AIR FORCE REPORT NO.
SAMSO-TR-71-192

AEROSPACE REPORT NO.
TR-0172(2220-60)-1

AD 729809

A Time-Resolved Ross Filter System for Measuring X-Ray Spectra in Z-Pinch Plasma Focus Devices

Prepared by H. L. L. VAN PAASSEN
Plasma Research Laboratory

71 SEP 15

Laboratory Operations
THE AEROSPACE CORPORATION

Prepared for SPACE AND MISSILE SYSTEMS ORGANIZATION
AIR FORCE SYSTEMS COMMAND
LOS ANGELES AIR FORCE STATION
Los Angeles, California

APPROVED FOR PUBLIC RELEASE:
DISTRIBUTION UNLIMITED

19

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author) The Aerospace Corporation El Segundo, California	2a REPORT SECURITY CLASSIFICATION Unclassified 2b GROUP

3 REPORT TITLE

A Time-Resolved Ross Filter System for Measuring X-Ray Spectra

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)

5 AUTHOR(S) (First name, middle initial, last name)

Hugo L. L. van Paassen

6 REPORT DATE 71 SEP 15	7a TOTAL NO. OF PAGES 22	7b NO. OF REFS 6

8a CONTRACT OR GRANT NO. F04701-71-C-0172 b PROJECT NO. c d	9a ORIGINATOR'S REPORT NUMBER(S) TR-017[illegible] 0-60)-1 9b OTHER REPORT NO(S) (Any other numbers that may be assigned this report) SAMSO-TR-71-192

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Space and Missile Systems Organization Air Force Systems Command Los Angeles, California

13. ABSTRACT

The development of plasma pinch and other flash x-ray devices has created the need for a system capable of measuring the spectra of 50-nsec x-ray pulses. A Ross filter system used in conjunction with silicon diode x-ray detectors gives nanosecond time resolution in spectral intervals between 5.46 and 115.6 keV.

LABORATORY OPERATIONS

The Laboratory Operations of The Aerospace Corporation is conducting experimental and theoretical investigations necessary for the evaluation and application of scientific advances to new military concepts and systems. Versatility and flexibility have been developed to a high degree by the laboratory personnel in dealing with the many problems encountered in the nation's rapidly developing space and missile systems. Expertise in the latest scientific developments is vital to the accomplishment of tasks related to these problems. The laboratories that contribute to this research are:

<u>Aerodynamics and Propulsion Research Laboratory</u>: Launch and reentry aerodynamics, heat transfer, reentry physics, propulsion, high-temperature chemistry and chemical kinetics, structural mechanics, flight dynamics, atmospheric pollution, and high-power gas lasers.

<u>Electronics Research Laboratory</u>: Generation, transmission, detection, and processing of electromagnetic radiation in the terrestrial and space environments, with emphasis on the millimeter-wave, infrared, and visible portions of the spectrum; design and fabrication of antennas, complex optical systems, and photolithographic solid-state devices; test and development of practical superconducting detectors and laser devices and technology, including high-power lasers, atmospheric pollution, and biomedical problems.

<u>Materials Sciences Laboratory</u>: Development of new materials; metal matrix composites and new forms of carbon; test and evaluation of graphite and ceramics in reentry; spacecraft materials and components in radiation and high-vacuum environments; application of fracture mechanics to stress corrosion and fatigue-induced fractures in structural metals; effect of nature of material surfaces on lubrication, photosensitization, and catalytic reactions; and development of prothesis devices.

<u>Plasma Research Laboratory</u>: Reentry physics and nuclear weapons effects; the interaction of antennas with reentry plasma sheaths; experimentation with thermonuclear plasmas; the generation and propagation of plasma waves in the magnetosphere; chemical reactions of vibrationally excited species in rocket plumes; and high-precision laser ranging.

<u>Space Physics Laboratory</u>: Aeronomy; density and composition of the atmosphere at all altitudes; atmospheric reactions and atmospheric optics; pollution of the environment; the sun, earth's resources; meteorological measurements; radiation belts and cosmic rays; and the effects of nuclear explosions, magnetic storms, and solar radiation on the atmosphere.

THE AEROSPACE CORPORATION
El Segundo, California

UNCLASSIFIED
Security Classification

14 KEY WORDS
Ross Filter X-Ray Spectra

Distribution Statement (Continued)

Abstract (Continued)

UNCLASSIFIED
Security Classification

ABSTRACT

The development of plasma pincl. and other flash x-ray devices has created the need for a system capable of measuring the spectra of 50-nsec x-ray pulses. A Ross filter system used in conjunction with silicon diode x-ray detectors gives nanosecond time resolution in spectral intervals between 5.46 and 115.6 keV.

Air Force Report No.
SAMSO-TR-71-192

Aerospace Report No.
TR-0172(2220-60)-1

A TIME-RESOLVED ROSS FILTER SYSTEM FOR MEASURING X-RAY SPECTRA IN Z-PINCH PLASMA FOCUS DEVICES

Prepared by

H. L. L. van Paassen
Plasma Research Laboratory

71 SEP 15

Laboratory Operations
THE AEROSPACE CORPORATION

Prepared for

SPACE AND MISSILE SYSTEMS ORGANIZATION
AIR FORCE SYSTEMS COMMAND
LOS ANGELES AIR FORCE STATION
Los Angeles, California

FOREWORD

This report is published by The Aerospace Corporation, El Segundo, California, under Air Force Contract No. F04701-71-C-0172.

This report, which documents research carried out from July 1967 through January 1970, was submitted for review and approval on 23 June 1971 to Lt Edward M. Williams, Jr., SYAE.

R. X. Meyer

R. X. Meyer, Director
Plasma Research Laboratory

Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

Edward M. Williams, Jr.

Edward M. Williams, Jr., 1st Lt, USAF
Project Officer

CONTENTS

FIGURES

I. INTRODUCTION

Several problems are present in the measurement of x-ray spectra from flash x-ray machines and plasma pinches. The short pulse length, typically 50 nsec, precludes the use of any system that requires pulse height analysis of individual photons. Furthermore, some plasma pinch devices exhibit large random variations in intensity, spatial distributions, and spectral shape from shot to shot.[1] An effective system should be capable of measuring the entire spectrum from one shot while sampling the radiation from 1 sq deg with a source strength of the order of 1J over 4π sr.

The Ross[2] filter or balanced filter method of analyzing an x-ray spectrum is well suited for measuring the radiation from these plasma pinch devices. Experience has shown that the x-ray intensity from these plasma pinch devices is sufficient to produce useful readings on commercial x-ray film or silicon diode detectors at distances ranging from 0.5 to 5 m from the x-ray source. When film is used as the detector, each Ross filter pair yields the information for the time integral of the radiation in a discrete energy interval. At this laboratory, a group of seven Ross filter pairs was mounted on a film cassette to obtain spectra of x-rays emitted by a plasma focus discharge.

The use of silicon diode detectors in conjunction with Ross filters to provide the information for a time-resolved spectrum has now been demonstrated. The spectrum of the x radiation under investigation was strongly peaked at about 10 keV, and Ross filter data were obtained in the interval from 5.46 to 29.2 keV. The energy interval can be extended to 115 keV through the use of Ross filters fabricated from readily available materials.

II. ROSS FILTER

The Ross filter[3,4,5] or balanced filter consists of two foils made from elements that are adjacent or nearly adjacent in the periodic system. Adjustment of the thicknesses of these two foils controls the amount of radiation transmitted through each one. This amount of transmitted radiation can be made nearly the same for all x-ray energies except in the energy range between the absorption K-edges of the two elements. The difference in transmitted x-ray energy is then a measure of the radiation in the energy interval between the two K-edges. The highest K-edge available is that of uranium at 116 keV, which places an upper limit on the energy range for Ross filters. The lower limits are determined by the difficulty in making uniform foils[6] of filter elements that will transmit measurable amounts of x-rays. This limit occurs at approximately 1 keV. In addition to K-edges, L-edges of various elements can also be used but with some loss of resolution.

As the production of Ross filters is already well described in the literature, it is not necessary to go into detail here. A Ross filter pair consists of two elements whose thickness ratio meets the aforementioned criteria. The absolute thicknesses of the foils can be varied considerably for various applications, but their ratio must remain constant. Because the sensitivity of a Ross filter pair within the energy range between the two K-edges is a function of the absolute thicknesses of the elements, a

Ross filter system may be tailored to match the sensitivitv of the detector used with them in order that the response of the filter-detector system is flat in the K-edge interval.

III. X-RAY DETECTORS

The x-ray detectors used in this experiment were 125-μm thick, fully depleted, double-diffused silicon diodes.* Spectral sensitivity curves for these detectors, which were obtained from the manufacturer, were basically the energy absorption curve for a 125-μm thick slab of silicon. With the diodes operated at 210 V and terminated in 50 ohms, the peak signals of several tens of volts were obtained. This is well above the 0.01 V noise associated with the operation of a plasma focus device.

For each Ross filter interval, two filter foils were used with two silicon diodes. The detectors were placed near each other so that both were irradiated by substantially the same radiation. This is important, because in this experiment there were large spatial variations in the x-ray fluence. Any radiation in the interval measured by the Ross filter pair produces a difference in the output signal from each of the two detectors. Both signals can be displayed and photographed on a fast oscilloscope, and the difference between the two signals can be obtained by subtraction of the ordinates of the two traces to obtain the time history of the x-ray signal in that particular Ross filter interval. This method has the advantage of preserving the total x-ray signal information so that it can be compared with

---

*Solid State Radiations, Inc., Model No. 025-NPS-300 the x-ray signal in the Ross filter interval. The limiting factors here are the rise times of the silicon diode and the oscilloscope, both of which were of the order of 2 nsec.

An alternate method is shown in Fig. 1. The signals from the two diodes are "subtracted" electronically by means of a differential amplifier whose output is displayed on the oscilloscope. While this method is far simpler to use, some information was lost because of the amplifier's long rise time of 15 nsec. With a fast amplifier, this problem can be eliminated.

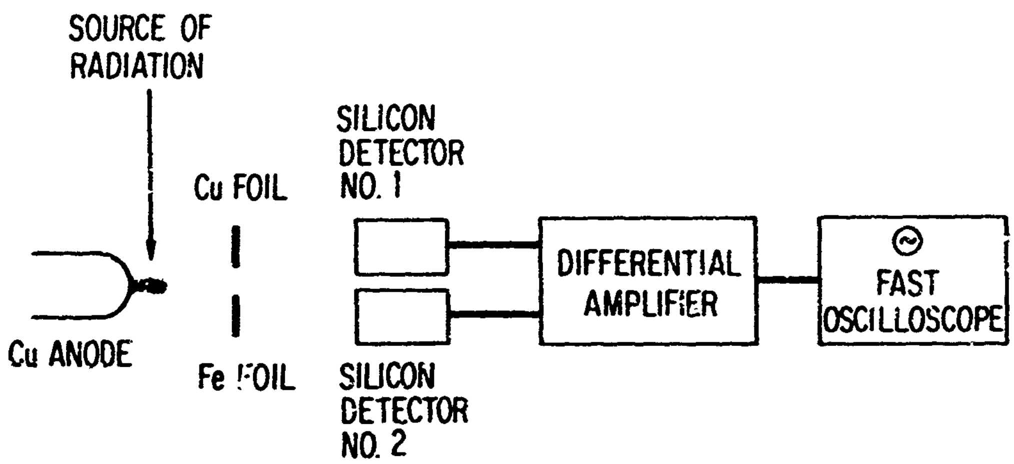

Fig. 1. Ross Filter - Silicon Diode Radiation Measuring System

IV. EXPERIMENTAL RESULTS

The output signals from a pair of diodes, one with an iron filter and the other with a copper filter, are shown in Fig. 2. This Ross filter pair covers the energy interval from 7.11 to 8.89 keV in which is found the $K_{\alpha 1}$, $K_{\alpha 2}$, $K_{\beta 1}$, and $K_{\beta 2}$ characteristic line radiation from copper. These diodes were exposed to the radiation from a plasma focus device that had a copper anode, with the radiation being substantially that of an x-ray tube operated at approximately 20 kV. As seen in Fig. 2, there is a strong burst of fluorescence radiation in the 7.11 to 8.98 keV interval that varies differently in time than the continuum radiation. This fluorescence radiation is believed to be associated with a cloud of copper vapor that is ejected from the anode tip shortly after the plasma focus occurs.

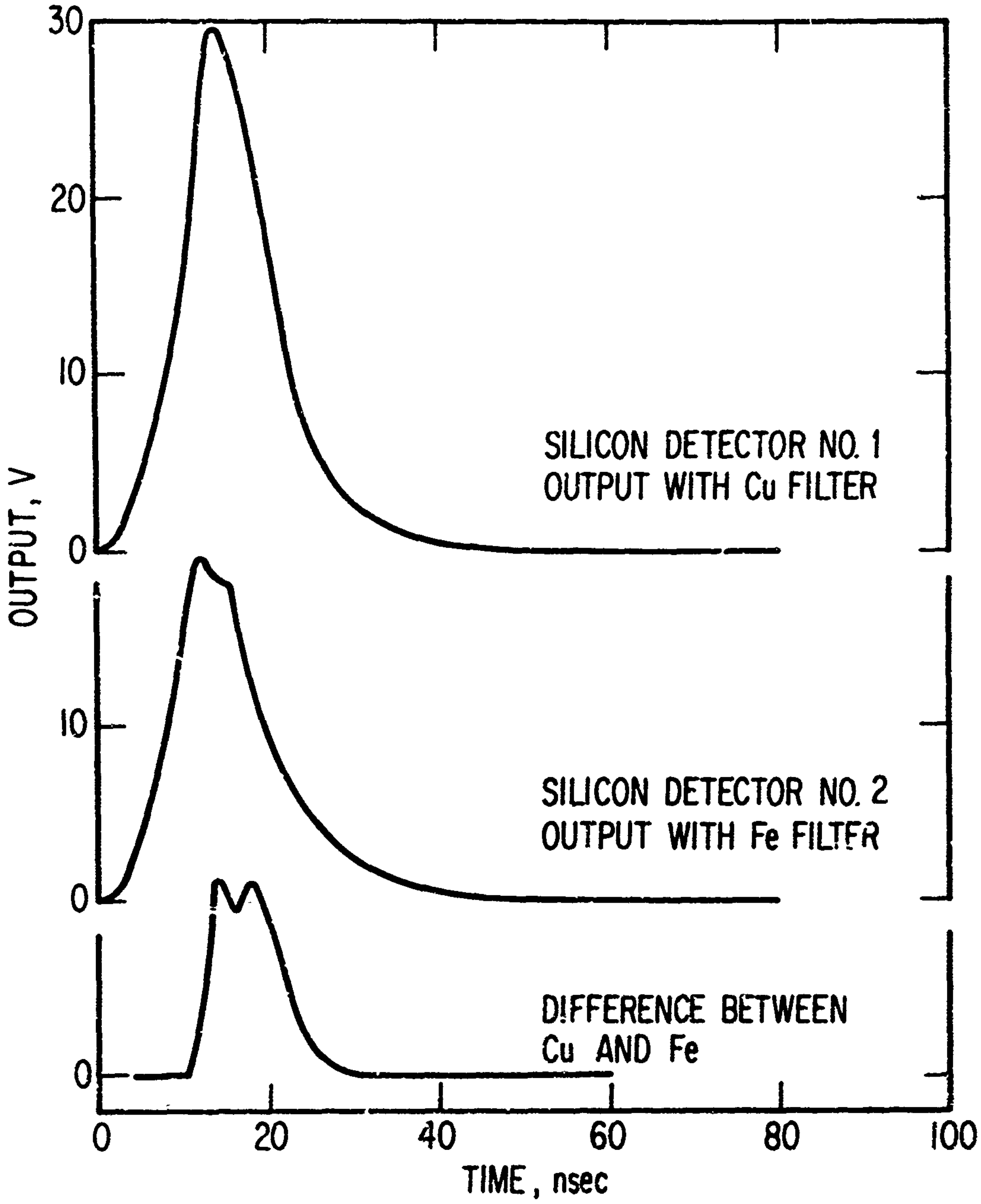

Fig. 2. Typical Oscilloscope Traces Obtained from Ross Filter - Silicon Diode System

V. CONCLUSIONS

The use of silicon detectors in conjuction with Ross filters is a simple and practical solution to the problem of measuring the time-resolved spectrum from some fast x-ray pulses. This system employs readily available materials to measure an x-ray spectrum whose time duration is too short for pulse height analysis of individual photons and whose intensity is too low for fluorescence detection techniques.

REFERENCES

1. D. A. Meskan and H. L. L. van Paassen, Proceedings of the APS Topical Conference on Pulsed, High-Density Plasmas, LA-3770, Paper C-6, Los Alamos Scientific Laboratories, Los Alamos, New Mexico (September 1967).
2. P. A. Ross, "A New Method of Spectroscopy for Faint X-Radiations," J. Opt. Soc. Am. and Rev. Sci. Instr., 16, 433 (1928).
3. H. A. Liebhafski, X-Ray Absorption and Emission in Analytical Chemistry, John Wiley and Sons, Inc., New York (1960).
4. A. H. Compton and S. K. Allison, X-Rays in Theory and Experiment, D. Van Nostrand Company, Inc., Princeton, New Jersey (1963).
5. P. Bogen, Plasma Diagnostics, North-Holland Publishing Company, Amsterdam, Netherlands (1968).
6. F. O. Halliday, A. K. Keast, J. F. Kelman, and T. O. Passell, Preparation and Use of K- and L-Edge X-Ray Foil Filters, Stanford Research Institute, Menlo Park, California (1966).