Excimer Lasers – Choice, Size, & Wavelength?

With some oversimplification, an excimer laser is a box full of high pressure exotic gas mixture with a circulating fan, a pair of electrodes to generate a discharge which creates a population of **exci**ted di**mer**s, which then decay emitting their specific UV **wavelength**, + 2 mirrors to make an optical cavity. Typically high reflector HR & output coupler OC, but **gain is huge** & a cavity equipped with 2X OC works almost as well,- just emits half the output in each direction!

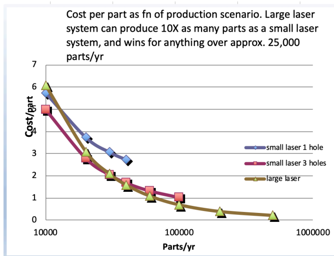
Excimerland is a sparsely populated territory. There are only a few suppliers, and limited range of sizes, which can be roughly broken down as below;- curiously, there is almost nothing to fill the gap between a) & b):-

a) Small, (KrF) output 10-20mJ, beam 3x6mm, rep. rates typically 200Hz-1kHz , 10W; 60-80kg.
b) Medium, around 400mJ, 10x30mm, 25-200Hz, or 700mJ, to 100Hz, 80W; 300-400kg
c) Large, 500-1000mJ, 100-300Hz - 100-300W; 850kg
d) Very large, 1-6J @ 500/600Hz - 500W - 3,6kW; 3,2 tons!!

www.coherent.com is the only supplier to cover all this range, & the only credible supplier of c) & d), reserved for high duty production scenarios. www.lightmachinery.com is the only other widely known supplier of b); there are a few other suppliers of a), reliable ones include www.atl-laser.de , www.mlase.com . Optec is an independent system builder with in-depth experience from all these suppliers; preference is on a case-by-case basis; in any category the lasers can be considered as close equivalents.

Examples of a):-

Example of b):-



Note that the raw beam energy density (e.d.),- which is what counts!,- from a) & b) is comparable, it is just that b) can provide that e.d. over a larger area. Also, depending on the model, b) provides 10-30X the output power, at < 5X the price!,- & so will always win on COO, *provided* throughput requirements & system architecture use the larger laser to its full potential. Optec can & does commonly supply such comparative COO estimates.

With a change of gas and cavity optics, most excimer lasers a) & b) can operate on several discrete wavelengths;- **XeF** (351nm), **XeCl** (308nm), **KrF** (248nm), **ArF** (193nm) & **F_2** (157nm). KrF operation gives the highest energy/power; de-rating for other wavelengths depends somewhat on cavity & discharge circuit design. Changing between different flourine mixes is relatively easy, with full performance being obtained after some hours operation & 2-3 fills; **changing between halogens is** strongly **disadvised** and can semi-permanently ruin performance.

For **metals** (for which excimer is almost never the best tool!), and ceramics, **wavelength is of little or no importance**, so KrF is the natural choice, giving the highest power o/p, and nowadays with no particular operational difficulty.

XeF o/p is typically 50% of that on KrF. Applications include some LLO (Laser Lift Off) from substrates which are opaque at lower wavelengths, and similarly for some specialized security marking applications where a polymer film has to be transparent to the laser beam. The wavelength has also been used for simulation of behaviour of materials at 355nm.

XeCl, with typically 75% o/p but generally longer fill lifetimes, lower stress on discharge components & better optics performance, used to be more popular in the early days of excimers, partly due to shortage of Kr, and remains important for some specific applications like Si annealing, using lasers optimized on this transition,- for e.g. Coherent SX series as d). As noted above a laser operated on XeCl will generally not later run well on F mixtures.

For machining of **polymers**, at which excimer lasers excel, **both of the above wavelengths are too long** for efficient ablation of all but a handful of polymers.

KrF operation **is adequate for the machining of many polymers**, and should always be tried first in any particular application since efficiency is higher & **COO** (Cost of Operation) **will always be lower than ArF**.

ArF typically gives a **very slightly better result** for almost all polymers, and is essential for some. The situation can also be intermediate , as for e.g. drilling of 50μm holed in undoped Nylon, where KrF (left) works, and gives faster drilling, but leaves a small amount of surface splatter, which may or may not be acceptable.

Against this, there are several **objections to using ArF**:-

a) Compared to KrF, o/p is typically not more than 50%.

b) Gas fill lifetimes are shorter, and since the discharge is more aggressive cavity & discharge component lifetimes are shorter.

c) Beam delivery optics are less efficient, and have shorter lifetime via a number of bulk effects including formation of colour centres, densification. Irradiation of airborne hydrocarbons deposited on optics surfaces can result in the formation of a thin graphite layer, impossible to remove.

d) 193nm beams propagating in air generate ozone, which absorbs 193nm radiation, creating significant losses, and is both a health hazard & injurious to equipment. For this reason, ArF beam delivery systems must be sealed & flushed with pure inert gas, usually nitrogen. This requirement increases machine costs a little, but may add significantly to COO, and can be a hazard risk in itself. On more than one occasion, impure nitrogen has been the source of contaminants which damage the BDU optics. Lastly, the necessity for sealing the BDU reduces flexibility,- particularly important for R&D systems.

e) Material removal per shot is somewhat lower, which may be an advantage for depth resolution, but is usually just another factor acting negatively on process time.

For all these reasons, ArF operation for polymers gives longer process times & increased COO. Depending on the application these effects may be marginal or up to a factor of 2-4X. Optec advice is clear; **if the process can possibly work on KrF, this is the transition to use**; ArF should be used only when necessary, and in full knowledge of the implications.

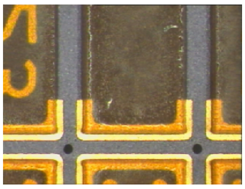
One factor sometimes in favour of ArF is that 193nm ablation threshold is usually lower, so lower e.d. can be used, giving even better depth resolution and which may help avoid concomitant damage to underlying layers.

ArF is **usually necessary for machining glasses**, but KrF is always worth trying.

F2 operation gives typically <10% o/p and requires highly specialized optics operating in vacuum; for practical purposes it is not really an option & Optec does not propose this wavelength at all.

It would be nice to give a list of polymers & recommended wavelength & e.d., but we prefer to treat every case on its merits, which is why we have a well-equipped applications lab. For e.g. it has been claimed that F2 is the only way to machine chloro-flourocarbons, e.g. PTFE , but a small amount of dopant can make these machinable even at 248nm. Similarly, we have seen copolymers in the PMMA family which could not be machined at all at 193nm, but became so once annealed. Similarly, one can say with certainly that PI & PC are absolutely fine on KrF, but that PMMA & Nylon, as weak absorbers, generally require ArF. However, the former can be machined at 248nm using the shorter pulses typical of small excimers in group a), and the latter is fine at KrF if coloured. Feasibility can also depend on motif size & desired throughput, since both can affect thermal load.

Alternatives to Excimer



No such discussion would be complete without mention of **CO2 TEA lasers**, particularly those running in the 9μm band; the only credible supplier being www.lightmachinery.com . Most polymers can be machined with something like **10X higher efficiency** using such lasers, and **COO** is **significantly lower** than for excimer, whilst **selectivity** for polymer vs metal is **enhanced**. Here, 320μm wide cleared paths in polymer packaging of SAW filters on Au printed ceramic.

Against this, **lateral resolution is poorer** by factor >25X, **depth resolution effectively non-existent**, and there is always a very thin (**1-2μm**) layer of **polymer remaining**, which may require a further processing step to remove.

Short pulse (femto/pico) lasers can also be used for processing all materials, including polymers, but are essentially complementary to excimers, their high rep. rate & low pulse energy is used for focal point processing with a galvo head; for e.g. they are better at cutting round a large or arbitrary contour. **Selectivity**, for e.g. metal/polymer, **is poor**, since these laser beams will machine practically anything put in their way,- a good or bad attribute depending on needs.