MAST Soft X-Ray Cameras

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This manual documents the MAST Soft X-Ray Cameras. It is available in html (http://fuslpcjs.fusion.-culham.ukaea.org.uk/sxr/doc/manual/html/index.html)and pdf formats, generated from xml source.

The document tree is stored in a Subversion repository. You can check it out, edit the source and check changes back in, and the html and pdf files will be regenerated. To check out the document tree under Linux do

```
svn co http://fuslpcjs/repos/jstorrs/trunk/sxr/
```

This will create a subdirectory called sxr in your current directory, containing the tree. To check in changes to the xml files do

```
svn ci
```

For further information about Subversion see this tutorial (http://fuslpcjs.fusion.culham.ukaea.org.-uk/tutorials/subversion/html/index.html). If you want to generate the html and pdf files in your own workspace, see the Practical XML (http://fuslpcjs.fusion.culham.ukaea.org.uk/tools/practicalxml/-doc/html/index.html) documentation.

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1 Introduction

Soft X-ray (SXR) diagnostic techniques provide a valuable tool to investigate many properties of plasmas in fusion devices. Applications vary from very simple analysis of line integrated SXR emission allowing for example the determination of the position of the inversion radius associated with saw-tooth crashes to more sophisticated tomographic reconstructions of the shape of the magnetic surfaces inside the plasma.

This document gives details of the SXR cameras on MAST. A schematic of lines of sight and a table of main parameters is provided for each camera. Camera parameters are also available in a C include file and an IDL data file, generated from xml source. They can be used by anyone to develop software tools for the analysis of SXR measurements. The files can be downloaded from the Configuration page.

MAST is equipped with six SXR cameras. Each camera is based on the principle of the pin-hole camera (for a fun introduction to pin-hole cameras see for example Wikipedia (http://en.wikipedia.-org/wiki/Pinhole_camera) and links within). It has no focusing optics and is essentially made of a slit and an array of silicon photo-diodes that generate a current when illuminated by photons. The slit is equipped with a beryllium foil to stop the low-energy (<1keV) part of the electromagnetic spectrum and each photo-diode collect the radiation from a specific line of sight across the plasma.

Four of the MAST cameras are situated at sector 12. Two of them sit at the mid-plane port (upper and lower horizontal cameras), one is at the inner top port (outer vertical camera) and another at the outer top port (inner vertical camera). All these cameras have lines of sight lying on the poloidal cross-section of the plasma.

Two more camera are situated at the mid-plane port sector 2. One is similar to the two horizontal cameras (third horizontal camera) with lines of sight lying on the poloidal cross section of the plasma, whereas the other has lines of sight lying in the equatorial plane of the plasma (tangential camera). Because of the limited number of acquisition channels available, until now data where collected either from the third horizontal or from the tangential camera. It is in the plans to increase the number of acquisition channels and start to routinely collect data from both cameras at the same time.

1.1 References

A very nice and instructive paper about SXR tomography on JET is:

Granetz and Smeulders, X-ray tomography on JET, Nuclear Fusion 28 457.

More general introduction to the physics of SXR emission from plasmas can be found in:

Hutchinson, Principle of plasma diagnostics (second ed.), section 5.3, Cambridge university press, 2002.

Presentations on the MAST SXR cameras can be found here:

Turri (2004)

Garzotti (2008)

2 Configuration

2.1 XML Configuration File

Camera configuration data is defined centrally in an XML file. This is processed to generate documentation and code files for use in analysis programs.

2.2 C Binding

A C include file is generated from the XML configuration file. You can include it in your program to use the up-to-date structures defined in it. A small C test program is also provided.

2.3 IDL Binding

The IDL data file is called sxr.dat . If you want to use the information in this file you will have first to download it by clicking on the link. Since Windows will try to save it as an mpg file named sxr.mpg, on saving the file you will have to rename it sxr.dat. You can then restore it in you IDL session by typing:

```
IDL> restore,'sxr.dat'
```

You will then end up with six structures: UH, LH, IV, OV, TH, TA containing the parameters of the upper horizontal, lower horizontal, inner vertical, outer vertical, third horizontal and tangential camera respectively. You can inspect the content of these structures by typing:

```
IDL> help
% At $MAIN$
IV              STRUCT    = -> <Anonymous> Array[1]
LH              STRUCT    = -> <Anonymous> Array[1]
OV              STRUCT    = -> <Anonymous> Array[1]
TA              STRUCT    = -> <Anonymous> Array[1]
TH              STRUCT    = -> <Anonymous> Array[1]
UH              STRUCT    = -> <Anonymous> Array[1]
Compiled Procedures:
    $MAIN$

Compiled Functions:
```

To see the details of each structure (e. g. IV corresponding to the inner vertical camera) type:

```
IDL> more,IV
 IV                              STRUCT    = -> <Anonymous> Array[1]
   ID                            STRING    = 'IV'
   NAME                          STRING    = 'Inner Vertical Camera'
```

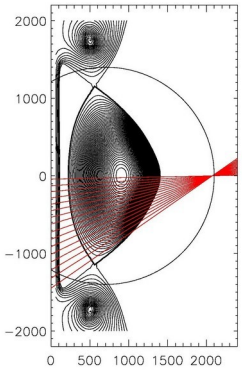
```
FIGURE                          STRING    = 'iv.jpg'
SECTOR                          INT       =       12
PORT                            STRING    = 'TO'
VIEW                            STRING    = 'Poloidal'
SLIT_WIDTH                      FLOAT     =       1.00000
SLIT_HEIGHT                     FLOAT     =       3.00000
DIODE_DISTANCE                  FLOAT     =       62.0000
FOIL_MATERIAL                   STRING    = 'Be'
FOIL_THICKNESS                  FLOAT     =       15.0000
DIODE_ARRAY                     STRING    = 'Centronics L35-5T'
DIODE_COUNT                     INT       =       12
DIODE_WIDTH                     FLOAT     =      0.960000
DIODE_HEIGHT                    FLOAT     =       4.60000
POLE_R                          FLOAT     =       700.000
POLE_Z                          FLOAT     =       0.00000
COMMENT                         STRING    = 'Camera description.'
CHANNELS                        STRUCT    = -> CHANNEL Array[12]
  ID                            INT       = Array[12]
  NAME                          STRING    = Array[12]
  R1                            FLOAT     = Array[12]
  Z1                            FLOAT     = Array[12]
  R2                            FLOAT     = Array[12]
  Z2                            FLOAT     = Array[12]
  P                             FLOAT     = Array[12]
  PHI                           FLOAT     = Array[12]
  COMMENT                       STRING    = Array[12]
```

The content of each field should be self explanatory, but if in doubt you can ask the RO. It is worth mentioning that, for each element of the structure array CHANNELS, (R1,Z1) and (R2,Z2) are the coordinates in the R-Z plane of two points identifying the line of sight of that particular channel, P is the impact parameter with respect to the pole identified by the coordinates (POLE_R,POLE_Z) and PHI is the angle between the Z=0 axis and the line passing through the pole and perpendicular to that line of sight. These quantities are useful for the tomographic inversion of the SXR signals (see paper by Granetz and Smeulders below). Note also that if you want the parameters P and PHI with respect to a different pole you will have to recalculate them starting from (R1,Z1) and (R2,Z2).

For the tangential camera the situation is sligthly different, since the line of sight lie on the machine midplane, instead of on a poloidal cross section. For the tangential camera we have defined a reference frame R-Z where the origin is the centre of the machine, the R axis is the axis separating sector three and sector four and the Z axis is the axis separating sector twelve and sector one.

3 Upper Horizontal Camera

Looks at the plasma below the equatorial plane from the low field side of the machine.



3.1 Camera Details

id	UH
sector	12
port	HM
view	Poloidal
slit width	1.0
slit height	3.0
diode distance	50.0
foil material	Be
foil thickness	12.5
diode array	Centronics L35-5T
diode count	18
diode width	0.96
diode height	4.60
pole R	700.0
pole Z	0.0

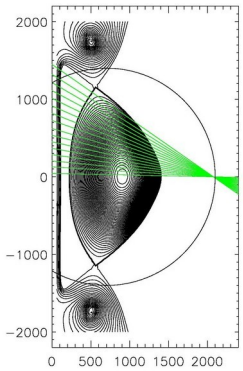
3.2 Channel Details

name	**r1 mm**	**z1 mm**	**r2 mm**	**z2 mm**	**p mm**	**theta rad**	**comment**
XSX_HCAMU#1	0.0	0.0	0.0	0.0	0.0	0.0	Channel viewing slightly above midplane.
XSX_HCAMU#2	196.0	-39.5	2076.0	0.0	28.9	4.733	SXR emissivity - Centrally viewing channel.
XSX_HCAMU#3	196.0	-115.7	2076.0	0.0	84.5	4.774	

name	r1 mm	z1 mm	r2 mm	z2 mm	p mm	theta rad	comment
XSX_HCAMU#4	196.0	-186.0	2076.0	0.0	135.5	4.811	
XSX_HCAMU#5	196.0	-258.0	2076.0	0.0	187.1	4.849	
XSX_HCAMU#6	196.0	-331.0	2076.0	0.0	239.1	4.887	
XSX_HCAMU#7	196.0	-407.2	2076.0	0.0	291.1	4.926	
XSX_HCAMU#8	196.0	-484.7	2076.0	0.0	343.5	4.965	
XSX_HCAMU#9	196.0	-564.0	2076.0	0.0	395.4	5.004	
XSX_HCAMU#10	196.0	-657.2	2076.0	0.0	454.1	5.049	
XSX_HCAMU#11	196.0	-741.0	2076.0	0.0	504.6	5.088	
XSX_HCAMU#12	196.0	-827.0	2076.0	0.0	554.1	5.127	
XSX_HCAMU#13	196.0	-915.5	2076.0	0.0	602.4	5.166	
XSX_HCAMU#14	196.0	-1006.2	2076.0	0.0	649.3	5.204	
XSX_HCAMU#15	202.7	-1095.5	2076.0	0.0	694.6	5.242	
XSX_HCAMU#16	243.0	-1165.3	2076.0	0.0	738.2	5.279	
XSX_HCAMU#17	280.0	-1253.0	2076.0	0.0	787.3	5.322	Extreme lower channel.
XSX_HCAMU#18	0.0	0.0	0.0	0.0	0.0	0.0	Blanked passive channel.

4 Lower Horizontal Camera

Looks at the plasma above the equatorial plane from the low field side of the machine.



4.1 Camera Details

id	LH
sector	12

port	HM
view	Poloidal
slit width	1.0
slit height	3.0
diode distance	50.0
foil material	Be
foil thickness	12.5
diode array	Centronics L35-5T
diode count	18
diode width	0.96
diode height	4.60
pole R	700.0
pole Z	0.0

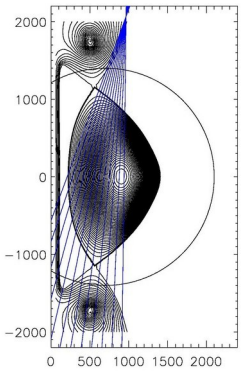
4.2 Channel Details

name	**r1 mm**	**z1 mm**	**r2 mm**	**z2 mm**	**p mm**	**theta rad**	**comment**
XSX_HCAML#1	0.0	0.0	0.0	0.0	0.0	0.0	Channel viewing slightly below midplane.
XSX_HCAML#2	196.0	39.5	2076.0	0.0	28.9	1.550	SXR emissivity - Centrally viewing channel.
XSX_HCAML#3	196.0	115.7	2076.0	0.0	84.5	1.509	
XSX_HCAML#4	196.0	186.0	2076.0	0.0	135.5	1.472	
XSX_HCAML#5	196.0	258.0	2076.0	0.0	187.1	1.434	
XSX_HCAML#6	196.0	331.0	2076.0	0.0	239.1	1.396	
XSX_HCAML#7	196.0	407.2	2076.0	0.0	291.3	1.358	
XSX_HCAML#8	196.0	484.7	2076.0	0.0	343.5	1.318	
XSX_HCAML#9	196.0	564.0	2076.0	0.0	395.4	1.279	
XSX_HCAML#10	196.0	657.2	2076.0	0.0	454.1	1.235	
XSX_HCAML#11	196.0	741.0	2076.0	0.0	504.6	1.195	
XSX_HCAML#12	196.0	827.0	2076.0	0.0	554.1	1.156	
XSX_HCAML#13	196.0	915.5	2076.0	0.0	602.4	1.118	
XSX_HCAML#14	196.0	1006.2	2076.0	0.0	649.3	1.079	
XSX_HCAML#15	202.7	1095.5	2076.0	0.0	694.6	1.042	
XSX_HCAML#16	243.0	1165.3	2076.0	0.0	738.2	1.005	

name	r1 mm	z1 mm	r2 mm	z2 mm	p mm	theta rad	comment
XSX_HCAML#17	280.0	1253.0	2076.0	0.0	787.3	0.962	Extreme upper channel
XSX_HCAML#18	0.0	0.0	0.0	0.0	0.0	0.0	Blanked passive channel.

5 Inner Vertical Camera

Looks at the plasma high field side and core from the top of the machine.



5.1 Camera Details

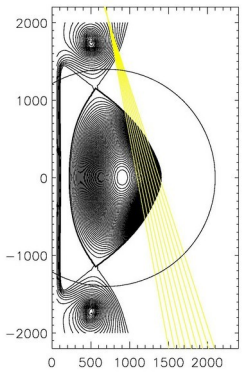
id	IV
sector	12
port	TO
view	Poloidal
slit width	1.0
slit height	3.0
diode distance	62.0
foil material	Be
foil thickness	15.0
diode array	Centronics L35-5T
diode count	12
diode width	0.96
diode height	4.60
pole R	700.0
pole Z	0.0

5.2 Channel Details

name	r1 mm	z1 mm	r2 mm	z2 mm	p mm	theta rad	comment
XSX_V_STE29_1	966.1	2068.4	207.3	0.0	462.6	2.790	Innermost channel.
XSX_V_STE29_2	966.1	2068.4	278.3	0.0	400.2	2.821	
XSX_V_STE29_3	966.1	2068.4	348.4	0.0	336.9	2.851	
XSX_V_STE29_4	966.1	2068.4	417.6	0.0	273.0	2.882	
XSX_V_STE29_5	966.1	2068.4	485.8	0.0	208.6	2.913	
XSX_V_STE29_6	966.1	2068.4	553.2	0.0	144.0	2.945	
XSX_V_STE29_7	966.1	2068.4	620.4	0.0	78.5	2.976	
XSX_V_STE29_8	966.1	2068.4	686.0	0.0	13.9	3.007	
XSX_V_STE29_9	966.1	2068.4	750.8	0.0	50.5	6.179	
XSX_V_STE29_10	966.1	2068.4	814.8	0.0	114.5	6.210	
XSX_V_STE29_11	966.1	2068.4	877.9	0.0	177.7	6.241	
XSX_V_STE29_12	966.1	2068.4	940.3	0.0	240.3	6.271	

6 Outer Vertical Camera

Looks at the plasma low field side edge from the top of the machine.



6.1 Camera Details

id	VO
sector	12
port	TC
view	Poloidal
slit width	1.0
slit height	8.0
diode distance	120.0

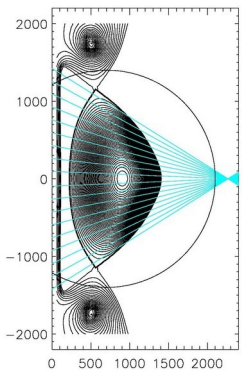
foil material	Be
foil thickness	15.0
diode array	Centronics L35-5T
diode count	12
diode width	0.96
diode height	4.60
pole R	700.0
pole Z	0.0

6.2 Channel Details

name	**r1 mm**	**z1 mm**	**r2 mm**	**z2 mm**	**p mm**	**theta rad**	**comment**
XSX_V_STE36_1	712.9	2071.8	1381.3	0.0	648.4	0.312	Outermost channel.
XSX_V_STE36_2	712.9	2071.8	1344.7	0.0	616.7	0.296	
XSX_V_STE36_3	712.9	2071.8	1308.3	0.0	584.6	0.280	
XSX_V_STE36_4	712.9	2071.8	1272.2	0.0	552.4	0.264	
XSX_V_STE36_5	712.9	2071.8	1236.5	0.0	520.1	0.248	
XSX_V_STE36_6	712.9	2071.8	1201.0	0.0	487.7	0.231	
XSX_V_STE36_7	712.9	2071.8	1165.5	0.0	454.8	0.215	
XSX_V_STE36_8	712.9	2071.8	1131.8	0.0	423.2	0.200	
XSX_V_STE36_9	712.9	2071.8	1095.9	0.0	389.3	0.183	
XSX_V_STE36_10	0.0	0.0	0.0	0.0	0.0	0.0	Blinded by divertor.
XSX_V_STE36_11	0.0	0.0	0.0	0.0	0.0	0.0	Blinded by divertor.
XSX_V_STE36_12	0.0	0.0	0.0	0.0	0.0	0.0	Blinded by divertor.

7 Third Horizontal Camera

Looks at the whole plasma from the low field side of the machine. Located at the same toroidal location as the tangential camera.



7.1 Camera Details

id	HT
sector	2
port	HM
view	Poloidal
slit width	1.0
slit height	3.0
diode distance	50.0
foil material	Be
foil thickness	15.0
diode array	Centronics L35-5T
diode count	18
diode width	0.96
diode height	4.60
pole R	700.0
pole Z	0.0

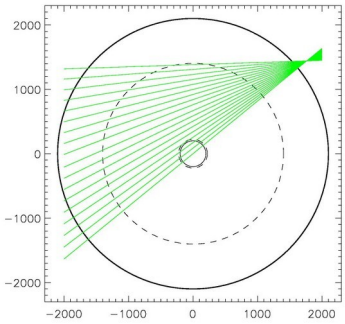
7.2 Channel Details

name	**r1 mm**	**z1 mm**	**r2 mm**	**z2 mm**	**p mm**	**theta rad**	**comment**
XSX_HPZR_1	277.0	-1249.0	2264.0	0.0	832.3	5.274	Extreme lower channel.
XSX_HPZR_2	222.0	-1134.0	2264.0	0.0	759.3	5.219	
XSX_HPZR_3	198.0	-998.0	2264.0	0.0	680.3	5.162	
XSX_HPZR_4	198.0	-846.0	2264.0	0.0	592.7	5.101	
XSX_HPZR_5	198.0	-694.0	2264.0	0.0	498.0	5.036	

name	r1 mm	z1 mm	r2 mm	z2 mm	p mm	theta rad	comment
XSX_HPZR_6	198.0	-542.0	2264.0	0.0	396.9	4.969	
XSX_HPZR_7	198.0	-390.0	2264.0	0.0	290.1	4.899	
XSX_HPZR_8	198.0	-239.0	2264.0	0.0	179.7	4.828	
XSX_HPZR_9	198.0	-87.0	2264.0	0.0	65.8	4.754	
XSX_HPZR_10	198.0	87.0	2264.0	0.0	65.8	1.529	
XSX_HPZR_11	198.0	239.0	2264.0	0.0	179.7	1.456	
XSX_HPZR_12	198.0	390.0	2264.0	0.0	290.1	1.384	
XSX_HPZR_13	198.0	542.0	2264.0	0.0	396.9	1.314	
XSX_HPZR_14	198.0	694.0	2264.0	0.0	498.0	1.247	
XSX_HPZR_15	198.0	846.0	2264.0	0.0	592.7	1.182	
XSX_HPZR_16	198.0	998.0	2264.0	0.0	680.3	1.121	
XSX_HPZR_17	222.0	1134.0	2264.0	0.0	759.3	1.064	
XSX_HPZR_18	277.0	1249.0	2264.0	0.0	832.3	1.010	Extreme upper channel.

8 Tangential Camera

Looks at the whole plasma tangentially (as interferometer and HOMER camera).



8.1 Camera Details

id	TA
sector	2
port	HM
view	Tangential
slit width	1.0
slit height	3.0
diode distance	55.0

foil material	Be
foil thickness	15.0
diode array	Centronics L35-5T
diode count	18
diode width	0.96
diode height	4.60
pole R	0.0
pole Z	0.0

8.2 Channel Details

name	**r1 mm**	**z1 mm**	**r2 mm**	**z2 mm**	**p mm**	**theta rad**	**comment**
XSX_TCAM#1	1763.0	1441.0	0.0	0.0	0.0	0.0	Extreme inner channel (central column).
XSX_TCAM#2	1763.0	1441.0	0.0	86.49	68.6	2.226	
XSX_TCAM#3	1763.0	1441.0	0.0	171.60	139.3	2.195	
XSX_TCAM#4	1763.0	1441.0	0.0	256.04	212.5	2.163	
XSX_TCAM#5	1763.0	1441.0	0.0	339.81	288.2	2.129	
XSX_TCAM#6	1763.0	1441.0	0.0	422.93	366.3	2.094	
XSX_TCAM#7	1763.0	1441.0	0.0	505.41	446.4	2.059	
XSX_TCAM#8	1763.0	1441.0	0.0	587.24	528.5	2.022	
XSX_TCAM#9	1763.0	1441.0	0.0	668.46	612.3	1.984	
XSX_TCAM#10	1763.0	1441.0	0.0	760.39	709.4	1.940	
XSX_TCAM#11	1763.0	1441.0	0.0	840.27	795.4	1.899	
XSX_TCAM#12	1763.0	1441.0	0.0	919.54	881.8	1.858	
XSX_TCAM#13	1763.0	1441.0	0.0	998.21	968.1	1.817	
XSX_TCAM#14	1763.0	1441.0	0.0	1076.28	1054.0	1.775	
XSX_TCAM#15	1763.0	1441.0	0.0	1153.77	1138.8	1.732	
XSX_TCAM#16	1763.0	1441.0	0.0	1230.68	1222.0	1.690	
XSX_TCAM#17	1763.0	1441.0	0.0	1308.94	1305.3	1.646	
XSX_TCAM#18	1763.0	1441.0	0.0	1382.77	1382.0	1.604	Extreme outer channel (plasma edge).