Flexible Optical B.V.

Adaptive Optics • Optical Microsystems • Wavefront Sensors

79-channel 50mm piezoelectric deformable mirror system

technical passport

OKO Technologies,

OKO Technologies is the trade name of Flexible Optical BV

1 Technical data

The mirror, shown in Fig. 1, consists of 79 piezoelectric column actuators bonded to the base holder. Reflective plate is bonded to the top of the actuator structure and coated to form the mirror. The shape of the faceplate is controlled by the voltages applied to the actuators.

The device can be used for fast dynamic correction of low-order optical aberrations such as defocus, astigmatism, coma, etc, in lasers, telescopes, ophthalmology, displays and general imaging optics.

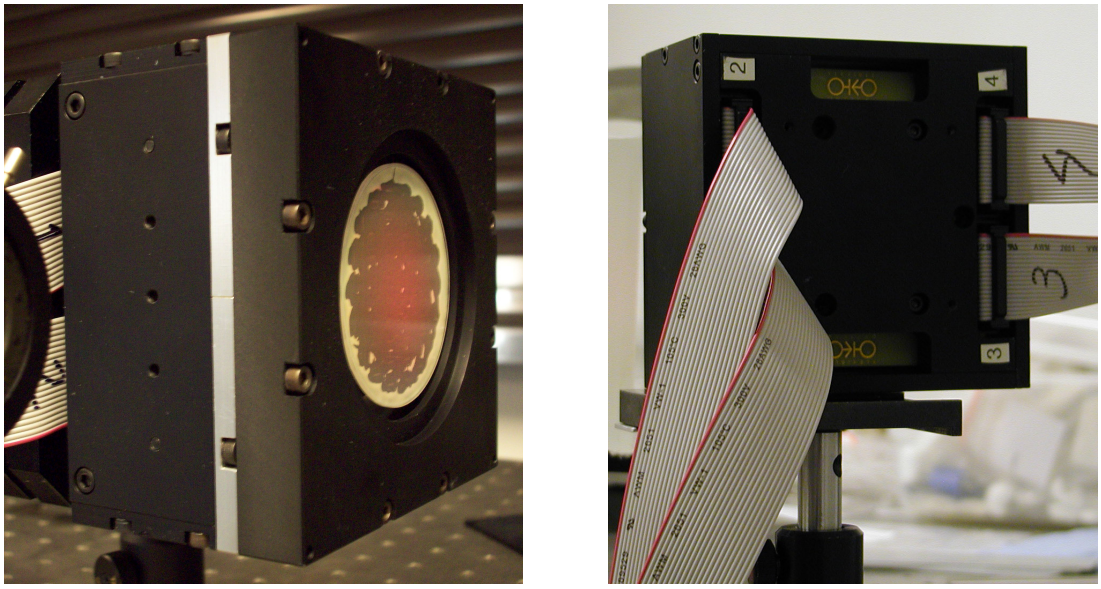

Figure 1: Typical front and back view of a 79-ch 50mm piezoelectric deformable mirror. Please note that these mirrors can be fabricated with different package designs, so the mirror you have may look differently.

The mirror can be supplied with initially curved spherical surface. This sphericity is caused by the stress in the mirror coating. It does not influence the parameters of the mirror, but should be taken into account when the mirror is incorporated into the optical setup.

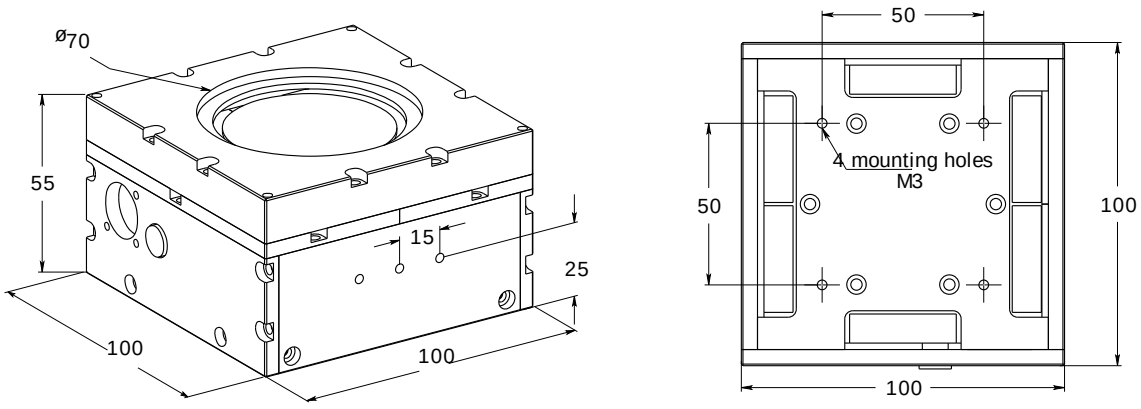

Figure 2: Technical drawing of the mirror case. Three mounting holes on the case bottom and side walls have M3 threading.

Table 1: Technical parameters of the mirror.

Parameter	Value
Aperture shape	circular 50mm in diameter
Mirror coating	HR@1020-1040nm ($> 99.95\%$)
Maximum actuator voltage range	$0 \ldots + 400$V
Recommended voltage range	$0 \ldots + 300$V
Number of electrodes	79 (see Fig. 3)
Actuator capacitance C_a	~ 5nF
Initial RMS deviation from reference sphere	less than 0.1 μm
Main initial aberration	convex sphere with ROC ≈ 10 m
Maximum stroke	8μm at $+400V$ 6μm at $+300V$
Actuator pitch	4.72mm
Size	see Fig. 2

Due to hysteresis of actuators, the initial aberration may change during the mirror usage and deviate more from the reference sphere. This deviation is a superposition of actuator response functions and is irrelevant in active setups with closed-loop control, though it may slightly reduce the correction range.

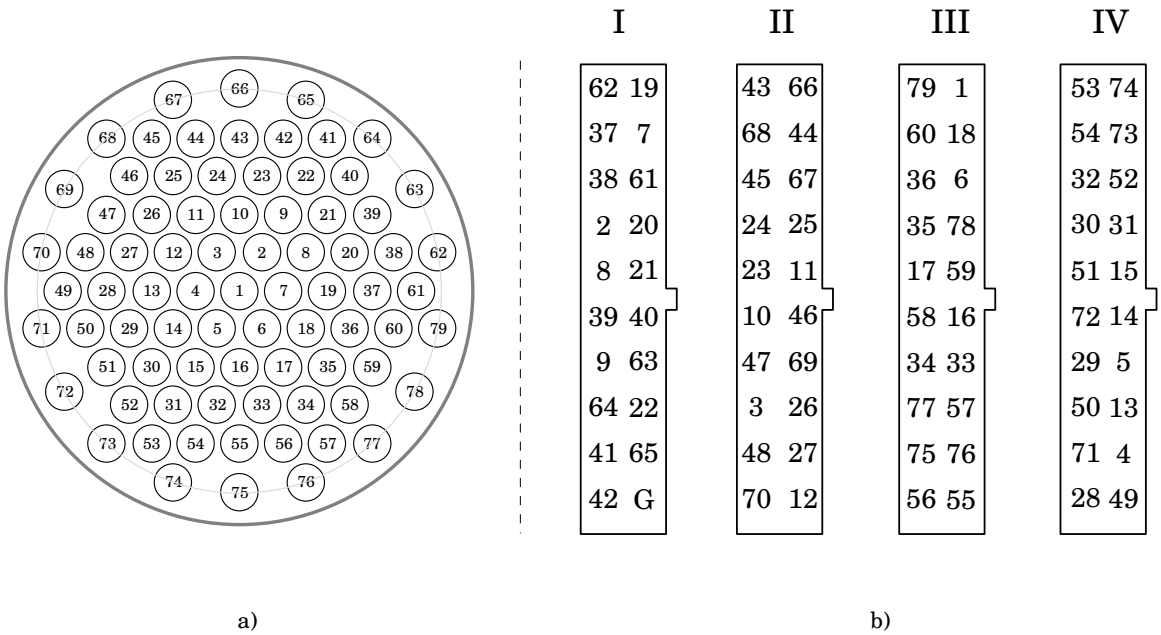

Figure 3: The geometry of mirror actuators (view from the mirror side) and its correspondence to the pins of the mirror connectors

2 Active cooling

The mirror case might be equiped with a fan for active cooling of the mirror. Please use the power supply shipped with the mirror to power the the fan.

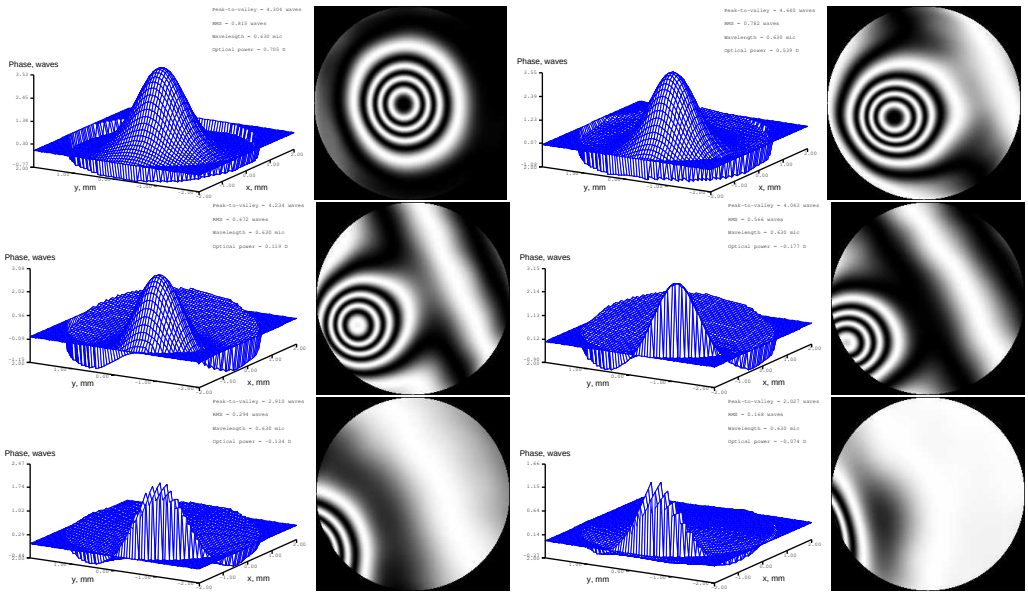

Figure 4: Results of Shack-Hartmann measurement of the response functions of the mirror in 30mm aperture: wavefront reconstruction and simulated interferogram. Left to right, top to bottom: actuators 1, 3; 11, 25; 45, 67.

3 Control amplifier unit

Figure 5: 40 channel high-voltage amplifier unit.

The mirror is controlled by two high-voltage amplifier units. To use the units, you must connect them to the mirror, to DAC units (or PCI boards) and to the wall outlet (85 to 250V AC, 50 to 60 Hz). Connect the mirror with a supplied flat ribbon cables to the 20-pin connectors on the front side, and the driver boards or the DAC unit to the 26-pin connectors. Connect together ground sockets of both HV amplifier units.

The HV unit supplied with your mirror is tuned to secure safe operation of the mirror.

In case of OEM version of the system, the mirror is controlled by two high-voltage amplifier boards. Each board contains 20 non-inverting DC amplifiers with gain 35, 59, or 79 depending on the board type, and should be connected to a high-voltage (< 400V) power supply and to a stabilized ± 15V DC supply. Connect the ground, +15V and -15V to the pins marked G,+

Figure 6: Front and back panels of 40 channel high-voltage amplifier unit.

and –. Connect positive high-voltage stabilized DC supply to the pin marked V_high, connect negative high voltage terminal to the ground (see Fig. 7). **The high voltage supply should not exceed 400 V DC.** Use the flat ribbon cable supplied to connect the driver board to the mirror socket.

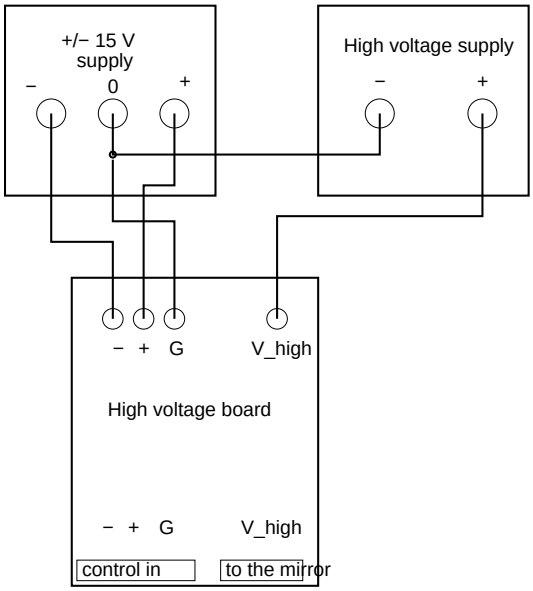

Figure 7: Power supply wiring for OEM version of the system. Position of the connectors can be different; refer to the board manual and/or marking on the board.

4 Digital boards

The output voltage of the channel N [N=0...23] of the 8-bit 24-channel DAC board is controlled by sending control byte V [0...255] to the output port BA+N*4. Please see the separate board description for detailed installation guide.

The pinout of the board and the pinouts of the board cable and the cable coming from the high voltage board are shown in Fig. 8. The board connector pinout is given for the board make connector. The cable pinouts are given for the cable female connectors viewed from the front side.

The actuator addresses of the 79ch mirror are given below:

```
i=PCI_CH_OFFSET;
```

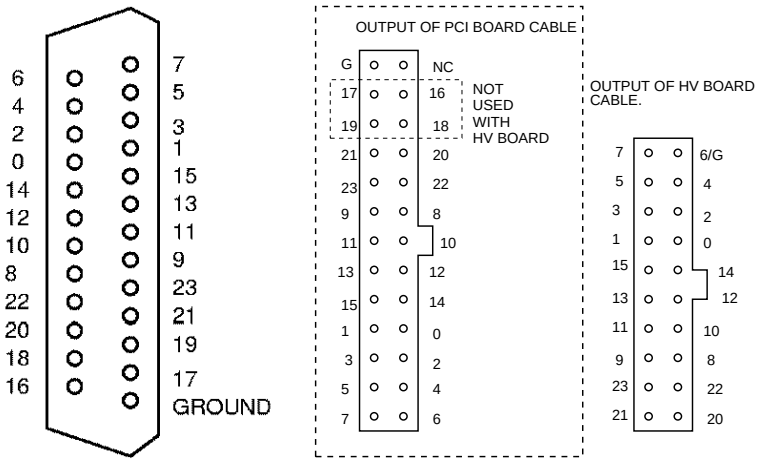

Figure 8: Pinouts of the digital board and cables. The numbers correspond to the addresses of the pin with respect to the base address of the board.

```
addr[42]=b1+ 7*i; addr[41]=b1+ 5*i; addr[65]=b1+ 4*i;
addr[64]=b1+ 3*i; addr[22]=b1+ 2*i; addr[ 9]=b1+ 1*i;
addr[63]=b1+ 0*i; addr[39]=b1+15*i; addr[40]=b1+14*i;
addr[ 8]=b1+13*i; addr[21]=b1+12*i; addr[ 2]=b1+11*i;
addr[20]=b1+10*i; addr[38]=b1+ 9*i; addr[61]=b1+ 8*i;
addr[37]=b1+23*i; addr[ 7]=b1+22*i; addr[62]=b1+21*i;
addr[19]=b1+20*i;


addr[70]=b2+ 7*i; addr[12]=b2+ 6*i; addr[48]=b2+ 5*i;
addr[27]=b2+ 4*i; addr[ 3]=b2+ 3*i; addr[26]=b2+ 2*i;
addr[47]=b2+ 1*i; addr[69]=b2+ 0*i; addr[10]=b2+15*i;
addr[46]=b2+14*i; addr[23]=b2+13*i; addr[11]=b2+12*i;
addr[24]=b2+11*i; addr[25]=b2+10*i; addr[45]=b2+ 9*i;
addr[67]=b2+ 8*i; addr[68]=b2+23*i; addr[44]=b2+22*i;
addr[43]=b2+21*i; addr[66]=b2+20*i;

addr[56]=b3+ 7*i; addr[55]=b3+ 6*i; addr[75]=b3+ 5*i;
addr[76]=b3+ 4*i; addr[77]=b3+ 3*i; addr[57]=b3+ 2*i;
addr[34]=b3+ 1*i; addr[33]=b3+ 0*i; addr[58]=b3+15*i;
addr[16]=b3+14*i; addr[17]=b3+13*i; addr[59]=b3+12*i;
addr[35]=b3+11*i; addr[78]=b3+10*i; addr[36]=b3+ 9*i;
addr[ 6]=b3+ 8*i; addr[60]=b3+23*i; addr[18]=b3+22*i;
addr[79]=b3+21*i; addr[1]=b3+20*i;


addr[28]=b4+ 7*i; addr[49]=b4+ 6*i; addr[71]=b4+ 5*i;
addr[ 4]=b4+4 *i; addr[50]=b4+ 3*i; addr[13]=b4+ 2*i;
addr[29]=b4+ 1*i; addr[ 5]=b4+ 0*i; addr[72]=b4+15*i;
addr[14]=b4+14*i; addr[51]=b4+13*i; addr[15]=b4+12*i;
addr[30]=b4+11*i; addr[31]=b4+10*i; addr[32]=b4+ 9*i;
addr[52]=b4+ 8*i; addr[54]=b4+23*i; addr[73]=b4+22*i;
addr[53]=b4+21*i; addr[74]=b4+20*i;
```

5 DAC Unit

A single “DAC-40-USB” or “EDAC-40” unit can control up to 40 channels. Please see the separate unit description for detailed installation guide.

The pinout of the DAC unit and the pinouts of the board cable and the cable coming from the high voltage board are shown in Fig. 9. The DAC unit connector pinout is given for one of its male connectors. The cable pinouts are given for the cable female connectors viewed from the front side.

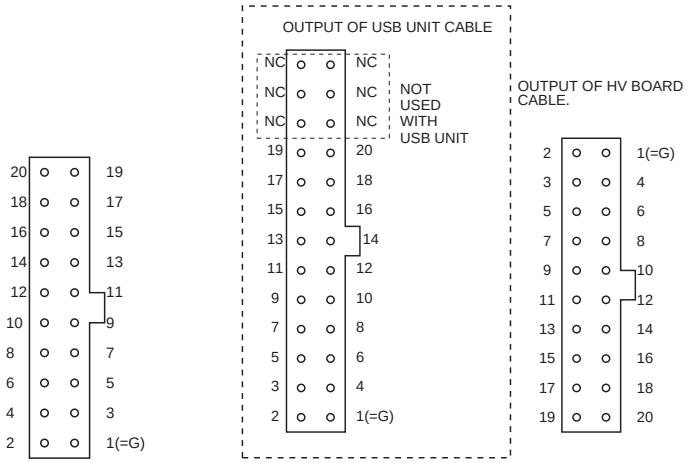

Figure 9: Pinouts of the first connector of the DAC USB/Ethernet unit and cables. The numbers correspond to the numeration of “DAC-40-USB” output channels (channels 1 and 2 may be swapped by jumper setting — see the label on the bottom of the unit for its settings). Second connector is connected in a similar way.

When using two or more USB DAC units, connect together their ground sockets.

Please see the SDK on the CD supplied with the mirror for examples of control programs with DAC unit.

6 Optical quality

The interferograms of the mirror obtained before shipping are shown in Fig. 10.

NB! The interferograms were registered at wavelength $\lambda = 632$ nm.

The results of wavefront measurements with the Shack-Hartmann sensor are shown in Fig. 11.

7 First run of the system

- **Read this document through before performing any practical steps**. Follow the instructions exactly, if it’s written `connect the board, connect the mirror` — **first** connect the board and **then** connect the mirror.

- All following operations refer to:

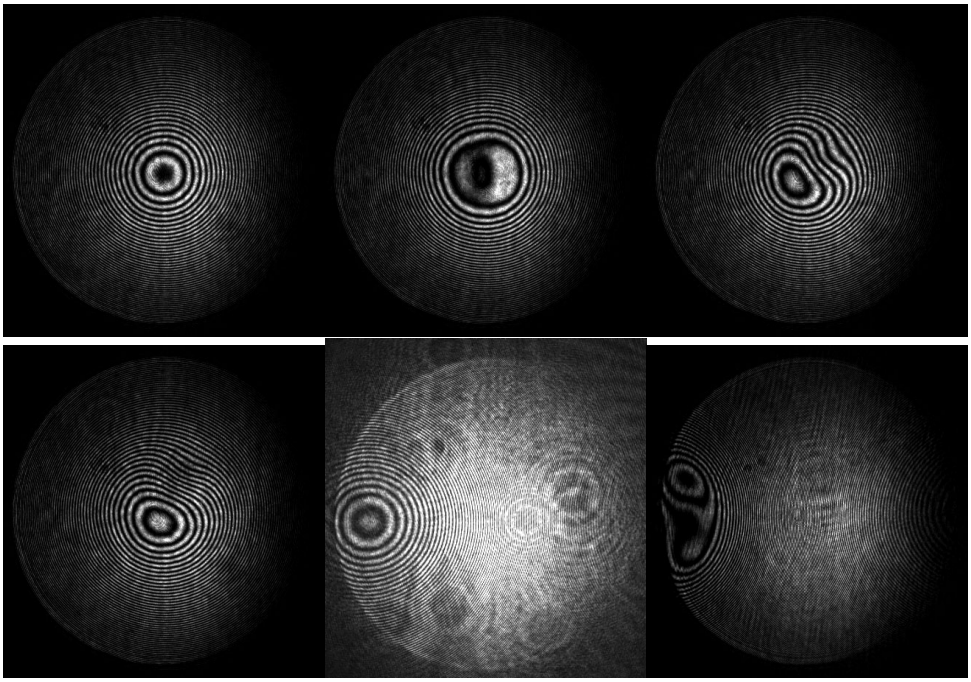

Figure 10: Test of the mirror. Top row: initial shape, maximum voltage applied to actuator 1 /actuator 2. Bottom row: maximum voltage applied to actuator 8; initial shape with fringe pattern centred on actuator 75; maximum voltage applied to actuator 75. Please see also the demo movie supplied on the accompanying CD.

  - either *DAC-40-USB unit or EDAC40 unit* connected to a computer running Windows - we used XP SP2 for final tests
  - or *digital boards* installed in a computer running Linux - we used RH 7.2 for final tests.

- *For DAC-40-USB unit.* Connect the DAC USB units to the computer USB ports. Connect the ground sockets of the units together. Install the software (refer to the DAC USB unit guide). Jumpers of the USB unit are already preset to the correct position (one connector provides 19-channel output and ground, and three other connectors provide 20 output channels each). You may now run the example programs supplied with the CD to test the DAC USB unit functionality.

- *For EDAC40 unit.* Connect the Ethernet DAC units to the computer ethernet ports or to a router/switch in the same local network. Connect the ground sockets of the units together. Power up the units using the power supplies shipped with the mirror (5-9 V DC). You don't need to install any software. Jumpers of the EDAC40 unit are already preset to the correct position (one connector provides 19-channel output and ground, and three other connectors provide 20 output channels each). You may now run the example programs supplied with the CD to test the EDAC40 unit functionality.

- Connect toghether the ground sockets of the HV amplifier units. Connect with the ribbon cables outputs of the HV amplifiers to the connectors of the mirror. *Mind the cables/connectors numbering!* Power off the USB/EDAC units and connect the amplifier units to the DAC units. *Mind the cables/connectors numbering!* Power up the DAC units again. At this stage the system is fully assembled but the adaptive mirror is not used yet. Use the test program (e.g. ‘‘`am_set 0`’’) to set minimum voltage value to all channels.

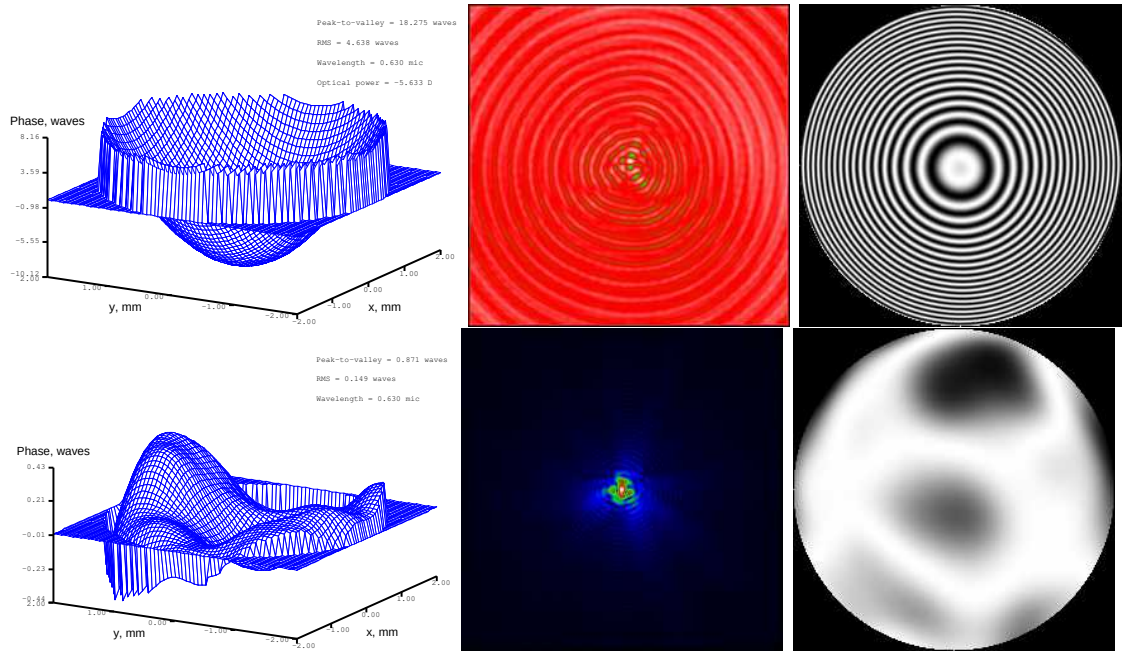

Figure 11: Results of Shack-Hartmann measurement of the mirror, left to right: wavefront reconstruction, calculated far field and interferogram. In the bottom row the defocus term is removed.

- Switch on the amplifier units. The control LEDs should glow evenly, without blinking. Blinking LED indicates failure of a hardware component of the HV amplifier unit. *Never use an HV amplifier unit with blinking LED!* Run the test programs. Control all channels. When you are finished with testing, set again minimum voltage value to all channels and switch off the amplifier.

- *For digital boards.* Insert digital boards into computer slots. Install the software (refer to the PCI board guide) and determine the base address (look at /proc/pci for PROTO 3 boards). Connect the bandcables to the digital boards. Switch the computer on. Run the example programs supplied with the CD to test the board functionality.

- *For OEM version.* Switch the computer off. Connect band cables to the connectors in the mirror holder. Connect the amplifier boards to mirror driver boards. Connect the driver boards to low and high voltage power supplies. At this stage the system is fully assembled but the adaptive mirror is not used yet. Switch on the power supplies in the order: +15V, -15V, +V_high. Do not use V_high higher than 120V for the first test. The current (positive supply to ground) should not exceed 0.125A for one board (zero output of all 20 amplifiers) and 0.25A for two boards (40 amplifiers). The high voltage current should not exceed 0.05A for V_high=150V for two boards. Test the output voltages in the mirror socket. These voltages must be in the range 0...1V. Turn the computer on. While turned on, the boards are initialized to random output voltages. At this stage the voltages in mirror socket may have values between 0V and V_high. Run the test programs. Control all channels. Switch off power supplies and computer (in the order V_high, +15V, -15V, computer).

- You may start to use the mirror if all channels work. Use “am_set” and “rotate” as templates to write your own control programs.

8 Remarks

For OEM version. **Use high-quality stabilized filtered high-voltage supply.** Some high-voltage supplies generate short high-voltage spikes at the output, these deviations can destroy the mirror, driver electronics and even the control computer. Do not turn on V_high directly to its maximum value. Set V_high to 100V before switching the system off. Switch the system on with V_high not higher than 120V. Increase V_high to its working value after switching on the digital boards and setting the control voltages to zero.

The jumpers on the amplifier board or in the amplifier unit, in the DAC control units are preset before shipping; this configuration should not be changed. **The system and jumper configuration were tested before shipping.**

The mirror surface can be cleaned using any standard procedure for cleaning dielectric mirrors.

9 Warranty

The equipment is covered by a one-year factory-defect warranty.

If the mirror is damaged during shipping, it will be replaced by a similar device within two months. A photo of the damaged device should be sent to Flexible Optical B.V. (OKO Technologies) within 3 days after the damaged device is received.

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10 Contact person

All questions about the technology, quality and applications of adaptive mirror should be addressed to:
Flexible Optical B.V.
Polakweg 10-11,
2288 GG Rijswijk
The Netherlands

Date: Signature: