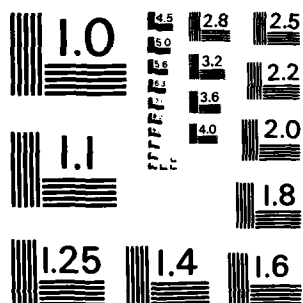END
DATE
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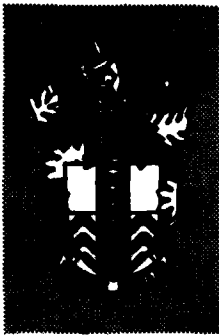
MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

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RSRE
MEMORANDUM No. 3512

ROYAL SIGNALS & RADAR ESTABLISHMENT

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E BEAM : AN OPERATING SYSTEM FOR PARTICLE
BEAM LITHOGRAPHY

Author: B C MERRIFIELD

PROCUREMENT EXECUTIVE,
MINISTRY OF DEFENCE,
RSRE MALVERN,
WORCS.

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ROYAL SIGNALS AND RADAR ESTABLISHMENT

Memorandum 3512

Title: EBEAM:AN OPERATING SYSTEM FOR PARTICLE BEAM LITHOGRAPHY

Author: B C Merrifield

Date: October 1982

SUMMARY

A modular suite of subroutines, designed to provide an operating environment
for the RSRE Electron Beam Lithography Machine (EBLM-1) is described. The suite
(EBEAM) will run on any PDP-11 16-bit minicomputer with sufficient memory under the
RT11 or RSX-11M operating systems.

Module names, peripheral addresses and instructions for installation and
operation under both operating systems are given together with detailed descriptions
of available commands and a list of error messages with possible causes and
remedies.

This memorandum is intended to be a general introduction and guide to users
wishing to install and operate such a system. It does not give detailed descriptions
of the individual modules and algorithms or of the hardware, as these are described
elsewhere.

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RSRE MEMORANDUM NO 3512

EBEAM:AN OPERATING SYSTEM FOR PARTICLE BEAM LITHOGRAPHY

B C Merrifield

CONTENTS

1   INTRODUCTION

EBEAM is a modular suite of Fortran and Macro-11 subroutines designed to control the operation of the particle beam microfabricators in P2 division. The suite is designed to run on a PDP11 16-bit minicomputer with at least 28K words of usable store, disc mass storage and a VT100, VT52, or Decwriter terminal.

Two versions of the suite are available, one intended for use on a small system with a minimum of 32K of store, running under the RT11 (V4) operating system with the single job monitor, and one for use on a larger system with at least 128K words of store and memory management, running under the RSX-11M(V3.2) operating system. The difference between the versions is mainly concerned with making use of the additional memory of the larger system and is transparent to

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the user. Both versions are overlaid but the RSX version makes use of the greater
storage available to it to use memory-resident overlays and virtual arrays which
considerably improve the speed and the amount of data which can be handled com-
pared to the disc-resident overlays of the small system version.

If a VT100 series terminal is available EBEAM can make use of its program-
ming and advanced video (if installed) capabilities to make a permanent display
of the commands available to the system together with the system status, while
terminal I/O is scrolled on the bottom 4 lines of the screen. Figures 1a and
1b show typical displays on RT11 and RSX-11M systems respectively. Figure 1b
highlights one of the facilities offered by the advanced video option whereby
those parts of the display which in Figure 1a are underlined are shown in
reverse video.

EBEAM is specifically intended to operate the electron beam lithography
machine (EBLM-1) in P2 division which is a modified twin lens scanning electron
microscope. Beam deflection is achieved by an electro-magnetic dual deflection
system comprising a high-sensitivity, high inductance set of coils and a lower
sensitivity, low inductance set. Electromagnetic blanking is provided to permit
beam deflection without exposure. The high sensitivity coils have a relatively
slow response and are used to position the beam to the centre of 100 µm square
subfields within a 1mm square exposure field. The pattern is drawn within this
subfield using a vector scan technique with the low inductance coils. The high
sensitivity system is hereafter referred to as the 'slow' deflection system and
the lower sensitivity system as the 'fast' deflection system. Movements larger
than 1mm are performed using a simple x-y stage driven by stepped motors provi-
ding nominally 1 µm of movement per step. The main causes of positional error
in uncorrected exposure are the stage inaccuracies and distortion in the electron
optics. Corrections are applied to the system to compensate for these errors
by measurements of a set of markers applied optically to the slice. This techni-
que is known as the RSRE transparent marker technique and is described elsewhere
(Ref 1). Separate programs are described in section 7 which set up lookup
tables to correct distortions in the 'slow' and 'fast' system electron optics.
Simplified schematic diagrams of the EBLM-1 and the exposure technique are shown
in Figures 2 and 3.A modified version of EBEAM will be available for single
lens systems.

The present memorandum is intended to be a users guide to EBEAM and not
a description of the modules themselves, the data structure or the hardware and
software techniques used to perform the operations, these are described in
detail elsewhere (Refs 2,3). Information contained in this memorandum is correct
at the time of writing, it is however under continual development to reflect
changes and additions to the hardware.

2   PERIPHERAL ADDRESSES

The following table lists the addresses of the various peripherals driven
by EBEAM. It does not include terminal, discs, etc which are installed at the
standard DEC addresses for these devices (Ref 4). The table includes the file
name, or names, of the modules using these addresses. These modules must be
altered to reflect any differences between the addresses listed here and those
in the users system.

ADDRESS	FUNCTION	INT.VECTOR	DEVICE	FILE
176772	DATA BUFFER	130	AD01	NEWSCN.MAC
176770	CONTROL/STATUS		A/D CONVERTER	DRAWBS.MAC
167776	F2		R.G.U	DRAWRT.MAC
167774	L2			DRAWBS.MAC
167772	F1/Y FAST DEFLN			FSTDEF.MAC
167770	L1/X FAST DEFLN	170		
167760	R.G.U STATUS			
167756	X-SLOW/X-DISPLAY		SLOW AMPS &	SLODEF.MAC
167754	Y-SLOW/Y-DISPLAY		611 DISPLAY	TEK611.MAC
167753			HARWELL UNIT	HARWEL.MAC
167752				
167751				
167750				
167744	INPUT BUFFER		ALIGNMENT UNIT	NEWSCN.MAC
167742	OUTPUT BUFFER/			DRAWBS.MAC
	BEAM STAB S/H			
167740	CONTROL/STATUS	310		
167574	DISPLAY STATUS		TEKTRONIX 611	TEK611.MAC
167572	RANGE		FREQUENCY	SETOSC.MAC
167570	FREQUENCY		CONTROL	
167562	Y		VARIABLE GAIN	VGAIN.MAC
167560	X		UNIT	
167556			STAGE MOTORS	STAGE.MAC
167554				
167552				
167550	STATUS			
167547	DFX		DISTORTION	DCUNIT.MAC
167546	CFX		CORRECTION	
167545	BFX		UNIT	
167544	AFX			
167543	DFY			
167542	CFY			
167541	BFY			
167540	AFY			
167402	Y COUNTER		STAGE COUNTERS	STREAD.MAC
167400	X COUNTER			

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3   MODULE NAMES

The following tables are a list of file names of the modules comprising EBEAM together with a brief indication of their function. The filename extension (eg .FOR) indicates the language used where FOR=Fortran, MAC=Macro-11, FTN=Fortran-77 and .DAT signifies a data file.

3.1   RT11 System

FILE NAME	FUNCTION
EBEAM.FOR	ROOT SEGMENT : OVERALL PROGRAM CONTROL
DATAIN.FOR	DATA INPUT
EXPOSE.FOR	EXPOSURE ROUTINE
ANGLE.FOR	CALCULATES STAGE AXIS ANGLE
CALSET.FOR	PERFORMS A CALIBRATION
FWEDGE.FOR	EXPOSES A WEDGE (FREQUENCY TEST)
EBTEXT.FOR	PRINTS CHARACTERS ON SLICE
VGROOV.FOR	CALCULATES VGROOVE OFFSETS
INCMOV.FOR	PERFORMS ON INCREMENTAL MOVE
VTSET.FOR	SETS UP VT100 DISPLAY
STATUS.FOR	UPDATES VT100 DISPLAY
EBMENU.FOR	DISPLAY COMMANDS FOR NON VT100 DISPLAY
CORSXY.FOR	PERFORMS A COARSE ALIGNMENT
FINE.FOR	PERFORMS A FINE ALIGNMENT
SLOSET.FOR	PERFORMS A SLOW SYSTEM SETUP
ANGSC.FOR	CALCULATE FAST SYSTEM ANGLE AND SCALE
STAGER.FOR	CONTROLS STAGE MOVEMENTS
COUNTR.FOR	CONTROLS STAGE COUNTERS
NEWMRK.FOR	PERFORMS A SINGLE MARKER SCAN
SCAN5M.FOR	PERFORMS A FIVE-MARKER SCAN
SDAPPL.FOR	APPLIES SLOW DISTORTION CORRECTION
FDAPPL.FOR	APPLIES FAST DISTORTION CORRECTION
SLOAMP.FOR	CALCULATES SLOW DEFLECTION
FASTAN.FOR	APPLIES FAST ANGLE CORRECTIONS
FSTSCA.FOR	APPLIES FAST SCALE CORRECTIONS
DISTOR.FOR	CALCULATES DISTORTION CORRECTION COEFFICIENTS
FREQEN.FOR	CALCULATES RANGE FOR OSCILLATOR DRIVER
CSCAN5.FOR	LOCATES A FIVE MARKER GROUP
CSCAN1.FOR	LOCATES A SINGLE MARKER
ROTATE.FOR	DRAWS A ROTATED RECTANGLE
SDELAY.MAC	SOFTWARE DELAY
TEK611.MAC	TEKTRONIX STORAGE SCOPE DRIVER
SLODEF.MAC	DRIVE THE SLOW DEFLECTION COILS
FSTDEF.MAC	DRIVE THE FAST DEFLECTION COILS
STREAD.MAC	READS STAGE COUNTERS
STAGE.MAC	STAGE MOTOR DRIVER
MOTDIS.MAC	DISABLES STAGE MOTORS
MOTENB.MAC	ENABLES STAGE MOTORS
DRAWRT.MAC	DRAWS A RECTANGLE ON THE R.G.U
DRAWBS.MAC	DRAWS A RECTANGLE AND RECORDS BEAM CURRENT
HARWEL.MAC	DRIVES THE HARWELL UNIT
DCUNIT.MAC	DRIVES THE DISTORTION CORRECTION UNIT
VGAIN.MAC	DRIVES THE VARIABLE GAIN UNIT
SETOSC.MAC	DRIVES THE PROGRAMMABLE OSCILLATOR
NEWSCN.MAC	DRIVES THE ALIGNMENT UNIT
MACROS.MAC	MACROS FOR SOFTWARE DELAY
SETUP.MAC	INITIALISES SYSTEM PERIPHERALS
FAST.DAT	SCALE AND ANGLE VALUES FOR FAST AND SLOW SYSTEMS

3.2 RSX-11M System

The above Macro-11 files remain unchanged for the RSX-11 version, as do most of the Fortran files with the exception of the following additions and replacements dictated by the RSX overlay structure and/or virtual arrays. The RSX versions of the Fortran files will also have the extension .FTN instead of .FOR.

FILE NAME	FUNCTION
EBEAMVIRT.FTN	ROOT SEGMENT : OVERALL PROGRAM CONTROL (replaces EBEAM)
VIRTDATA.FTN	DATA INPUT WITH VIRTUAL ARRAYS (replaces DATAIN)
VIRTEXPOS.FTN	PATTERN EXPOSURE WITH VIRTUAL ARRAYS (replaces EXPOSE)
VIRMOTCON.FTN	MOTOR CONTROL WITH VIRTUAL ARRAYS (an additional file)
VIRINCMOV.FTN	INCREMENTAL MOVE WITH VIRTUAL ARRAYS (replaces INCMOV)
VIRDCINPT.FTN	DISTORTION CORRECTION INPUT WITH VIRTUAL ARRAYS (an additional file)
VIRTFDAPP.FTN	FAST DISTORTION CORRECTION WITH VIRTUAL ARRAYS (replaces FDAPPL)
CLEAR.FTN	CLEAR OFFSETS (an additional file)
FRECON.FTN	FREQUENCY CONTROL (an additional file)

The file SDELAY.MAC contains a MACRO-11 routine and MACROS.MAC a MACRO-11 macro to provide a programmable software delay for beam settlement etc. Clearly these routines will be greatly dependant on the processor used and on the characteristics of the EBEAM system and may require alteration.

4 INSTALLATION

Distribution of EBEAM is in the form of Fortran and Macro-11 source files together with indirect command files for compilation and task building or linking. The modules must be recompiled and relinked (taskbuilt) for the system on which EBEAM is to run.

Apart from the Macro and Fortran files listed in section 3 and the various system and library files referred to below, a number of data files are required by EBEAM. The first of these, FAST.DAT, contains scale and angle values for the slow and fast deflection systems and is created by the calibration module. For the initial set up a file FAST.DAT containing values relevant to the P2 microfabricator is included in the distribution but the data may not be suitable for another system. If suitable default values are known FAST.DAT can be edited but in any case a calibration should be performed as soon as possible.

The remaining files are required if distortion correction is requested as they contain lookup tables for the fast and slow system distortions which will be unique to a particular system. The files are:

    XDISTN.TAB
    YDISTN.TAB
    FASTDC.DAT

Once created these files remain unaltered unless changes are made to the hardware ie alterations to the lens settings etc. Because of this they are created by separate programs which are described in section 7.

4.1 Installation on RT11 System

An RT11 single job monitor and a Fortran compiler should be built for the specific system on which the program is to run. The Fortran library FORLIB should be included with the system library SYSLIB, the MACRO compiler and system macro library (SYSMAC.SML) together with the librarian and linker utilities is also assumed to be available. Note that timer and device time out support is not required.

An indirect command file FORCOM.COM is provided to compile the Fortran modules and should be invoked as follows:

@FORCOM

A number of warnings may be reported for several of the modules (mainly due to names exceeding 6 chars) but no errors should be reported.

A similar file MACCOM.COM is provided for the Macro-11 modules and is invoked as follows:

@MACCOM

No error messages should be reported. Note that the macro library MACLIB.OBJ is also created by this command file.

Finally a command file for linking the overlaid files EBEAM.COM is provided and is invoked as follows:

@EBEAM

No errors should be reported by the linker and a file EBEAM.SAV should now exist.

4.2 Installation on RSX-11M System

The RSX-11M system was developed on a PDP11/44 with 0.5M bytes of store and two RL02 disc drives. RSX-11M was built for a 256K word mapped system with a full-duplex terminal driver, escape sequence handling and FCS support. A Fortran 77 compiler and OTS was built with OTS included in the system library. Note that although the RSX-11M modules have been compiled with the recently available Fortran-77 compiler they were originally written in Fortran 4 and do not make use of the additional features of Fortran 77. It is assumed that all the usual utilities TKB, LBR, PIP etc have also been built and are available.

An indirect command file FORCOM.CMD is provided to compile the Fortran modules and should be invoked as follows:

@FORCOM

A number of warnings (but no errors) may be reported. A similar file MACCOM.CMD is provided for the Macro-11 modules and is invoked as follows:

@MACCOM

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No error messages should be reported. Again the macro library MACLIB.OBJ
is also created by this command file. Finally a command file for task
building the overlaid modules EBEAMBLD.CMD is provided and is invoked
as follows:

    TKB @EBEAMBLD

Note that this command file requires the overlay description file
MRESEBEAM.ODL (memory resident EBEAM).

    No errors should be reported during task build and the file EBEAM.TSK
should be created. The task builder may report that the file is NON-
CONTIGUOUS in which case unwanted files should be erased until there is
sufficient continuous space (about 200 blocks). A continuous file can
now be created with the PIP command:

    PIP EBEAM. TSK/NV/CO=EBEAM.TSK

5 OPERATION

    If installation has been performed without error there should be a file
named EBEAM.SAV on RT11 systems and EBEAM.TSK on RSX-11M systems. The program
can now be run with the command:

    R EBEAM

for RT11 systems and

    INS EBEAM
    RUN EBEAM

for RSX-11M systems. For RSX systems the INSTALL command can be included in
the startup file if desired.

    Note that information input on the terminal is held in a buffer and is
not sent to the computer until the RETURN key is depressed, your responses or
commands to the program should always therefore be terminated by 'RETURN'.

    The following question should now be displayed on the terminal:

    IS TERMINAL A VT100 (Y/N)?

if your terminal is a VT100 you can respond with either 'Y' or 'N', on any
other terminal the reply should be 'N' (beware, you may lock your terminal if
you reply Y on a non-VT100 terminal).

    If the reply is 'Y' the screen should immediately display a list of single
character commands together with information on the system status and various
parameters (no actual values are displayed at this time). This display will now
remain on the screen and the information will be continually updated, only the
last four lines will now scroll the current terminal I/O.

    If the reply is 'N' the terminal should display the message 'RSRE ELECTRON
BEAM LITHOGRAPHY PROGRAM" followed by the version number and the statement
"TYPE Q TO QUERY MENU".

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• The next question to be displayed is:

COMPUTER CONTROLLED FREQUENCY (Y OR N)?

Answer 'N' if you wish to manually select the exposure frequency (N.B don't forget the console switch). The program will now ask:

SLOW DISTORTION CORRECTION? (Y/N)

Answer 'Y' if you wish to apply slow distortion corrections (See Section 7). The final question should now be displayed:

FAST DISTORTION CORRECTION? (Y/N)

Answer 'Y' if you wish to apply fast distortion corrections (See Section 7). Whatever the response the VT100 display will now fill in the values of the para- meters and the system status information.

If you said yes to computer controlled frequency you will now be asked:

ENTER FREQ IN KHZ(REAL)

following which you should enter the required frequency in kilohertz as a real number (ie with a decimal point).

The terminal should now display the prompt character as follows:

- >

This indicates that the program is ready to accept a command.

If you have the VT100 display a list of acceptable commands is shown in the center of the screen, otherwise a list can be printed on the terminal by typing 'Q'. The action of each command is now considered in turn.

5.1   Command Summary

A   The purpose of the command 'A' is to disable or enable the coarse
       alignment ie if disabled, from then on no attempt to correct positional
       errors (following stage movement for example) will be made.

       On a VT100 terminal coarse alignment will be shown ENABLED or
       DISABLED.DISABLED will be shown in reverse video if the advanced
       video option is present, or underlined if not. On any other terminal
       the message 'COARSE ALIGNMENT DISABLED' or 'COARSE ALIGNMENT ENABLED'
       will be printed.

       The default is ENABLED.

B   The purpose of the command 'B' is similar to 'A' except that its
       effect is to enable/disable the fine alignment which is a further
       attempt at correction after a coarse alignment by making measurements
       over a wider area. The default is ENABLED. Note that fine alignment
       should not be enabled if coarse alignment is disabled.

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C   The effect of the command 'C' is to perform a calibration, which is the calculation of the fast and slow deflection systems scale and angle values for the particular sample being exposed. This will usually need to be done at least once a day or if the type of sample is changed (ie from a glass mask to a silicon slice). This operation will expose the resist and should be performed on a scratch area at the edge of the area to be exposed. A file FAST.DAT is created to hold the values in order that they can be accessed during subsequent runs or by other programs.

         Calibration requires a scratch area (with markers) at least 1mm square.

D   The purpose of the command 'D' is to enable/disable the DEBUG facility. This is mainly provided for 'debugging' during program development but can be very useful to check data input. If DEBUG is enabled various intermediate print-outs provided within the individual modules are activated and displayed on the terminal. In the case of data input if DEBUG is enabled before reading the data a print out of the data arranged in the correct hierarchies is made on channel 6. The default for Debug is DISABLED. If a VT100 terminal is available debug ENABLED is displayed in flashing reverse video until disabled with a further 'D'. Note do not leave debug enabled longer than necessary as a large amount of output may be produced.

E   The purpose of the command 'E' is to expose a pattern (the data for which is assumed to have already been input) on the sample. If the stage motors are disabled a message 'STAGE MOTORS ARE OFF IS THAT OK? (Y/N)' is displayed, the user can respond 'N' in which case the command is cancelled, or 'Y' to continue. (This provides the means to check pattern data without moving the stage). If enabled the program will perform a coarse and fine alignment and then display:

         'EXPOSURE STARTED'

         On RT11 systems an additional facility is available to interrupt an exposure at any time by depressing RETURN followed by 'S' to stop, or 'C' to continue and a message to this effect is output at this stage. At the present time this facility is not available on RSX systems.

         During the exposure a continual display of the current 1mm field of the pattern is drawn on the Tektronix storage scope. At the end of the exposure the message:

         'EXPOSURE FINISHED'

         is displayed.

F   The effect of this command is to terminate the program and return control to the monitor. The stage is returned to the Faraday cage and any VT100 display is erased.

H   This command performs the calculation of the angle between the axes of stage movement and the axes of the transparent marker system. The angle correction is applied manually and the calculation repeated

until a zero correction is obtained. The procedure is not able to cope with large angular errors, these are expected to be corrected visually using the SEM display. Calculation of the angle requires a scratch area of the sample (with markers) 1cm long in either X or Y. Assuming the stage to have been positioned at the start of this area the sequence starts with the following invitation to the user:

STAGE ANGLE TEST, TYPE 1 FOR X, 2 FOR -X, 3 FOR Y, 4 FOR -Y,
0 TO EXIT

The program now expects an integer in the range 1 to 4 to denote the direction in which the stage can move to perform the angle calculation or a 0(zero) to terminate the command. Having been given a direction (1 say) the program performs a coarse alignment then moves 1mm (in X) does another coarse alignment and moves another mm and so on for ten moves. The displacement of the markers at each alignment is summed so that the total displacement (in Y) over a distance of 10mm is known and hence the angular correction can be calculated and is displayed as follows:

DECREASE (or increase) ANGLE READING BY *****

where ***** denotes the actual correction to be applied to the stage angle vernier. Because of slack in the mechanical linkage it is rarely possible to correct exactly the first time and so the program repeats the above message until the user is satisfied and types a zero to exit.

If the sequence stops due to alignment errors examine the sample for marker defects and check the beam current. The stage can be returned to the start position with the 'L' command.

Note that the correction of angular misalignments will result in stage movement and it is necessary therefore to return to the Faraday cage to reset the counters before commencing exposure.

I   The effect of this command is to move the stage in increments from the present position to a specified new position. The difference between this command and the 'N' (new position) command is that alignment takes place after each 1mm of stage movement whereas 'N' is an absolute move which because of stage inaccuracies may be many microns out by the end of the move. Clearly this command can only be used on a sample with transparent markers. The following message is displayed:
MOVE STAGE TO X,Y (REAL).

Enter the coordinates of the new position as real numbers (ie with a decimal point) separated by a comma, for example 40000., 20000.
Failure to include the decimal point will result in an error.

See 'N' command for remaining dialogue and error messages.

K   This command provides the means to change the exposure frequency provided computer control was selected at the start and the manual/computer switch is set to computer. The following message is displayed:

ENTER FREQ IN KHZ(REAL)

Enter a frequency in kilohertz as a real number in the range
0.0 to 1500.0. If a negative or zero number is entered the computer
will reverse the manual/computer selection (ie if frequency control
is set to manual it will be changed to computer control and vice
versa) and the appropriate message will be displayed ie:

MANUAL FREQ CONTROL
or
COMPUTER FREQ CONTROL

If the change is to 'manual' the command is terminated, if to
'computer' the 'enter frequency' message is repeated. If a
frequency grester than 1500.0Khz is requested the message

FREQ OUT OF RANGE: ****.***

is displayed. If an attempt is made to enter a frequency while
manual control is selected the message:

MANUAL FREQ CONTROL

is displayed and the command is terminated.

L   The effect of this command is to move the stage to the coordinates
        of the last position input by a 'N' or 'I' command. The principal
        use of this command is to return the stage to its original position
        following a return to the Faraday cage with a 'Z' command or to
        return to the starting position after an error in the stage angle
        calculation for example. The last position is always shown on the
        VT100 display.

M   The effect of this command is to enable/disable the stage motors.
        When the motors are disabled the stage will not move but the stage
        counters will. This enables pattern data to be checked without
        moving the stage but beware-the stage position will now no longer
        correspond to the stage counters -do a '=' command or reret the
        counters with a 'U' command. On a VT100 display the motor status
        is always displayed, on other terminals the message:

MOTORS ENABLED or MOTORS DISABLED is output.

The default is ENABLED.

N   The effect of this command is to make an absolute stage move from
        the present position to a new position. Unlike the 'I' command no
        alignment takes place. The following invitation is displayed:

MOVE STAGE TO X, Y(REAL)

Enter the X and Y coordinates of the new position as real numbers
separated by a comma. A final opportunity is now offered to check
the position prescribed and that the console motor switch is set to
computer. The program displays:

GO?

to whch the reply is 'G' to make the move. Any other reply will
terminate the command. If 'G' is typed and the motors are still
switched to manual the message:

ARE YOU STILL ON MANUAL?

will be displayed and the command terminated.

O   This command is used to prescribe multilayer offsets and angles, the message

ENTER MULTILAYER OFFSETS AND ANGLES

is displayed and the program expects four real numbers to be input separated by commas. These numbers should be the multilayer offsets in X and Y (in microns), and the multilayer angles in X and Y.

P   The purpose of this command is to enable text to be written directly on slice. To simplify the program the text is restricted to three sizes and is limited to the upper case alphabet, the numerals 0 to 9, space, and the characters (+.=&). The text is further restricted to a 1mm square field without stage movement. The program prompts for the size with the message:

ENTER HEIGHT CODE (1=14, 2=35, 3=70 MICRONS)

and expects one of the integers 1,2 or 3 corresponding to the heights 14,35 or 70 microns. The program is now ready for the text and displays the message:

ENTER TEXT (MAX 100 CHARS)

The required text can now be input up to a maximum of 100 characters on any one line, however the size of the characters imposes a further restriction in that only a certain number can be fitted across the 1mm field. If the width of the field is exceeded the message

1MM EXEEDED IN X, LINE TERMINATED

is printed, and if the depth of field is exceeded the message

1MM EXCEEDED IN Y, MOVE STAGE AND REPEAT

is displayed.

A line of text is terminated by 'RETURN', further lines can then be input until the depth of field is exceeded. The first line of text following a 'P' command starts at the top left of the field. Text can, however, be placed at any position within the field by using spaces, ie a space followed by 'RETURN' will leave a blank line. The command is terminated by typing 'RETURN' without any text.

Q   This command is provided for non-VT100 terminals to show the menu of commands available. The message

SCREEN(5) OR PRINT(6)?

is displayed. Enter 5 to display the menu on your terminal, enter 6 to print (note this will depend on your configuration, in RSX channel 6 is assigned to a serial printer during task build).

R   The effect of this command is to restart the program.

S   The effect of this command is to clear any offsets on the beam and to reset the fast scale and variable gain ratios. On completion the message:

OFFSETS CLEARED

is displayed.

T   The purpose of this command is to input pattern data. The data will already have been input to a file and the program prompts for this name with the following message:

ENTER FILE NAME

A standard file name including extension is expected, the extension will normally (but not necessarily) be .DAT. The file name is restricted to 6 characters in RT11 and 9 in RSX, and may include a device name and, in RSX, a UIC, for example DL1:[2,3] PATTERN.DAT. If the data is successfully read in, the message

DATA IN, NO OF ENTRIES=****

is displayed, where **** is the number if data entries stored. At present this number is restricted to 3000 and if it is exceeded the message:

ERROR-MORE THAN 3000 ENTRIES

is output and the command terminated. If an error is detected during data input the message

DATA READ ERROR, INPUT TERMINATED

is displayed and the command is terminated.

If debug is enabled before the 'T' command a data listing will be produced on channel 6.

U   The purpose of this command is to reset the stage counters. The message:

RESET COUNTERS TO X,Y (REAL)

is output and the program expects the coordinates to which the counters are to be set to be input as real numbers separated by a comma. The error message

ARE YOU STILL ON MANUAL?

is output if the motor switch is not on 'computer'.

V   The purpose of this command is to calculate multilayer offsets and angles from measurements of the position of 'vgroove' markers relative to the transparent markers to enable electron beam

features to be aligned with existing optical features. The offsets are calculated from measurements of groups of five 'vgroove' markers, similar to the transparent markers, arranged as shown in figure 4, in 12 vertical and horizontal groups within a 1mm square. The transparent markers are imprinted (using the 4 crosses shown) so that the vgroove markers lie within the clear areas inbetween the transparent markers. Four groups of markers are provided outside each corner of the active area of the slice.

It is assumed that the stage has been positioned (visually) at the center of one such 1mm field before the command is invoked. The beam is deflected to the first set of vgroove markers and the user invited to centralise the markers by prescribing an X or Y offset to the beam in response to the following messages

     ENTER X OFFSET
and ENTER Y OFFSET

A real offset in microns is expected. The twelve sets of vertical and horizontal vgrooves are now scanned and their respective offsets measured. These offsets (including the prescribed offsets) are displayed and, in conjunction with similar offsets at other positions on the slice, can be used to calculate multilayer offsets and angles for input to EBEAM via the 'O' command.

Figure 4 shows the transparent alignment marker system and the absolute (vgroove) markers on a 1mm field. The four crosses are for transparent marker alignment.

W   The effect of this command is to produce a frequency 'wedge' for exposure tests. Before this command is invoked the manual/computer frequency switch must be set to 'computer'. The program will then draw a series of adjacent rectangles 5 μm wide by 20 μm high, each rectangle being exposed at a different frequency from 1600 KHz to 800 KHz in 5KHz steps. Every 200 μm a 20 μm gap is inserted and markers are exposed along the top and bottom of the rectangles as a guide to the frequency. Three of these 'wedges' are exposed in one 1mm field, the lower wedge is exposed once, the middle twice, and the top four times. Figure 5 is a plot of a frequency wedge within a 1mm field also showing the 100 μm subfields.

Z   The purpose of this command is to move the stage to the position of the Faraday cage (ie 32000., 62000.) or to rest the stage counters to those values. The message

ENABLE MOTORS? (0=NO, 1=YES)

is output and the program expects either a 0 in which case the motors are disabled and only the counters are moved, or 1 in which case both the motors and the counters are moved.

?   This command is included for non-VT100 displays and causes a print out of the current status and parameters to be displayed on the terminal.

■   The effect of this command is to read the stage counters and to display the results on the terminal as follows:

STAGE COUNTERS=*******,*******

If any other characters are typed in response to a prompt the system will display:

PARDON?

and prompt for another command. Various error messages may be produced at any time, some of them have already been mentioned and it is hoped that they are self-explanatory but a list together with probable causes and suggested remedies is given in section 6.

5.2 Illustrative Example

The listing given in Appendix A is the actual decwriter output from a typical exposure on the EBLM-1 running under RSX11M on a PDP 11/44 except that some of the commands have been included purely for demonstration purposes. Prior to running the program the sample to be exposed has been loaded into the machine and the beam current, stage height, focus, etc adjusted as described elsewhere (5). The following is a brief explanation of Appendix A.

Clearly the terminal is not a VT100 and for this example manual frequency control without fast or slow distortion correction has been selected. An '=' is typed to establish the current values of the stage counters (they may take any values when first switched on), an 'S' clears any offsets on the beam and a 'Q' demonstrates the menu table for non-VT100 terminals. The stage will have been moved manually to the Faraday cage in order to set the beam current, it is now necessary to reset the stage counters to 32000., 62000. (the position of the Faraday cage). This could be achieved with either the 'U' or 'Z' commands, in this case 'Z' has been chosen as it requires less typing (no coordinates need be input) with the motors disabled (temporarily). The new values of the stage counters are now checked and the stage is moved so that the beam is positioned over a scrap area of the slice. This is achieved with the 'N' command (in this case to the position 30000,30000) and the stage counters are checked again (note that this is unnecessary on a VT100 terminal as a continual display of the stage counters is shown).

The next task is to align the transparent marker axes with the stage axes using the 'H' command. The integer '1' has been typed in response to the question regarding direction of movement thereby ensuring that the angle check will be made in the positive X direction. Initially the command reports a coarse alignment error and an 'S' is typed to clear any offsets while a check is made on the beam current etc. The command is now retried, this time with success and the stage will be seen to move 10mm in the X direction (in 1mm steps), return to its original position and print out an adjustment which is to be made to the stage rotation vernier. This adjustment is made manually and the angle check restarted by typing another '1'. It is worth noting that the stage rotation is achieved by means of a mechanical linkage which has a certain amount of play in it and it may happen, particularly following a change in direction of rotation, that no change or even an increase in correction is reported until this slack has been taken up. Finally however a zero or very small correction will be reported and a '0' is then typed to terminate the command and return control to the main program.

The offsets are once again cleared and a 'C' typed to commence calibration, in this case the corrections are reduced to below 0.001 within two iterations and the results are output to file. The offsets are cleared again and a move would normally be made to the starting exposure position (with the 'N' command). The exposure pattern data is now input using the 'T' command (a hangover from tape input) followed by the data file name (in this case PATTY.DAT).If the data is correctly input the number of entries will be printed.

The command 'E' is now used to expose the pattern, each 1mm field of which should now be displayed, in turn, on the storage scope. At the end of a successful exposure 'exposure complete' is printed and control is returned to the main program.

The next few commands are included for demonstration purposes, the 'P' command enables the user to print text directly on the slice (eg date, reference numbers etc) with three sizes of text to choose from. In this example the text 'DISPLAY THIS' is printed at the current position in characters 14 microns high. The 'P' command is terminated by pressing RETURN without any text. Switching the coarse alignment on and off is demonstrated with the 'A' command and similar effects are obtained with 'B' and 'M' for the fine alignment and stage motors respectively. Finally the 'F' command terminates the program and returns the stage to the Faraday cage (or resets the counters if the motors are disabled).

6   ERROR MESSAGES

ARE YOU STILL ON MANUAL?

This message may occur whenever an attempt is made to move the stage or alter the stage counters. The probable cause is that the manual/computer switch on the console is still set to 'manual' but it can also be caused by the switch on the SAR unit being set to 'osc' instead of 'computer'.

COARSE ALIGNMENT FAILURE

This error can occur whenever a coarse alignment is performed, ie during exposure, incremental move, stage angle calculation etc. It may be caused by marker imperfections, dirt, unstable beam current, incorrect focus, incorrect height setting. If encountered prior to exposure, control is returned to the main program which prompts for another command, the above suggestions can then be checked before continuing. If encountered during an incremental move the message

X (or Y) MOVE COARSE ALIGNMENT FAILURE NO. n

is displayed where n is the failure number. Up to 3 failures are allowed before the move is halted with the message

3 COARSE ALIGNMENT FAILURES, CONTINUE (Y/N)?

If the response is 'Y' the move will be continued and the message

MOVE RESUMED WITHOUT ALIGNMENT

is output. If the response is 'N' the move is terminated.

If encountered during an angle check the command is terminated. Check focus, markers etc, move to another position and try again.

DATA READ ERROR, INPUT TERMINATED

This message occurs during data input and indicates some sort of read error probably due to a non-numeric character in the data. Examine the data and try again.

DATA ERROR: NO OF ENTRIES=nnnn ATTEMPT TO REFERENCE NO nnn

This error occurs during exposure. Data has been input successfully but contains an error (eg number of rectangles incorrect) the program has attempted to reference a data array element greater than the total number of entries. Check the data and try again.

ERROR IN FAST/SLOW SETUP

This error, which may occur during calibration, terminates the command. It indicates that the program has been unable to find some or all of the transparent markers during the scale and angle set-up. Assuming that the beam is in focus etc, a failure to detect marks is usually due to one of two main reasons: either the marks are not there (because of slice imperfections, processing errors etc) in which case the remedy is to move, or the beam is being deflected to the wrong place. A possible reason for this might be a large angular offset due to not performing a stage angle check prior to calibration.

FINE ALIGN FAIL IN X (or Y)

The program was unable to perform a fine alignment. Usually occurs when a calibration has not been performed for this slice but may be due to faulty markers, dirt on or flaws in the resist or even an unstable beam current. This is a warning and program execution is not halted, if it is continually repeated however, exposure should be halted and the above possibilities investigated.

FAST DISIN COEFFS TOO LARGE
nnnnn nnnnn nnnnn nnnnn nnnnn nnnnn nnnnn nnnnn

The fast distortion coefficients are used to correct for angular differences between the axes of the fast and slow deflection systems as well as for fast distortions. As only one byte (8 bits) is available for each coefficient, there is a limit on the amount of correction that can be made. The fast angle correction is also affected by changes in the slow angle. This warning may be caused by a local irregularity on the slice (eg height change) but if it persists is probably an indication that a calibration is required, go to a scratch area and perform a calibration. On a VT100 display this error will be indicated by flashing the coefficients and by LIMITS EXCEEDED.

FREQUENCY OUT OF RANGE nnnnnn.nnn

This error occurs if an attempt is made to enter a frequency outside the range 0 to 1600 KHz. Use the 'K' command to input a valid frequency.

PARDON?

This message occurs when an unrecognised command is typed. Check against the menu of commands and retype.

SLOW SET-UP FAILED ON PATTERN NO. nn

This error occurs during slow set-up in calibration. The pattern referred to is the pattern of measurements taken which is repeated a number of times at increasing distances from the center to give increasing accuracy. Pattern number one therefore is the innermost pattern, pattern number two is the same pattern increased by 100 μm in X and Y and so on. The cause may well be marker damage (towards the outside of the area, if nn > 1) or initial values of scale and angle that are wildly out (unlikely if nn > 1). Check stage height etc or move to another area and try again.

STAGE COORD OUT OF RANGE: nnnnnn.n nnnnnn.n

If this error occurs the stage has been asked to move outside the range 9000.0 to 62000.0 in X and 10000.0 to 64000.0 in Y. The probable cause is either mistyping or failure to coordinate the actual stage position with the stage counters. The remedy is in the one case to retype the coordinates and in the other to move the stage manually to the Faraday cage and reset the counters with the 'Z' or 'U' commands.

STAGE ERROR, TRY AGAIN
STAGE ERROR IN ANGLE
STAGE ERROR (ON MANUAL)
STAGE ERROR - TYPE CR TO CONTINUE

See 'ARE YOU STILL ON MANUAL' comments. This error may occur in several modules and in general the command is cancelled and a prompt for another command displayed unless the message indicates otherwise - for example TYPE CR TO CONTINUE permits continuation after checks have been made by pressing 'RETURN' (CR) (Not RSX).

WARNING:VGAIN RATIO OUT OF RANGE nnn.n nnn.n NO CHANGE MADE

This warning will occur if an attempt is made to set a variable gain ratio outside the range 0.5 to 1.0. The ratios remain unchanged.

WARNING:CURRENT FLUCTUATION > 10% UP {or DOWN}

This warning may occur if computer frequency control is selected. Beam current readings are monitored and the above warning is printed if the current fluctuates by more than 10%. Execution is not interrupted, adjust the final lens control on the console as appropriate until the message is no longer printed.

7   DISTORTION CORRECTION

The following sub-sections describe the additional programs required to calculate the look-up tables for the slow and fast distortion corrections. These programs have not been provided as facilities within EBEAM because, unlike calibration, distortion corrections are dependent only on the electron optics and should not vary unless any adjustments or alterations are made to the lens systems. They will therefore be required only infrequently.

7.1   Slow Distortion Correction

Distortions in the slow deflection system are corrected by means of look-up tables (Ref 2), ie whenever a deflection is made to a particular

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subfield corresponding corrections are extracted from the tables and added to the X and Y components of the deflection. These distortion corrections are measured using the transparent markers technique with a program called SDCORR which outputs them to files named XDISTN.TAB and YDISTN.TAB. These files remain until overwritten by further runs of SDCORR and are read by EBEAM if slow distortion correction is requested.

In order to perform a slow distortion correction a slice imprinted with the transparent markers must be used. The stage is moved to a scratch area on the slice at least 1mm square and the program invoked with the command:

        R SDCORR

under RT11

or   INS SDCORR
        RUN SDCORR

under RSX-11M. Note that compilation of SDCORR is included in FORCOM but linking and task building is performed by:

        SDLINK.COM for RT11
and   SDTASK.CMD for RSX-11M.

The file FAST.DAT is also required.

The program displays the following message

SLOW DISTORTION CORRECTION
TYPE NUMBER OF REPEATS? NREP (-NREP FOR DEBUG,0 TO STOP)

The user should now enter an integer number of times the slow distortion measurements should be made, these results are then averaged. A negative number of repeats will produce a considerable amount of diagnostic output, and a zero value will terminate the program. Three repeats is generally found to be quite adequate. Throughout the calculation the measurements at each stage are recorded in a disc file SLOWDC.LST which may be printed if required at the end of the program.

Prior to the slow distortion calculation a coarse alignment is performed, followed, if successful, by a fine alignment. See section 6 for corrective action following an error report from either of these. The program now calculates the X and Y offsets for each subfield, these offsets are then added to the slow amplifier deflections and the calculations repeated until the offsets are less than 0.1 microns. The total offsets are then stored in the files XDISTN.TAB and YDISTN.TAB to be accessed by EBEAM.

If after applying three sets of corrections the offsets are still greater than 0.1 microns an error message:

        n PASSES WITH NO CONVERGENCE, CONTINUE? (Y/N)

is displayed. If the reply 'N' is entered the program is terminated, if the reply 'Y' is entered the calculation continues. It is suggested that if 5 or 6 passes are made without convergence the program should be terminated and the stage moved to another position for a further attempt.

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If the program is successful the message

OUTPUT TO FILE? (Y/N)

is displayed. The reply 'Y' will overwrite the existing files XDISTN.TAB
and YDISTN.TAB with the new values, the reply 'N' will leave them unchanged.

Finally, the message

PRINT SLOWDC.LST FOR COMPLETE LISTING

is displayed as a reminder that a record of the displacements at each pass
can be printed if required.

A further error message may occur during the calculations, ie

>10 ERRORS DETECTED IN DISCOR

followed by

TOO MANY ERRORS

This error indicates that the program was unable to detect the
markers at more than ten positions and is probably due to marker imperfec-
tions in a particular area. Control is returned to the beginning of the
program to allow for a manual stage movement to a more consistent area.

7.2 Fast Distortion Correction

Distortions in the 'fast' deflection system are corrected by means
of best fit quadratics in X and Y (Ref 2). Individual polynomials are
calculated for each subfield within a 1mm field and are stored, in the
form of coefficients for the distortion correction unit, in the file
FASTDC.DAT for access by EBEAM. Once again a scratch area of at least 1mm
square with transparent marker is required. The program is invoked by the
command

R FDCORR

under RT11, and

INS FDCORR
RUN FDCORR

under RSX-11M. The program is compiled by FORCOM but linking and task
building is performed by

FDLINK.COM for RT11
FDTASK.CMD for RSX-11M

The files FAST.DAT,XDISTN.TAB and YDISTN.TAB are also required.

The program displays the following message

ENTER NUMBER OF REPEATS

Enter the integer number of times the measurements are to be made and averaged. Throughout the calculation the measurement are recorded and stored in a file FASTDC.LST which can be printed later if required. Prior to the measurements a coarse alignment and fine alignment are performed and slow distortion corrections are input from the files XDISTN.TAB and YDISTN.TAB. A coarse alignment error will terminate the program - see section 6 for possible causes and corrective measures. During the calculations the following warning message may occur.

ERROR IN X(or Y) FAST DISTORTION. ID,JD=nnnnnn nnnnnn

where ID and JD indicate marker positions in the 1mm field. The program is not terminated but if very many warnings occur the program should be aborted and the stage moved to a new position. At the end of the calculation the message

OUTPUT to FILE? (Y/N)

is displayed. The reply 'Y' will overwrite any existing file FASTDC.DAT with the new values, the reply 'N' will leave them unchanged. Finally the message

PRINT FASTDC.LST FOR COMPLETE LISTING

is displayed as a reminder that a record of the distortion coefficients can be printed if required.

REFERENCES

1   A C Prior, Some Compensation Techniques for Electron Beam Microfabrication, Microcircuit Engineering 1978.

2   V J Mifsud, Automatic Alignment and calibration on an Electron-beam microfabricator using the RSRE transparent alignment marker technique, Unpublished MOD(PE) Report.

3   V J Mifsud, B C Merrifield, A simple data input format for an Electron-beam Lithography machine. RSRE MEMO No 3361 June 1981.

4   Digital Equipment Co. PDP-11 Processor Handbook.

5   S H Mortimer, Operating Instructions for the EBLM1. Unpublished Internal Memorandum.

APPENDIX A

Sample Output

```
RUN  EBEAM
>
 IS TERMINAL A VT100?(Y/N) N
RSRE ELECTRON BEAM LITHOGRAPHY PROGRAM,RSX-VERSION    1.9

          TYPE Q TO QUERY MENU



COMPUTER CONTROLLED FREQUENCY?(Y OR N) N
SLOW DISTORTION CORRECTION?(Y/N)N
FAST DISTORTION CORRECTION?(Y/N)N
->=
STAGE COUNTERS=    14184.0    61471.0
->S
OFFSETS CLEARED
->Q
SCREEN(5) OR PRINT(6)? 6
          MENU TABLE FOR EBEAMX

A=COARSE ALIGNMENT(DEFAULT ON)P=PRINT TEXT
B=FINE ALIGNMENT(DEFAULT ON)  Q=QUERY MENU
C=CALIBRATION                 R=RESTART
D=DEBUG SWITCH                S=CLEAR OFFSETS
E=EXPOSE PATTERN              T=ENTER DATA
F=FINISH                      U=RESET COUNTERS
G=                            V=VGROOVE MEASUREMENTS
H=STAGE ANGLE                 W=FREQUENCY WEDGE
I=INCREMENTAL MOVE            X=
J=                            Y=
K=CHANGE FREQUENCY            Z=MOVE TO FARADAY CAGE
L=MOVE TO LAST POSITION       @
M=MOTOR STATUS(DEFAULT ON)    ?=CURRENT STATUS
N=MOVE TO NEW POSITION        '='=STAGE POSITION
O=OFFSETS (MULTILAYER)

->?
ENABLE MOTORS? (0=NO,1=YES)0
OH MASTER,ARE YOU STILL ON MANUAL?
->?
ENABLE MOTORS? (0=NO,1=YES)0
->=
STAGE COUNTERS=    32000.0    62000.0
->N
MOVE STAGE TO X,Y (REAL)30000.,30000.
60?6
->=
STAGE COUNTERS=    30000.0    30000.0
->H
STAGE ANGLE TEST ,TYPE 1 FOR X,2 FOR -X,3 FOR Y,4 FOR -Y ,0 TO EXIT  1
COARSE ALIGNMENT ERROR IN ANGLE
->S
OFFSETS CLEARED
```

```
->H
STAGE ANGLE TEST ,TYPE 1 FOR X,2 FOR -X,3 FOR Y,4 FOR -Y ,0 TO EXIT   1
DECREASE ANGLE READING BY    1.47
STAGE ANGLE TEST ,TYPE 1 FOR X,2 FOR -X,3 FOR Y,4 FOR -Y ,0 TO EXIT   1
DECREASE ANGLE READING BY    1.97
STAGE ANGLE TEST ,TYPE 1 FOR X,2 FOR -X,3 FOR Y,4 FOR -Y ,0 TO EXIT   1
DECREASE ANGLE READING BY    0.37
STAGE ANGLE TEST ,TYPE 1 FOR X,2 FOR -X,3 FOR Y,4 FOR -Y ,0 TO EXIT   1
INCREASE ANGLE READING BY    0.00
STAGE ANGLE TEST ,TYPE 1 FOR X,2 FOR -X,3 FOR Y,4 FOR -Y ,0 TO EXIT   0
->S
OFFSETS CLEARED
->C
CALIBRATION STARTED
SLOW SET-UP SUCCESSFUL
ANGLE SETUP COMPLETE,MOVE IN X;MEASURE IN Y
IFA=  0 ANGLE CORRECTION=  0.4731E-03
ANGLE SETUP COMPLETE,MOVE IN Y;MEASURE IN X
IFA=  0 ANGLE CORRECTION= -0.3417E-03
SCALE SETUP COMPLETE, IN Y, IFA=   0
SCALE SETUP COMPLETE, IN X, IFA=   0
FAST/SLOW ANGLE=     0.4702E-03     0.2371E-02
LAST CORRECTIONS=    0.4731E-03    -0.3417E-03
VGAIN RATIOS=  0.7260  0.7941
ANGLE SETUP COMPLETE,MOVE IN X;MEASURE IN Y
IFA=  0 ANGLE CORRECTION=  0.4676E-04
ANGLE SETUP COMPLETE,MOVE IN Y;MEASURE IN X
IFA=  0 ANGLE CORRECTION= -0.9377E-04
SCALE SETUP COMPLETE, IN Y, IFA=   0
SCALE SETUP COMPLETE, IN X, IFA=   0
FAST/SLOW ANGLE=     0.4234E-03     0.2277E-02
LAST CORRECTIONS=    0.4676E-04    -0.9377E-04
VGAIN RATIOS=  0.7262  0.7941
OUTPUT TO FILE? (Y/N) Y
PRINT CALIBR.LST FOR COMPLETE LISTING
->S
OFFSETS CLEARED
->T
ENTER FILE NAME  PATTY.DAT
DATA IN,NO OF ENTRIES=   766
->E
EXPOSURE STARTED
EXPOSURE COMPLETE
->P
ENTER HEIGHT CODE (1-14,2-35,3-70 MICRONS) 1
ENTER TEXT (MAX 100 CHARS)
DISPLAY THIS
ENTER TEXT (MAX 100 CHARS)

->A
COARSE ALIGNMENT DISABLED
->A
COARSE ALIGNMENT ENABLED
->E
ENABLE MOTORS? (0=NO,1=YES)1
 BREAK  --  STOP
```

Figure 1a. VT100 Display on RT11 System (Without Advanced Video Option)

Figure 1b. VT100 Display on RSX-11M System (With Advanced Video Option)

FIGURE 2 SIMPLIFIED SCHEMATIC DIAGRAM OF THE EBLM-1

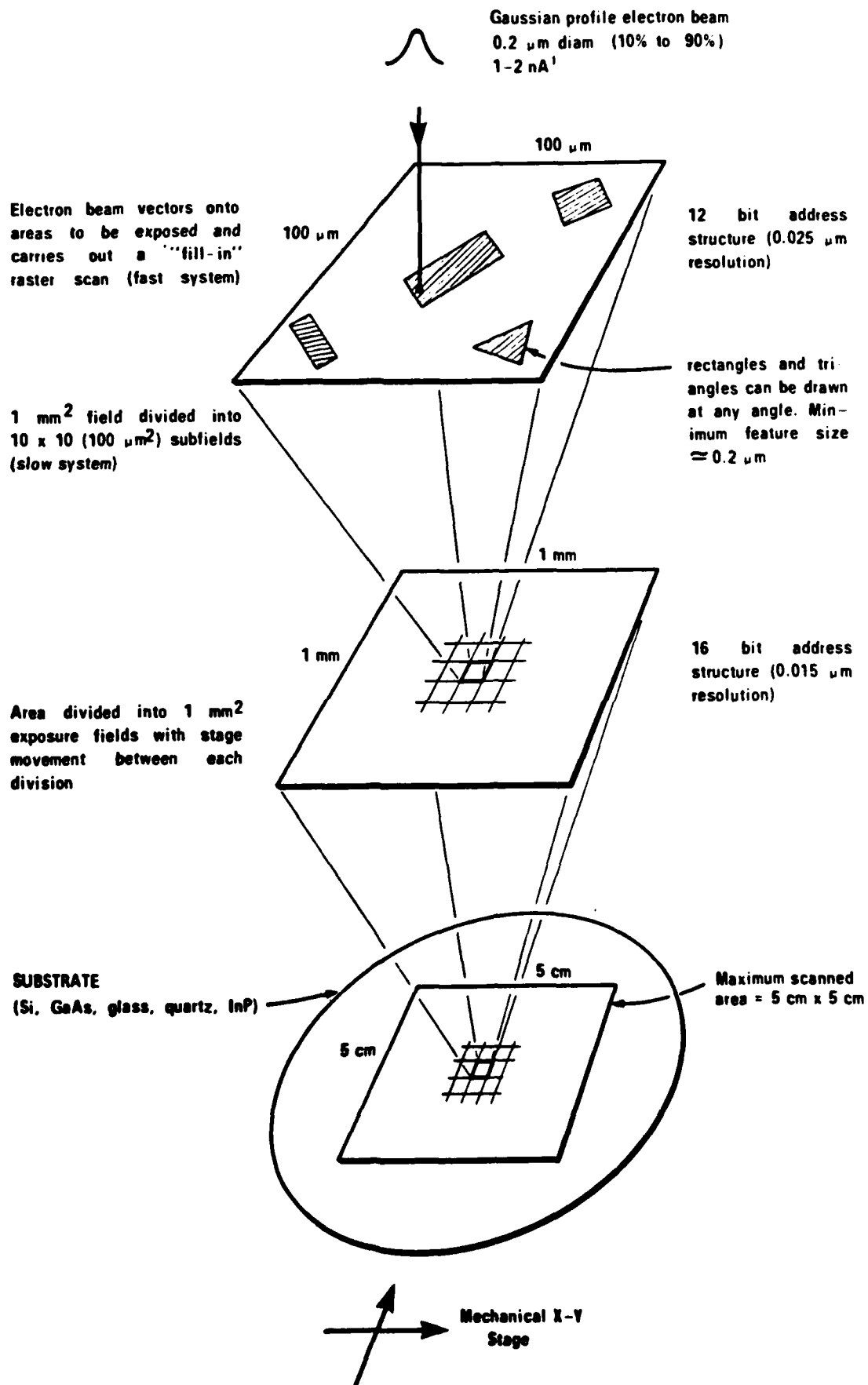Gaussian profile electron beam
0.2 μm diam (10% to 90%)
1-2 nA

100 μm

Electron beam vectors onto areas to be exposed and carries out a "fill-in" raster scan (fast system)

100 μm

12 bit address structure (0.025 μm resolution)

1 mm² field divided into 10 x 10 (100 μm²) subfields (slow system)

rectangles and triangles can be drawn at any angle. Minimum feature size ≃ 0.2 μm

1 mm

1 mm

16 bit address structure (0.015 μm resolution)

Area divided into 1 mm² exposure fields with stage movement between each division

SUBSTRATE
(Si, GaAs, glass, quartz, InP)

5 cm

Maximum scanned area = 5 cm x 5 cm

5 cm

Mechanical X-Y Stage

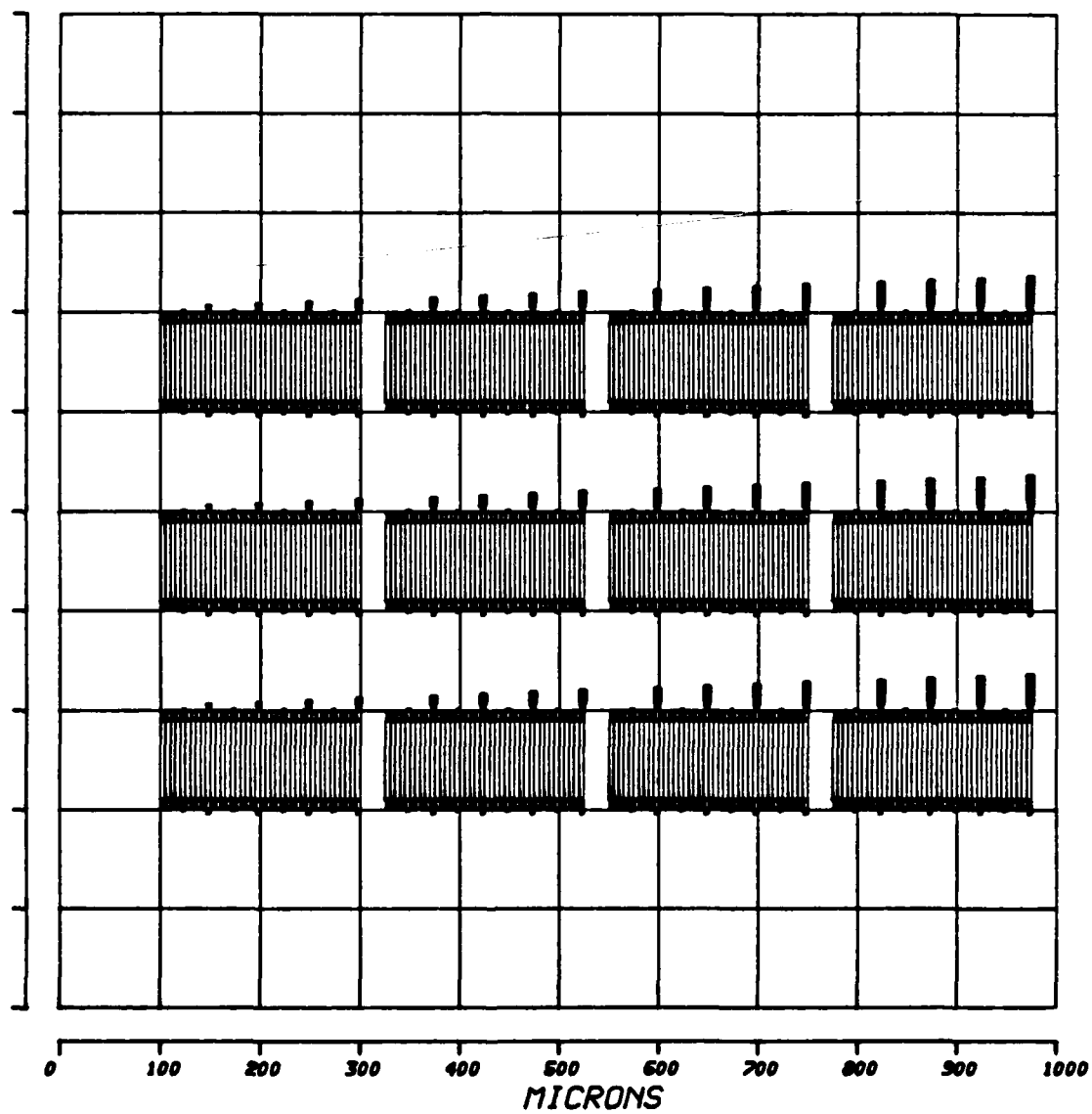FIGURE 3 SCHEMATIC OF EXPOSURE TECHNIQUE

MICRONS

FIG.4 FREQUENCY WEDGE PATTERN
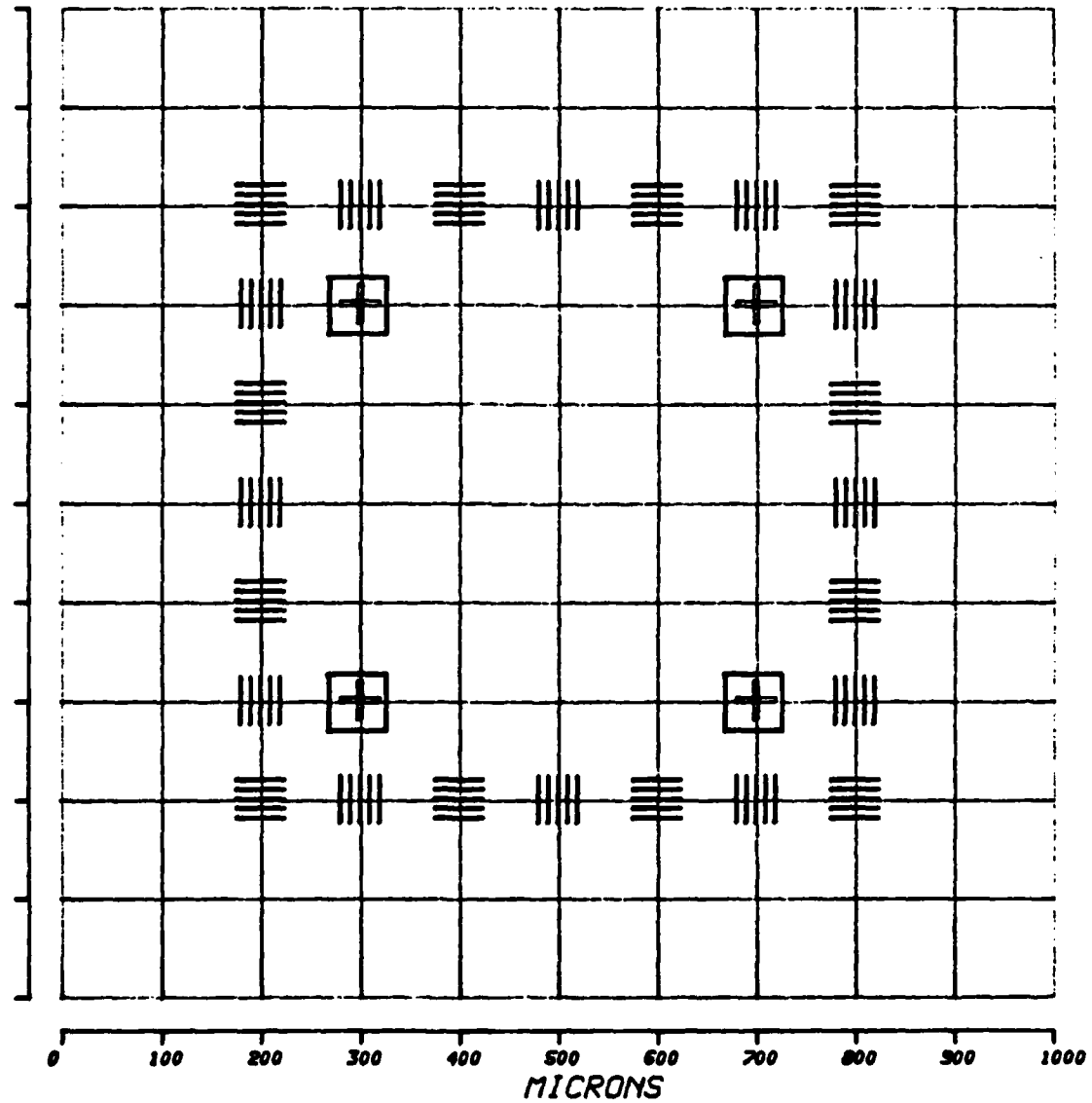
DATA FILE NAME: ABSAL.DAT

ON 05-OCT-82

LIST NO.0

FIG.5 ABSOLUTE ALIGNMENT (VGROOVE) PATTERN

END

DATE
FILMED

3-83

DTIC