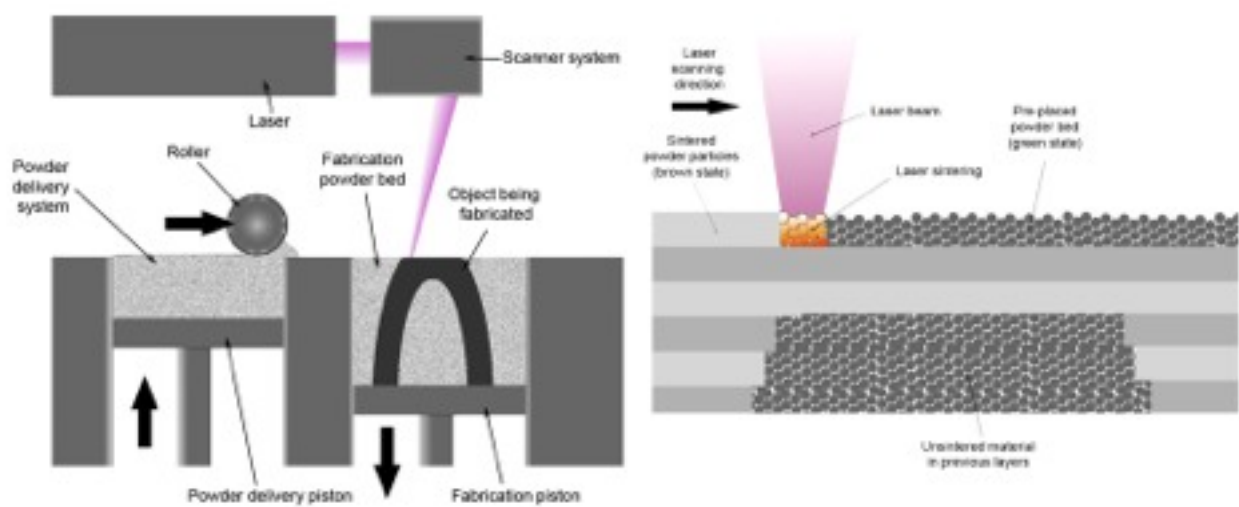


Thinking about SLS printing



Selective laser melting system schematic, from Wikipedia as uploaded by Materialgeeza on May 11th, 2008.

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Introduction

This document is a way to free my mind of the ideas I'm having about creating a 3D printer. As I am thinking about releasing the design as copy left in the end if I get so far, it would be strange not releasing my "research" documents as well.

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Revisions

22 March, by Michael Zandstra
Initial version

25 March, by Michael Zandstra
Changed error in empowering laser (calculation of laser area size, used $\pi \times \text{diameter}^2$, instead of $\pi \times \text{radial}^2$).

29 March, by Michael Zandstra
Added a section about using several LED's.

Inhoudsopgave

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Basics

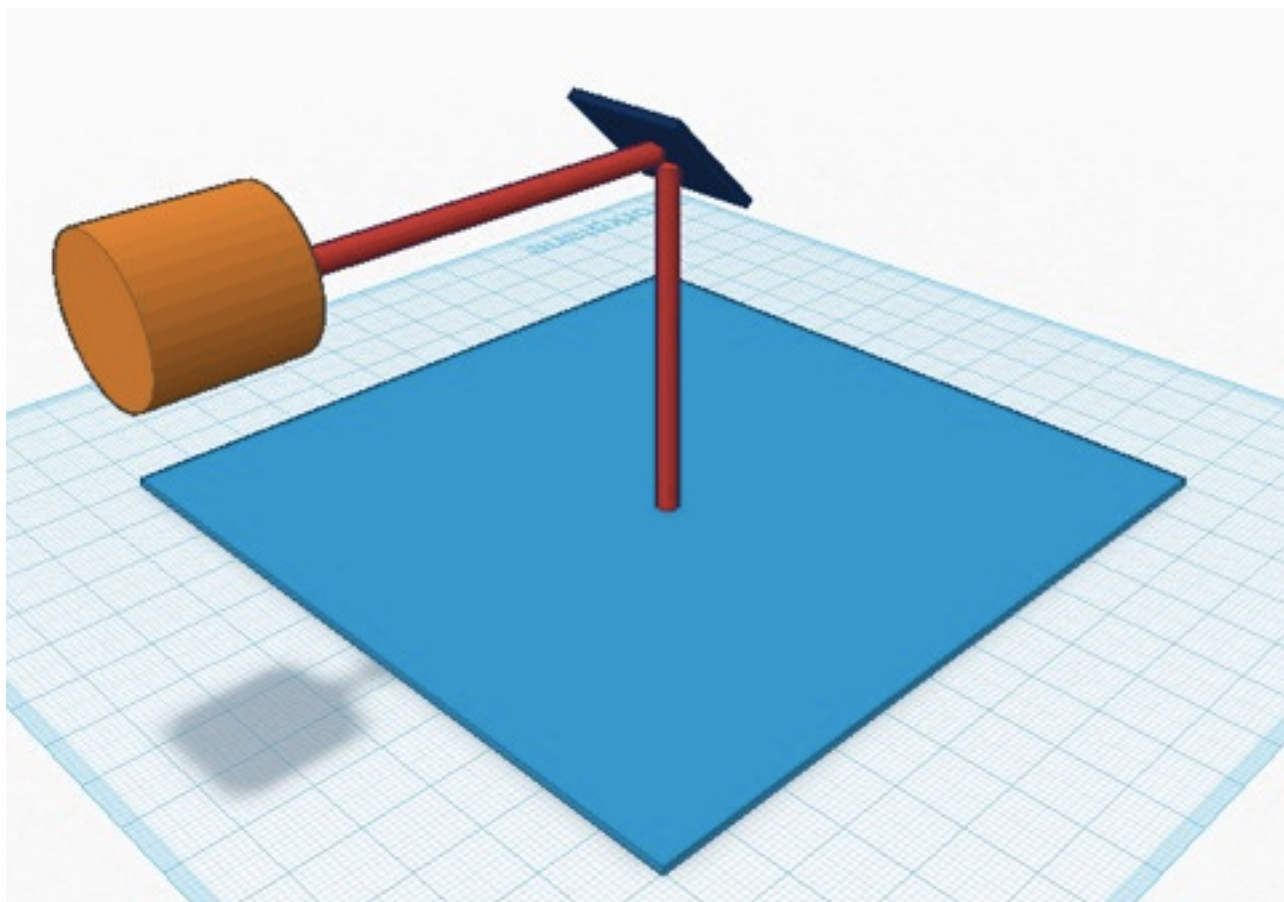
Selective Laser Sintering (SLS) is a method to print 3D objects. A SLS 3D printer puts down layers of a powder, and every layer it selectively heats the powder so it bonds to the connecting powder and/or previous layers. This heating can be done by all kinds of means, but since it's Selective Laser Sintering, we use a laser.

After printing, the not sintered material can be brushed and/or scrapped from the printed object(s).

Positioning the laser

Positioning the laser can be done by several means. When you look at most DIY movies, then you'll see that the laser is being moved in a grid. The laser is used as a pen, from point x_1, y_1 to x_2, y_2 at a certain speed. This is relative easy, as you only have to figure out the wheel to move the laser along one axis, and then copy that way to the other axis. Most people who did produced such an SLS printer, reused spare parts or at least some ideas from the RepRap printers.

When you see professional printers, they often use mirroring to move the dot across the layer. Personally I think this is the better way, since this is easier for cooling and controlling the laser. Since it's stationary, the cooling and the controls don't move through the printer. The mirror(s) can be positioned easily by several means. On this moment I'm considering using accurate but cheap 4-phase stepper motors. By using gears the mirror(s) should make the correct angles.



Picture 1 Simplified design, as visualised in tinkercad.

When you look at this, you see the laser positioned horizontal. The mirror is placed in a 45° angle, bending the laser beam 90° down. If we place the sweet spot (where the laser hits the mirror) 10 centimetres above the layer, we can calculate the angle to let the laser beam touch a specific position. If we consider a 12×12 cm layer, and the centre the $0,0$ point, we have all the information we need to calculate the angle with the inverse tangent of offset/height.

Just imagine I want to heat a spot at the side. This is 6 centimetres away from the centre, thus we have to get the laser beam to an angle of $30,96^\circ$ ($\text{Tan}^{-1}(6/10)=30,96^\circ$). Since we are talking about a mirror, we are actually making a swing of $15,48^\circ$. This is because a mirror makes a Equilateral triangle of the incoming laser beam. I won't get into the precise mechanics between this, but just compare it to the beginning scenario. The laser beam makes an 90° angle, because the mirror is in a 45° angle measured relatively to the laser beam.

Now this angle isn't a very big deal. The big deal in SLS printing, is that for accuracy, you need to place the beam both at 6.0 cm from the startingpoint, as on 5.98 cm. The laser beam has to make an angle of $30,88^\circ$ ($\text{Tan}^{-1}(5.98/10)=30,88^\circ$) and the mirror just $15,44^\circ$. The mirror has to make a swing of $0,04^\circ$ in this case, which is incredibly small. This is also why you don't want the laser too high from the layer, since this would make the angles even smaller.

In the vertical plane, we can use the same calculations. If we want to reach the furthest spot away from the laser, the laser beam will have to make an angle of $90^\circ + 30,96^\circ = 120,96^\circ$. The mirror will have to make an angle of $45^\circ + 15,48^\circ = 60,48^\circ$ (Hint for easy calculations later on; this is the same as $120,96^\circ/2$). For the closest spot towards the laser, the laser beam will have to make an angle of $90^\circ - 30,96^\circ = 59,04^\circ$. The mirror will have to go move to $29,52^\circ$.

Empowering the laser

A default laser you can buy like in a laser pen, is just 5 milliwatt and the laser beam has a diameter of 3mm. Professional SLS printers often use a laser of 20 - 100 watt. Now this is probably a bit much to ask for a simple DIY 3D SLS printer. But if you do some searching on the web, you can find a more powerful laser of for example 100 milliwatt. This is already eye damaging, so be very very careful if you're going to play with those.

100 milliwatt should be powerful enough for black plastic and is probably closer than you think. CD/DVD burners should have a 200 - 400 milliwatt laser. For safety measures, I'm probably going to experiment with the cheaper 5 milliwatt lasers. When we take a laser beam of 5 milliwatt power, that has a diameter of 3 mm, we can do the same thing as little boys do. Little boys tend to play with the sun and a simply lens to fry ants. Now using just such a lens (biconvex) wouldn't serve the purpose. The focal point would be fixed, and that wouldn't work, as the mirror would lengthen the laser beam and thus the layer beyond the focal point.

If we place a (bi)concave lens behind the mirror with the same focal point placement, the laser would be narrowed down but straight again. So we can change the laser beam of 3mm diameter into a 1mm laser beam. For the math behind this, 3mm gives us a area of $(\pi \times 1.5^2 =)7.07\text{mm}^2$. A 1mm laser beam would give us an area of $(\pi \times 0.5^2 =)0,79\text{mm}^2$. The energy of 5 milliwatt, will go up by $7.07/0,79=9$ times. So instead of a 5 milliwatt 3mm wide beam, we have a 45 milliwatt 1mm wide beam.

There will probably be some loss, for example from the lenses when they aren't of a high enough quality. Most of the times this will be negligible.

Why lasers and not LED's or lamps?

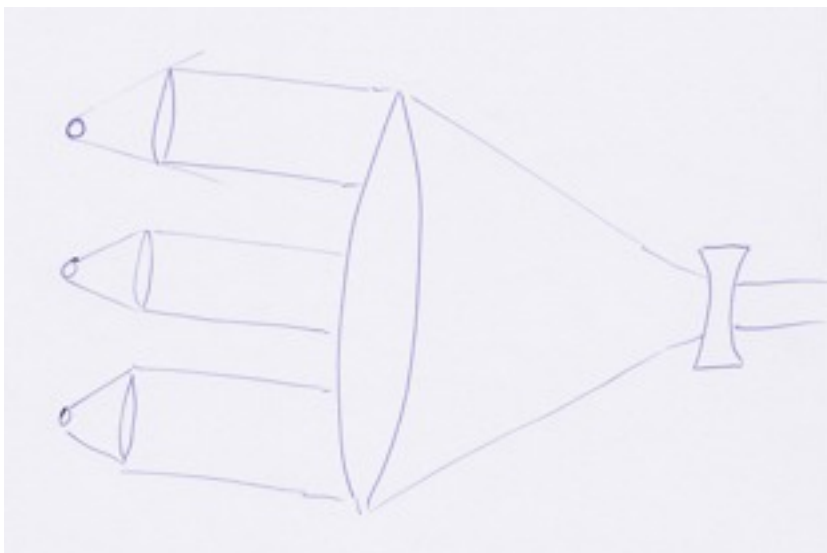
While thinking about empowering lasers, I started wondering if I actually need a laser. Wouldn't it be enough to use a regular lamp, a convex lens and a concave lens? It's something to investigate for sure, as a 100Watt lamp is very cheap and easy to acquire. The big benefit would be colour-spectrum. A lamp can have a spectrum from 0 - 6500 Kelvin, while a laser is often just one specific wavelength (550nm for example). This bigger spectrum would probably make it easier to use different materials and colours.

The main reason to go for a laser, is that it readily bundles all the energy on one beam. A regular lamp defuses the light to all areas, but with some mirroring and using a few lenses, I think this could bundle light almost as narrow and probably good enough. I think that it would also be possible, to just use a bunch of LED's. They defuse light in a specific direction, so a lens could pick it up and direct it the right way. As long as you can make a bundle of about 1 - 2 mm diameter I think you can get away with using this. It would most definitely be cheaper.

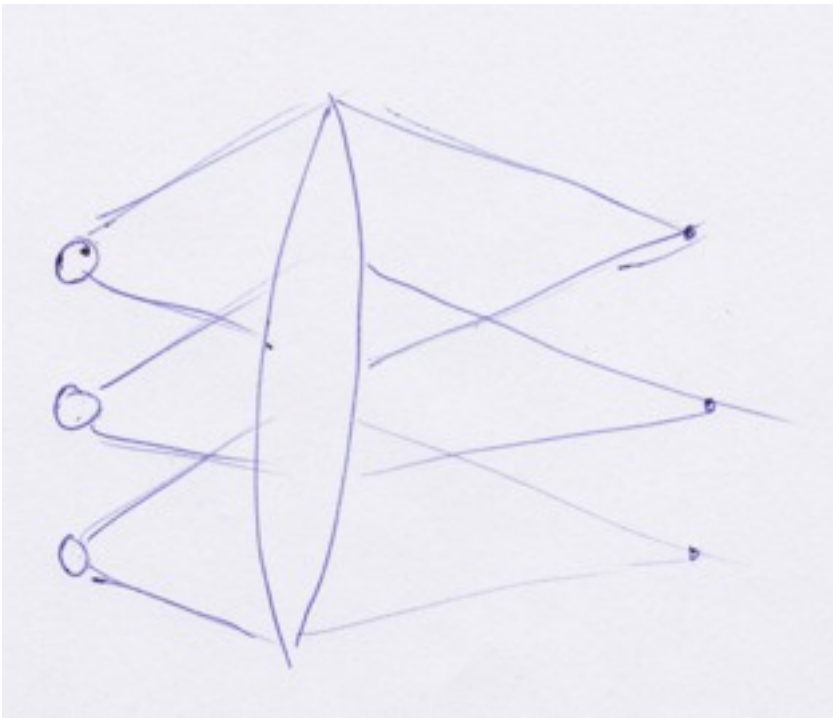
I think two approaches could be used. First of is using a lamp / bunch of LED's, creating a bundle and using the same approach as the laser; using mirror's to point the beam to a specific spot and heating the layer. The other is more simplistic, for example using a lens with a focal point of 15 cm and placing the lens 15 cm above the layer. The lamp just above that, so the focal point would burn the material just as a little boy would do with ants. This is the same principle as the 3d printer by Markus Kayser (Solar Sinter), but then we use a lot less energetic source of light (he used the sun).

Several LED's

An array of LED's that are in for example the 850nm IR-section could be used to join together in a powerful single beam using a few lenses. It would take some calculation, but it would be possible to do something like this;



This has to be done in several steps, because otherwise you would get something like this;



A big advantage of this, it that the concave (or biconcave) lens, (the last one making everything straight); could be mounted flexible. By moving the lens a little bit, you can change the beam from 1 or 2 mm diameter and powerful enough for sintering, into a beam that is less powerful but great for testing without hurting the eyes and sintering the material.

You would also be allowed to change the power of the beam, by disabling one or two LED's. This makes the system flexible enough to use both ABS and PLA for example. PLA would probably burn away what you would use the same amount of power as with ABS.