SPEED AND OSP DETECTION

For a passive gamma scanner, the speed at which fuel rods can be passed through the detector while maintaining a specified level of OSP detection is directly proportional to the number of detectors. Similarly, at the same speed, increasing the number of detectors allows more reliable detection of smaller OSP values.

Actual numbers vary and depend on other factors such as desired spatial resolution, but in one system we've done (Figure 3) 30 BGO detectors allow us to scan uranium fuel rods at a rate of 2500 mm/minute hour, detecting a 15% OSP with 85% reliability at 95% confidence.

SPATIAL RESOLUTION

We use a combination of BGO crystals, high density tungsten collimators and tight mechanical design to give us very good collimation and spatial resolution. Our plutonium detectors used with MOX fuel give us a FWHM of 18 mm for single OSP's with a crystal and pellet width of ~ 12mm. That is for the higher, more difficult to collimate, 400 KeV gamma ray energies associated with ²³⁹Pu. Since the date of that measurement we've improved our mechanical design to more closely couple the collimators with the crystals. Our uranium performance would be much better than that, approaching 1 pellet width.

Zone lengths are typically measured to an accuracy of +/- 1/2 pellet length. We've developed special processing algorithms that let us detect OSP reliably at zone interfaces, including the beginning and end of the fuel stacks with only minimal degradation.

Detector crystal width depends on the application and is a function of nominal pellet width, desired spatial resolution and collection efficiency. Higher spatial resolution for detection of single OSP and zone length resolution results in reduced collection efficiency per detector, increasing the number of detectors needed.

We've developed dynamic software models that simulate passage of streams of pellets of various enrichments through detectors with various crystal and collimator dimensions to evaluate these tradeoffs.

²³⁸U DAUGHTERS

Passive gamma scanners are particularly sensitive to variations in fuel pellet activity due to varying levels of ²³⁸U decay since processes that remove thorium and protactinium. These variations are often seen between different lots of pellets used in different zones. Our hardware supports advanced software algorithms we've developed to mitigate that effect.

While we can't entirely eliminate the effects, we can reduce them giving more flexibility to the manufacturing process – i.e., shorter cycle times between pellet manufacture and gamma scanning in fuel rod product.

DETECTOR MATERIAL AND TEMPERATURE COMPENSATION

We typically use BGO scintillation crystals as its non-hygroscopic nature lets us tightly couple it to our collimators. We have also used LYSO, CsI and NaI, but much prefer the BGO for both UO₂ and MOX applications. BGO scintillation material though is sensitive to variations in ambient temperature. This sensitivity is regular and well characterized. Our detector assemblies have integrated temperature sensors that allow us to compensate for peak shifts in BGO spectra due to temperature.

Our next generation passive scanners use CsI(Tl) detector crystals coupled to solid state silicon photomultipliers to great advantage. They are insensitive to temperature variations and magnetic fields, as are BGO and PM tubes.

NUCLEAR ELECTRONIC HARDWARE:

Macro Inc. has designed and built a family of electronics boards used in processing of data from gamma ray detectors.

KC97

Our KC97 unit is typically used in Active Gamma Scanners and Through Transmission measurement gamma and X-ray systems. The KC97 independently controls two PM tubes connected to a scintillation crystal. It has two programmable high voltage power supplies and two digital picoamp level current integrators. Energy discrimination is **not** performed; the total output current of the PM tubes, representing the total photons detected is digitized in programmable time intervals on the order of milliseconds.

KC99

Our KC99 unit connects to existing NIM Single Channel Analyzers to accumulate counts over programmable time intervals. Twenty counting channels are provided per card.

KC03

Our KC03 unit combines a fixed gain amplifier, pulse height analyzer with programmable lower and upper thresholds, and a scalar accumulating counts over a programmable interval. Eight independent channels are provided on each KC03. The KC03 accepts 50 ohm coaxial cable inputs from up to eight preamplifiers (KV03).

KV03

Our KV03 unit combines a programmable HV output to a PM tube and a PM tube output preamplifier. Up to 8 PM tubes can be independently controlled by 1 KV03 unit. It has coaxial cable outputs for connection to a companion KC03 unit. The **KV03** unit is standalone requiring a single 12 vdc power

supply. The KV03 is typically mounted alongside the detector assembly (Figure 3) when possible, or in a nearby electronic enclosure (Figure 2).

The **KC97**, **KC99** and **KC03** units are all individually addressable and plug into an ISA bus for data access, control and are easily replaced.

The **KC03** and **KV03** have each accumulated over 850,000 unit hours of operation with a lower figure of MTBF of 225,000 hours at 95% confidence.

Any number of units may be used in any application. For one customer we provided a high speed passive gamma scanner with 60 detectors, using 16 **KV03** and 16 **KC03** units.

The system shown in Figure 2 controls 10 detectors using 3 **KV03** and 3 **KC03** units, which are shown in their control enclosure.

BUDGET FIGURES:

Cost of a basic Passive Gamma Instrument can be estimated at approximately \$7,000 per detector (in groups of 4), plus an additional \$40,000 per system for processing controls, source codes for example analysis applications, and an enclosure for the electronics. For each detector this includes the detector crystal (BGO), mechanical housing, two PM tubes per crystal and the processing electronics (KV03 high voltage supply and pre-amps) and KC03 (amplifier, single channel analyzers and scalars) and associate cables.

Size wise, Uranium detectors are typically arranged 24mm on centers, MOX detectors are 32mm on centers.

FIGURES:

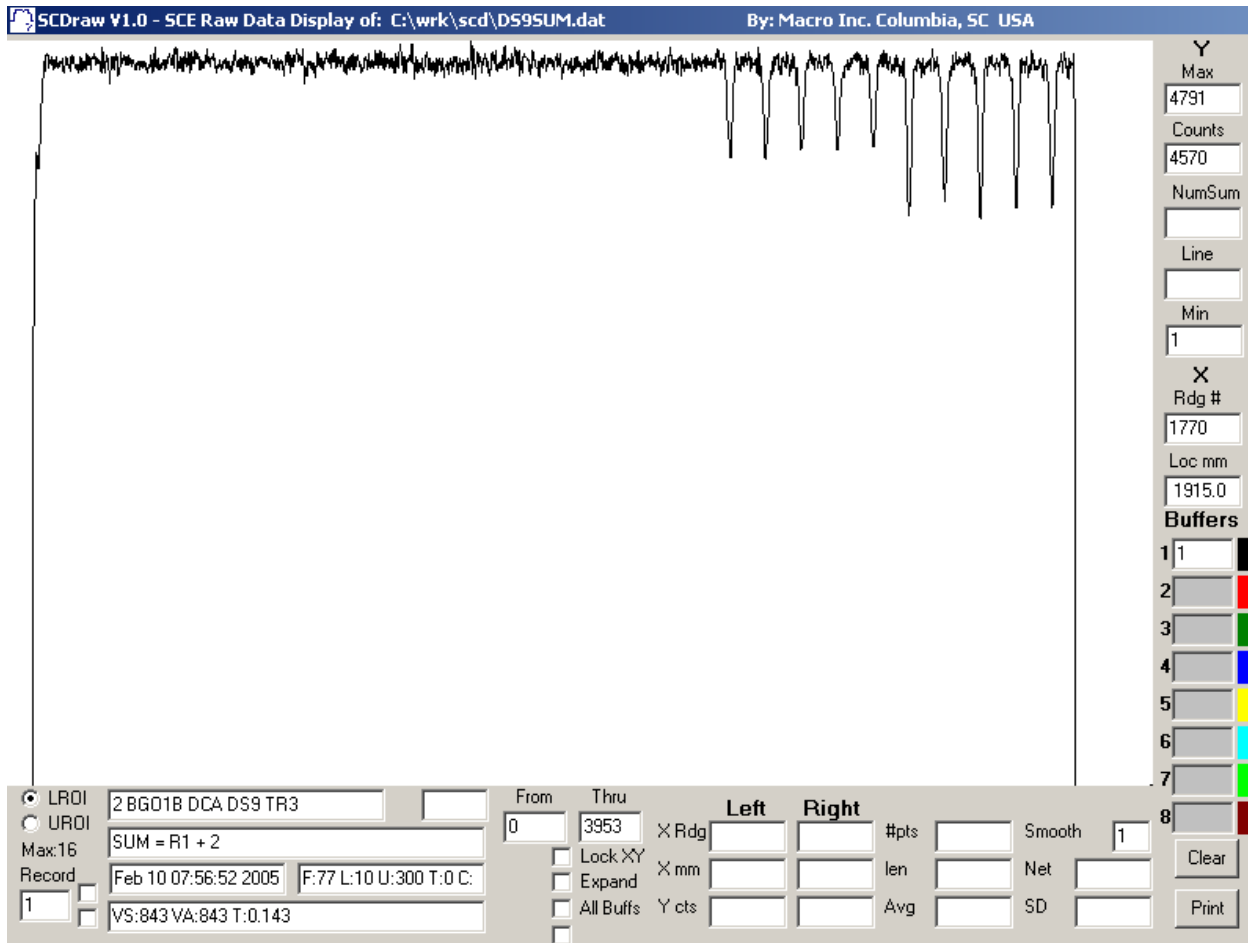


Figure 1 - Fuel Rod Gamma Profile. Displays variation in gamma ray counts along the length of the fuel rod at discrete intervals (~1-2mm). This is a composite from x number of detectors. This is screen shot of a program we, and our customers, use to analyze gamma ray data from detectors. This happens to be a scan of a MOX fuel rod.

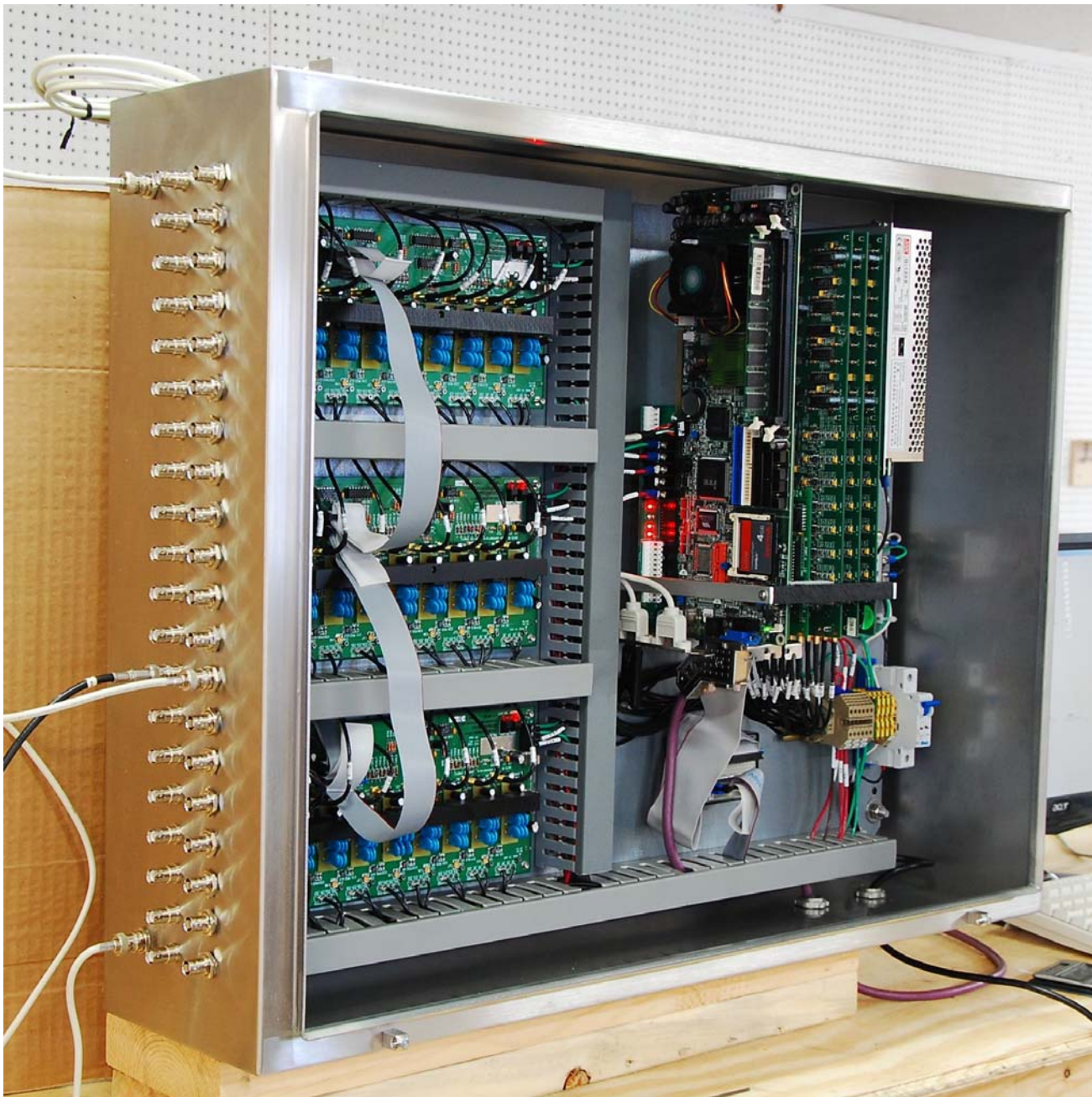


Figure 2 - 10 Detector Electronic Instrument. This unit collects and composites the data from 10 detectors (20 PM tubes, detector assembly not shown but similar to Figure 3) and sends the gamma data profile (Figure 1) to a Process Control PC over the Profibus (purple cable). No operator controls or interface required, all interface is via the Profibus and the control application. Temperature detector inputs (2) are shown at the top and bottom of the connector panel.

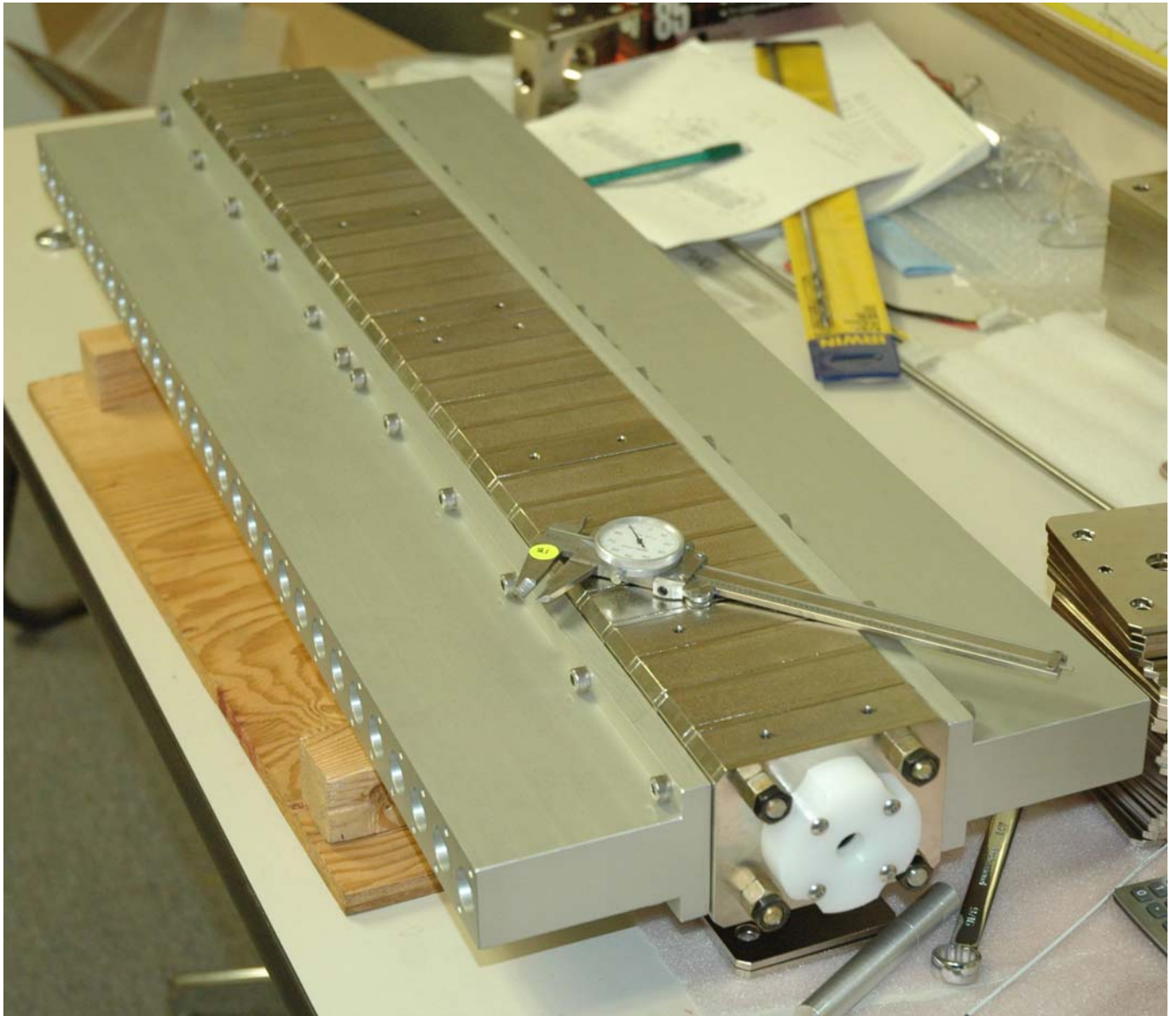


Figure 3 – Passive gamma detector (30 BGO) assembly. Fuel rod passes through 30 donut like BGO detectors, each having a PM tube to either side. Four KV03 boards go to either side of the detector assembly in its shielded enclosure, connecting to the PM tubes in the detector assembly (not shown).

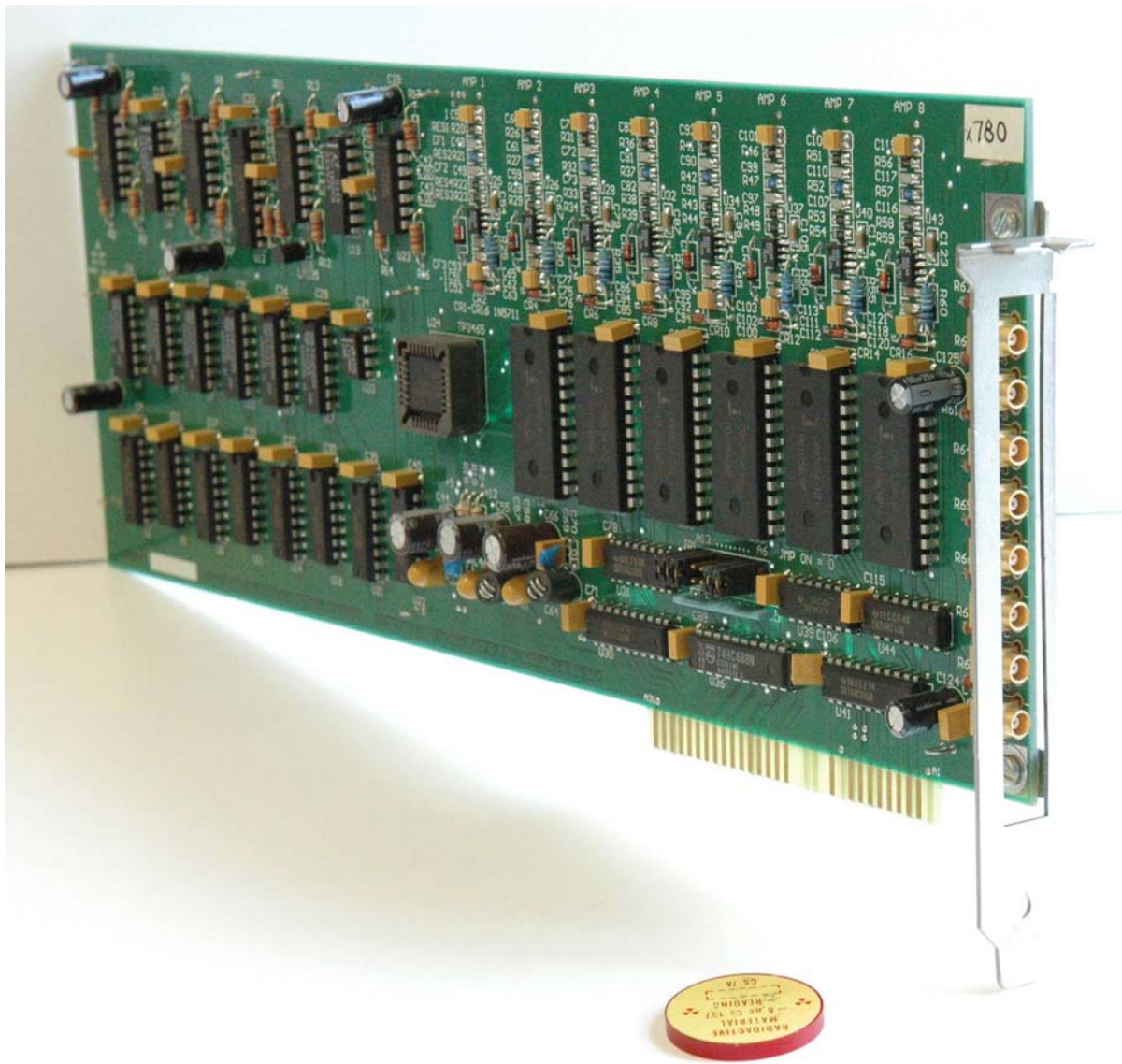


Figure 4 - KC03 8 channel amplifier, pulse height discriminator and scalar. It has 8 50 ohm coaxial cable inputs from the preamplifiers and is connects to standard ISA bus for data collection and control by a computer. Eight of these would be used to interface to 32 Detectors (64 PM tubes).

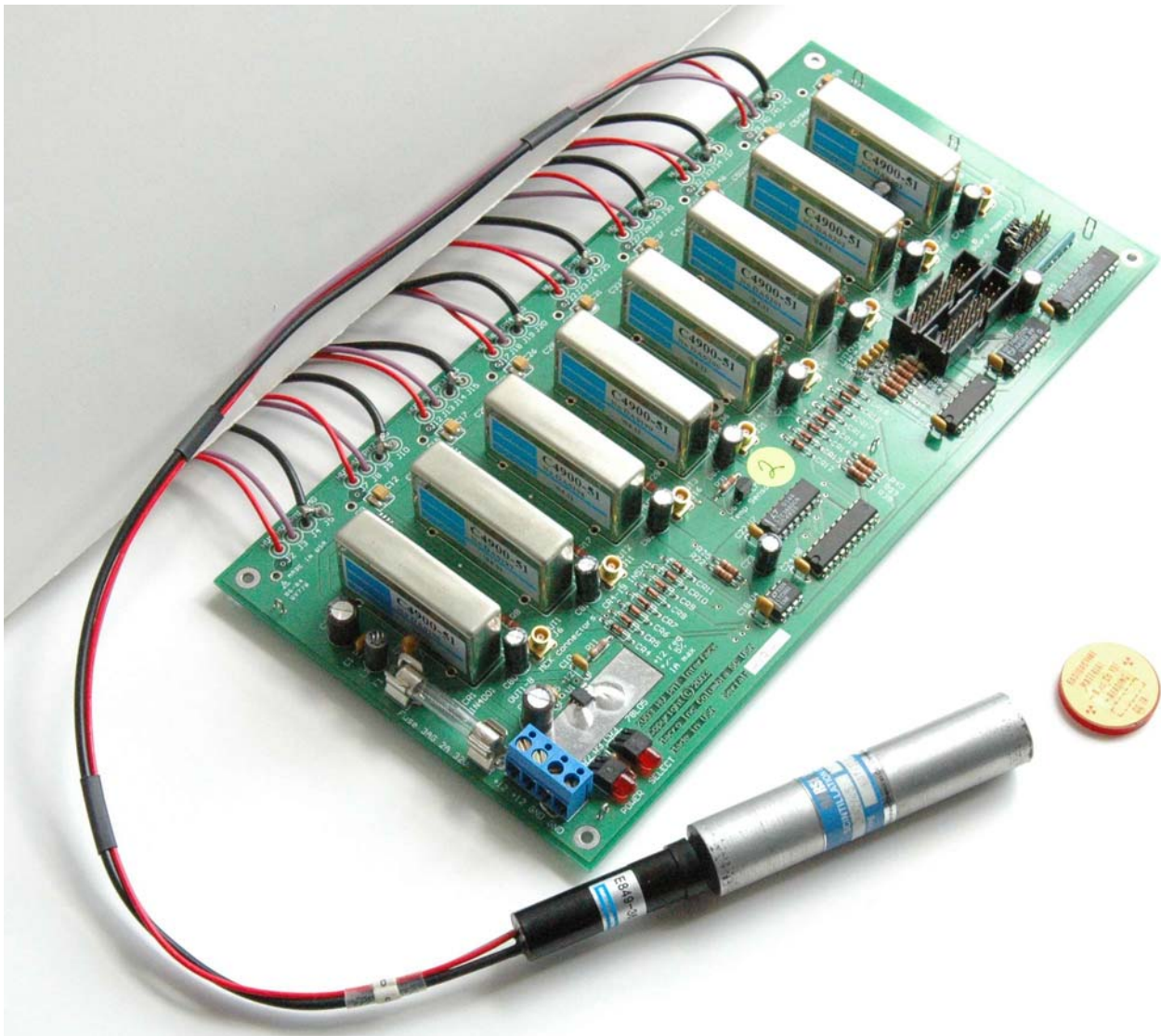


Figure 5 - KV03 8 channel high voltage PM tube supply and PM tube preamplifier. It has 50 ohm coaxial cable outputs. Unit is 5" x 10". Eight of these would be used to interface to 32 Detectors (64 PM tubes).

For more information, please contact **Ed Kelleher**, Pres@Macro-Inc.com

MACRO Inc. 1730 Augusta Road West Columbia South Carolina 29169 USA
Phone (Voice/Fax): (0101) 803.796.8858