MAX LEVY AUTOGRAPH

MLA 4000 SERIES ULTRA PRECISION MICRO MACHINING/CONTOURING SYSTEM

120 YEARS OF PRECISION MANUFACTURING

BULLETIN 2050

The **MLA4000 ULTRA PRECISION MICRO MACHINING/CONTOURING SYSTEM** and our post machining replication technology allow the designer freedom to create new and high quality components. We offer a unique combination of options for the fabrication of products which include three dimensional optics, forms and arrays.

PRODUCT APPLICATIONS INCLUDE:

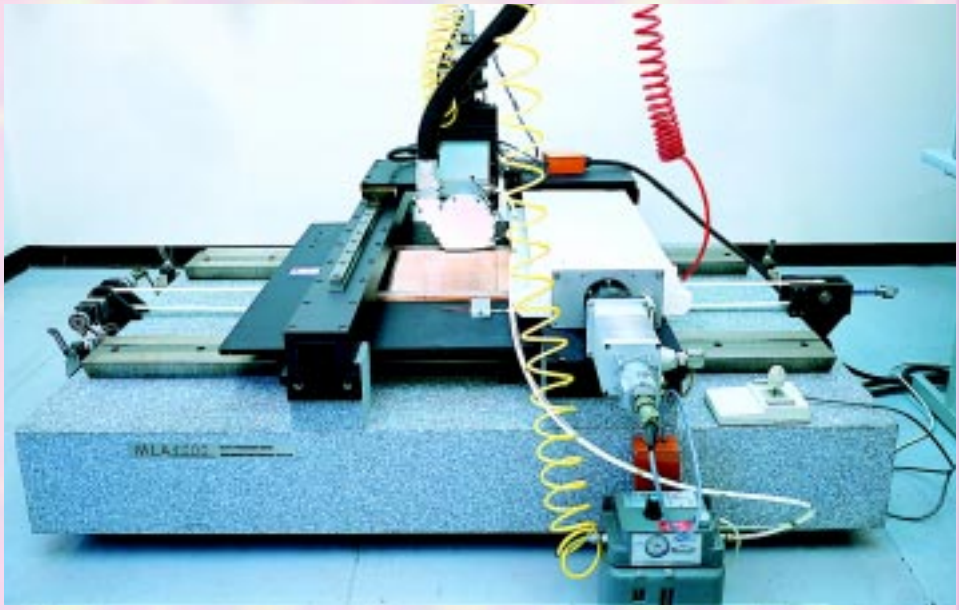
SCIENTIFIC/TECHNICAL OPTICS: Lenticular Lens Arrays, Light Shaping Diffusers, Corner Cube Reflectors/Absorbers, Light Pipe Arrays, and other Macro/Micro Optical Arrays.

METROLOGY: Three Dimensional Calibration Standards, Field Distortion and Depth of Field Calibration Standards. (Used for Machine Vision Camera System Testing.) Macro/Micro custom 3D Calibration Artifacts. (Such as Step Wedge Standards that are used for non-destructive X-Ray analysis of material density/thickness.)

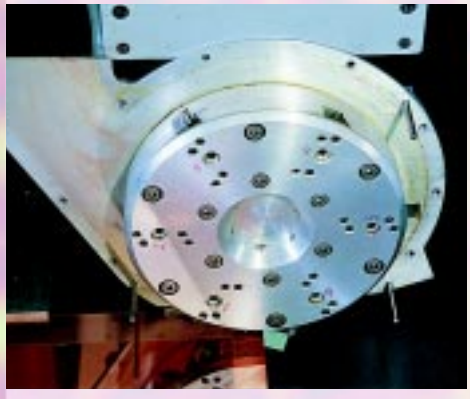
PRECISION THREE DIMENSIONAL TOOLING STRUCTURES: 3D High Aspect Ratio/High Strength Forms such as Screen Molds for the production of Ultra Fine Mesh, Tension Screens and Electroforming Mandrels.

ELECTRONIC IMAGING: Front and Rear Projection Screens for Display Terminals, Rear Projection TV and Flat Panel Displays. Miniature Optical Arrays for Stereoscopic, Micro-Surgical and other Custom Imaging Devices.

PUBLISHED GRAPHICS: Animated Art, 3D Art, and 3D Animated Art for Print Advertising, Trade Show Exhibits, Point of Purchase Graphic Displays, Video Arcade Game Displays, Menu Boards, Billboards and Advertising Specialties.

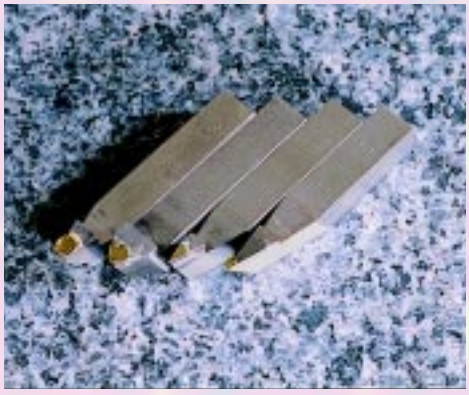


The **MLA4000 ULTRA PRECISION MICRO MACHINING/CONTOURING SYSTEM** is pictured above. The pattern being machined into the substrate is a High Aspect Ratio, Fine Pitch Lenticular Lens Array. The Spindle and Carriage are Air Bearing supported for maximum optical surface quality of the fabricated part. Pictured below are the Cutting Head, Diamond Tools, and a closer view of the substrate being machined on the **MLA4000 SYSTEM.**



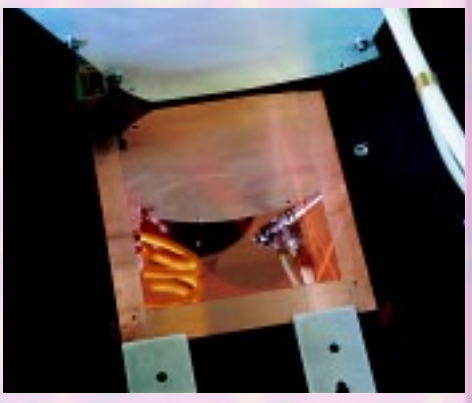
AIR BEARING CUTTING HEAD

The **CUTTING HEAD** is a variable speed, 6” diameter air bearing supported spindle. The Cutting Head Tool Adapter is designed to accommodate six individual Single Crystal Cutting Diamonds. The Single Crystal Roughing and Finishing Diamonds are manufactured with the required contours and mounted in the Cutting Head. By combining up to six different shaped diamonds in the Cutting Head, complex features can be machined into the substrate.



DIAMOND TOOL HOLDER

Each Single Crystal contouring diamond is mounted in a Precision Tool Holder and ground and polished to a very precise contour and extremely fine finish. Shapes include flats, convex and concave spherical and parabolic contours, wedges and sharp points in various geometric configurations. Up to six individual Diamond Contouring Tools can be mounted on the Air Bearing Cutting Head and aligned so that they work together to produce the desired part shape.



CUTTING HEAD WITH SHROUD

A pure copper substrate is shown being contoured with a high aspect ratio lenticular lens array pattern on the MLA4000 System. The optical quality surface finish of the lens contour reflects the image of the air supply hose and housing. The MLA4000 has an X-Y machining capacity of 1.0 X 1.02 meters, (39.37” x 40”). For larger products, the MLA5400 has an X-Y machining capacity of 1.37 X 1.52 meters. (54” x 60”).

Masters created by the **MLA4000** Series Ultra Precision Micro-Machining/Contouring Systems are used to produce a wide range of products. These products include:

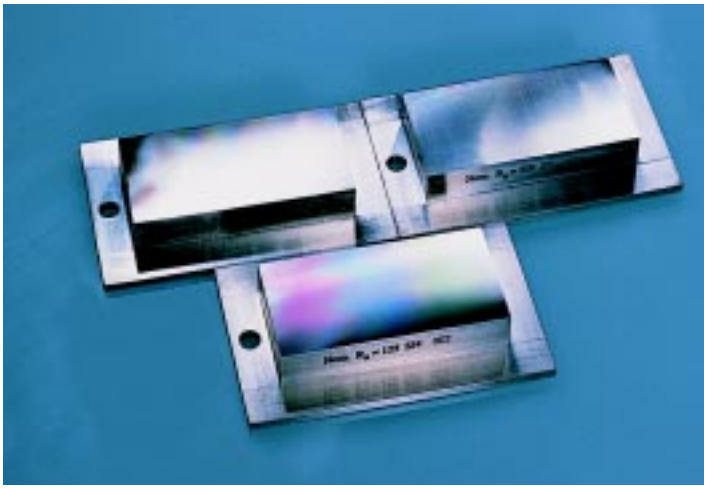
- **LINEAR LENTICULAR LENS ARRAYS**
- **THREE DIMENSIONAL MEASUREMENT STANDARDS**
- **THREE DIMENSIONAL LIGHT PIPE ARRAYS**
- **X-RAY STEP WEDGE DENSITY STANDARDS**
- **HIGH ASPECT RATIO REAR PROJECTION VIEWING SCREENS**
- **OPTICAL STRUCTURES, ARRAYS AND CORNER CUBES**

These Masters may be used for Tooling or Part Replication by Electroforming as explained on Page 4 and in Bulletin 2100. Tooling Replications may be used to mass produce lenses and parts in plastics.

One example is our proprietary High Aspect Ratio Lenticular Plastic Lens that is formed in combination with our Focusing Plane Micro Random Lenticular Lens. This mass produced assembly is custom designed to function as a Rear Projection Screen with high gain, excellent uniformity, and controlled illumination over a specific viewing angle. We also manufacture other value added products such as High Quality Artistic and Graphic Displays that feature Animated Art, 3D Art and 3D Animated Art. These products are manufactured by forming the lenticular lens integral with Photos, Transparencies and Prints to an alignment tolerance of 1 part per 10,000.

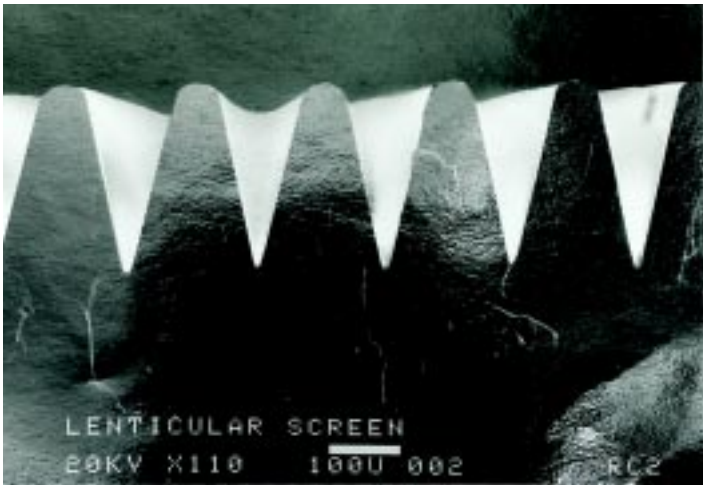
LENTICULAR LENS MASTER & REPLICATED NICKEL ELECTROFORM

The Diamond Machined Substrate shown at the top of the photo has been Machined with a Concave Lenticular Lens Pattern, Nickel Plated, Passivated, and used to manufacture a Nickel Convex Lenticular "Father" Electroform. This "Father" in turn, is used as a Master to Electroform Concave Lenticular Hard Nickel Replication Dies. These Dies are then used to mass produce the Convex Lenticular Lenses in Plastic. This process is diagramed on page 4 of this brochure. The entire process of Diamond Machining, Electroforming and Economic Replication, provides the engineer with the ability to design, prototype and economically mass produce complex micro structures in very large formats.



SURFACE FINISH REFERENCE STANDARDS

This photo shows three Diamond Machined, Nickel Plated, NIST Traceable Surface Finish Master Reference Standards. The Surface Profile of each Reference Standard has been machined into the surface with a Single Point Diamond with a specific "V" shaped point and pitch. The actual surface finish of the "V" shaped Reference Standard Profile is better than .025 microns/1 microinch. These standards are suitable for the calibration of Surface Finish Instruments. To economically provide these Reference Standards in quantity, they are Replicated as Nickel Electroforms.



ENLARGED END VIEW OF HIGH ASPECT RATIO LENTICULAR LENS ARRAY.

This Lens Array has a pitch of less than 200 microns/.0079". It was formed from a Diamond Machined Master and replicated in Acrylic. Large format High Aspect Ratio Replicated Lenticular Lens Arrays with this and other profiles can be fabricated with pitches as small as 100 microns/.004". Standard Lenticular Lens Arrays can be fabricated with pitches that range from about 50 microns/.002", to as large as 6.1mm/.24"

MLA4000 SERIES ULTRA PRECISION MICRO MACHINING/CONTOURING SYSTEMS - SPECIFICATIONS

MATERIALS SUITABLE FOR DIAMOND MACHINING

The materials suitable for Diamond Machining include **PURE COPPER, ALUMINUM AND NICKEL. ACRYLICS, POLY-CARBONATES, PETG®,** and all **PLASTICS** can be Diamond Machined; however, each plastic has its own characteristic Diamond wear and finish. *S*ome other **OPTICAL SUBSTRATES** can also be Diamond Machined**. DIAMOND WEAR** is the least with Copper, Aluminum and Acrylic*.* Nickel, Polycarbonate and Optical Materials such as Germanium cause the most Diamond wear.
We also offer **POST MACHINING ELECTROFORMING, REPLICATION, PLATING, VACUUM COATING DEPOSITION** and other **SPECIALITY PROCESSING AND FINISHING SERVICES** to support the customer in obtaining the desired finished product.

X - AXIS
40” and 60” Long Stroke with Encoder Feedback.
Air Bearing Supported Ways.
Positional Accuracy along Axis: 0.001”
Repeatability: 0.001”

Y - AXIS
Cutting Travel: 39.37” and 54.00”
Programming Resolution: 508 Steps/Micron with Encoder Feedback.
Minimum Pitch: Dependent on Single Point Diamond Configuration. (Typically 50 to 75 microns)
Maximum Pitch: 0.24” Single Diamond, 0.30” Multiple Diamonds.
Standard Cutting Head: One to Six Individual Diamonds. In-Line or Staggered Pitch.
Positional Step to Step Accuracy: 0.1 microns.
Overall Accuracy: 1 micron/10” of travel.
Repeatability: 2 microns, full travel, out and back to same position.

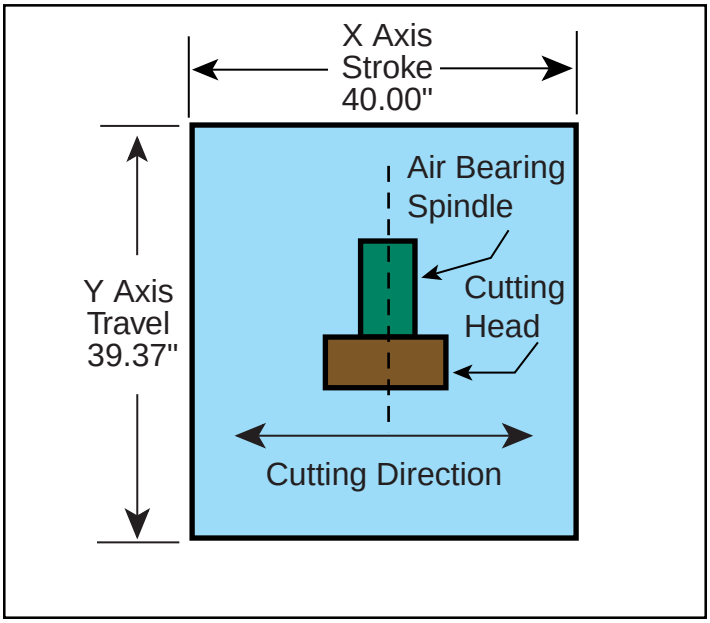
Z - AXIS (VERTICAL)
1.25” Vertical Travel in Standard Configuration
Servo Controlled with Encoder Feedback
Programming Resolution - 400 steps/micron
Positional Accuracy: 0.05 to 0.1 microns for vertical movements of 1 to 2mm
Repeatability: 0.05 microns for movements of 2mm or less.
Overall Accuracy: 1 micron full scale.

CUTTING HEAD
Air Bearing with 6” Diameter

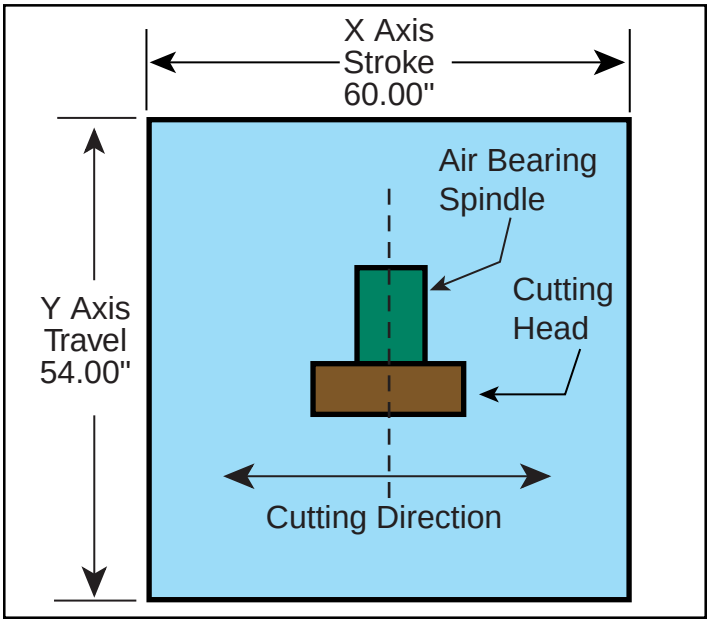
CUTTING HEAD ROTATIONAL SPEED
Variable: 1000 To 12,000 RPM

ACTIVE MACHINING/CONTOURING AREA
MODEL MLA4000: 39.37” Wide x 40.00” Long
[1.0 Meters Wide X 1.02 Meters Long]
MODEL MLA5400: 54.00” Wide x 60.00” Long
[1.37 Meters Wide X 1.52 Meters Long]

MLA 4000



MLA 5400

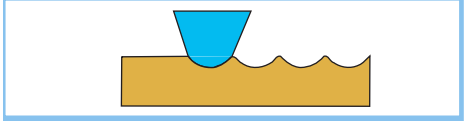


DIAMOND CONTOURING MASTERING PROCESS

Machined Surface Substrate: Pure Copper, Aluminum, Nickel, Mineral, Plastic, or, Plastic, Metallic or Mineral Composite

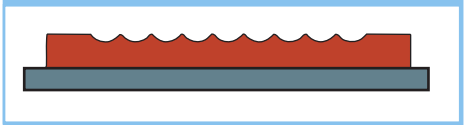
Planarize Top Surface with Flat Diamond to Establish Mirror Finish Reference Surface

Cut Lens or Feature using Contoured Single Crystal Diamond

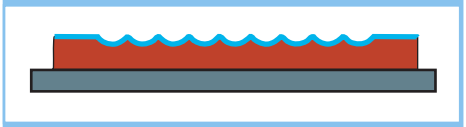


Enlargement of Surface with Machined Cuts

TYPICAL TOOLING MANUFACTURING FOR REPLICATED PLASTIC OPTICS

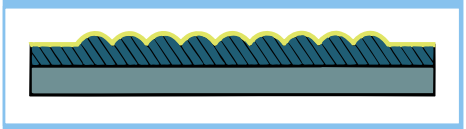


Diamond Machined Lens Contour, with Electroplated Copper Substrate (Base)

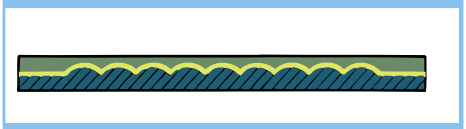


Electroless Nickel Flash & Passivate Lens Surface

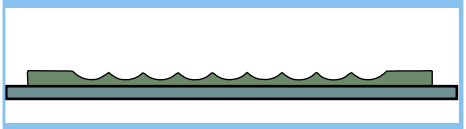
Electro-Deposit Nickel to Grow Master Electroform, (Father)



Remove Father Electroform & Mount To Backing Plate & Passivate Lens Surface



Electro-Deposit Nickel to Grow Replication Electroform, (Daughter)



Mount Daughter Electroform to Backing Plate For Lens Manufacturing

Vacuum Forming or Injection Molding of Replicated Optics

TYPICAL TWO SIDED LENS FOR REAR PROJECTION IMAGING

Random Micro-Lenticular Master Electroform

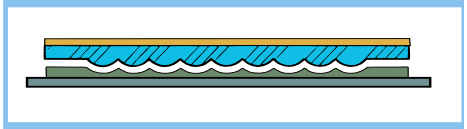
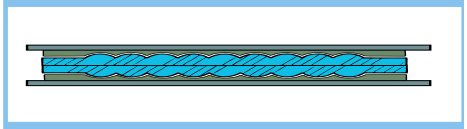


Image Plane, Imaging Lens and Lenticular Lens with Lenticular Lens Electroform

DISCRETE LENS ARRAY FORMED ON BOTH SURFACES



X-RAY DENSITY WEDGE

Enlargement of Side View of Step Density Wedge

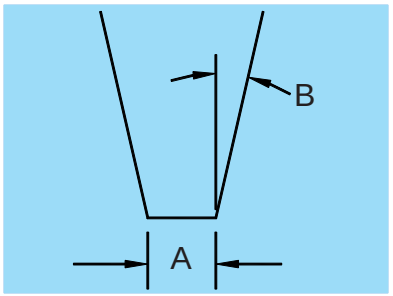
X-Ray Print of Graduated Step Wedge

Photo of Step Wedges Showing a Variety of Sizes and Materials

MLA4000 SERIES ULTRA PRESISION MICRO MACHINING/CONTOURING SYSTEMS TYPICAL DIAMOND CONFIGURATIONS

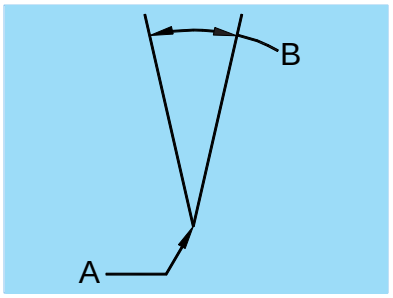
FLAT POINT

A: FROM 13 MICRONS/.0005" TO 6100 MICRONS/0.24"
B: 16° MINIMUM WITH 25 MICRON/.001" FLAT
5° MINIMUM WITH 200 MICRON/.005" FLAT DECREASING TO .1° AT 1500 MICRONS/.06" OR GREATER FLAT.
TYPICAL DEPTH OF CUT: 254 MICRONS/.010" TO 380 MICRONS/.015"/PASS.



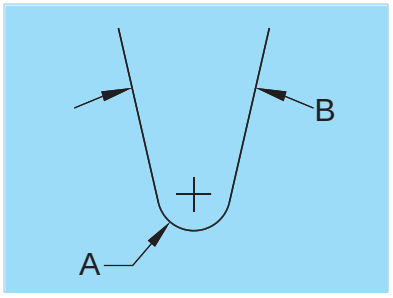
SHARP POINT

A: 1 MICRON TIP RADIUS REQUIRED FOR TOOL WEAR.
B: 20° TO 179° (ALMOST FLAT).
TYPICAL DEPTH OF CUT: 254 MICRONS/.010" TO 380 MICRONS/.015"/PASS.



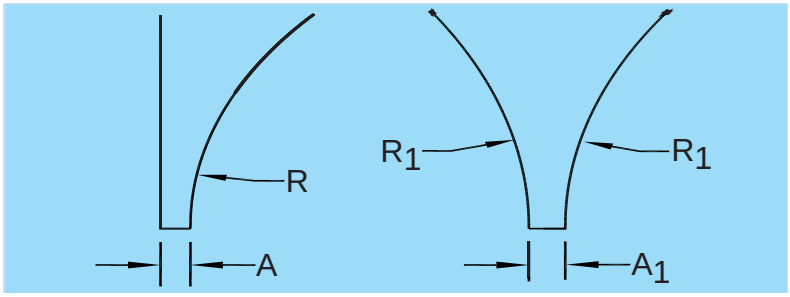
ROUNDED POINT

A: RADIUS, PARABOLIC OR SHAPED POINT, 1.0 MICRON TO 12.7MM/0.5" RADIUS*
B: 20° TO 40° FOR TIP RADIUS OF LESS THAN 64 MICRONS/.0025".
20° MINIMUM FOR TIP RADIUS OF 64 MICRONS/.0025".
10° MINIMUM FOR TIP RADIUS OF 127 MICRONS/.005".
TYPICALLY THE "B" ANGLE IS SET BASED ON THE REQUIRED CUT GEOMETRY AND TOOL STRENGTH.
DEPTH OF CUT: SKIM CUT TO 1.27mm/.050" PER PASS.



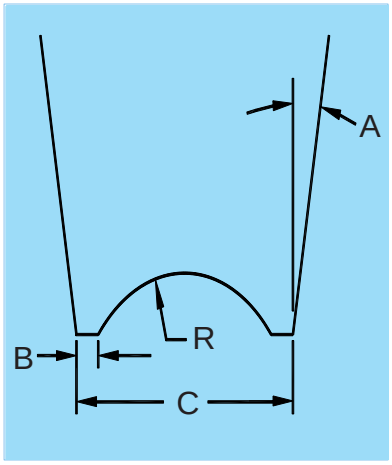
HIGH ASPECT RATIO DESIGNS

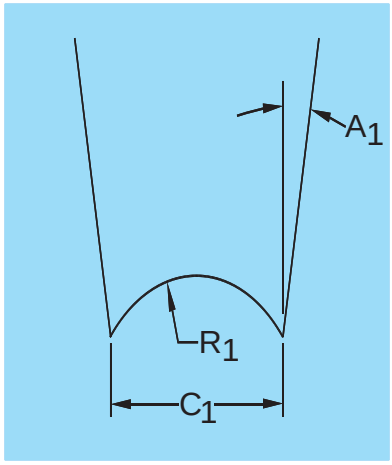
FLAT, RADIUS, OR SHAPED POINT
A: MINIMUM WIDTH 25 MICRONS @ R = 762 MICRONS/.030"
A1: MINIMUM WIDTH 25 MICRONS @ R1 = 1575 MICRONS/.062"
DEPTH OF CUT IS A FUNCTION OF THE DIAMOND GEOMETRY



CONCAVE & CONCAVE WITH FLATS

A, A_1: 0.1° TO 5° MINIMUM; BASED ON R, B AND C, OR R_1 AND C_1
R, R_1: MINIMUM 2.6 TIMES DEPTH OF CUT TO 12.7mm/0.5"
B: 10 MICRONS MINIMUM
C: 70 MICRONS MINIMUM TO 6.1mm/.24"
C_1: 50 MICRONS MINIMUM TO 6.1mm/.24"





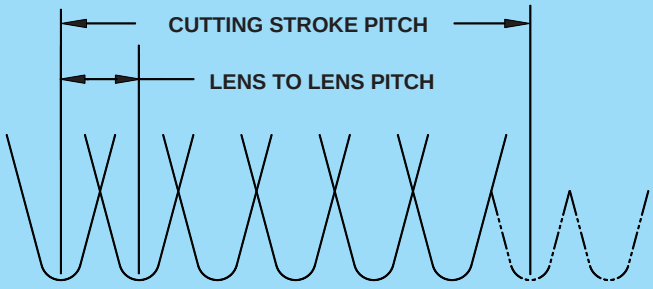
**FOR LENTICULAR LENSES WE OFFER COMPUTER GENERATED OPTICAL DESIGN SERVICES TO ESTABLISH THE CORRECT LENS SHAPE FOR A SPECIFIC GRAPHIC AND VIEWING SPECIFICATION.*

MLA4000 SERIES ULTRA PRECISION MICRO MACHINING/CONTOURING SYSTEMS ALLOW FOR MULTIPLE DIAMOND CONFIGURATIONS

THESE ARE SAMPLE TYPES OF CUTTING HEAD SETUPS

SEQUENTIAL DIAMOND CUTTING CONFIGURATION

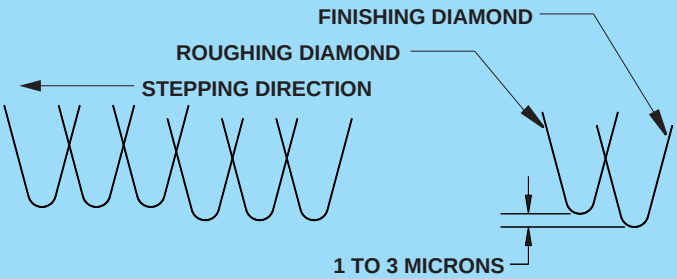
Up to six individual diamonds can be staggered to provide six linear cuts per pass. Each Diamond Cutting Tool may have a different contour and/or depth of cut. The Cutting Head replicates the series of matched cuts by stepping the entire group of Diamond Cutting Tools. (As shown in the sketch to the right.) For machining with identical Diamond Cutting Tools, this configuration permits a shorter machine running time; however, the setup is more difficult than the Co-planar configuration described below.



SEQUENTIAL DIAMOND CUTTING CONFIGURATION

ROUGH CUT/FINISH CUT CONFIGURATION

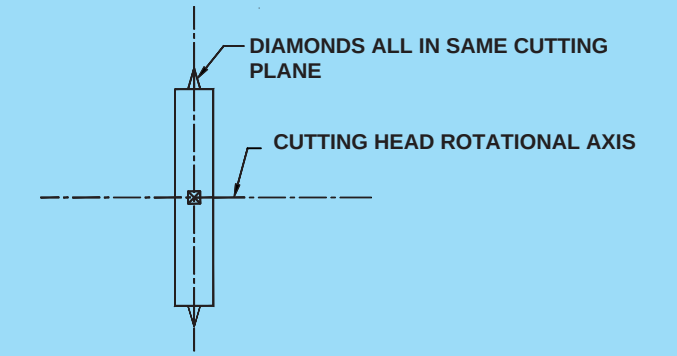
Sets of two or three diamonds can be staggered to provide the Rough Cut/Finish Cut configuration. The Cutting Head replicates the series of matched cuts by stepping the entire group of Diamond Cutting Tools. The stepping pitch is either two or three times the individual Diamond Cutting Tool Pitch as determined by the pairing of the Diamond Tool Sets. The sketch to the right illustrates the Roughing Diamond cut, followed by the Finishing Diamond cut of 1 to 3 microns. This technique is used to lessen the tool wear of the finishing Diamond Cutting Tools and maintain the optical finish for arrays with long runs.



ROUGH CUT/FINISH CUT DIAMOND PLACEMENT CONFIGURATION

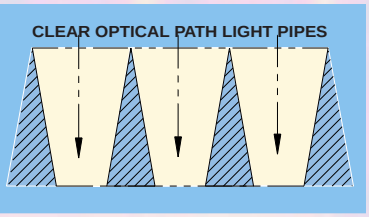
CO-PLANAR DIAMOND CONFIGURATION

This configuration of Diamond Tool Placement is the most common. Up to 6 co-planar Diamond Cutting Tools are mounted in the Cutting Head. The number of Diamond Cutting Tools utilized depends on the length of the run and the speed of the cut.



CO-PLANAR DIAMOND CONFIGURATION

The front and back cover background is a magnified photo of a replicated Diamond Machined 128 x 128 Element Light Pipe Array. It has an element pitch of 177 microns and 9.9 degree side walls.



To explore your application and obtain additional information contact our Technical Sales and Engineering Applications Specialists at

MAX LEVY AUTOGRAPH, INC.

220 WEST ROBERTS AVENUE PHILADELPHIA, PA 19144-4298
TOLL FREE: 1-800-798-3675 OR DIRECT: 215-842-3675
FAX: 215-842-3637 E-MAIL: sales@maxlevy.com
VISIT OUR WEBSITE AT http://www.maxlevy.com

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