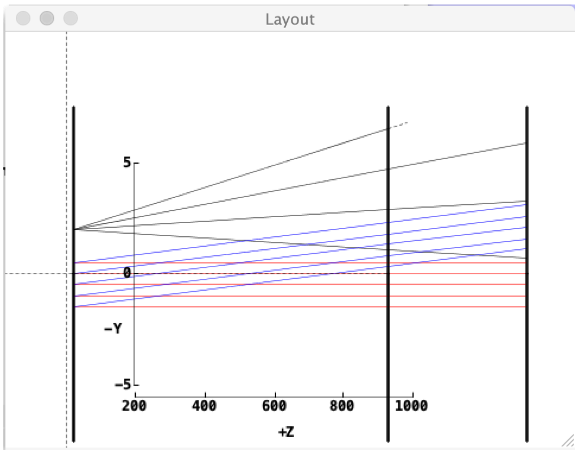
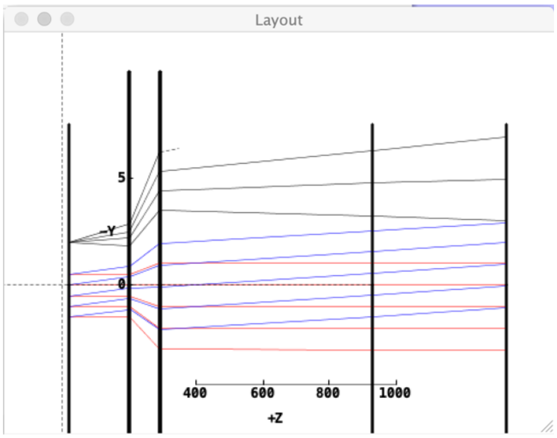
Excimer Laser Beam Delivery, Telescopes & Relays

As everyone knows, when not passing close to a black hole, light rays,- that convenient fiction,- proceed in a straight line….

As here;- ideally axially collimated rays (red) stay so, rays heading off at an angle (blue) move progressively further away from the axis, and rays diverging from a point source (black) continue to do so;- normal stuff.



This can be a problem with excimer lasers when the **system architecture** is such that the mask has to be at some distance from the laser output bezel. If the laser behaved like the red rays than there would be no problem, but in fact as one moves away from the output the beam spreads & can move off target due to **pointing instability**, whilst the ideal top-hat NF profile degrades into the more gaussian FF profile,- & so behaves more like a combination of black & blue rays; other RA Technotes deal with how to best model the laser using the BEAM 4 Ray Tracer.

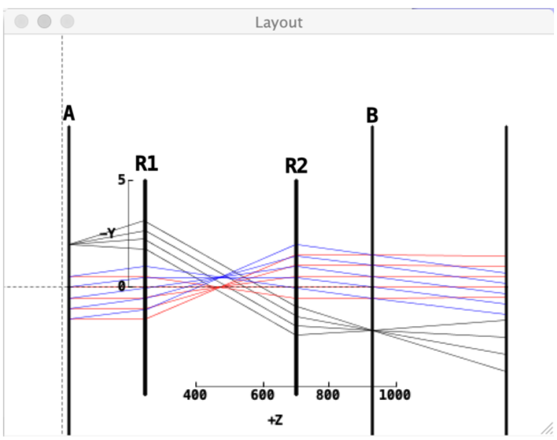


One solution is to expand the beam using a **Beam Expanding Telescope** or BET. Galilean is generally preferred over Keplerian since shorter, and avoids a sharp beam waist which can result in beam instability due to air breakdown.

Note that the red rays remain collimated but are spaced further apart, i.e. the beam is expanded. However note that the drift of the blue rays away from the axis is reduced, and the black rays are spreading less; i.e. the **BET reduces divergence** by the same factor as the beam size magnification, a well known,- and inevitable!- result which can be used to good effect.

In about 1992 Optec had a customer who wanted to **transport an excimer beam** over 12m to another lab. The solution was to use a high magnification BET to expand the beam, reduce divergence & pointing error by the same factor, & then use a **BCT** (just inversed BET) at the receiving end; we have used the same trick to demonstrate than we could preserve beam quality over a large panel size on a gantry motion system.

Quite commonly, we want to have a beam with similar size in V & H axes, & to do this we can use a BET composed of **cylindrical lenses** to expand the beam short axis SA, typically 2-2,5X.



An alternative solution to the beam spreading problem is an **optical relay**. In its most basic form this is composed of two identical lenses R1 & R2, separated by twice their focal length.

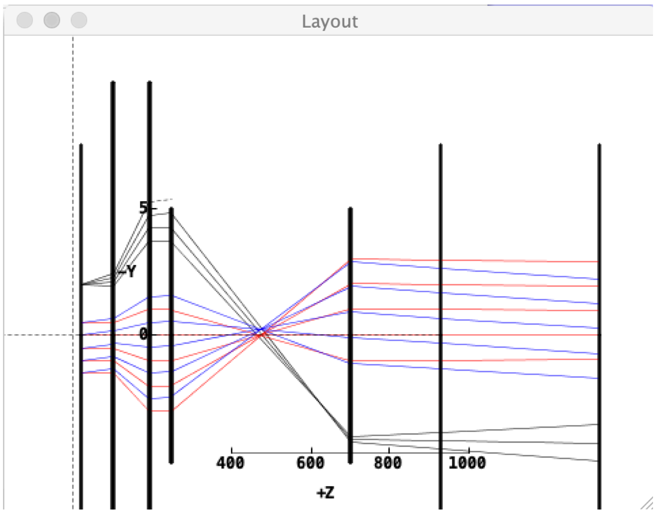
Rays starting in the back focal plane of R1 are imaged onto the focal plane of R2, as shown by the black rays; i.e. planes A&B,- in this case located at 20mm & 930mm,- are conjugates w.r.t. the relay, Profile, collimation & pointing are all preserved, and apart from an inversion, it is just as if the laser,- whose output bezel here would be at the vertical dashed line at extreme left,- had been moved to 20mm before plane B and turned upside down!

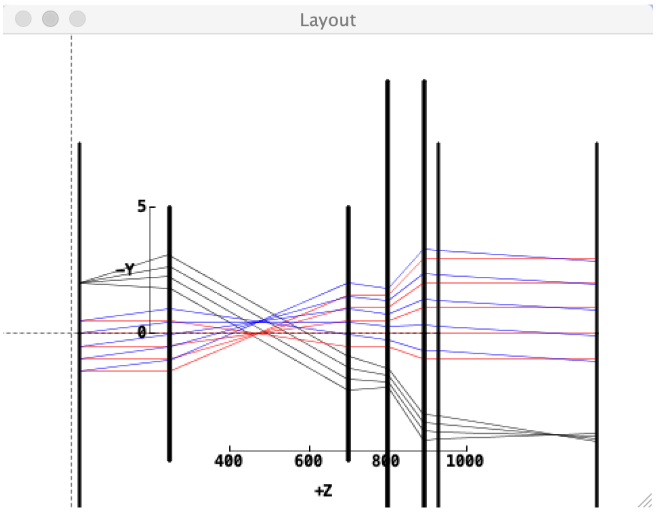
The relay can also be made with non-identical lenses, producing magnification (+ve or -ve) at the same time, which has an advantage over a spherical BET/BCT with different power, because of the relay effect.

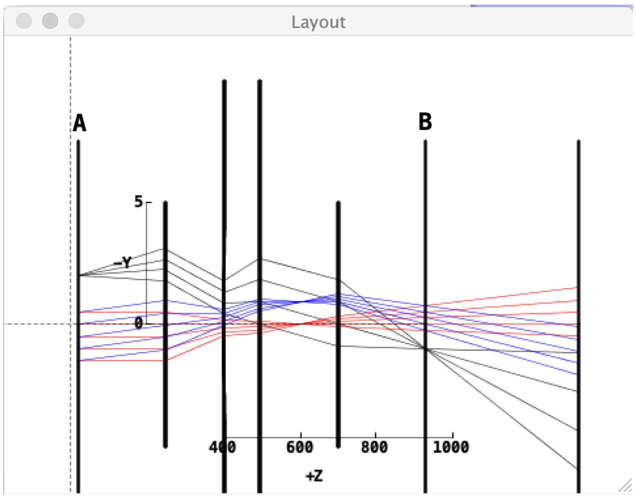
The down side of a relay is the **intermediate beam waist**, not so much for air breakdown since focal lengths here are greater & hence beam waist less tight, but which still has to be kept well clear of other optics,- turning mirrors etc

Sometimes it would be nice to do both of these things, expand the laser SA with a cylindrical BET at the same time as having a relay effect. Can this be done? The answer turns out to be no, but also yes in a completely counterintuitive way.

If we place the BET between plane A & R1 (left below), or between R2 & plane B (right), we preserve the collimation but destroy the relay imaging condition, compared to the orthogonal LA:-







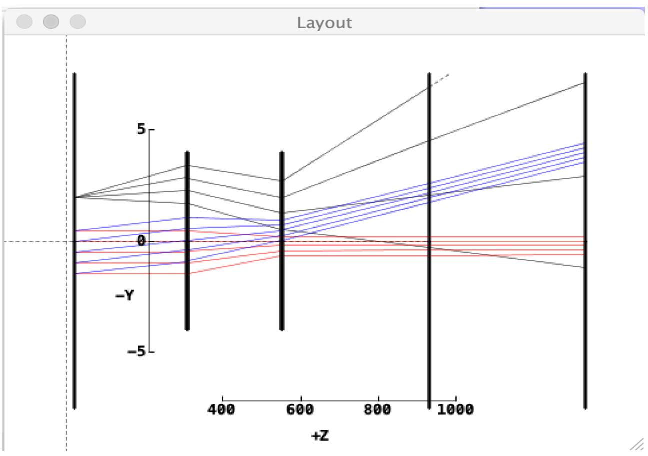
If, on the other hand, we put the BET in between R1 & R2, as at left, then we preserve the relay imaging, but destroy the collimation, as at left....

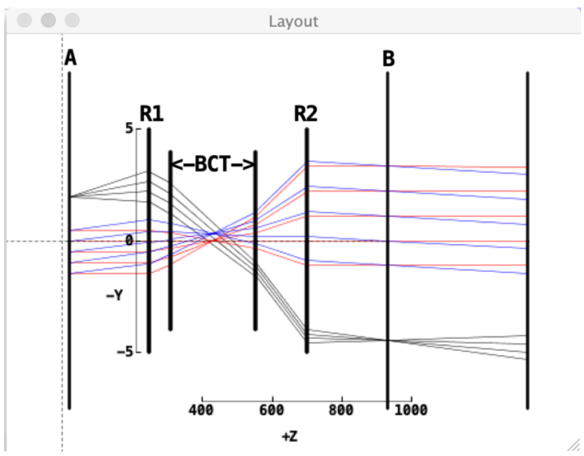
It turns out that the axial position of the BET within the relay affects the collimation, and there is just ONE position where it is preserved. There must be a rule here but I have not looked for it,- just easier to do the simulation!.

However, an observant reader will also see that the beam on plane B is now not expanded, but ***reduced*** in size, and therein is an important clue.

The amazing answer is that we can preserve the relay imaging by having a telescope between R1 & R2, but it has to be not a BET, but a BCT!, i.e a beam condensing telescope with one lens either side of the relay beam waist and the location has to be carefully chosen to optimize the collimation.

So, (at left below) we have the cylindrical BCT alone acting on the short axis,- doing all the opposite things to what a BET does, and of course to what we want!,- and then (at right) the ***same*** BCT correctly placed within the relay, and achieving the desired result of beam expansion in the short axis combined with an optical relay & all its advantages; the relay acts alone in the long axis.





There is a bonus,- a rare example of getting something for nothing; the point beam waist of the relay alone is degraded into two line foci with lower e.d., thus further reducing risk of instability due to air breakdown by plasma formation.