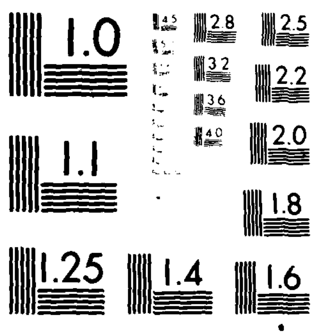
AD-A110 542 STANFORD UNIV CA INST FOR PLASMA RESEARCH F/G 9/1
STUDY OF NOISE IN CROSSED-FIELD ELECTRON GUNS.(U)
DEC 81 F W CRAWFORD AFOSR-77-3306
UNCLASSIFIED SU-IPR-861 AFOSR-TR-82-0014 NL

1 of 1
AD
A110542

END
DATE
FILMED
8-82
DTIC



MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS 1963-A

(13)

STUDY OF NOISE IN CROSSED-FIELD ELECTRON GUNS

Prepared for:

Air Force Office of Scientific Research
Bolling Air Force Base
Washington, D.C.

AFOSR Research Grant No. [redacted]
AFOSR-77-3306

Principal Investigator:

Professor F. W. Crawford

Final Technical Report

1 May 1977 - 31 October 1981

SU-IPR Report No. 861

December 1981

Institute for Plasma Research
Stanford University
Stanford, California 94305

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	AFOSR-TR- 82 -0014
2. GOVT ACCESSION NO.	
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle)	STUDY OF NOISE IN CROSSED-FIELD ELECTRON GUNS
5. TYPE OF REPORT & PERIOD COVERED	Final Technical Report 1 May 1977 - 31 Oct 1981
6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s)	F. W. Crawford
8. CONTRACT OR GRANT NUMBER(s)	AFOSR 77-3306
9. PERFORMING ORGANIZATION NAME AND ADDRESS	The Board of Trustees of Leland Stanford Jr. University, Sponsored Projects Office, Stanford, California 94305
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	61102F 2305/C1
11. CONTROLLING OFFICE NAME AND ADDRESS	Air Force Office of Scientific Research Bldg. 410, Bolling AFB, Washington, D.C. 20332
12. REPORT DATE	December 1981
13. NO. OF PAGES	8
14. MONITORING AGENCY NAME & ADDRESS (if diff. from Controlling Office)	
15. SECURITY CLASS. (of this report)	UNCLASSIFIED
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	

16. DISTRIBUTION STATEMENT (of this report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Noise	Tube	Transit time
Crossed-field	Planar	Perturbation expansion
Electron gun	Space-charge-limited	Electron dynamics

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A theoretical program was carried out for determining the source of excess noise in crossed-field diodes. The theory was based on the assumption that the noise was due to instabilities arising from the continuous interaction between the reflection of electrons back to the cathode and the effective beam potential in front of the cathode. The generation of noise by the interaction was studied for unbounded parallel-plate short circuited diodes. The theory was carried out first in the absence of transit time effects and then later with the inclusion

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

19. KEY WORDS (Continued)

20 ABSTRACT (Continued)

of transit time effects. Although the numerical results for the theory in the absence of transit time effects showed noise factors always less than unity, it is believed that numerical calculations yet to be carried out for the case including transit time effects will show noise factors in excess of unity and therefore the required condition for excess noise generation.

STAFF

AFOSR Research Grant No. AFOSR 77-3306
for the period
1 May 1977 to 31 October 1981

SENIOR STAFF

Prof. F. W. Crawford (Part-time)
(Principal Investigator)

Dr. K. J. Harker (Part-time)

GRADUATE RESEARCH ASSISTANT

S. E. Rosenthal

CONTENTS

I. INTRODUCTION

The performance of crossed-field microwave tubes depends critically on the electron gun used. At present, several electron gun designs exist for the injected beam crossed-field amplifier (CFA) [8]. However, a long-standing difficulty with such guns has been the seemingly uncontrollable noise in the tube RF output. The purpose of this study has been to develop a theory to account for this noise and, from this, to determine the means whereby this noise can be controlled and its adverse effect mitigated.

The theory which we developed was based on the assumption that the noise was due to instabilities arising from the continuous interaction between the reflection of electrons by the electron beam and the electron beam potential in the boundary region in front of the cathode. Investigation of this feedback mechanism as the agent responsible for the noisiness of crossed-field guns has been the goal of this study. We used as the basis for our study the extension of the analytical noise theory, developed many years ago by Schottky and Spenky [9], Rack [10], and North [11], to the crossed-field case. We also made use of the method developed by Lindsay [12,13,14] to determine the static characteristics of the beam, such as potential profiles and transmitted current to the anode.

II. PROGRESS

All of the theories developed during the course of this investigation were for an unbounded parallel-plate crossed-field diode operating in the short-circuit mode. These assumptions were necessary in order to reduce this exceedingly complex problem into a tractable form.

Another assumption was that the diode operated in the space-charge-limited regime. This assumption can be clarified as follows. There are basically two forms of flow in a crossed-field gun. One is the magnetic-field-limited regime [12], and the other is the space-charge-limited regime [13,14]. If we divide the electrons into classes based on their initial velocity transverse to both the magnetic field and the cathode surface normal, then each class has associated with it an effective potential function. If an effective potential function has a minimum, then this minimum is described as a critical plane for the corresponding class of electrons [15]. If each plane in a slab of the diode is a critical plane, then that diode is said to be in the space-charge-limited regime. If the diode does not have critical planes, then it is said to be in the magnetic-field-limited regime. We assume that the diode is operating in the former regime, since only it has critical planes, and therefore the sorting characteristic that the transmitted current depends on the potential profile. The existence of this characteristic is, of course, the basic premise of this study.

There were two distinct phases to this project. The first was a solution by perturbation expansion in the fluctuating RF quantities but valid for arbitrary magnetic field. We refer to this as the exact theory. The second phase of the project was a perturbation expansion in both RF fluctuations and magnetic field, which we shall refer to as the weak magnetic field theory. We discuss first the exact theory.

A. Exact Theory

Our first accomplishment in this project was the development of a noise theory for the low frequency regime [1,2], roughly defined as the region below the plasma frequency. The theory begins with the development of general equations for the potential and transmitted current.

The low frequency condition appeared in the assumption that the fluctuations were slow enough for the potential to appear constant during an electron transit time from the cathode to either cathode or anode. The general equations were then subjected to a perturbation expansion, the zero-order terms describing the steady-state potential and transmitted current and the first-order terms the linear response of the potential and transmitted current resulting from the injection of a small additional emission composed of electrons of a specified velocity. The theory then combined these perturbations to determine the current noise power at the anode and thereby the noise factor. The special case where the average potential showed a parabolic distribution in space was also considered.

The equations developed above were solved numerically by the quadrature method [3]. The results were obtained in terms of the dependence of the noise factor on the magnetic field. The noise factor so obtained was always less than unity in the space-charge-limited regime. Since excess noise must be associated with noise factors greater than unity, it is clear that it must stem from an effect not included in the model.

One of the effects not included which could possibly give rise to noise factors greater than unity was the effect of finite transit time. The final act in the exact solution portion of the project was the development of a theory for transit time effects [4].

Unfortunately, although the transit time theory was developed completely, it was not possible to complete the accompanying numerical calculations because of time restrictions. However, when these calculations are performed, we expect them to shed considerable light on the problem of excess noise in crossed-field tubes since, with finite transit time, one expects positive feedback and therefore the possibility of noise ratios in excess of unity. This stems from the following fact. Assume that the frequency and transit time are such that a 180 degree phase shift occurs between the cathode and the effective potential minimum. Then, an increase in emission current corresponds to an increase in the potential minimum and thereby allows more current to be transmitted to the anode than was emitted from the cathode. The existence of noise ratios in excess of unity has already been predicted by theory for unmagnetized diodes [16], and there seems little doubt that the same situation should carry into the case of magnetized diodes. The main question is to determine whether the effect is large enough to explain the experimentally observed excess noisiness.

B. Weak Magnetic Field Theory

The purpose of the weak magnetic field theory for crossed-field diodes was to provide a check on the exact theory and to provide a theory which could be represented more analytically and which was less dependent on numerical techniques. Also, whereas in the exact case numerical solutions were only obtained for a parabolic (and therefore non-self-consistent) static potential profile, the weak magnetic field theory allowed the determination of a self-consistent solution, i.e., a solution based on a static potential profile which satisfied the Poisson equation.

The first step in this phase of the project was the development of a theory for the static potential profile [5,6]. The theory here involved the extension of the Fry-Langmuir equation for an unmagnetized diode to a generalized Fry-Langmuir equation for magnetized diodes and the extension of the usual potential profile to an effective potential which was velocity dependent and combined the action of both static electric and magnetic fields. Another outcome of the theory was the development of four universal functions (the Fry-Langmuir and three additional functions) from which one can determine the potential and density profiles of any space-charge-limited diode for which the magnetic field is small. The theory also showed that, with increasing magnetic field, the crossed-field potential minimum is deepened and shifted toward the anode with respect to the unmagnetized potential minimum.

The next step in this phase of the program was the final extension of the theory to include RF effects [7]. With RF effects included, it was possible (with certain simplifying assumptions) to derive the theory from four universal diode functions in addition to the usual Fry-Langmuir function. Evaluating the universal functions allowed the calculation of the noise factor as a function of diode width, beam voltage, and magnetic field. The results obtained were generally in agreement with the exact theory, exact agreement being impossible to obtain since the exact theory is not self-consistent. In particular, the noise level of the space-charge-limited diode increased monotonically from the reduced level at zero magnetic field. The results were for a range of magnetic fields well below the threshold where the diode enters the region of magnetic-field-limited flow in which the noise power reaches the temperature-limited level. Thus, the range of the space-charge-limited region was always associated with a reduced noise level which was, nevertheless, greater than the unmagnetized space-charge-limited level.

PH.D. DISSERTATIONS AND REPORTS RESULTING FROM THE GRANT

Stephen E. Rosenthal, "Self-Consistent Perturbation Theory for Noise in Crossed-Field Diodes," Stanford University Institute for Plasma Research Report No. 828, Jan 1981 (Ph.D. dissertation).

Annual Report No. 1 (1 May 1977 to 30 April 1978), IPR Report No. 745 (June 1978).

Annual Report No. 2 (1 May 1978 to 30 April 1979), IPR Report No. 788 (June 1979).

Annual Report No. 3 (1 May 1979 to 30 April 1980), IPR Report No. 812 (June 1980).

PUBLICATIONS AND CONFERENCE PAPERS RESULTING FROM THE GRANT

1. K. J. Harker and F. W. Crawford, "Study of Noise in Crossed-Field Electron Guns," Technical Digest 1978 International Electron Devices Meeting, Washington, D.C. (IEEE, New York, 1978), pp. 168-172.

2. Kenneth J. Harker and Frederick W. Crawford, "Noise in Planar Crossed-Field Electron Guns--I: Theory," IEEE Trans. on Electron Devices ED-26, 1623-1633, 1979.

3. Kenneth J. Harker and Frederick W. Crawford, "Noise in Planar Crossed-Field Electron Guns--II: Numerical Solution," IEEE Trans. on Electron Devices ED-26, 1634-1641, 1979.

4. K. J. Harker and F. W. Crawford, "Transit Time Effects on Noise in Planar Crossed-Field Electron Guns," to be published in IEEE Trans. on Electron Devices, May 1982.

5. Stephen E. Rosenthal, Frederick W. Crawford, and Kenneth J. Harker, "Weak Magnetic-Field Expansion for the Self-Consistent Steady-State Potential in a Planar Crossed-Field Diode," IEEE Trans. on Electron Devices ED-27, 472-482, 1980.

6. S. E. Rosenthal, F. W. Crawford, and K. J. Harker, "Potential Minimum Determination for Crossed-Field Electron Guns," J. Appl. Phys. 51, 3520-3523, 1980.

7. S. E. Rosenthal, F. W. Crawford, and K. J. Harker, "Self-Consistent Theory for Crossed-Field Diode Current Fluctuations," to be published in J. Appl. Phys., Dec 1981.

REFERENCES

8. G. S. Kino, IRE Trans. on Electron Devices ED-7, 179, 1960.

9. W. Schottky and E. Spenke, Wiss. Veröffentl. Siemens-Werken 16, 1, 1937.

10. A. J. Rack, Bell System Tech. J. 17, 529, 1938.

11. D. O. North, RCA Review 4, 441, 1940.

12. P. A. Lindsay, J. Electron. Contr. 8, 177, 1960.

13. P. A. Lindsay, J. Electron. Contr. 17, 67, 1964.

14. P. A. Lindsay, Proc. Roy. Soc. A315, 479, 1970.

15. R. Y. C. Ho and T. van Duzer, IEEE Trans. on Electron Devices ED-15, 70, 1968.

16. Y. Fujii and S. Saito, IEEE Trans. on Electron Devices ED-14, 207, 1967.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: **AFOSR-TR- 82-0014**
2. GOVT ACCESSION NO: AD-A111 842
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): STUDY OF NOISE IN CROSSED-FIELD ELECTRON GUNS
5. TYPE OF REPORT & PERIOD COVERED: Final Technical Report, 1 May 1977 - 31 Oct 1981
6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s): F. W. Crawford
8. CONTRACT OR GRANT NUMBER(s): AFOSR 77-3306
9. PERFORMING ORGANIZATION NAME AND ADDRESS: The Board of Trustees of Leland Stanford Jr. University, Sponsored Projects Office, Stanford, California 94305
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 61102F 2305/C1
11. CONTROLLING OFFICE NAME AND ADDRESS: Air Force Office of Scientific Research, Bldg. 410, Bolling AFB, Washington, D.C. 20332
12. REPORT DATE: December 1981
13. NO. OF PAGES: 8
14. MONITORING AGENCY NAME & ADDRESS (if diff. from Controlling Office):
15. SECURITY CLASS. (of this report): UNCLASSIFIED
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:
16. DISTRIBUTION STATEMENT (of this report): Approved for public release; distribution unlimited.
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from report):
18. SUPPLEMENTARY NOTES:
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Noise	Tube	Transit time
Crossed-field	Planar	Perturbation expansion
Electron gun	Space-charge-limited	Electron dynamics

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A theoretical program was carried out for determining the source of excess noise in crossed-field diodes. The theory was based on the assumption that the noise was due to instabilities arising from the continuous interaction between the reflection of electrons back to the cathode and the effective beam potential in front of the cathode. The generation of noise by the interaction was studied for unbounded parallel-plate short circuited diodes. The theory was carried out first in the absence of transit time effects and then later with the inclusion

DD FORM 1473, 1 JAN 73
EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

19. KEY WORDS (Continued)

20 ABSTRACT (Continued)

of transit time effects. Although the numerical results for the theory in the absence of transit time effects showed noise factors always less than unity, it is believed that numerical calculations yet to be carried out for the case including transit time effects will show noise factors in excess of unity and therefore the required condition for excess noise generation.

DD FORM 1 JAN 73 1473 (BACK)

EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

FILMED

3-8