Keck Adaptive Optics Note #368

Centroid, Subaperture and Actuator Conventions

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1 Introduction

This note documents the labeling conventions of the Keck Observatory adaptive optics systems. We define the subaperture and deformable mirror actuator numbering system and the centroid sign and magnitude conventions.

1.1 Deformable Mirror Actuator Numbering System

The deformable mirror has 349 actuators, numbered 0-348, spread over a 21x21 array. The numbering system is shown on Table 1. The Xinetics manual numbers the actuators from 1-349. This difference does not matter: what matters is that the actuator voltages are in the right order.

							342	343	344	345	346	347	348									
					331	332	333	334	335	336	337	338	339	340	341							
				318	319	320	321	322	323	324	325	326	327	328	329	330						
			303	304	305	306	307	308	309	310	311	312	313	314	315	316	317					
		286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302				
	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285			
	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266			
227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247		
206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226		
185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205		
164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184		
143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163		
122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142		
101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121		
	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100			
	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81			
		46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62				
			31	32	33	34	35	36	37	38	39	40	41	42	43	44	45					
				18	19	20	21	22	23	24	25	26	27	28	29	30						
					7	8	9	10	11	12	13	14	15	16	17							
							0	1	2	3	4	5	6									

Table 1: Actuator numbering system. The DM is looked at from the front, with the bottom of the DM corresponding to actuators 0-6.

Note that due to possibly a wiring problem, the actuators on Keck I are numbered (349-actuator number), where actuator number is the actuator number of Keck II, shown on Table I. We intend to use the convention on Table 1 only.

1.2 Subaperture Numbering System

There are 304 subapertures distributed over a 20x20 lenslet array. The selected subapertures correspond to regions in the pupil that are illuminated and are displayed in Table 2.

							298	299	300	301	302	303								
					288	289	290	291	292	293	294	295	296	297						
			274	275	276	277	278	279	280	281	282	283	284	285	286	287				
		258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273			
		242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257			
	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241		
	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223		
186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	
168	169	170	171	172	173	174	175	176	0	0	177	178	179	180	181	182	183	184	185	
152	153	154	155	156	157	158	159	0	0	0	0	160	161	162	163	164	165	166	167	
136	137	138	139	140	141	142	143	0	0	0	0	144	145	146	147	148	149	150	151	
118	119	120	121	122	123	124	125	126	0	0	127	128	129	130	131	132	133	134	135	
98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	
	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97		
	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79		
		46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61			
		30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45			
			16	17	18	19	20	21	22	23	24	25	26	27	28	29				
					6	7	8	9	10	11	12	13	14	15						
							0	1	2	3	4	5								

Table 2: Subaperture numbering system

1.3 Centroid ordering system

There are 304 subapertures, resulting in 608 centroid measurements. For consistency with our current code, we would prefer if the centroids were output in the following order: $[c_{0x}, c_{0y}, c_{1x}, c_{1y}, c_{2x}, c_{2y} c_{3x}, c_{3y} \ldots]$.

1.4 Centroid sign and magnitude convention

For a quad cell, the raw centroid (ignoring pixel thresholding, etc.) is defined as:

$$\begin{bmatrix} I_2 & I_3 \\ I_0 & I_1 \end{bmatrix}$$

$$c_x = \frac{-I_0 + I_1 - I_2 + I_3}{I_0 + I_1 + I_2 + I_3} \quad c_y = \frac{-I_0 - I_1 + I_2 + I_3}{I_0 + I_1 + I_2 + I_3}$$

The reader will notice that the definition of the y-centroids is inconsistent: a positive centroid means that the spot is down, but the subapertures numbers increase as you go up. By contrast, a positive x-centroid means that the spot is to the right, which is also the direction of increasing subaperture numbers. While the y-centroid definition is confusing, we prefer to keep it as a lot of user software has been written around this convention.

For the 4x4 centroid, the definition of the centroid is:[1]

$c_x = \frac{\sum_x x\left(\sum_y i(x,y)\right)}{\sum_x \sum_y i(x,y)}$, where x is the vector [-3, -1, 1, 3], consistent with the definitions for a quad cell.

[1] Erik Johansson *et al.*, NGWFC RTC Requirements, KAON 311