MEMS Grating Modulator

Component for intensity modulation

User Manual (v1.1)

This document describes the following products:

- **MEMS Grating Modulator Component**
  Reflective diffraction grating for efficient high-speed modulation

BMC Document Number: DOC-0005 Rev 1.1

Table of Contents

1. Manufacturer Declarations

About this document

This manual is designed to help the reader operate the MEMS Grating Modulator. It assumes that the reader has a fundamental understanding of electronic components, electronic instruments, optics, and applicable safety procedures.

The manual describes the physical specifications of the MEMS Grating Modulator as well as the installation procedures that are required to use the system.
This document is available as a PDF file. Updated releases may be available by contacting moreinfo@bostonmicromachines.com.

Certification

Boston Micromachines Corporation certifies that the MEMS Grating Modulator is fully functional at time of shipment.

Warranty

Any software or hardware failures due to manufacturing or inherent defects will be repaired or replaced (at Boston Micromachines Corporation's discretion) for a period of one year after delivery.

Limitations of Warranty

Warranty does not include any damage incurred from mishandling or misuse of the modulator or driver including failure due to Electrictrostatic Discharge (ESD), excessive optical intensity, or by not following the instructions included in this document.

WARNINGS

Shock Hazard
Voltages up to 200 V can be present on the MEMS Grating Modulator, packaging, electrodes, cable, and electronics driver.

MEMS Grating Modulator Damage
The MEMS Grating Modulator is highly sensitive to electrostatic discharge. Always handle the Modulator in an electrostatically sensitive environment while wearing a Grounding Wrist Strap (shipped with system).

Symbols

The following symbols designate risk to the system operator and risk to the MEMS Grating Modulator.

Operator Safety Alert

System Damage Alert

2. Introduction

2.1. Features

- MEMS Grating Modulator capable of high-speed optical modulation with large aperture beam

2.2. General Specifications

MEMS Grating Modulator (MGM) Specifications

- Frequency range: 0Hz to 200kHz
  - o Device will function beyond this speed at reduced extinction. See Section 4 for more details.
- Dimensions: 2.5"L x 1.2"Dia.
- Reflective coating: Gold
- Protective window with anti-reflective coating mounted at 10 degrees

2.3. Model Specifications

	MGM-1100
Rise/Fall Time: 90%-10% (µs)	<2.5
Rise/Fall Time: 97%-3% (µs)	<4
Peak Extinction Ratio (at 635 nm)*†	200:1
Optimal Wavelength Range (nm)*†	650-1100
Angle-of-Incidence for Peak Extinction (°)	<10 (lateral incident angle)
Max. Extinction Frequency Limit, -3dB (kHz)[β]	100
Active Aperture (mm)	6.0
Total Reflected Wavefront Error (P-V)	λ/4
Maximum Operating Voltage (V)	~200 (device dependent)
Maximum Recommended Supply Voltage Slew Rate (V/µs)	200
Maximum Extinction Voltage	Angle dependent above 10°
Protective window angle†	10°
Protective window size (inch)†	1
Protective window thickness (mm)†	5

* Devices measured using 635nm light and 650-1050nm anti-reflective protective window

[β] Maximum Extinction Frequency Limit is the frequency of the device above which the maximum extinction of the beam as noted on the data sheet is no longer attained.

† Custom Options available

3. System Components Overview

3.1. MEMS Grating Modulator

An image of the modulator can be seen in *Figure 1*. The circular gold coated region contains the active modulator aperture, which consists of an array of electrostatic actuators. A gold wire trace is located in the corner of the die for supplying biased control. A 10 degree angled optic mount houses a window with anti-reflective coating to protect the modulator device. To connect voltage to the MEMS Grating Modulator, connect a cable to the receptacle on the rear of the housing. We recommend installing a switch between the voltage source and the modulator, if possible. This should disconnect the modulator from the voltage source whenever a step-change in conditions is necessary. Be sure not to introduce any voltage spikes which are common from high-voltage amplifiers when turning them on. See section 3.3 for more information.

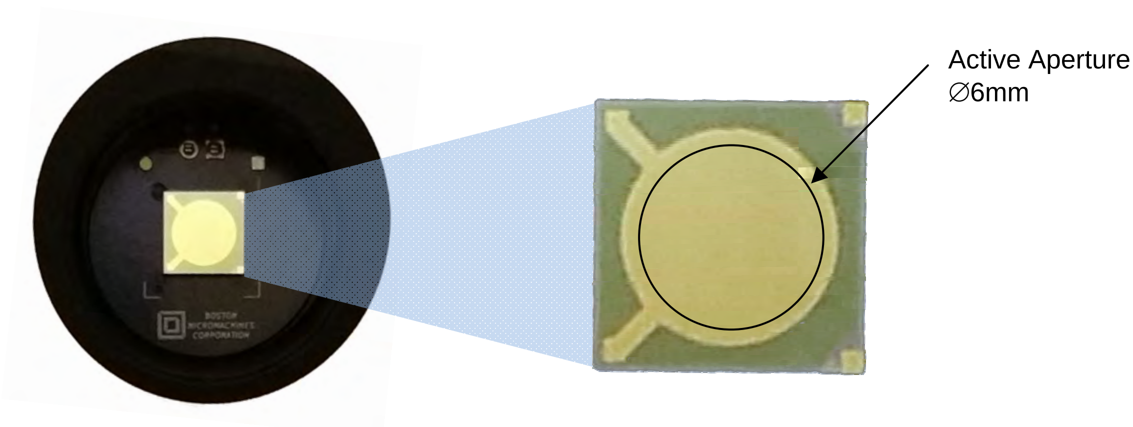


Figure 1: MEMS Grating Modulator (left) and Modulator Die Layout (right).

3.2. MEMS Grating Modulator Interface and Accessories

3.2.1. SMB Connector

The electrical interface for the MGM is an SMB male connector on the rear of the modulator housing, as shown in Figure 2.

Figure 2: Rear of MEMS Grating Modulator showing compatible cable attached to the male-pin SMB connector.

3.2.2. ESD Wrist Strap

ESD Wrist strap should be worn and plugged in at all times while handling the Modulator.

4. Getting Started

4.1. Mounting and Connecting the Modulator

4.1.1. Modulator Handling Guidelines

- **Always handle the modulator in a statically sensitive manner by wearing a grounded ESD wrist strap.**
- Know your modulator’s maximum applied voltage.
- A window with anti-reflective (AR) coating is mounted over the modulator; this is to prevent inadvertent contact with the modulator surface and minimize dust accumulation. **Do Not Touch the Window**. AR coatings can be destroyed by using improper cleaning techniques.
- Store the modulator in a cool, dry place.
- Connect the modulator to a driver.

4.2. MEMS Grating Modulator Mount Setup

4.2.1. Standard Mount

The MEMS Grating Modulator can be inserted into a slip ring (Thorlabs C1RC) which is easily mounted to a standard optical post. See *Figure 3* for a picture.

4.2.2. Gimbal Mount

The MEMS Grating Modulator can also be housed in a tube component expansion adapter (Thorlabs SM2A21). The adapter is easily inserted into the Ø2" Precision Kinematic Mirror Mount (Thorlabs KM200). See *Figure 3* for the complete assembly.

Figure 3: MEMS Grating Modulator in Slip Ring (left) and Gimbal Mount (right)

4.3. Voltage/Signal Sources

4.3.1. Third Party Voltage Sources

The MEMS Grating Modulator requires operation using any high-voltage power source that is free from noise that exceeds the maximum rated voltage. It is imperative that modulator control voltages do not exceed the maximum value listed in the system data sheet. Users should first verify that their control voltages are well conditioned and produces no voltage spikes, such as that illustrated in *Figure 4*. In this example, a voltage spike is created by changing the frequency of a pre-amplified waveform generated sine wave.

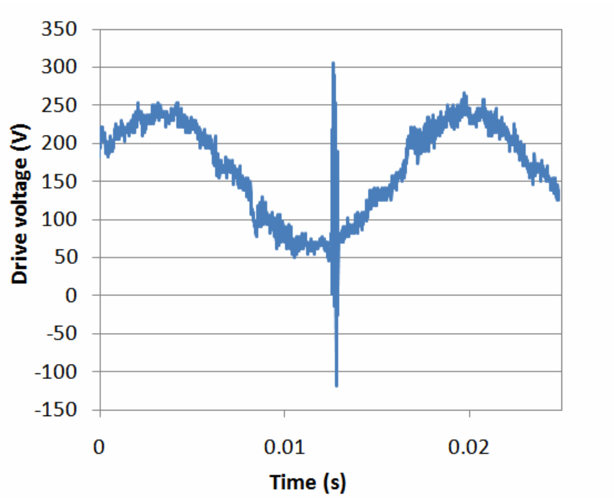


Figure 4 : Example of voltage spike capable of irreversibly damaging the modulator.

In general, BMC recommends all modulator drive signals first be examined on an oscilloscope prior to being applied to the device. Measured voltage spikes exceeding the maximum device voltage and greater than 40ns in time can lead to modulator damage. This time resolution is within the bounds of a typical 100MHz bandwidth oscilloscope.

Please contact Boston Micromachines if there is any question regarding the voltage source to be used with your system. We have had experience with a few sources and may be able to offer guidance as to what has been proven to work both in-house and with customers.

4.3.2. Slew Rate of Voltage Source vs. Slew Rate of Modulator

The modulator behaves electrically as a capacitor. As such, the driver should be verified for stability with the total equivalent capacitive load. In addition, the driver should have the bandwidth and slew rate to drive the modulator across all frequencies of interest. For reference, the modulator should be assumed to have capacitance of 270pF when selecting a driver. For slew rate, users should be aware of the slew rate of the drive electronics in that a signal that transmits voltage too quickly to the modulator could potentially cause harm to the modulator. We recommend drivers with slew rate of less than 200V/µs. Any system with a higher slew rate should have this rate reduced to prevent damage to the modulator.

4.4. MEMS Grating Modulator Device Properties and General Operation Recommendations

4.4.1. Optical Element Performance

The modulator is a reflective, very low modulation diffraction grating with controllable groove depth. It is capable of continuous far field intensity variation of a reflected laser beam by switching between an unpowered flat mirror-state to a powered diffractive state. The diffraction efficiency of the specularly reflected beam is a function of the modulator groove depth, which is controlled through electrostatic actuation of the mirror surface. The modulator is capable of achieving high extinction with 600-1100nm illumination at 10 degree angle-of-incidence (AOI) or less. As AOI is reduced, the extinction improves. As the wavelength of light is reduced, the extinction improves as well.
When powered, the modulator achieves >99% extinction with response times described in *Section 1.3 Model Specifications*. At higher speeds above the maximum extinction frequency limit, the extinction of the modulator degrades.

4.4.2. Operation Recommendations

Given the properties of the MEMS Grating Modulator, it is recommended that the following guidelines be followed:

4.4.2.1. Minimum Beam Size

In order for the modulator to function properly as a diffractive element, a minimum number of grooves needs to be utilized to produce the diffractive effect. With this in mind, the recommended minimum beam size is 1mm.

4.4.2.2. Diffracted Beam Elimination

- **Optical Aperture**
  Since the MEMS Grating Modulator diffracts incident light, the resulting pattern spreads out continuously. To prevent the diffracted orders from entering the beam path further on in the optical setup, it is recommended that an optical aperture (not included) be used. See *Figure 5* for an example of this. In this case, the modulator is operating at high speed (100kHz) and the resultant spot pattern is shown. The central beam is allowed to continue through the optical aperture and the diffracted light is blocked.

Figure 5: Resultant pattern of 2mm beam on iris after reflecting off the MEMS Grating Modulator

- **Optical Element Offset**
  Even with the use of an optical aperture, if the size of the beam is large enough, it may require that the optical aperture be placed a certain distance from the Modulator. For larger beam sizes, it is recommended that subsequent optical elements be placed far enough away from the Modulator to prevent overlapping of the non-diffracted and diffracted beams. For the setup example in *Figure 5*, an offset distance of approximately 24 inches was used.

4.4.2.3. Angle of Incidence

To improve exinction, it is recommended that the angle of incidence be below 30 degrees, however the housing of the device may interfere with this high of an angle (the housing can be customized upon request). For maximum extinction and reduced beam distortion, it is recommended that the angle be below 20 degrees. *Figure 6* shows the extinction for various angles of incidence on a typical modulator device. As seen below, the extinction decreases slightly as the angle increases. If higher angles of incidence are required, it is recommended that the user re-optimize the optimum voltage for the higher angle. This will most likely lead to a higher voltage setting. See Section 3.5 for more information on varying the voltage to optimize extinction.

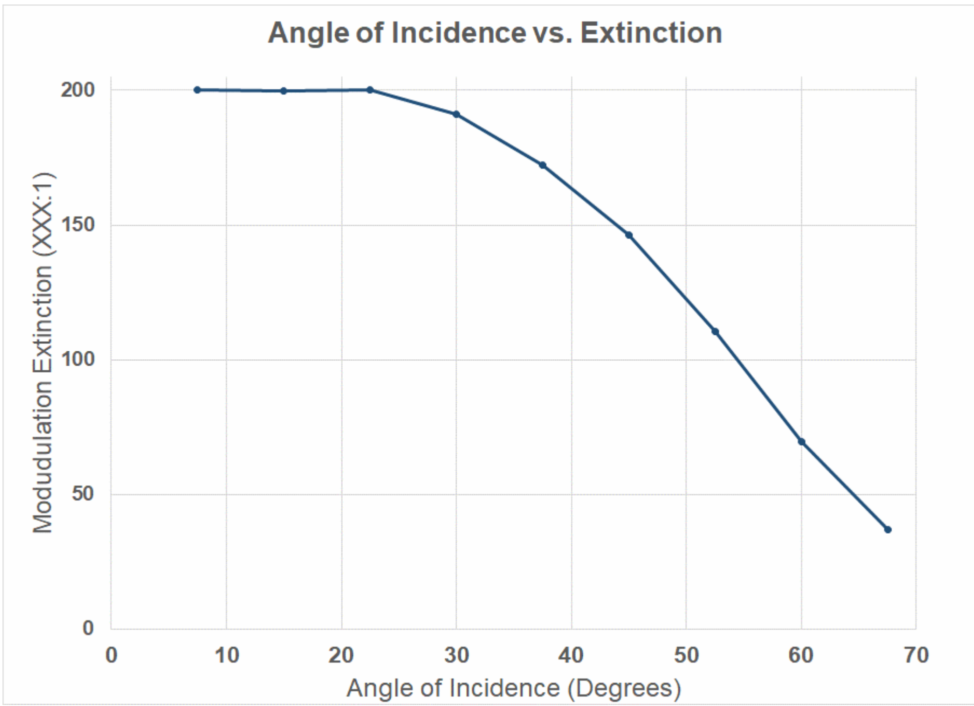


Figure 6: Modulator extinction as a function of incident beam angle. Extinction decreases beyond an angle of ~20 degrees.

4.4.2.4. Alternate Use: First Order Diffraction

The standard operation mode of the modulator is to utilize the non-diffracted beam as the light of interest. In this case the 0^{th} order light is considered. This operation ensures the highest level of throughput.

If beam intensity can be sacrificed and maximum extinction is desired, it is possible to use the first order diffraction as the light of interest, with the chopping action effectively inverted. In order to operate in this manner, subsequent optical elements may be placed so that the 1^{st} order diffraction to one side of the 0^{th} order beam is included in the beam path.

4.5. Modulation Extinction Settings

In order for the modulator to function most effectively, the maximum extinction between the scattered and unscattered beam should be attained. For each wavelength and AOI, the optimal high voltage power supply (HVPS) setting will be different: The higher the wavelength or AOI, the higher the optimal voltage setting.

REMINDER

Under no circumstances should the maximum voltage of your MEMS Grating Modulator device be exceeded, even if the optimal extinction has not been reached for a given wavelength.

Your modulator was tested at 632nm, at ~0 degrees AOI. The optimal voltage settings and associated extinction for these variations are noted in your system data sheet. A typical extinction vs. voltage curve is shown in *Figure 7*. As you can see, the optimal extinction is achieved by gradually increasing the applied voltage, stopping before the extinction begins to decline. For the pictured modulator, the maximum extinction at 632nm, 0 degrees AOI is approximately 110V. By increasing the voltage beyond this point, the extinction decreases. For 30 degrees AOI, the optimal voltage is approximately 115V.

YOU SHOULD KNOW THE MAXIMUM RATED VOLTAGE OF THE MODULATOR BEFORE ADJUSTING THE INPUT VOLTAGE. DO NOT EXCEED THE MAXIMUM RATED VOLTAGE UNDER ANY CIRCUMSTANCES OR YOUR DEVICE WILL BE IRREPARABLY DAMAGED.

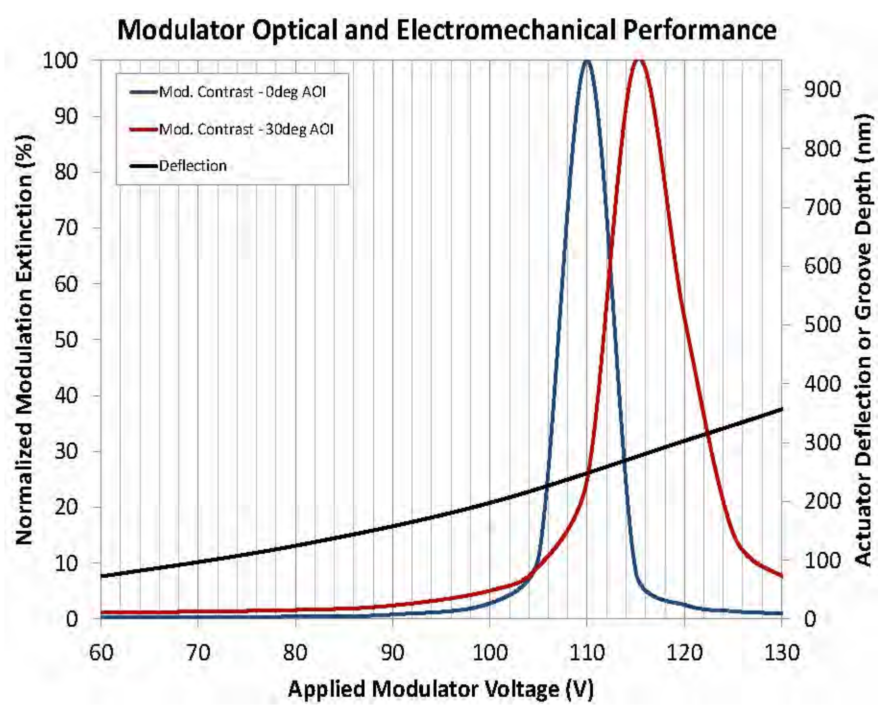


Figure 7: Example Modulator Extinction vs. Voltage

If you are operating at a wavelength other than that measured by BMC, an adjustment may be necessary to obtain optimal extinction. To obtain the optimal extinction, there are two ways in which the value can be determined:

1) Visually:
   By relaying your beam on to a surface on which the beam can be clearly viewed and setting the speed to DC or a low level (e.g. 0.5Hz), the brightness of the scattered and unscattered beam can be evaluated. By adjusting the voltage to minimize the brightness of the central spot when the modulator is in the "on" state, maximum extinction is attained. This is a simple low-tech method of achieving improved extinction.

2) Use of a Photodetector and Oscilloscope:
   This method allows fine tuning of the voltage level. By relaying the beam into a photodetector with the output connected to an oscilloscope, the extinction can be viewed by maximizing the peak-to-valley magnitude of the signal. This can be achieved at both high and low speeds by properly setting the oscilloscope display output. Below is a typical oscilloscope display with the peak-to-valley quantity highlighted both graphically and numerically. The diagram below corresponds to the 1st order diffraction signal as the driver output signal (in purple) and is in sync with that of the photodectector output (in yellow).

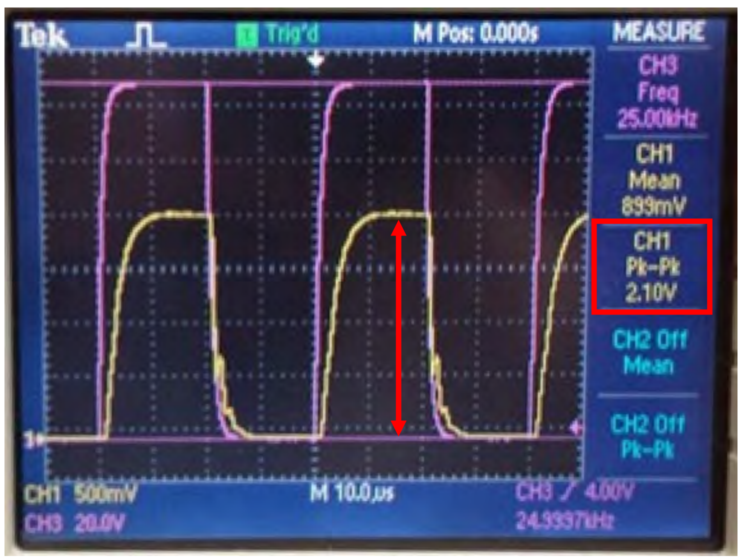
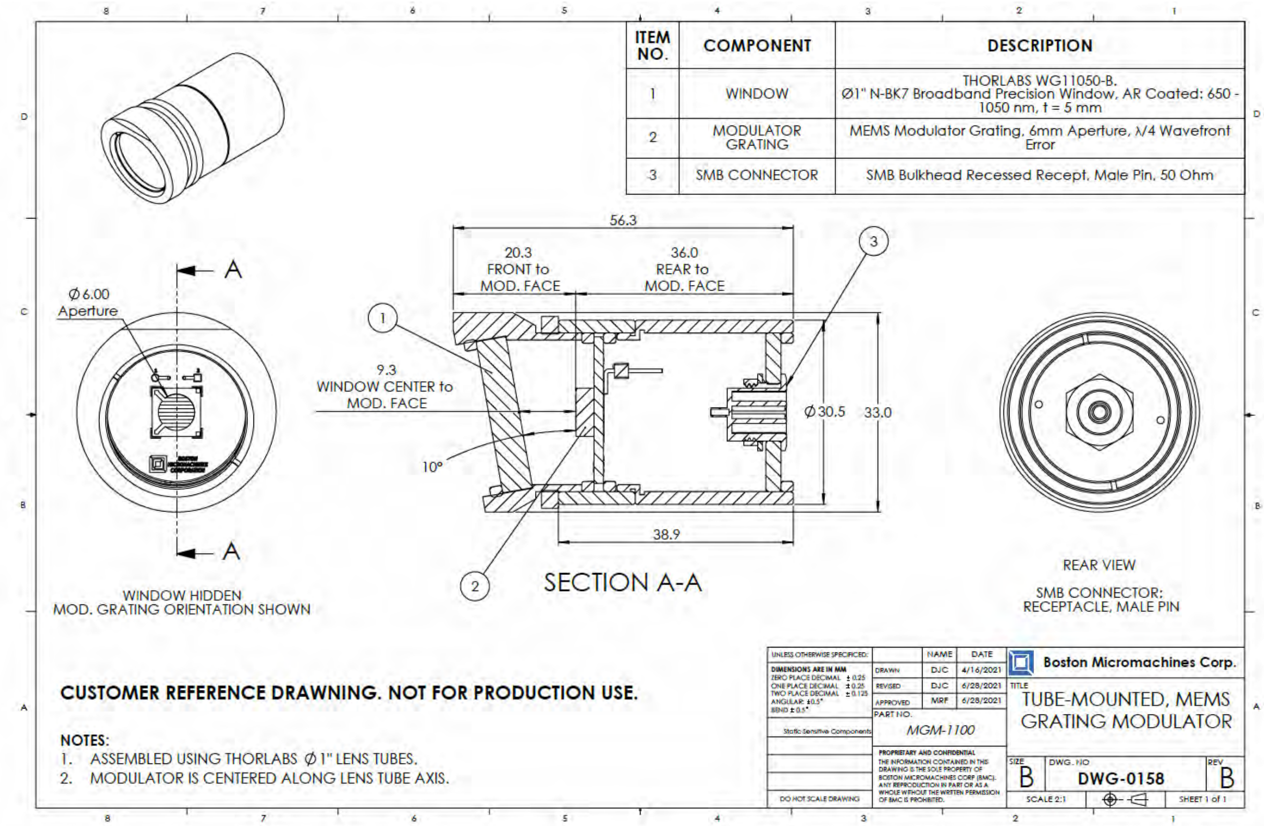


Figure 8: Oscilloscope display showing 25kHz signal. Peak-to-Valley of signal value and graphical representation is shown (2.10V). Purple curve is the monitored drive voltage signal. Yellow curve is the measured photodector signal (maximum 11V).

5. Miscellaneous

5.1. Drawing



5.2. Version Information

Rev.	Description	By	Date
1.0	Initial release	MRF	03/2021
1.1	Name change, added figure 2, added 5.1 drawing, expanded and added text	MRF	06/2021

30 Spinelli Place
Cambridge, MA 02138
T: 617 868 4178 | F: 617 868 7996
www.bostonmicromachines.com

Customer Support:
moreinfo@bostonmicromachines.com