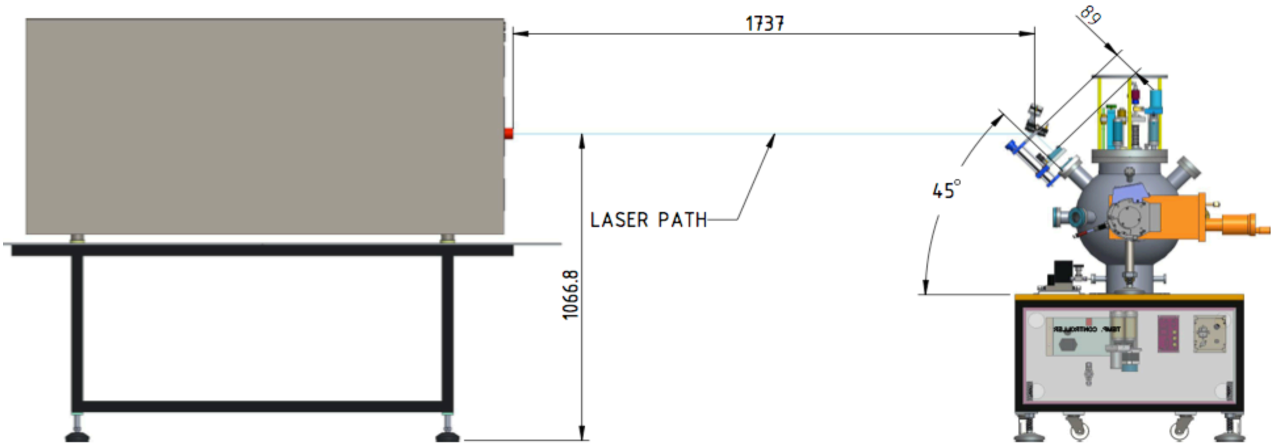
Beam Delivery for Pulsed Laser Deposition

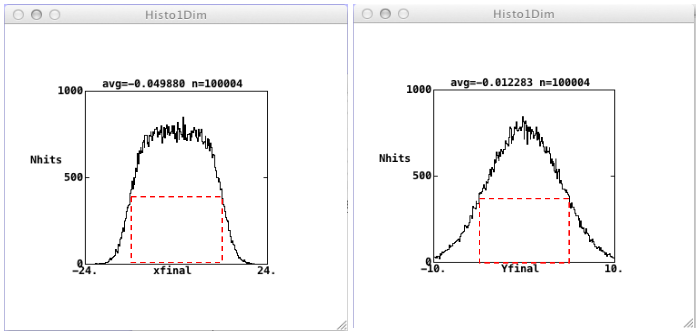
Pulse Laser Deposition (PLD) uses the beam of a powerful KrF excimer laser, here CompexPro 205, concentrated onto a composite target(s) mounted in a vacuum chamber; ablated species condense on a substrate, thus building up layers of the desired elemental composition.



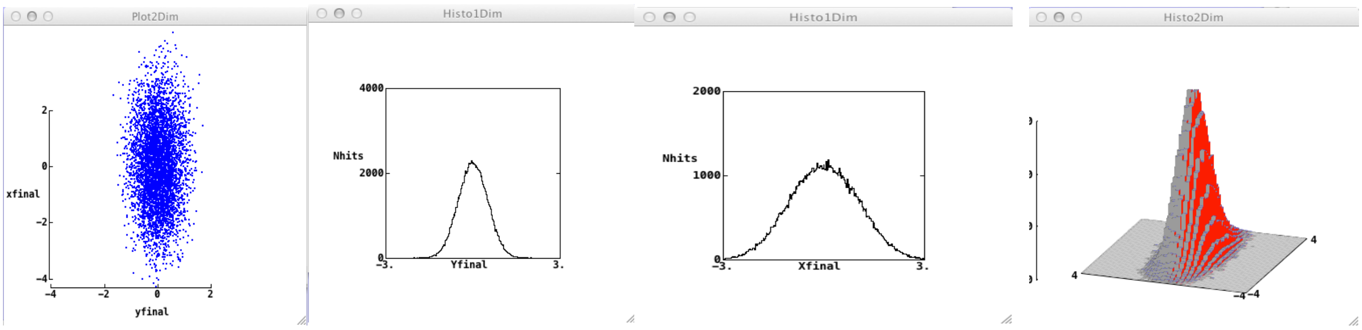
Most simply, the laser beam is simply concentrated onto the target using an external lens acting via a window, so that the intensity profile of the beam on target is close to the far-field distribution of the laser. The distance from window to target in the PLD chamber is typically on the order of 300mm, so lens-target distance >300mm, and can be adjusted to control incident e.d.; for example a catalogue UVFS lens with 400mm f.l.@546nm has 360mm f.l. @248nm.

Typical near field (NF) profiles,-i.e. close to the laser o/p,- are shown here; the red rectangle shows fitting to quoted FWHM values. By default, FF profiles are generally quasi-gaussian.

Typically, e.d. in excess of 100J/cm2 would be obtained by focusing the beam exactly on the target. More commonly, some degree of defocus is used so that peak e.d. is in the range 5-10J/cm2.



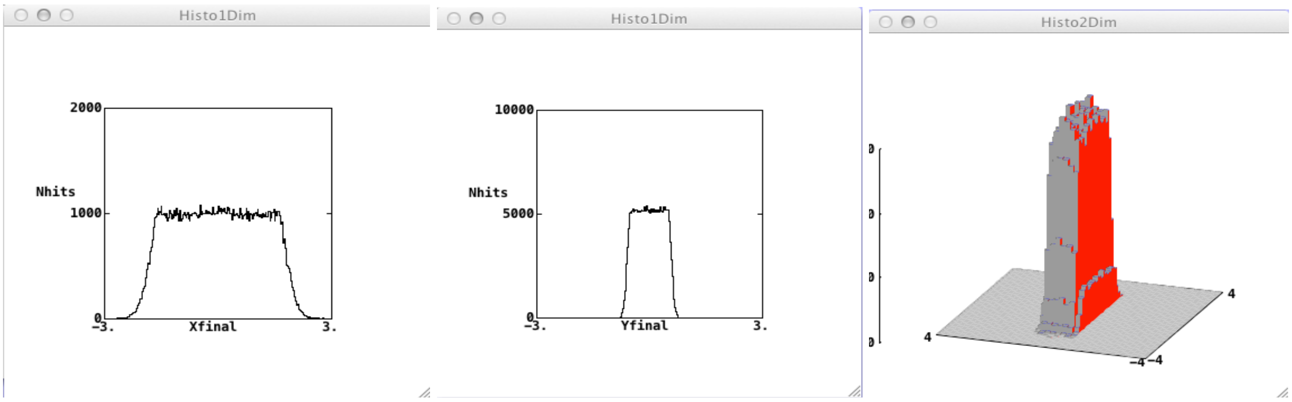
The elliptical nature & asoect ratio of the beam spot (left) is further accentuated by the 45° tilt of the target with profiles as shown. Correspondingly smaller spots of higher e.d. can be obtained by moving closer to the focus.



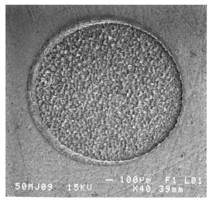
The disadvantage here is the highly non-uniform intensity distribution, which of affects ablation efficiency and therefore the stoichiometry of deposits.

The desirable aim is a beam of more uniform e.d. PLD poses something of a problem for BDU design because of the combination of high energy density, large working distance and limited dia of the entrance window. Known beam homogenization techniques using integrating arrays, diffractive elements or engineered diffusers all introduce a significant amount of additional divergence into the beam, which is incompatible with the geometrical constraints.

We have successfully used the Optec HY series Beam Shapers, fully described in other Technotes, to generate a top-hat profile on an external intermediate plane, which is then imaged onto the target with some demagnification to obtain the required energy density. Simulated raw profiles are as shown overleaf, obtained with typically >90° BDU efficiency

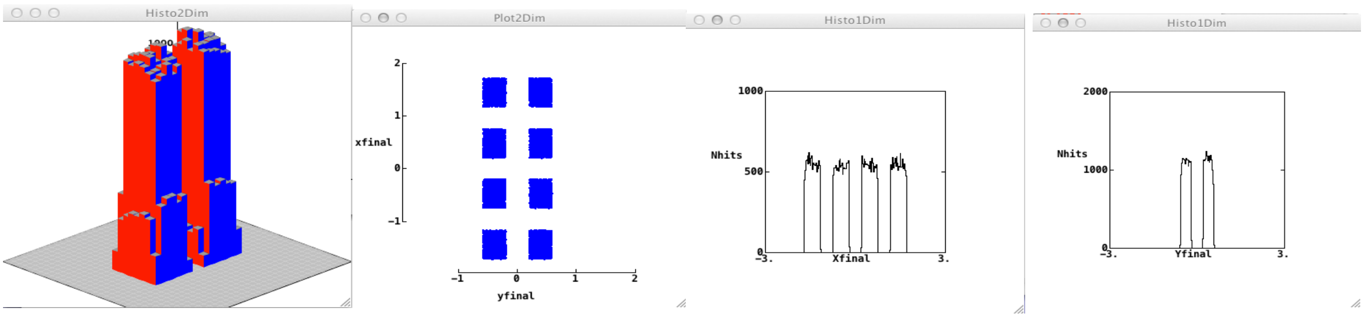


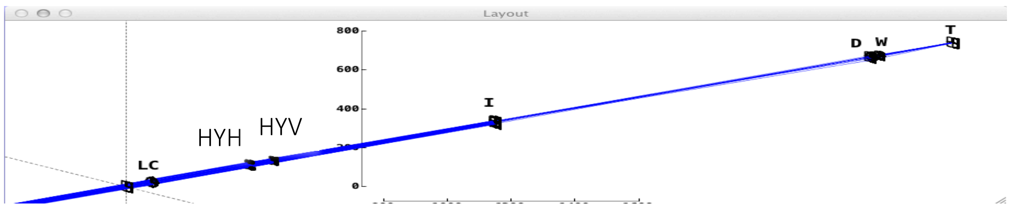
However, because the intermediate plane is external to the chamber, a rectangular mask can be used in that location to precisely delimit the beam, at a cost of approximately a further 15% of the beam lost.



Alternatively, a circular mask can be used, as in this case>>>>>>>>>>>>>>

Further, that mask can be more complex than a simple limiting rectangle, & used to structure the beam. Since it is known that closely spaced ablation plumes can interact, this raises new & intriguing possibilities:-





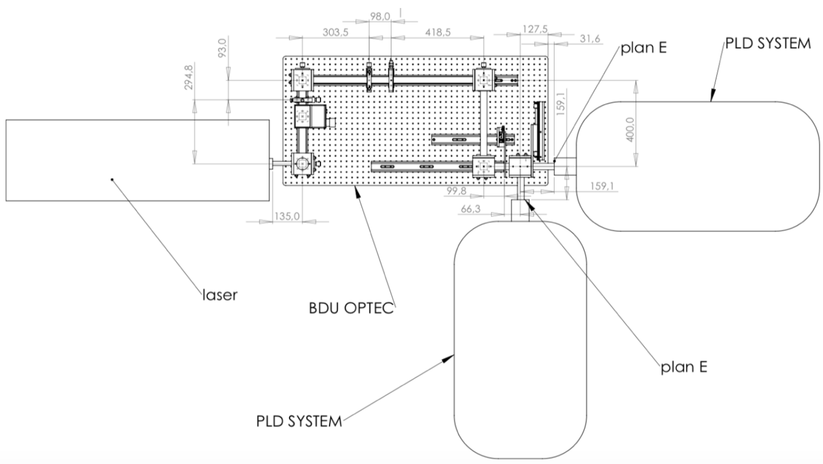
Such control over the beam comes at some cost, mostly in the inevitable length of the complete BDU, shown here in a straight line layout.

With reference to the laser bezel, the necessary components are now:-

LC lens, **HYH & HYV modules** for top hat profile in H & V directions some positional adjustments may be necessary to obtain optimum profiles, depending on exact input laser profile.

I = Intermediate plane, where a mask may be used (not obligatory); **D** is the Optec PLD doublet lens some provision for axial motion is required to set up the exact imaging condition at selected demag. **W** is the chamber window; **T** is the target.

Typically, laser to target is 3500-4000mm. There is no way to shorten the beam path whilst maintaining uniformity, energy density and beam size at **D** & **W**; this is not a technical limitation,- just physics. However the beam path can of course be folded, for e.g. in an L or N fashion, provided axial distances are respected; exactly how this is done depends on individual lab layout; the same intermediate plane can be used with a flip mirror to supply multiple systems,- this example from 2020.



Optec can supply all components & design study optimized for a particular laser, PLD chamber and target specifications.

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