Wavefront measurement from IPA-13 spot (09.06.2010) after COL new alignment:

Hardware: - OGSE (IPA, SHS2, MEC2)   *Autor:*   Jean-François Pittet
          - NIRSpec (FOR, dummy filter)   *Coordinates:*   SHS2-FRF
          - COM2, COM1 mirrors
          - RMA
          - FOM
          - COL

Path := "\\Founas2\JWST_bcd\Inputs\83_Alignment\50_Documents\25_Procedures FM\"

Path := verkett(Path, "100_0108 - COL FM\40_Analysis\40_Delta^3 COL after CAL\WFE_IPA-13_2010-06-09\")

Wavefront measurement :

IPA13_zern := PRNLESEN(verkett(Path, "Zernike_IPA_13.dat"))

IPA13_INT := CodeV_lesen("WFE_IPA-13_2010-06-09\IPA_13_WF.int" , 1)

Calibration mirror:

Wavefront measurement with DIRECT100 interferometer

Name := "WFS_CalMirrD76mmd10mmMask69mm.wve"

Cal1_wave := wve_lesen(Name, 1)

Cal1_wave := rotate270(Re(Cal1_wave)) + i·rotate270(Im(Cal1_wave))

Rotation of the wavefront: Cal1_wave := submatrix(Cal1_wave, zeilen(Cal1_wave), 1, 1, spalten(Cal1_wave))

Cal1_wave := submatrix(Cal1_wave, 2, zeilen(Cal1_wave) − 1, 2, spalten(Cal1_wave) − 1)

Calibration measurement with the SHS2 optic:

Wavefront with SHS2 and calibration mirror :

W1_zern := PRNLESEN(verkett(Path, "cal_zernike.dat"))

CalFibre_INT := CodeV_lesen("WFE_IPA-13_2010-06-09\Cal_Fibre_14h40m_WF.int" , 1)
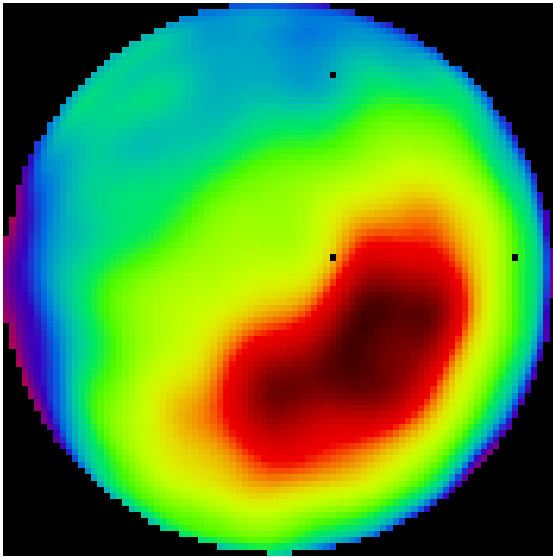
Wavefront with calibration mirror after beamsplitter :

W2_zern := PRNLESEN(verkett(Path, "cal_launch_zernike.txt"))

W2_INT := CodeV_lesen("..\..\30_Measurements\05 SHS2_wavefront_reference_2010_05_04\Launch_#2_WF.int" , 1)

Beamsplitter Wavefront measurement :

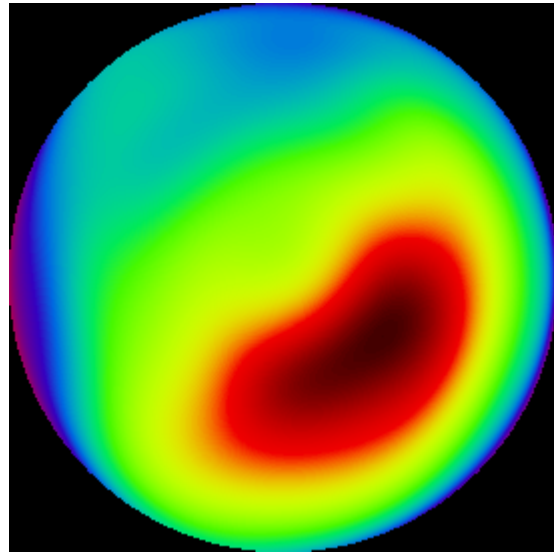BS_wave := PRNLESEN(verkett(Path, "WFE_beamsplitter.txt"))

IPA 13 wavefront (INT-file) :

$$\text{rms(IPA13\_INT)} = \begin{pmatrix} 0.138 \\ -0.312 \\ 0.272 \end{pmatrix} \begin{pmatrix} \text{rms} \\ \text{min} \\ \text{max} \end{pmatrix}$$
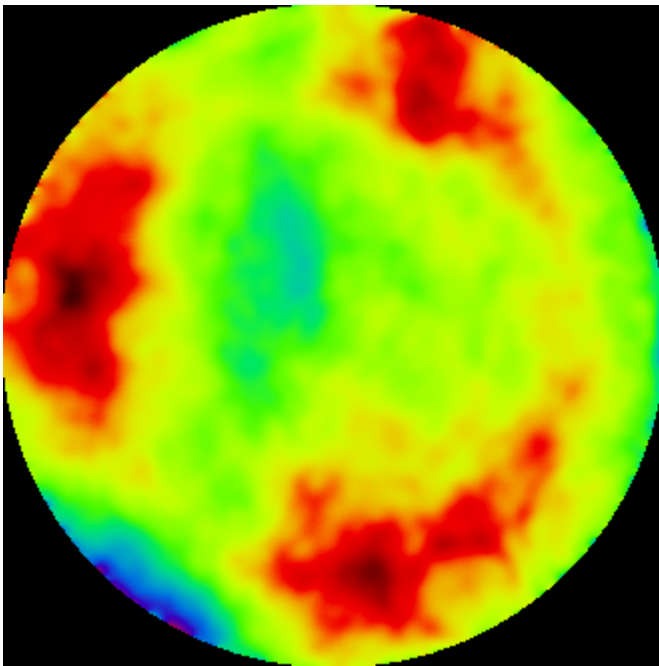
IPA 13 wavefront :

$$\text{IPA13\_wave} := \text{Zernike\_all}(2 \cdot \text{ceil}(R), \text{IPA13\_zern}, 0)$$

$$\text{rms(IPA13\_wave)} = \begin{pmatrix} 0.139 \\ -0.312 \\ 0.281 \end{pmatrix} \begin{pmatrix} \text{rms} \\ \text{min} \\ \text{max} \end{pmatrix}$$
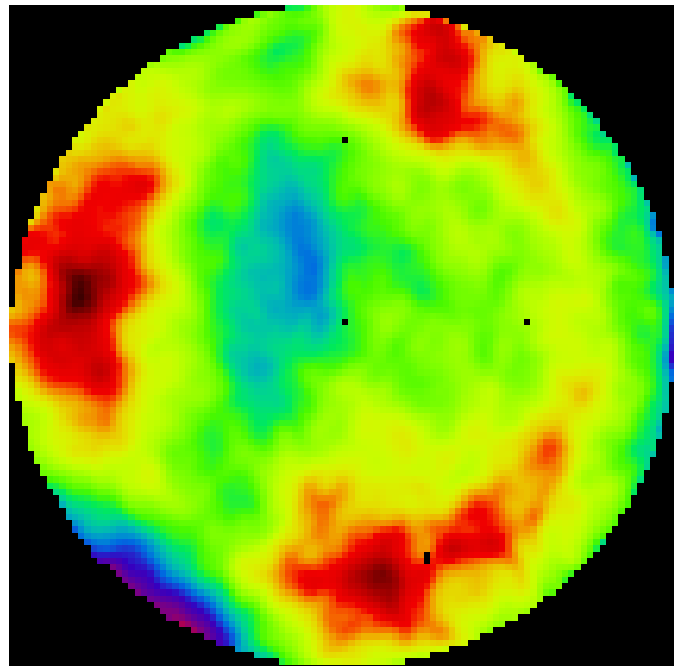
Calibration mirror (DIRECT100), full aperture:

$$\text{rms(Cal1\_wave)} = \begin{pmatrix} 0.008 \\ -0.036 \\ 0.020 \end{pmatrix} \begin{pmatrix} \text{rms} \\ \text{min} \\ \text{max} \end{pmatrix}$$

$$\begin{pmatrix} \text{zeilen(Cal1\_wave)} \\ \text{spalten(Cal1\_wave)} \end{pmatrix} = \begin{pmatrix} 330 \\ 330 \end{pmatrix}$$
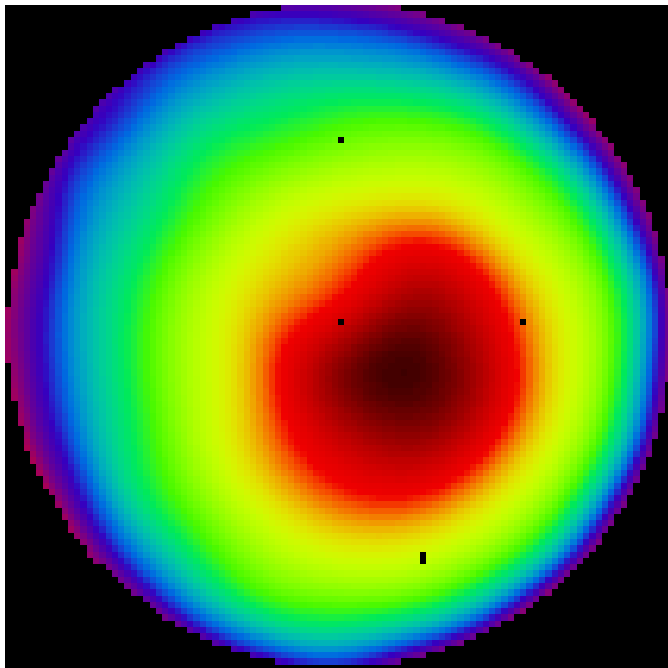
Calibration mirror (DIRECT100), scaled:

$$\text{rms(Cal1\_wave\_scale)} = \begin{pmatrix} 0.008 \\ -0.028 \\ 0.020 \end{pmatrix} \begin{pmatrix} \text{rms} \\ \text{min} \\ \text{max} \end{pmatrix}$$

$$\begin{pmatrix} \text{zeilen(Cal1\_wave\_scale)} \\ \text{spalten(Cal1\_wave\_scale)} \end{pmatrix} = \begin{pmatrix} 106 \\ 106 \end{pmatrix}$$
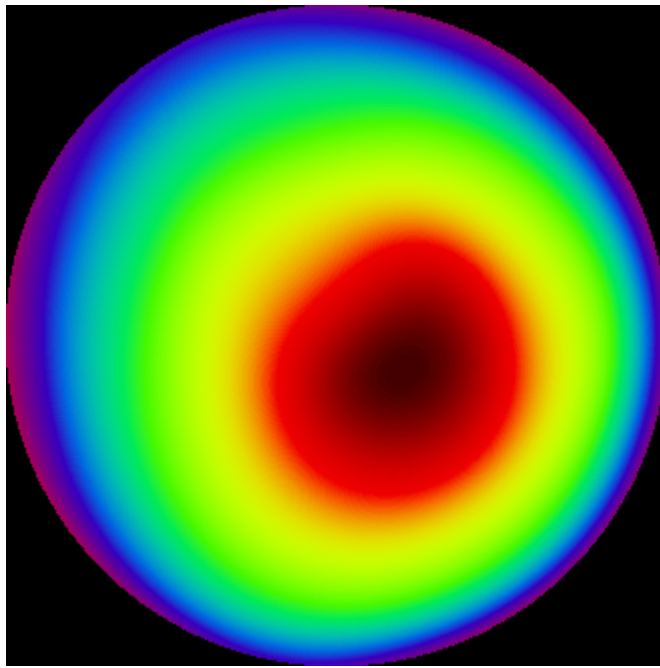
Calibration wavefront with the SHS2 (INT-file):

$$\text{rms}(\text{CalFibre\_INT}) = \begin{pmatrix} 0.442 \\ -0.863 \\ 0.855 \end{pmatrix} \begin{pmatrix} \text{rms} \\ \text{min} \\ \text{max} \end{pmatrix}$$

$$\begin{pmatrix} \text{zeilen}(\text{CalFibre\_INT}) \\ \text{spalten}(\text{CalFibre\_INT}) \end{pmatrix} = \begin{pmatrix} 106 \\ 106 \end{pmatrix}$$
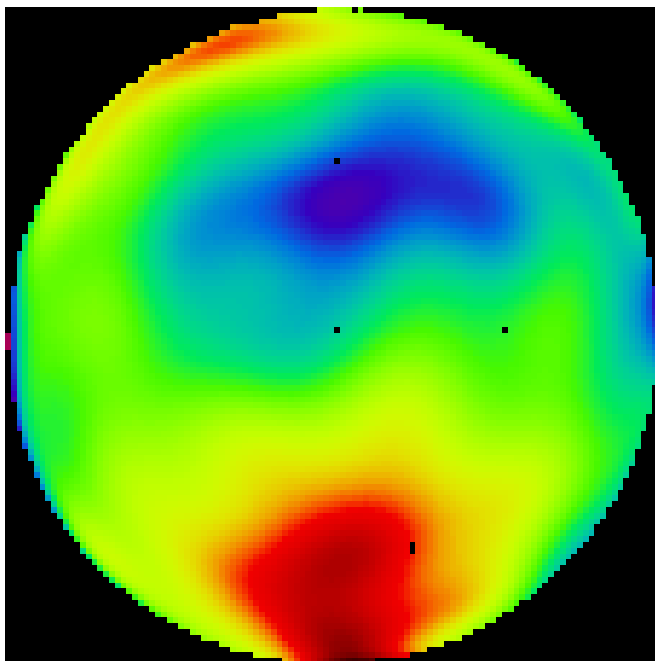
Calibration wavefront with the SHS2 :

$$\text{rms}(\text{W1\_wave}) = \begin{pmatrix} 0.448 \\ -0.851 \\ 0.858 \end{pmatrix} \begin{pmatrix} \text{rms} \\ \text{min} \\ \text{max} \end{pmatrix}$$
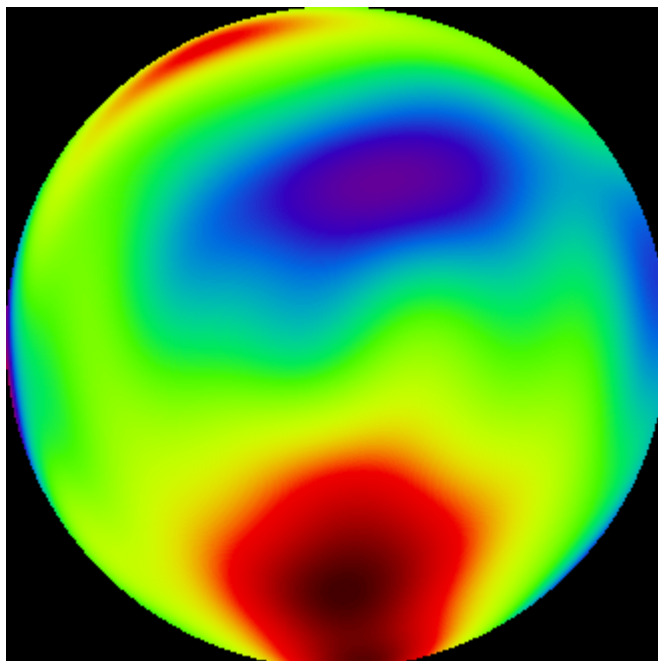
$$\begin{pmatrix} \text{zeilen}(\text{W1\_wave}) \\ \text{spalten}(\text{W1\_wave}) \end{pmatrix} = \begin{pmatrix} 330 \\ 330 \end{pmatrix}$$

Wavefront of the Launch optic :

$$\text{rms}(\text{W2\_INT}) = \begin{pmatrix} 0.048 \\ -0.125 \\ 0.126 \end{pmatrix} \begin{pmatrix} \text{rms} \\ \text{min} \\ \text{max} \end{pmatrix}$$
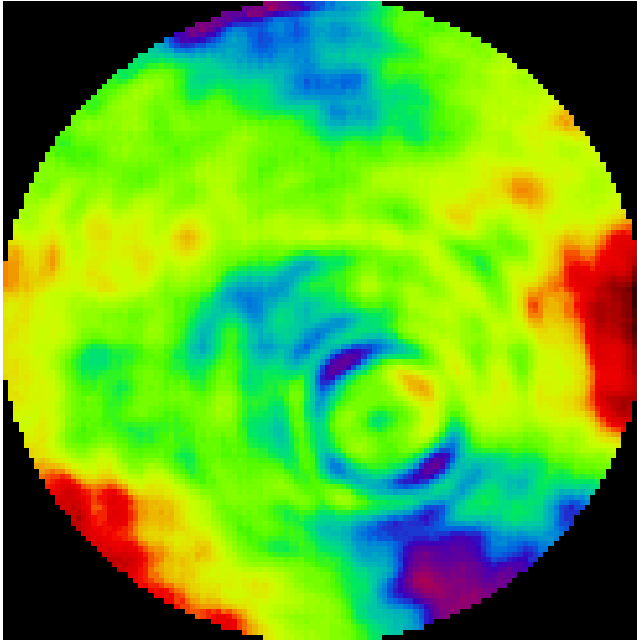
$$\begin{pmatrix} \text{zeilen}(\text{W2\_INT}) \\ \text{spalten}(\text{W2\_INT}) \end{pmatrix} = \begin{pmatrix} 113 \\ 113 \end{pmatrix}$$
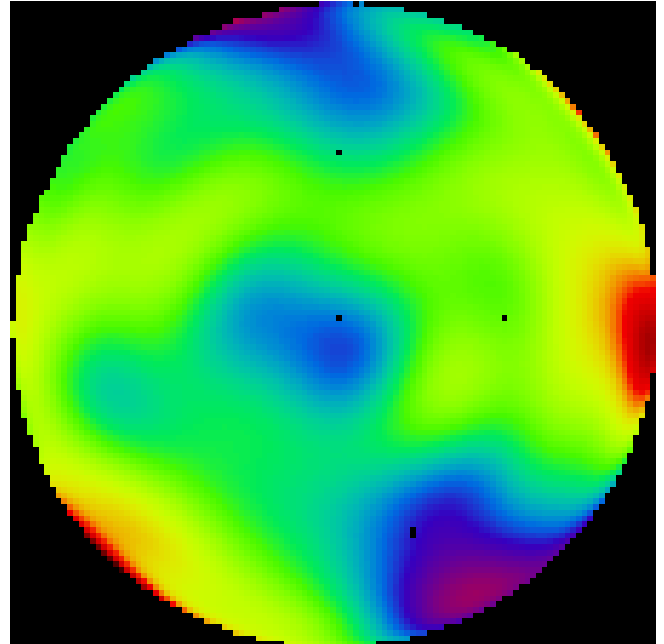

$$\text{rms}(\text{W2\_wave}) = \begin{pmatrix} 0.048 \\ -0.106 \\ 0.105 \end{pmatrix} \begin{pmatrix} \text{rms} \\ \text{min} \\ \text{max} \end{pmatrix}$$

$$\begin{pmatrix} \text{zeilen}(\text{W2\_wave}) \\ \text{spalten}(\text{W2\_wave}) \end{pmatrix} = \begin{pmatrix} 330 \\ 330 \end{pmatrix}$$

Beamsplitter Wavefront, full aperture:

Beamsplitter Wavefront, scaled:

$$\text{rms(BS\_Wave)} = \begin{pmatrix} 0.005 \\ -0.015 \\ 0.015 \end{pmatrix} \begin{pmatrix} \text{rms} \\ \text{min} \\ \text{max} \end{pmatrix}$$

$$\text{rms(BS\_wave\_scale)} = \begin{pmatrix} 0.005 \\ -0.014 \\ 0.018 \end{pmatrix} \begin{pmatrix} \text{rms} \\ \text{min} \\ \text{max} \end{pmatrix}$$

$$\begin{pmatrix} \text{zeilen(BS\_Wave)} \\ \text{spalten(BS\_Wave)} \end{pmatrix} = \begin{pmatrix} 123 \\ 123 \end{pmatrix}$$

$$\begin{pmatrix} \text{zeilen(BS\_wave\_scale)} \\ \text{spalten(BS\_wave\_scale)} \end{pmatrix} = \begin{pmatrix} 113 \\ 113 \end{pmatrix}$$

Calibration setups:

Up: W1 wavefront measurement with the calibration mirror in front of the SHS2 optic
Down: W2 wavefront measurement with the calibration mirror placed between the beamsplitter and the telescope

$$W1 = \text{Launch} + P + \text{Telescope} + \text{Cal\_1} + \text{Telescope} + BS$$ and $$W2 = \text{Launch} + P + \text{Cal\_2} + BS$$

Wavefront calibration calculation:

$$W1 - W2 = \text{Launch} + P + \text{Telescope} + \text{Cal\_1} + \text{Telescope} + BS - (\text{Launch} + P + \text{Cal\_2} + BS) = 2 \cdot \text{Telescope} + \text{Cal\_1} - \text{Cal\_2}$$

Wanted wavefront for the calibration: $$W = \text{Telescope} + BS$$ where the BS-wavefront is measured on component level with an interferometer
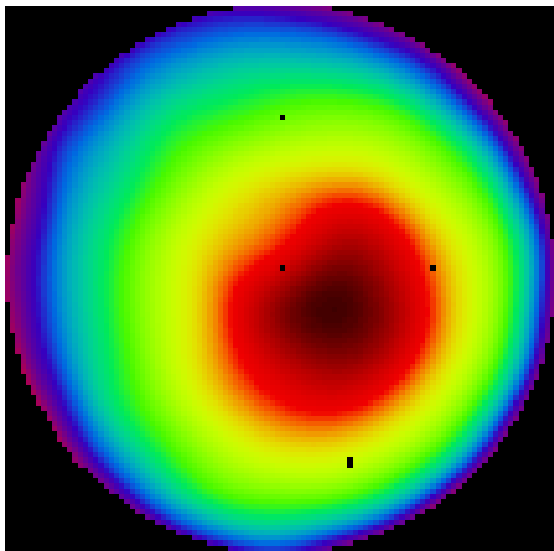
With : $$\text{Cal\_2} = 0$$

$$W = \frac{W1 - W2 - (\text{Cal\_1} - \text{Cal\_2})}{2} + BS$$
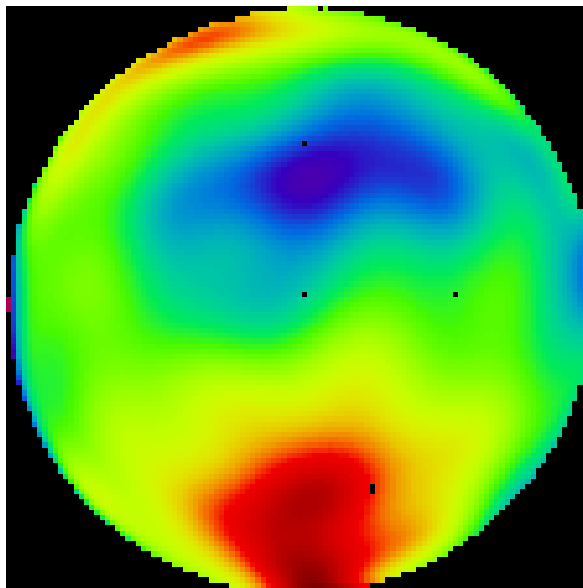
$$W = \frac{W1 - W2 - \text{Cal\_1}}{2} + BS$$

Note: the interferometer WFE is inverse from the SHS measurement

$$W = \frac{\text{CalFibre\_INT} - \text{W2\_INT} + \text{Cal1\_wave\_scale}}{2} - \text{BS\_wave\_scale}$$
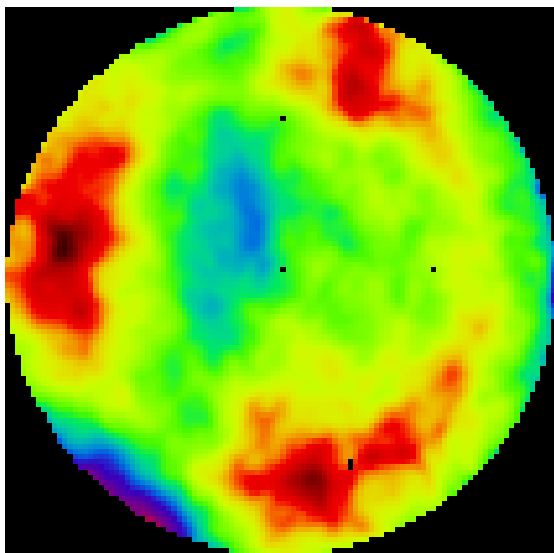
Calibration wavefront with the SHS2:
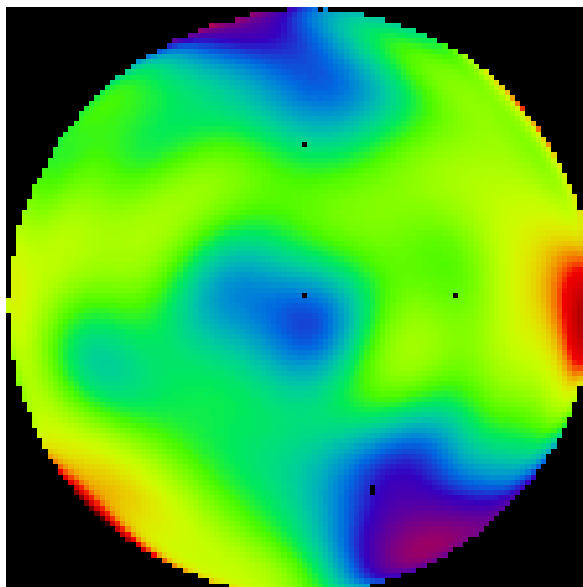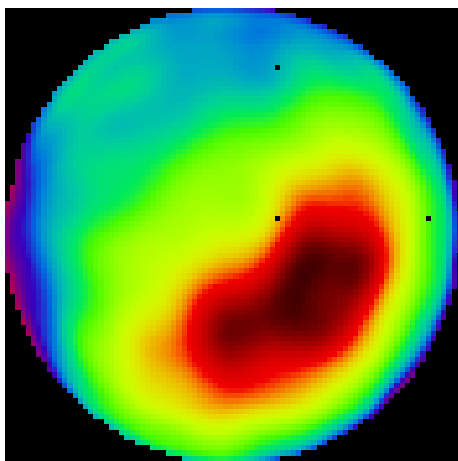

Wavefront of the Launch optic :

Calibration mirror (DIRECT100), scaled:

Beamsplitter Wavefront, scaled:

IPA 13 wavefront :

$$\begin{pmatrix} \text{zeilen(CalFibre\_INT)} \\ \text{spalten(CalFibre\_INT)} \end{pmatrix} = \begin{pmatrix} 106 \\ 106 \end{pmatrix}$$

$$\begin{pmatrix} \text{zeilen(W2\_INT)} \\ \text{spalten(W2\_INT)} \end{pmatrix} = \begin{pmatrix} 113 \\ 113 \end{pmatrix}$$

$$\begin{pmatrix} \text{zeilen(Cal1\_wave\_scale)} \\ \text{spalten(Cal1\_wave\_scale)} \end{pmatrix} = \begin{pmatrix} 106 \\ 106 \end{pmatrix}$$
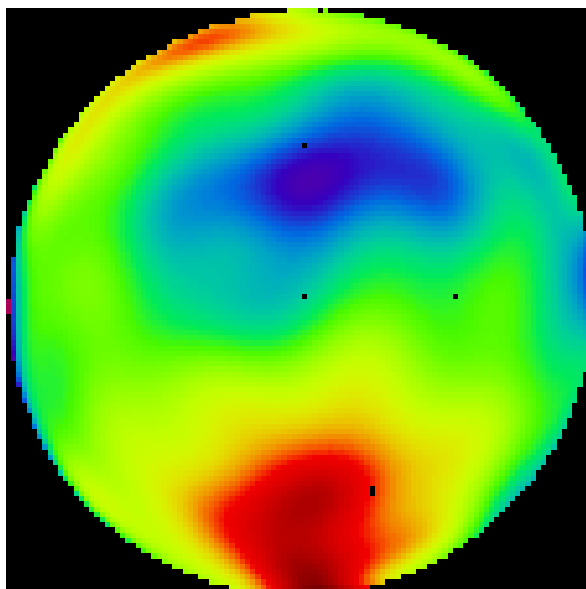
$$\begin{pmatrix} \text{zeilen(BS\_wave\_scale)} \\ \text{spalten(BS\_wave\_scale)} \end{pmatrix} = \begin{pmatrix} 113 \\ 113 \end{pmatrix}$$

$$\begin{pmatrix} \text{zeilen(IPA13\_INT)} \\ \text{spalten(IPA13\_INT)} \end{pmatrix} = \begin{pmatrix} 88 \\ 88 \end{pmatrix}$$
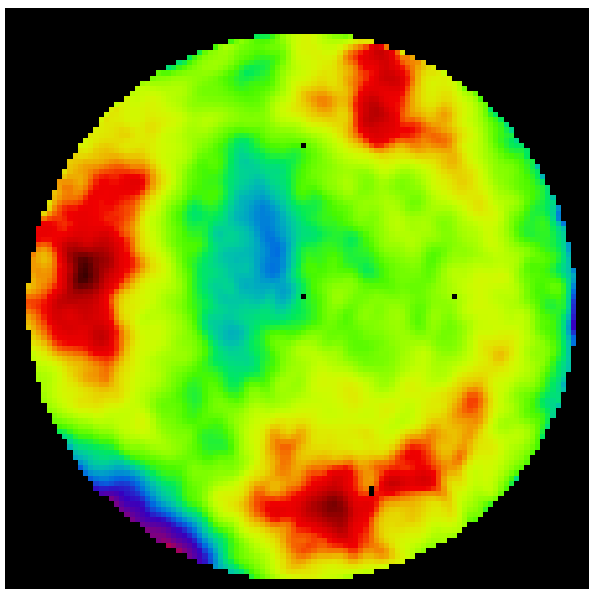
Calibration wavefront with the SHS2:
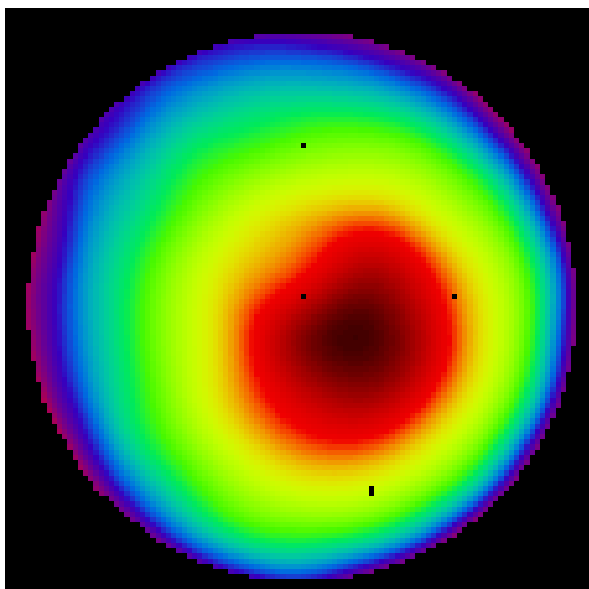
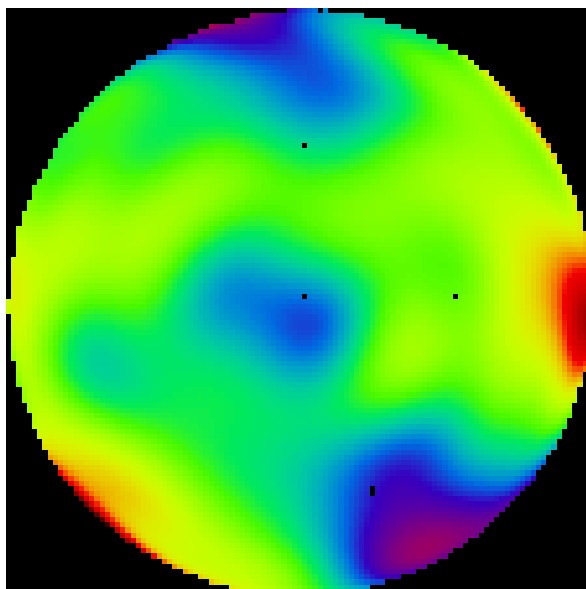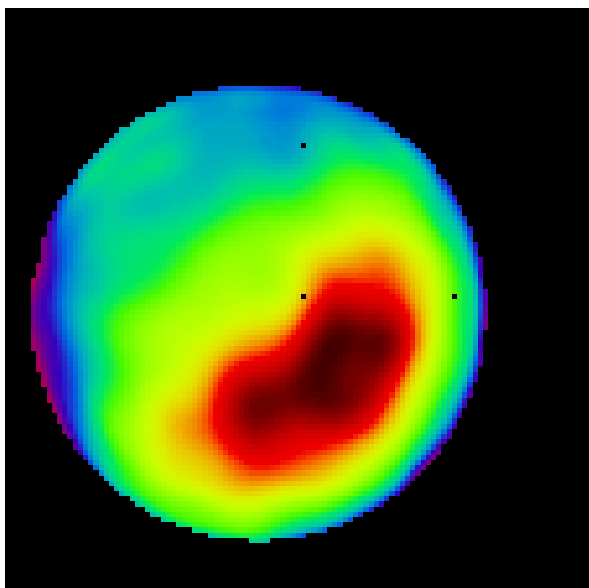## Wavefront of the Launch optic :

Calibration mirror (DIRECT100), scaled:
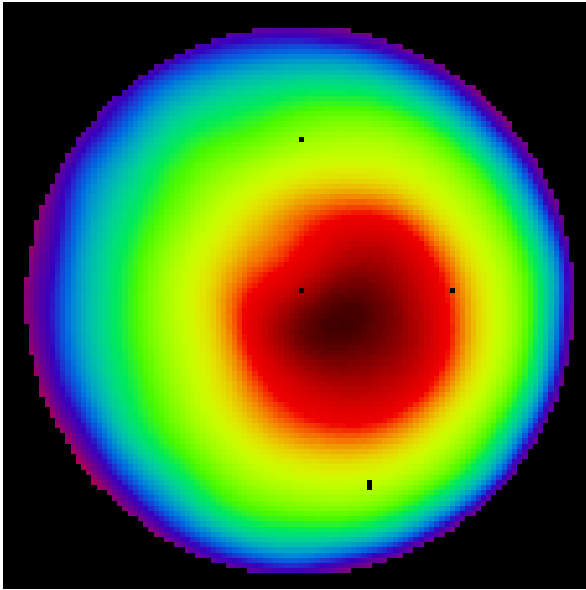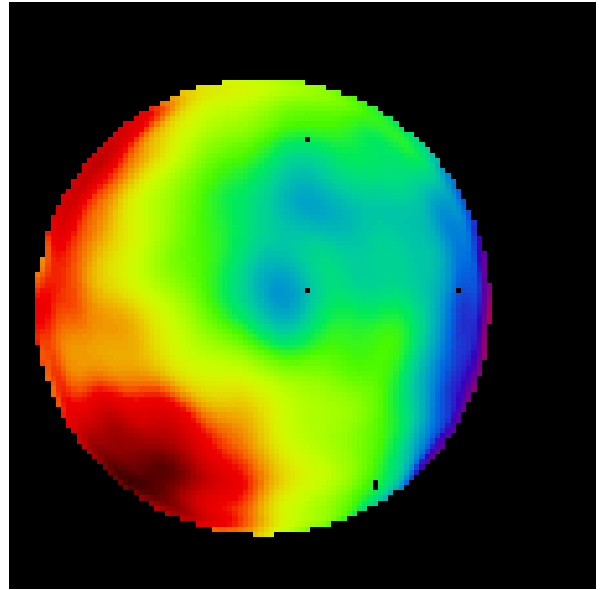
Beamsplitter Wavefront, scaled:

IPA 13 wavefront :

Wavefront calibration calculation:

$$\text{Calibration} := \text{Sub\_INT}\left(\frac{\text{Add\_INT}\left(\text{Sub\_INT}\left(Q1_1, Q1_2\right), Q2_1\right)}{2}, Q2_2\right)$$

IPA 13 wavefront after calibration :

$$\text{IPA13} := \text{Sub\_INT}\left(Q3_1, \text{Calibration}\right)$$

IPA 13 wavefront after calibration :

$$\text{IPA13} := \text{Find\_min\_Area(IPA13)}$$

$$\text{IPA13\_zern} := \text{Zernike\_Fit\_100}(\text{IPA13}, \text{Zer81}, 1)$$

$$\text{IPA13\_wave} := \text{Zernike\_all}(335, \text{IPA13\_zern}, 0)$$
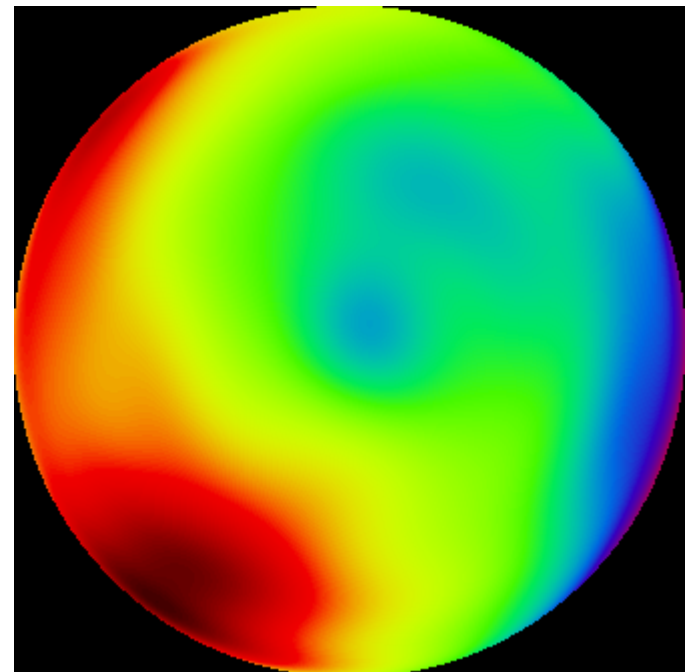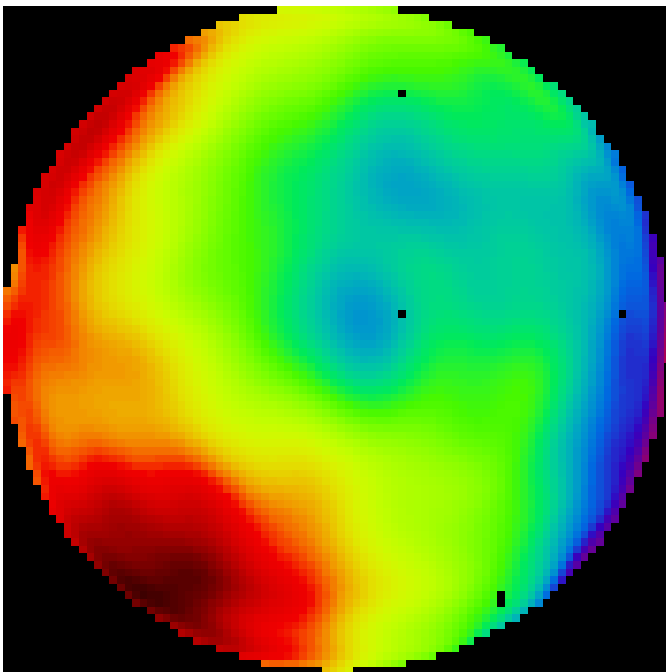
$$\text{rms(IPA13)} = \begin{pmatrix} 0.141 \\ -0.437 \\ 0.211 \end{pmatrix} \begin{pmatrix} \text{rms} \\ \text{min} \\ \text{max} \end{pmatrix}$$

$$\text{rms(IPA13\_wave)} = \begin{pmatrix} 0.141 \\ -0.448 \\ 0.213 \end{pmatrix} \begin{pmatrix} \text{rms} \\ \text{min} \\ \text{max} \end{pmatrix}$$
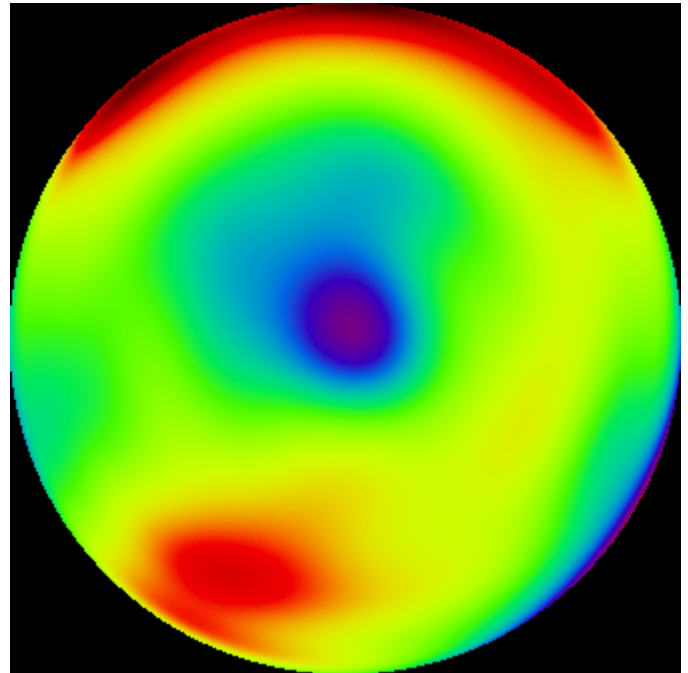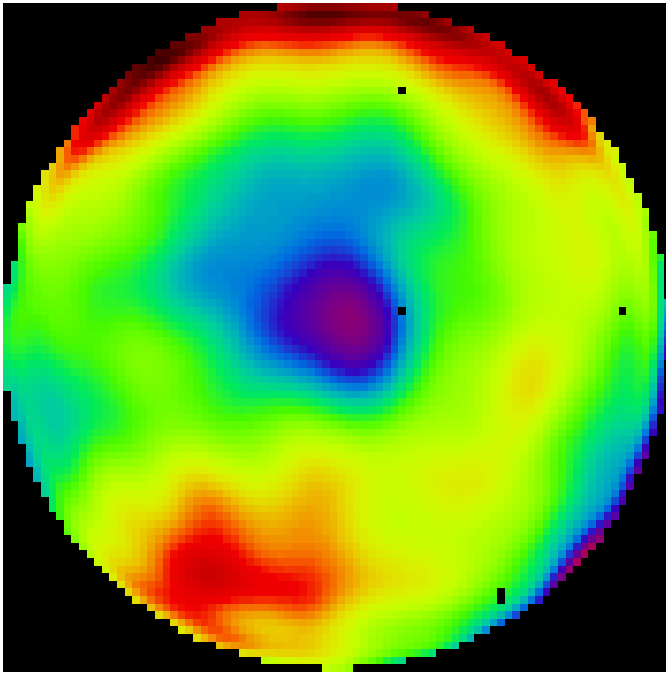
IPA 13 wavefront after calibration and after substraction of piston and tilts :

$$\text{IPA13} := \text{Find\_min\_Area(IPA13)} \qquad \text{Zern\_sub} := \text{Zernike\_2}\left[-\begin{pmatrix} \text{zeilen(IPA13)} \\ \text{spalten(IPA13)} \end{pmatrix}, \begin{pmatrix} 1 & \text{IPA13\_zern}_{1,2} \\ 2 & \text{IPA13\_zern}_{2,2} \\ 3 & \text{IPA13\_zern}_{3,2} \end{pmatrix}, 0\right]$$

$$\text{IPA13\_zern}_{1,2} := 0 \qquad \text{IPA13\_zern}_{2,2} := 0$$
$$\text{IPA13\_zern}_{3,2} := 0$$

$$\text{IPA13\_sub} := \text{IPA13} - \text{Zern\_sub}$$

$$\text{IPA13\_wave} := \text{Zernike\_all}(335, \text{IPA13\_zern}, 0)$$

$$\text{rms(IPA13\_sub)} = \begin{pmatrix} 0.067 \\ -0.182 \\ 0.153 \end{pmatrix} \begin{pmatrix} \text{rms} \\ \text{min} \\ \text{max} \end{pmatrix} \qquad\qquad \text{rms(IPA13\_wave)} = \begin{pmatrix} 0.066 \\ -0.196 \\ 0.157 \end{pmatrix} \begin{pmatrix} \text{rms} \\ \text{min} \\ \text{max} \end{pmatrix}$$

IPA measurement (9.6.2010) :

Zernike Fit Wavefront measurement :

Path_zern := "..\..\30_Measurements\40 Delta^3 COL after CAL\CCD-SHS\ILL Sequence 2010-06-09_IPA\"

Name := "WfZernikePolynomial_ILL1_"

$Z\_Liste := Zernike\_Lesen(Path\_zern, Name)$ $Q := Zernike\_S(Z\_Liste, 88)$ $M\_Q := List\_to\_matrix(Q, 5, 5, 8)$

Path := "..\..\\30_Measurements\40 Delta^3 COL after CAL\CCD-SHS\ILL Sequence 2010-06-09_IPA\INT_files\Session_ILL1_"

$M := INT\_Lesen(Path, "\_WF.int")$

$$Z20 := Zernike\_all\_2\left[-\begin{pmatrix} zeilen(M_{19}) \\ spalten(M_{19}) \end{pmatrix}, Z\_Liste_{19}, 0\right]$$
   $Z20 := b\_mask(Z20, Im(M_{19}))$ $M_{19} := Z20 + i \cdot Im(M_{19})$

$$WVE := List\_to\_matrix(M, 5, 5, 8) \qquad F := Image\_Bild\_M\left[GleichDim(WVE, 1), \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}, 1\right]$$
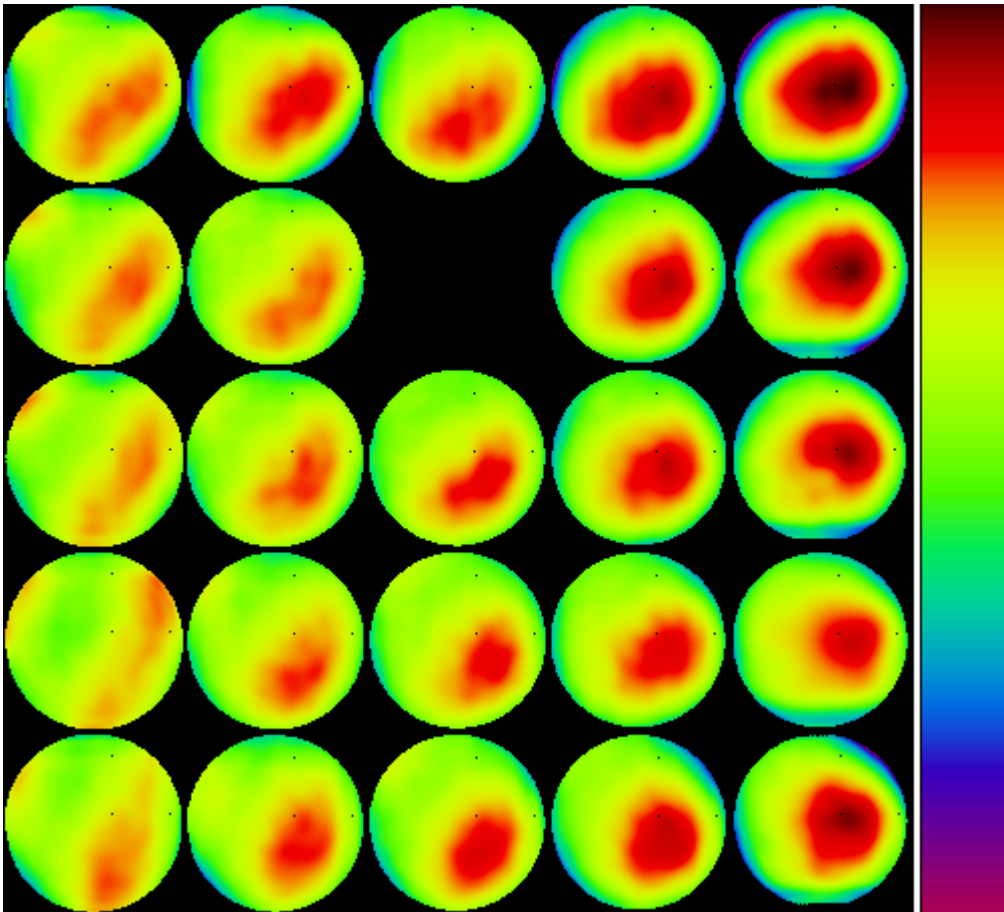
IPA measurement after calibration :

$IPA := Grid\_INT\_serie(M, W2\_INT, Calibration)$ $WVE := List\_to\_matrix(IPA, 5, 5, 8)$

$$RMS\_Serie(WVE, 1) = \begin{pmatrix} 0.153 & 0.141 & 0.158 & 0.174 & 0.202 \\ 0.156 & 0.146 & 0.000 & 0.137 & 0.160 \\ 0.171 & 0.143 & 0.141 & 0.135 & 0.151 \\ 0.196 & 0.152 & 0.145 & 0.137 & 0.142 \\ 0.180 & 0.146 & 0.150 & 0.147 & 0.162 \end{pmatrix}$$

IPA measurement after calibration :
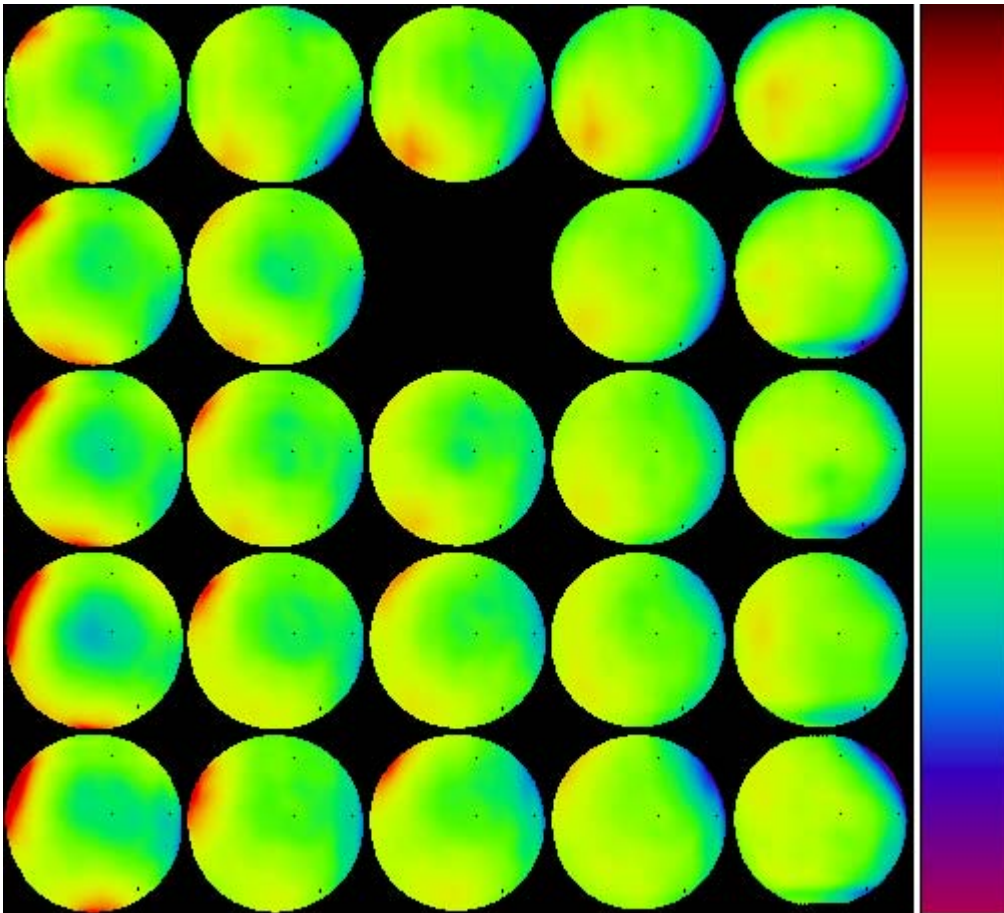
IPA measurement after calibration (each wavefront scaled) :
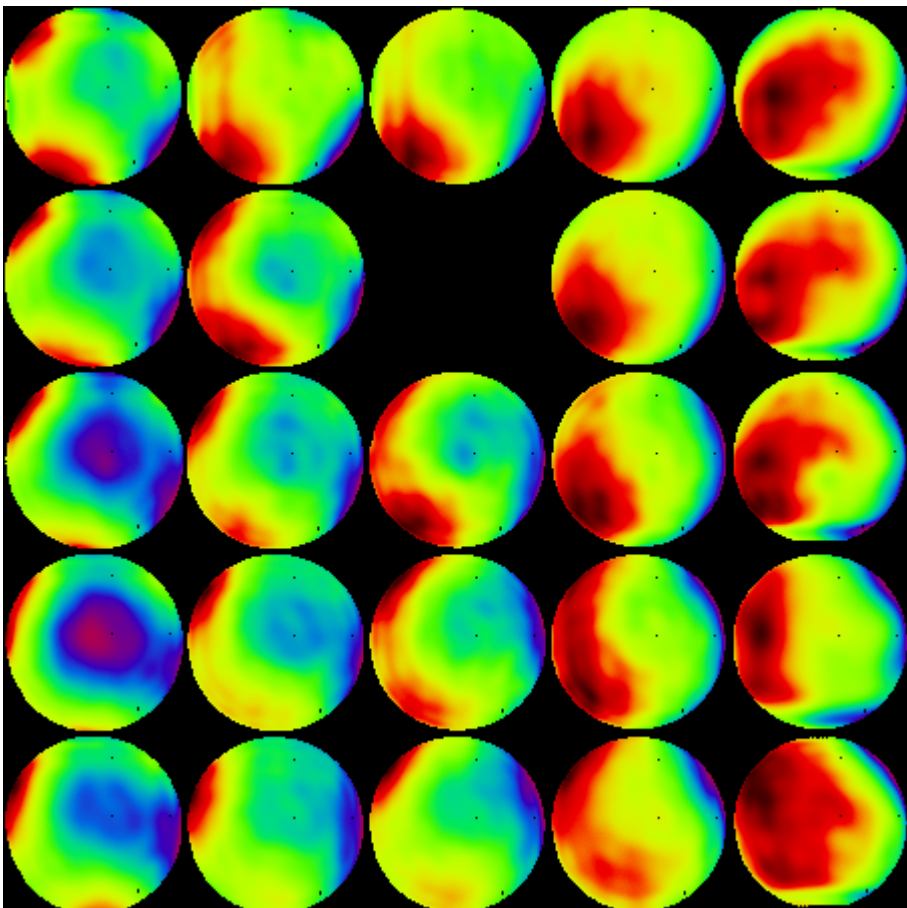
IPA measurement after calibration (without piston and tilts) :
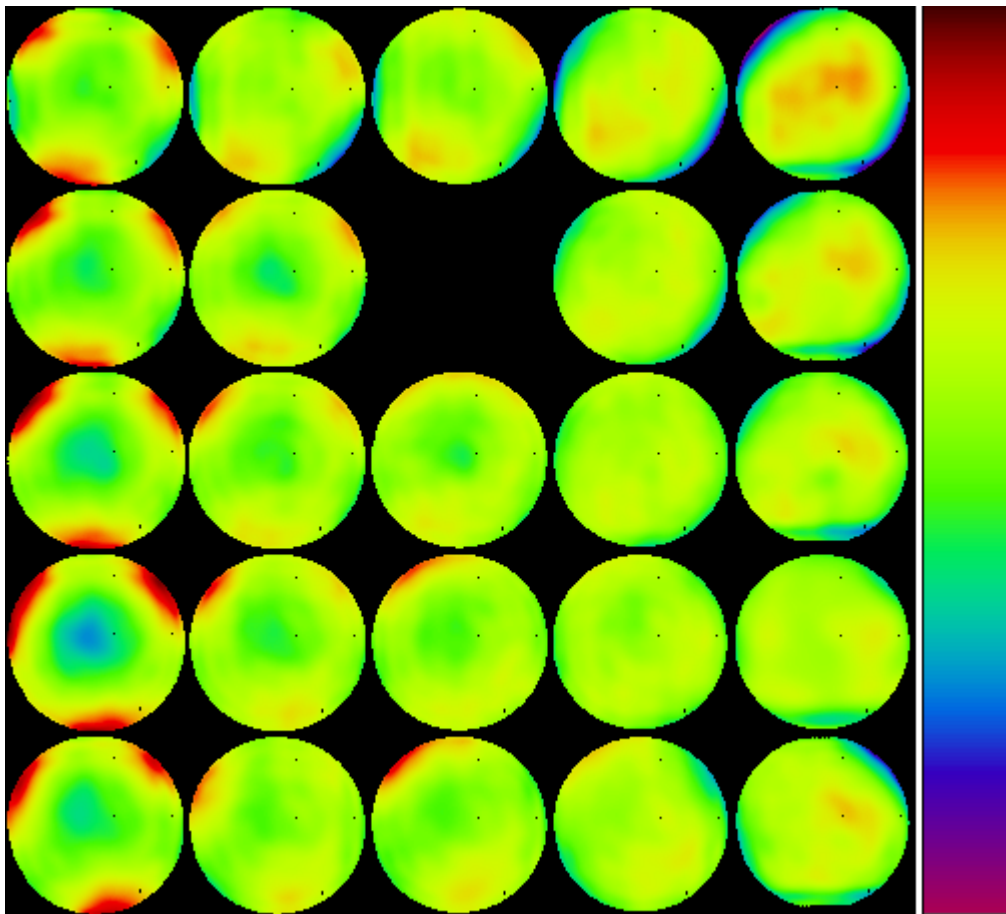
IPA measurement after calibration (without piston and tilts, each wavefront scaled) :
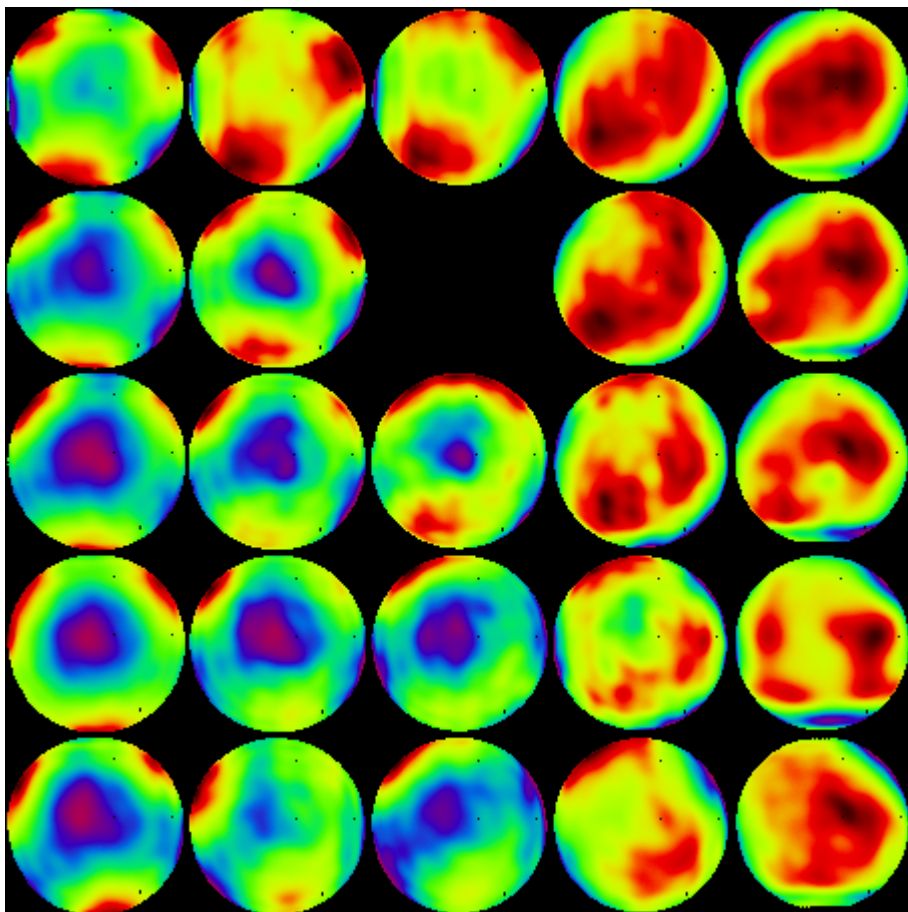
RMS_Serie

$$\begin{pmatrix} 0.108 & 0.091 & 0.088 & 0.121 & 0.163 \\ 0.110 & 0.085 & 0.000 & 0.079 & 0.119 \\ 0.127 & 0.079 & 0.067 & 0.055 & 0.093 \\ 0.160 & 0.080 & 0.069 & 0.048 & 0.066 \\ 0.124 & 0.068 & 0.081 & 0.074 & 0.102 \end{pmatrix}$$

Path := "WFE_INT_IPA_2010-06-09\Session_ILL1_corr_"　　　INT_Schreiben(Path, Diff , 1 , 8) = ∎

IDG measurement (9.6.2010) :

Path := "..\..\\30_Measurements\40 Delta^3 COL after CAL\CCD-SHS\ILL Sequence 2010-06-09_IDG\INT_files\Session_ILL2_"

M := INT_Lesen(Path, "_WF.int")

$$\text{WVE} := \text{List\_to\_matrix}(M, 10, 10, 0) \qquad F := \text{Image\_Bild\_M}\left[\text{GleichDim}(\text{WVE}, 1), \begin{pmatrix} -1 \\ 0 \\ 0 \end{pmatrix}, 1\right]$$

IDG measurement after calibration :

$$IDG := Grid\_INT\_serie(M, W2\_INT, Calibration) \qquad WVE := List\_to\_matrix(IDG, 10, 10, 0)$$

$$RMS\_Serie(WVE, 1) = \begin{pmatrix} 0.162 & 0.154 & 0.149 & 0.148 & 0.152 & 0.152 & 0.157 & 0.160 & 0.172 & 0.191 \\ 0.156 & 0.145 & 0.145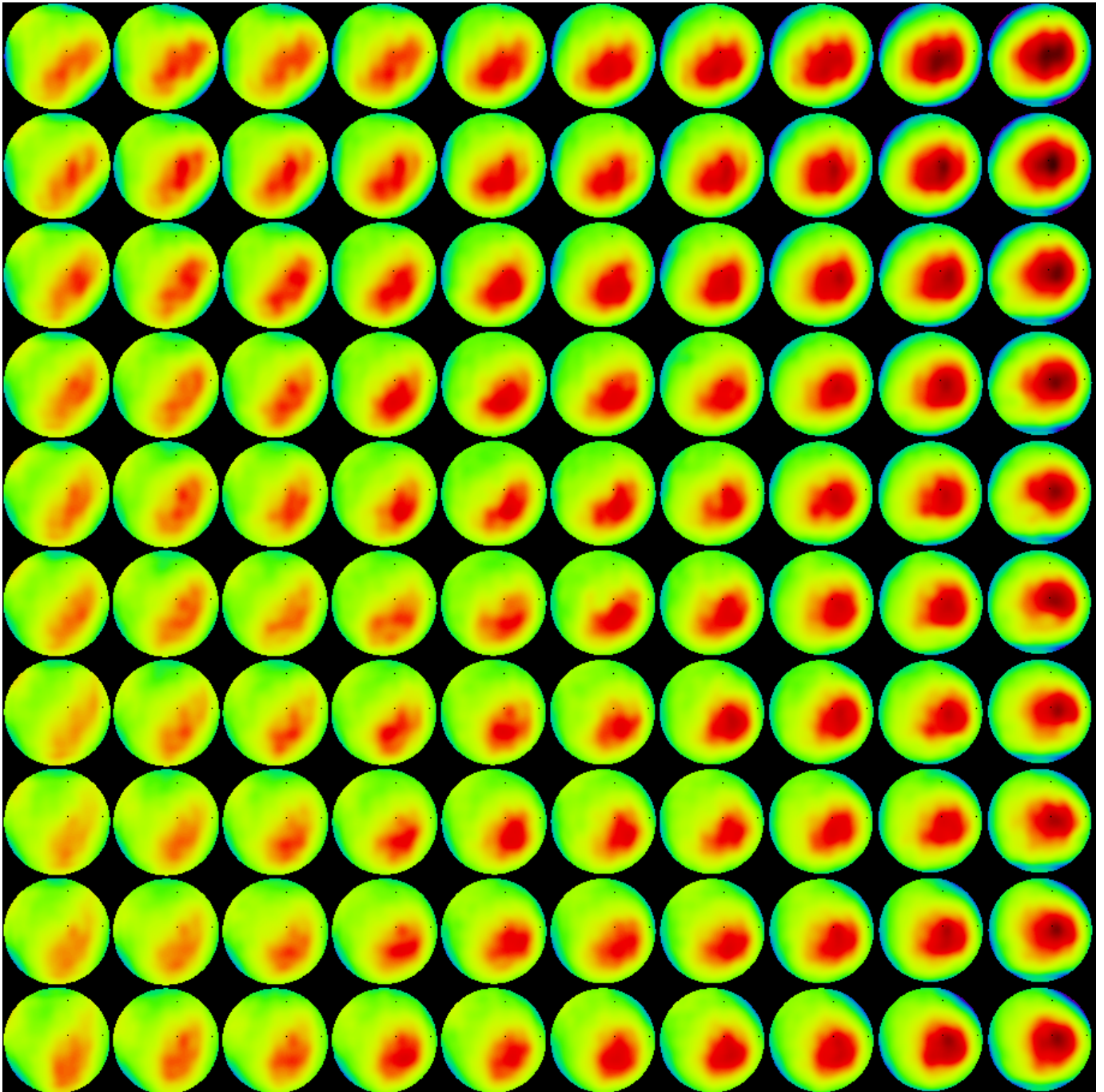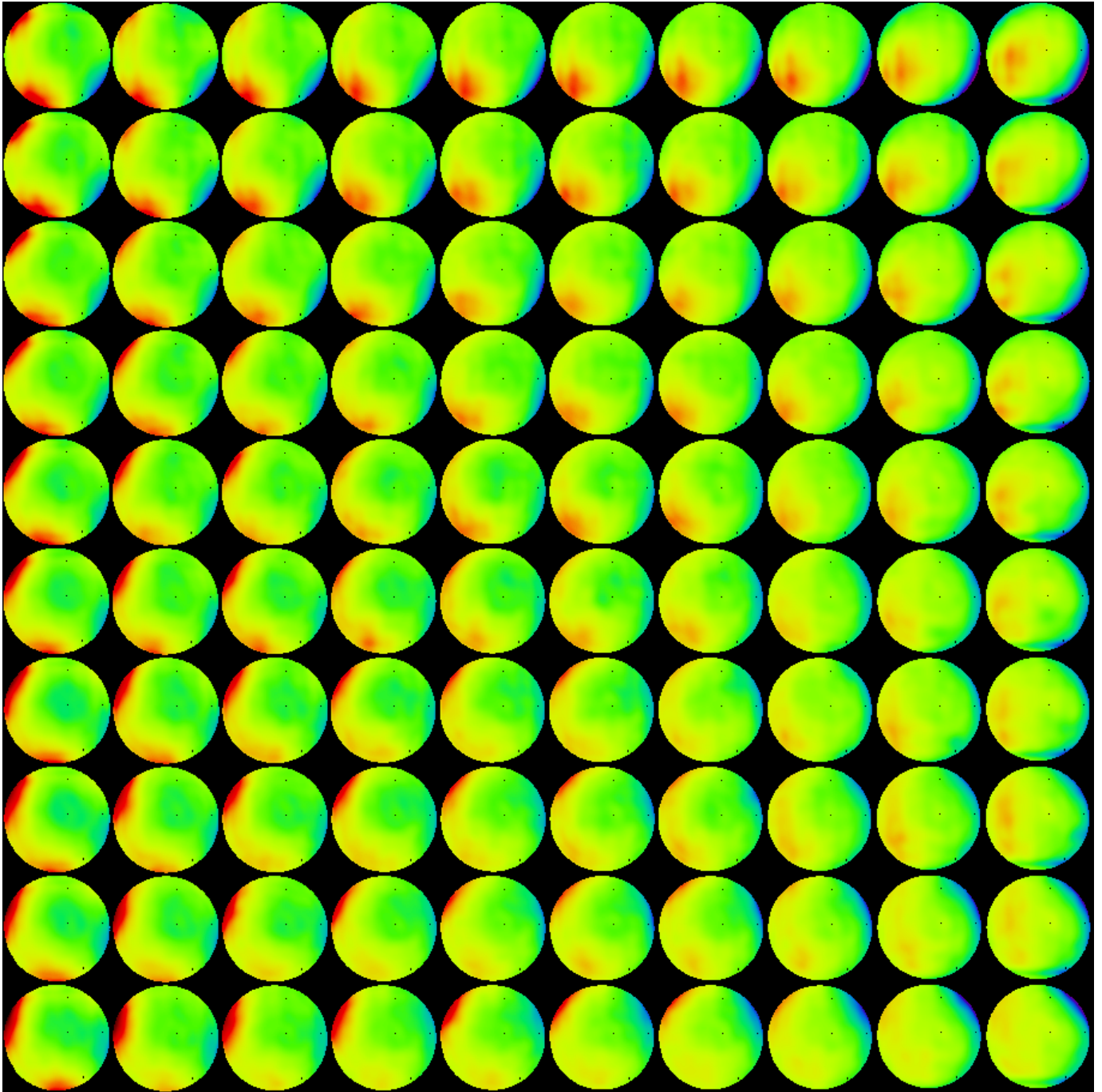 & 0.147 & 0.149 & 0.146 & 0.143 & 0.149 & 0.157 & 0.169 \\ 0.147 & 0.140 & 0.138 & 0.135 & 0.137 & 0.138 & 0.136 & 0.139 & 0.145 & 0.159 \\ 0.148 & 0.145 & 0.138 & 0.134 & 0.133 & 0.131 & 0.130 & 0.127 & 0.133 & 0.148 \\ 0.156 & 0.143 & 0.138 & 0.137 & 0.140 & 0.138 & 0.134 & 0.130 & 0.132 & 0.146 \\ 0.157 & 0.149 & 0.150 & 0.149 & 0.144 & 0.134 & 0.136 & 0.129 & 0.130 & 0.145 \\ 0.166 & 0.158 & 0.152 & 0.149 & 0.139 & 0.137 & 0.126 & 0.118 & 0.126 & 0.139 \\ 0.171 & 0.160 & 0.152 & 0.152 & 0.142 & 0.141 & 0.140 & 0.140 & 0.141 & 0.155 \\ 0.165 & 0.158 & 0.150 & 0.143 & 0.138 & 0.140 & 0.140 & 0.139 & 0.145 & 0.155 \\ 0.168 & 0.156 & 0.151 & 0.145 & 0.149 & 0.145 & 0.143 & 0.144 & 0.146 & 0.153 \end{pmatrix}$$

$$Path := \text{"WFE\_INT\_IDG\_2010-06-09}\backslash\text{Session\_ILL2\_corr\_"} \qquad INT\_Schreiben(Path, Diff, 1, 0) = 1 \ \blacksquare$$

IDG measurement after calibration (without piston and tilts) :

$$\text{RMS\_Serie}(\text{List\_to\_matrix}(Diff,10,10,0),1) = \begin{pmatrix} 0.100 & 0.087 & 0.086 & 0.082 & 0.084 & 0.084 & 0.094 & 0.105 & 0.128 & 0.152 \\ 0.102 & 0.084 & 0.082 & 0.077 & 0.075 & 0.072 & 0.079 & 0.089 & 0.108 & 0.130 \\ 0.096 & 0.084 & 0.079 & 0.074 & 0.071 & 0.072 & 0.075 & 0.080 & 0.092 & 0.116 \\ 0.097 & 0.091 & 0.079 & 0.071 & 0.064 & 0.063 & 0.063 & 0.060 & 0.080 & 0.103 \\ 0.106 & 0.083 & 0.077 & 0.071 & 0.070 & 0.065 & 0.055 & 0.054 & 0.063 & 0.088 \\ 0.103 & 0.088 & 0.088 & 0.073 & 0.066 & 0.062 & 0.056 & 0.049 & 0.062 & 0.085 \\ 0.114 & 0.095 & 0.086 & 0.079 & 0.062 & 0.066 & 0.056 & 0.052 & 0.052 & 0.075 \\ 0.107 & 0.091 & 0.079 & 0.077 & 0.065 & 0.065 & 0.058 & 0.047 & 0.050 & 0.077 \\ 0.103 & 0.088 & 0.076 & 0.069 & 0.063 & 0.068 & 0.066 & 0.062 & 0.069 & 0.089 \\ 0.108 & 0.084 & 0.074 & 0.068 & 0.076 & 0.071 & 0.069 & 0.067 & 0.076 & 0.090 \end{pmatrix}$$