PFC/JA-92-11

MIT Modular X-Ray Source Systems for the Study of Plasma Diagnostics

J. W. Coleman, K. W. Wenzel, R. D. Petrasso, D. H. Lo,

C. K. Li, J. R. Lierzer, T. Wei

March 1992

Submitted for publication in: *Review of Scientific Instruments*

Plasma Fusion Center

Massachusetts Institute of Technology

Cambridge, MA 02139

This work was supported by U.S.DOE Grant No DE-FG02-91ER54109
and LLNL Subcontract B116798

MIT Modular X-ray Source Systems

For The Study Of Plasma Diagnostics

J.W.Coleman, K.W.Wenzel*, R.D.Petrasso, D.H.Lo**,

C.K.Li, J.R.Lierzer, T.Wei

MIT Plasma Fusion Center, Cambridge, MA

ABSTRACT

Two new X-ray source systems are now on line at our facility. Each provides an e-beam to 25 kV. Targets are interchangeable between machines, and four x-ray detectors may be used simultaneously with a target. The gridded e-gun of the *RACEHORSE* system gives a 0.5 to 1.0-cm pulsable spot on target. The non-gridded e-gun of the *SCORPION* system provides a 0.3-mm or smaller DC microspot on target. *RACEHORSE* is being used to study and characterize Type-II Diamond photoconductors for use in diagnosing plasmas, while *SCORPION* is being used to develop a slitless spectrograph using photographic film. Source design details and some *RACEHORSE* results are presented.

I. INTRODUCTION

Work in our laboratory includes the characterization and calibration of x-ray detectors (1) to refine/develop new calibration standards, and (2) to study/select types of detectors for plasma diagnostics. To expand our capability we have built two new x-ray sources [1]: *RACEHORSE*, a pulsable macrosource, and *SCORPION*, a DC microsource. Both sources employ metal targets bombarded with e-guns. With either source, four detectors may monitor the target simultaneously.

II. *RACEHORSE* DESIGN

The gridded e-gun design has a theoretical pulsing limit of 1 GHz (Fig 1). The e-gun operates at 2-25 kV, with beam currents to 10 mA (Fig 2). A telefocus cathode housing aids beam auto-collimation, while *PULSE* and *ACCEL* grids provide pulse tailoring to 1 MHz with pulse widths of 100 - 10 ns. The electron spot on target is 0.5 to 1.0- cm in diameter.

A control panel provides Variac power to five isolation transformers which energize the e-gun circuits: (a) filament heating; (b) $+5volts_{ref}$; (c) $Pulsevolts_{-}$; (d) $Pulsevolts_{+}$; and (e) *ACCEL volts*. The high voltage itself is selected from the HV power supply unit. An optical emitter driver converts an externally-generated TTL pulse to an optical pulse which drives the e-gun switching grid via fiberoptc cable. All system power is supplied through a 6-connector relay controlled by an interlock system, which also enables the high voltage. A circuitry block diagram is shown in Fig 3.

III. *SCORPION* DESIGN

The purpose of the *SCORPION* non-gridded e-gun is to produce a DC microspot or 'point-source' of x-rays. Shown in Fig 4, the e-gun incorporates a thermionic point emitter, an energy filter aperture, and a Butler electrostatic lens. The e-gun operates optimally at 10-20kV with beam currents to 10 μA, delivering a spot variable from 0.3-mm diameter downward depending upon filtering voltage. The total circuitry for the system is the bleeder resistor chain.

IV. TARGETS

Targets for the two systems are interchangeable, mounting coaxially with the e-beam in either instrument. The target support is a 1.0-inch diameter copper bar, insertable with bayonet-seal into either vacuum chamber. The bar is finned at the *atmosphere* end for air-cooling. At the *vacuum* end, there is provision for mounting metal discs or foils or a Faraday cup. The *vacuum* end face is machined either perpendicular to the bar axis (circular target area) or at an angle to the bar axis (elliptical target area). When the elliptical target area is rotated, the x-rays may be 'flashed' from position to position with frequencies as high as 360Hz. The detector access to target in both systems is by means of 2.75-inch diameter vacuum flanges, and four ports for such flanges face the target position. Fig 5 shows a typical spectrum from a *Cu* target taken with *RACEHORSE.*

V. EXAMPLES OF USAGE

RACEHORSE is now being used to study diamond photoconductor detectors (PCDs) for plasma diagnostics. Type II diamond transmits to 5.49 eV, and has flat spectral and excellent time responses and driftless sensitivity [2,3]. It is also rugged, dependable, and long-lived, and smoothly saturates as x-ray fluxes become higher, allowing continuous operation over a broad range of incident power $(10 - 10^4 W/cm^2)$. Due to the large band gap in Type-II diamond, the detector can operate in visible light without sacrificing its x-ray detection characteristics.

We are studying diamond PCD as a means of obtaining high temporal resolution rather than as a means for measuring total output from a pulsed x-ray source. We monitor targets with diamond PCD and a SBD simultaneously, recording both pulse outputs photographically from dual traces on an oscilloscope. Data for a *Cu* target are shown in Fig 6a; for an *Al* target in Fig 6b; and for a *Mo* target in Fig 6c.

Low-fidelity response in PCDs is exhibited when excitation times are much longer than the primary response time (carrier lifetimes) of the PCD. For Type II diamond, carrier lifetimes are about equal and are between 90 and 200 ps. For a known pulse shape and rise time into the gridded e-gun, we can elicit a variety of output pulse shapes and rise times from both the PCD and the SBD, primarily because of signal amplification problems. This is especially true as we go to higher repetition rates. We are now in the process of isolating the variables involved in the electronic effects and artifacts.

The *SCORPION* source is being used at present to develop a slitless spectrograph with photographic emulsion output. Use of the spectrograph involves long exposure times, but will enable us to derive spectral dispersions without recourse to an electronic link in obtaining the data. This bent-crystal spectrograph will be used primarily for purposes of cross-verification and absolute calibration of our electronic detectors.

VI. ACKNOWLEDGEMENTS

We acknowledge support by U.S.DOE Grant No DE-FG02-91ER54109 and LLNL Subcontract B116798

*USDOE Postdoctoral Fellow

** USDOE MFET Fellow

References

[1]. J.W.Coleman, K.W.Wenzel, R.D.Petrasso, C.K.Li, D.H.Lo, J.R.Lierzer, T.Wei, and X. Chen. "X-Ray Sources for the Characterization of Plasma Diagnostics". *Proceedings of the 8th Topical Conference on Atomic Processes in Plasmas*, Portland, ME, August. 1991.

[2]. D.R.Kania, L.S.Pan, P.Bell, O.Landen, H. Kornblum,P.Pianetta, M.D.Perry. "Absolute X-Ray Power Measurements with Subnanosecond Time Resolution Using Type IIa Diamond Photoconductors". *J. Appl. Phys.* **68** *(1), 1 July 1990.*

[3]. D.R.Kania, L.Pan, H. Kornblum, P.Bell, O.Landen, P.Pianetta. "Soft X-Ray Detection With Diamond Photoconductive Detectors". *Rev. Sci. Instrum.* **61** *(10), October 1990.*

Figure Captions

Fig 1. In this tetrode gridded e-gun. the axial electrode spacing is not time-of-flight limiting for beam pulsing to 1 MHz at e-gun voltages as low as 2kV.

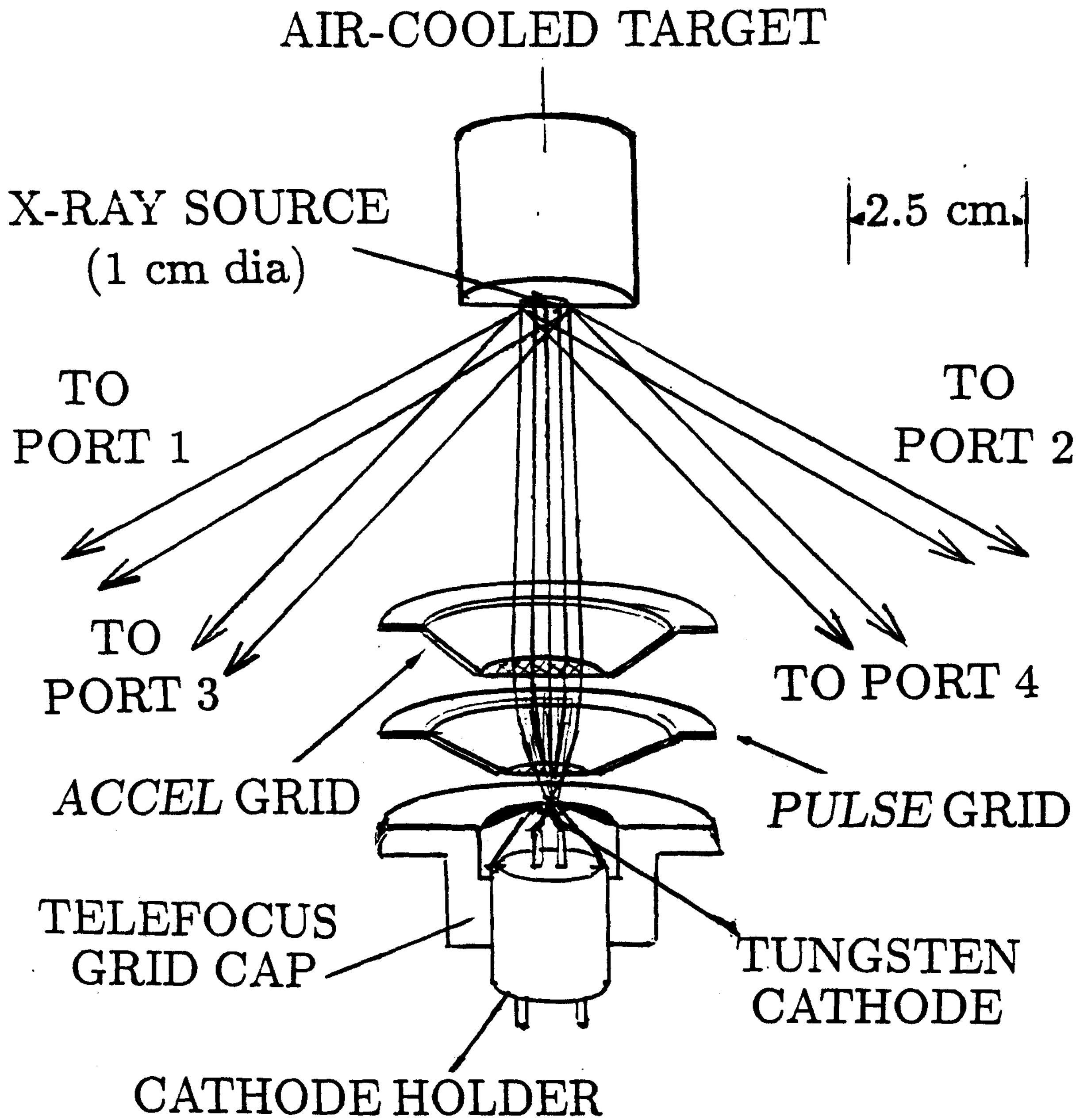
Fig 2. Shown are three curves for I_{beam} (arbitrary units) vs High Voltage, for fixed filament Variac heating settings. Beam current is in arbitrary units (absolute values depend upon all gun electrode voltages as well as on pulse repetition rate and shape). The upper limit on I_{beam} is near 10 mA.

Fig 3. *RACEHORSE* electrical supply and control.

Fig 4. The purpose of this non-gridded e-gun is to provide a finely-focused microsource. The beam may be chopped or deflected post-anode only.

Fig 5. *Cu* Target Spectrum

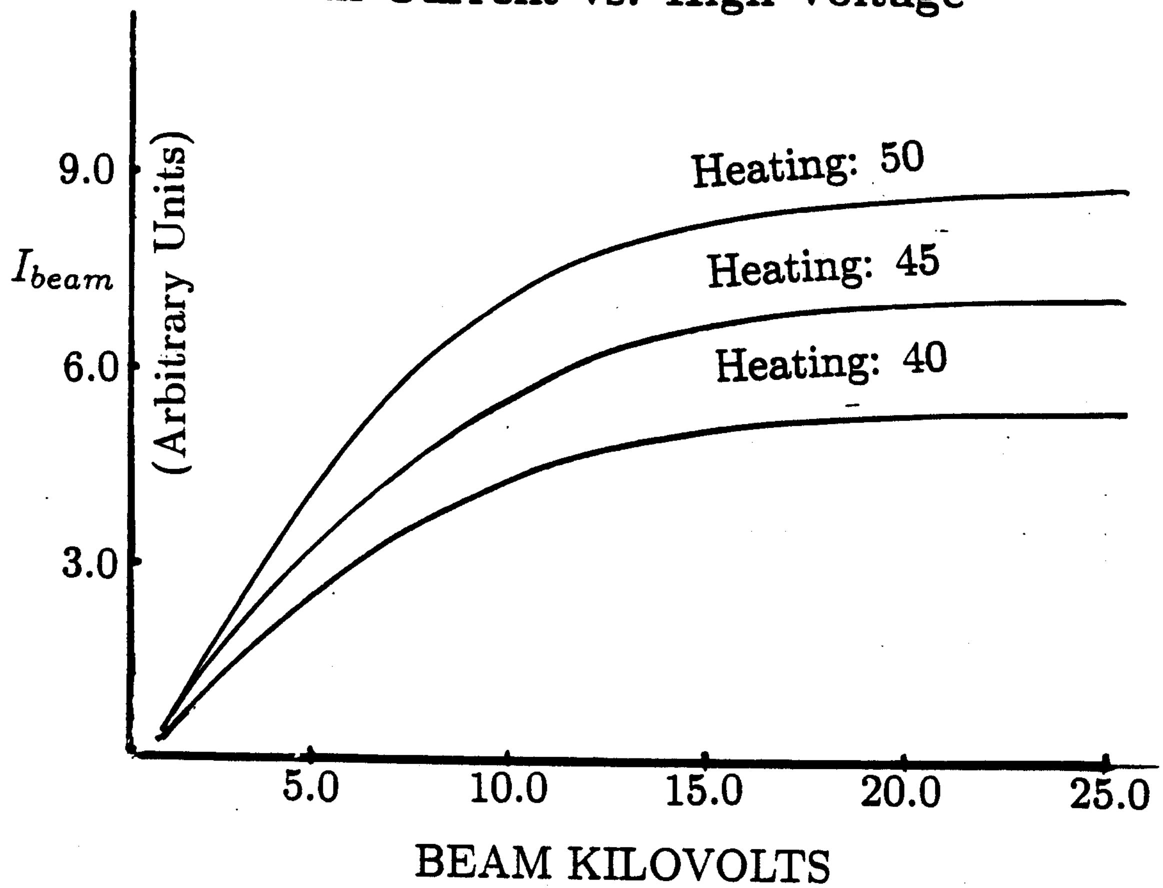
Fig 6. (a) shows dual-trace oscilloscope signals from *Cu* at $HV_{beam} = 18.0Kv$ and $I_{beam} = 0.5mA$. (b) is from *Al* at 20.0Kv, and (c) is from Mo at 21.0Kv. Pulse frequency is 30-50 KHz. The disparity between SBD and PCD signal amplitudes is due in part to detector collection area (SBD:PCD = 12:1).



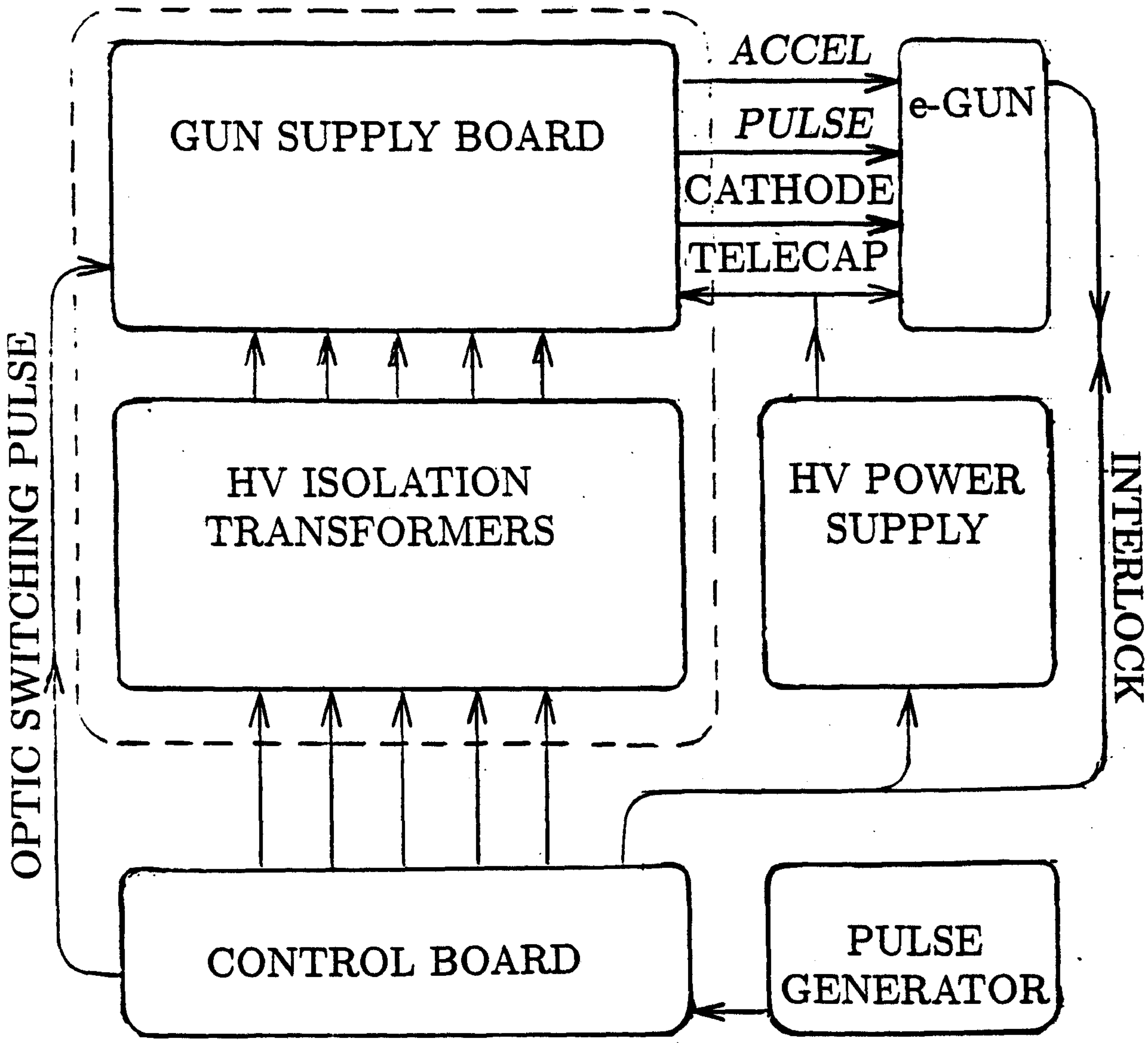
RACEHORSE GRIDDED e-GUN

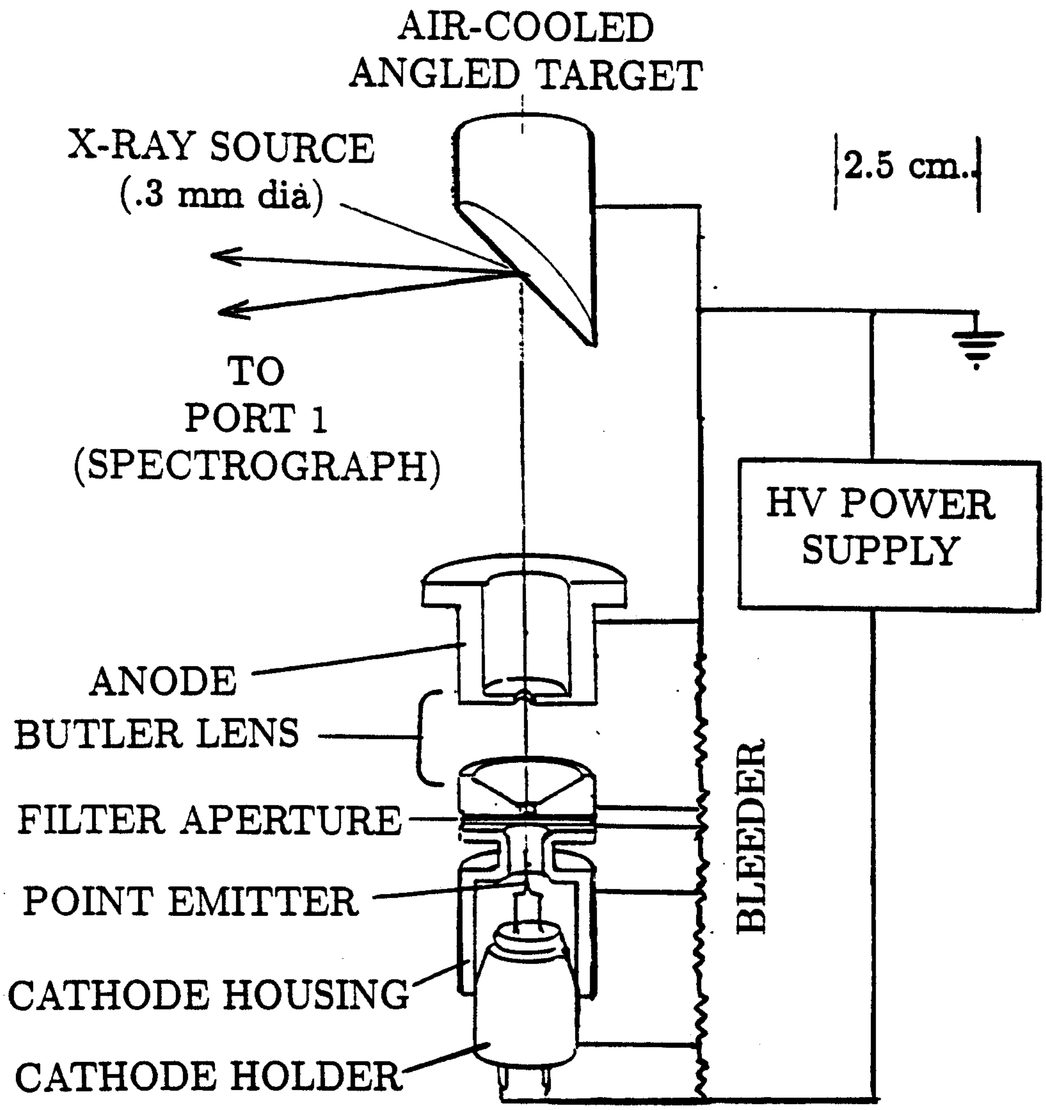
RACEHORSE e-GUN

Beam Current vs. High Voltage

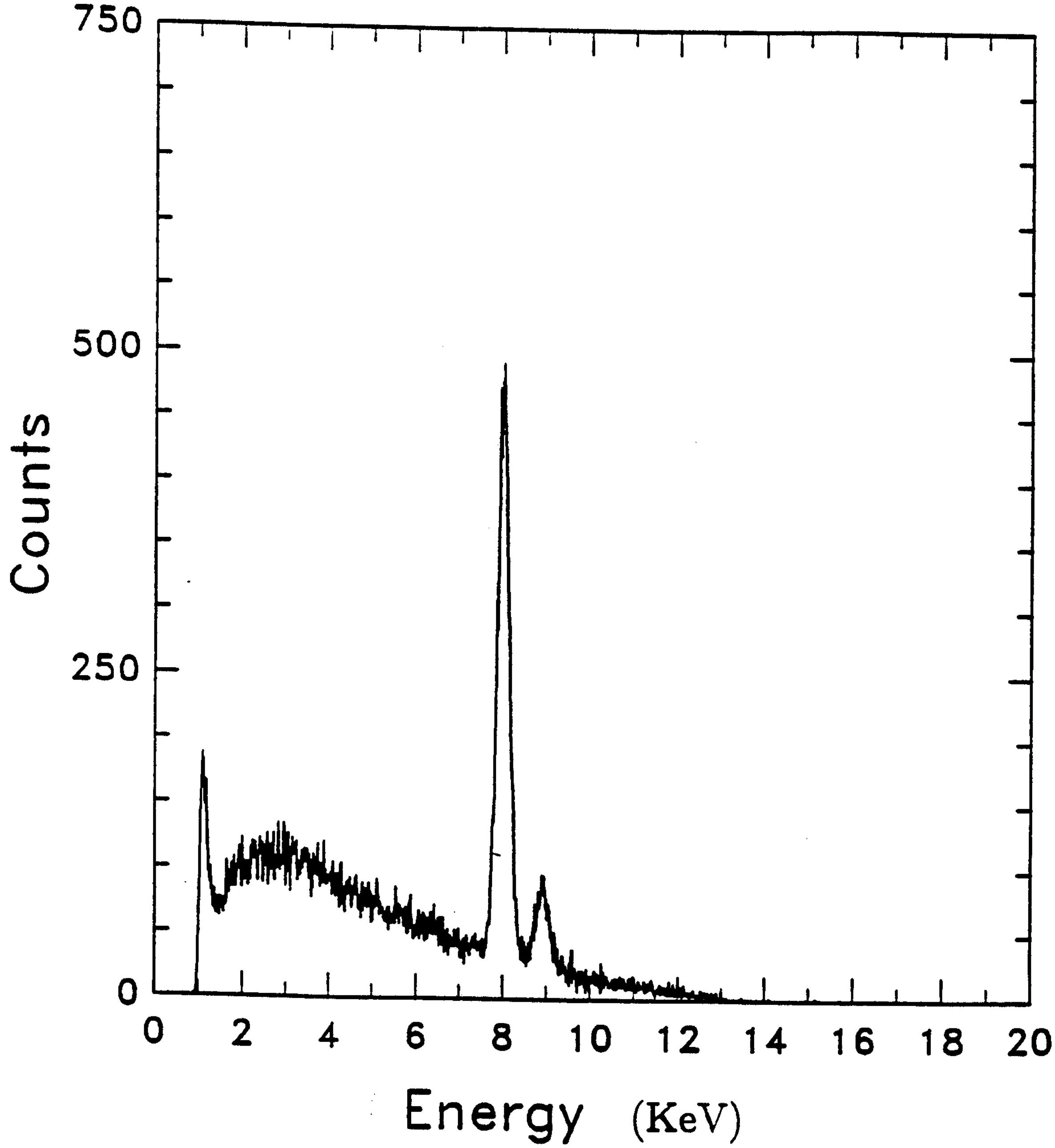


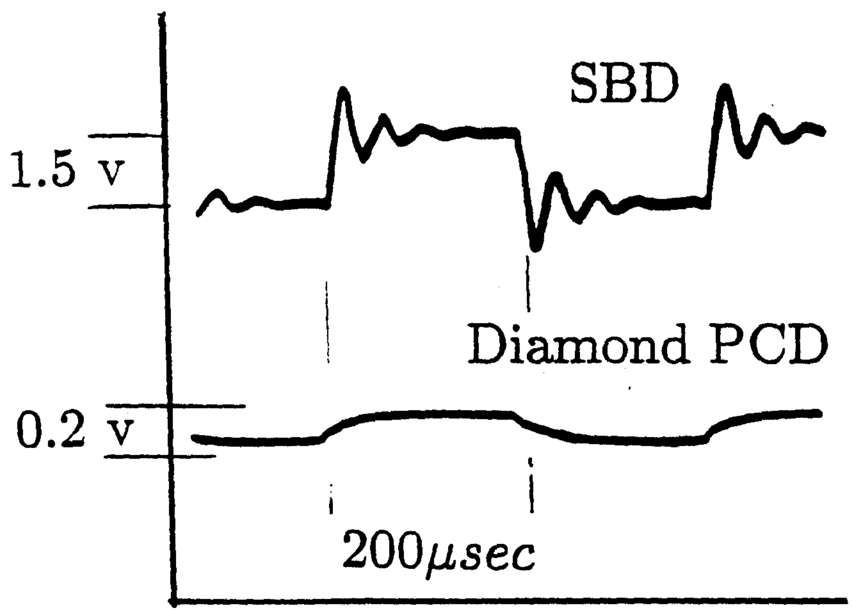
RACEHORSE
ELECTRICAL BLOCK DIAGRAM



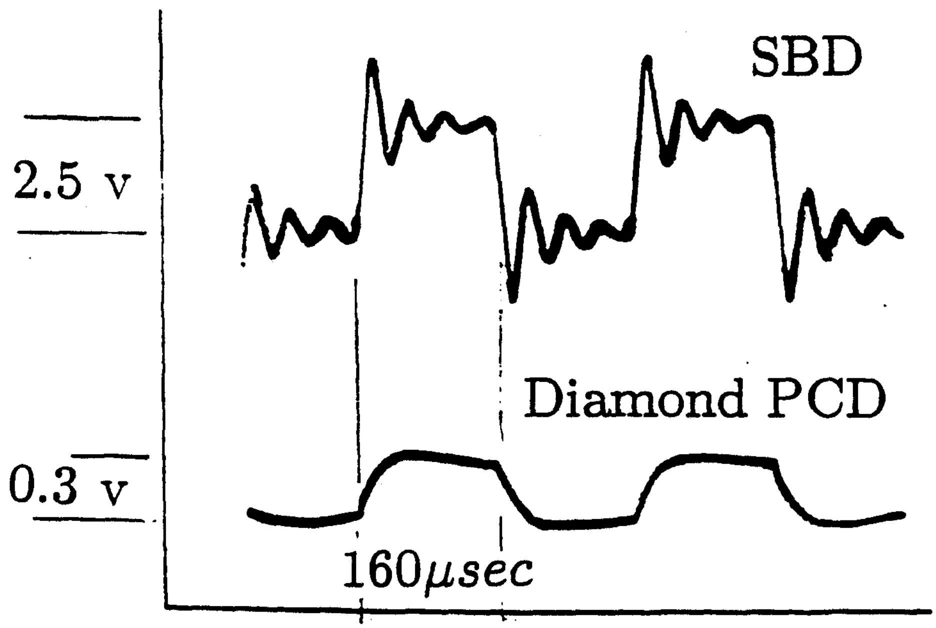


SCORPION MICROSOURCE e-GUN SYSTEM

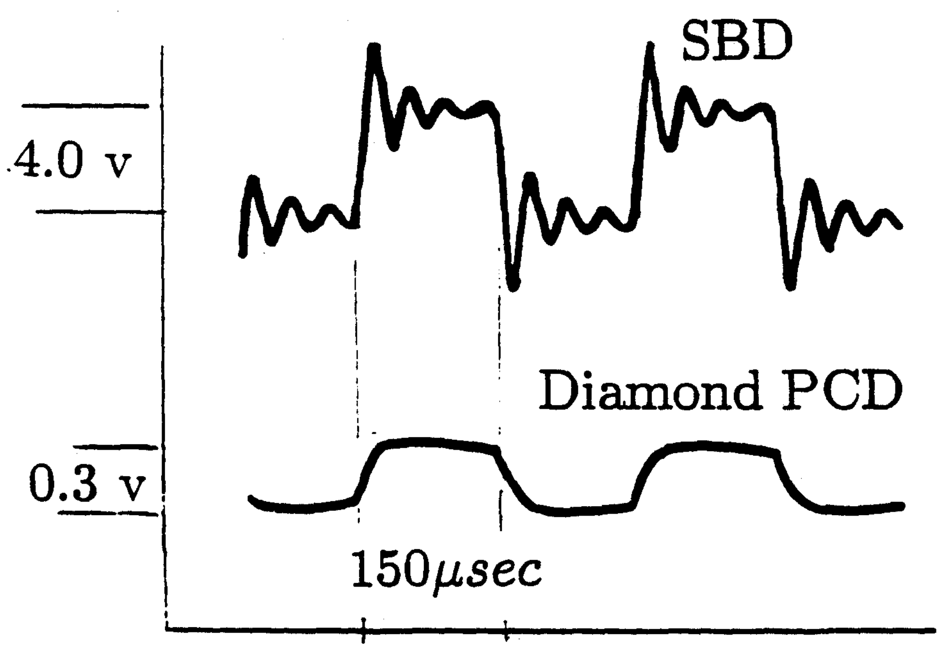

750
500
250
0
Counts
0
2
4
6
8
10
12
14
16
18
20
Energy (KeV)



(a): *Cu* TARGET



(b): *Al* TARGET



(c): *Mo* TARGET