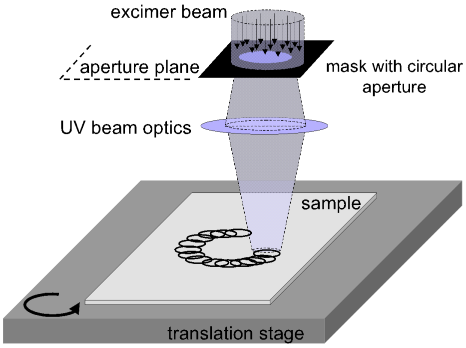
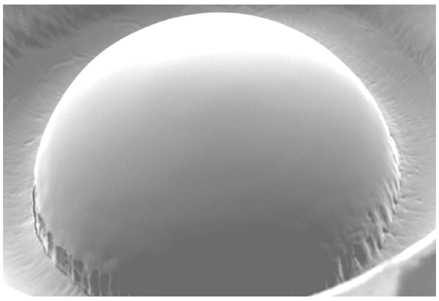
Excimer Laser Machining of Optical Components

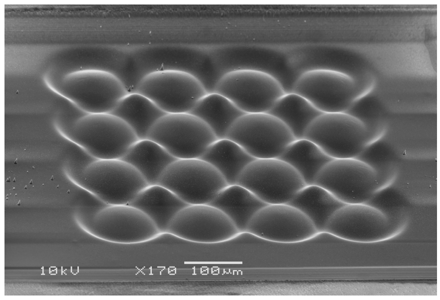
In suitable materials and with the right processing parameters, excimer lasers are capable of machining surfaces which are **optically smooth**, whilst there are different process strategies which can produce **3D forms**. In all cases, structuring results from the basic assumption that machined depth is proportional to accumulated shot dose; the assumption is reasonable;- the question is just how to do that in any particular case.

Glasses, including FS, can be machined at 193nm, but require high energy density (e.d.), resulting in rather slow processing rate, and, depending on glass type, some risk of cracking due to formation of color centres, induced internal stresses etc. By contrast **polymers machine smoothly** and efficiently by the process of **'photoablative decompositon'**. PMMA requires 193nm(ArF); Polycarbonate (PC) machines perfectly at 248nm(KrF),, with easier operating logistics, and is the default choice.

An Optec customer developed the technique summarized here to machine **fibre coupling lenses** in PMMA . In the centre example below, ROC=400µm. With some limitations, the same technique can be extended to **small arrays of features** machined in parallel by using a mask with an array of defining apertures.

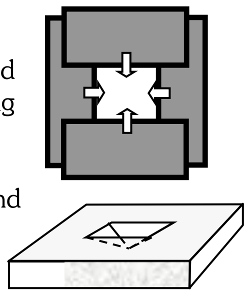


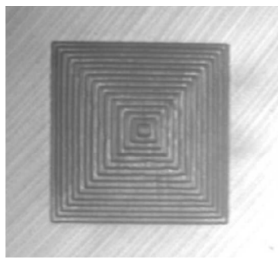




CS & DCS (Dynamic Contour Sectioning)

Any shape which is not re-entrant can be machined by CS (contour sectioning), by slicing into vertical slices corresponding the depth of material removed with a single shot.

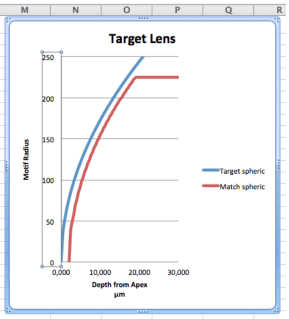




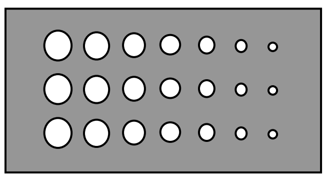
As an example, the dynamic MRA(motorized Rectangular Aperture) is used as a mask with single shots fired for a wide range of openings of decreasing size, resulting in the **ziggurat shaped crater**, here in PC(248nm).

If the order of selecting motifs is reversed, starting with the smallest one and increasing in size, then successive shots smooth out the steps resulting from previous shots, and an optically smooth surface can result.

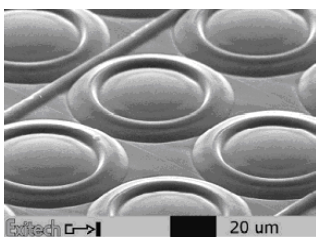
	A	B	C	E	F	G	H	J	K	L
1	Model Lens for Motif Set			Target Lens Ellipsoid						
2										
3	Lens OD	500		Lens OD	450					
4	ROC	1500		c	0,000667					
5	c	0,000667		k	-0,587					
6	Spherical surface			semi-axes	3632	maj. min.	2334			
7	SAG	20,980		SAG	16,914		H offset			
8										
9	N motifs in set	130		Depth/shot	0,4		2			recalculate z
10	SAG/N	0,1614		N Shots	42	max 100			Truncate	Check fn
11							Nearest	Motif	at	
12	Slice	Z	Slice Radius	Slice	Z	Slice Radius	From set	No	Rmax	
13	0	0,000	0	0	0,000	0	0	0	0	0,0
14	1	0,161	22	1	0,400	35	38	3	38	0,4
15	2	0,323	31	2	0,800	49	49	5	49	0,8
16	3	0,484	38	3	1,200	60	58	7	58	1,2
17	4	0,646	44	4	1,600	69	70	10	70	1,6
18	5	0,807	49	5	2,000	77	76	12	76	2,0
19	6	0,968	54	6	2,400	85	85	15	85	2,4
20	7	1,130	58	7	2,800	92	91	17	91	2,8
21	8	1,291	62	8	3,200	98	98	20	98	3,2
22	9	1,452	66	9	3,600	104	103	22	103	3,6
23	10	1,614	70	10	4,000	110	110	25	110	4,0
24	11	1,775	73	11	4,400	115	114	27	114	
25	12	1,937	76	12	4,800	120	120	30	120	
26	13	2,098	79	13	5,200	125	124	32	124	



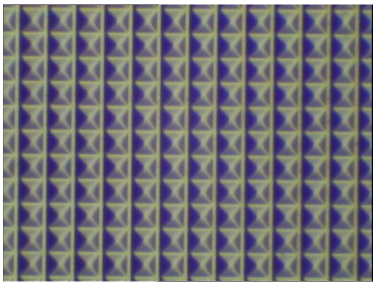
In a similar way, small **lens shapes including ellipsoids,** can be made by vertical slicing into different sized circular motifs, though the number of separate motifs becomes unweildy as lens size increases.



In an extension of this method, **arrays of such features** can be made by **DCS** in which all the motifs in the set are on the same mask plate, and at constant pitch. A large laser is used with a beam big enough to illuminate one or more complete lines containing the complete set of motifs, and the virgin part is translated at constant speed with PSO (Pulse Synchronized Output) firing of the laser ensuring that the images of successive motifs in the set fall on top on each other. In this way an arbitrarily long line(lines) of finished motifs is produced in a single operation. (N.B. The ends of the line(s) contain elements of the array which have not 'seen' all the motifs in the set, and are thus incomplete).



Arrays generated in this way can be **several m2 in size & contain a billion identical elements!**

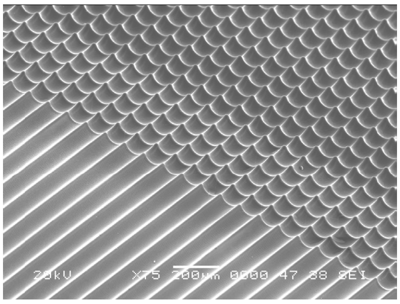
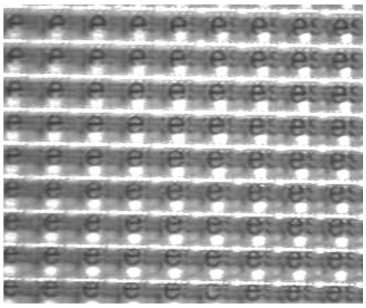
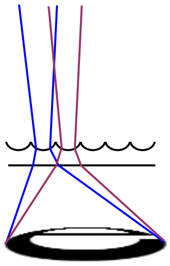
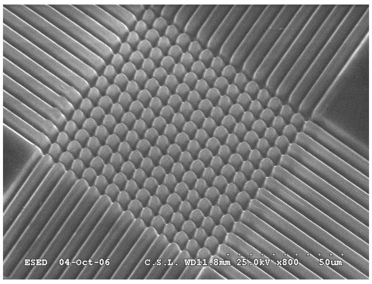



Another example using DCS is an **array of pyramid features**, 60μm pitch, in PC. Feature regularity requires highly accurate placing of superimposed shots, typically with air bearing stages and massive granite structures ; the machine below can generate arrays 150mm x 150mm.

OG (Orthogonal Grooving)

Another technique that can be used to generate arrays is OG. Here a linear array of simple motifs is used in combination with part motion to generate a 1D array of semicircular grooves In a second operation the same array is machined in the orthogonal direction. This example shows an array of identical concave lenslets, 50μm x 90μm, x 36μm deep with a well-defined shape factor. **Surface roughness** was measured **<15nm**.

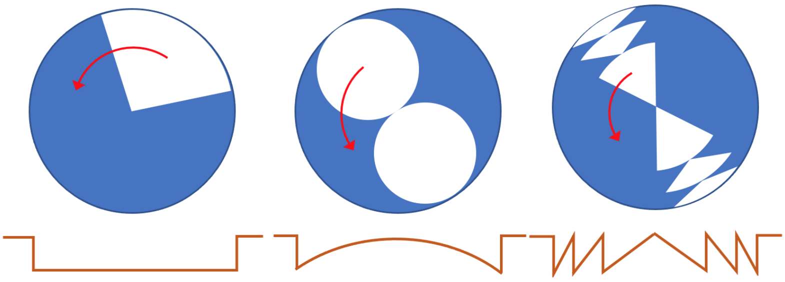
The two stages of the array generation are shown, together with a view of a printed character through a completed array using binocular microscope.

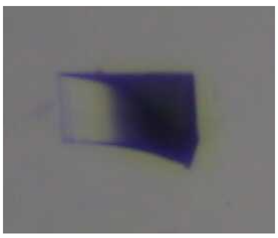
Both Si and Ge can be machined at 193nm. ZnSe can be machined at 248nm, and the example here is of a '**moth's eye' absorbing structure** in ZnSe (6μm pitch) generated by OG.

Rotating Masks

Isolated components including classical & **Fresnel lenses**, can be made using a rotating mask, here showing the clear area (white) & the profile so produced.

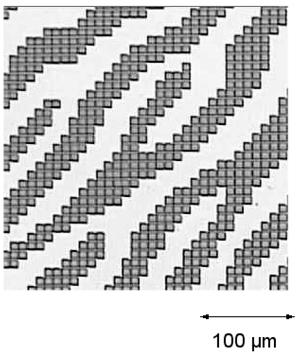


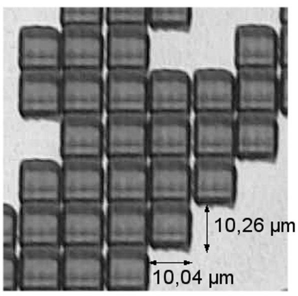
Other Components

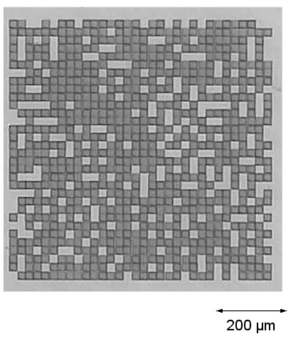


Here an oblique view of structures which are small (100μm wide) rectangular wells which have an **inclined floor of parabolic shape.** The application is extraction mirrors for optical waveguides ; the example here was done in Optec apps lab as a demo using 248nm in PC ; a machine subsequently installed for the customer uses 193nm on polymer waveguide structures of proprietary composition. Single structures are made by using a dynamic mask which starts as a small vertical slit, gradually opening to the left in a programmed manner synchronized to laser firing so that each part of the ramp accumulates the desired number of shots.

Diffractive optics, including OVD, can also be manufactured using excimer laser; the examples below were made in Sol-Gel for replication as IR optics, at left a binary structure with 10μm cell size, at right a 4-level device with 25μm cell size.







See other Lasea & Optec Technotes - - - Use your Photons!