Camera Calibration Certificate
No: DMC IIe 230 - 23536

For

Richard Crouse & Associates

467 Aviation Way
Frederick, MD 21701

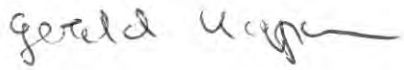
USA

This calibration certificate complies with DIN 18740-4

Camera:	DMC IIe 230
Manufacturer:	Leica Geosystems Technologies GmbH, 73430 Aalen, Germany
Reference:	PAN
Serial Number:	00120741 (PAN Head)
Date of Calibration:	22. December 2016
Date of Report:	22. December 2016
Number of Pages:	81

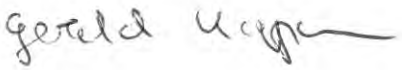
This camera system is certified by Leica Geosystems Technologies and is fully functional within its specifications and tolerances.

Date of Calibration: December 2016



Dipl.Ing. Gerald Kapoun, Technical Consultant

Date of Certification: December 2016



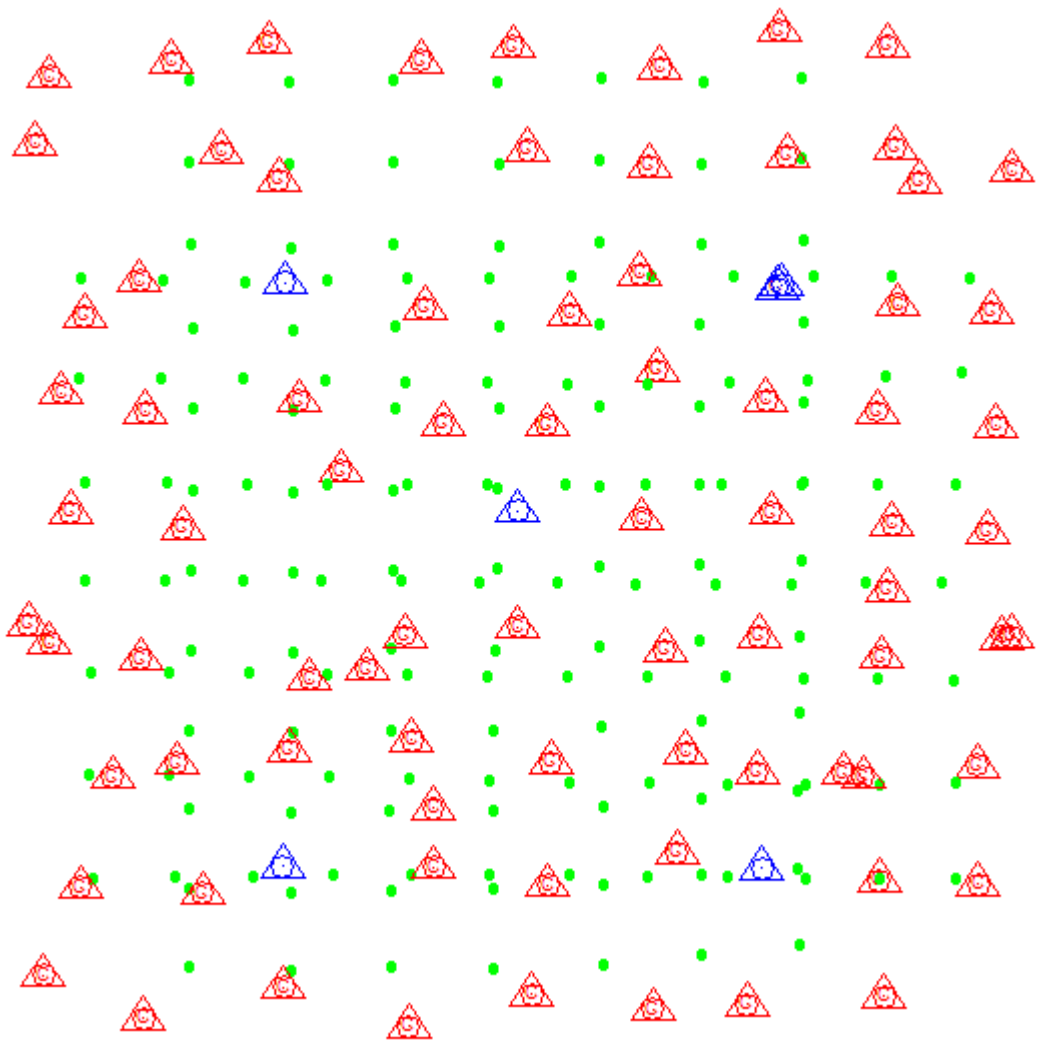
Dipl.Ing. Gerald Kapoun, Technical Consultant

Camera Serial Numbers and Calibration flight

Camera Head	Serial Number	Calib. Date
PAN (reference)	00120741	22.12.2016
MS1 (NIR)	00121884	22.12.2016
MS2 (Blue)	00125498	22.12.2016
MS3 (Red)	00118779	22.12.2016
MS4 (Green)	00122307	22.12.2016

Calibration flight performed: 20. December 2016

Flight parameters of 5cm Calibration Flight



Parameter	Burn-in flight
GSD [cm]	5
End-lap [%]	75
Side-lap [%]	75
Number of Exposures	168
Number of Flight Lines	7
Number of Cross Flight Lines	7
Number of Control Points	5
Number of Check Points	80
GPS/INS	YES

Application

Parameter	Burn-in flight
Weighting for manual measured image points	1.0
Weighting for automatic measured image points	1.0
Weighting for Control Points	2.8 / 2.8 / 1.6
Weighting for GPS	1.6 / 1.6 / 1.6
Weighting for INS	0.3 / 0.3 / 0.1
Modeling of GPS systematic residuals	NO
Bore Sight Alignment (YES/NO)	NO
Camera Self Calibration (YES/NO)	NO

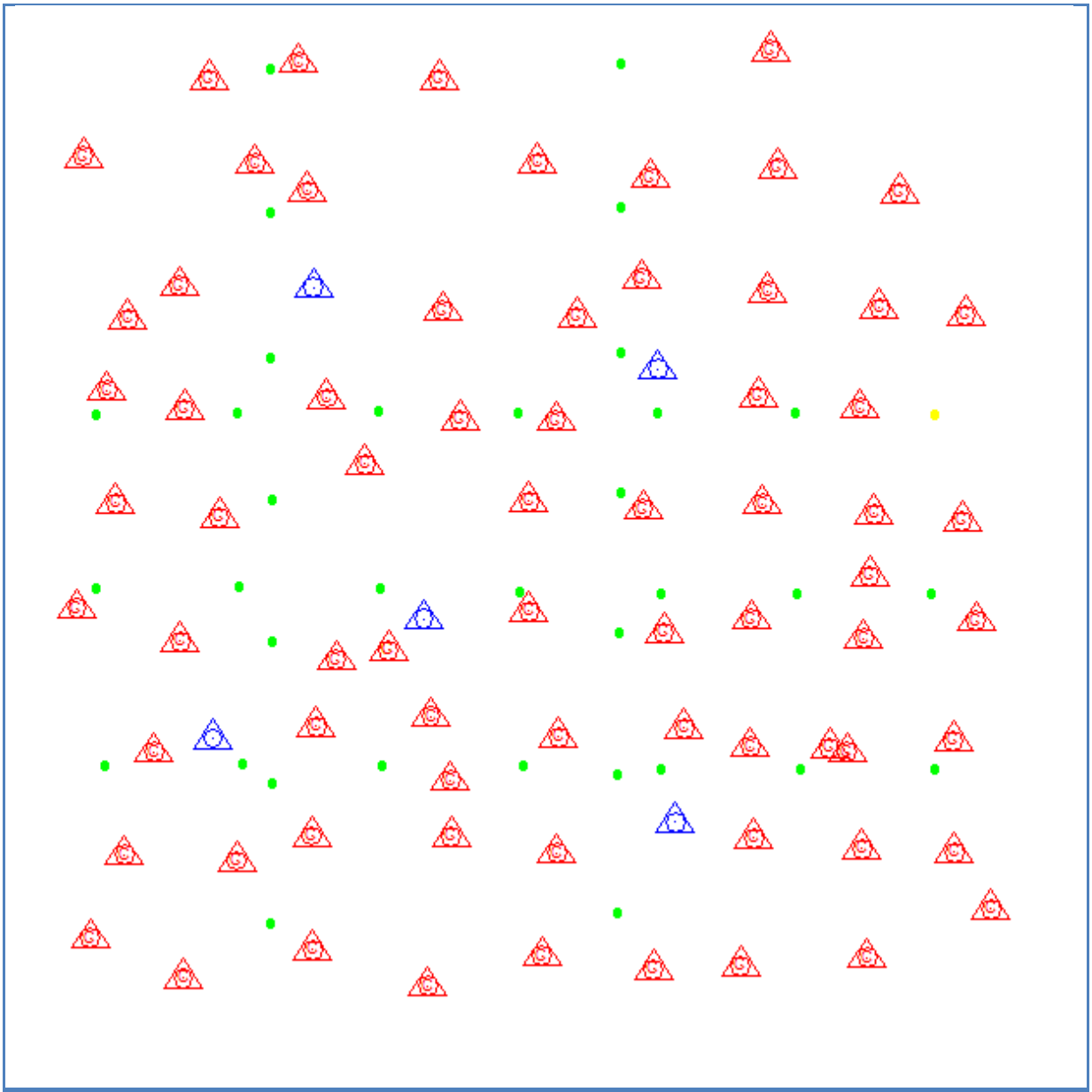
Statistics – Bundleblockadjustment

Parameter	Burn-in flight
Sigma0 [µm]	1.255
Mean Std Dev Photo Position [cm]	1.0 / 1.0 / 0.4
Mean Std Dev Photo Attitude [mdeg]	0.6 / 0.7 / 0.3
Mean Std Dev Control Points [cm]	0.4 / 0.4 / 0.8
Mean Std Dev Check Points [cm]	0.6 / 0.6 / 1.6
RMS Photo Position [cm]	1.4 / 1.3 / 1.3
RMS Photo Attitude [mdeg]	5.9 / 2.1 / 2.1

Statistics – Results

Parameter	Burn-in flight
RMS of Control Points – horizontal [cm]	0.9 / 0.8
Max Ground Residual of Control Points – horizontal [cm]	1.3 / 1.1
RMS of Control Points – vertical [cm]	1.3
Max Ground Residual of Control Points – vertical [cm]	2.2
RMS of Check Points – horizontal [cm]	1.5 / 1.5
Max Ground Residual of Check Points – horizontal [cm]	3.9 / 4.0
RMS of Check Points – vertical [cm]	3.0
Max Ground Residual of Check Points – vertical [cm]	7.1

Flight parameters of independent 8cm Reference Block



Parameter	Burn-in flight
GSD [cm]	8
End-lap [%]	70
Side-lap [%]	60
Number of Exposures	35
Number of Flight Lines	3
Number of Cross Flight Lines	2
Number of Control Points	5
Number of Check Points	71
GPS/INS	YES

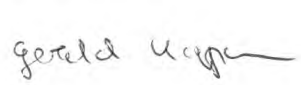
Statistics – Bundleblockadjustment

Parameter	Burn-in flight
Sigma0 [µm]	1.125
Mean Std Dev Photo Position [cm]	1.2 / 1.2 / 0.6
Mean Std Dev Photo Attitude [mdeg]	0.5 / 0.6 / 0.4
Mean Std Dev Control Points [cm]	0.7 / 0.7 / 1.2
Mean Std Dev Check Points [cm]	1.1 / 1.2 / 3.4
RMS Photo Position [cm]	1.4 / 1.6 / 1.0
RMS Photo Attitude [mdeg]	3.4 / 3.0 / 1.0

Statistics – Results from independent Referenceblock

Parameter	Burn-in flight
RMS of Control Points – horizontal [cm]	1.6 / 1.1
Max Ground Residual of Control Points – horizontal [cm]	3.0 / 1.8
RMS of Control Points – vertical [cm]	1.4
Max Ground Residual of Control Points – vertical [cm]	2.5
RMS of Check Points – horizontal [cm]	2.0 / 2.3
Max Ground Residual of Check Points – horizontal [cm]	4.8 / 7.3
RMS of Check Points – vertical [cm]	3.6
Max Ground Residual of Check Points – vertical [cm]	8.7

The results of the aerial triangulation were generated with ImageStation Automatic Triangulation (ISAT), 2016, from Intergraph Inc.. The maximum RMS in check points is ≤ 0.5 GSD in x,y and ≤ 0.7 GSD in z.

Aerial Triangulation performed by 

Dipl. Ing. Gerald Kapoun

22.12.2016
Date

Geometric Calibration

The output image geometry is based on the Pan Camera head (reference head = master camera). All other camera heads are registered and aligned to this head. Aerial triangulation checks overall system performance based on.

Output image

Reference Camera	PAN	
Serial Number	00120741	
Number of rows/columns [pixels]	15552 x 14144	
Pixel Size [μm]	5.600 x 5.600	
Image Size [mm]	87.0912 x 79.2064	
Focal Length [mm]	92.0000 mm	+ /- 0.002 mm
Principal Point [mm]	X= 0.0000 mm, Y= 0.0000 mm	+ /- 0.002 mm

The geometric calibration takes place at Carl Zeiss Jena on a certified test stand. More than 800 “light targets”, projected on 28 lines that are distributed diagonally on the focal plane, are automatically measured by finding their centers light with a precision of less than 1/10 of a pixel. The light targets are projected from the “infinity” by using a collimator (Figure 1).

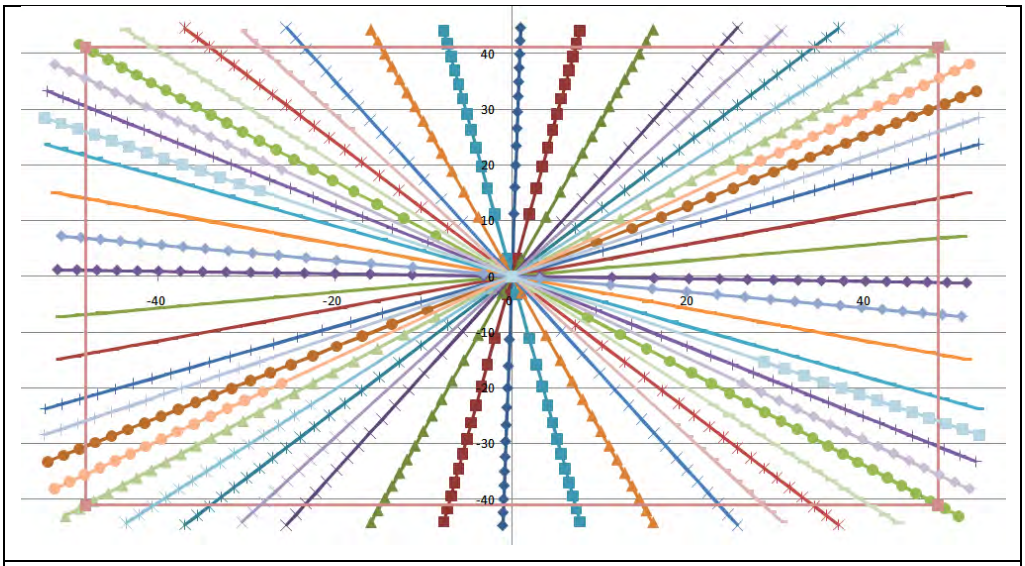


Figure 1: Light Target Pattern by Collimator

Geometric Calibration

Image Residuals

Figure 2 shows the image residuals, split in radial and tangential directions after the calibration adjustment. The maximum residuals are less than or equal to 1.0 microns and the RMSE values are below 0.5 microns.

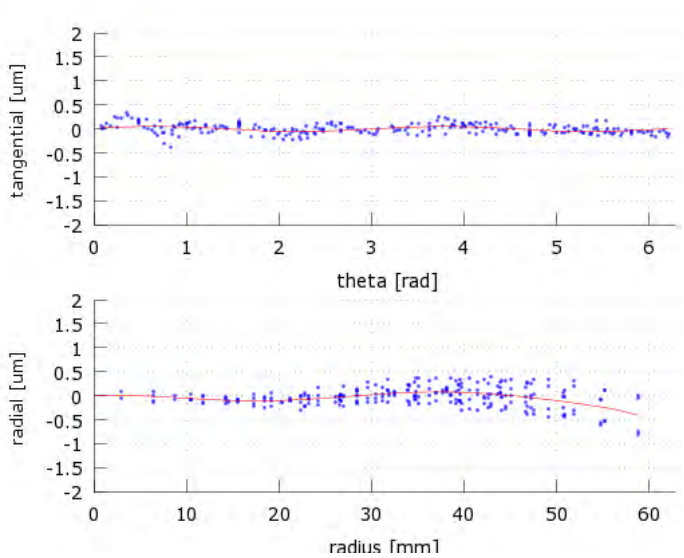


Figure 2: Tangential/Radial Distortion Residuals

Figure 3 shows the 2-D plot of the image residuals in mm.

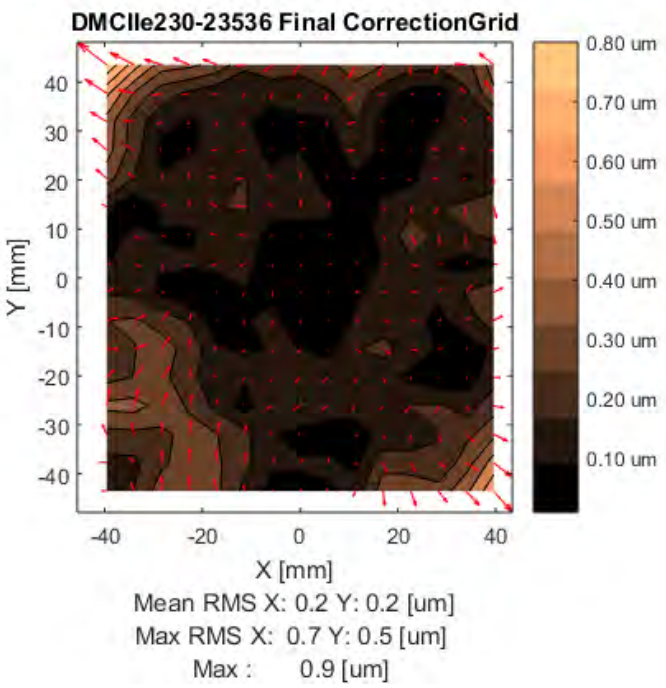


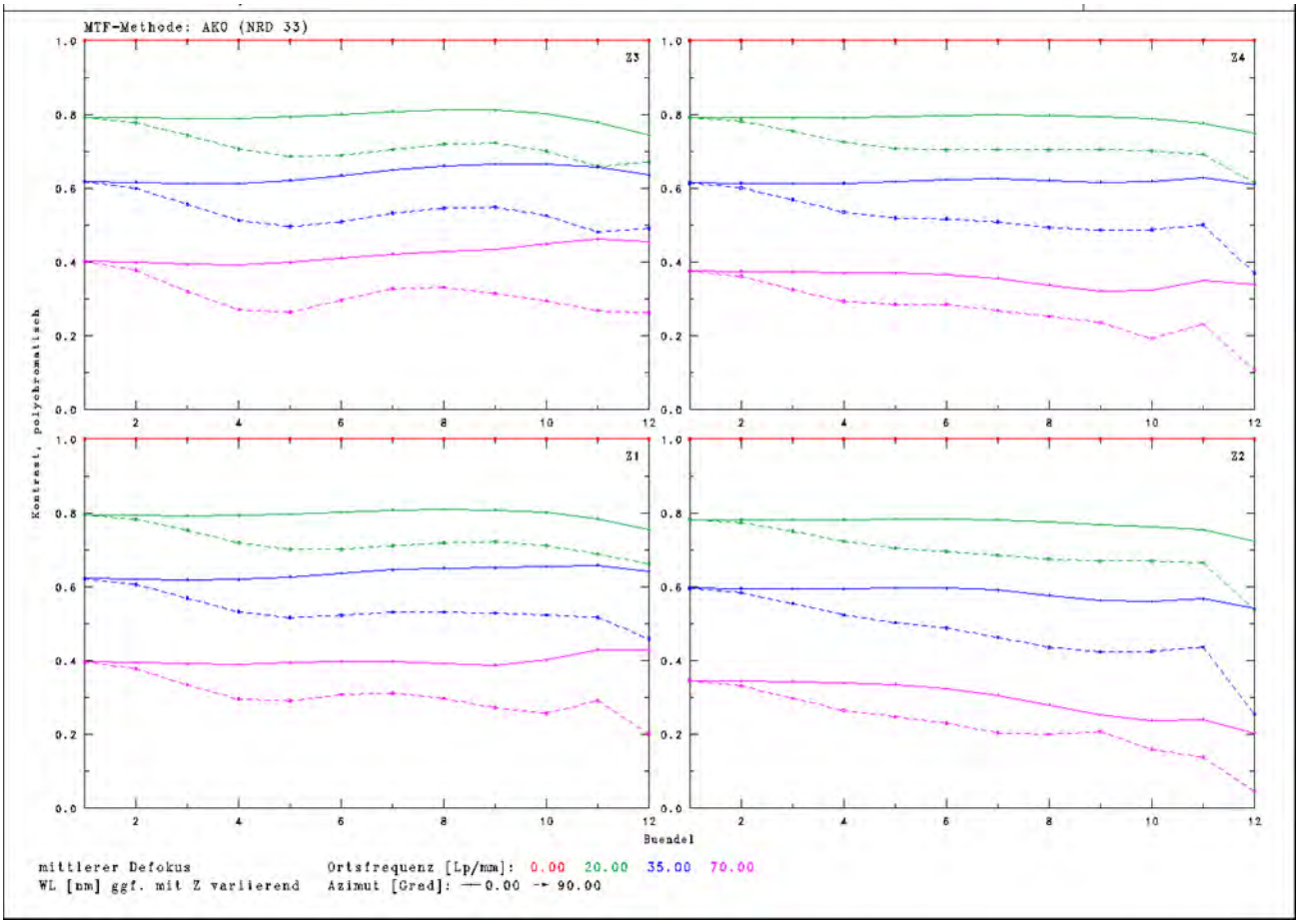
Figure 3: 2-D Image Residuals.

Mean RMS ≤ 0.2 um (maximum 0.9 microns)

Optical System

Modulation Transfer Function, MTF of PAN Camera (Reference)

RMK DX / DMC II PAN – MTF Polychromatic F/5.6 ; 92 mm – Temperature Stability

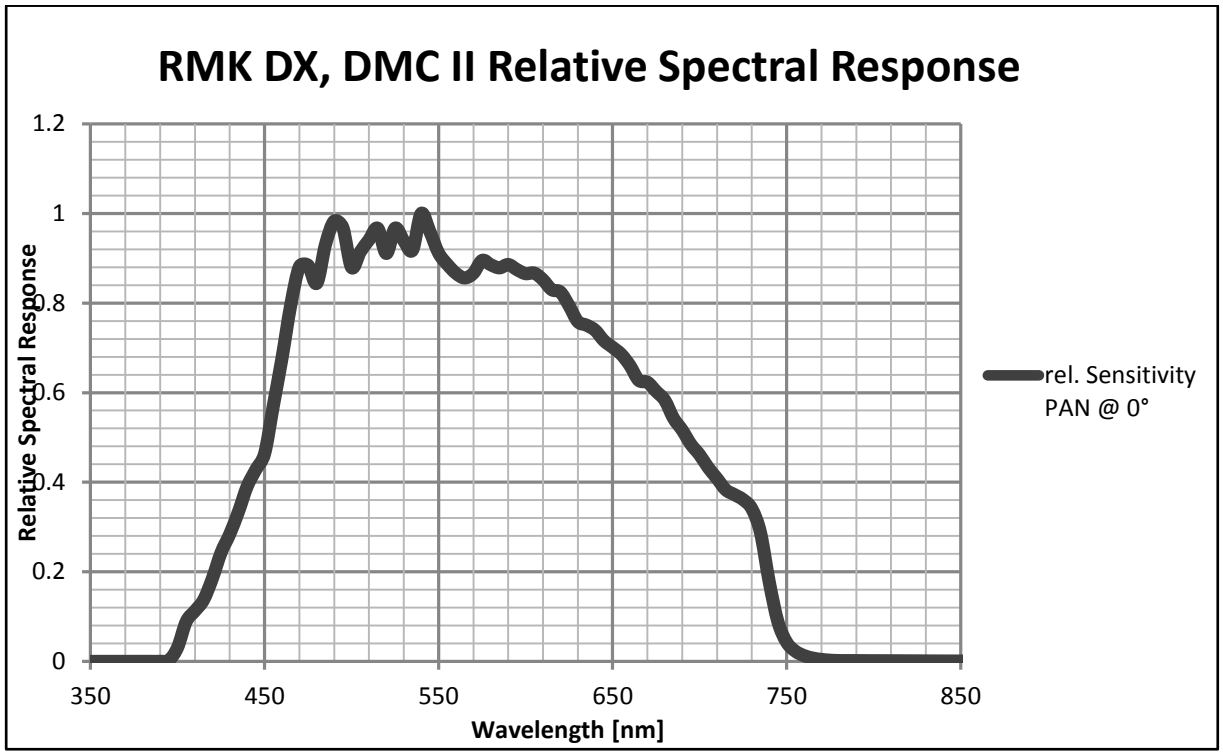


The MTF measurement is camera type specific and shows variation of the MTF within the specified temperature range.

This is a camera type specific measurement.

Radiometric Calibration

Sensitivity of PAN camera (Reference)

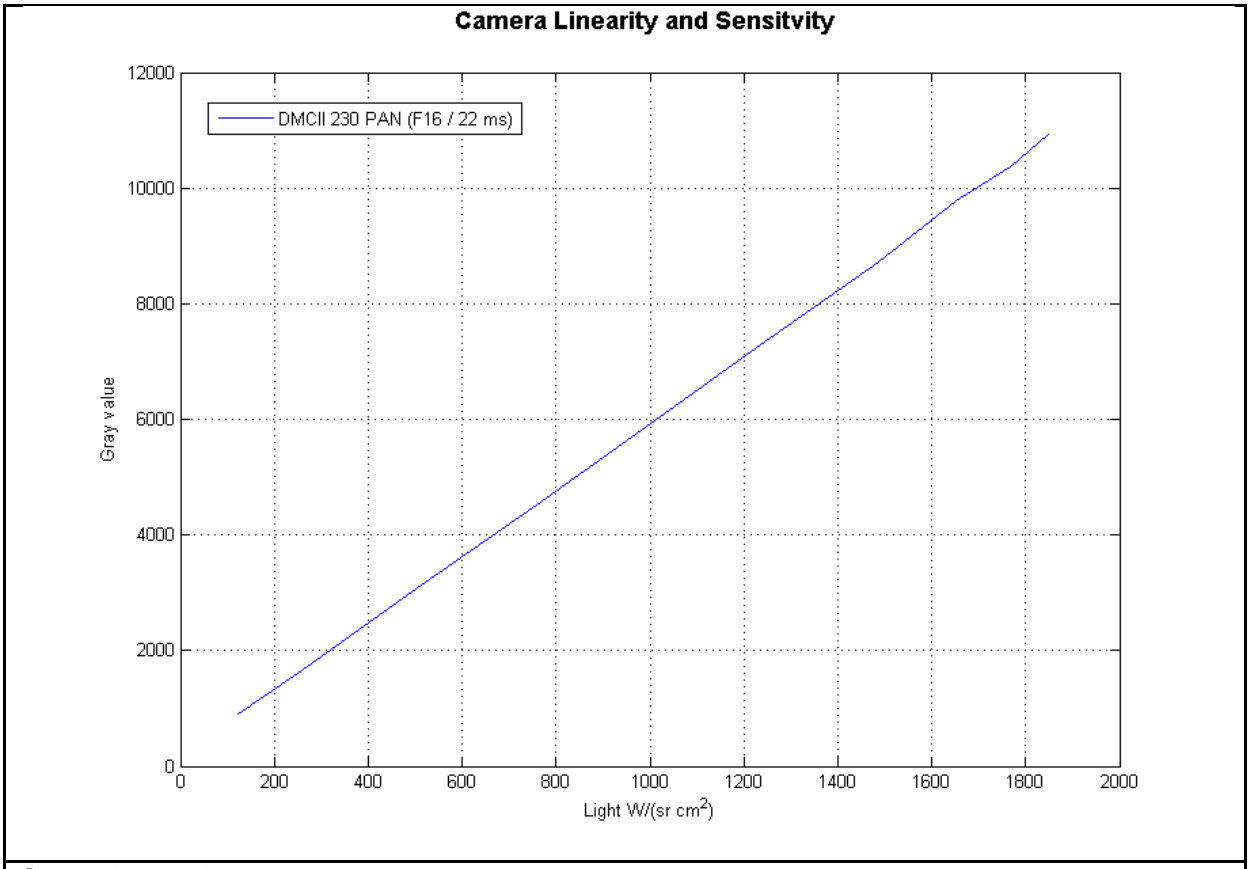


The sensitivity shows the spectral response curve of the single camera head including the optical system (optics, filter) and the sensor response. The DMC II 230 is calibrated with respect to the absolute spectrometer. This allows computing pixel radiance values from pixels digital numbers and is a camera type specific calibration.

This is a camera type specific measurement.

Sensor Linearity (Reference)

The sensor linearity is measured in the Lab with calibrated spectrometer. This is a camera type specific calibration.
Below figure shows the linearity of the raw sensor and after flat fielding:



Senor Linearity

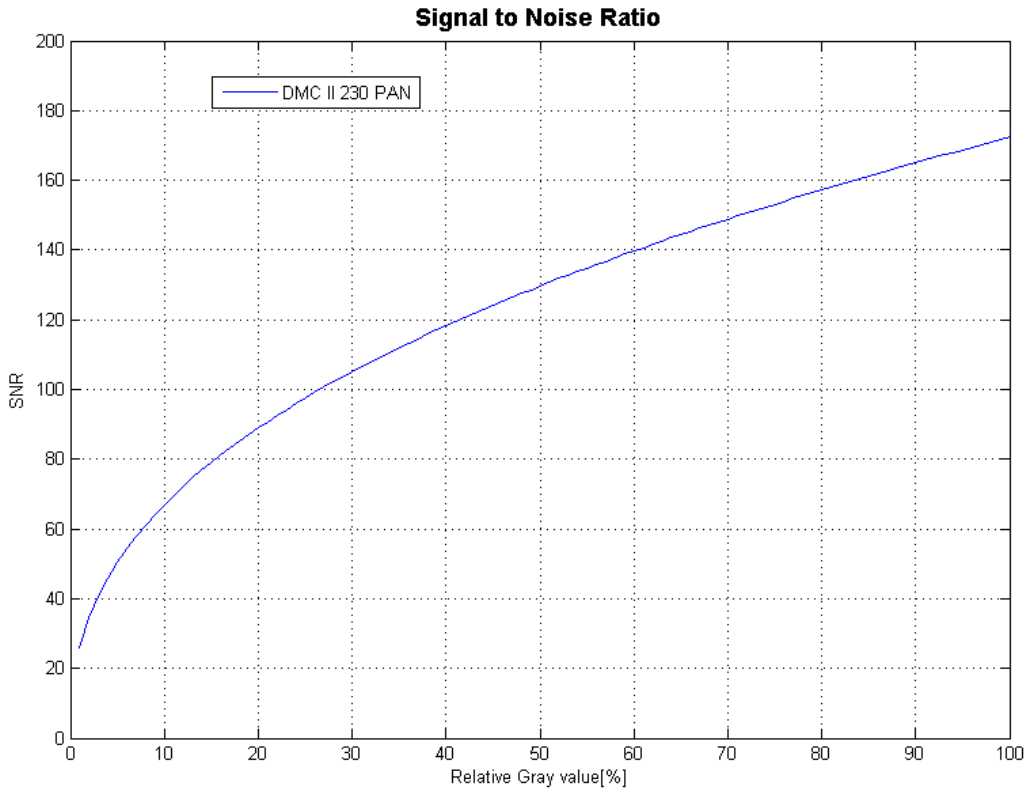
The deviation from the linearity is below 1%.

This is a camera type specific measurement.

Radiometric Calibration

Sensor Noise (Reference)

Sensor noise shows image noise with respect to the image center measured at an aperture of 16 with exposure time of 16msec.



Sensor Signal to Noise Ratio

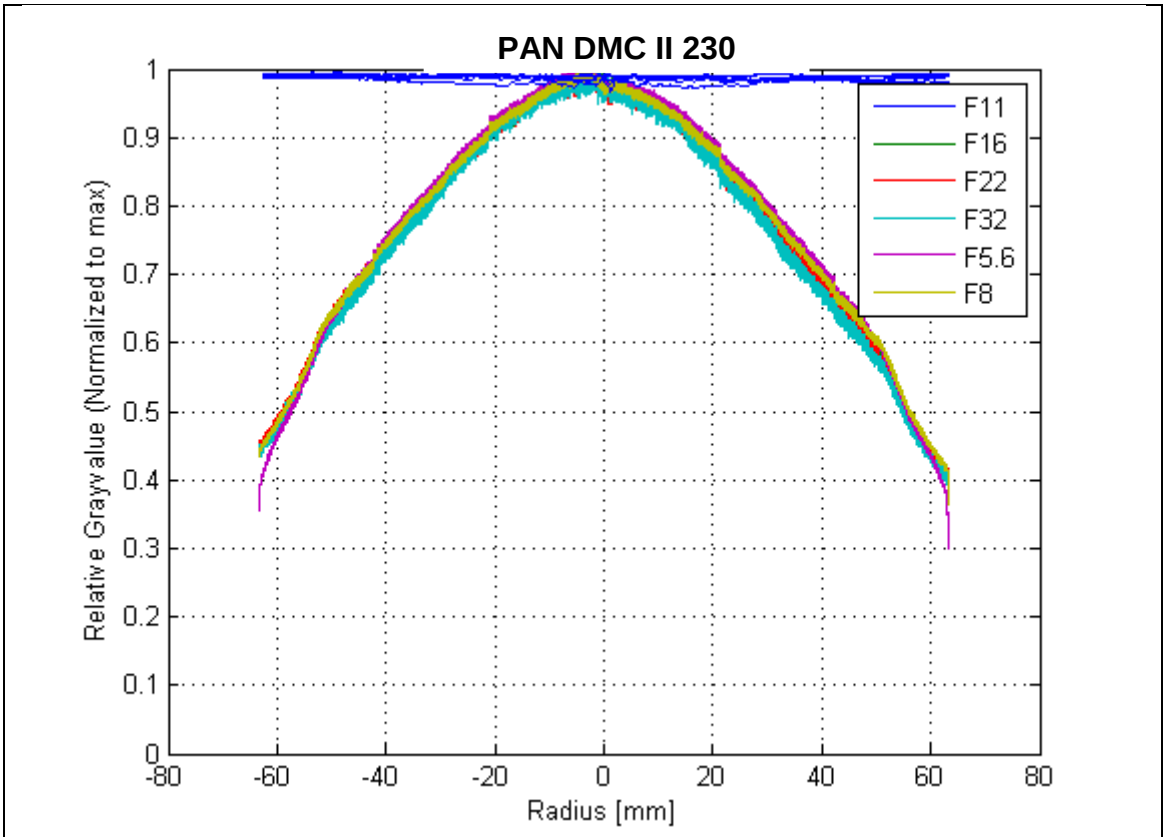
This is from a camera type specific calibration.

Radiometric Calibration

Aperture Correction (Reference)

Camera PAN (00120741)

The light fall off to the border due the influence of the optics depends on the aperture used. Therefore this calibration approach delivers individual calibration images for each aperture (Full F-Stop). In general the light fall off is a function of the image height (radial distance from center). The figure below shows the profile from the upper left corner to the lower right corner of the calibration images. Compensation of the light fall off can be measured after normalization and is within ± 2.5% of the dynamic range.



Light fall off and correction after normalization (blue) for PAN sensor

This is from a camera type specific calibration.

Radiometric Calibration

Defect Pixel

Camera PAN (00120741)

Defect pixels are detected during radiometric calibration and will be corrected during radiometric processing of the images. The quantity and cumulative percentage and specification of defects is described in Appendix “Defect Pixel Recognition”.

Revision of calibration:	131073
CCDRevision:	1
Date Number:	1481554144
Date:	161212
Number of defect pixels:	295
Number of defect clusters:	0
Number of defect columns:	0

Nr	Row	Column
0	5289	27
1	2889	246
2	13578	311
3	5367	445
4	2113	498
5	656	507
6	13820	531
7	2977	597
8	12424	678
9	9860	726
10	8739	787
11	10640	937
12	195	1046
13	6989	1215
14	4436	1223
15	4885	1235
16	12685	1297
17	3932	1298
18	13233	1318
19	6695	1367
20	4385	1389
21	13661	1472
22	6742	1573
23	13752	1716
24	5596	1818
25	5597	1818
26	2489	1959
27	3255	2020
28	12189	2048
29	8488	2075
30	1384	2178
31	14584	2180
32	11049	2204
33	10973	2273
34	8295	2301
35	1062	2304
36	2616	2402
37	1893	2500
38	2710	2500
39	2436	2504
40	2437	2504
41	2438	2504
42	5470	2529
43	7969	2724
44	6527	2852
45	4505	3045

46	14566	3074
47	1911	3147
48	1910	3148
49	1911	3148
50	1910	3149
51	1911	3149
52	1910	3150
53	1911	3150
54	9554	3161
55	7685	3195
56	3515	3232
57	3516	3232
58	10954	3329
59	14434	3340
60	10112	3347
61	7840	3547
62	7864	3586
63	3005	3746
64	3350	3912
65	8184	3996
66	1635	4106
67	7098	4284
68	4474	4318
69	10801	4442
70	10801	4443
71	10801	4444
72	10801	4445
73	10802	4445
74	9109	4477
75	12818	4479
76	2631	4579
77	11490	4595
78	13859	4595
79	5494	4704
80	5230	4750
81	3608	4970
82	14591	5010
83	4380	5121
84	1957	5155
85	7096	5229
86	6396	5363
87	14621	5502
88	5467	5536
89	3482	5622
90	13239	5941
91	3142	6037
92	5490	6110
93	1306	6388
94	2294	6530
95	7911	6538
96	1743	6586
97	6177	6615
98	5753	6940
99	168	7055
100	2627	7086
101	8218	7254
102	13425	7265
103	14536	7321
104	1885	7348
105	11992	7663
106	7888	7752
107	8328	7828
108	9643	7841
109	13044	7895
110	2193	8085
111	6849	8102
112	5713	8114
113	7464	8114
114	2303	8156
115	5684	8237
116	177	8252
117	178	8252
118	177	8253
119	5447	8506
120	12224	8520
121	12225	8520
122	12225	8521

123	6452	8529
124	11988	8531
125	10198	8739
126	61	8832
127	6690	8898
128	8218	8959
129	9217	8999
130	11790	9070
131	1340	9106
132	4551	9108
133	9434	9129
134	11779	9206
135	8570	9233
136	8570	9234
137	8571	9234
138	8571	9235
139	8572	9235
140	5836	9266
141	2512	9378
142	7977	9381
143	5090	9401
144	2982	9565
145	11986	9602
146	5550	9664
147	6665	9666
148	13662	9774
149	5438	9990
150	5438	9991
151	9358	10081
152	8411	10133
153	7713	10344
154	12468	10386
155	4588	10431
156	12922	10514
157	908	10523
158	7007	10552
159	4725	10766
160	8212	10892
161	2936	11103
162	4064	11135
163	13369	11210
164	1230	11280
165	5455	11300
166	4984	11400
167	11869	11676
168	14165	11878
169	10545	11921
170	6568	11973
171	2682	12026
172	11119	12067
173	10332	12235
174	13949	12270
175	4115	12300
176	816	12457
177	7852	12572
178	9011	12650
179	12136	12704
180	1739	12748
181	4357	13008
182	2696	13150
183	417	13156
184	7628	13353
185	6589	13410
186	1535	13490
187	6974	13588
188	12400	13709
189	12750	13784
190	2466	13964
191	7561	14058
192	2293	14065
193	143	14067
194	12861	14103
195	12862	14103
196	3704	14106
197	8525	14113
198	11133	14322
199	11743	14345

200	13574	14353
201	13573	14354
202	13573	14355
203	13575	14355
204	13574	14356
205	787	14358
206	1716	14373
207	509	14561
208	13774	14609
209	13775	14609
210	639	14680
211	12792	14796
212	1483	14803
213	13195	15051
214	2042	15087
215	2988	15090
216	14299	15128
217	10186	15214
218	12618	15303
219	13923	15314
220	13923	15315
221	10923	15341
222	7353	15419
223	7354	15419
224	7352	15420
225	7353	15420
226	7354	15420
227	7352	15421
228	7353	15421
229	14551	15480
230	13134	15681
231	7724	15778
232	1338	15788
233	9251	15845
234	5527	15932
235	14385	16159
236	6298	16211
237	10539	16461
238	5151	16565
239	7943	16606
240	7943	16607
241	7943	16608
242	11442	16668
243	11443	16668
244	11444	16668
245	11445	16668
246	11441	16669
247	11442	16669
248	11443	16669
249	11444	16669
250	11445	16669
251	11446	16669
252	11441	16670
253	11442	16670
254	11443	16670
255	11444	16670
256	11445	16670
257	11446	16670
258	11441	16671
259	11442	16671
260	11443	16671
261	11444	16671
262	11445	16671
263	11446	16671
264	11441	16672
265	11442	16672
266	11443	16672
267	11444	16672
268	11445	16672
269	11446	16672
270	11442	16673
271	11443	16673
272	11444	16673
273	11445	16673
274	11446	16673
275	8612	16682
276	7743	16697

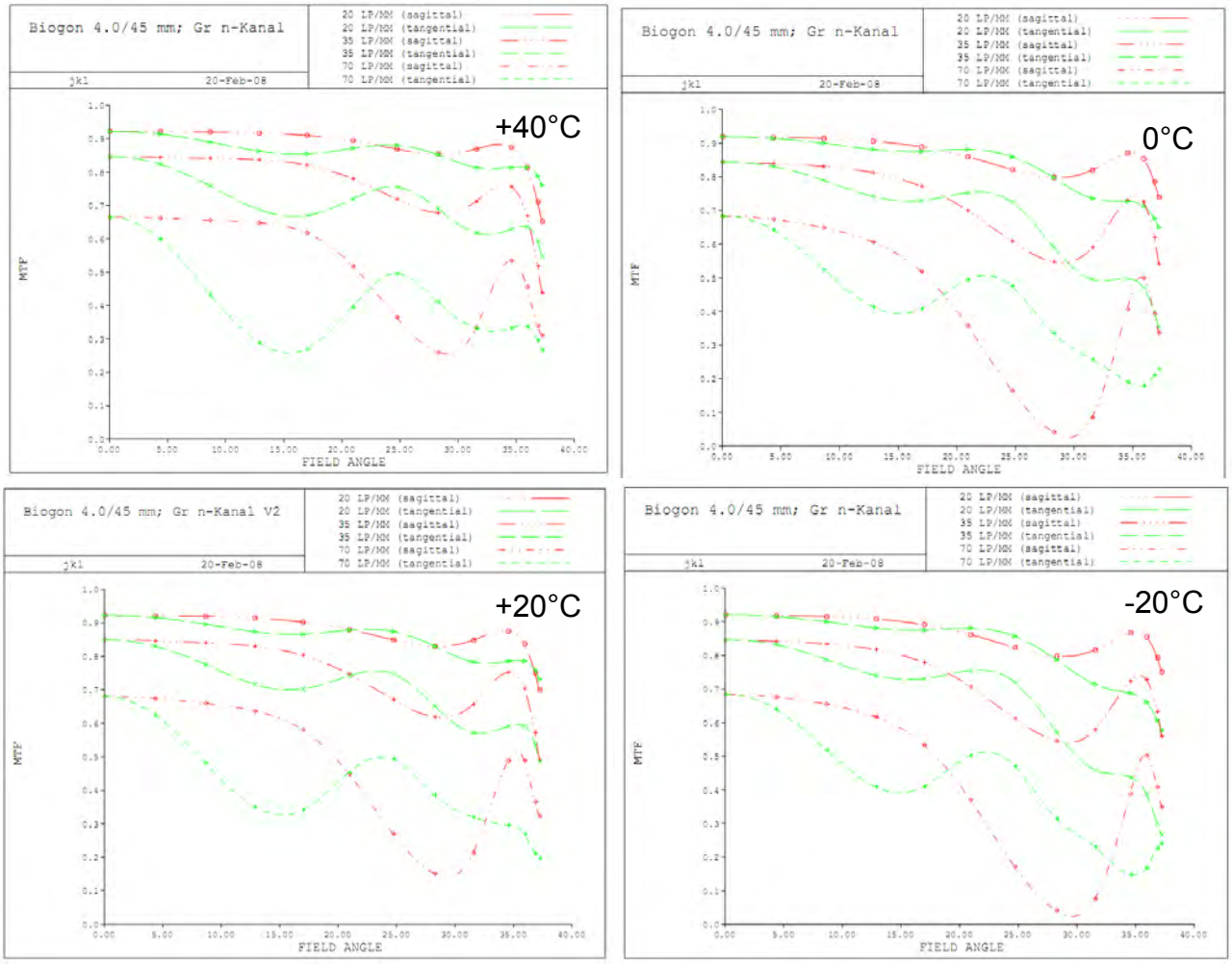
277	7742	16698
278	7743	16698
279	7741	16699
280	7742	16699
281	13449	16749
282	6542	16785
283	1499	16841
284	9192	16905
285	11268	16968
286	9586	17017
287	1177	17084
288	9203	17120
289	11171	17135
290	2594	17144
291	3168	17162
292	1023	17173
293	4764	17187
294	6157	17197

Defect	Column	RowStart	ColumnStart	RowEnd	ColumnEnd

Optical System

Modulation Transfer Function, MTF of Green camera

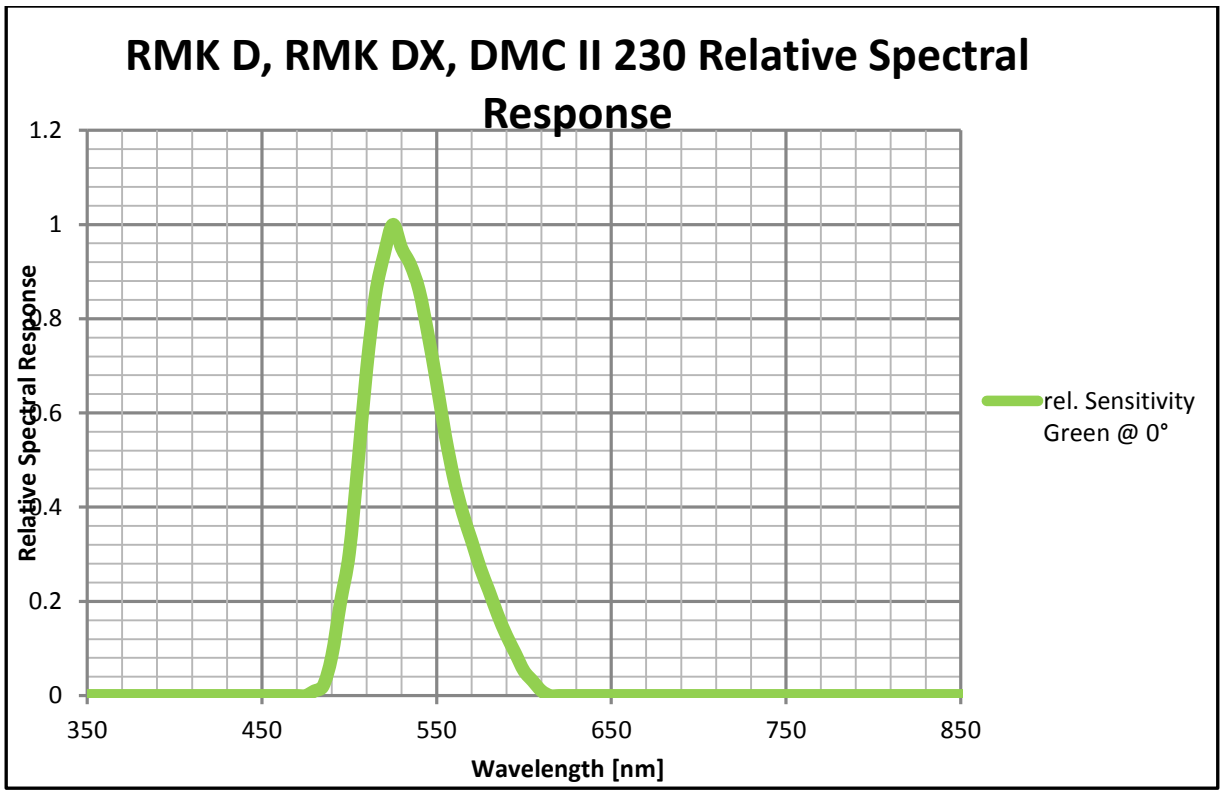
RMK D / RMK DX / DMC II MS Green – MTF F/4.0 ; 45 mm– Temperature Stability



Radiometric Calibration

Sensitivity of Green camera

Spectral response curve of the single camera head.

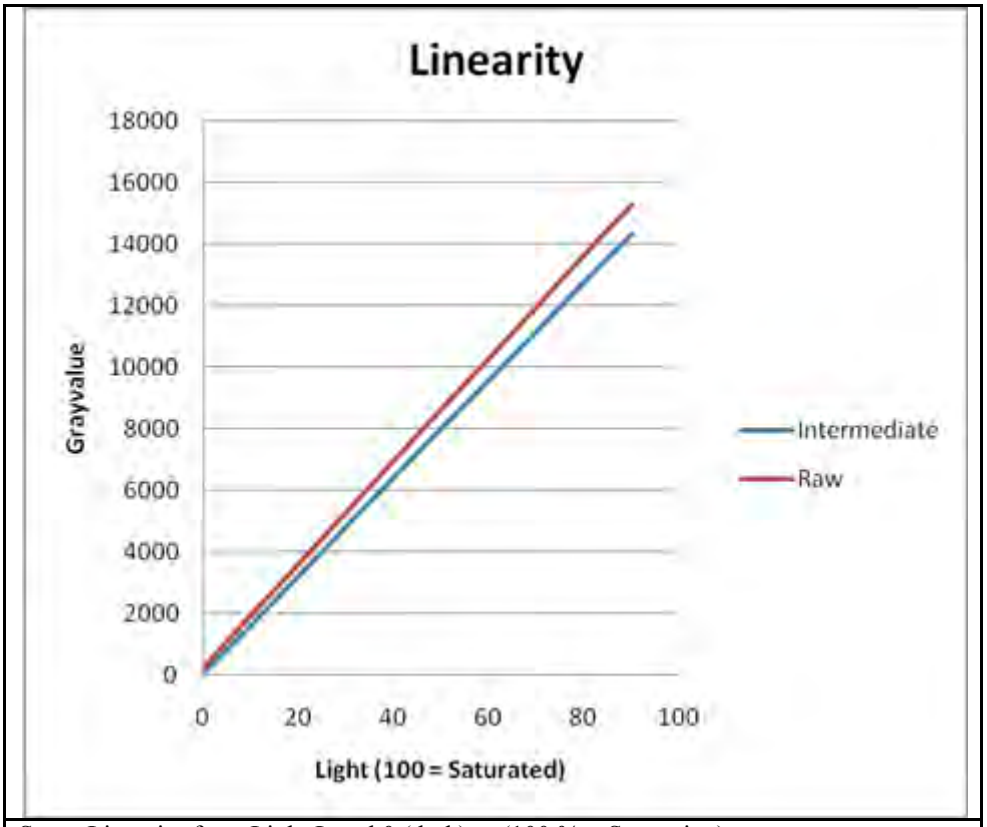


The sensitivity shows the spectral response curve of the single camera head including the optical system (optics, filter) and the sensor response. The DMC II 230 is calibrated with respect to the absolute spectrometer. This allows computing pixel radiance values from pixels digital numbers and is a camera type specific calibration.

Radiometric Calibration

Sensor Linearity (Reference)

The sensor linearity is measured in the Lab with calibrated spectrometer. This is a camera type specific calibration.
Below figure shows the linearity of the raw sensor and after flat fielding:



Senor Linearity from Light Level 0 (dark) to (100 % = Saturation)

The deviation from the linearity is below 1%.

Radiometric Calibration

Sensor Noise (Reference)

Sensor noise shows image noise with respect to the image center measured at an aperture of 8 with exposure time of 22msec. Sensor noise after calibration shall be less or equal 0.5% of radiometric resolution. At 14bit radiometric resolution 0.5% (of 16384) is equal to 82 gray values. This is a camera type specific calibration.

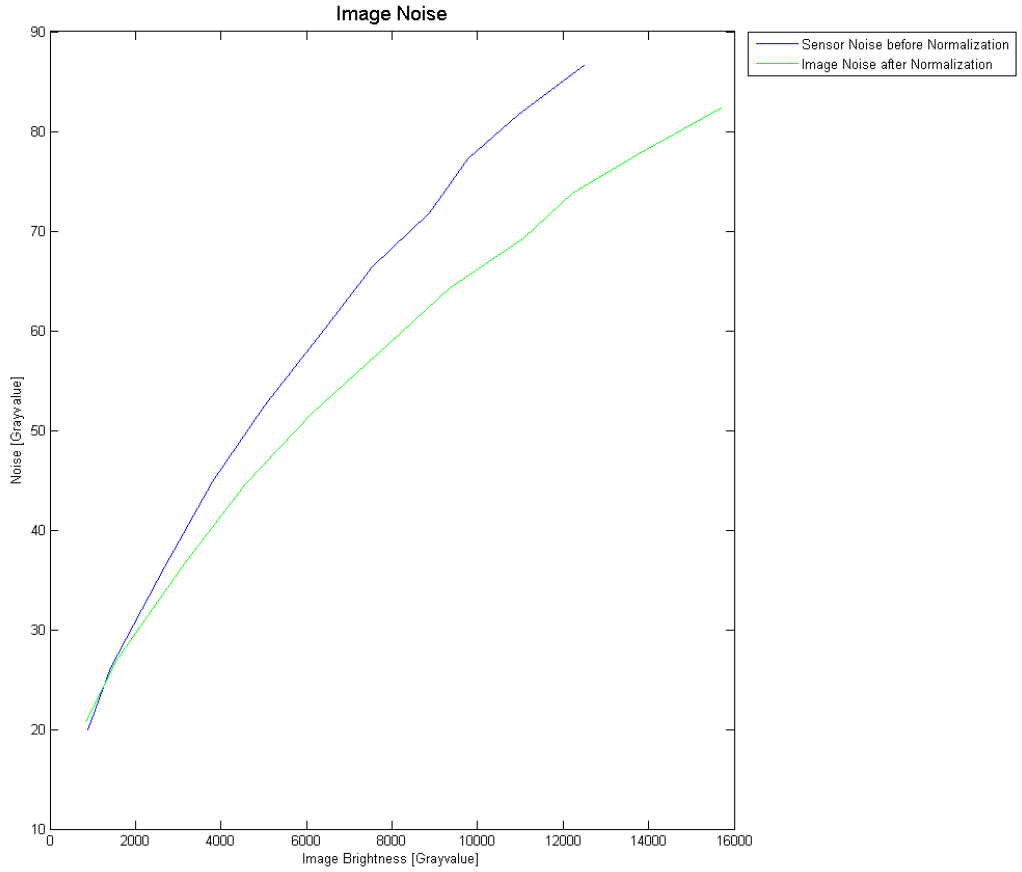


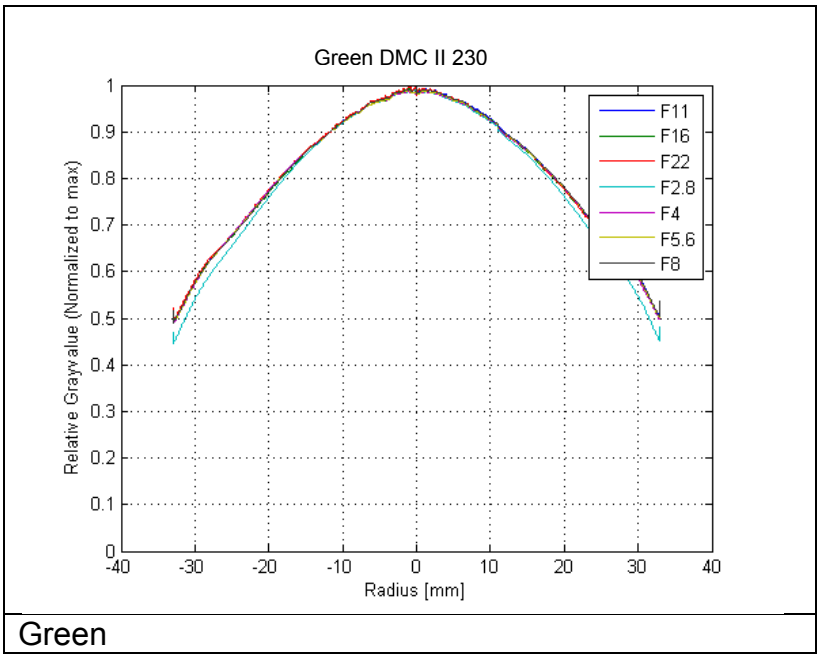
Image Noise before and after radiometric calibration

Radiometric Calibration

Aperture Correction

Green (00122307)

The light fall off to the border due the influence of the optics depends on the aperture used. Therefore this calibration approach delivers individual calibration images for each aperture (Full F-Stop). In general the light fall off is a function of the image height (radial distance from center). The figure below shows the profile from the upper left corner to the lower right corner of the calibration images.



Green

This is a camera type specific calibration.

Radiometric Calibration

Defect Pixel

Green (00122307)

Defect pixels are detected during radiometric calibration and will be corrected during radiometric processing of the images. The quantity and cumulative percentage and specification of defects is described in Appendix “Defect Pixel Recognition”.

Revision of calibration:	131073
CCDRevision:	1
Date Number:	1482148635
Date:	161219
Number of defect pixels:	859
Number of defect clusters:	0
Number of defect columns:	0

Nr	Row	Column
1	24	553
2	27	78
3	30	586
4	34	2633
5	36	5888
6	45	458
7	50	434
8	55	854
9	56	4279
10	58	2287
11	59	5420
12	111	4009
13	112	4371
14	113	4371
15	120	5698
16	144	4202
17	152	5236
18	178	6063
19	180	1664
20	183	1456
21	184	2682
22	251	5014
23	269	202
24	271	2702
25	280	4760
26	291	3288
27	304	1924
28	309	991
29	325	3987
30	327	2051
31	337	1461
32	363	4618
33	373	3237
34	374	4342
35	376	818
36	379	3390
37	380	1091
38	402	5183
39	421	1951
40	424	3815
41	425	1187
42	425	1559
43	429	1902
44	446	5640

45	473	2637
46	485	5012
47	511	4420
48	512	4391
49	518	2239
50	527	1843
51	532	5921
52	577	5810
53	594	2062
54	640	1125
55	658	2635
56	665	761
57	675	3429
58	696	1214
59	718	3904
60	720	5457
61	743	5001
62	755	2528
63	762	3961
64	763	4897
65	764	777
66	766	1015
67	769	439
68	771	349
69	779	1032
70	781	2521
71	798	2375
72	802	2681
73	816	1756
74	827	1195
75	838	2532
76	840	5301
77	846	1054
78	850	745
79	861	4777
80	875	2112
81	877	4168
82	879	6032
83	883	4178
84	899	1088
85	903	2222
86	908	643
87	910	5669
88	925	976
89	939	5366
90	955	1621
91	958	4803
92	983	2428
93	995	660
94	1015	746
95	1015	2120
96	1021	2594
97	1036	5401
98	1044	2084
99	1050	2657
100	1079	2442
101	1087	1763
102	1091	5177
103	1105	4970
104	1111	167
105	1113	473
106	1125	2458
107	1154	589
108	1155	1753
109	1159	2002
110	1159	2259
111	1179	1635
112	1192	4284
113	1195	3390
114	1196	5640
115	1199	4538
116	1201	1702
117	1216	2341
118	1224	5520
119	1230	5693
120	1276	4121
121	1337	4181

122	1344	1406
123	1347	3757
124	1350	3013
125	1353	2728
126	1353	3655
127	1361	4080
128	1379	2229
129	1385	587
130	1395	2578
131	1397	4804
132	1404	2580
133	1406	3041
134	1409	1054
135	1416	2606
136	1423	4196
137	1423	5288
138	1437	4070
139	1455	2337
140	1462	2919
141	1473	3739
142	1479	4948
143	1507	4993
144	1511	2447
145	1512	1978
146	1525	2196
147	1549	4998
148	1555	126
149	1556	1189
150	1561	2006
151	1565	194
152	1565	2009
153	1565	2264
154	1571	1988
155	1582	4634
156	1599	1058
157	1605	1497
158	1610	2136
159	1620	2353
160	1625	2145
161	1637	3689
162	1647	3104
163	1648	2781
164	1650	4700
165	1654	4362
166	1657	2801
167	1666	3356
168	1686	3364
169	1693	2388
170	1696	3463
171	1702	365
172	1729	3258
173	1766	3320
174	1775	4541
175	1776	2880
176	1783	905
177	1785	3658
178	1788	4336
179	1791	2530
180	1816	4103
181	1825	1300
182	1826	1300
183	1831	4475
184	1839	2871
185	1851	312
186	1866	1522
187	1883	4057
188	1897	4537
189	1900	3235
190	1912	1955
191	1916	2336
192	1921	4956
193	1925	2976
194	1928	1106
195	1930	2383
196	1932	2269
197	1932	5766
198	1933	4270

199	1945	5096
200	1962	3600
201	1963	2785
202	1967	4470
203	1969	129
204	1974	4288
205	1978	1505
206	1982	2001
207	1992	2470
208	2007	3711
209	2017	612
210	2028	3163
211	2037	5655
212	2050	1007
213	2054	5624
214	2071	2706
215	2076	4085
216	2080	41
217	2091	4911
218	2110	642
219	2110	2847
220	2120	2887
221	2121	822
222	2131	2080
223	2150	6076
224	2159	4247
225	2171	1608
226	2183	2844
227	2198	4725
228	2198	4900
229	2201	5447
230	2202	2256
231	2215	5379
232	2235	3350
233	2242	4975
234	2248	2963
235	2267	4570
236	2271	3228
237	2285	5354
238	2285	5686
239	2296	4838
240	2298	1531
241	2308	5600
242	2309	1892
243	2314	1292
244	2365	1912
245	2368	6055
246	2372	2198
247	2373	2802
248	2378	2608
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250	2385	4684
251	2388	5732
252	2391	553
253	2398	229
254	2402	3507
255	2408	1016
256	2414	2389
257	2415	4011
258	2416	1323
259	2422	5982
260	2423	4174
261	2427	5751
262	2445	4695
263	2489	1860
264	2492	1708
265	2496	1169
266	2500	5246
267	2504	5120
268	2515	200
269	2523	938
270	2554	542
271	2561	4002
272	2574	2182
273	2579	4784
274	2602	1571
275	2604	4724

276	2613	1638
277	2625	4388
278	2640	4792
279	2644	2145
280	2665	4265
281	2693	3254
282	2699	2441
283	2699	5179
284	2714	5560
285	2721	5753
286	2734	3122
287	2737	2530
288	2756	5482
289	2780	59
290	2790	3661
291	2793	4569
292	2801	3964
293	2814	82
294	2815	4114
295	2828	3122
296	2830	1576
297	2831	5639
298	2837	1111
299	2842	4069
300	2843	5152
301	2848	5555
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304	2877	1237
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306	2878	1616
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308	2901	2469
309	2902	4537
310	2904	5652
311	2906	3764
312	2908	4496
313	2909	1759
314	2910	2429
315	2939	26
316	2941	5001
317	2943	5623
318	2954	1899
319	2960	2949
320	2973	5363
321	2986	788
322	3007	520
323	3010	2216
324	3036	5608
325	3038	2306
326	3041	3797
327	3047	492
328	3066	3831
329	3074	554
330	3076	2007
331	3082	4432
332	3091	6063
333	3096	177
334	3101	1201
335	3101	1931
336	3103	350
337	3118	5408
338	3119	4005
339	3143	262
340	3150	3694
341	3152	1641
342	3166	2899
343	3169	4016
344	3170	2007
345	3175	5569
346	3177	4388
347	3189	5286
348	3205	1059
349	3206	2979
350	3210	173
351	3215	4591
352	3217	5609

353	3218	2240
354	3222	3254
355	3222	3872
356	3236	4569
357	3241	3269
358	3250	2406
359	3257	3646
360	3265	723
361	3293	499
362	3298	1936
363	3311	1570
364	3318	1998
365	3329	1445
366	3334	2582
367	3336	5425
368	3344	1397
369	3349	475
370	3373	21
371	3381	4566
372	3383	1882
373	3388	2544
374	3393	1083
375	3394	2922
376	3398	2123
377	3405	3463
378	3410	3032
379	3411	4079
380	3418	2771
381	3420	466
382	3421	1749
383	3424	3458
384	3428	3161
385	3441	3508
386	3459	67
387	3470	3278
388	3471	3277
389	3472	3276
390	3473	3275
391	3474	3273
392	3475	3272
393	3477	3269
394	3478	3268
395	3479	3267
396	3480	3266
397	3481	3265
398	3482	3263
399	3483	3262
400	3486	507
401	3486	3258
402	3492	3372
403	3495	3383
404	3506	2017
405	3509	1630
406	3514	3693
407	3519	1632
408	3522	752
409	3524	1797
410	3548	6008
411	3549	2626
412	3550	2802
413	3551	6094
414	3552	125
415	3552	3597
416	3559	4222
417	3560	3882
418	3562	2768
419	3566	5120
420	3574	2234
421	3581	3869
422	3582	4466
423	3597	2227
424	3598	3169
425	3601	148
426	3603	1824
427	3606	5835
428	3611	1580
429	3614	3996

430	3641	4148
431	3644	927
432	3653	3472
433	3654	4313
434	3664	2236
435	3670	4185
436	3672	648
437	3680	3610
438	3691	3835
439	3694	1612
440	3697	6024
441	3702	1559
442	3716	3303
443	3720	3700
444	3722	2715
445	3726	2630
446	3734	566
447	3739	3780
448	3757	5052
449	3758	2996
450	3780	2804
451	3793	4899
452	3803	4119
453	3807	1076
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455	3811	5353
456	3812	852
457	3815	5553
458	3818	1959
459	3820	1541
460	3830	5483
461	3834	5970
462	3838	1176
463	3857	6084
464	3863	1947
465	3864	2802
466	3869	1888
467	3870	5350
468	3874	5211
469	3880	1883
470	3883	4561
471	3885	3329
472	3890	4187
473	3902	5742
474	3910	4346
475	3925	1291
476	3926	3210
477	3934	2319
478	3934	4041
479	3962	267
480	3963	2101
481	3973	4212
482	3982	5741
483	3987	148
484	3995	2623
485	3998	1426
486	4002	1178
487	4013	2749
488	4014	3680
489	4030	3751
490	4039	5837
491	4040	4823
492	4066	2513
493	4066	2938
494	4072	1532
495	4081	719
496	4082	3373
497	4090	826
498	4095	835
499	4095	836
500	4096	837
501	4096	5239
502	4098	4050
503	4099	1074
504	4105	5321
505	4109	6050
506	4123	950

507	4128	3440
508	4132	3334
509	4151	2386
510	4157	1713
511	4161	2584
512	4166	6027
513	4172	2450
514	4175	777
515	4181	2878
516	4182	3839
517	4184	2377
518	4187	5113
519	4194	2520
520	4194	4639
521	4195	2626
522	4195	5950
523	4208	2259
524	4228	2558
525	4230	552
526	4244	536
527	4253	2473
528	4256	2971
529	4260	5946
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531	4274	4583
532	4275	1404
533	4305	2305
534	4318	1390
535	4319	3256
536	4330	514
537	4331	514
538	4335	1760
539	4347	4189
540	4355	705
541	4357	390
542	4357	3840
543	4360	3449
544	4376	4690
545	4380	3400
546	4385	3477
547	4395	2530
548	4397	417
549	4403	2878
550	4418	2066
551	4420	665
552	4423	929
553	4423	2265
554	4441	94
555	4443	3264
556	4444	4536
557	4446	4231
558	4446	4988
559	4454	5722
560	4471	4610
561	4473	1818
562	4484	4056
563	4498	940
564	4498	978
565	4499	4007
566	4509	4479
567	4520	1213
568	4520	3243
569	4520	4165
570	4524	5330
571	4530	3682
572	4531	5813
573	4533	2263
574	4573	1789
575	4578	4591
576	4581	3811
577	4586	952
578	4601	3133
579	4601	3709
580	4603	1934
581	4605	1382
582	4628	2683
583	4635	5290

584	4639	3020
585	4646	2131
586	4653	4868
587	4655	949
588	4658	2311
589	4661	3547
590	4666	5319
591	4667	3158
592	4681	1986
593	4694	5860
594	4695	1299
595	4702	2267
596	4710	910
597	4716	4062
598	4718	2597
599	4726	2488
600	4732	3652
601	4732	4692
602	4743	4537
603	4753	3667
604	4762	831
605	4767	3774
606	4768	5303
607	4769	1529
608	4773	322
609	4777	5328
610	4780	2133
611	4792	3557
612	4796	5728
613	4798	2318
614	4809	997
615	4809	6011
616	4853	742
617	4853	2367
618	4856	5443
619	4861	3819
620	4872	4463
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622	4898	4052
623	4901	3482
624	4914	4340
625	4917	3557
626	4926	3203
627	4933	1455
628	4934	98
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630	4946	446
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632	4966	4136
633	4993	2476
634	4993	6019
635	5004	2358
636	5015	1576
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640	5056	276
641	5056	5191
642	5071	1073
643	5081	3812
644	5092	4976
645	5105	882
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647	5126	2405
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651	5138	3220
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654	5156	418
655	5158	331
656	5171	1844
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658	5204	1562
659	5206	672
660	5210	3229

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671	5267	2398
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673	5282	5570
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676	5302	87
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678	5327	4932
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682	5358	1925
683	5362	4523
684	5379	5109
685	5418	2533
686	5434	3184
687	5436	2631
688	5437	2501
689	5442	5777
690	5443	4008
691	5448	272
692	5460	60
693	5466	3196
694	5475	1708
695	5476	140
696	5480	476
697	5481	5179
698	5484	6066
699	5487	4548
700	5493	976
701	5524	4299
702	5526	4934
703	5534	865
704	5534	2627
705	5539	3532
706	5544	4095
707	5552	4242
708	5563	4919
709	5570	95
710	5578	2446
711	5579	1870
712	5604	2069
713	5620	1245
714	5623	3939
715	5624	5265
716	5625	5872
717	5627	5494
718	5652	5660
719	5660	530
720	5672	1399
721	5683	5207
722	5690	3435
723	5698	3728
724	5699	3821
725	5700	3381
726	5700	3415
727	5706	1615
728	5707	4198
729	5709	4836
730	5742	2813
731	5762	4431
732	5769	5003
733	5775	2240
734	5782	1823
735	5786	867
736	5787	389
737	5793	326

738	5796	3640
739	5802	5995
740	5810	1553
741	5814	5067
742	5819	3724
743	5819	5193
744	5823	4933
745	5824	197
746	5833	4617
747	5834	4391
748	5848	4342
749	5858	2092
750	5887	4780
751	5891	3233
752	5893	2567
753	5927	2669
754	5957	1001
755	5967	3120
756	5983	3394
757	5991	4288
758	5996	3719
759	5997	1727
760	5999	5483
761	6006	3681
762	6012	263
763	6038	2624
764	6039	84
765	6046	4074
766	6061	1991
767	6071	3798
768	6081	3680
769	6083	5344
770	6087	643
771	6091	170
772	6114	3304
773	6135	2297
774	6137	712
775	6156	2634
776	6160	1739
777	6165	5158
778	6166	905
779	6169	149
780	6172	2142
781	6173	4917
782	6182	5222
783	6194	5410
784	6196	874
785	6229	3790
786	6240	5771
787	6245	309
788	6250	2512
789	6255	2751
790	6263	2635
791	6272	4436
792	6275	5169
793	6295	3860
794	6298	5416
795	6301	827
796	6315	3293
797	6318	2369
798	6318	4086
799	6322	2215
800	6331	351
801	6335	4268
802	6356	261
803	6373	973
804	6405	1866
805	6411	5672
806	6415	495
807	6425	3546
808	6426	4486
809	6428	5485
810	6457	1124
811	6475	189
812	6491	4670
813	6494	3768
814	6501	891

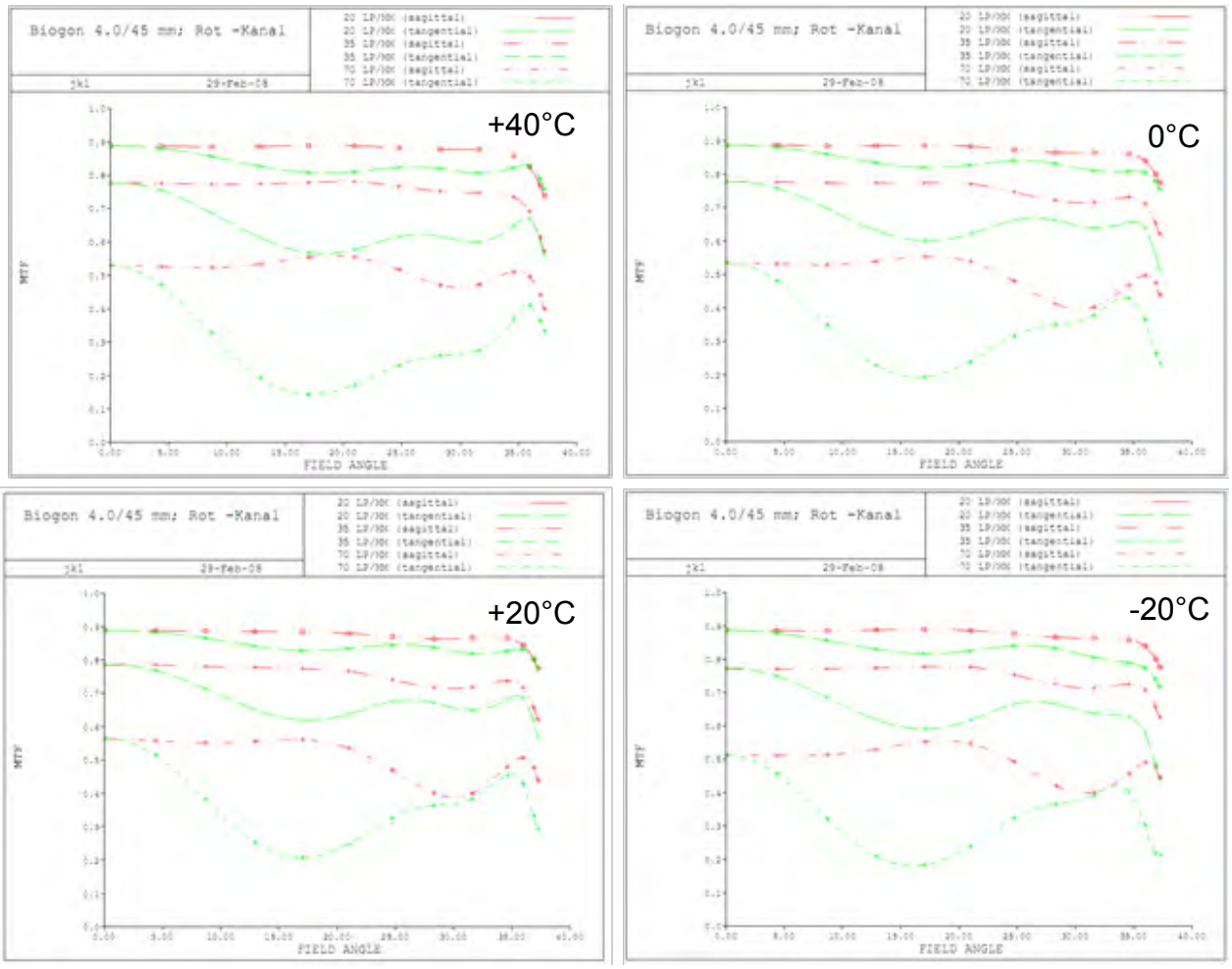
815	6510	4792
816	6515	3703
817	6525	280
818	6535	3950
819	6542	4797
820	6543	5473
821	6546	1987
822	6548	2258
823	6550	1971
824	6556	692
825	6556	5563
826	6569	1935
827	6571	2592
828	6579	1527
829	6579	3169
830	6582	5225
831	6583	5151
832	6590	4327
833	6596	3761
834	6609	472
835	6616	1726
836	6618	4180
837	6645	4361
838	6658	2955
839	6667	4345
840	6671	1548
841	6674	95
842	6696	4762
843	6697	3461
844	6699	2760
845	6718	3715
846	6718	5982
847	6730	3355
848	6764	3975
849	6774	2247
850	6787	1303
851	6799	4370
852	6801	2932
853	6806	4132
854	6807	1262
855	6829	2754
856	6829	5591
857	6840	3360
858	6842	3216

Defect	Column	RowStart	ColumnStart	RowEnd	ColumnEnd

Optical System

Modulation Transfer Function, MTF of Red camera

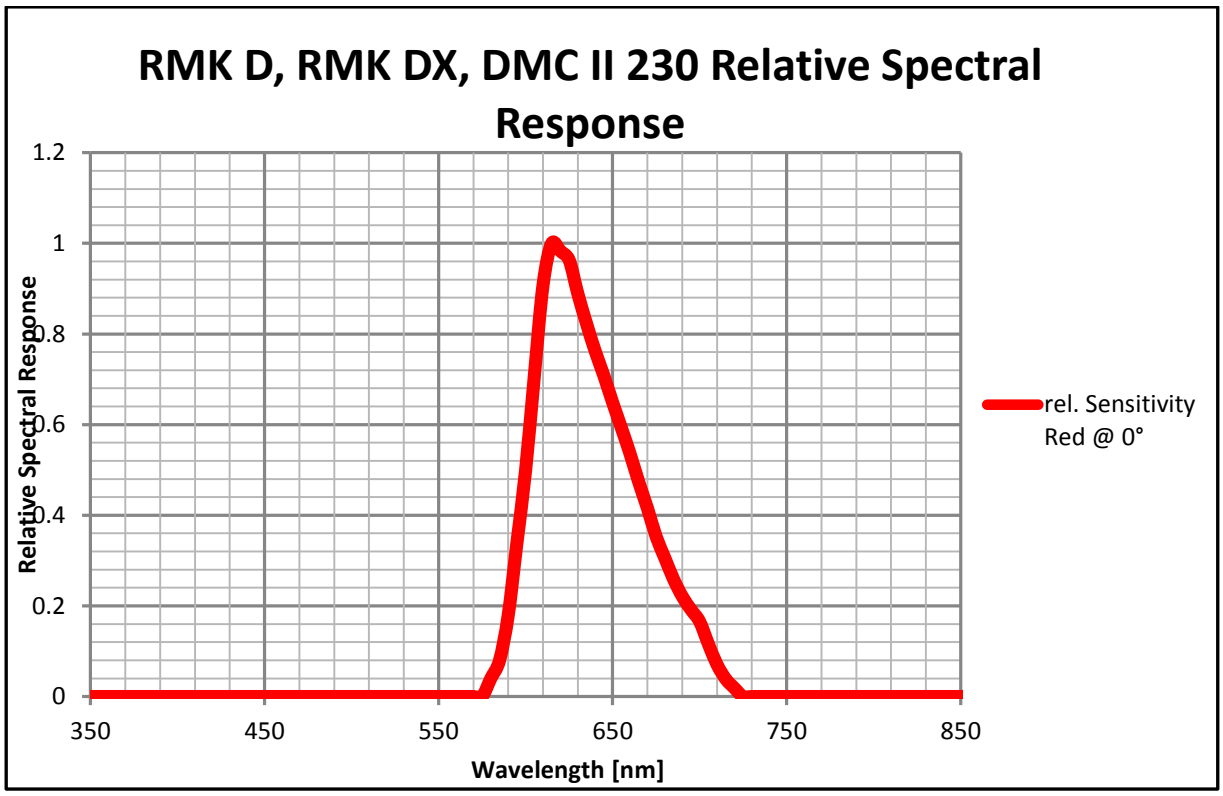
RMK D / RMK DX / DMC II MS Red – MTF F/4.0 ; 45 mm– Temperature Stability



Radiometric Calibration

Sensitivity of Red camera

Spectral Response Curves of the single camera head.

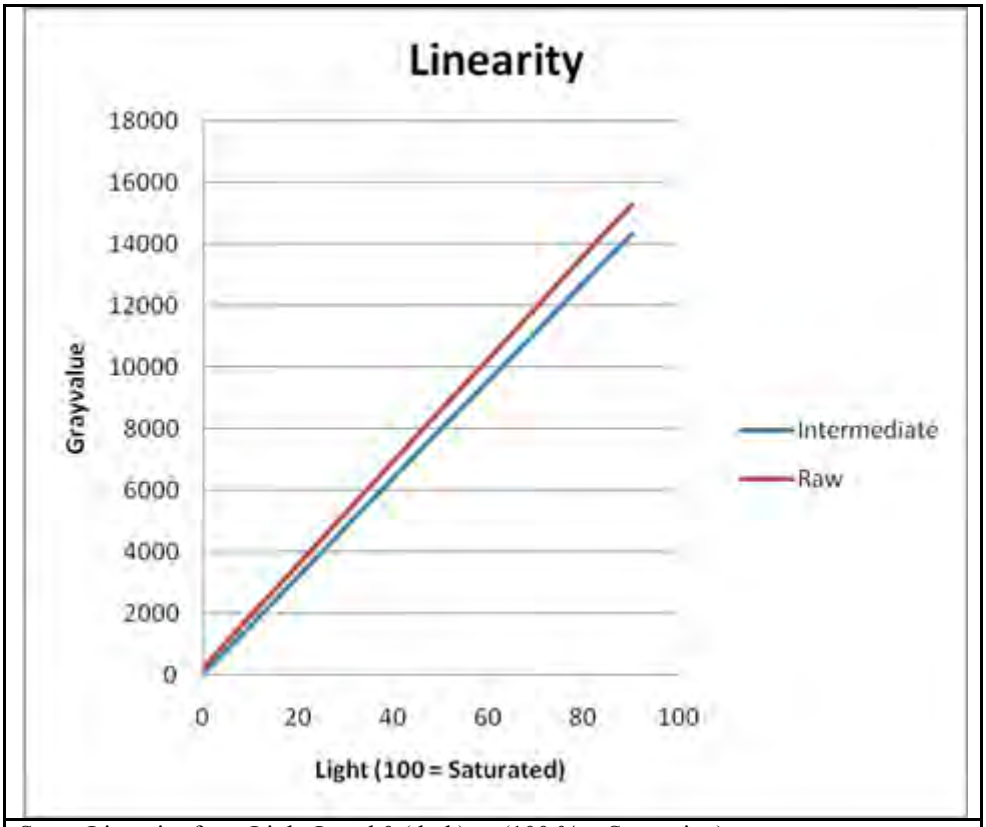


The sensitivity shows the spectral response curve of the single camera head including the optical system (optics, filter) and the sensor response. The DMC II 230 is calibrated with respect to the absolute spectrometer. This allows computing pixel radiance values from pixels digital numbers and is a camera type specific calibration.

Radiometric Calibration

Sensor Linearity (Reference)

The sensor linearity is measured in the Lab with calibrated spectrometer. This is a camera type specific calibration.
Below figure shows the linearity of the raw sensor and after flat fielding:



Senor Linearity from Light Level 0 (dark) to (100 % = Saturation)

The deviation from the linearity is below 1%.

Radiometric Calibration

Sensor Noise (Reference)

Sensor noise shows image noise with respect to the image center measured at an aperture of 8 with exposure time of 22msec. Sensor noise after calibration shall be less or equal 0.5% of radiometric resolution. At 14bit radiometric resolution 0.5% (of 16384) is equal to 82 gray values. This is a camera type specific calibration.

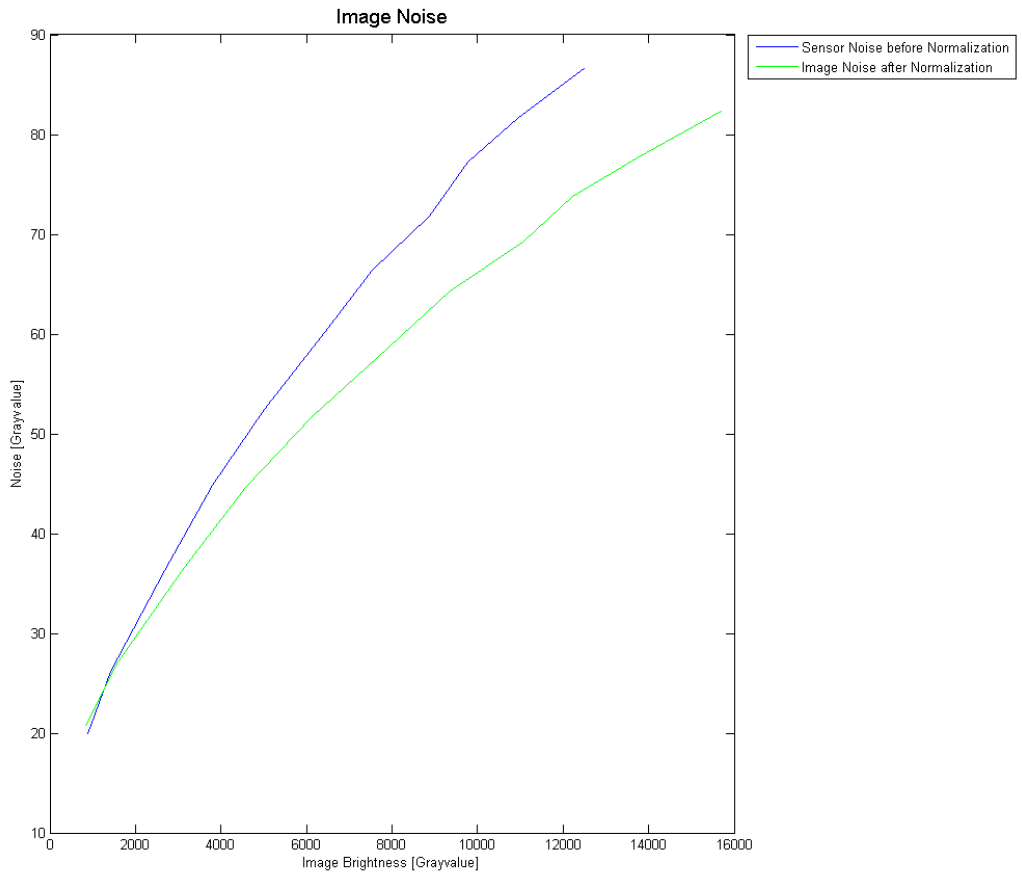


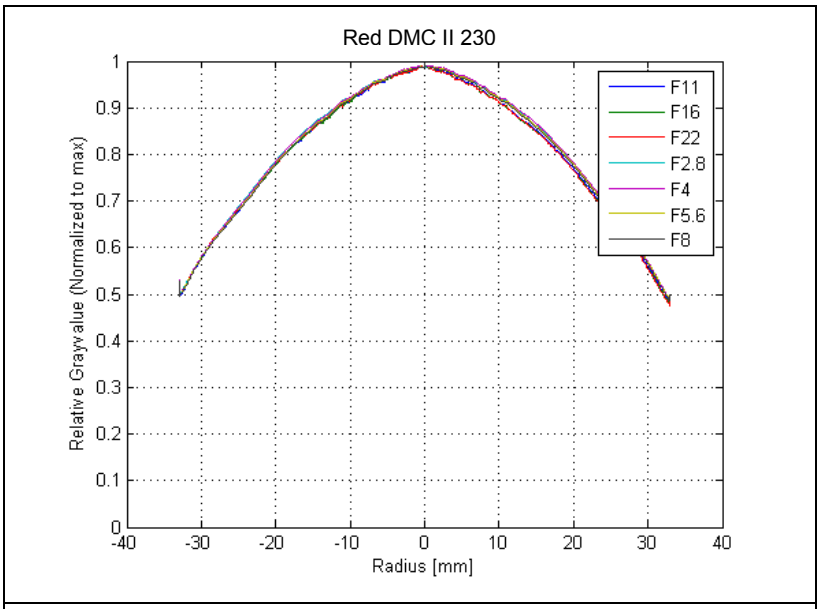
Image Noise before and after radiometric calibration

Radiometric Calibration

Aperture Correction

Red (00118779)

The light fall off to the border due the influence of the optics depends on the used aperture. Therefore this calibration approach has for each aperture (Full F-Stop) its own calibration image. In general the light fall off is a function of the image radius. In this calibration approach instead of function the real measured values in the image is used. The figure below shows the profile from the upper left corner to the lower right corner of each of this calibration images to give a feeling on the amount of correction.



Red

This is a camera type specific calibration.

Radiometric Calibration

Defect Pixel

Red (00118779)

Defect pixels are detected during radiometric calibration and will be corrected during radiometric processing of the images. The quantity and cumulative percentage and specification of defects is described in Appendix “Defect Pixel Recognition”.

Revision of calibration:	65537
CCDRevision:	1
Date Number:	1368518143
Date:	130514
Number of defect pixels:	860
Number of defect clusters:	0
Number of defect columns:	0

Nr	Row	Column
0	11	3268
1	26	4993
2	30	502
3	34	2648
4	56	3321
5	69	4117
6	76	1295
7	80	2
8	80	3248
9	91	3330
10	96	5837
11	116	2391
12	136	4179
13	144	1790
14	144	2650
15	144	3786
16	148	4980
17	151	485
18	152	605
19	174	5037
20	184	3164
21	198	1617
22	199	1572
23	232	6034
24	234	3750
25	237	1917
26	237	2518
27	239	3092
28	241	1067
29	242	5333
30	275	973
31	280	2377
32	285	1961
33	286	3036
34	287	1878
35	289	830
36	298	1378
37	308	4775
38	310	4234
39	315	1606
40	339	3767
41	343	3440
42	347	4032

43	357	3963
44	360	2224
45	365	3188
46	398	1745
47	399	3603
48	400	139
49	400	4369
50	403	3209
51	404	3938
52	409	301
53	413	3208
54	426	1083
55	435	213
56	441	1514
57	442	164
58	446	4006
59	453	4997
60	458	639
61	492	3259
62	504	4965
63	506	4032
64	518	1933
65	544	2489
66	548	4079
67	565	692
68	568	3122
69	570	3911
70	577	4589
71	583	3700
72	619	5580
73	630	3497
74	651	4147
75	654	3247
76	654	5047
77	656	1500
78	659	3404
79	663	2854
80	682	955
81	707	2382
82	721	791
83	744	66
84	744	1230
85	753	2041
86	762	4393
87	785	4613
88	791	5369
89	792	2078
90	804	134
91	822	4158
92	832	3407
93	837	4996
94	839	1050
95	842	3108
96	844	874
97	857	3954
98	874	336
99	874	6081
100	880	2234
101	884	3518
102	893	1803
103	895	4982
104	901	906
105	903	4964
106	928	5532
107	945	2610
108	958	5972
109	962	5112
110	974	1436
111	975	5280
112	981	1079
113	987	794
114	995	2041
115	995	4978
116	1010	2581
117	1010	4400
118	1013	1555
119	1023	1847

120	1023	4540
121	1038	5926
122	1041	4096
123	1066	1796
124	1068	3767
125	1070	3868
126	1073	1703
127	1079	4802
128	1086	2037
129	1108	1037
130	1133	3424
131	1140	1528
132	1143	407
133	1154	4774
134	1172	5620
135	1172	5810
136	1188	169
137	1192	937
138	1223	1488
139	1228	5731
140	1241	2303
141	1247	1827
142	1250	640
143	1301	990
144	1308	3327
145	1321	4711
146	1322	3168
147	1323	3645
148	1324	720
149	1335	5878
150	1338	122
151	1345	4806
152	1346	2743
153	1347	679
154	1352	3314
155	1358	3210
156	1358	5664
157	1359	365
158	1359	1292
159	1383	3394
160	1417	3503
161	1419	1244
162	1419	2063
163	1423	1114
164	1424	3486
165	1424	4321
166	1428	5721
167	1430	1100
168	1451	2771
169	1451	2776
170	1471	184
171	1476	4268
172	1483	5269
173	1490	4854
174	1506	6080
175	1520	3943
176	1526	17
177	1532	2140
178	1535	4427
179	1537	2232
180	1538	4354
181	1542	2450
182	1546	5720
183	1560	335
184	1569	5806
185	1588	1278
186	1590	5202
187	1600	5251
188	1613	5582
189	1620	673
190	1620	1823
191	1622	519
192	1639	3860
193	1643	2177
194	1691	3436
195	1693	3877
196	1698	2033

197	1700	1525
198	1700	3748
199	1710	2007
200	1725	4133
201	1732	3445
202	1742	3610
203	1781	5836
204	1797	2227
205	1826	4341
206	1832	2710
207	1835	1287
208	1835	2470
209	1842	4160
210	1858	4492
211	1858	5943
212	1874	4746
213	1879	5396
214	1885	931
215	1889	1227
216	1890	456
217	1903	432
218	1913	410
219	1924	3677
220	1952	1969
221	1971	1633
222	1974	4058
223	2009	5989
224	2010	3728
225	2011	635
226	2020	5855
227	2023	120
228	2023	382
229	2025	2369
230	2038	5414
231	2042	827
232	2077	1953
233	2083	653
234	2092	17
235	2106	597
236	2106	4405
237	2108	3969
238	2117	1041
239	2117	2195
240	2122	2804
241	2127	1389
242	2132	5713
243	2133	5713
244	2150	3353
245	2151	1325
246	2187	5291
247	2189	5814
248	2197	4083
249	2202	2721
250	2203	4331
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252	2210	2615
253	2238	2602
254	2252	1733
255	2256	4013
256	2286	3263
257	2299	4139
258	2305	4142
259	2314	3012
260	2316	5677
261	2336	3758
262	2346	1573
263	2346	4956
264	2350	4016
265	2353	360
266	2355	3285
267	2367	2954
268	2392	4061
269	2407	3209
270	2408	2407
271	2414	3383
272	2415	2723
273	2426	3979

274	2427	1382
275	2431	2292
276	2432	2143
277	2433	1301
278	2434	4579
279	2445	2525
280	2447	330
281	2480	1458
282	2480	3138
283	2497	1318
284	2501	1573
285	2506	2199
286	2516	6019
287	2532	4195
288	2546	35
289	2549	1699
290	2554	5789
291	2559	1706
292	2567	6016
293	2569	2064
294	2573	3983
295	2589	2877
296	2596	3703
297	2596	4368
298	2638	2138
299	2650	1680
300	2662	1275
301	2674	3897
302	2676	1101
303	2677	1071
304	2680	2599
305	2681	4016
306	2682	5627
307	2692	4069
308	2702	4568
309	2706	539
310	2732	264
311	2733	5414
312	2743	4893
313	2756	175
314	2760	2597
315	2765	5779
316	2780	53
317	2793	2777
318	2809	4250
319	2810	433
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321	2827	3460
322	2832	4886
323	2833	2263
324	2840	2770
325	2844	3553
326	2849	5196
327	2850	1543
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331	2872	2717
332	2878	2859
333	2880	2927
334	2892	3590
335	2907	5458
336	2932	4192
337	2938	3726
338	2941	3964
339	2962	2434
340	2980	5262
341	2985	5717
342	2992	2098
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344	3019	3565
345	3022	835
346	3037	5397
347	3039	1823
348	3049	2960
349	3070	4769
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351	3081	5501
352	3096	458
353	3101	4195
354	3111	589
355	3111	688
356	3112	4641
357	3117	4830
358	3140	5840
359	3149	4975
360	3158	3777
361	3174	226
362	3184	5850
363	3186	5113
364	3186	5484
365	3209	4216
366	3213	2259
367	3219	500
368	3232	3050
369	3241	4984
370	3248	6051
371	3252	4413
372	3279	3966
373	3283	4405
374	3287	2478
375	3296	3205
376	3299	5046
377	3322	4556
378	3334	1440
379	3334	1443
380	3358	4698
381	3367	1295
382	3370	3272
383	3405	4633
384	3406	2673
385	3409	3344
386	3409	5332
387	3412	5430
388	3422	4630
389	3424	682
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392	3433	2444
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395	3447	1256
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397	3480	346
398	3483	289
399	3493	1744
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401	3496	4806
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405	3549	3825
406	3550	323
407	3555	661
408	3561	978
409	3571	238
410	3572	3361
411	3576	402
412	3587	2092
413	3591	2219
414	3594	4383
415	3599	762
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417	3605	3107
418	3607	4159
419	3608	3085
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438	3743	2387
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440	3783	2288
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443	3814	2854
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445	3826	254
446	3826	518
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448	3857	5726
449	3863	860
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454	3900	5827
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466	3983	912
467	3987	1431
468	3993	3470
469	3996	334
470	3999	4229
471	3999	6032
472	4006	5941
473	4052	5601
474	4063	1951
475	4064	5848
476	4065	5620
477	4068	4835
478	4076	4416
479	4082	2523
480	4088	563
481	4089	2510
482	4094	150
483	4121	811
484	4122	3271
485	4123	2137
486	4130	1975
487	4137	12
488	4139	1585
489	4142	192
490	4159	2609
491	4174	4762
492	4180	250
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494	4187	4719
495	4190	2601
496	4196	248
497	4207	5423
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499	4209	2107
500	4209	2201
501	4224	576
502	4234	2129
503	4240	149
504	4241	5634

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506	4265	2503
507	4269	5617
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509	4274	4779
510	4275	3533
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514	4298	5364
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516	4320	1962
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518	4334	1725
519	4336	3902
520	4348	5528
521	4359	2045
522	4363	4215
523	4367	3407
524	4374	4385
525	4382	4599
526	4388	2866
527	4410	4318
528	4410	4333
529	4410	5931
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537	4487	4383
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539	4492	3067
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545	4524	2023
546	4527	5287
547	4538	5786
548	4541	1653
549	4565	803
550	4567	3
551	4570	3020
552	4570	3407
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554	4588	2093
555	4591	3887
556	4599	1832
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558	4619	1941
559	4634	2553
560	4650	3486
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562	4654	1674
563	4665	2900
564	4675	3044
565	4694	3619
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567	4722	1254
568	4722	1634
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571	4743	2124
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573	4759	3148
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575	4778	1273
576	4793	3547
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578	4794	3127
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584	4852	3344
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586	4864	1310
587	4868	6022
588	4878	3844
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590	4890	712
591	4899	5549
592	4916	398
593	4917	400
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596	4928	198
597	4932	2263
598	4937	2948
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601	4951	3146
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603	4984	1728
604	4997	2589
605	4999	1816
606	5007	1572
607	5021	1330
608	5021	1713
609	5022	1356
610	5031	2797
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613	5052	3677
614	5054	1856
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617	5065	1113
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623	5088	3066
624	5093	6021
625	5100	179
626	5118	3171
627	5143	4608
628	5158	4958
629	5165	185
630	5165	186
631	5173	2103
632	5178	5105
633	5184	2952
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636	5223	1317
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655	5321	4156
656	5322	3289
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665	5353	1268
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668	5383	136
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673	5419	1768
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679	5440	1440
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682	5451	2733
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684	5454	1209
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687	5470	1415
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693	5501	4274
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712	5611	2588
713	5628	1756
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715	5639	5599
716	5644	4706
717	5646	5791
718	5653	31
719	5665	5712
720	5665	6042
721	5681	5916
722	5688	3272
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724	5694	2604
725	5709	1463
726	5714	5022
727	5720	2268
728	5722	2057
729	5732	3680
730	5749	4172
731	5762	2060
732	5763	3101
733	5766	2021
734	5771	4359
735	5775	5242

736	5782	2265
737	5789	846
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739	5818	2260
740	5837	5753
741	5848	4355
742	5882	5766
743	5884	4601
744	5889	3988
745	5907	3934
746	5919	2800
747	5928	4485
748	5928	5720
749	5938	5792
750	5941	2176
751	5943	127
752	5944	2178
753	5945	5376
754	5958	4149
755	5959	1133
756	5966	1647
757	5975	2196
758	5980	769
759	5984	5127
760	6002	3949
761	6002	6022
762	6009	3637
763	6026	3532
764	6027	3531
765	6027	3532
766	6031	2924
767	6032	4363
768	6065	2770
769	6067	2345
770	6076	3590
771	6082	3222
772	6083	1631
773	6114	678
774	6130	4347
775	6136	1358
776	6142	5510
777	6145	3622
778	6154	1309
779	6155	4715
780	6180	5605
781	6185	3007
782	6187	2859
783	6189	2038
784	6198	1942
785	6208	2744
786	6211	1000
787	6214	4640
788	6226	3671
789	6274	3798
790	6281	2912
791	6299	3173
792	6307	3851
793	6320	1433
794	6344	2753
795	6360	2946
796	6366	1095
797	6375	2333
798	6381	3813
799	6386	3377
800	6394	5137
801	6402	2267
802	6404	1271
803	6414	4308
804	6414	5666
805	6419	4188
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807	6433	4165
808	6434	727
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810	6440	3212
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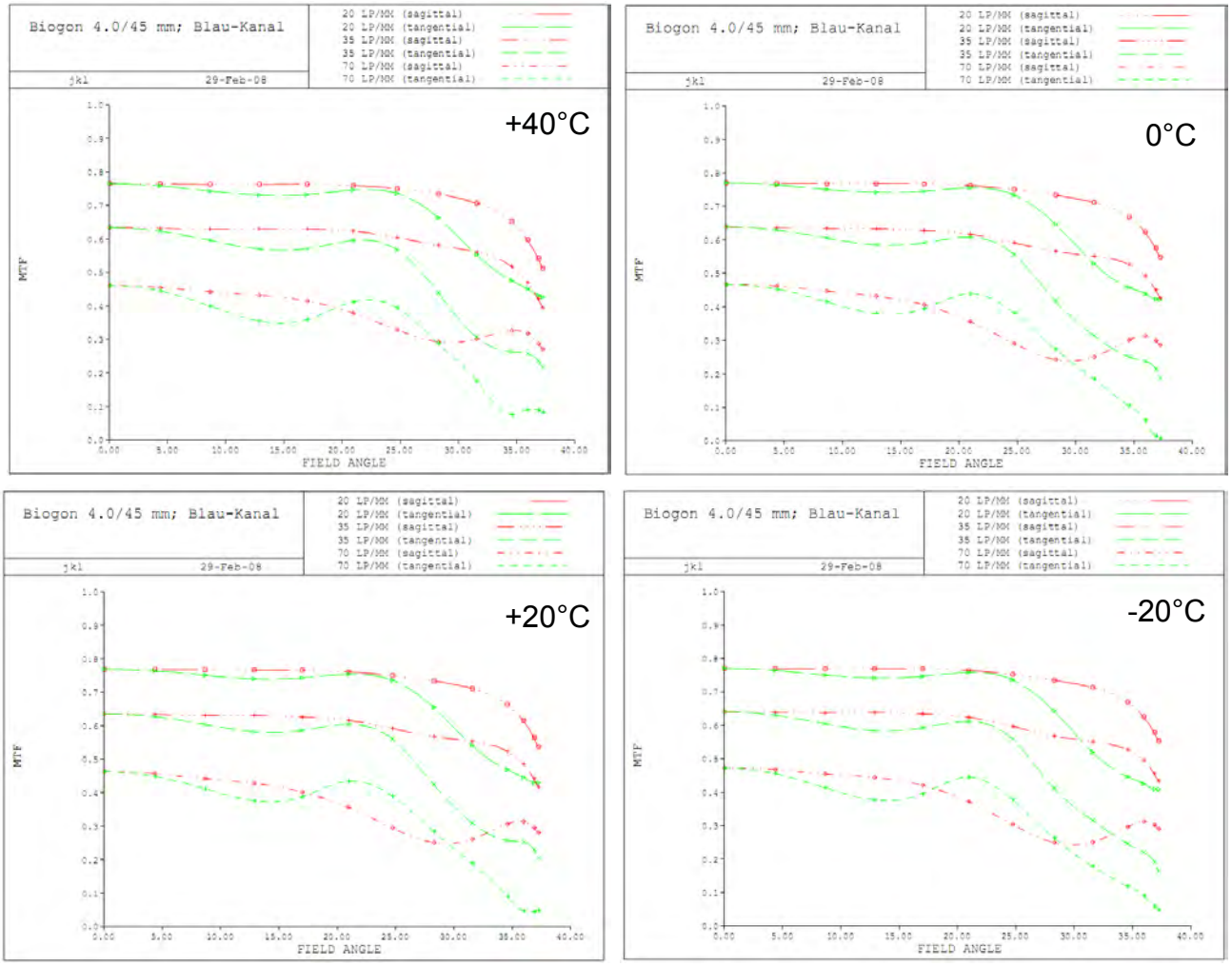
816	6499	1245
817	6500	2560
818	6501	2093
819	6503	2742
820	6504	3775
821	6513	4924
822	6529	5280
823	6551	2306
824	6553	5578
825	6555	5228
826	6557	3560
827	6570	1686
828	6571	3648
829	6571	5054
830	6577	444
831	6589	4036
832	6638	110
833	6644	1372
834	6653	958
835	6655	1861
836	6660	5386
837	6665	1977
838	6670	1251
839	6680	6017
840	6682	797
841	6683	4260
842	6687	1017
843	6689	92
844	6692	4336
845	6695	5828
846	6701	2055
847	6709	1740
848	6712	1382
849	6727	1762
850	6730	5802
851	6731	4246
852	6742	5000
853	6755	3625
854	6756	5723
855	6763	4484
856	6796	895
857	6804	2699
858	6811	1365
859	6817	5080

Defect Column	RowStart ColumnStart	RowEnd ColumnEnd

Optical System

Modulation Transfer Function, MTF of Blue camera

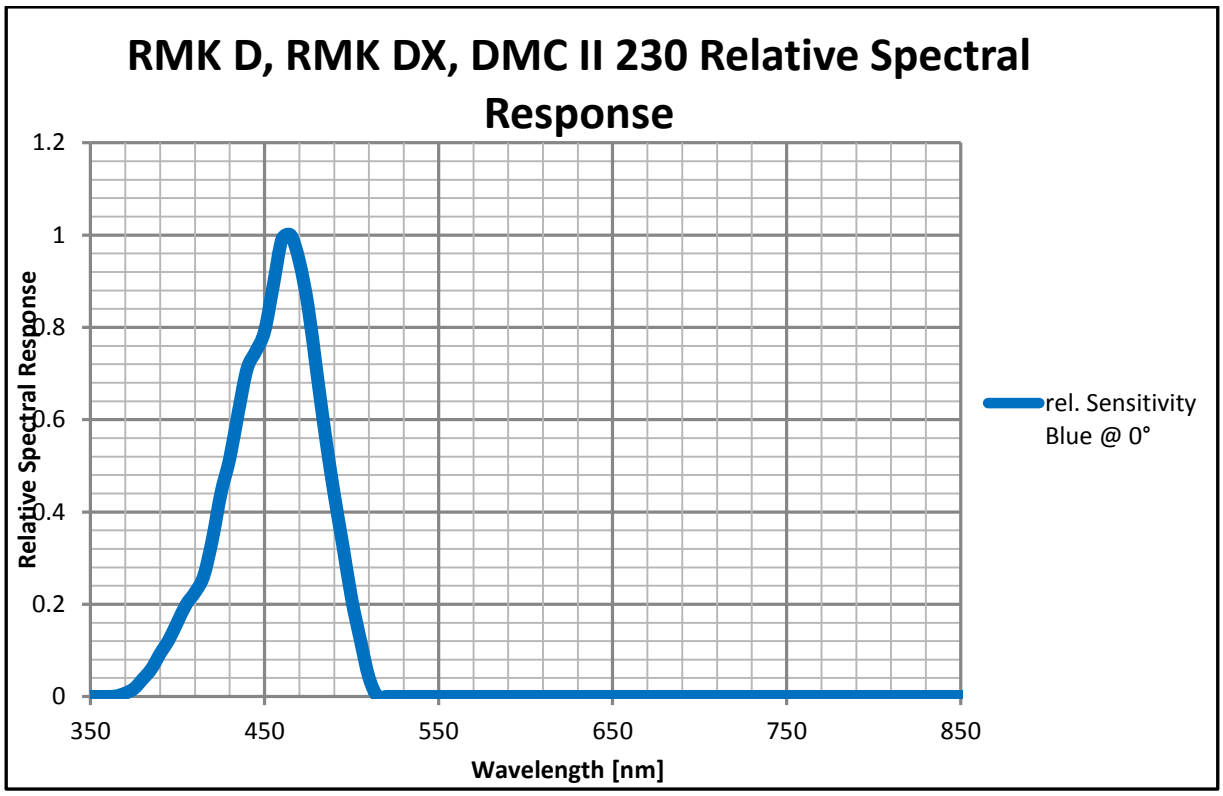
RMK D / RMK DX / DMC II MS Blue – MTF F/4.0 ; 45 mm– Temperature Stability



Radiometric Calibration

Sensitivity of Blue camera

Spectral Response Curves of the single camera head.

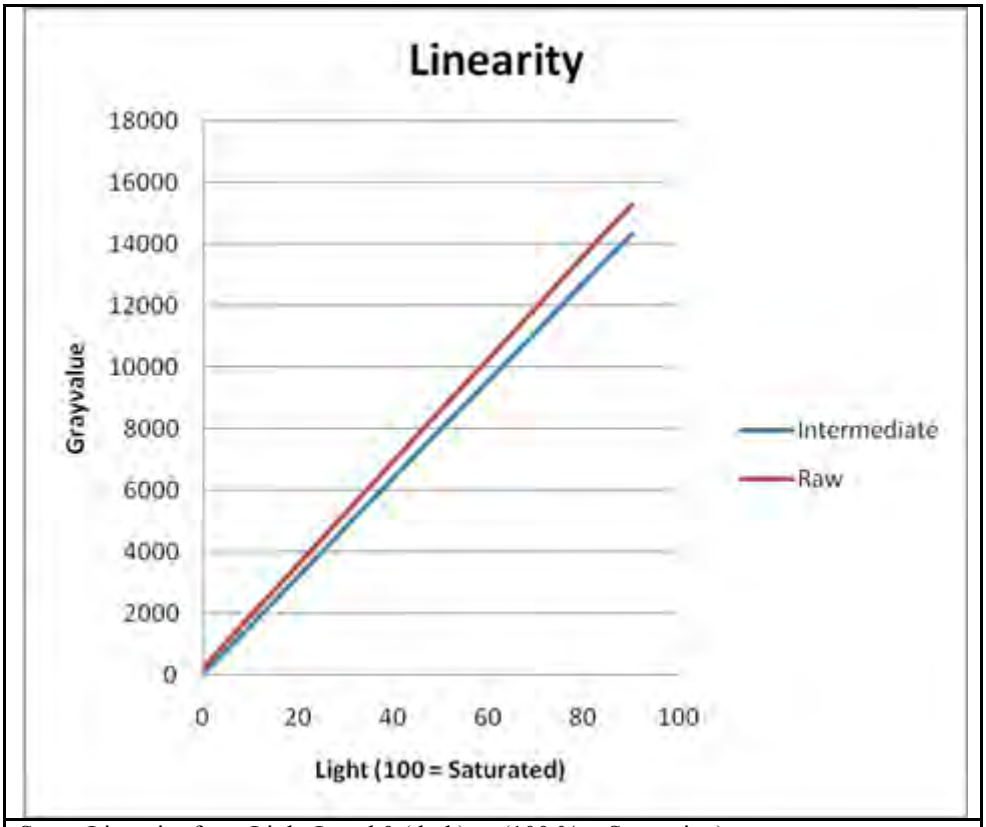


The sensitivity shows the spectral response curve of the single camera head including the optical system (optics, filter) and the sensor response. The DMC II 230 is calibrated with respect to the absolute spectrometer. This allows computing pixel radiance values from pixels digital numbers and is a camera type specific calibration.

Radiometric Calibration

Sensor Linearity (Reference)

The sensor linearity is measured in the Lab with calibrated spectrometer. This is a camera type specific calibration.
Below figure shows the linearity of the raw sensor and after flat fielding:



Senor Linearity from Light Level 0 (dark) to (100 % = Saturation)

The deviation from the linearity is below 1%.

Radiometric Calibration

Sensor Noise (Reference)

Sensor noise shows image noise with respect to the image center measured at an aperture of 8 with exposure time of 22msec. Sensor noise after calibration shall be less or equal 0.5% of radiometric resolution. At 14bit radiometric resolution 0.5% (of 16384) is equal to 82 gray values. This is a camera type specific calibration.

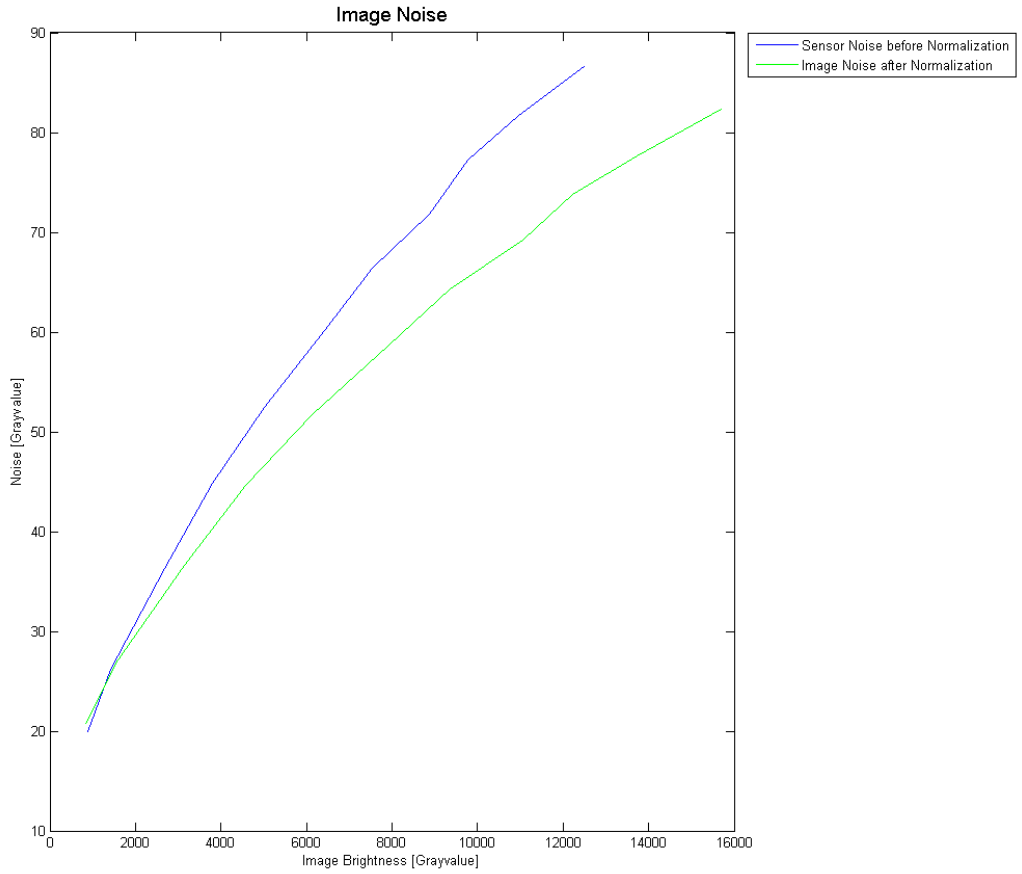


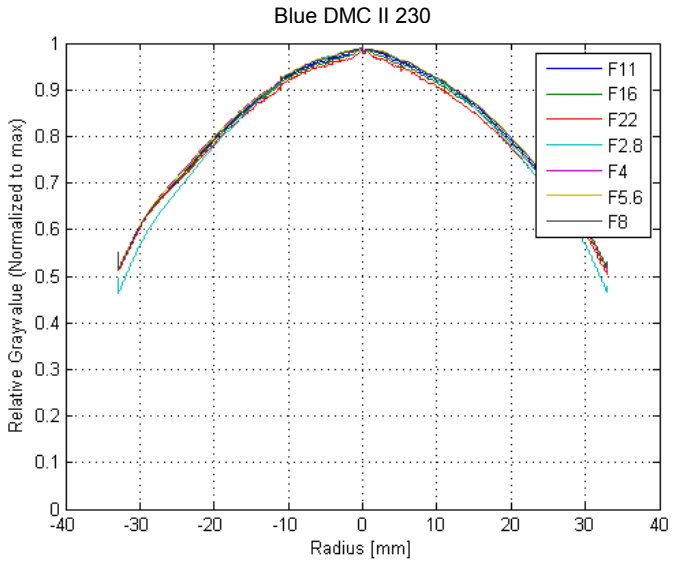
Image Noise before and after radiometric calibration

Radiometric Calibration

Aperture Correction

Blue (00125498)

The light fall off to the border due the influence of the optics depends on the used aperture. Therefore this calibration approach has for each aperture (Full F-Stop) its own calibration image. In general the light fall off is a function of the image radius. In this calibration approach instead of function the real measured values in the image is used. The figure below shows the profile from the upper left corner to the lower right corner of each of this calibration images to give a feeling on the amount of correction.



Blue

This is a camera type specific calibration.

Radiometric Calibration

Defect Pixel

Blue (00125498)

Defect pixels are detected during radiometric calibration and will be corrected during radiometric processing of the images. The quantity and cumulative percentage and specification of defects is described in Appendix “Defect Pixel Recognition”.

Revision of calibration:	131073
CCDRevision:	1
Date Number:	1482149197
Date:	161219
Number of defect pixels:	454
Number of defect clusters:	0
Number of defect columns:	0

Nr	Row	Column
0	5	3339
1	6	4640
2	20	4794
3	22	3141
4	30	2458
5	35	2718
6	78	764
7	83	1962
8	88	5134
9	89	1797
10	109	1826
11	114	4103
12	115	5832
13	146	4976
14	146	5099
15	154	4188
16	202	1886
17	202	4157
18	214	4599
19	228	2283
20	299	3992
21	315	5286
22	345	102
23	404	965
24	404	1889
25	428	4330
26	456	3608
27	465	2976
28	490	5684
29	497	1238
30	503	223
31	505	1581
32	523	5494
33	531	1251
34	535	649
35	550	5365
36	563	824
37	589	1673
38	617	1935
39	635	3456
40	652	2078

41	653	3987
42	691	594
43	697	4945
44	716	599
45	719	3414
46	724	1623
47	725	2033
48	745	2896
49	763	5383
50	765	5511
51	767	5513
52	791	4234
53	802	162
54	803	4501
55	839	3423
56	865	2610
57	881	852
58	893	4388
59	902	315
60	972	5630
61	975	4155
62	981	3750
63	996	1079
64	998	1315
65	1022	4786
66	1034	1395
67	1034	5715
68	1087	1981
69	1148	2326
70	1159	2495
71	1195	3554
72	1223	5346
73	1246	610
74	1274	547
75	1322	4440
76	1334	113
77	1337	5035
78	1372	981
79	1386	5369
80	1396	3632
81	1401	2028
82	1423	2336
83	1434	4347
84	1449	4041
85	1526	2571
86	1527	5360
87	1550	1816
88	1559	4157
89	1560	4157
90	1581	3952
91	1600	425
92	1605	244
93	1612	1740
94	1616	4229
95	1634	4662
96	1644	5139
97	1646	5448
98	1670	598
99	1672	5019
100	1703	1372
101	1708	82
102	1739	1403
103	1740	3576
104	1752	5130
105	1762	3741
106	1777	5443
107	1781	233
108	1791	4922
109	1804	3261
110	1818	6066
111	1819	6066
112	1844	5529
113	1850	4658
114	1854	3197
115	1882	544
116	1888	591
117	1889	1203

118	1907	1598
119	1912	4131
120	1929	1894
121	1929	5659
122	1942	2921
123	1957	4648
124	1962	2309
125	1963	2309
126	1988	245
127	2015	4702
128	2028	734
129	2031	3610
130	2045	4857
131	2068	927
132	2110	3451
133	2178	5718
134	2211	3031
135	2242	1272
136	2249	5163
137	2256	1901
138	2256	4102
139	2259	5894
140	2302	265
141	2312	5965
142	2315	40
143	2323	3125
144	2326	2277
145	2329	1568
146	2330	3362
147	2331	2891
148	2354	5882
149	2360	857
150	2368	1796
151	2402	2769
152	2433	3009
153	2443	5542
154	2544	2326
155	2563	5007
156	2664	5308
157	2665	5647
158	2681	4816
159	2682	862
160	2704	5833
161	2739	1438
162	2744	3231
163	2750	3116
164	2754	4816
165	2768	339
166	2785	1232
167	2787	3849
168	2797	2818
169	2811	5164
170	2828	1093
171	2833	1362
172	2876	1117
173	2882	5036
174	2884	1439
175	2908	4050
176	2923	5903
177	2975	3810
178	2976	5956
179	2978	3876
180	2991	2715
181	3004	478
182	3041	1410
183	3092	450
184	3142	2378
185	3181	726
186	3189	5810
187	3192	744
188	3209	1031
189	3222	3722
190	3279	5036
191	3309	5786
192	3330	6026
193	3331	5584
194	3335	1264

195	3345	2947
196	3367	266
197	3368	5475
198	3375	5445
199	3377	2225
200	3382	398
201	3384	2978
202	3407	3214
203	3420	2651
204	3441	3114
205	3463	5415
206	3467	2837
207	3468	4514
208	3470	2857
209	3480	5902
210	3481	2590
211	3483	1891
212	3504	1904
213	3542	5315
214	3553	1589
215	3556	890
216	3564	3087
217	3564	3109
218	3570	2995
219	3582	3719
220	3597	973
221	3632	5971
222	3641	2856
223	3650	1919
224	3650	3835
225	3657	3559
226	3662	1876
227	3664	5102
228	3668	1242
229	3694	6055
230	3726	2777
231	3738	5392
232	3770	5042
233	3776	6072
234	3780	5961
235	3781	5739
236	3808	4705
237	3814	5703
238	3815	5703
239	3844	5916
240	3855	3152
241	3867	4629
242	3880	1622
243	3885	3117
244	3913	720
245	3928	2740
246	3932	5843
247	3941	4966
248	3953	3646
249	3957	1642
250	3960	2398
251	3987	4533
252	3993	486
253	3994	262
254	4024	2286
255	4028	5802
256	4041	473
257	4042	473
258	4046	2520
259	4063	5397
260	4127	5141
261	4134	821
262	4144	5658
263	4152	3110
264	4169	2366
265	4179	5405
266	4181	3031
267	4188	614
268	4192	1117
269	4192	5130
270	4227	3108
271	4242	1071

272	4249	3761
273	4259	4153
274	4272	3447
275	4278	5323
276	4315	4462
277	4332	3034
278	4388	2800
279	4396	2656
280	4409	3638
281	4431	4513
282	4457	529
283	4461	5888
284	4467	3540
285	4480	291
286	4494	4422
287	4497	4462
288	4524	189
289	4578	5754
290	4591	2779
291	4620	489
292	4620	4648
293	4622	1258
294	4630	4632
295	4646	5623
296	4667	5575
297	4671	885
298	4675	3118
299	4688	4582
300	4692	6027
301	4699	1382
302	4709	525
303	4731	2197
304	4738	2921
305	4743	2710
306	4748	2624
307	4789	4818
308	4789	5874
309	4827	5861
310	4840	383
311	4845	5250
312	4847	633
313	4849	2087
314	4941	3874
315	4960	242
316	4965	1217
317	4966	4563
318	4968	1052
319	4979	5634
320	4979	5891
321	4994	5423
322	5018	4588
323	5020	1846
324	5031	4035
325	5039	3204
326	5064	694
327	5065	3078
328	5098	4818
329	5115	2641
330	5122	963
331	5129	2827
332	5140	428
333	5151	5580
334	5162	5088
335	5171	2971
336	5198	4860
337	5214	3833
338	5239	3814
339	5241	1066
340	5279	4328
341	5285	3843
342	5291	139
343	5293	5576
344	5306	4502
345	5311	2214
346	5324	993
347	5364	5577
348	5365	5164

349	5367	5023
350	5370	4961
351	5375	1166
352	5383	2991
353	5384	1719
354	5385	1719
355	5417	4821
356	5450	5859
357	5490	2323
358	5544	4685
359	5557	4576
360	5586	5930
361	5598	2367
362	5631	3495
363	5632	3495
364	5637	5269
365	5638	5269
366	5666	3395
367	5688	2547
368	5692	4971
369	5758	3120
370	5762	2333
371	5763	232
372	5811	5466
373	5817	3335
374	5826	5773
375	5861	132
376	5862	4942
377	5874	863
378	5904	4208
379	5914	3275
380	5941	1608
381	5943	2466
382	5951	4337
383	5952	5018
384	5961	1183
385	5962	1620
386	5996	1208
387	6009	5727
388	6009	6058
389	6035	1757
390	6042	5445
391	6044	614
392	6046	3609
393	6058	904
394	6062	4605
395	6065	4782
396	6069	3210
397	6090	1191
398	6091	774
399	6103	5934
400	6144	2186
401	6154	694
402	6165	1358
403	6165	4201
404	6176	1796
405	6194	711
406	6218	1493
407	6226	3983
408	6243	816
409	6244	3648
410	6265	4594
411	6293	4782
412	6294	4390
413	6298	1394
414	6300	480
415	6301	4887
416	6315	2858
417	6330	2946
418	6331	4837
419	6332	3225
420	6358	1002
421	6391	2225
422	6404	3474
423	6410	4761
424	6419	2009
425	6435	4909

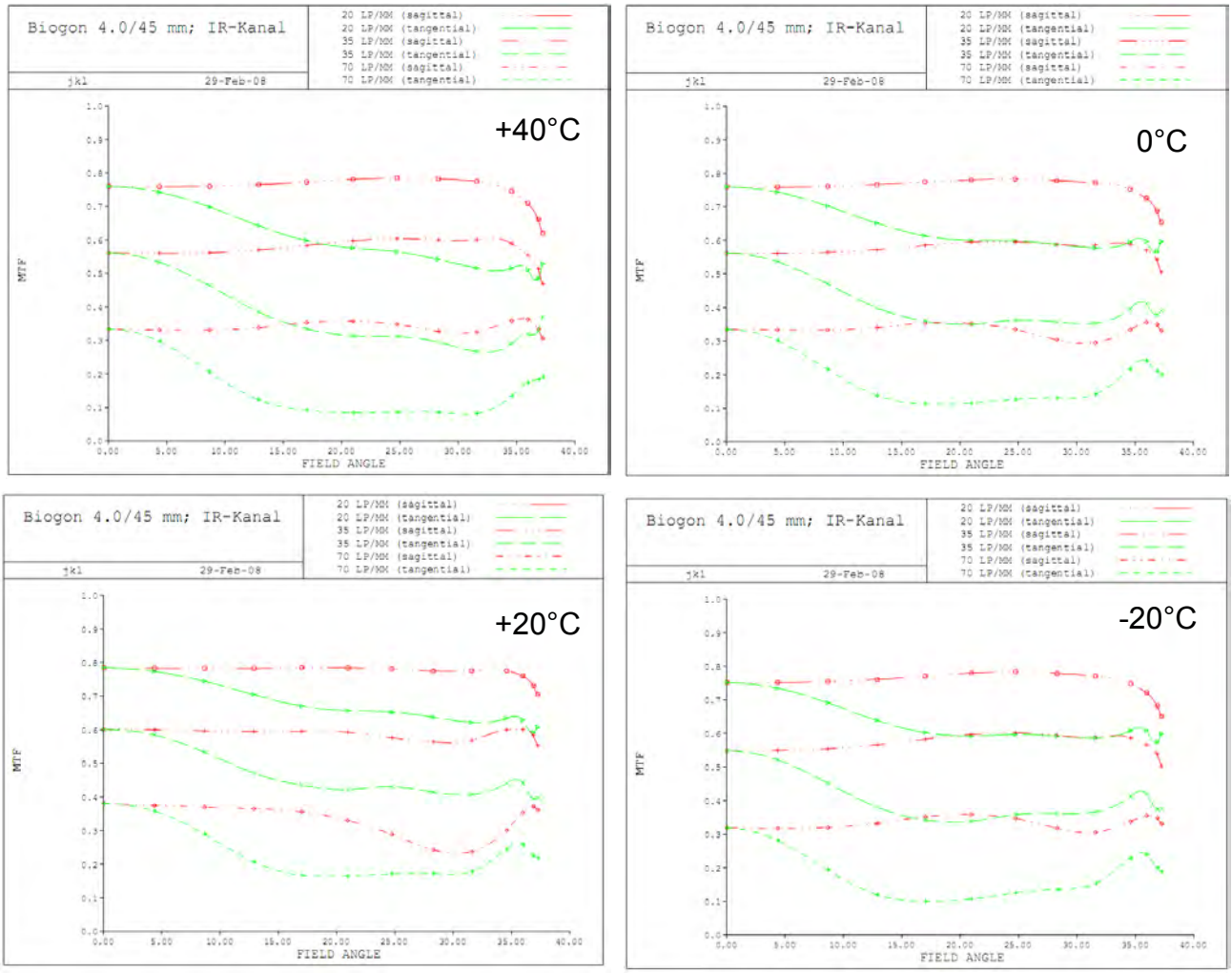
426	6442	2534
427	6452	1076
428	6460	5071
429	6489	3370
430	6517	4725
431	6530	2792
432	6534	2243
433	6554	5698
434	6612	5803
435	6638	1118
436	6643	6078
437	6644	2437
438	6648	1823
439	6653	5416
440	6654	4354
441	6662	3102
442	6690	3268
443	6719	4544
444	6724	6038
445	6760	5800
446	6766	3802
447	6774	871
448	6777	3830
449	6782	2844
450	6800	5486
451	6804	5057
452	6812	3776
453	6838	5785

Defect Column	RowStart ColumnStart	RowEnd ColumnEnd

Optical System

Modulation Transfer Function, MTF of IR camera

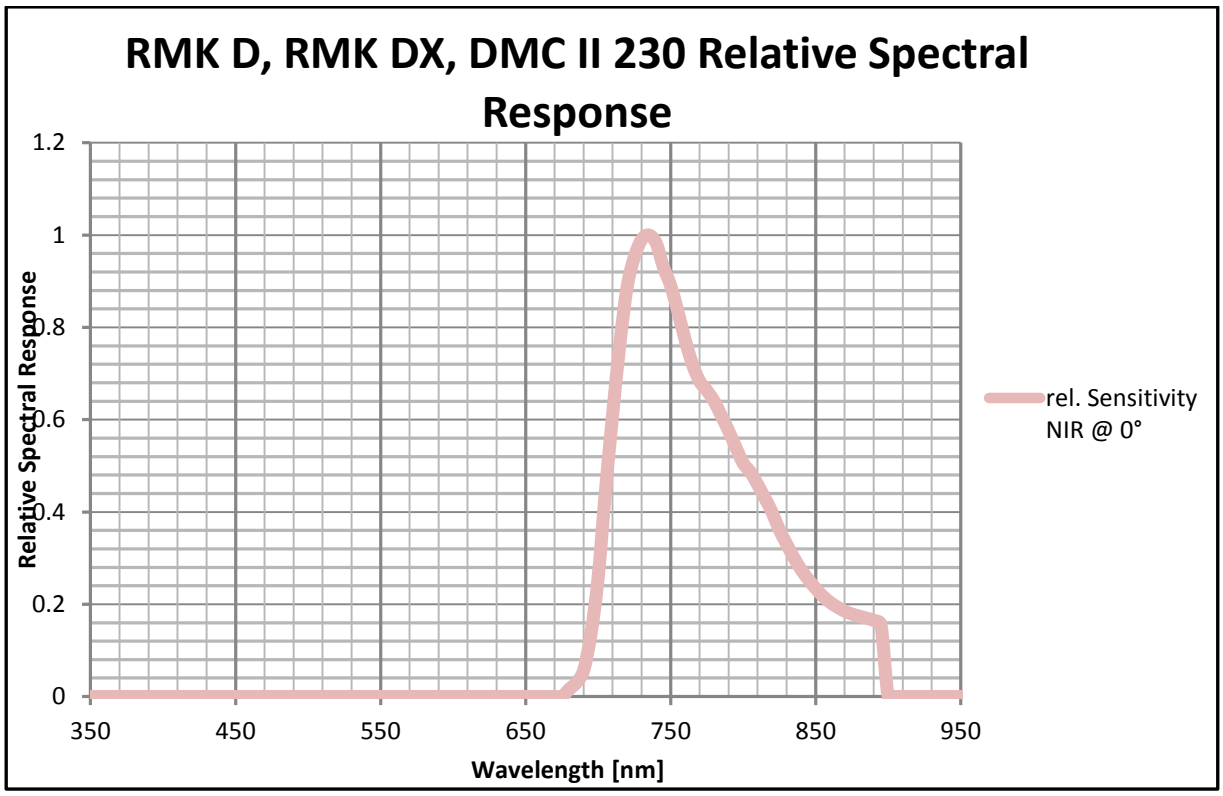
RMK D / RMK DX / DMC II MS IR – MTF F/4.0 ; 45 mm– Temperature Stability



Radiometric Calibration

Sensitivity of NIR camera

Spectral Response Curves of the single camera head.

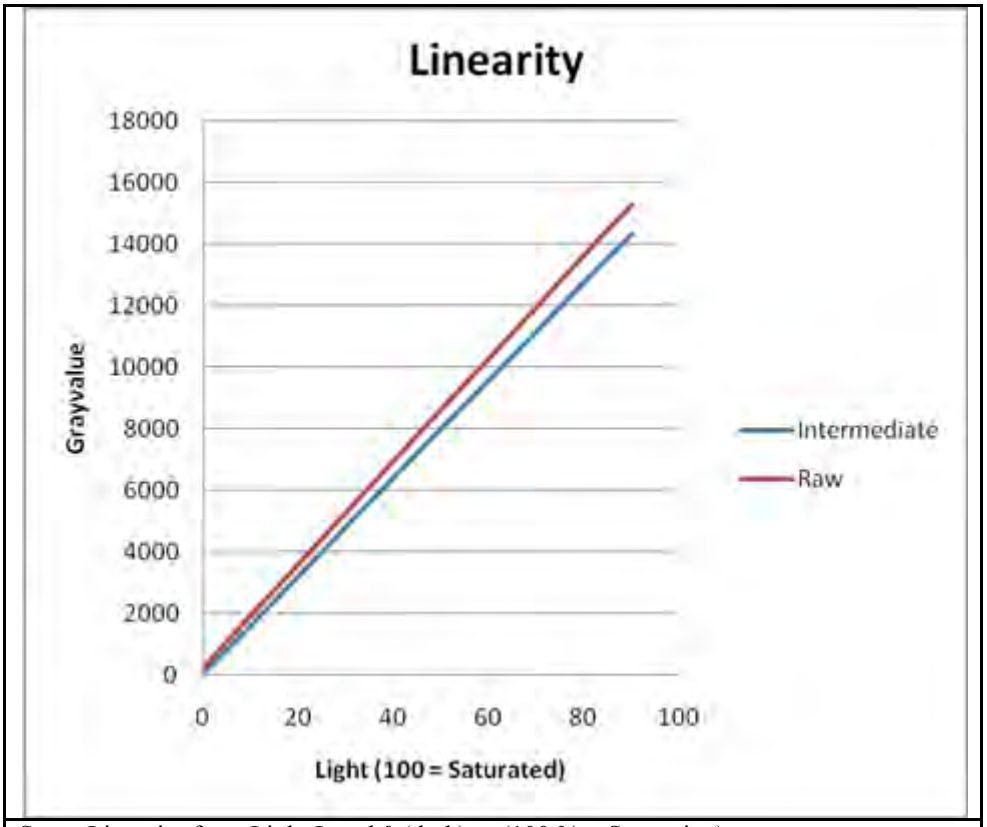


The sensitivity shows the spectral response curve of the single camera head including the optical system (optics, filter) and the sensor response. The DMC II 230 is calibrated with respect to the absolute spectrometer. This allows computing pixel radiance values from pixels digital numbers and is a camera type specific calibration.

Radiometric Calibration

Sensor Linearity (Reference)

The sensor linearity is measured in the Lab with calibrated spectrometer. This is a camera type specific calibration.
Below figure shows the linearity of the raw sensor and after flat fielding:



Senor Linearity from Light Level 0 (dark) to (100 % = Saturation)

The deviation from the linearity is below 1%.

Radiometric Calibration

Sensor Noise (Reference)

Sensor noise shows image noise with respect to the image center measured at an aperture of 8 with exposure time of 22msec. Sensor noise after calibration shall be less or equal 0.5% of radiometric resolution. At 14bit radiometric resolution 0.5% (of 16384) is equal to 82 gray values. This is a camera type specific calibration.

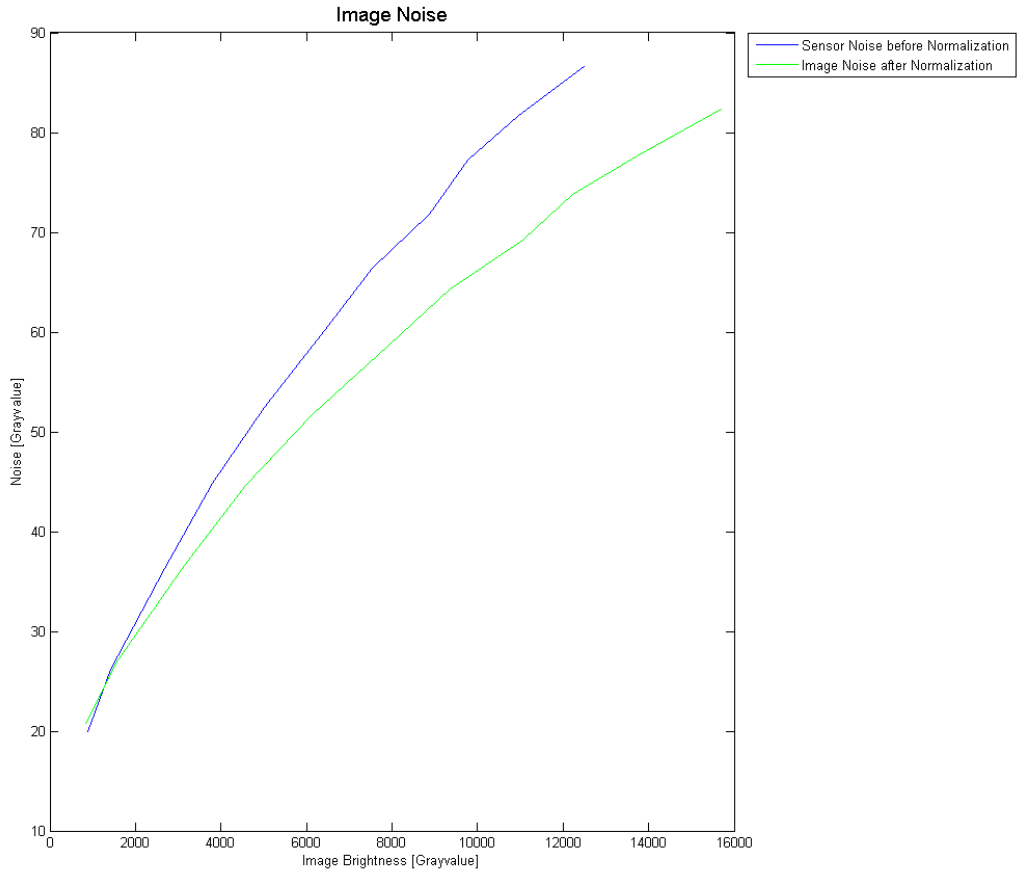


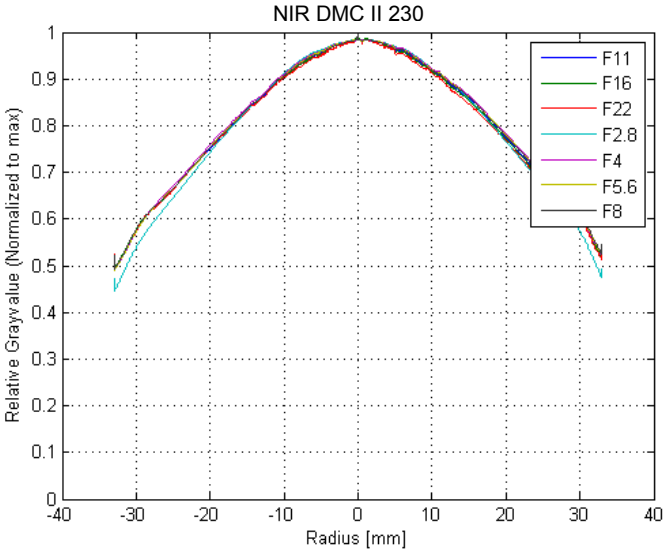
Image Noise before and after radiometric calibration

Radiometric Calibration

Aperture Correction

NIR (00121884)

The light fall off to the border due the influence of the optics depends on the used aperture. Therefore this calibration approach has for each aperture (Full F-Stop) its own calibration image. In general the light fall off is a function of the image radius. In this calibration approach instead of function the real measured values in the image is used. The figure below shows the profile from the upper left corner to the lower right corner of each of this calibration images to give a feeling on the amount of correction.



NIR

This is a camera type specific calibration.

Radiometric Calibration

Defect Pixel

NIR (00121884)

Defect pixels are detected during radiometric calibration and will be corrected during radiometric processing of the images. The quantity and cumulative percentage and specification of defects is described in Appendix “Defect Pixel Recognition”.

Revision of calibration:	131073	
CCDRevision:	1	
Date Number:		1482336077
Date:		161221
Number of defect pixels:	518	
Number of defect clusters:	0	
Number of defect columns:	1	

Nr	Row	Column
0	47	4698
1	51	4513
2	51	5975
3	76	2730
4	84	2852
5	117	3446
6	129	4162
7	179	1980
8	186	5264
9	208	5493
10	217	4482
11	233	97
12	247	2862
13	257	5260
14	277	1505
15	315	3362
16	353	1228
17	362	5755
18	368	1745
19	379	3462
20	381	1583
21	383	3319
22	384	998
23	400	2604
24	408	232
25	432	4432
26	469	99
27	476	3414
28	486	896
29	501	2524
30	501	4512
31	508	775
32	510	3094
33	531	3077
34	537	1710
35	588	4211
36	611	406
37	673	4431
38	689	3704
39	690	1904
40	698	1434

41	743	1713
42	749	4607
43	759	1604
44	760	1955
45	761	1955
46	767	4261
47	779	5901
48	780	1641
49	804	1826
50	819	2798
51	841	3623
52	845	1380
53	858	5118
54	875	3159
55	883	5103
56	886	2738
57	908	3527
58	912	2203
59	913	2030
60	917	341
61	926	1374
62	940	1859
63	941	4653
64	950	2042
65	950	3471
66	959	4204
67	972	4460
68	985	2527
69	1003	942
70	1043	3807
71	1050	3567
72	1054	2097
73	1059	4122
74	1085	4139
75	1103	4234
76	1120	4588
77	1122	3514
78	1168	738
79	1174	5803
80	1210	759
81	1232	1570
82	1238	1682
83	1241	3773
84	1269	2452
85	1298	4404
86	1314	3471
87	1315	2720
88	1380	3403
89	1401	3597
90	1424	4663
91	1447	5158
92	1451	4719
93	1455	1190
94	1455	1686
95	1461	4652
96	1464	3393
97	1480	1205
98	1506	4320
99	1521	728
100	1541	6072
101	1547	1037
102	1580	2980
103	1592	6034
104	1598	4608
105	1665	1322
106	1678	4959
107	1688	3547
108	1733	2560
109	1734	2402
110	1743	5755
111	1755	5591
112	1763	5705
113	1775	3845
114	1793	23
115	1793	2260
116	1820	4064
117	1833	4007

118	1845	4913
119	1862	3026
120	1862	3027
121	1875	5991
122	1900	3800
123	1915	1630
124	1921	3155
125	1944	5113
126	1962	3437
127	1983	5638
128	1988	1620
129	2011	4561
130	2019	27
131	2030	5910
132	2033	3003
133	2056	2385
134	2091	5836
135	2096	1050
136	2105	4499
137	2139	444
138	2146	3565
139	2158	1382
140	2163	3367
141	2166	452
142	2171	35
143	2211	4464
144	2214	1172
145	2218	4768
146	2220	1869
147	2224	5365
148	2255	3801
149	2268	5188
150	2282	1371
151	2283	1371
152	2317	228
153	2327	3992
154	2339	4275
155	2352	5907
156	2355	989
157	2364	2545
158	2374	3103
159	2388	2011
160	2400	4433
161	2402	1702
162	2416	3570
163	2437	4427
164	2441	1775
165	2467	5746
166	2481	1170
167	2507	3480
168	2508	3894
169	2508	4048
170	2510	5234
171	2528	3853
172	2545	673
173	2550	1805
174	2558	3639
175	2575	3255
176	2590	2036
177	2620	790
178	2624	1382
179	2641	3262
180	2660	962
181	2668	377
182	2677	2282
183	2684	3069
184	2700	1341
185	2703	918
186	2728	2417
187	2734	2010
188	2761	6013
189	2775	333
190	2776	3732
191	2799	2843
192	2819	3741
193	2830	353
194	2857	4557

195	2866	4260
196	2885	2859
197	2893	4586
198	2898	3378
199	2927	472
200	2931	1136
201	2934	3241
202	2961	2011
203	2970	5313
204	2971	5461
205	2989	4267
206	3016	5677
207	3037	154
208	3038	811
209	3041	1853
210	3058	775
211	3062	99
212	3062	876
213	3064	6092
214	3077	792
215	3093	2948
216	3117	390
217	3120	640
218	3120	2252
219	3142	738
220	3156	1462
221	3195	1576
222	3197	3927
223	3201	4451
224	3207	1126
225	3248	5945
226	3262	5126
227	3287	1105
228	3293	686
229	3342	776
230	3348	374
231	3355	1801
232	3355	1920
233	3386	291
234	3410	1753
235	3429	27
236	3439	3322
237	3457	4078
238	3475	660
239	3479	3837
240	3483	5337
241	3484	4759
242	3498	2455
243	3501	5824
244	3535	2880
245	3537	4787
246	3553	3392
247	3590	1345
248	3607	4661
249	3616	579
250	3644	5835
251	3664	971
252	3666	5633
253	3681	3417
254	3698	2424
255	3714	3111
256	3745	4676
257	3747	433
258	3763	2615
259	3767	954
260	3768	3767
261	3786	86
262	3791	352
263	3797	1211
264	3807	57
265	3808	1177
266	3811	5996
267	3822	2545
268	3828	5620
269	3846	14
270	3850	3492
271	3852	3495

272	3857	2042
273	3876	4334
274	3887	5983
275	3903	4362
276	3933	574
277	3933	4579
278	3934	115
279	3942	5015
280	3948	5624
281	3967	653
282	3979	5725
283	3997	302
284	3997	1920
285	4069	3608
286	4076	3490
287	4081	927
288	4093	2069
289	4155	3608
290	4158	4142
291	4166	2606
292	4190	101
293	4222	5156
294	4223	2349
295	4246	3753
296	4274	1948
297	4285	1449
298	4306	5786
299	4315	5610
300	4341	4480
301	4367	2848
302	4372	459
303	4376	1743
304	4411	5008
305	4432	5499
306	4467	4782
307	4472	3398
308	4474	1979
309	4498	2567
310	4501	4944
311	4502	1573
312	4522	4075
313	4524	2339
314	4530	3079
315	4541	4659
316	4560	5783
317	4562	2203
318	4577	2836
319	4585	2992
320	4597	5549
321	4603	1949
322	4609	3717
323	4613	2208
324	4621	2652
325	4638	2328
326	4642	4385
327	4646	2404
328	4666	3220
329	4685	661
330	4685	2651
331	4694	4331
332	4710	5659
333	4767	5741
334	4779	4069
335	4779	4717
336	4787	5257
337	4789	2554
338	4790	120
339	4791	839
340	4806	3667
341	4810	2560
342	4818	2922
343	4835	3970
344	4842	3518
345	4851	1719
346	4854	145
347	4881	4204
348	4915	5195

349	4921	3718
350	4941	4447
351	4942	4782
352	4950	5437
353	4961	3815
354	4963	5227
355	4965	5846
356	4967	1129
357	4994	2590
358	4997	5370
359	5006	2348
360	5012	1935
361	5023	4828
362	5025	4035
363	5039	3525
364	5054	5768
365	5067	2821
366	5071	5088
367	5100	3512
368	5101	760
369	5124	5094
370	5136	889
371	5149	3700
372	5187	4018
373	5264	267
374	5278	1017
375	5279	1273
376	5282	11
377	5285	2328
378	5299	4697
379	5301	5235
380	5302	4076
381	5312	3590
382	5318	3694
383	5326	5221
384	5337	1919
385	5359	1529
386	5374	3078
387	5386	2661
388	5389	5835
389	5418	2883
390	5421	6095
391	5430	582
392	5433	127
393	5457	3240
394	5459	2377
395	5474	4713
396	5509	4383
397	5513	208
398	5514	2167
399	5519	5276
400	5531	5765
401	5557	5385
402	5558	5385
403	5587	3503
404	5601	1334
405	5610	637
406	5616	1761
407	5618	5209
408	5627	5924
409	5628	5041
410	5634	2416
411	5639	5595
412	5644	2082
413	5646	4586
414	5658	1708
415	5658	5868
416	5662	3360
417	5671	5651
418	5675	4477
419	5699	332
420	5707	3445
421	5723	1269
422	5723	4234
423	5724	5829
424	5732	631
425	5740	2612

426	5746	245
427	5756	4449
428	5757	2012
429	5767	3767
430	5791	93
431	5855	1043
432	5860	5021
433	5861	1312
434	5866	1343
435	5872	5511
436	5874	5151
437	5875	251
438	5875	1527
439	5893	6058
440	5900	3147
441	5906	2820
442	5913	4342
443	5925	4521
444	5943	852
445	5947	1405
446	5962	619
447	5965	1762
448	5979	1694
449	5990	5563
450	5997	3045
451	6004	697
452	6008	1442
453	6017	1235
454	6050	5075
455	6070	4191
456	6119	4357
457	6126	2399
458	6131	1281
459	6145	1442
460	6147	1871
461	6150	151
462	6168	9
463	6168	4244
464	6206	3442
465	6214	497
466	6224	5087
467	6236	1085
468	6236	5604
469	6239	5080
470	6252	4176
471	6253	1499
472	6262	103
473	6272	5405
474	6273	1589
475	6317	4163
476	6327	45
477	6337	3108
478	6338	3822
479	6360	3307
480	6365	5498
481	6375	616
482	6391	3768
483	6415	1514
484	6439	5399
485	6453	4253
486	6472	5651
487	6478	1961
488	6483	2630
489	6516	3571
490	6532	5759
491	6533	5758
492	6533	5759
493	6537	5760
494	6538	5760
495	6538	5874
496	6539	5760
497	6540	5760
498	6541	5760
499	6542	5760
500	6543	5760
501	6544	5760
502	6545	5760

503	6546	5760
504	6547	5760
505	6538	5759
506	6538	5761
507	6561	5811
508	6574	4080
509	6586	1375
510	6635	1886
511	6674	4167
512	6681	4643
513	6744	183
514	6755	2500
515	6775	1241
516	6787	3297
517	6830	4395

Defect Column	RowStart	ColumnStart	RowEnd	ColumnEnd
0	6510	5760	6845	5760

Sensor Geometric Accuracy

Large area CCD imagers are composed (stitched) from several blocks. Stitching on wafer with semiconductor lithographic equipment results in geometric accuracy better than 0.1µm (Stoldt, H. (2010).
Therefore the geometric accuracy of individual pixels within a block can be assumed as better or equal the stitching accuracy.

Defect Pixel Recognition

The table below shows the maximal allowed physical defects on the CCD Sensor and its definitions.

	Description	CCD Spec
Pixel	Bright image	Pixel whose signal, at nominal light (illumination at 50% of the linear range), deviates more than ±30% from its neighboring pixels.
	Dark image	Pixel whose signal, in dark, deviates more than 6mV from its neighboring pixels (about 1% of nominal light).
	Max Count	PAN ≤ 3500 MS < 2000

	Description	CCD Spec
Column	Definition	A column which has more than 8 pixel defects in 1 1x 12 kernel Column defects must be horizontally separated by 5 columns for single line defects and 10 for double line defects
	Recognition (bright and dark)	Same as defect pixel recognition
	Max Single column	PAN ≤ 140 MS ≤ 20
	Max double Column	PAN ≤ 40 MS ≤ 6

The Post-Processing-Software is correcting following pixel and columns:

	PPS Correction
Pixel	Pixel whose gray value in a 16 x16 kernel differs from the median more than 30%

	PPS Correction
Column	Pixel whose gray value in a 16 x16 kernel differs from the median more than 5% and more than 15 defects in one column

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