

Flexible Optical B.V.

Adaptive Optics • Optical Microsystems • Wavefront Sensors

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# 17-channel micromachined deformable mirror with built-in tip-tilt stage: technical passport

OKO Technologies,

OKO Technologies is the trade name of Flexible Optical BV

# 1 Membrane mirrors

Silicon micromachined mirrors are fabricated using the technology of silicon bulk micromachining.

The mirror, shown in Fig. 1, consists of a silicon chip mounted over a PCB holder. The chip contains silicon nitride (composite) membrane, which is coated to form a mirror. The PCB contains the control electrode structure, spacer, connector, and a tip-tilt stage. The shape of the reflective membrane is controlled by voltages applied to the control electrodes with the membrane grounded. The tip-tilt stage is controlled by the voltages applied to two piezoelectrical 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.**

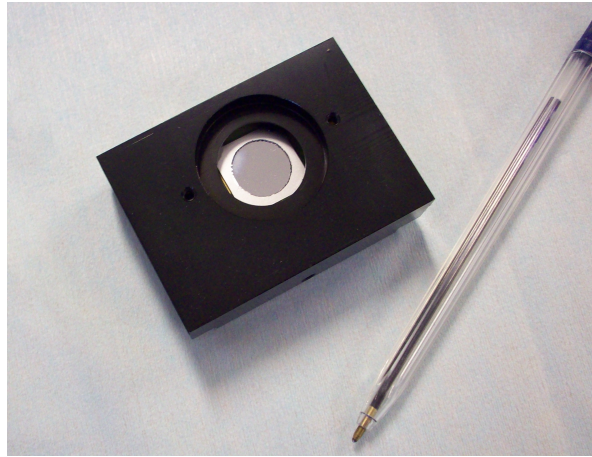


Figure 1: Typical view of a 17-channel micromachined deformable mirror with the built-in tip-tilt stage. Please note that these mirrors can be fabricated with different package designs, so the mirror you have may look differently.

The scheme of the assembled mirror and the principle of control are illustrated in Fig. 2.

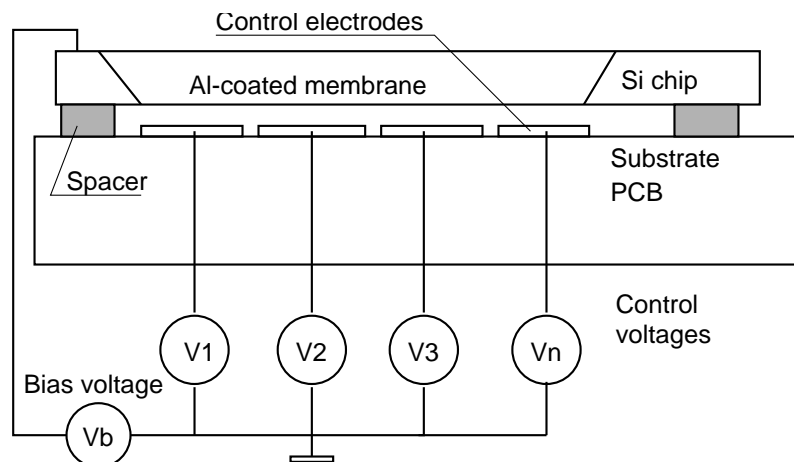


Figure 2: Schematic section of the micromachined adaptive mirror.

## 2 Technical data

Table 1: Technical parameters of the mirror.

Parameter	Value
Aperture shape	approximately circular
Mirror coating	Al or Au
Aperture dimensions	15mm diameter
Number of electrodes	17 (see Fig. 3)
Control voltages $V_c$	0 ... 235 V
Initial RMS deviation from plane	less than 0.2 $\mu\text{m}$
Main initial aberration	1.5 fringes at 630nm
Maximum deflection of the mirror center	9.4 $\mu\text{m}$

See Table 1 for technical parameters of the mirror before shipping.

Small surface defects are possible. They do not influence the quality of the mirror.

## 3 Actuator structure

The membrane is mounted over the printed actuator structure shown in Fig. 3. The actuator are arranged into three circles with radii 1.81902, 4.06745, and 7.5 mm.

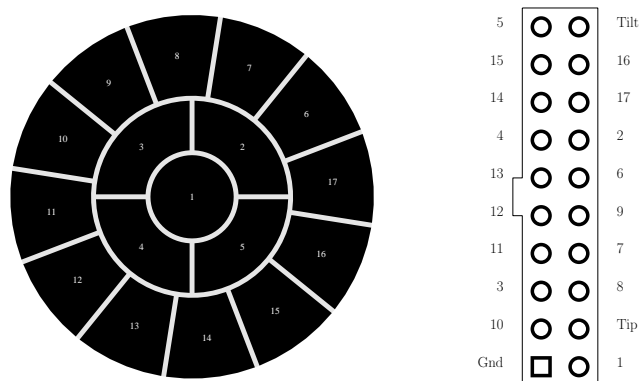


Figure 3: The PCB actuator structure and the pinout (actuator numbers) of its connector, shown from the top (mirror surface) view. The cables should be connected from the back side with red-colored wire oriented to the “Ground” pin.

19 amplifiers of the driver board connected to the first connector are used to drive the mirror actuators. The membrane is grounded (check the bottom of the HV unit for configuration or the HV board jumper description). The membrane can be connected to the amplifier number 20 (bias) by setting both jumpers on the amplifier board to the lower position - **this is not recommended**.

## 4 Control amplifier unit

The mirror is controlled by a high-voltage amplifier unit. To use the unit, you must connect it to the mirror, to a DAC USB unit (or PCI boards) and to the wall outlet (85 to 250V AC,

50 to 60 Hz). Connect the mirror with a supplied flat ribbon cable to the 20-pin connectors on the front side, and the driver boards or the USB unit to the 26-pin connectors.



Figure 4: 40 channel high-voltage amplifier unit.



Figure 5: Front and back panels of 40 channel high-voltage amplifier unit.

In case of OEM version of the system, the mirror is controlled by one high-voltage amplifier board. The 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 ( $\leq 240$  V) power supply and to a stabilized  $\pm 15$ V DC supply. Connect the ground, +15V and -15V to the pins marked G, + and -. Connect positive high-voltage stabilized DC supply to the pin marked V\_high, connect negative high voltage terminal to the ground (see Fig. 6). **The high voltage supply should not exceed 240 V DC.** Use the flat ribbon cable supplied to connect the driver board to the mirror socket.

## 5 Digital boards

The output voltage of the channel N [ $N=0\dots 23$ ] of the 8-bit 24-channel DAC board is controlled by sending control byte V [ $0\dots 255$ ] 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. 7. 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.

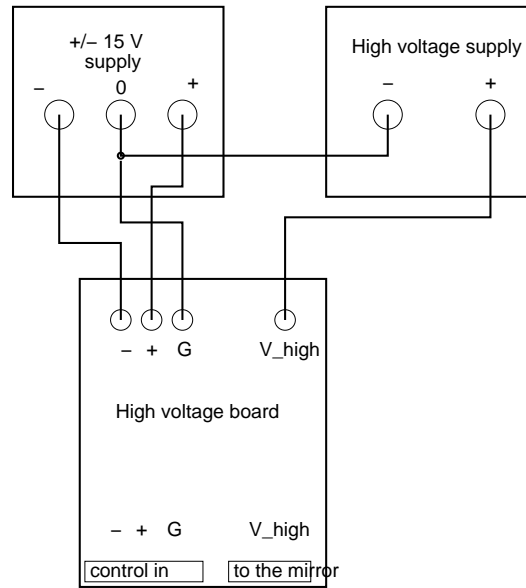


Figure 6: Power supply wiring for OEM version of the system. Position of the connectors can be different; refer to the board manual and/or marking on the board.

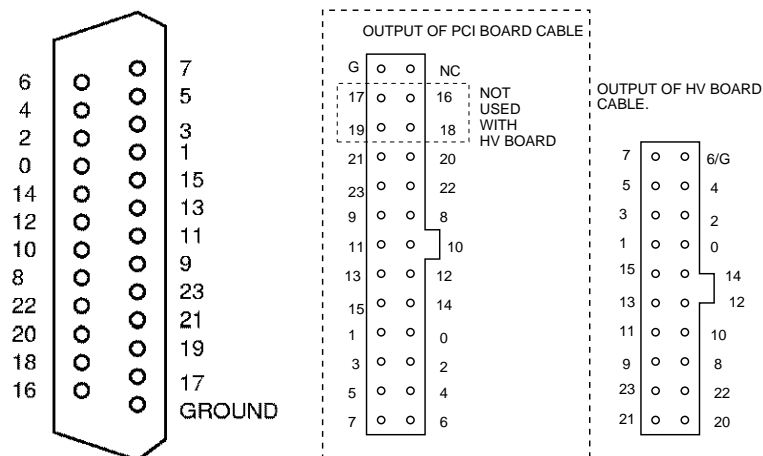


Figure 7: Pinouts of the digital board and cables. The numbers correspond to the addresses of the pin with respect to the base address of the board.

## 6 DAC Unit

A single “DAC-40-USB” 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. 8. 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.

## 7 Optical quality

The interferograms of the mirror obtained before shipping are shown in Fig. 9.

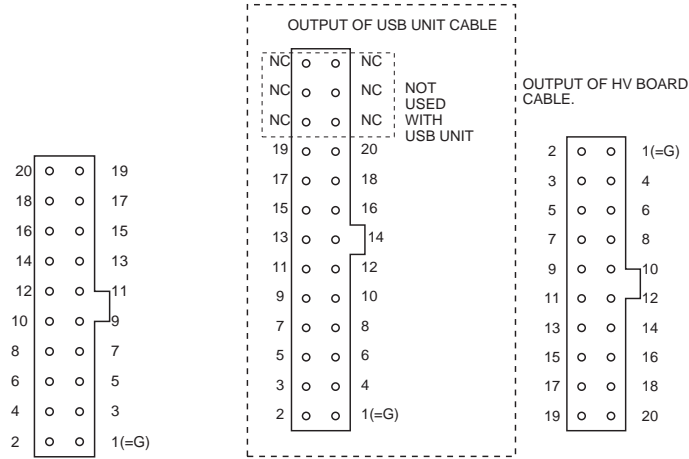


Figure 8: Pinouts of the first connector of the “DAC-40-USB” unit and cables. The numbers correspond to the numeration of “DAC-40-USB” output channels. Second connector is connected in a similar way.

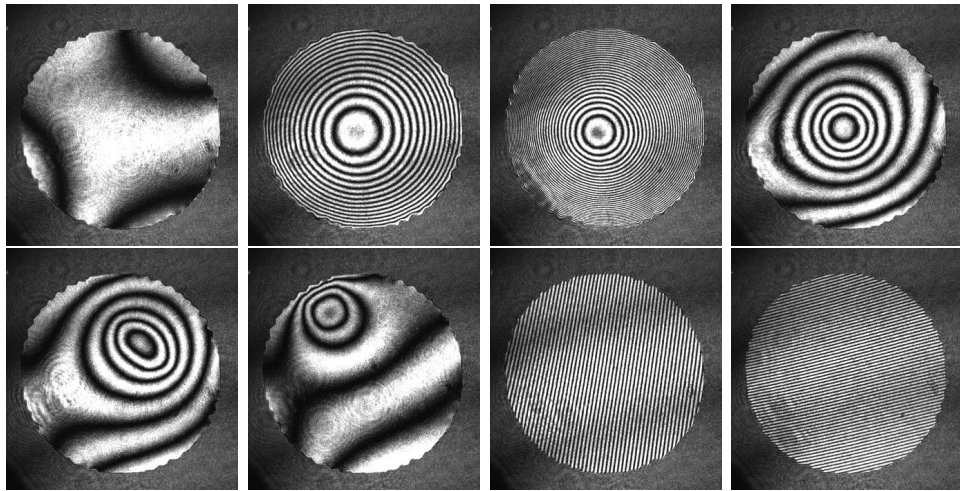


Figure 9: Test of the mirror: zero voltage applied, control byte 180 applied to all actuators, control byte 255 applied to all actuators, control byte 255 applied to central, middle and edge actuators, control byte 255 applied to tip and tilt actuators (left to right, top to bottom)

## 8 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:
  - either *DAC-40-USB 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 unit to the computer USB port. Install the software (refer to the DAC USB unit guide). Jumpers of the USB unit are already preset to the correct position (every connector provides 19-channel output and ground). Run the example programs supplied with the CD to test the DAC USB unit functionality.



- Switch the computer off. Connect band cables to the connector(s) in the mirror holder. Connect the amplifier unit to the DAC USB unit. At this stage the system is fully assembled but the adaptive mirror is not used yet. Switch on the amplifier unit. Test the output voltages in the mirror socket. These voltages must be in the range 0...2V. Turn the computer on. At this stage the voltages in mirror socket may have values between 0V and 235 V. Run the test programs. Control all channels. Switch off the amplifier unit and computer.
- *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 235 /2 V 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).
- For mirrors shipped separately from the PCB holder, position the marked corner of the mirror to the mark on the mirror holder and insert (gently) the mirror into the socket. Place the mirror into interferometer or a setup with a wavefront sensor. Fix the cables to the optical table. You may also test the mirror by reflecting a good collimated beam from the mirror surface and observing the near field intensity distribution. **Clamp the mirror holder, do not clamp the mirror**, clamping the mirror will cause extra deformation of the socket and the the mirror package. At this stage you do not have to feed any supply voltages to the control boards but the power supplies must be grounded appropriately.
- Control the initial mirror figure (astigmatic up to 1 fringes P-V).
- Switch on all supply voltages (*For OEM version* in the order +15V, -15V, V\_high. Do not use V\_high higher than 100V at this stage.)
- Switch on the computer. After the system is loaded, the mirror figure represents strongly distorted concave surface. Use test programs to control the mirror figure.
- You may start to use the mirror if all channels work. Use “am\_set” and “rotate” as templates to write your own control programs.

## 9 Remarks

The maximum voltage for the mirror is 235 V.

The amplifier unit is already tuned to the output voltage 235 V, **do not use an amplifier unit shipped with another mirror!**

*For OEM version.* Supply voltage for the amplifier boards should not exceed 240 V.

**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<sub>high</sub> directly to its maximum value. Set V<sub>high</sub> to 100V before switching the system off. Switch the system on with V<sub>high</sub> not higher than 120V. Increase V<sub>high</sub> to its working value after switching on the digital boards and setting the control voltages to zero.

The jumpers on the amplifier board are configured to ground the membrane.

**Do not touch or clean the membrane. Never think about touching or cleaning the membrane.**

## 10 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.

EXCEPT WHEN OTHERWISE STATED IN WRITING FLEXIBLE OPTICAL B.V. (OKO TECHNOLOGIES) AND/OR OTHER PARTIES PROVIDE THE SYSTEM "AS IS" WITHOUT WARRANTY OF ANY MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. THE ENTIRE RISK AS TO THE QUALITY AND PERFORMANCE OF THE EQUIPMENT IS WITH YOU.

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## 11 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 ZH,  
the Netherlands

Date:

Signature: