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DFM-P01- Feb. 19, 2016

Item # DFM-P01 was discontinued on Feb. 19, 2016. For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

30 MM CAGE-COMPATIBLE BEAM TURNING CUBES

- ► **Removable Right-Angle Mirror in 30 mm Cage Cube**
- ► **Compatible with Fluorescence Filter Cube**

Application Idea

Beam Turning Cube shown with Cage Assembly Rods

DFM-E02 Beam Turning Cube To

with Mounted Dielectric-Coated Right-Angle Mirror

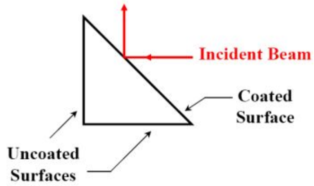
DFM-E02

Hide Overview

OVERVIEW

Features

- Prealigned, Removable Right-Angle Mirror in 30 mm Cage Cube
- 30 mm Cage and SM1 Lens Tube Compatible
- Compatible with Fluorescence Filter Cube Systems
- Easily Swap Between Transmission or Right-Angle Reflection Modes
- Includes One of Four Premounted Right-Angle Mirrors:
  - Silver-Coated (MRA25-P01) Mirror
  - Gold-Coated (MRA25-M01) Mirror
  - Dielectric-Coated, 400 - 750 nm, (MRA25-E02) Mirror
  - Dielectric-Coated, 750 - 1100 nm, (MRA25-E03) Mirror



The Turning Mirror is a right-angle prism with a front-surface coating on the hypotenuse and is designed to have the beam path as shown.

Thorlabs' Beam Turning Cubes provide the ability to swap between transmissive and right-angle-deflected beam paths within a 30 mm Cage System. This cube is ideal for laser steering applications. Using the same innovative kinematic design as the Fluorescence Filter Cubes, the Beam Turning Cube consists of a base and top with insert. The top includes a pre-mounted right-angle mirror (see selection below).

The top of each cube is engraved with a diagram of the mirror location and indicates the light path through the cube. The same base included in the Fluorescence Filter Cube is provided in the Beam Turning Cube, thereby enabling exchange between right-angle mirrors/prisms and fluorescence filter sets.

Click to Enlarge
ERSCA Cage Rod Adapters are Used to Connect the DFM-E03 Turning Cube to a VBA05-780 Variable Beamsplitter Cube

The Beam Turning Cube is a 2.0" (50.8 mm) light-tight square cube that contains a pre-aligned, mounted optic for easy integration into Thorlabs' SM1 (1.035"-40) Lens Tube and 30 mm Cage Systems. Shown to the left is the DFM-E03 connected to a VBA05-780 Variable Beamsplitter Cube using cage rods and four ERSCA Rod Adapters. All four sides of the turning cube have an SM1-threaded port for Ø1.0" (Ø25.4 mm) optics and four 4-40 tapped holes on 30.0 mm centers for compatibility with Thorlabs' Cage Systems. The Beam Turning Cube has a bottom-located 1/4"-20 (M6) tap that is directly compatible with our Ø1" and Ø1.5" mounting posts. The cubes can also be directly attached to our Ø1/2" posts using a user-supplied 1/4"-20 (M6) setscrew; alternately, an AE8E25E (AE4M6M) adapter can be used for compatibility with our Ø1/2" posts' 8-32 (M4) threaded studs. For details on all of the mounting features, please see the mechanical drawing above.

Our cubes are available as a complete unit with a mirror preloaded. The cube tops (DFMT2) and bases (DFMB and DFMB/M) are also available separately. The DFMT2 tops are not provided with mirrors, which is ideal for customers who wish to mount their own turning mirror or other right angle prism into our cubes. Please note that the cube is designed to hold right-angle prisms with sides measuring 25 mm x 25 mm.

Hide Specs

SPECS

Item #		DFM(/M)-P01	DFM(/M)-M01	DFM(/M)-E02	DFM(/M)-E03
Mirror Item #		MRA25-P01	MRA25-M01	MRA25-E02	MRA25-E03
Hypotenuse Coating		Protected Silver	Protected Gold	Dielectric 400 - 750 nm	Dielectric 750 - 1100 nm
Reflectivity		R_{avg} >97.5% (450 nm - 2 µm) R_{avg} >96% (2 - 20 µm)	R_{avg} >96% (800 nm - 20 µm)	Refer to *Graphs* Tab	Refer to *Graphs* Tab
Substrate Material		BK7	BK7	BK7	BK7
Dimensional Tolerance		±0.1 mm	±0.1 mm	±0.1 mm	±0.1 mm
Surface Quality (Coated Surface)		40-20 Scratch-Dig	40-20 Scratch-Dig	10-5 Scratch-Dig	10-5 Scratch-Dig
Flatness (Coated Surface)		λ/10 @ 632.8 nm (70% of Face Length and Width)	λ/10 @ 632.8 nm (70% of Face Length and Width)	λ/10 @ 632.8 nm (70% of Face Length and Width)	λ/10 @ 632.8 nm (70% of Face Length and Width)
45°-45°-90° Prism Angular Tolerance		±3 arcmin	±3 arcmin	±3 arcmin	±3 arcmin
Damage Threshold	Pulse	3 J/cm^2 at 1064 nm, 10 ns, 10 Hz, Ø1.000 mm	2 J/cm^2 at 1064 nm, 10 ns, 10 Hz, Ø1.000 mm	0.25 J/cm^2 at 532 nm, 10 ns, 10 Hz, Ø0.803 mm	1.0 J/cm^2 at 810 nm, 10 ns, 10 Hz, Ø0.133 mm 0.5 J/cm^2 at 1064 nm, 10 ns, 10 Hz, Ø0.433 mm
	CW[a]	1750 W/cm at 1.064 µm, Ø0.044 mm 1500 W/cm at 10.6 µm, Ø0.339 mm	1500 W/cm at 1.064 µm, Ø0.044 mm 750 W/cm at 10.6 µm, Ø0.339 mm	-	-

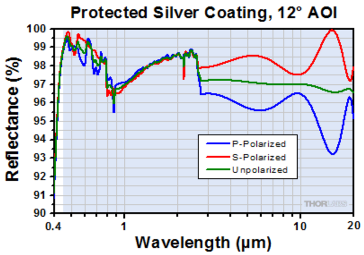
- The power density of your beam should be calculated in terms of W/cm. For an explanation of why the linear power density provides the best metric for long pulse and CW sources, please see the *Damage Thresholds* tab.

Hide Graphs

GRAPHS

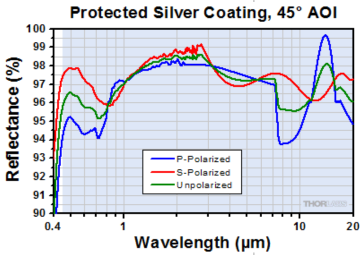
The shaded regions in the graphs denote the ranges over which we guarantee the specified reflectance. Please note that the reflectance outside of these bands is typical and can vary from lot to lot, especially in out-of-band regions where the reflectance is fluctuating or sloped.

Protected Silver Coating (450 nm - 20 µm)



Click to Enlarge

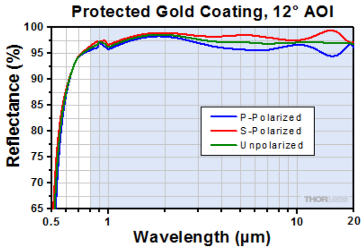
Excel Spreadsheet with Raw Data for Protected Silver



Click to Enlarge

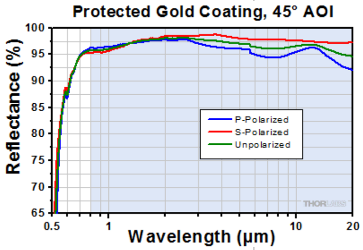
Excel Spreadsheet with Raw Data for Protected Silver

Protected Gold Coating (800 nm - 20 µm)



Click to Enlarge

Excel Spreadsheet with Raw Data for Protected Gold

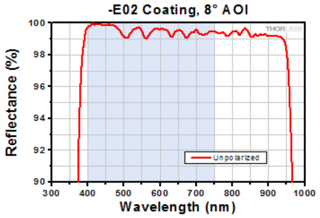


Click to Enlarge

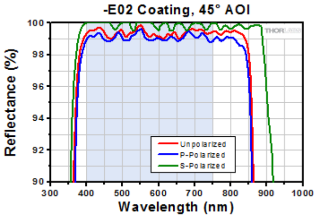
Excel Spreadsheet with Raw Data for Protected Gold

These plots show the reflectivity of our -E02 (400 - 750 nm) and -E03 (750 - 1100 nm) dielectric coatings for a typical coating run. The shaded region in each graph denotes the spectral range over which the coating is highly reflective. Due to variations in each run, this recommended spectral range is narrower than the actual range over which the optic will be highly reflective. If you have any concerns about the interpretation of this data, please contact Tech Support. For applications that require a mirror that bridges the spectral range between the dielectric coatings, please consider a metallic mirror.

-E02 Coating (400 - 750 nm)



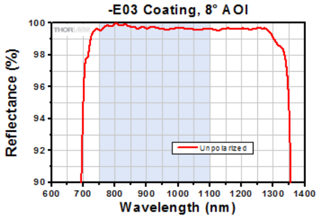
Click to Enlarge



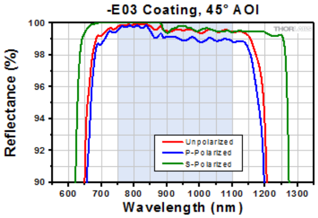
Click to Enlarge

Excel Spreadsheet with Raw Data for -E02 Coating, 8° and 45° AOI

-E03 Coating (750 - 1100 nm)



Click to Enlarge



Click to Enlarge

Excel Spreadsheet with Raw Data for -E03 Coating, 8° and 45° AOI

Hide Damage Thresholds

DAMAGE THRESHOLDS

Damage Threshold Data for Thorlabs' Beam Turning Cubes

The specifications to the right are measured data for Thorlabs' beam turning cubes. Damage threshold specifications are constant for a given coating type, regardless of the measurement system of the beam turning cube.

Damage Threshold Specifications	
Coating Designation (Item # Suffix)	**Damage Threshold**
-P01 (Pulse)	3 J/cm^2 at 1064 nm, 10 ns, 10 Hz, Ø1.000 mm
-P01 (CW)[a]	1750 W/cm at 1.064 µm, Ø0.044 mm 1500 W/cm at 10.6 µm, Ø0.339 mm
-M01 (Pulse)	2 J/cm^2 at 1064 nm, 10 ns, 10 Hz, Ø1.000 mm
-M01 (CW)[a]	1500 W/cm at 1.064 µm, Ø0.044 mm 750 W/cm at 10.6 µm, Ø0.339 mm
-E02	0.25 J/cm^2 at 532 nm, 10 ns, 10 Hz, Ø0.803 mm
-E03	1.0 J/cm^2 at 810 nm, 10 ns, 10 Hz, Ø0.133 mm 0.5 J/cm^2 at 1064 nm, 10 ns, 10 Hz, Ø0.433 mm

- The power density of your beam should be calculated in terms of W/cm. For an explanation of why the linear power density provides the best metric for long pulse and CW sources, please see the "Continuous Wave and Long-Pulse Lasers" section below.

Laser Induced Damage Threshold Tutorial

The following is a general overview of how laser induced damage thresholds are measured and how the values may be utilized in determining the appropriateness of an optic for a given application. When choosing optics, it is important to understand the Laser Induced Damage Threshold (LIDT) of the optics being used. The LIDT for an optic greatly depends on the type of laser you are using. Continuous wave (CW) lasers typically cause damage from thermal effects (absorption either in the coating or in the substrate). Pulsed lasers, on the other hand, often strip electrons from the lattice structure of an optic before causing thermal damage. Note that the guideline presented here assumes room temperature operation and optics in new condition (i.e., within scratch-dig spec, surface free of contamination, etc.). Because dust or other particles on the surface of an optic can cause damage at lower thresholds, we recommend keeping surfaces clean and free of debris. For more information on cleaning optics, please see our *Optics Cleaning* tutorial.

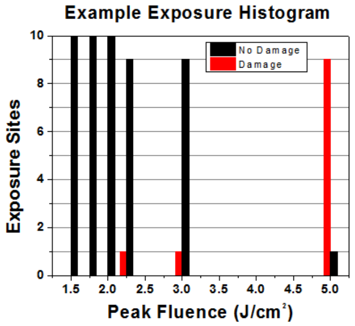
Testing Method

Thorlabs' LIDT testing is done in compliance with ISO/DIS11254 specifications. A standard 1-on-1 testing regime is performed to test the damage threshold.

First, a low-power/energy beam is directed to the optic under test. The optic is exposed in 10 locations to this laser beam for a set duration of time (CW) or number of pulses (pulse repetition frequency specified). After exposure, the optic is examined by a microscope (~100X magnification) for any visible damage. The number of locations that are damaged at a particular power/energy level is recorded. Next, the power/energy is either increased or decreased and the optic is exposed at 10 new locations. This process is repeated until damage is observed. The damage threshold is then assigned to be the highest power/energy that the optic can withstand without causing damage. A histogram such as that below represents the testing of one BB1-E02 mirror.

The photograph above is a protected aluminum-coated mirror after LIDT testing. In this particular test, it handled 0.43 J/cm^2 (1064 nm, 10 ns pulse, 10 Hz, Ø1.000 mm) before damage.

According to the test, the damage threshold of the mirror was 2.00 J/cm^2 (532 nm, 10 ns pulse, 10 Hz, Ø0.803 mm). Please keep in mind that these tests are performed on clean optics, as dirt and contamination can significantly lower the damage threshold of a component. While the test results are only representative of one coating run, Thorlabs specifies damage threshold values that account for coating variances.



Example Test Data			
Fluence	# of Tested Locations	Locations with Damage	Locations Without Damage
1.50 J/cm^2	10	0	10
1.75 J/cm^2	10	0	10
2.00 J/cm^2	10	0	10
2.25 J/cm^2	10	1	9
3.00 J/cm^2	10	1	9
5.00 J/cm^2	10	9	1

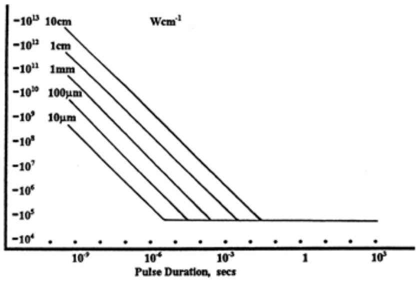
Continuous Wave and Long-Pulse Lasers

When an optic is damaged by a continuous wave (CW) laser, it is usually due to the melting of the surface as a result of absorbing the laser's energy or damage to the optical coating (antireflection) [1]. Pulsed lasers with pulse lengths longer than 1 µs can be treated as CW lasers for LIDT discussions. Additionally, when pulse lengths are between 1 ns and 1 µs, LIDT can occur either because of absorption or a dielectric breakdown (must check both CW and pulsed LIDT). Absorption is either due to an intrinsic property of the optic or due to surface irregularities; thus LIDT values are only valid for optics meeting or exceeding the surface quality specifications given by a manufacturer. While many optics can handle high power CW lasers, cemented (e.g., achromatic doublets) or highly absorptive (e.g., ND filters) optics tend to have lower CW damage thresholds. These lower thresholds are due to absorption or scattering in the cement or metal coating.

Pulsed lasers with high pulse repetition frequencies (PRF) may behave similarly to CW beams. Unfortunately, this is highly dependent on factors such as absorption and thermal diffusivity, so there is no reliable method for determining when a high PRF laser will damage an optic due to thermal effects. For beams with a large PRF both the average and peak powers must be compared to the equivalent CW power. Additionally, for highly transparent materials, there is little to no drop in the LIDT with increasing PRF.

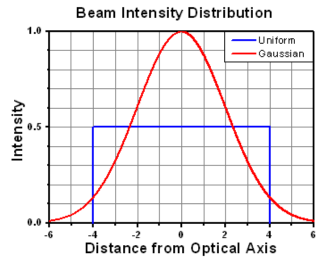
In order to use the specified CW damage threshold of an optic, it is necessary to know the following:

1. Wavelength of your laser
2. Linear power density of your beam (total power divided by 1/e^2 spot size)
3. Beam diameter of your beam (1/e^2)
4. Approximate intensity profile of your beam (e.g., Gaussian)



LIDT in linear power density vs. pulse length and spot size. For long pulses to CW, linear power density becomes a constant with spot size. This graph was obtained from [1].

The power density of your beam should be calculated in terms of W/cm. The graph to the right shows why the linear power density provides the best metric for long pulse and CW sources. Under these conditions, linear power density scales independently of spot size; one does not need to compute an adjusted LIDT to adjust for changes in spot size. This calculation assumes a uniform beam intensity profile. You must now consider hotspots in the beam or other nonuniform intensity profiles and roughly calculate a maximum power density. For reference, a Gaussian beam typically has a maximum power density that is twice that of the uniform beam (see lower right).



Now compare the maximum power density to that which is specified as the LIDT for the optic. If the optic was tested at a wavelength other than your operating wavelength, the damage threshold must be scaled appropriately. A good rule of thumb is that the damage threshold has a linear relationship with wavelength such that as you move to shorter wavelengths, the damage threshold decreases (i.e., a LIDT of 10 W/cm at 1310 nm scales to 5 W/cm at 655 nm):

$$\text{Adjusted LIDT} = \text{LIDT Power}\left(\frac{\text{Your Wavelength}}{\text{LIDT Wavelength}}\right)$$

While this rule of thumb provides a general trend, it is not a quantitative analysis of LIDT vs wavelength. In CW applications, for instance, damage scales more strongly with absorption in the coating and substrate, which does not necessarily scale well with wavelength. While the above procedure provides a good rule of thumb for LIDT values, please contact Tech Support if your wavelength is different from the specified LIDT wavelength. If your power density is less than the adjusted LIDT of the optic, then the optic should work for your application.

Please note that we have a buffer built in between the specified damage thresholds online and the tests which we have done, which accommodates variation between batches. Upon request, we can provide individual test information and a testing certificate. The damage analysis will be carried out on a similar optic (customer's optic will not be damaged). Testing may result in additional costs or lead times. Contact Tech Support for more information.

Pulsed Lasers

As previously stated, pulsed lasers typically induce a different type of damage to the optic than CW lasers. Pulsed lasers often do not heat the optic enough to damage it; instead, pulsed lasers produce strong electric fields capable of inducing dielectric breakdown in the material. Unfortunately, it can be very difficult to compare the LIDT specification of an optic to your laser. There are multiple regimes in which a pulsed laser can damage an optic and this is based on the laser's pulse length. The highlighted columns in the table below outline the relevant pulse lengths for our specified LIDT values.

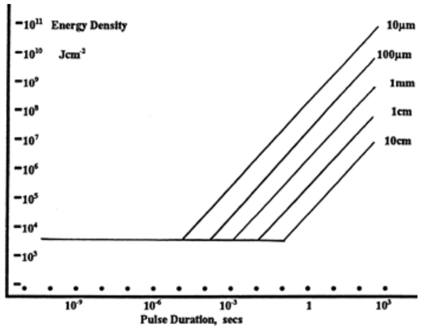
Pulses shorter than 10^{-9} s cannot be compared to our specified LIDT values with much reliability. In this ultra-short-pulse regime various mechanics, such as multiphoton-avalanche ionization, take over as the predominate damage mechanism [2]. In contrast, pulses between 10^{-7} s and 10^{-4} s may cause damage to an optic either because of dielectric breakdown or thermal effects. This means that both CW and pulsed damage thresholds must be compared to the laser beam to determine whether the optic is suitable for your application.

Pulse Duration	$t < 10^{-9}$ s	$10^{-9} < t < 10^{-7}$ s	$10^{-7} < t < 10^{-4}$ s	$t > 10^{-4}$ s
Damage Mechanism	Avalanche Ionization	Dielectric Breakdown	Dielectric Breakdown or Thermal	Thermal
Relevant Damage Specification	N/A	Pulsed	Pulsed and CW	CW

When comparing an LIDT specified for a pulsed laser to your laser, it is essential to know the following:

1. Wavelength of your laser
2. Energy density of your beam (total energy divided by 1/e^2 area)
3. Pulse length of your laser
4. Pulse repetition frequency (prf) of your laser
5. Beam diameter of your laser (1/e^2)
6. Approximate intensity profile of your beam (e.g., Gaussian)

The energy density of your beam should be calculated in terms of J/cm^2. The graph to the right shows why the energy density provides the best metric for short pulse sources. Under these conditions, energy density scales independently of spot size, one does not need to compute an adjusted LIDT to adjust for changes in spot size. This calculation assumes a uniform beam intensity profile. You must now adjust this energy density to account for hotspots or other nonuniform intensity profiles and roughly calculate a maximum energy density. For reference a Gaussian beam typically has a maximum energy density that is twice that of the 1/e^2 beam.



LIDT in energy density vs. pulse length and spot size. For short pulses, energy density becomes a constant with spot size. This graph was obtained from [1].

Now compare the maximum energy density to that which is specified as the LIDT for the optic. If the optic was tested at a wavelength other than your operating wavelength, the damage threshold must be scaled appropriately [3]. A good rule of thumb is that the damage threshold has an inverse square root relationship with wavelength such that as you move to shorter wavelengths, the damage threshold decreases (i.e., a LIDT of 1 J/cm^2 at 1064 nm scales to 0.7 J/cm^2 at 532 nm):

$$Adjusted\ LIDT = LIDT\ Energy\sqrt{\frac{Your\ Wavelength}{LIDT\ Wavelength}}$$

You now have a wavelength-adjusted energy density, which you will use in the following step.

Beam diameter is also important to know when comparing damage thresholds. While the LIDT, when expressed in units of J/cm2, scales independently of spot size; large beam sizes are more likely to illuminate a larger number of defects which can lead to greater variances in the LIDT [4]. For data presented here, a <1 mm beam size was used to measure the LIDT. For beams sizes greater than 5 mm, the LIDT (J/cm2) will not scale independently of beam diameter due to the larger size beam exposing more defects.

The pulse length must now be compensated for. The longer the pulse duration, the more energy the optic can handle. For pulse widths between 1 - 100 ns, an approximation is as follows:

$$Adjusted\ LIDT = LIDT\ Energy\sqrt{\frac{Your\ Pulse\ Length}{LIDT\ Pulse\ Length}}$$

Use this formula to calculate the Adjusted LIDT for an optic based on your pulse length. If your maximum energy density is less than this adjusted LIDT maximum energy density, then the optic should be suitable for your application. Keep in mind that this calculation is only used for pulses between 10^{-9} s and 10^{-7} s. For pulses between 10^{-7} s and 10^{-4} s, the CW LIDT must also be checked before deeming the optic appropriate for your application.

Please note that we have a buffer built in between the specified damage thresholds online and the tests which we have done, which accommodates variation between batches. Upon request, we can provide individual test information and a testing certificate. Contact Tech Support for more information.

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[1] R. M. Wood, Optics and Laser Tech. **29**, 517 (1997).
[2] Roger M. Wood, *Laser-Induced Damage of Optical Materials* (Institute of Physics Publishing, Philadelphia, PA, 2003).
[3] C. W. Carr *et al*., Phys. Rev. Lett. **91**, 127402 (2003).
[4] N. Bloembergen, Appl. Opt. **12**, 661 (1973).

Hide Cubes with Premounted Turning Mirrors

Cubes with Premounted Turning Mirrors

Part Number	Description	Price	Availability
DFM/M-E02	Complete Kinematic Beam Turning 30 mm Cage Cube with Dielectric-Coated Right-Angle Mirror, 400 - 750 nm (Metric)	$381.00	Today
DFM/M-E03	Complete Kinematic Beam Turning 30 mm Cage Cube with Dielectric-Coated Right-Angle Mirror, 750 - 1100 nm (Metric)	$386.00	Today
DFM/M-M01	Complete Kinematic Beam Turning 30 mm Cage Cube with Gold-Coated Right-Angle Mirror, 800 nm - 20 µm (Metric)	$314.00	Today
DFM/M-P01	Complete Kinematic Beam Turning 30 mm Cage Cube with Silver-Coated Right-Angle Mirror, 450 nm - 20 µm (Metric)	$314.00	Today
DFM-E02	Complete Kinematic Beam Turning 30 mm Cage Cube with Dielectric-Coated Right-Angle Mirror, 400 - 750 nm	$381.00	Today
DFM-E03	Complete Kinematic Beam Turning 30 mm Cage Cube with Dielectric-Coated Right-Angle Mirror, 750 - 1100 nm	$386.00	Today
DFM-M01	Complete Kinematic Beam Turning Cube with Gold-Coated Right-Angle Mirror, 800 nm - 20 µm	$314.00	Today
DFM-P01	Complete Kinematic Beam Turning 30 mm Cage Cube with Silver-Coated Right-Angle Mirror, 450 nm - 20 µm	$314.00	Today

Hide Empty Cube Base and Top

Empty Cube Base and Top

Part Number	Description	Price	Availability
DFMB/M	30 mm Cage Cube Base for Turning Cubes and Fluorescence Filter Cubes (Metric)	$103.00	Today
DFMT2	Kinematic Beam Steering 30 mm Cage Cube Top (Imperial and Metric Compatible)	$237.00	Today
DFMB	30 mm Cage Cube Base for Turning Cubes and Fluorescence Filter Cubes	$103.00	Today