Grid distorsion on D2am CCD cameras.

J.-F. Bérar, D2am-CRG/F, ESRF

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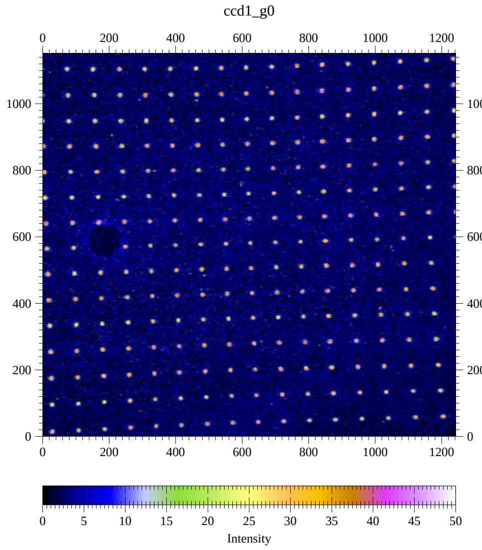
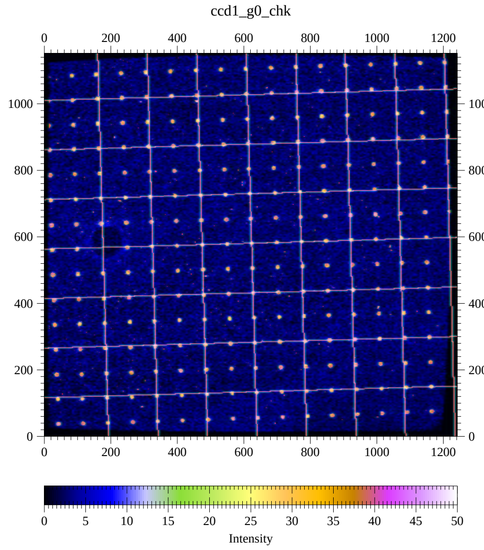
1 D2am 1242x1152 camera : Fiber Optic Coupled CCD.

Uncorrected grid image and corrected one.





SAXS users have noticed that distorsions on D2am CCD camera were significant and lead to some troubles when data have been collected both at high and at low Q with separate settings. Using a copper grid (holes diameter .3mm on a 3mm square lattice) etched by electronic board technics by Cyrile Rochas (LSP, Grenoble), these distorsions have been characterised and a correction procedure deduced.

The added lines on the right image have been drawn to figure a perfect grid located around the "central" node.

1.1 Characterization of distorsions

As distorsions seem very weak near the center, they have been expressed by a polynomial function using the center as origin : $X = f(X - X_o) = f(x)$ The adjustement lead to a grid size of 74.9 pixels corresponding to $40.1\mu m/pixel$ in the horizontal direction.

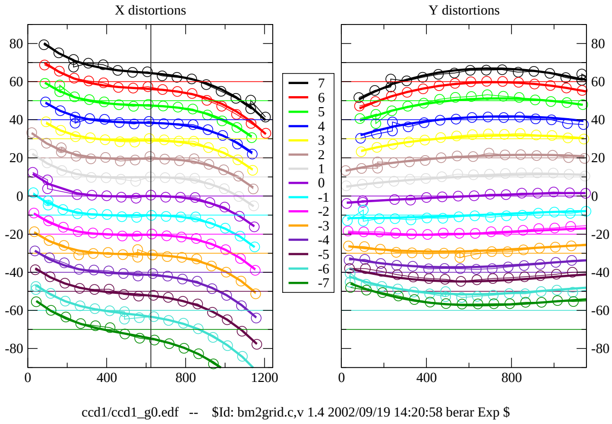
Following table contain the coefficients of X and Y expansions :

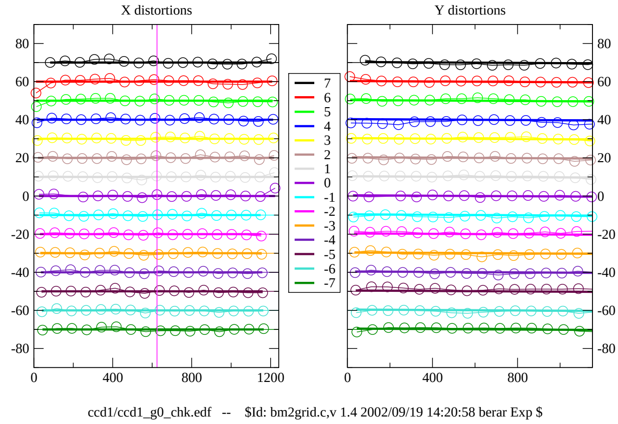
$X = X_o + A_x x + A_y y + A_{x^2} x^2 + A_{xy} xy + A_{y^2} y^2 + ...$

	X					Y				
scale	x^0y^0					x^0y^0				
factor	x^1y^0	x^0y^1				x^1y^0	x^0y^1			
on	x^2y^0	x^1y^1	x^0y^2			x^2y^0	x^1y^1	x^0y^2		
$A_{x^iy^j}$	x^3y^0	x^2y^1	x^1y^2	x^0y^3		x^3y^0	x^2y^1	x^1y^2	x^0y^3	
	x^4y^0	x^3y^1	x^2y^2	x^1y^3	x^0y^4	x^4y^0	x^3y^1	x^2y^2	x^1y^3	x^0y^4
1	621					576				
10^3	1000	0.00				4.70	1003			
10^5	−1.92	0.60	−1.62			−0.13	0.17	2.66		
10^8	−7.34	1.92	−5.20	−0.32		−0.09	−5.01	−0.24	−6.50	
10^{11}	1.63	−0.63	−0.19	2.39	−0.50	−0.44	2.38	−1.83	1.53	−3.60

The A_y value, 1.003 shows that the lattice is nearly a perfect square. The maximum deviation is observed in X (bottom right) is near 30 pixels, in Y (botom left) near 24 pixels.

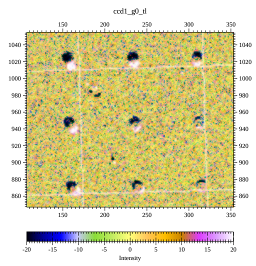
The 246 nodes located on the grid are then adjusted with a standard error of 1.5 pixels to be compared with an error of 8.9 pixels before correction. Following pictures show the distorsions on each nodes and the remaining values after correction of the image.

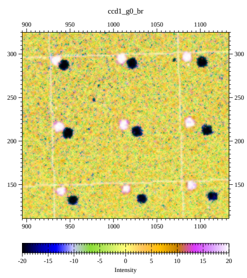




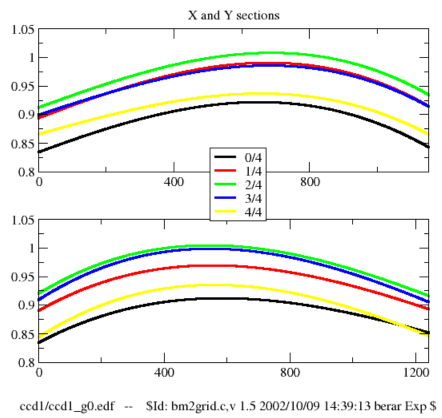
1.2 Camera distortions

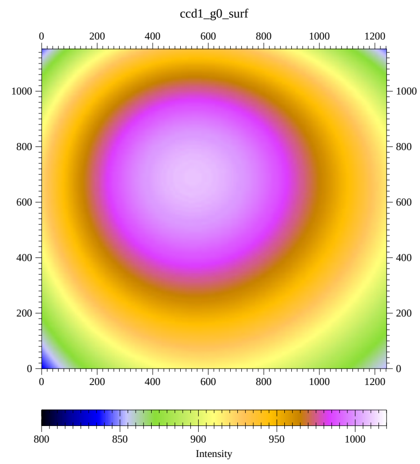
The difference between the image after and before correction allows to visualise easily the effect of the correction. The following zoom on the grid corners (top, left) and (bottom, right) proof that the correction improve greatly the image quality.





The relative size of the pixels is represented in the following figures : the pixel size far from the center is reduced by more than 10%.





2 Correcting image with *bm2img* procedure

The correction of the position of the pixels is obvious when the grid is known but some problems may occur with the intensity.

2.1 Method of correction.

In a constant flux, due to the pixel size the counts in each pixel are proportional to the pixel surface as represented on the figure of a distorded camera.

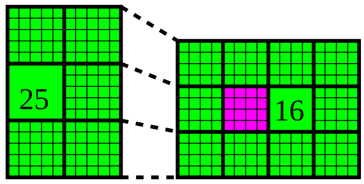


Fig. 2-1

In the natural view, the intensity are shown on a regular non corrected grid and the surface distortion appear like an intensity change.

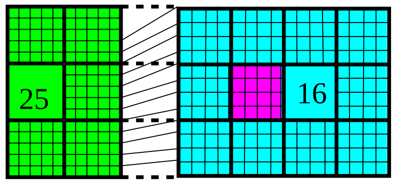


Fig. 2-2

The easiest way to correct the grid is to split the intensity of the real pixel in proportion of the surface common to the new pixel.

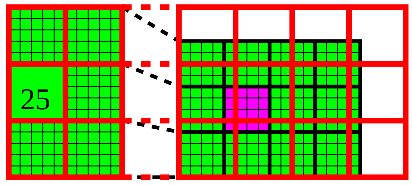


Fig. 2-3

Applying this calculation, this image is obtained. There is no problem for all the inner pixel, for very sharp signal a small convolution may occurs, for the case in which the detector resolution is very important, local fit of intensity may allow a better splitting of the intensity on the new array. But pixels in the border lines may are affected by this remapping.

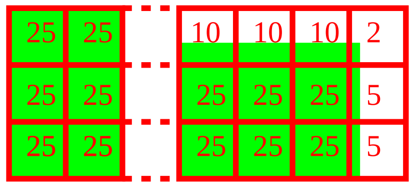


Fig. 2-4

A solution is to extend the intensity of these pixels, if the surface concerned is not too tiny. After this operation the excluded pixel have to be redefined by generating a new mask including the effect of the distortion. change

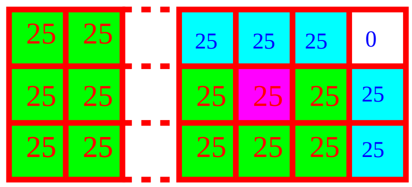


Fig. 2-5

2.2 Interaction with the flatfield correction.

When a flatfield correction is applied before the grid correction, the content of pixels changes.

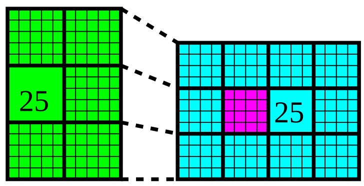


Fig. 2-6

Applying the normal correction lead to overestimate the pixel with small size. However the normal result can be achieved if a surface correction is applied.

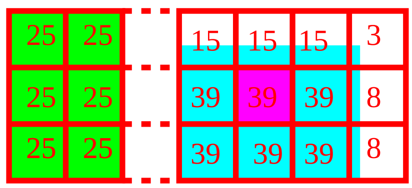


Fig. 2-7

2.3 Practical correction of images with *bm2img*

2.3.1 Geometrical grid parameters.

The coefficient calculated by *bm2grid* can be used to correct images in *bm2img*, this is done by writing the following tags and lines in *bm2img.ini*.

GRID_DCOR=	15			number of coefs
GRID_XCOR=	621	1	2.71678e-07	...
GRID_YCOR=	576	0.00424391	1.00337	...

To avoid typing mistakes lines writen by *bm2grid* command can be added to the *bm2img.ini* file.

2.3.2 Interaction with excluded pixel

Excluded pixels are often defined on the uncorrected image. As grid correction modify the position of excluded pixels, it interacts with some standard parameters in *bm2img* and the following extensions have been implemented : %g=filename will produce a excluded pixels file named *filename* to be read using the *F_EXCLUDED=filename* in *bm2img.ini*.

2.3.3 Other grid related parameters.

GRID_AUTO= use grid correction always or on input request

NONE grid correction is performed only on the *%G* command

AUTO the grid correction is done automaticaly after flat correction, no *%G* required.

GRID_MODE= this parameter uses NONE as default value.

NONE it provides standart correction as shown in Fig.2-5, border effect are corrected for surface higher than 1/2.

STRICT it provides standart correction as shown in Fig.2-4, no border effects are taken into account..

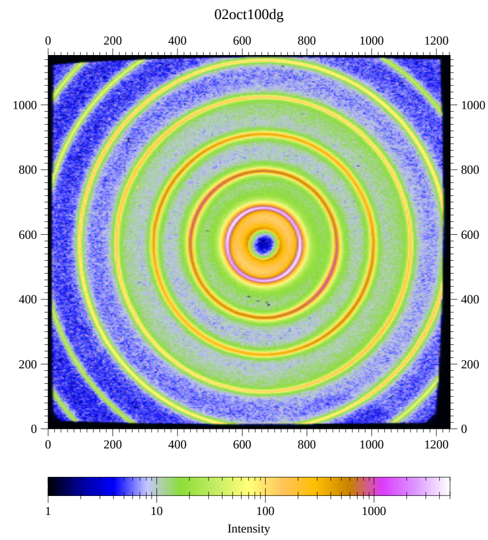
FLAT the result is surface corrected to avoid effect shown in Fig.2-7.

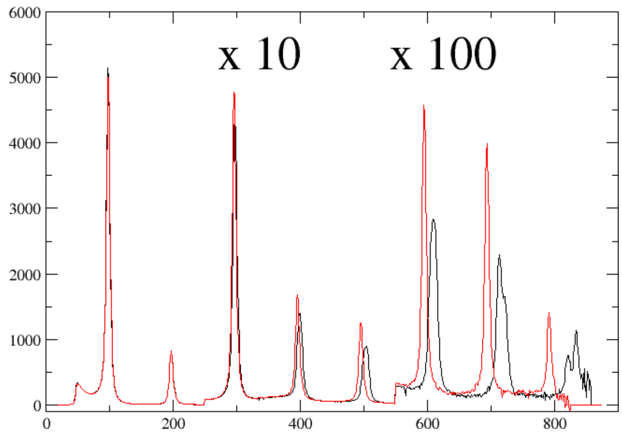
GRID_ORIG= : this parameter has to be used by users who calculate directly radial distribution from the original image file : with value *CONVERT*, it allows the coordinates of the distribution center to be converted on the fly from orinal space to grid corrected space.

2.4 Example : radial distribution.

When extracting a radial distribution using *bm2img* , it is possible to operate as usual with a single pass. In this case, the center is defined by its position on the uncorrected image and its position is modified on the fly if a grid correction is done.

As it can be seen on the following example, the correction of the grid distortion increase the contrast at high angles and allows the very weak outer ring which can be noticed only in the corner to be taken in consideration. The radial distribution obtained after correction is drawn in red and can be compared to the raw one in black. The peaks become sharper but the integrate counts in the peak remain constant : in case of the second peak we obtain 7070 before correction and 7080 after; for the 7th the digits are 403 before and 398 after. In both case the difference is lower than 1% and seem mostly related to the base line definition before integrating. On a construted uniform image we proof that on the whole detector the integration remain stable within 2/14300.





3 Grid determination : *bm2grid* procedure

3.1 *bm2grid* program method

The program is divided into internal modules which are responsable of specific operatio, these modules are called by the initialisation file which can be quite simple as in the case of this CCD in which the grid is easy to extract and fit.

After assigning coordinates to grid nodes, the program try to fit some polynomial grid function in order to minimise the residual distortions.

3.2 Correction parameters.

The grid coefficients have been calculated using *bm2grid*. No special care have been necessary to extract the grid, the following parameters were given :

GRID_LEVEL=20 minimum count on pixel used in grid nodes

GRID_COUNT=10 minimum pixels number in grid nodes

GRID_ERROR=0.2 tolerance around translation for nodes extraction

3.3 Command keys.

@GRID_IMAGE= this key is used to specify the file containing the grid image. After reading the image a search is done to extract the node and assign them to a reasonable lasuare lattice.

@GRID_OUT_NODES= optional key used to print out in the specified file all the nodes with their counts and assignement. The node references of this file can be used to cancel some of them during anaysing procedure.

@GRID_PROCESS= try to fit the polynomial grid function. This command may be repeated if the number of nodes to take into account change.

@GRID_OUT_XMGR= optional key used to print out in the specified *xmgrace* project file a figure showing the distorsions along X and Y on the surface detector

@GRID_OUT_RES= optional key used to print out in the specified file the parameters of the polynomial distorsion function. This file can be used as entry for other applications. specified *xmgrace* project file a figure showing the distorsions along X and Y on the surface detector

@GRID_OUT_SURF= optional key used to print out in the specified file an image showing the surface variation on the detector.

@GRID_INPUT= this key is used to read the result produced by *@GRID_OUT_RES*

@GRID_CHECK= similar to *@GRID_IMAGE* but apply on the image the known grid correction. A corrected image will be output by adding "_chk" to the input name. This module allows to see the consistency of previously obtained polynomial distorsion function.

@GRID_LIM_NODES= optional key to restrict the node indices used. It allow to used only a part of the detector and to increase its surface in some PROCESS pass. The arguments are xmin xmax ymin ymax in which xy are the minimum or the maximum values allowed for the nides indices. The limits are applied at each time this command is found. Join with *@GRID_PROCESS* it allows to enlarge the fitted surface.

@GRID_DEL_NODES this command delete the nodes which references number are given. It uses the reference given by *@GRID_OUT_NODES*.

```
GRID_DCOR=15
GRID_XCOR=      621        1 2.10727e-07 ....
GRID_YCOR=      576 0.00470413   1.0034 -1.31391e-06 ....
```

3.4 Initialisation file used for the 1242x1152 CCD

No special care have been necessary to extract the grid, the following parameters were given :

```
# bm2grid.ini   input file for grid calibration
# cvs_id =" $Id: bm2grid.ltx,v 1.3 2002/10/21 14:58:28 berar Exp $ ";
#
# C Rochas grid used with 1242x1152 CCD
GRID_LEVEL=20
GRID_ERROR=0.2
GRID_COUNT=10
GRID_SIZE=3.00
```

Then the following inputs define the operations.

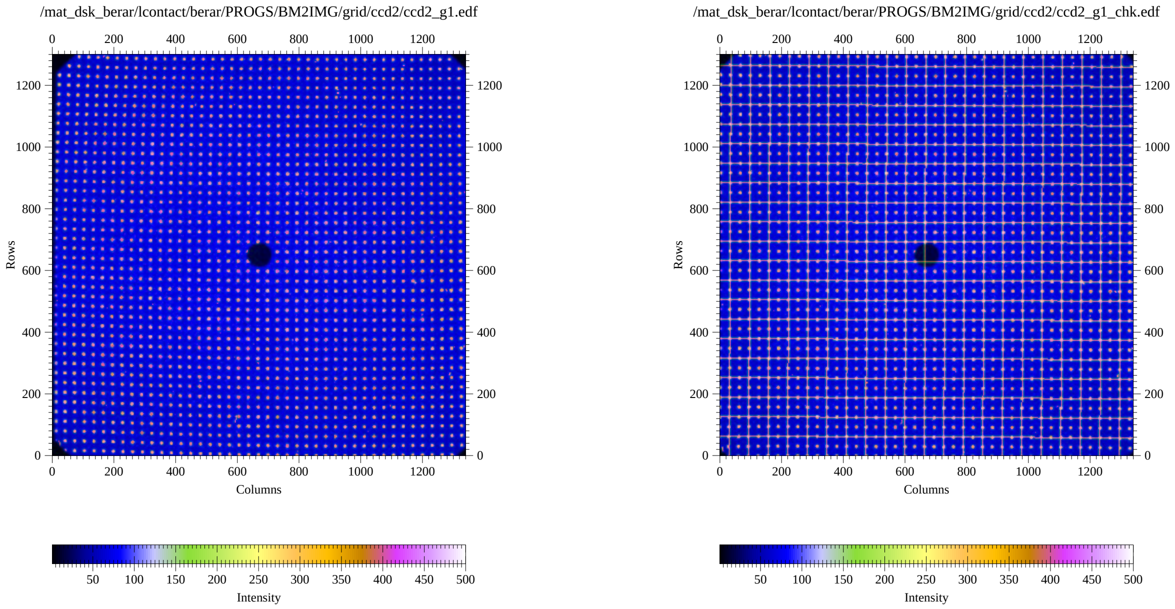
```
@GRID_IMAGE=ccd1/ccd1_g0.edf
@GRID_OUT_NODES=ccd1/ccd1_g0.nod
@GRID_PROCESS=
@GRID_OUT_XMGR=ccd1/ccd1_g0.agr
@GRID_OUT_SURF=ccd1/ccd1_g0_surf.edf
@GRID_OUT_RES=ccd1/ccd1_g0.res
@GRID_INPUT=ccd1/ccd1_g0.res
@GRID_CHECK=ccd1/ccd1_g0.edf,1000,2
```

```
@GRID_PROCESS=
@GRID_OUT_NODES=ccd1/ccd1_g0_chk.nod
@GRID_OUT_XMGR=ccd1/ccd1_g0_chk.agr
```

4 D2am 1340x1300 camera : Fiber Optic Coupled CCD.

These preliminary result have been obtained with the grid image provided by Roper Scientific (about 0.6mm) in the file "flm-4-1.SPE" (August 14th, 2002). The very high contrast om this grid image shows it has been realised with visible light and not X-ray. But ths step used in this grid was too small and it was very difficult to achieve some reliable result. A new grid has then been prepared by Cyrile Rochas (LSP, Grenoble), using a copper grid (holes diameter .3mm on a 1.5mm square lattice) etched by electronic board technics. This grid has been illuminated by X-rays suing fluorescence at Sr edge. Then distorsions have been characterised.

Uncorrected grid image and corrected one.



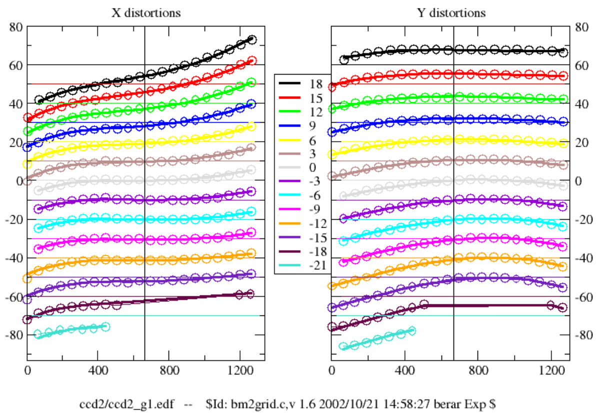
4.1 Characterization of distorsions

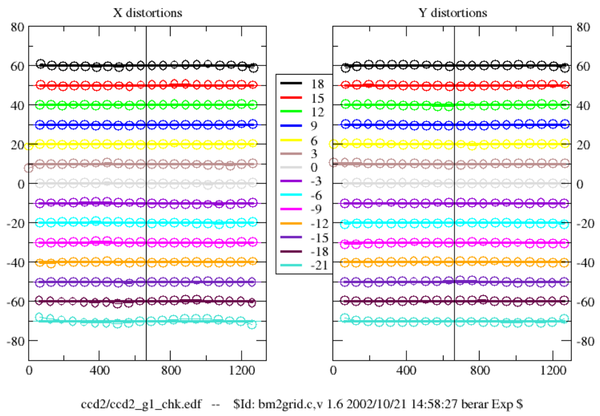
On the corrected grid image a regular lattice has been reported. Due to the amplitude of the distortion, the correction parameters have been reached using a small loop. In the first step, only the 436 nodes near the center (-10 .. +10) have been considered and the correction function restricted to the 4th degree. Then the zone has been enlarged increasing the degree. In the last step 1758 nodes have been considered and 1641 kept covering 0.94 of the surface.

Using the same expension, the coefficents are :

	X					Y				
scale factor on $A_{x^iy^j}$	x^0y^0 x^1y^0 x^2y^0 x^3y^0 x^4y^0	x^0y^1 x^1y^1 x^2y^1 x^3y^1	x^0y^2 x^1y^2 x^2y^2	x^0y^3 x^1y^3	x^0y^4	x^0y^0 x^1y^0 x^2y^0 x^3y^0 x^4y^0	x^0y^1 x^1y^1 x^2y^1 x^3y^1	x^0y^2 x^1y^2 x^2y^2	x^0y^3 x^1y^3	x^0y^4
1	670					650				
10^3	1000	−0.00				5.24	1004			
10^5	0.74	1.09	−1.42			−1.70	−1.54	0.65		
10^8	2.34	1.01	3.21	−0.42		−0.07	1.61	0.23	1.62	
10^{11}	−2.04	1.02	0.94	−0.10	0.17	0.02	2.25	0.13	1.07	−0.11

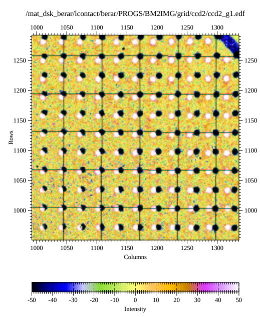
After the correction process, the worst node is located in the corner with an error of about 4 pixels. The standard error remains weak : 0.7 pixels.

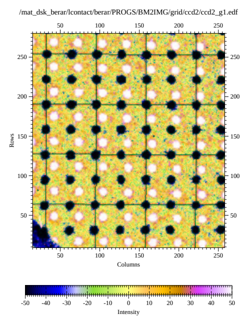




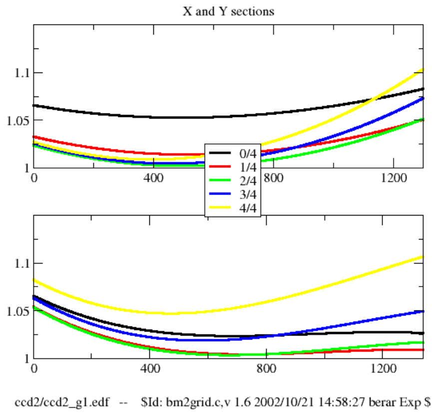
4.2 Camera distortions

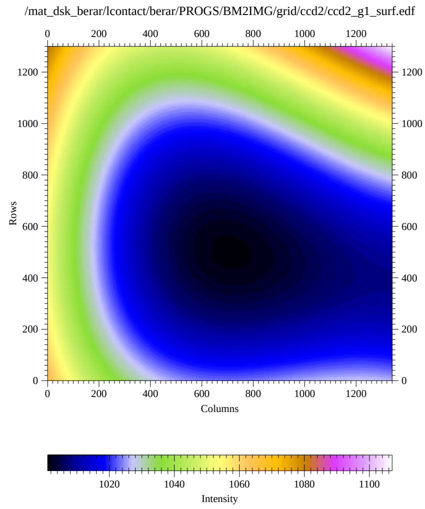
The difference between the image after and before correction allows to visualise easily the effect of the correction. The following zoom on the grid corners (top, right) and (bottom, left) proof that the correction improve greatly the image quality.





The relative size of the pixels is represented in the following figures : the pixel size far from the center is reduced by more than 10%.


X and Y sections
1.1
1.05
1
0
400
800
1200
0/4
1/4
2/4
3/4
4/4
ccd2/ccd2_g1.edf -- $Id: bm2grid.c,v 1.6 2002/10/21 14:58:27 berar Exp $


/mat_dsk_berar/lcontact/berar/PROGS/BM2IMG/grid/ccd2/ccd2_g1_surf.edf
Rows
Columns
0
200
400
600
800
1000
1200
1020
1040
1060
1080
1100
Intensity