PRELIMINARY

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Dual axis mirror with position feedback
MR-15-30

Optotune's dual axis mirror series MR-15-30 is the ideal choice for applications that require large deflections in a compact form factor. With a mirror size of 15mm the MR-15-30 achieves up to ±25° mechanical tilt, which results in up to ±50° optical deflection. The mirror includes a position feedback system which allows it to be accurately controlled with a standard PID controller.

The actuator is based on proven technologies. In contrast to galvo mirror systems, the virtual rotation point is very close to the mirror surface. The mirror can be fabricated with various coatings such as gold or protected silver.

Advantages

- Large scan angle
- Compact
- Precise

Applications

- Automotive (LiDAR, dynamic headlights, ADAS)
- Vision (field-of-view (FOV) expansion, zoom)
- Biometric (eye-tracking) & diagnostic equipment
- 3D printing

The following table outlines the specifications of our standard tunable 2D-mirror MR-15-30. Custom mirror substrates and coatings are possible.

Specifications

Mechanical specifications[1]

Actuator Type	4-Quadrant (2 axis, bi-directional)		
Mechanical tilt angle DC	±25 X axis; ±25 Y axis (circular FOV)	°	
Mechanical tilt angle dynamic	±25 X axis; ±25 Y axis (circular FOV)	°	
Mirror diameter	15	mm	
Center of rotation to mirror surface	1.3	mm	
Housing diameter	30.0	mm	
Mechanical clamping	4x M2 screws		
Height	14.5	mm	
Weight	29.3	g	
Magnetic shielding	yes		
Scale drift	T.B.D	ppm/°C	Max
Zero drift (typical)	25	µrad/°C	Max
Sensor resolution	22	µrad	with 14bit ADC
Repeatability	40	µrad	RMS value over entire FOV
Calibration accuracy	0.25	°	RMS value over entire FOV, factory calibration may degrade to 0.5° (typ. 0.3°) long-term, MR-E-2 interpolates from 50 points
Static displacement constant	3	rad/A	Linearized full range
Angular acceleration constant	1.4 * 10^4	rad/(A s^2)	Linearized full range
Control specs:			
Full scale bandwidth Sine wave (±25°)	20	Hz	
Small signal bandwidth (< ±0.1°)	350	Hz	

[1] All angle values are with respect to mechanical angle.

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Large angle step settling time (20° step)	12	ms	Measured with MR-E-2 driver board with 700mA peak current
Small angle step settling time (0.1° step)	2	ms	Measured with MR-E-2 driver board with 700mA peak current

Optical specifications

Surface finish	Gold and protected silver, other coatings available as custom		
Reflectivity	Gold (45° AOI): - Avg >95% (800 nm < λ < 6 um) Protected Silver (45° AOI): - Avg >96% (450 nm < λ < 2 um)		
Surface quality	60-40	Scratch-Dig	
Mirror flatness	λ/2	@549nm (ISO Norm 10110)	

Electrical specifications

Control interface	Analog interface for driver coils and for feedback readout		
Max continuous current (RMS)	0.3	A	Per coil. See thermal management
Peak current	2	A	For 10 ms duration
Max mean actuation power	1.5	W	Both coils together
Coil resistance	11	Ohm	Typical
Coil inductivity	6	mH	Typical
Position sensor supply current (@1.5V)	30	mA	
Position sensor output current	0.1	mA	4 channels, typical
Temperature sensor	LM75B		I2C-Address: 0x48 (+R/W bit)
EEPROM	M24C08		I2C-Addresses: 0x50 to 0x53 (+R/W bit)

Environmental specifications

Operating temperature	-20 to +85	°C	for higher temp. ranges contact Optotune
Storage temperature	-40 to +85	°C	for higher temp. ranges contact Optotune
Rel. humidity	85	%	See [2]
Shock	200	g	
Cycle life	>10^9	cycles	ongoing

Overview of configurations

Configuration	Coating
MR-15-30-G-25x25D	gold
MR-15-30-PS-25x25D	Protected silver

[2] Despite the protective coating layer, it is best to avoid exposing silver mirrors to high humidity environments due to the associated tarnishing risk.

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Static response

Current vs angle

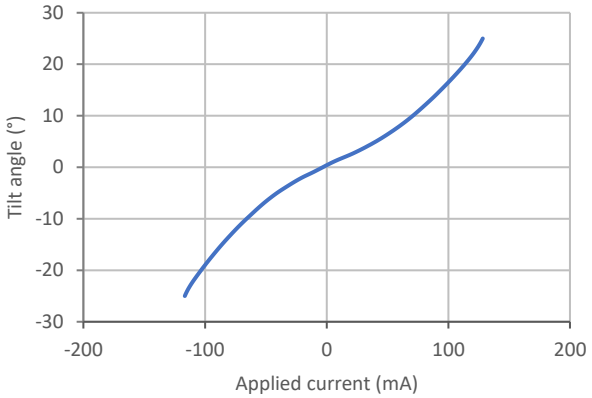

Figure 1: Mechanical tilt angle versus applied current for single axis.

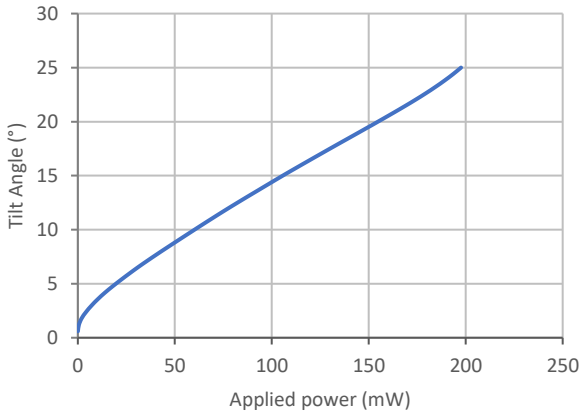

Figure 2: Tilt angle (mechanical) versus applied power (~8.58 mW/°)

Dynamic response

Magnitude response

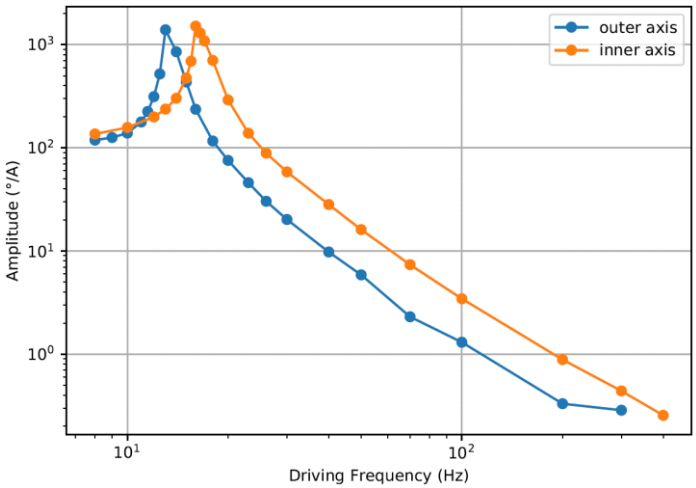

Figure 3: Magnitude response of outer axis (x) and inner axis (y) with sinusoidal excitation (15 mA amplitude).

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Small step response

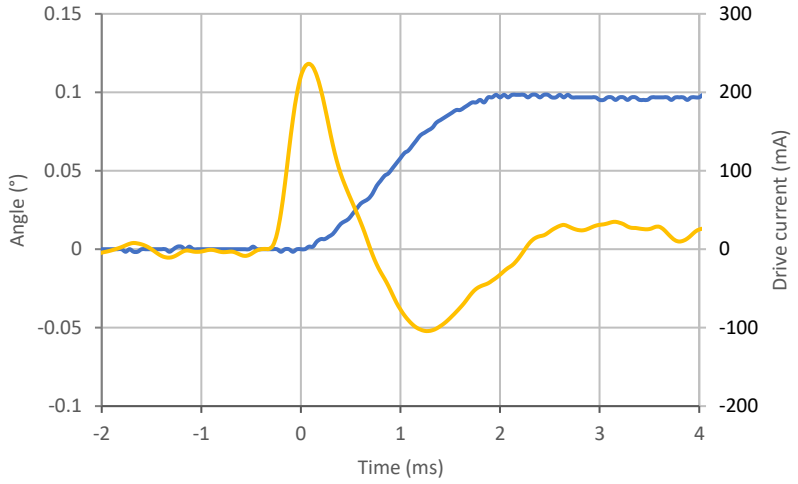

Figure 4: Small step settling time (blue curve) of outer axis (0.1° step) is 2.3 ms. Mirror operated with closed loop PID controller. The yellow curve shows the corresponding current driving signal.

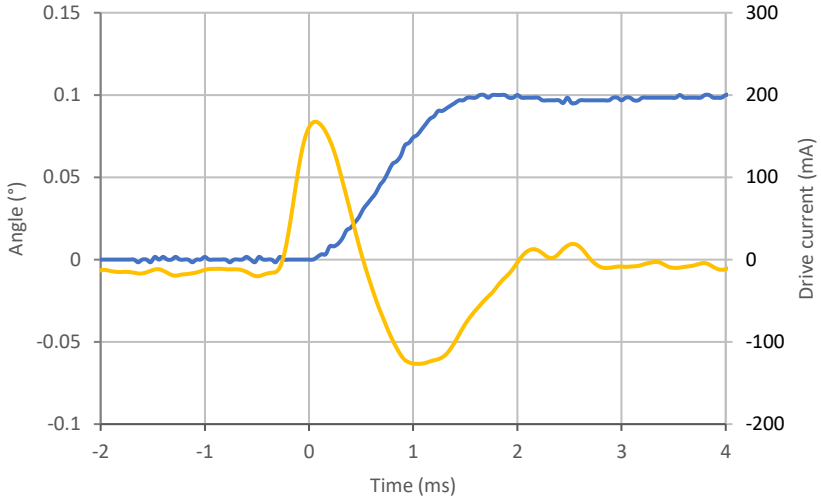

Figure 5: Small step settling time (blue curve) of inner axis (0.1° step) is 2ms. Mirror operated with closed loop PID controller. The yellow curve shows the corresponding current driving signal.

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Large step response

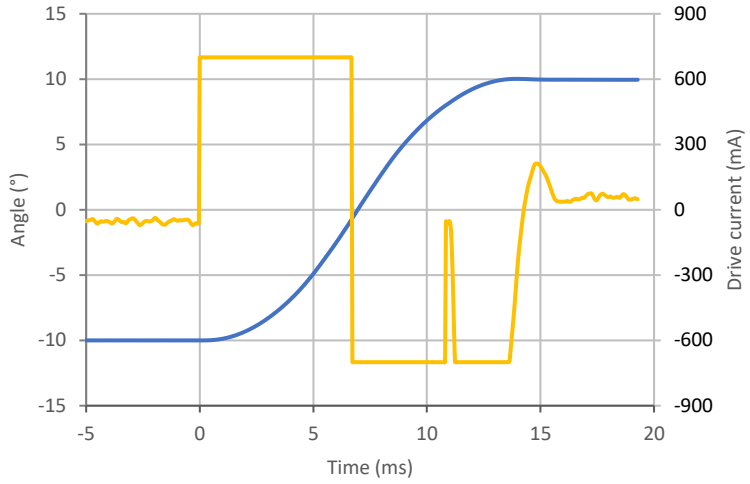

Figure 6: Large step settling time (blue curve) of outer axis (20° step) is 13 ms. Mirror operated with a combination of pinning algorithm and closed loop PID controller. The yellow curve shows the corresponding current driving signal.

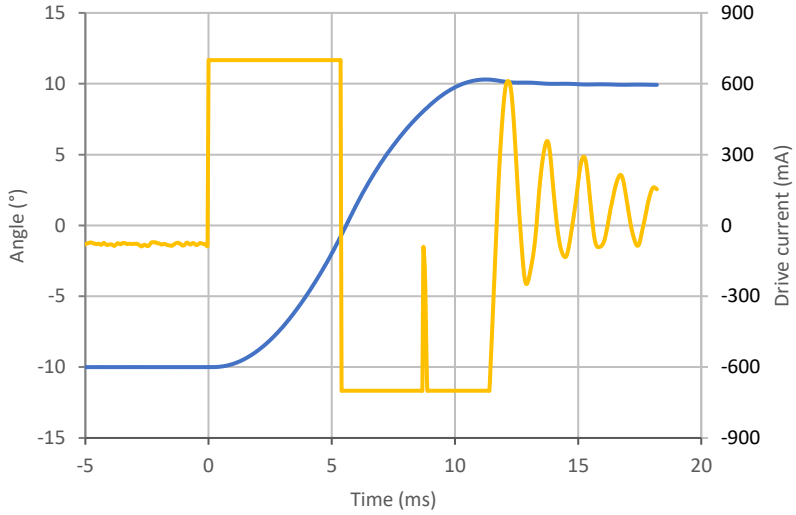

Figure 7: Large step settling time (blue curve) of inner axis (20° step) is 12 ms. Mirror operated with a combination of pinning algorithm and closed loop PID controller. The yellow curve shows the corresponding current driving signal

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Maximum oscillation frequency

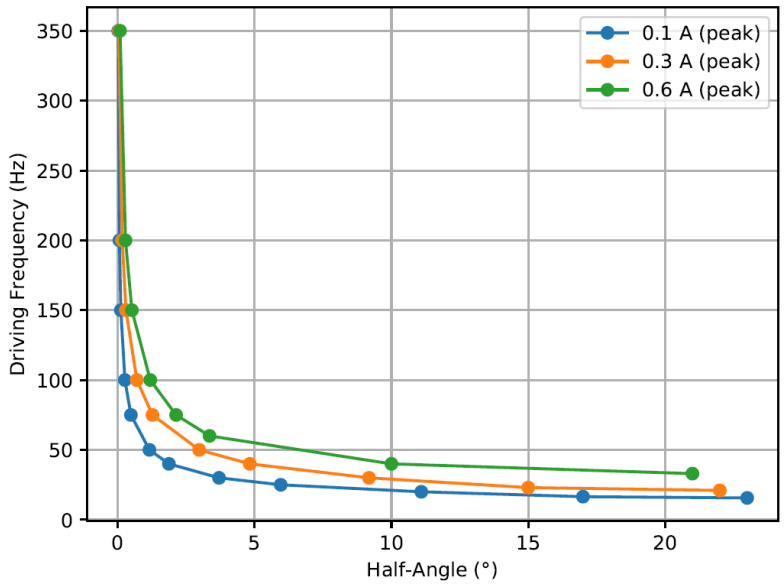

Figure 8: Max. oscillation speed (sinus) of outer axis as a function of mechanical half-angle and driving current. The total optical FOV is 4 times the mechanical half-angle.

Reflectivity

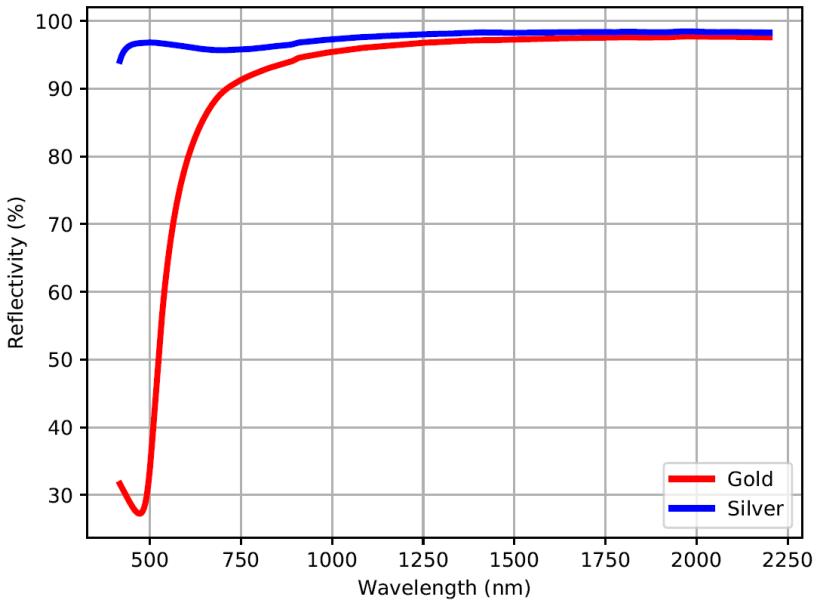

Figure 9: Reflectivity for different wavelengths at 0° angle of incidence (AOI).

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Mounting

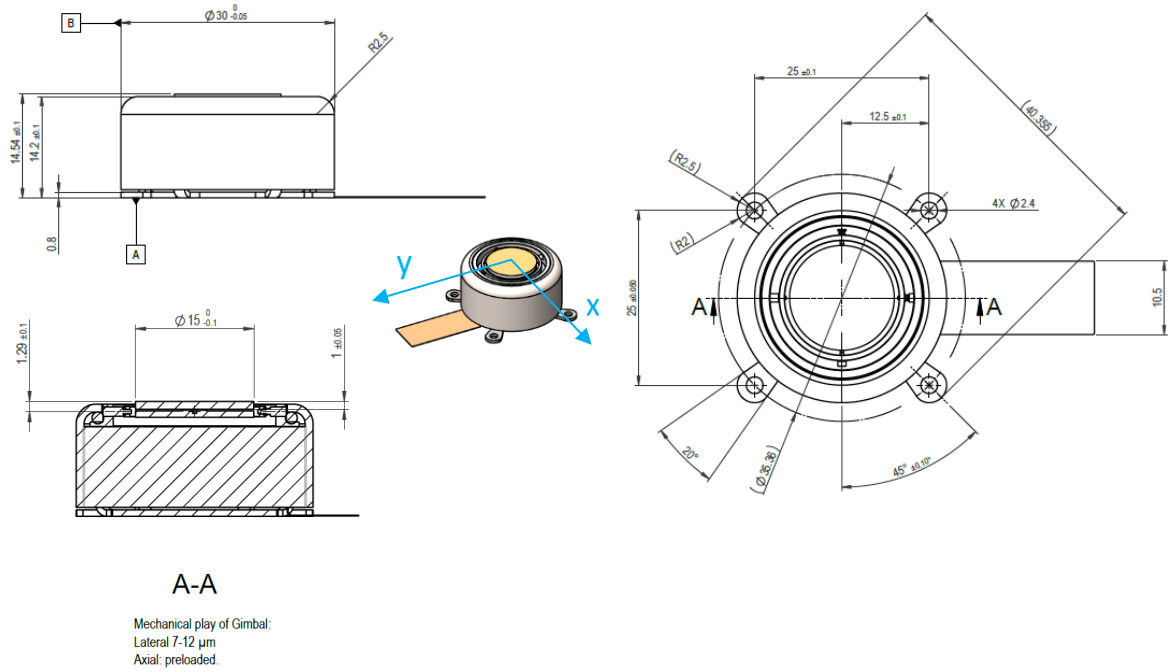

Figure 10: Mechanical drawing of MR-15-30 (unit: mm)

When screwed in place, make sure the mirror is in firm contact with the heat sink. It is recommended that the heatsink dissipates about 2-5 W.

In terms of lateral alignment, it is recommended to use the outer diameter of the housing as an alignment feature.

Electrical connection

Pin	Function	Value	Pin	Function	Value
1	Position feedback supply Cathode	40 mA 1.5 V	11	VDD	3.3V
2	Position feedback supply Anode		12	SCL	Digital 3.3 V
3	Y Coil +	± 1 A ± 15 V	13	SDA	Digital 3.3 V
4			14	GND	
5	Y Coil -		15	Position feedback Anode	currents (µA range)
6			16	Position feedback Y2 Cathode	
7	X Coil +		17	Position feedback Y1 Cathode	
8			18	Position feedback X2 Cathode	
9	X Coil -		19	Position feedback X1 Cathode	
10			20	Position feedback Anode	

Table 1: Electrical pinout MR-15-30

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Beam clipping

Clipping of beam depends on beam diameter and tilt angle. For a beam incident at 0° beam sizes up to 10 mm can be used without clipping.

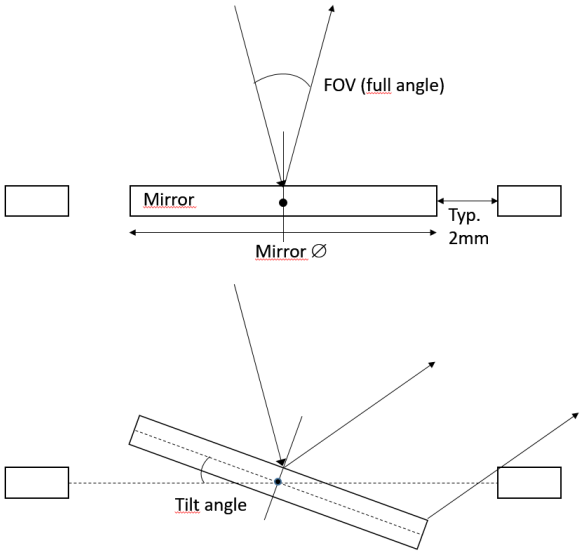

Figure 11: The maximum allowed beam diameter depends on input angle and mirror tilt angle.

Optotune can supply by request an EXCEL based calculation tool to evaluate beam clipping.

Environmental testing

The MR-15-30 is going through environmental and accelerated aging tests as outline in the table below.

Test	MR-15-30
Mechanical cycling: 1 billion cycles reached (status Dec 31, 2019) with no signs of fatigue. 10 Hz on 1. axis, 9 Hz on 2. axis, room temperature.	On-going
Temperature cycling – non-operational 85°C/60h, -40°/60h; 2 cycles, non-operational No significant change in repeatability	Passed
Temperature cycling –operational -20°C ... 90°C operational (steady state jumps over entire FOV every 5 sec, 20 cycles 60 hours)	Passed
Temperature drift & heating effects Temperature drift: approx. 20 urad/K No significant self-heating at low frequency	Passed
Temperature & Humidity 85°C / 85% (duration: 1 week, gold coating)	Passed

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Shock test According to DIN EN 60068-2-27. Mirror is not affected by shocks up to 200 g	Passed
Vibration test According to DIN EN 60068-2-64. Preliminary data available on request.	On-going

Table 2: Environmental tests performed on the MR-15-30

Custom Products:

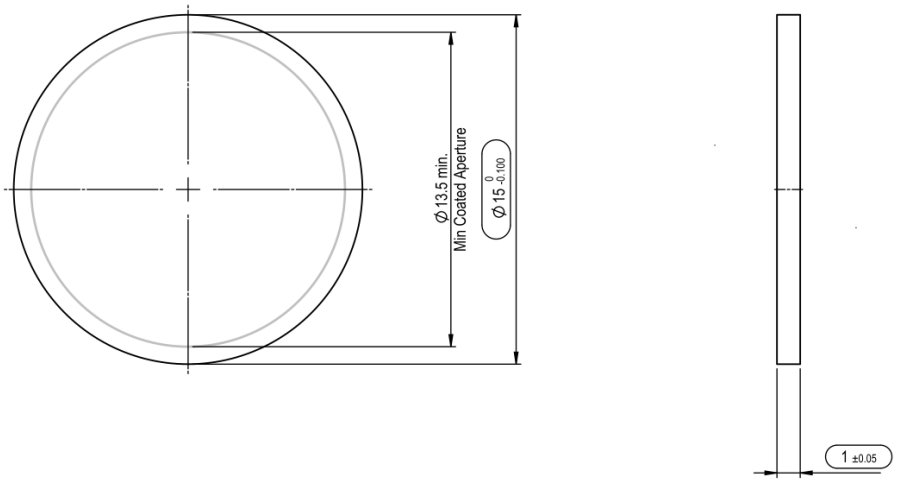

Figure 12: Dimensions of standard mirror substrate

Optotune offers customizations of mirror substrates and coatings upon request. Substrates with a thickness of more than the standard 1 mm need to have a smaller diameter to maintain the full FOV. For a diameter of 12.7 mm the thickness can be as large as 3.5 mm. A change in inertia will influence mirror dynamics.

For more information on optical, mechanical and electrical parameters, please contact sales@optotune.com.

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